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SECTION 4 - DRAFT CMS

I WOULD CHANGE A FEW THINGS.

AT SWMU 11/12/15 A CASE FOR EXCAVATION OF ARSENIC SOIL SHOULD BE MADE CONSISTENT WITH THE SWMU 11/12/15 CORRECTIVE MEASURES IMPLEMENTATION PLAN - NOVEMBER 2000

TURNED OUT TO BE MORE PAGES THAN I THOUGHT. WILL SEND EXPRESS MAIL.

D.K

ATTACHED 4-1 TO 4-54

RESEND 4-44 TO 4-54

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D.K

DRAFT

CORRECTIVE MEASURES STUDY

Prepared for:
Harcros Chemical Inc.

Re:
Vicksburg Chemical Site
Vicksburg, Mississippi

October 2002

Prepared by:
Scenic Bluffs Inc.
135 Scenic Bluffs Drive
Boerne, TX 78006

4.1 INTRODUCTION

The purpose of the following detailed analysis is to evaluate the retained alternatives and provide a basis for selection of the most appropriate alternative. The analysis was performed using the following evaluation criteria:

- Overall protection of human health and the environment
- Institutional
- Performance
- Reliability
- Safety
- Implementability
- Cost

The first two criteria (overall protection of human health and the environment and compliance with institutional needs) are designated as threshold criteria because in most cases, these criteria must be met by the selected alternative. After evaluating compliance with the threshold criteria, the alternatives were analyzed using the next criteria to determine how they compare to one another and to identify possible compromises between them.

Overall Protection of Human Health and the Environment

This criterion addresses whether the remedy is protective of human health and the environment considering the site's characteristics. The corrective action's long-term effectiveness and permanence, short-term effectiveness, and reduction of toxicity, mobility, and volume affect the overall protection of human health and the environment. How each alternative achieves protection over time and whether site risks are eliminated, reduced, or controlled are also analyzed.

Institutional

This criteria evaluates the effects of Federal, state, and local environmental and public health standards, regulations, guidance, advisories, ordinances or community relations on the design, operation, and timing of each alternative.

Performance

This criterion relates to the effectiveness and useful life of the alternative in maintaining protection of human health and the environment after corrective action objectives have been met. The focus is on any residual risk remaining at the site after completion of the corrective action and the reliability of engineering and institutional controls and monitoring to manage hazardous substances remaining at the site.

Reliability

This evaluation criterion addresses the general preference for treatment methods that would reliably result in the reduction of toxicity, mobility, or volume of a waste. The specific factors to be considered are the frequency and complexity of operations and maintenance; the expected degree of reduction in toxicity, mobility, or volume; the degree to which the remediation would be irreversible; and the nature and quantity of treatment residuals that would remain on-site.

Safety

This criterion relates to the potential for adverse effects to the community or environment during construction and implementation of the corrective action. The length of time required to achieve protection, the short-term reliability of the technology, and protection of the community and of workers during corrective action are considered.

Implementability

This criterion relates to the technical and administrative feasibility of the corrective action alternative. The specific factors to be considered are ability to construct, operate, and maintain the technology; ability to monitor the effectiveness of the corrective action; and the ability to obtain approvals from other agencies.

Cost

The cost estimates presented in this report are typically in the +50 percent to -30 percent accuracy range. The estimates are based on a variety of information, including estimates from technology vendors, generic unit costs, conventional cost estimating guides, prior

experience, and information from other sites. The estimates have been prepared for guidance in the alternative evaluation from the information available at the time of the estimate. The actual costs of the project would depend on the negotiated labor and material costs, actual site conditions, final project scope, the implementation schedule, competitive market conditions, and other variable factors.

Capital and operation maintenance (O&M) costs are estimated for each alternative and used to calculate present net worth. Capital costs include the direct and indirect expenditures required to implement a corrective action. Direct costs include construction costs or expenditures for equipment, labor, and materials required to implement a corrective action. Indirect costs include those associated with engineering services, permitting, legal services, construction services, and other services necessary to carry out a corrective action.

Annual O&M costs include operation labor, maintenance materials, maintenance labor, energy, and other costs needed for continued post-construction operation and maintenance. For purposes of comparing the long-term corrective actions, typically 30 years of operation, maintenance and monitoring were utilized in the present net worth calculations at a five percent discount rate.

4.2 INDIVIDUAL ANALYSIS OF ALTERNATIVES FOR SOIL CONTAMINATED WITH TOXAPHENE AND DINOSEB

Alternative A-2; Removal Action with Containing Soil Cap

This alternative involves consolidation of contaminated soil not meeting Corrective Action Objectives into one soil pile. The soil pile would be covered with a soil cap consisting of six inches of clay and six inches of topsoil. The soil pile, which is depicted on Figure 3-1, would be constructed immediately to the southwest of the atrazine warehouse. The footprint of the soil pile is 650 feet by 75 feet by 15 feet high. Sides would be sloped 2:1. grass would be grown on the soil pile. The location would be graded such that rainwater runoff would flow to the east. Silt fences would be placed in erosional pathways. A portion of the south plant drainage ditch would be re-routed. Access to the soil pile would be restricted.

Overall Protection of Human Health and the Environment

Alternative A-2 is somewhat protective of human health and the environment. The average concentration of toxaphene is 23,610 ppb and the average concentration of dinoseb is 88,445 ppb. The pathways of exposure to toxaphene are closed. Movement by erosion is controlled and leaching by rainwater is controlled. Even though the dinoseb concentration is below the MDEQ Tier I TRG Table value of 204,000 ppb, the dinoseb can be leached out.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations. Since the South Plant Drainage Ditch drains into Hennessey's Bayou, some Corps of Engineers permitting may be required. A meeting would be held with the Vicksburg Corps of Engineers to review appropriate maps and drawings and a decision will be requested as to their jurisdictional interest. If they have interest, a permit would be obtained.

Since the waste pile is a permanent repository, restrictions on land use would have to be placed on the deed of the property.

Performance

This alternative offers protection for the spread of toxaphene and dinoseb contamination. It would be a permanent repository. Additional monitor wells would have to be placed around the pile. The vegetation on the cap would have to be established and maintained by mowing and filling in any erosional areas.

Reliability

Slow release of dinoseb plus naturally occurring biodegradation in the vadose zone and within the waste pile itself will in time reduce the toxicity and volume of that contaminant.

The mobility of the toxaphene contaminant will be significantly reduced by consolidating contaminated soil in one waste pile and containing it by covering it with clean soil and vegetation.

Safety

This alternative can be constructed in a span of two months. One month is required for site preparation and one month for completion of the waste pile. It is during the completion of the waste pile that care will have to be taken to prevent dusting and airborne transport of the toxaphene. There is a potential for exposure to plant workers in the south plant of VCC. There is very little chance that the dust could move off site. Dusting will be prevented by wetting the soil.

Implementability

This alternative would be implemented by first rerouting a portion of the South Plant Drainage Ditch. A section approximately 300 feet long would have to be excavated. The excavated soil would be placed in the existing ditch to help form a base for the soil pile. Then the relatively uncontaminated adjacent soil piles would be used to form a 700 foot by 90 foot by 0.5 foot base. The base and surrounding area would be sloped such that rainwater runoff would be diverted to the east. Drainage ditches and swales would be provided as necessary.

The first step is to move the adjacent contaminated soil piles atop the base. Next the soil piles atop the former toxaphene and dinoseb manufacturing areas would be moved to the engineered soil pile. Then the shallow surface soil would be excavated and moved to the new soil pile location. Approximately 5,400 cubic yards of clean fill would be placed in the excavations.

A soil cap would be constructed atop the soil pile. Approximately 1,400 cubic yards of clay would be placed and compacted to provide a six-inch clay cap. Then six inches of top soil would be established with 1,100 cubic yards of fill material.

As the soil pile is constructed, large chunks of concrete are removed and set aside to be used to cover the bottom slopes of the soil pile as a rip rap for erosion control.

Four monitor wells would be installed, one upflow and three downflow.

Cost

The capital cost of this alternative is $227,000. Details are presented in Table 4-1. The Present Value of the operating and maintenance costs for 30 years is $48,600. Details are presented in Table 4-2.

TABLE 4-1

CAPITAL COST ESTIMATE FOR ALTERNATIVE A-2 REMOVAL ACTION WITH CONTAINING SOIL CAP

• Mobilization	$5,000
• Clear and Grub 300' x 100' area for rerouting drainage ditch; (3,300 yd^2 @ $1.50/$yd^2$)	$4,950
• Excavate 300' x 10' x 5' new drainage ditch. Use soil excavated to fill old ditch; (560 yd^3 @ $2.50/$yd^3$)	$1,400
• Prepare 700' x 90' x 0.5' base of soil pile by using uncontaminated sections 20-GG, 20-HH, 20-JJ and 20-KK of existing piles; (1,200 yd^3 @ $1.50/$yd^3$)	$1,800
• Grade such that rainwater runoff will flow to the east (1,200 yd^3 @ $1.00/$yd^3$)	$1,200
• Move contaminated soil pile sections 20-II, 20-CC and 20-MM to soil pile; (1,000 yd^3 @ $1.50/$yd^3$)	$1,500
• Move contaminated soil pile sections 20-AA, 20-BB, 20-CC, 20-DD, 20-EE and 20-FF to soil pile by excavating, trucking, dumping and bulldozing; (1,800 yd^3 @ $3.50/$yd^3$)	$6,300
• Excavate contaminated soil areas surrounding former dinoseb and toxaphene manufacturing areas of SWMU 20 to 1.5 feet. Move by truck to soil pile, dump and bulldoze; (5,500 yd^3 @ $6.00/$yd^3$)	$33,000
• Separate all construction debris and utilize as rip rap on slopes of pile	$10,000
• Excavate fill material from Vicksburg site, truck to railroad area and use as compacted fill; (5,500 yd^3 @ $8.00/$yd^3$)	$44,000
• Excavate fill material from Vicksburg Site, truck to soil pile and use as soil cap; (1,400 yd^3 @ $8.00/$yd^3$)	$11,200
• Excavate top soil from Vicksburg Site, truck to soil pile and place atop cap to establish vegetation; (1,100 yd^3 @ $8.00/$yd^3$)	$8,800
• Establish vegetation; (6,400 yd^2 @ $1.00/$yd^2$)	$6,400
• Install four monitor wells	$10,000
• Engineering and construction management services @ 20%	$29,100
• Contingency @ 30%	$52,400
Total	**$227,000**

TABLE 4-2 PRESENT VALUE OF OPERATING AND MAINTENANCE COSTS OF ALTERNATIVE A-2 FOR THIRTY YEARS	
• Sample wells semi-annually	$2,000
• Analyze four samples for toxaphene and dinoseb semi-annually	$2,000
• Inspect the soil cap monthly	$1,200
• Mow the grass 20 times	$2,000
• Annual cost	$7,000
Present Value @ 30 Years and 5% Interest = 7,000 (30)(0.2314)	**$48,600**

Alternative A-3; Removal Action with Containing Geosynthethic Liner and Soil Cap

This alternative involves consolidation of contaminated soil not meeting Corrective Action Objectives into one soil pile. The soil pile would be covered with a soil cap consisting of six inches of clay. Then a geosynthetic liner with composite drainage layer would be installed. Then six inches of topsoil would be added. The soil pile, which is depicted on Figure 3-1, would be constructed immediately to the southwest of the atrazine warehouse. The footprint of the soil pile is 650 feet by 75 feet by 15 feet high. Sides would be sloped 2:1. Grass would be grown on the soil pile. The location would be graded such that rainwater runoff would flow to the east. Silt fences would be placed in erosional pathways. A portion of the south plant drainage ditch would be rerouted. Access to the soil pile would be restricted.

Overall Protection of Human Health and the Environment

Alternative A-3 is protective of human health and the environment. The average concentration of toxaphene is 23,610 ppb and the average concentration of dinoseb is 88,445 ppb. The pathways of exposure to toxaphene are closed. Movement by erosion is controlled and leaching by rainwater is controlled. Even though the dinoseb concentration is below the MDEQ Tier I TRG Table value of 204,000 ppb, the dinoseb has potential to be leached out. The addition of the geosynthetic liner effectively seals off that potential.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations. Since the South Plant Drainage Ditch drains into Hennessey's Bayou, some Corps of Engineers permitting may be required. A meeting would be held with the Vicksburg Corps of Engineers to review appropriate maps and drawings and a decision will be requested as to their jurisdictional interest. If they have interest, a permit would be obtained.

Since the waste pile is a permanent repository, restrictions on land use would have to be placed on the deed of the property.

Performance

This alternative offers protection for the spread of toxaphene and dinoseb contamination. It would be a permanent repository. Additional monitor wells would have to be placed around the pile. The vegetation on the cap would have to be established and maintained by mowing and filling in any erosional areas.

Reliability

Slow release of dinoseb, if there is any release, plus naturally occurring biodegradation in the vadose zone and within the waste pile itself will in time reduce the toxicity and volume of that contaminant.

The mobility of the toxaphene contaminant will be significantly eliminated by consolidating contaminated soil in one waste pile and containing it by covering it with clay, a geosynthetic cap, clean soil and vegetation.

Safety

This alternative can be constructed in a span of three months. One month is required for site preparation and two months for completion of the waste pile. It is during the completion of the waste pile that care will have to be taken to prevent dusting and airborne transport of the toxaphene. There is a potential for exposure to plant workers in the south plant of VCC.

There is very little chance that the dust could move off site. Dusting will be prevented by wetting the soil.

Implementability

This alternative would be implemented by first rerouting a portion of the South Plant Drainage Ditch. A section approximately 300 feet long would have to be excavated. The excavated soil would be placed in the existing ditch to help form a base for the soil pile. Then the relatively uncontaminated adjacent soil piles would be used to form a 700 foot by 90 foot by 0.5 foot base. The base and surrounding area would be sloped such that rainwater runoff would be diverted to the east. Drainage ditches and swales would be provided as necessary.

The first step is to move the adjacent contaminated oil piles atop the base. Next the soil piles atop the former toxaphene and dinoseb manufacturing areas would be moved to the engineered soil pile. Then the shallow surface soil would be excavated and moved to the new soil pile location. Approximately 5,400 cubic yards of clean fill would be placed in the excavations.

A soil cap would be constructed atop the soil pile. Approximately 1,400 cubic yards of clay would be placed and compacted to provide a six-inch clay cap. Next a geosynthetic liner and drainage layer would be placed. Then six inches of top soil would be established with 1,100 cubic yards of fill material.

As the soil pile is constructed, large chunks of concrete are removed and set aside to be used to cover the bottom slopes of the soil pile as a rip rap for erosion control.

Four monitor wells would be installed, one upflow and three downflow.

Cost

The capital cost of this alternative is $370,900. Details are presented in Table 4-3. The Present Value of the operating and maintenance costs for 30 years is $48,600. Details are presented in Table 4-4.

TABLE 4-3

COST ESTIMATE FOR ALTERNATIVE A-3
REMOVAL ACTION WITH CONTAINING GEOSYNTHETIC LINER AND SOIL CAP

• Mobilization	$5,000
• Clear and Grub 300' x 100' area for rerouting drainage ditch; (2,300 yd^2 @ $1.50/$yd^2$)	$4,950
• Excavate 300' x 10' x 5' new drainage ditch. Use soil excavated to fill old ditch; (560 yd^3 @ $2.50/$yd^3$)	$1,400
• Prepare 700' x 90' x 0.5' base of soil pile by using uncontaminated sections 20-GG, 20-HH, 20-JJ and 20-KK of existing piles; (1,200 yd^3 @ $1.50/$yd^3$)	$1,800
• Grade such that rainwater runoff will flow to the east (120 yd^3 @ $1.00/$yd^3$)	$1,200
• Move contaminated soil pile sections 20-II, 20-CC and 20-MM to soil pile; (1,000 yd^3 @ $1.50/$yd^3$)	$1,500
• Move contaminated soil pile sections 20-AA, 20-BB, 20-CC, 20-DD, 20-EE and 20-FF to soil pile by excavating, trucking, dumping and bulldozing; (1,800 yd^3 @ $3.50/$yd^3$)	$6,300
• Excavate contaminated soil areas surrounding former dinoseb and toxaphene manufacturing areas of SWMU 20 to 1.5 feet. Move by truck to soil pile, dump and bulldoze; (5,500 yd^3 @ $6.00/$yd^3$)	$33,000
• Separate all construction debris for utilization as rip rap on slope of pile after cap is constructed.	$10,000
• Excavate fill material from Vicksburg Site, truck to railroad area and use as compacted fill; (5,500 yd^3 @ $8.00/$yd^3$)	$44,000
• Install 60 mil HDPE liner with composite geonet drainage layer; (57,600 ft^2 @ $1.60/$ft^2$)	92,200
• Excavate fill material from Vicksburg Site, truck to soil pile and use as soil cap; (1,400 yd^3 @ $8.00/$yd^3$)	$11,200
• Excavate top soil from Vicksburg Site, truck to soil pile and place atop cap to establish vegetation; (1,100 yd^2 @ $8.00/$yd^3$)	$8,800
• Establish vegetation; (6,400 yd^2 @ $1.00/$yd^3$)	$6,400
• Install four monitor wells	$10,000
• Engineering and construction management services @ 20%	$47,550
• Contingency @ 30%	$85,600
Total	**$370,900**

TABLE 4-4 PRESENT VALUE OF OPERATING AND MAINTENANCE COSTS OF ALTERNATIVE A-3 FOR THIRTY YEARS	
• Sample wells semi-annually	$2,000
• Analyze four samples for toxaphene and dinoseb semi-annually	$2,000
• Inspect the soil cap monthly	$1,200
• Mow the grass 20 times	$2,000
• Annual cost	$7,000
Present Value @ 30 Years and 5% Interest = 7,000 (30)(0.2314)	**$48,600**

Alternative A-4; Removal Action with Complete Geosynthetic Liner and Soil Cap

This alternative involves consolidation of contaminated soil not meeting Corrective Action Objectives into one soil pile. The soil pile would be covered with a soil cap consisting of six inches of clay and a complete geosynthetic liner system with composite drainage layer would be installed to surround the pile. Six inches of topsoil would be added. The soil pile, which is depicted on Figure 3-1, would be constructed immediately to the southwest of the atrazine warehouse. The footprint of the soil pile is 650 feet by 75 feet by 15 feet high. Sides would be sloped 2:1. Grass would be grown n the soil pile. The location would be graded such that rainwater runoff would flow to the east. Silt fences would be placed in erosional pathways. A portion of the south plant drainage ditch would be re-routed. Access to the soil pile would be restricted.

Overall Protection of Human Health and the Environment

Alternative A-4 is protective of human health and the environment. The average concentration of toxaphene is 23,610 ppb and the average concentration of dinoseb is 88,445 ppb. The pathways of exposure to toxaphene are closed. Movement by erosion is controlled and leaching by rainwater is controlled. Even though the dinoseb concentration is below the MDEQ Tier I TRG Table value of 204,000 ppb, the dinoseb can be leached out. The addition of the complete geosynthetic liner system on the bottom, sides, and top seals off that potential.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations. Since the South Plant Drainage Ditch drains into Hennessey's Bayou, some Corps of Engineers permitting may be required. A meeting would be held with the Vicksburg Corps of Engineers to review appropriate maps and drawings and a decision will be requested as to their jurisdictional interest. If they have interest, a permit would be obtained.

Since the waste pile is a permanent repository, restrictions on land use would have to be placed on the deed of the property.

Performance

This alternative offers protection for the spread of toxaphene and dinoseb contamination. It would be a permanent repository. Additional monitor wells would have to be placed around the pile. The vegetation on the cap would have to be established and maintained by mowing and filling in any erosional areas.

Reliability

Slow dinoseb biodegradation within the waste pile itself will in time reduce the toxicity and volume of that contaminant.

The mobility of the toxaphene contaminant will be reduced by consolidating contaminated soil in one waste pile and containing it by enclosing it with clay, geosynthetic systems, and clean soil and vegetation.

Safety

This alternative can be constructed in a span of three months. One month is required for site preparation and two months for completion of the waste pile. It is during the completion of the waste pile that care will have to be taken to prevent dusting and airborne transport of the toxaphene. There is a potential for exposure to plant workers in the south plant of VCC.

There is very little chance that the dust could move off site. Dusting will be prevented by wetting the soil.

Implementability

This alternative would be implemented by first rerouting a portion of the South Plant Drainage Ditch. A section approximately 300 feet long would have to be excavated. The excavated soil would be placed in the existing ditch to help form a base for the soil pile. Then the relatively uncontaminated adjacent soil piles would be used to form a 700 foot by 90 foot by 0.5 foot base. The base and surrounding area would be sloped such that rainwater runoff would be diverted to the east. Drainage ditches and swales would be provided as necessary. A geosynthetic liner, drainage system, and clean fill would be placed as the bottom protection.

The next step is to move the adjacent contaminated oil piles atop the base. Next the soil piles atop the former toxaphene and dinoseb manufacturing areas would be moved to the engineered soil pile. Then the shallow surface soil would be excavated and moved to the new soil pile location. Approximately 5,400 cubic yards of clean fill would be placed in the excavations.

A soil cap would be constructed atop the soil pile. Approximately 1,400 cubic yards of clay would be placed and compacted to provide a six-inch clay cap. Next, a geosynthetic liner and drainage layer would be placed. Then six inches of top soil would be established with 1,100 cubic yards of fill material.

As the soil pile is constructed, large chunks of concrete are removed and set aside to be used to cover the bottom slopes of the soil pile as a rip rap for erosion control.

Four monitor wells would be installed, one upflow and three downflow.

Cost

The capital cost of this alternative is $397,700. Details are presented in Table 4-1. The Present Value of the operating and maintenance costs for 30 years is $48,600. Details are presented in Table 4-6.

TABLE 4-5

COST ESTIMATE FOR ALTERNATIVE A-4
REMOVAL ACTION WITH CONTAINING GEOSYNTHETIC LINER
ON BOTTOM AND TOP AND SOIL CAP

• Mobilization	$5,000
• Clear and Grub 300' x 100' area for rerouting drainage ditch; (2,300 yd^2 @ $1.50/$yd^2$)	$4,950
• Excavate 300' x 10' x 5' new drainage ditch. Use soil excavated to fill old ditch; (560 yd^3 @ $2.50/$yd^3$)	$1,400
• Prepare 700' x 90' x 0.5' base of soil pile by using uncontaminated sections 20-GG, 20-HH, 20-JJ and 20-KK of existing piles; (1,200 yd^3 @ $1.50/$yd^3$)	$1,800
• Grade such that rainwater runoff will flow to the east (1,200 yd^3 @ $1.00/$yd^3$)	$1,200
• Move contaminated soil pile sections 20-II, 20-CC and 20-MM to soil pile; (1,000 yd^3 @ $1.50/$yd^3$)	$1,500
• Move contaminated soil pile sections 20-AA, 20-BB, 20-CC, 20-DD, 20-EE and 20-FF to soil pile by excavating, trucking, dumping and bulldozing; (1,800 yd^3 @ $3.50/$yd^3$)	$6,300
• Excavate contaminated soil areas surrounding former dinoseb and toxaphene manufacturing areas of SWMU 20 to 1.5 feet. Move by truck to soil pile, dump and bulldoze; (5,500 yd^3 @ $6.00/$yd^3$)	$33,000
• Separate all construction debris for utilization as rip rap on slope of pile after cap is constructed	$10,000
• Excavate fill material from Vicksburg Site, truck to railroad area and use as compacted fill; (5,500 yd^3 @ $8.00/$yd^3$)	$44,000
• Install 60 mil HDPE liner with composite geonet drainage layer on bottom and top; (68,400 ft^2 @ $1.60/$ft^2$)	109,400
• Excavate fill material from Vicksburg Site, truck to soil pile and use as soil cap; (1,400 yd^3 @ $8.00/$yd^3$)	$11,200
• Excavate top soil from Vicksburg Site, truck to soil pile and place atop cap to establish vegetation; (1,100 yd^2 @ $8.00/$yd^3$)	$8,800
• Establish vegetation; (6,400 yd^2 @ $1.00/$yd^3$)	$6,400
• Install four monitor wells	$10,000
• Engineering and construction management services @ 20%	$50,990
• Contingency @ 30%	$91,780
Total	**$397,700**

TABLE 4-6 PRESENT VALUE OF OPERATING AND MAINTENANCE COSTS OF ALTERNATIVE A-4 FOR THIRTY YEARS	
• Sample wells semi-annually	$2,000
• Analyze four samples for toxaphene and dinoseb semi-annually	$2,000
• Inspect the soil cap monthly	$1,200
• Mow the grass 20 times	$2,000
• Annual cost	$7,000
Present Value @ 30 Years and 5% Interest = 7,000 (30)(0.2314)	**$48,600**

Alternative A-5; In-Situ Treatment by Composting Plus Iron Addition

This alternative consists of in-situ biodegradation. The contaminated soil exists in portions of the railroad area (SWMU 20) and in soil piles. With this alternative, biodegradation would be initiated by composting within the contaminated railroad areas. Contamination exists only to a depth of about 18 inches in the railroad area. When the contamination has met Corrective Action Objectives, then the same area will continue to be used as composting beds. The soil piles will be mixed with compost and placed atop the composting beds.

Overall Protection of Human Health and the Environment

Alternative A-5 is protective of human health and the environment. The concentration of toxaphene in the soil would be reduced until Corrective Action Objectives are met. The average concentration of dinoseb in the soil already meets Corrective Action Objectives. The long-term protection with this alternative is, therefore, excellent. In the short-term, during project execution, care will have to be taken to inhibit erosion, dusting, and leaching.

Silt fences will have to be installed to control erosion potential. The compost piles will have to be maintained in a moist condition to prevent dusting. During rainstorms there will be some leaching of dinoseb into rainwater runoff. Rainwater at the site is captured and pumped to the water impoundments. Water in the impoundments is pumped through activated carbon columns prior to discharges, under an NPDES permit, to the Mississippi River.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations. There is an existing Corrective Action Management Unit (CAMU) permit that allows for treatment by composting.

Performance

This alternative offers protection for the spread of toxaphene and dinoseb contamination by eliminating it. The solution would be permanent.

Reliability

The composting technology employed has been demonstrated in the literature and by VCC experience. It will be enhanced by the addition of zero valent iron and sodium lactate. Ultimately this alternative is very reliable in that toxaphene and dinoseb will be destroyed. The element of time is the potential "Achilles heel" of this alternative. Working through all the soil will take approximately three years.

During the three year time period diligent care will be have to be taken with regard to operation of the composting beds and short-term environmental concerns. The beds will have to be disced three times a week during aerobic cycles. During anaerobic cycles a tarpaulin will have to be placed and kept atop the composting beds. Silt fences will have to be maintained in place and drainage will have to be monitored.

Safety

This alternative will require three years to execute. During the entire three year period care will have to be taken to prevent dusting and airborne transport of the toxaphene. There is a potential for exposure to plant workers in the south plant of VCC. There is very little chance that the dust could move off site. Dusting will be prevented by monitoring and maintaining the moisture content of soil.

Implementability

There are no difficult operations associated with this alternative. What can, however, prove to be difficult is the element of time. Diligent effort to operate the composting beds will have to be made over a three year period.

The field verification testing will take place on grid location 20-F on Figure 3-2. The soil tested will be mixed 1:1 with soil from soil pile location 20-FF. The composite analysis of location 20-F is 1,078,018 ppb dinoseb and 10,318 ppb toxaphene. The composite analysis of location 20-FF is 130,675 ppb dinoseb and 76,683 ppb toxaphene. The 1:1 mixture will then be about 600,000 ppb dinoseb and 44,000 ppb toxaphene.

In order to implement the field test, four plots of soil, each 8 feet by 100 feet, are rototilled thoroughly to six inches on location 20-F. To each plot 15 cubic yards of soil (six-inch lift) from location 20-FF are spread as evenly as possible. Each of the plots is then rototilled thoroughly to a depth of 12 inches.

Once the soil from both sources is thoroughly mixed, the compost is added. The compost will consist of gin trash, 5% chicken manure, 5% fertilizer, and iron. A 6% solution of sodium lactate would be added. The ratio of soil to compost and the optimum operating conditions are obtained from the laboratory experimental results attached as Appendix A.

The full scale operation would be operated similarly to the pilot field test. There are 12 surface area grids (100' by 100') that require corrective action. In each of the grid areas soil would be rototilled to 18 inches deep in four beds 10 feet by 100 feet. Premixed compost would be added in an amount determined by optimization studies presented in Appendix A. The soil would be biodegraded to Corrective Action Objectives. The first episode will have treated 2,500 cubic yards. The second episode would commence by removing the treated soil and compost to 18 inches then adding new compost and 1,500 cubic yards of soil requiring treatment. Up to four more iterations of the same scenario would be required. The last soil to be treated would be left in place.

Cost

The capital cost of this alternative is $2,268,200. Details are presented in Table 4-7. There are no continuing operating and maintenance costs.

TABLE 4-7

COST ESTIMATE FOR ALTERNATIVE A-5
IN-SITU TREATMENT BY COMPOSTING PLUS IRON ADDITION

• Mobilization	$5,000
• Excavate in sections the contaminated surface soil areas surrounding former dinoseb and toxaphene manufacturing areas of SWMU 20 to 1.5 feet. Set to one side; (5,500 yd^3 @ $2.00/$yd^3$)	$11,000
• Purchase and prepare 11,000 yd^3 of compost plus iron; (11,000 yd^3 @ $35.00/$yd^3$)	$385,000
• Add compost and previously excavated contaminated soil to excavation space. Mix during addition; (16,500 yd^3 @ $2.00/$yd^3$)	$33,000
• Rototill 48 plots, each plot is 10' x 100'; (10 minutes/plot, 8 hours/day, 3 days/week, 26 weeks, $25.00/hour)	$15,600
• Excavate the plots to ground level only and truck to area needing fill; (11,000 yd^3 @ $4.00/$yd^3$)	$44,000
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and 2,500 yd^3 contaminated soil from soil piles. Mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill 48 plots, each plot is 10' x 100'; (10 minutes/plot, 8 hours/day, 3 days/week, 26 weeks, $25.00/hour)	$15,600
• Excavate the plots to ground level only and truck to area needing fill; (7,500 yd^3 @ $4.00/$yd^3$)	$30,000
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and second 2,500 yd^3 contaminated soil from soil piles. Mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill 48 plots, each plot is 10' x 100'; (10 minutes/plot, 8 hours/day, 3 days/week, 26 weeks, $25.00/hour)	$15,600
• Excavate the plots to ground level only and truck to area needing fill; (7,500 yd^3 @ $4.00 yd^3)	$30,000
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and third 2,500 yd^3 contaminated soil from soil piles. Mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill 48 plots, each plot is 10' x 100'; (10 minutes/plot, 8 hours/day, 3 days/week, 26 weeks, $25.00/hour)	$15,600
• Excavate the plots to ground level only and truck to area needing fill; (7,500 yd^3 @ $4.00/$yd^3$)	$30,000
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and third 2,500 yd^3 contaminated soil from soil piles. Mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill 48 plots, each plot is 10' x 100'; (10 minutes/plot, 8 hours/day, 3 days/week, 26 weeks, $25.00/hour)	$15,600
• Analysis for toxaphene; (48 plots, 2 analyses/plot, 5 episodes, $100.00/analysis)	$48,000
• Engineering and construction management services @ 20%	$290,800
• Contingency @ 30%	$523,400
Total	**$2,268,200**

Alternative A-6; In-Situ Treatment by Insertion of Fenton's Reagent

This alternative consists of in-situ chemical treatment. The contaminated soil exists in portions of the railroad area (SWMU 20) and in soil piles. With this alternative chemical treatment would be initiated by injecting Fenton's Reagent within the contaminated railroad areas and the soil piles. Contamination exists only to a depth of about 18 inches in the railroad area. Injections would continue until Corrective Action Objectives are met.

Overall Protection of Human Health and the Environment

Alternative A-6 is potentially protective of human health and the environment. The concentration of toxaphene in the soil would be reduced until Corrective Action Objectives are met. The average concentration of dinoseb in the soil already meets Corrective Action Objectives. During project execution, care will have to be taken to inhibit erosion, dusting, and runoff.

Silt fences will have to be installed to control erosion potential. The soil piles will be maintained in a moist condition to promote reaction and to prevent dusting. During rainstorms there will be some leaching of dinoseb into rainwater runoff. Rainwater at the site is captured and pumped to the water impoundments. Water in the impoundments is pumped through activated carbon columns prior to discharge, under an NPDES permit, to the Mississippi River.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations. There is an existing Corrective Action Management Unit (CAMU) permit that allows for treatment. The CAMU permit may have to be amended to specifically note the use of Fenton's Reagent (hydrogen peroxide and ferrous sulfate).

Performance

The effectiveness of Fenton's Reagent on toxaphene has not been established. It can be effective on chlorinated compounds but there is no data on toxaphene.

Reliability

The oxidation technology employed has been demonstrated in the literature. Its effectiveness of toxaphene has not been demonstrated.

The element of time is what is potentially attractive for this alternative. Previous experience (but not on toxaphene) indicates that treatment can be complete at three to six episodes of injections of Fenton's Reagent. The project would, therefore, be completed in a two- to three-month time frame.

Safety

This alternative will only require three months to implement. During that time period, problems of erosion and dusting can be dealt with.

Silt fences will have to be installed to control erosion potential. The compost piles will have to be maintained in a moist condition to prevent dusting. During rainstorms there will be some leaching of dinoseb into rainwater runoff. Rainwater at the site is captured and pumped to the water impoundments. Water in the impoundments is pumped through activated carbon columns prior to discharge, under an NPDES permit, to the Mississippi River.

During implementation of treatment by injection, great care will have to be taken that there is no direct exposure of hydrogen peroxide to anyone. The technicians handling the injection equipment will be properly protected to avoid potential direct exposure to hydrogen peroxide to any skin areas. Others there will be protected by roping off the areas and keeping everyone distant.

Implementability

Trailer-mounted remediation systems that use high-pressure, low-volume jetting systems to jet remediation agents into the subsurface for purposes of remediating contaminated soil or groundwater are recommended. In this alternative high pressure is not needed. The surface soil need only be treated to 18 inches and the soil piles have not been compacted.

Since jetting systems can use high pressure, there is typically no need for pre-drilling, pushing, or installation of temporary or permanent well points at most sites. In many

subsurface soils, jetting to 20 feet bgs can be accomplished in a matter of only a few minutes. After the jetting lance reaches the desired depth, the remediation agents are jetting into the treatment zone via a variety of specially-designed tips that distribute the remediation agents both radially and/or vertically. Sufficient jetting pressure can force the remediation agents outward into the soil or groundwater up to several feet from the point of jetting.

In jetting systems, the remediation agents, such as hydrogen peroxide and catalysts, are delivered to the site and then transferred from the product storage tanks into mixing tanks according to a pre-determined remediation "recipe." A gasoline-powered compressor powers the jetting system which jets the remediation solution into the subsurface soil and/or groundwater under high pressure through a specially designed jetting lance and tip system. The jetting lances come in various lengths, and can be connected in a series for deeper jetting.

The jetting lance is designed to rapidly jet through soils, including clays. The lance is less than one-inch in diameter, with specially designed jetting tips. Jetting ports on the tip allow high pressure (up to 20,000 psi), low volume (up to 20 gpm) jetting of remediation agents into the treatment zone. Depending on the application, tips with up to nine jetting ports can be used to inject remediation agents both vertically (downward) and radially in up to eight compass directions, effecting uniform distribution of remediation agents throughout the treatment zone. As the jetting lance jets downward from the top of the treatment zone to the terminal depth of the treatment zone, remediation agents are jetted laterally, thereby treating a cylindrically-shaped area. Typical radius of influence is on the order of two to ten feet, depending on the subsurface stratigraphy, jetting pressure, jetting volume, residence time, and other factors. Tightly-spaced and overlapping treatment "cylinders" result in effective remediation of the treatment zone with minimal "cold spots." Multiple treatment cycles are frequently used to effect remediation.

In the case of using Fenton's Reagent, jetting occurs in two steps. The first step involves the jetting of the ferrous sulfate catalyst, and if necessary, surfactant. At many sites, the surfactant solution will help increase the porosity of the treatment zone and help loosen any adsorbed contaminant within the soil or groundwater matrix. The second step involves the jetting of hydrogen peroxide through the same jetting holes into the treatment zone.

Cost

The capital cost of this alternative is $462,300. Details are presented on Table 4-8. There are no continuing operating and maintenance costs.

TABLE 4-8

COST ESTIMATE FOR ALTERNATIVE A-6
IN-SITU TREATMENT BY INJECTION OF FENTON'S REAGENT

• Mobilization of injection equipment; ($2,500.00/injection event)	$7,500
• High pressure jetting equipment; ($1,500.00/day, 5 days/event, 6 events)	$45,000
• Labor – field supervisor and 3 field technicians; ($1,750.00/day, 5 days/event, 6 events)	$52,500
• Labor – per diem and vehicle; ($450.00/day, 5 days/event, 6 events)	$13,500
• Personal protective equipment and expendable job materials	$6,800
• Inoculant costs; (4,500 gallons Ferrous Sulfate @ $6.00/gallon, 36,000 gallons hydrogen peroxide @ $4.00 gallon)	$171,000
• Engineering @ 20%	$59,300
• Contingency @ 30%	$106,700
Total	**$462,300**

Alternative A-7; Ex-Situ Treatment by Composting Plus Iron Addition

This alternative consists of ex-situ biodegradation. The contaminated soil exists in portions of the railroad area (SWMU 20) and in soil piles. With this alternative the soil would be moved to a separate location where biotreatment cells are established.

Overall Protection of Human Health and the Environment

Alternative A-7 is protective of human health and the environment. The concentration of toxaphene in the soil would be reduced until Corrective Action Objectives are met. The average concentration of dinoseb in the soil already meets Corrective Action Objectives. The long-term protection with this alternative is, therefore, excellent. In the short-term, during project execution, care will have to be taken to inhibit erosion, dusting, and leaching.

Silt fences will have to be installed to control erosion potential. The compost piles will have to be maintained in a moist condition to prevent dusting. During rainstorms there will be

some leaching of dinoseb into rainwater runoff. Rainwater at the site is captured and pumped to the water impoundments. Water in the impoundments is pumped through activated carbon columns prior to discharge, under an NPDES permit, to the Mississippi River.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations. There is an existing Corrective Action Management Unit (CAMU) permit that allows for treatment by composting.

Performance

This alternative offers protection for the spread of toxaphene and dinoseb contamination by eliminating it. The solution will be permanent.

Reliability

The composting technology employed has been demonstrated in the literature and by VCC experience. It will be enhanced by the addition of zero valent iron and sodium lactate. Ultimately this alternative is very reliable in that toxaphene and dinoseb will be destroyed. The element of time is the potential "Achilles heel" of this alternative. Working through all the soil will take approximately three years.

During the three year time period diligent care will be have to be taken with regard to operation of the composting beds and short-term environmental concerns. The beds will have to be disced three times a week during aerobic cycles. During anaerobic cycles a tarpaulin will have to be placed and kept atop the composting beds. Silt fences will have to be maintained in place and drainage will have to be monitored.

Safety

This alternative will require three years to execute. During the entire three year period care will have to be taken to prevent dusting and airborne transport of the toxaphene. There is a potential for exposure to plant workers in the south plant of VCC. There is very little chance that the dust could move off site. Dusting will be prevented by monitoring and maintaining the moisture content of soil.

Implementability

There are no difficult operations associated with this alternative. What can, however, prove to be difficult is the element of time. Diligent effort to operate the composting beds will have to be made over a three year period.

The field verification testing will take place on grid location 20-F on Figure 3-2. The soil tested will be mixed 1:1 with soil from soil pile location 20-FF. The composite analysis of location 20-F is 1,078,018 ppb dinoseb and 10,318 ppb toxaphene. The composite analysis of location 20-FF is 130,675 ppb dinoseb and 76,683 ppb toxaphene. The 1:1 mixture will then be about 600,000 ppb dinoseb and 44,000 ppb toxaphene.

In order to implement the field test, four plots of soil, each 8 feet by 100 feet, are rototilled thoroughly to six inches on location 20-F. To each plot 15 cubic yards of soil (six-inch lift) from location 20-FF are spread as evenly as possible. Each of the plots is then rototilled thoroughly to a depth of 12 inches.

Once the soil from both sources is thoroughly mixed, the compost is added. The compost will consist of gin trash, 5% chicken manure, 5% fertilizer, and iron. A 6% solution of sodium lactate would be added. The ratio of soil to compost and the optimum operating conditions are obtained from the laboratory experimental results attached as Appendix A.

The full scale operation would be set up by utilizing the bermed area atop the "Hill Area" of SWMU 2. The bermed area is depicted on Figure 3-3. The bottom surface area of the bermed area is 58,500 square feet. The entire quantity of soil not meeting Corrective Action Objectives could fit within the berms, if piled to a depth of 6.9 feet; however, the preferred method of treatment will be to treat soil in lifts of 18 inches. There will be five separate episodes of treatment. The first episode will begin by adding compost spread evenly into the bermed area. A lift of 18 inches of soil would be added and mixed thoroughly by rototilling with the compost. After degradation to Corrective Action Objectives, additional compost and another lift of contaminated soil would be added and rototilled. The same scenario would be carried out for a total of four to five iterations. When the last lift has degraded, the soil would be smoothed out and grassing vegetation would be established.

Cost

The capital cost of this alternative is $2,010,800. Details are presented in Table 4-8. There are no continuing operating and maintenance costs.

TABLE 4-9

COST ESTIMATE FOR ALTERNATIVE A-7
EX-SITU TREATMENT BY COMPOSTING PLUS IRON ADDITION

• Mobilization	$5,000
• Purchase and prepare 11,000 yd^3 of compost plus iron; (11,000 yd^3 @ $35.00/$yd^3$)	$385,000
• Add compost to bermed area atop the "Hill Area" of SWMU 2; (11,000 yd^3 @ $2.00/$yd^3$)	$22,000
• Excavate the contaminated surface: soil areas surrounding former dinoseb and toxaphene manufacturing areas of SWMU 20 to 1.5 feet. Truck to bermed area, mix with compost; (5,500 yd^3 @ $6.00/$yd^3$)	$33,000
• Excavate fill from Vicksburg Site, truck to railroad area and use as compacted fill (5,500 yd^3; @ $8.00/$yd^3$)	$44,000
• Rototill, 58,000 ft^2; (4 hours, 3 days/week, 26 weeks, $25.00/hour)	$7,800
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and 2,500 yd^3 contaminated soil from soil piles, mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill, 58,000 ft^2; (4 hours, 3 days/week, 26 weeks, $25.00/hour)	$7,800
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and second 2,500 yd^3 of contaminated soil from soil piles; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill, 58,000 ft^2; (4 hours, 3 days/week, 26 weeks, $25.00/hour)	$7,800
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and third 2,500 yd^3 of contaminated soil from soil piles. Mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill, 58,000 ft^2; (4 hours, 3 days/week, 26 weeks, $25.00/hour)	$7,800
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and fourth 2,500 yd^3 of contaminated soil from soil piles. Mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill, 58,000 ft^2; (4 hours, 3 days/week, 26 weeks, $25.00/hour)	$7,800
• Analyses for toxaphene (1 plot, 2 analyses/plot, 5 episodes, $100.00/analysis)	$1,000
• Engineering and Construction Management Services @ 20%q	$257,800
• Contingency @ 30%	$464,040
Total	**$2,010,800**

Alternative A-8; Off-Site Disposal in Landfill

This alternative involves movement of soil piles and surface soil to an off-site commercial landfill in Mississippi as a non-hazardous waste. The soil meets TCLP requirements as is, and is, therefore, not hazardous by characteristic. The specific source of contamination remains unknown. Although there can be speculation on the source or sources, there is no documentary evidence or incidence reports. The soil does contain hazardous constituents but may not be a listed hazardous waste. That decision, under this alternative, is left up to the USEPA and MSDEQ.

Overall Protection of Human Health and the Environment

Alternative A-8 is protective of human health and the environment. If this alternative is acceptable and could be implemented, it is protective of human health and the environment. Toxaphene is tightly bound to the soil. The average concentration of dinoseb in the soil already meets Corrective Action Objectives. The long-term protection with this alternative is, therefore, good. In the short-term, during project execution, care will have to be taken during the truck loading and transportation stage of work. Dusting and spillage are to be avoided.

As the soil is loaded into trucks or "tote bins" to be transported to the commercial landfill it will need to be kept moist to avoid dusting. During transportation the soil must be covered by a tarpaulin or other enclosing device.

Institutional

In order to exercise this alternative the USEPA and MSDEQ would have to make a determination that the contaminated soil is non-hazardous.

Performance

This alternative offers protection for the spread of toxaphene and dinoseb contamination. It would be a permanent repository. The commercial landfill facility would have a monitoring and maintenance program.

Reliability

The slow dinoseb biodegradation within the landfill itself will in time reduce the toxicity and volume of that contaminant. The mobility of the toxaphene contaminant will be substantially eliminated by consolidating the contaminated soil in one landfill as a permanent off-site repository.

Safety

This alternative can be implemented in a span of one month. During the excavation and loading and transportation, care will have to be taken to prevent dusting and airborne transport of the toxaphene. Dusting will be inhibited by wetting the soil during excavation. During transportation a tarpaulin or other enclosure will be placed atop the soil.

Implementability

This alternative involves excavation, loading, transportation, unloading and placement of soils. Backfilling of excavated shallow soil areas would be involved.

Dusting and spillage of contaminated soil must be avoided. All activities are routine soil handling operations.

Cost

The capital cost of this alternative is $1,216,000. See Table 4-10 for details. There would be no continuing maintenance and operating costs.

TABLE 4-10

COST ESTIMATE FOR ALTERNATIVE A-8
OFF-SITE DISPOSAL AND COMMERCIAL LANDFILL

• Mobilization	$5,000
• Excavate the contaminated surface soil areas surrounding former dinoseb and toxaphene manufacturing areas of SWMU 20 to 1.5 feet. Load onto 40 yd^3 waste bins; (5,500 yd^3 @ $6.00/$yd^3$)	$33,000
• Excavate fill from Vicksburg Site, truck to railroad area and use as compacted fill;	$44,000

TABLE 4-10

COST ESTIMATE FOR ALTERNATIVE A-8
OFF-SITE DISPOSAL AND COMMERCIAL LANDFILL

(5,500 yd^3 @ $8.00/$yd^3$)	
• Transport contaminated surface soil and soil piles to a commercial waste landfill. Note that the soil must not be considered to be a hazardous waste and the EPA and MSDEQ must agree; (15,500 yd^3 @ $45.00/$yd^3$)	$697,500
• Engineering and Construction Management Services @ 20%	$155,900
• Contingency @ 30%	$280,600
Total	**$1,216,000**

4.3 COMPARATIVE ANALYSIS OF ALTERNATIVES FOR SOIL CONTAMINATED WITH TOXAPHENE AND DINOSEB

The comparative analysis of all the factors noted in Section 4.2 is presented as Table 4-11.

TABLE 4-11

COMPARATIVE ANALYSIS OF ALTERNATIVES
FOR SOIL CONTAMINATED WITH
TOXAPHENE AND DINOSEB

Alternative	Overall Protection of Human Health & the Environment	Institutional	Performance	Reliability	Safety	Implementability	Cost	Total
A-2 Removal of Soil Cap	3	3	1	2	4	5	5	23
A-3 Removal with Cap of Geosynthetic & Soil	4	3	2	3	4	4	4	24
A-4 Removal with Complete Geosynthetic Liner & Soil Cap	4	3	2	3	4	4	4	24
A-5 In-Situ Treatment by Composting	5	4	5	4	3	3	3	27
A-6 In-Situ Treatment by Injection of Fenton's Reagent	5	3	2	4	4	4	4	26
A-7 Ex-Situ Treatment by Composting	5	4	5	4	3	3	3	27
A-8 Off-Site Disposal in Landfill	4	3	2	3	4	5	3	24

Legend: 5 = Highest Ranking
1 = Lowest Ranking

4.4 INDIVIDUAL ANALYSIS OF CORRECTIVE ACTION ALTERNATIVES FOR GROUNDWATER CONTAMINATED WITH DINOSEB, CHLOROFORM, CARBON TETRACHLORIDE, AND OTHER VOAs

Alternative B-1; No Action; Natural Attenuation Monitoring

This alternative involves no further corrective action. It does require continued monitoring and continued operation of the impoundment drainage trench. The plumes of interest are approximately 600 feet from the nearest point of the creek. There is a drainage layer or drainage trench constructed for dewatering during the lining of the surface impoundments. The drainage trench is located directly between the plumes and nearest point of the creek. It is depicted on Figure 3-4. The drainage trench does capture groundwater. The groundwater is pumped to the body of the surface impoundment and is treated directly by adsorption on carbon prior to discharge to the Mississippi River via an NPDES permit. Therefore, there is ongoing corrective action.

Overall Protection of Human Health and the Environment

This alternative provides for protection of human health and the environment. A portion of the dinoseb and VOA plume will not be picked up by the existing drainage trench; it will flow south toward Hennessey's Bayou. Modeling indicates that VOAs will not reach Hennessey's Bayou but will be retarded and degraded naturally. VCC experience indicates that dinoseb will also biodegrade. Two additional monitor wells will be used to verify natural attenuation assumptions.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations.

Performance

This alternative offers control of the dinoseb and VOA plumes and verification of the natural attenuation mechanism by monitoring. Continued operation of the existing drainage trench is a necessary part of adequate control.

Reliability

The slow biodegradation of dinoseb and VOAs moving toward Hennessey's Bayou will in time reduce the toxicity and volume. Continued operation of the trench drain will also reduce the toxicity and volume of dinoseb and VOAs. The captured groundwater is pumped to the surface impoundments. Water in the surface impoundments is pumped through activated carbon columns prior to discharge to the Mississippi River via an NPDES permit.

Safety

This alternative requires a minimum of corrective action effort. There is inherent safety associated with this alternative.

Implementability

The corrective action through collection of groundwater by the drainage layer will continue. In order to monitor natural attenuation two new permanent monitor wells will be constructed. Locations are provided on Figure 2-2 and Figure 2-3. The proposed locations are difficult to reach with a full-sized drilling rig without major preparatory bulldozer work; therefore, installation of one-inch diameter prepacked wells installed with a geoprobe are proposed.

Cost

The capital cost of this alternative is $15,000. See Table 4-13 for details. The present value of incremental operation and maintenance costs for 30 years is $24,300. See Table 4-13 for details. Continued operation of the drainage trench, surface impoundments, and activated carbon unit is not included since it would continue irrespective of this alternative.

TABLE 4-12

COST ESTIMATE FOR ALTERNATIVE B-1
NO ACTION, NATURAL ATTENUATION MONITORING

• Install two groundwater monitoring wells	$10,000
• Engineering @ 20%	$2,000
• Contingency @ 30%	$3,000
Total	**$15,000**

TABLE 4-13

PRESENT VALUE OF INCREMENTAL OPERATION AND MAINTENANCE COSTS OF ALTERNATIVE B-1 FOR 30 YEARS

• Sample wells semi-annually	$1,500
• Analyze two samples for dinoseb and VOAs semi-annually	$1,500
• Maintain wells	$500
• Annual cost	$3,500
Present Value @ 30 Years and 5% Interest = $3,500(3)(0.2314)	**$24,300**

Alternative B-2; In-Situ Treatment by Injection of Fenton's Reagent

This is an in-situ chemical treatment alternative. Fenton's reagent would be injected directly into the groundwater by high pressure jetting.

Overall Protection of Human Health and the Environment

This alternative provides for overall protection of human health and the environment. The dinoseb and VOAs are chemically destroyed by the free hydroxyl radical. The organic contaminant molecules are transformed to carbon dioxide, water, methane, and chloride salts.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations.

Performance

If sufficient number of injections are made, the dinoseb and VOAs will be destroyed. Another observation to be made is that "cross-communication" must be apparent. Cross-

communication is defined as the physical evidence (i.e., observation) that the jetting of remediation agents at one location is extending sufficiently in a lateral direction in the subsurface so as to intersect the adjacent jetting points.

Reliability

If sufficient injections are made and there is clearly observable overlap or cross-communication, then the treatment should be reliable. The problem associated with this type of system is that there is no way to reliably predict the number of injections or spacing of injections short of a full scale field trial.

Safety

This alternative would be implemented by a minimum of six episodes of injections spanning a probable period of at least three months. The key safety issue is avoidance of skin contact of hydrogen peroxide by technicians performing the injections. The skin contact can be avoided by careful selection of person protective equipment and by using only technicians with previous experience in the injection techniques.

Implementability

In jetting systems, the remediation agents, such as hydrogen peroxide and catalysts, are delivered to the site and then transferred from the product storage tanks into mixing tanks according to a predetermined remediation "recipe." A gasoline-powered compressor powers the jetting system which jets the remediation solution into the subsurface soil and/or groundwater under high pressure through a specially designed jetting lance and tip system. The jetting lances come in various lengths, and can be connected in a series for deeper jetting.

The jetting lance is designed to rapidly jet through subsurface soils, including clays. The lance is less than one inch in diameter, with specially designed jetting tips. Jetting ports on the tip allow high pressure (up to 20,000 psi), low volume (up to 20 gpm) jetting of remediation agents into the treatment zone. Depending on the application, tips with up to nine jetting ports can be used to inject remediation agents both vertically (downward) and radially in up to eight compass directions, effecting uniform distribution of remediation agents throughout the treatment zone.

Jetting to the top of the treatment zone is typically accomplished using fresh water (or remediation agents if the treatment zone is near the surface). Once the top of the treatment zone is encountered, jetting is accomplished with remediation agents. As the jetting lance jets downward from the top of the treatment zone to the terminal depth of the treatment zone, remediation agents are jetted laterally, thereby treating a cylindrically-shaped area. Typical radius of influence is on the order of two to ten feet, depending on the subsurface stratigraphy, jetting pressure, jetting volume, residence time, and other factors. Tightly-spaced and overlapping treatment "cylinders" result in effective remediation of the treatment zone with minimal "cold spots." Multiple treatment cycles are necessary to effect remediation.

In the case of using Fenton's Reagent, jetting occurs in two steps. The first step involves the jetting of the ferrous sulfate catalyst, and if necessary, surfactant. At many sites, the surfactant solution will help increase the porosity of the treatment zone and help loosen any adsorbed contaminant within the soil or groundwater matrix. The second step involves the jetting of hydrogen peroxide through the same jetting holes into the treatment zone.

Cost

The capital cost of this alternative with six treatment cycles is $715,000. Details are provided in Table 4-14. There are no continuing operation and maintenance costs.

TABLE 4-14

COST ESTIMATE FOR ALTERNATIVE B-2
IN-SITU TREATMENT BY INJECTION OF FENTON'S REAGENT

• Mobilization; (six times @ $2,500)	$15,000
• High pressure jetting equipment; (30,000 ft^2 treatment area, $1,500/day, 14 days/event, 6 events, 300 injections/event)	$126,000
• Labor – Field Supervisor and 3 Field Technicians; ($1,750/day, 14 days/event, 6 events)	$147,000
• Labor – per diem and vehicle; ($450/day, 14 days/event, 6 events)	$37,800
• Personal protective equipment and expendable job materials	$6,800
• Inoculant costs; (2,250 gallon ferrous sulfate @ $6.00/gallon, 18,000 gallons hydrogen peroxide @ $4.00/gallon)	$85,500
• Laboratory sampling and analytical costs – Install six prepackaged monitor wells for $20,000. Sample and analyze seven times for dinoseb and VOAs for $20,000	$40,000

• Engineering @ 20%	$91,600
• Contingency @ 30%	$165,000
Total	**$715,000**

Alternative B-3; Ex-Situ Treatment with Fenton's Reagent or Other Oxidation Technologies

This alternative involves capture and recovery of the plume with a trench drain. The recovered groundwater would be pumped to a vessel where it can be oxidized by addition of Fenton's Reagent or other oxidation technologies.

Overall Protection of Human Health and the Environment

This alternative provides for interception of the contaminant plume and chemical destruction of the contaminants prior to discharge to the surface impoundments. Water in the surface impoundments is again treated by pumping through activated carbon columns prior to discharge to the Mississippi River via an NPDES permit.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations.

Performance

This method of capture and treatment of contaminants is superior to in-situ injection of the same oxidation chemicals. The mixing of contaminants and oxidizing chemicals is more rigorous than relying on in-situ injection and mixing as in Alternative B-2. The disadvantage is that the interception of groundwater will take more time than a direct attack on the plume. On the other hand, this alternative would be completed more quickly than Alternative B-1, Natural Attenuation.

Reliability

The capture of groundwater in the trench over the prescribed area is routine and reliable technology. Continuing operation of the system plus the existing impoundment trench must also be assured in order to capture the entire contaminant plume.

The treatment itself can be counted on to be reliable. The oxidation of dinoseb and VOAs by the hydroxyl radical is proven technology. Mixing in an ex-situ reaction can assure good contact between oxidizing chemicals and contaminants.

Safety

This alternative employs well known techniques and can be safely implemented. A key safety concern is the storage, continuous pumping and reaction of hydrogen peroxides and the maintenance of the system.

Implementability

Groundwater recovery trenches have proven to be a highly effective, easy to implement, and cost-efficient method for recovering a wide range of dissolved and LNAPL contaminants from the subsurface. Trenches are particularly applicable in shallow aquifers where water tables are generally less than 15 feet and base of the aquifer is less than 40 feet. Trenches are also easily maintained and operational costs are generally lower than using multiple wells for groundwater recovery.

The recovered groundwater would be continuously pumped to a stirred vessel. Hydrogen peroxide and a solution of ferrous sulfate would be stored in 55-gallon drums. Metering pumps would pump hydrogen peroxide and ferrous sulfate to the stirred vessel. The vessel would continuously overflow to the surface impoundment.

Cost

The capital cost of this alternative is $231,000. Details are provided in Table 4-15. The present worth of operation and maintenance costs over a ten-year period is $389,000. Details are presented in Table 4-16.

TABLE 4-15

COST ESTIMATE FOR ALTERNATIVE B-3
EX-SITU TREATMENT WITH FENTON'S REAGENT OR OTHER OXIDATION TECHNOLOGIES

• Mobilization		$5,000
• Excavation for trench drain; 300' x 15' x 1.5'		$45,000
• Collection pipe; 300'		$6,000
• Collection sump; 15' x 3' diameter		$4,000
• Pump, piping and level control system		$6,000
• Backfill, including drainage sand		$4,000
• Treatment system		
- 100 gallon stainless steel reactor with agitator	$20,000	
- ferrous sulfate metering pump	$3,000	
- hydrogen peroxide metering pump	$3,000	
- foundation, electrical, instruments, piping	$52,000	$78,000
• Engineering @ 20%		$30,000
• Contingency @ 30%		$53,000
Total		**$231,000**

TABLE 4-16

PRESENT VALUE OF
OPERATION AND MAINTENANCE COSTS
OF ALTERNATIVE B-3
FOR 10 YEARS

• Chemical costs required over a ten-year treatment cycle; 4,500 gallons ferrous sulfate @ $6.00/gallon; 36,000 gallons hydrogen peroxide @ $4.00/gallon	$171,000
• Maintenance @ 10% capital each year for 10 years	$231,000
• Operation at 10% capital each year for 10 years	$231,000
Total	$633,000
Present Value @ 10 Years and 5% Interest = $633,000(0.6139)	**$389,000**

Alternative B-5; Ex-Situ Treatment with Carbon Adsorption

This alternative involves capture of the plume with a trench drain and pumping the groundwater to the surface impoundment. Water from the surface impoundment is treated by pumping through columns of activated carbon prior to discharge to the Mississippi River via an NPDES permit.

As previously noted, there is a drainage layer or drainage trench constructed for dewatering during the lining of the surface impoundments. The drainage trench is located directly between the plumes and the nearest point of the creek. It is depicted on Figure 3-4. The drainage trench does capture groundwater. The groundwater is pumped to the body of the surface impoundment and is treated directly by adsorption on carbon prior to discharge to the Mississippi River via an NPDES permit. This ongoing corrective action needs to be continued as part of the overall remedy.

The portion of the plume that flows south towards Hennessey's Bayou will be captured in a trench drain. The trench drain is depicted in Figure 3-5. The captured groundwater will be pumped to the surface impoundment.

Overall Protection of Human Health and the Environment

This alternative provides for interception of the contaminant plume and discharge to the surface impoundments. Water in the surface impoundments is again treated by pumping through activated carbon prior to discharge to the Mississippi River via an NPDES permit.

Institutional

This activity will be carried out under existing permit conditions and in compliance with appropriate regulations.

Performance

This method of capture and pumping to the surface impoundment for treatment by flowing through columns of activated carbon prior to discharge to the Mississippi River via an NPDES permit takes advantage of existing treatment systems and proven technology. A disadvantage is that the interception of groundwater will take time. On the other hand, this alternative would be completed more quickly than Alternative B-1, Natural Attenuation.

Reliability

The capture of groundwater in the trench over the prescribed area is routine and reliable technology. Continuing operation of the system plus the existing impoundment trench must also be assured in order to capture the entire contaminant plume.

The treatment itself can be counted on to be reliable. The wastewater treatment system consists of six vessels of activated carbon. The vessels are hydraulically too large for direct treatment of the groundwater but by pumping to the surface impoundment, it will be adequately treated prior to discharge to the Mississippi River.

Safety

This alternative employs well known techniques and an existing wastewater treatment system. There are no particular safety problems which would cause concern.

Implementability

Groundwater recovery trenches have proven to be a highly effective, easy to implement, and cost-efficient method for recovering a wide range of dissolved and LNAPL contaminants from the subsurface. Trenches are particularly applicable in shallow aquifers where water tables are generally less than 15 feet and the base of the aquifer is less than 40 feet. Trenches are also easily maintained and operational costs are generally lower than using multiple wells for groundwater recovery.

The recovered groundwater would be pumped to the surface impoundment and wastewater treatment system, both of which already exist.

Cost

The capital cost of this alternative is $109,000. Details are provided in Table 4-17. The present worth of operation and maintenance costs over a ten-year period is $156,200. Details are presented in Table 4-18.

TABLE 4-17 COST ESTIMATE FOR ALTERNATIVE B-5 EX-SITU TREATMENT WITH CARBON ADSORPTION	
• Mobilization	$5,000
• Excavation for trench drain; 300' x 15' x 1.5'	$45,000
• Collection pipe; 300'	$6,000
• Collection sump; 15' x 3' diameter	$4,000
• Pump, piping and level control system	$6,000
• Backfill, including drainage sand	$4,000
• Engineering @ 20%	$14,000
• Contingency @ 30%	$25,000
Total	**$109,000**

TABLE 4-18 PRESENT VALUE OF INCREMENTAL OPERATION AND MAINTENANCE COSTS OF ALTERNATIVE B-5 FOR 10 YEARS	
• Carbon consumed over a ten-year period; 10 pounds per day @ $1.00/pound	$36,500
• Maintenance @ 10% capital each year for 10 years	$109,000
• Operation at 10% capital each year for 10 years	$109,000
Total	**$254,500**
Present Value @ 10 Years and 5% Interest = $254,500(0.6139)	**$156,200**

4.5 COMPARATIVE ANALYSIS OF ALTERNATIVES FOR GROUNDWATER CONTAMINATED WITH DINOSEB AND VOAs

The comparative analysis of all the factors noted in Section 4.4 is presented as Table 4-19.

TABLE 4-19

COMPARATIVE ANALYSIS OF ALTERNATIVES FOR GROUNDWATER CONTAMINATED WITH DINOSEB AND VOAs

Alternative	Overall Protection of Human Health & the Environment	Institutional	Performance	Reliability	Safety	Implementability	Cost	Total
B-1 No Action; Natural Attenuation	4	4	3	4	5	5	5	30
B-2 In-Situ Treatment with Fenton's Reagent	4	3	4	4	3	3	3	24
B-3 Ex-Situ Treatment with Fenton's Reagent	5	4	5	4	3	4	3	28
B-5 Ex-Situ Treatment with Carbon Adsorption	5	5	5	5	5	4	4	33

Legend: 5 = Highest Ranking
1 = Lowest Ranking

Alternative C-1; In-Situ Treatment with Injection of Precipitating Agents

This alternative involves injection of chemicals directly into the shallow zone of the groundwater aquifer. The objective is to cause precipitation of arsenic and adherence of that arsenic to subsurface media. Injection of a slurry of zero valent iron or injection of Fenton's Reagent (hydrogen peroxide and ferrous sulfate) is intended to achieve that objective. The injection tool is a wand with multiple injection jets at the end. The jets can be modified to accommodate the particular innoculant. Upwards of 20,000 psi can be generated at the jet tips to allow horizontal penetration by jetting fissures in the formation as the wand is moved vertically from 10 feet bgs to 20 feet bgs.

Overall Protection of Human Health and the Environment

This alternative provides for protection of human health and the environment. The chemistry of the process is that the arsenic will precipitate subsurface as ferric-arsenate complex and/or are adsorbed onto an amorphous iron oxyhydroxide. The effectiveness of overall protection

is initially dependent on good contact subsurface during injection and resultant precipitation and/or adherence of the arsenic onto the subsurface media. While in the short term this alternative may work as intended by multiple injections and multiple injection events, there is no projection of effectiveness in the long term as fresh groundwater slowly intrudes into the formation. Arsenic may resolubilize.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations.

Performance

The merit of this alternative is the potential that it will be a "fix" in a short period of time, that is, a few months. As noted previously, long term performance is questionable. There is potential for arsenic to resolubilize into the groundwater stream.

Reliability

The intent of this alternative is to reduce the mobility of arsenic. There is no reduction in volume or toxicity. While the mobility can effectively be reduced in the short term, the reduction may in time be reversible.

Safety

This alternative would be safe to implement. The technicians implementing the injections would be adequately prepared with personal protective equipment such that all contact of hydrogen peroxide with skin is avoided. The technicians would all have previous experience with the injection equipment.

Implementability

Jetting of remediation agents can be accomplished at many sites to depths of 30 feet. Jetting is usually performed under high pressure and at low volume using specially designed jetting lances and tips that can jet remediation agents at pressures ranging from 500 to up to 20,000 psi. Flow rates can range from 1 to 20 gpm. The high pressure can be sufficient to fracture

soils event with low permeability, and to overcome ground pressures in the areas of treatment of up to several feet from the vertical point of jetting. Once the soil is fractured, the remediation agents are effectively dispersed into the contaminated soil and/or water matrix.

In many subsurface soils, jetting to 20 feet bgs can be accomplished in a matter of only a few minutes. After the jetting lance reaches the desired depth, the remediation agents are jetting into the treatment zone via a variety of specially-designed tips that distribute the remediation agents both radially and/or vertically. Sufficient jetting pressure can force the remediation agents outward into the soil or groundwater up to several feet from the point of jetting. At the source of the arsenic plume there will be a need to predrill through concrete areas and install temporary well points. A gasoline-powered compressor powers the jetting system which jets the remediation solution into the subsurface soil and/or groundwater under high pressure through a specially designed jetting lance and tip system. The jetting lance is designed to rapidly jet through subsurface soils, including clays. The lance is less than one inch in diameter, with specially designed jetting tips. Jetting ports on the tip allow high pressure (up to 20,000 psi), low volume (up to 20 gpm) jetting of remediation agents into the treatment zone. Tips with up to nine jetting ports can be used to inject remediation agents both vertically (downward) and radially in up to eight compass directions, effecting uniform distribution of remediation agents throughout the treatment zone.

In the case of using Fenton's Reagent, jetting occurs in two steps. The first step involves the jetting of the ferrous sulfate catalyst, and if necessary, surfactant. At many sites, the surfactant solution will help increase the porosity of the treatment zone and help loosen any adsorbed contaminant within the soil or groundwater matrix. The second step involves the jetting of hydrogen peroxide through the same jetting holes into the treatment zone.

Jetting to the top of the treatment zone is typically accomplished using fresh water (or remediation agents if the treatment zone is near the surface). Once the top of the treatment zone is encountered, jetting is accomplished with remediation agents. As the jetting lance jets downward from the top of the treatment zone to the terminal depth of the treatment zone, remediation agents are jetted laterally, thereby treating a cylindrically-shaped area. Typical radius of influence is on the order of two to ten feet, depending on the subsurface stratigraphy, jetting pressure, jetting volume, residence time, and other factors. Tightly-spaced and overlapping treatment "cylinders" result in effective remediation of the treatment zone with minimal "cold spots." Multiple treatment cycles are necessary to effect remediation.

Cost

The capital cost of this alternative is $1,335,000. Details are presented in Table 4-20. There are no continuing operation and maintenance costs.

TABLE 4-20

COST ESTIMATE FOR ALTERNATIVE C-1
IN-SITU TREATMENT WITH INJECTION OF PRECIPITATING AGENTS

• Mobilization; (six times @ $2,500)	$15,000
• High pressure jetting equipment; (84,000 ft^2 treatment area, $1,500.00/day, 28 days/event, 6 events, 600 injections/event)	$252,000
• Labor – Field Supervisor and 3 Field Technicians; ($1,750.00/day, 28 days/event, 6 events)	$294,000
• Labor – Per diem and vehicle; ($450.00/day, 28 days/event, 6 events)	$75,600
• Personal protective equipment and expendable job materials	$13,600
• Innoculant cost; (6,300 gallons ferrous sulfate @ $6.00/gallon, 50,400 gallons hydrogen peroxide @ $4.00/gallon)	$239,400
• Engineering @ 20%	$178,000
• Contingency @ 30%	$267,000
Total	**$1,335,000**

Alternative C-2; Ex-Situ Treatment by Precipitation/Flocculation/Settlement

This alternative involves capture of the plume with a trench drain. The recovered groundwater would be discharged to a reactor where a precipitation chemical would be added. Reactor contents would be pumped to a clarifier where flocculants would be added and the arsenic precipitant then through a polish filter into the surface impoundment. The clarified stream would be pumped through a separate polish filter into the surface impoundment. The accumulated arsenic would be disposed at a commercial waste landfill. The surface impoundment is discharged through activated carbon columns into the Mississippi River via an NPDES permit.

Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment. Movement of the arsenic plume is stopped by construction of the trench drain to intercept the groundwater. The pathway to the environment is, therefore, broken.

Once the groundwater is intercepted it has to be adequately treated so as not to open up another pathway caused by discharge of the groundwater. The pathway is kept closed by precipitating the arsenic and removing the filter cake. The filter cake is properly disposed at a hazardous waste landfill.

Institutional

This alternative will be implemented under existing permit conditions and in compliance with appropriate regulations. One permit of particular applicability is the NPDES permit. The groundwater will be treated to MCL levels prior to discharge to the surface impoundments. Water in the surface impoundments is treated by pumping through activated carbon columns prior to discharge to the Mississippi River via an NPDES permit.

Performance

The trench drain will effectively intercept the flow of the arsenic plume. The trench will be constructed at the source of the plume where apparent historic arsenic spillage occurred. The intent is not only to block and intercept arsenic plume flow but also to remove the arsenic at the source. The alternative will have to be maintained and operated for several years.

The treatment of the intercepted groundwater is also implemented with proven technology. The long-term performance is expected to be good.

Reliability

Implementation of this alternative results in the reduction of the mobility and volume of arsenic. The solution is permanent. The arsenic is removed from the environment, stabilized, and placed in a permitted, secure hazardous waste landfill.

Safety

Construction of this alternative will have to proceed by paying attention to and adhering to standard safety precautions. The trenching will be done in a former process area. Probing for obstructions will have to precede the excavation. When the trench is excavated any

necessity to enter the trench to construct the collection piping or collection sump will have to be done in adherence to shoring requirements of OSHA.

Construction of the treatment system itself is standard process plant construction to be carried out by experienced craftsmen.

Implementability

A trench must be capable of lowering the water table 50 percent of the saturated thickness of the uppermost water bearing unit. Therefore, the minimum trench depth should be at least the depth to the water table plus one-half the saturated thickness of the upper water bearing zone. Generally, the practical depth limitations for trenches are static water levels of 15 feet or less and depth to base of the aquifer of 40 feet or less.

The most important factor to life of the trench is the selection of the material selected for use in the filter pack placed between the natural sediments and the collection lateral. A common mistake is to use too large of a filter pack material such as crushed rock or gravel. Fine grained sediments of the formation will tend to migrate between the "large" filter material and plug the filter pack.

Selection of a filter pack material comprised of a clean washed fine quartz sand close to the mean grain size of the formation material or slightly larger is recommended. The permeability of any clean fine quartz sand will usually be many times greater than the formation. A minimum of six inches of filter pack material is recommended below and beside the lateral to separate the formation from the collection lateral. The height of the sand pack may extend any length above the lateral, however, the depressed water level at steady state will most likely be only a few feet above the lateral. Extending the filter pack to the static water level is generally not necessary. The use of geomembranes is generally not necessary and may cause plugging if not selected or installed properly.

Although it is not absolutely necessary to install a collection lateral in the filter pack material, it is highly recommended for a number of reasons. The lateral is much less likely to "plug" as compared to the filter pack without the lateral.

Another advantage of a collection lateral is the installation of an "S" trap to keep the lateral constantly saturated. It is important not to entirely dewater the filter pack in order to minimize the potential for bacterial (algae) growth in the filter pack.

Very little maintenance is required for a properly constructed infiltration trench system. A large diameter sump is recommended to provide ample storage of water to minimize cycling of the sump pump. A 3- or 4-foot diameter reinforced concrete pipe with manhole cover and built-in ladder has proven to be useful. On-off levels for the pump can be set with float switches or transducers calibrated to measure water levels.

Groundwater would be continuously removed from the interceptor trench at a rate of 0.1 gpm and pumped to a continuously stirred 10-gallon reactor. There would additionally be pumped to the reactor 0.0015 gph of 22% caustic, 0.21 gph of pickle liquor (byproduct of steel mills with 87,000 ppm iron content), and 0.18 gph of 5% hydrogen peroxide. Residence time for oxidation of arsenic (III) and organoarsenicals to arsenic (V) is 30 minutes at pH 2.5.

The reactor contents are continuously removed on level control to an aeration reactor where the precipitation, adsorption, and coprecipitation of oxidized arsenic is completed by aerating for another 30 minutes with an air sparge under a pH of 7.5. The pH of 7.5 is achieved by continuous addition of another 0.0015 gph caustic.

The aerator contents are continuously removed on level control to a 20-gallon settling tank. Anionic polymeric flocculant is metered into the tank at 0.01 cc per hour. Settling residence time in the tank is 120 minutes. The insoluble ferric-arsenate precipitant adsorbed onto the iron settles out in the floc. Solids are removed in a filter via a circulation loop with the pump suction at the bottom of the settling tank. Filtered water is discharged back to the settling tank. Clean water is continuously removed under level control and pumped to the wastewater pond to eventually be discharged to the Mississippi River via the site NPDES permit. The clean water will contain less than 10 ppb arsenic. Contents of the filter are removed once per month and placed in two 55-gallon drums for disposal in an offsite commercial landfill.

The following are the key parameters for the design:

- Fe/As ratio – 10/1
- Hydrogen peroxide/Fe ratio – 1/2

- Residence time for initial oxidation at pH 2.5 = 30 minutes
- Residence time for aeration at pH 7.5 – 30 minutes
- Residence time for settling – 120 minutes

Cost

The capital cost of this alternative is $242,000. Details are presented in Table 4-21. The present value of operation and maintenance costs for 10 years at 5% interest is $445,300. Details are presented in Table 4-22.

TABLE 4-21

COST ESTIMATE FOR ALTERNATIVE C-2
EX-SITU TREATMENT BY PRECIPITATION/FLOCCULATION/SETTLEMENT

• Mobilization		$5,000
• Concrete removal in trench drain area		$5,000
• Excavation for trench drain; (30' x 15' x 1.5')		$4,500
• Collection pipe; 30'		$1,000
• Collection sump; 15' x 3' diameter		$4,000
• Pump, piping and level control system		$6,000
• Backfill, including drainage sand		$500
• Treatment system		
- 10 gallon stainless steel reactor with agitator	$6,000	
- 10 gallon stainless steel aeration tank with aeration style agitator	$6,000	
- 50 gallon settling tank	$5,000	
- filter, 8 ft^2 filtering area, 4" cake	$11,000	
- ferrous sulfate metering pump	$2,500	
- Hydrogen peroxide metering pump	$2,500	
- Caustic metering pump	$2,500	
- A__ polymeric flocculant metering pump	$2,500	
- F___ co____ pumps	$5,000	
- Foundation, electrical, instruments, piping	$86,000	$129,000
• Engineering @ 20%		$31,000
• Contingency @ 30%		$56,000
Total		**$242,000**

TABLE 4-22 PRESENT VALUE OF OPERATION AND MAINTENANCE COSTS OF ALTERNATIVE C-2 FOR 10 YEARS	
• Chemical cost over 10 years; 6,300 gallons ferrous sulfate @ $6.00/gallon, 50,400 gallons hydrogen peroxide @ $4.00/gallon	$239,400
• Transportation and disposal of arsenic	$2,000
• Operation at 10% capital for 10 years	$242,00
• Maintenance at 10% maintenance for 10 years	$242,00
Total	**$725,400**
Present Value @ 10 Years and 5% Interest = $725,400(0.6139)	**$445,300**

Alternative C-4; Ex-Situ Treatment by Phytoremediation

This alternative involves capture of the plume with a trench drain. The recovered groundwater would be discharged to a hydroponic bed of ladder brake ferns. Overflow from the hydroponic bed would be pumped to the surface impoundment. Contents of the surface impoundment would be discharged to the Mississippi River through activated carbon columns via an NPDES permit. Fern fronds would be periodically harvested, dried, and disposed in a hazardous waste landfill.

Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment. Movement of the arsenic plume is stopped by construction of the trench drain to intercept the groundwater. The pathway to the environment is, therefore, broken.

Once the groundwater is intercepted it has to be handled and in a manner that will not open up another pathway of potential exposure. In this alternative the pathway is kept closed by pumping the captured groundwater to several hydroponic beds of ladder break ferns. The ferns hyperaccumulate arsenic. The treated groundwater would flow to the surface impoundments and would be pumped through activated carbon beds prior to discharge to the Mississippi River via an NPDES permitted outfall. There is, of course, potential exposure to

arsenic in the hydroponic bed areas. Care will have to be taken by those who maintain the beds.

Reliability

Implementation of this alternative results in the reduction of the mobility and volume of arsenic. The solution is permanent. The arsenic is removed from the environment with the ferns, the ferns are dried, stabilized, and placed in a permitted, secure hazardous waste landfill.

Safety

Construction of this alternative will have to proceed by paying attention to and adhering to standard safety precautions. The trenching will be done in a former process area. Probing for obstructions will have to precede the excavation. When the trench is excavated any necessity to enter the trench to construct the collection piping or collection sump will have to be done in adherence to shoring requirements of OSHA.

Construction of the treatment system itself involves standard process plant construction to be carried out by experienced craftsmen.

Operation of the treatment system will require care in order to avoid potential skin contact with arsenic. Both the water and the fern fronds will contain high concentrations of arsenic.

Institutional

This alternative will be implemented under existing permit conditions and in compliance with appropriate regulations. One permit of particular applicability is the NPDES permit. The groundwater will be treated to MCL levels prior to discharge to the surface impoundments. Water in the surface impoundments is treated by pumping through activated carbon columns prior to discharge to the Mississippi River via an NPDES permit.

Performance

The trench drain will effectively intercept the flow the arsenic plume. The trench will be constructed at the source of the plume where apparent historic arsenic spillage occurred. The

intent is not only to block and intercept arsenic plume flow but also to remove the arsenic at the source. The alternative will have to be maintained and operated for several years.

The treatment of the intercepted groundwater by phytoremediation; that is, pumping the groundwater to hydroponic beds of ladder brake ferns has been tested in the laboratory. Extrapolation of the available data lead to the conclusion that with enough time and enough ferns the MCL for arsenic in groundwater can be met. The residence time is 140 days. After 140 days exposure, 72 pounds of ferns is required per pound of arsenic accumulated.

A trench must be capable of lowering the water table 50 percent of the saturated thickness of the uppermost water bearing unit. Therefore, the minimum trench depth should be at least the depth to the water table plus one-half the saturated thickness of the upper water bearing zone. Generally, the practical depth limitations for trenches are static water levels of 15 feet or less and depth to base of the aquifer of 40 feet or less.

The most important factor to life of the trench is the selection of the material selected for use in the filter pack placed between the natural sediments and the collection lateral. A common mistake is to use too large of a filter pack material such as crushed rock or gravel. Fine grained sediments of the formation will tend to migrate between the "large" filter material and plug the filter pack.

Selection of a filter pack material comprised of a clean washed fine quartz sand close to the mean grain size of the formation material or slightly larger is recommended. The permeability of any clean fine quartz sand will usually be many times greater than the formation. A minimum of 6 inches of filter pack material are recommended below and beside the lateral to separate the formation from the collection lateral. The height of the sand pack may extend any length above the lateral, however, the depressed water level at steady state will most likely be only a few feet above the lateral. Extending the filter pack to the static water level is generally not necessary. The use of geomembranes is generally not necessary and may cause plugging if not selected or installed properly.

Although it is not absolutely necessary to install a collection lateral in the filter pack material, it is highly recommended for a number of reasons. The lateral is much less likely to "plug" as compared to the filter pack without the lateral.

Another advantage of a collection lateral is the installation of an "S" trap to keep the lateral constantly saturated. It is important not to entirely dewater the filter pack in order to minimize the potential for bacterial (algae) growth in the filter pack.

Very little maintenance is required for a properly constructed infiltration trench system. A large diameter sump is recommended to provide ample storage of water to minimize cycling of the sump pump. A 3- or 4-foot diameter reinforced concrete pipe with manhole cover and built-in ladder has proven to be useful. On-off levels for the pump can be set with float switches or transducers calibrated to measure water levels.

Groundwater would be continuously removed from the interceptor trench at a rate of 0.1 gpm and pumped to the system consisting of 21 cells in series.

At start-up, the first cell would be filled with 1,000 gallons of arsenic groundwater and the other cells would each be filled with 1,000 gallons of potable water. Each cell would contain 400 ferns and appropriate fertilizer. Water from cell 21 would be discharged to the drainage system leading to the surface impoundment.

On a monthly basis, a sample of fronds in cell 1 and water discharge from cell 21 would be analyzed for arsenic. The water discharge would have to remain below 10 ppb. The fronds in cell 1 would increase in arsenic concentration.

When the arsenic concentration of the fronds in cell 1 has increased to 7,500 ppm, they are ready for harvesting. At this time, the supply stream of 0.1 gpm arsenic contaminated groundwater is diverted to cell 2. When fronds are harvested in cell 1, the water in cell 1 is pumped with a temporary pump to cell 2. Potable water is introduced to cell 1. Then the discharge from cell 21 is diverted to the drainage system. The fronds in cell 2 and discharge of water from cell 1 would be monitored on a monthly basis. This same pattern would be continued for about 8.6 to 10 years.

Cost

The capital cost of this alternative is $1,307,000. Details are presented in Table 4-23. The present value of operation and maintenance costs for 10 years at 5% interest is $802,000. Details are presented in Table 4-24.

TABLE 4-23

COST ESTIMATE FOR ALTERNATIVE C-4
EX-SITU TREATEMENT BY PHYTOREMEDIATION

• Mobilization		$5,000
• Concrete removal in trench drain area		$5,000
• Excavation for trench drain; (30' x 15' x 1.5')		$4,500
• Collection pipe; 30'		$1,000
• Collection sump; 15' x 3' diameter		$4,000
• Pump, piping and level control system		$6,000
• Backfill, including drainage sand		$500
• Treatment system		
- 21 troughs, plastic construction 1,400 gallons each	$105,000	
- Foundation, electrical, instruments, piping, green house roof and walls. Constructed on former MSMA plant structures	$210,000	$315,000
• Engineering @ 20%		$68,000
• Contingency @ 30%		$123,000
Total		**$532,000**

TABLE 4-24

PRESENT VALUE OF OPERATION AND MAINTENANCE COSTS
OF ALTERNATIVE C-4
FOR 10 YEARS

• Cost of 54,00 plants at $4.50/plant	$243,000
• Operation at 10% capital for 10 years	$532,000
• Maintenance at 10% capital for 10 years	$532,000
Total	**$1,307,000**
Present Value @ 10 Years and 5% Interest = $1,307,000(0.6139)	**$802,000**

4.6 COMPARATIVE ANALYSIS OF ALTERNATIVES FOR GROUNDWATER CONTAMINATED WITH ARSENIC

The comparative analysis of all the factors noted in Section 4.6 is presented as Table 4-25.

TABLE 4-25
COMPARATIVE ANALYSIS OF ALTERNATIVES
FOR GROUNDWATER CONTAMINATED WITH ARSENIC

Alternative	Overall Protection of Human Health & the Environment	Institutional	Performance	Reliability	Safety	Implementability	Cost	Total
C-1 In-Situ Treatment with Injection of Precipitating Agents	3	3	3	2	3	4	3	21
C-2 Ex-Situ Treatment by Precipitation/Flocculation/ Settling	5	5	5	5	4	3	4	31
C-4 Ex-Situ Treatment by Phytoremediation	4	4	4	3	3	3	3	24

Legend: 5 = Highest Ranking
1 = Lowest Ranking

lbutler

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March 22, 2002

Ms. Lael H. Butler
U.S. EPA
Region 4
Atlanta Federal Center
61 Forsyth Street, S.W.
Atlanta, Georgia 30303-8960

Re: Progress Report
Corrective Measures Study
Vicksburg Chemical, DIP
URS File No. 35-092B007C.00-03007

2002 MAR 26 P 3:47

Dear Lael:

I have sent this at the direction of Steve Boswell for your review. It is the first draft of the first three sections of the Corrective Measures Study (CMS). The first three sections lead to proposed Corrective Action Alternatives.

The first three sections contain assumptions which will be modified as work progresses. One of the next important pieces of work is to gain information from laboratory studies. Suggestions on laboratory work are noted in Tables A, B, and C which are attached to this cover letter. Vicksburg Chemical, DIP would like to obtain an informal sense of correct direction or suggestions for modification from you. At this time the future of operations at the Vicksburg site is under deliberative review by senior management and lending institutions; both, of course, are aware of the environmental responsibilities.

Section One, the Introduction to the CMS, was obtained directly from the Groundwater Assessment Report.

Section Two, the Identification and Development of CMS Technologies, is an important section. In Subsection 2.1, the Corrective Action Objective is stated for soil to be to meet background or MDEQ Tier 1 TRG Table ***restricted*** values in the event there is an actual or potential pathway for exposure. The Corrective Action Objective for groundwater is stated to be to meet MDEQ Tier 1 TRG Table values at the Point of Exposure which is defined to be Hennessey's Bayou. In Subsection 2.2, Description of Current Situation, the areas requiring corrective action are defined for soil and groundwater. By modeling corrective action is focused on three areas:

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DEC-03D

A. Soil in SWMU 20 – limited to that in surface soil and soil piles that do not meet Corrective Action Objectives.

B. Groundwater in the SWMU 20 source area; that is, the dinoseb and VOA plumes.

C. Groundwater in the SWMU 11, 12, 15 source area; that is, the arsenic plume.

In Subsection 2.3, pertinent technologies are listed and screened in formalized Corrective Measures Study format and reduced in two steps (presented in tables) to a retained list. For example, the original list has technologies such as thermal treatment which is then screened out because of lack of public acceptance.

Section Three, Identification of CMS Alternatives, is where alternatives for the three areas noted above are formulated from the technologies retained in Section Two. Eight alternatives were formulated for "A" in Subsection 3.1, five for "B" in Subsection 3.2, and four for "C" in Subsection 3.3. The pilot effort is part of the implementation. Subsections 3.4, 3.5, and 3.6 are discussions of effectiveness, implementability and relative cost for each of the alternatives. Effectiveness, implementability and relative cost were briefly noted within the screening tables (2-1A through 2-1I) for the technologies.

The following are the proposed Corrective Action Alternatives that survive the screening in Subsections 3.4, 3.5, and 3.6:

SOIL CONTAMINATED BY TOXAPHENE

A-2; Removal and Soil Cap
Construct a consolidated soil pile and add a soil cap plus vegetation.

A-3; Removal with Cap of Geosynthetics and Soil
Construct a consolidated soil pile and add a cap of geosynthetics and soil plus vegetation.

A-4; Removal with Complete Geosynthetic Lining and Soil Cap
Construct a consolidated soil pile atop a geosynthetic liner. Cap is constructed of geosynthetics and soil plus vegetation.

A-5; In-Situ Treatment by Composting Plus Iron Addition
Add compost and iron to surface soil. In time add the soil piles.

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A-6; In-Situ Treatment by Injection of Fenton's Reagent
Inject hydrogen peroxide and ferrous sulfate into surface soil and soil piles.

A-7; Ex-Situ Treatment by Composting Plus Iron
Move soil piles and surface soil to location on-site and set up biotreatment cells.

A-8; Offsite Disposal in Landfill
A viable alternative only if soil can be considered by the EPA and MSDEQ to be non-hazardous.

GROUNDWATER CONTAMINATED BY DINOSEB AND VOAS

B-1; No Action, Natural Attenuation Monitoring
Continue operation of drainage layer. Natural attenuation monitoring for contamination moving southward.

B-2; In-Situ Treatment with Fenton's Reagent
Inject Fenton's reagent.

B-3; Ex-Situ Treatment with Fenton's Reagent
Capture in-trench drain. Pump to reactor and mix with Fenton's reagent.

B-5; Ex-Situ Treatment with Carbon Adsorption
Capture in trench drain. Pump to surface impoundment.

GROUNDWATER CONTAMINATED BY ARSENIC

C-1; In-situ Treatment by Injection of Precipitating Agents
Inject chemicals which will precipitate arsenic and cause it to adhere to the formation.

C-2; Ex-Situ Treatment by Precipitation/Flocculation/Settling
Capture in trench drain. Pump to reactor then clarifier.

C-4; Ex-Situ Treatment by Phytoremediation
Capture in trench drain. Pump to hydroponic beds of ladder brake ferns.

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Section Four, Evaluation of CMS Alternatives, when written will involve sufficient design to allow realistic cost estimates to be made for Corrective Action Alternatives. The cost and time schedule of any pilot effort will be included.

Very truly yours,

Dick Karkkainen

RDK:cm

cc: *Scott Mills*
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Got from Dick

TABLE A

PROPOSED CORRECTIVE ACTION ALTERNATIVES AND SUGGESTIONS FOR LABORATORY AND PILOT WORK FOR SOIL CONTAMINATED WITH TOXAPHENE AND DINOSEB

Alternative	Description	Laboratory Work	Pilot/Plan Effort
A-2; Removal and Soil Cap	Construct soil pile in one location where access can be controlled and erosion can be controlled. Add a soil cap.	None required. None required.	None required. None required.
A-3; Removal and Geosynthetic Plus Soil Cap	Add a geosynthetic liner cap to Alternative A-2.	None required.	None required.
A-4; Removal and Geosynthetic Bottom, Sides and Top Plus Soil Cap	Add a geosynthetic liner on bottom and sides to Alternative A-3.	None required.	None required.
A-5; In-Situ Composting Plus Iron and A-7; Ex-Situ Composting Plus Iron	Add compost and iron to surface soil. In time add in the soil piles. If ex-situ, move soil to location on-site and set up biotreatment cells.	Obtain 3 five gallon buckets full of soil from surface grid 20-F and 3 five gallon buckets of soil from soil pile 20-FF. Dump onto a plastic liner spread atop grid 20-F. Remove, manually or by screening, rock particles greater than ½ inch (½ inch sieve number). Place 10 gallons of the screened soil into a 1.5 cubic feet cement mixer. Mix for one hour and dump onto liner. Place another 10 gallons of the screened soil into the cement mixer. Mix for one hour and dump. Place on-half of soil pile into the cement mixer and mix for one hour, then dump. Do the same for the remaining soil. Once again, take one-half of each pile and mix and dump the remaining soil. Obtain a sample for analysis of toxaphene and dinoseb. (Results might be 77 ppm toxaphene and 131 ppm dinoseb.	Pick the two best operating conditions and create two field plots, each 2,500 square feet by 18 inches deep. Operate for 6 months.

$227K Capital
$49,600K O&M/30y
$370,900 C
$48,600 O&M
$397,700 C
$48,600 O&M
A-5 $2,288,200 no O&M

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TABLE A (Continued)

PROPOSED CORRECTIVE ACTION ALTERNATIVES AND SUGGESTIONS FOR LABORATORY AND PILOT WORK FOR SOIL CONTAMINATED WITH TOXAPHENE AND DINOSEB

Alternative	Description	Laboratory Work	Pilot/Plan Effort
A-5; In-Situ Composting Plus Iron and A-7; Ex-Situ Composting Plus Iron (Continued)		Onto another plastic liner, dump 15 gallons of gin trash. Add 5 percent chicken manure and 5 percent fertilizer. Mix manually very thoroughly for an hour. This is the compost. Create one pile (Pile 1) consisting of 10 gallons of previously mixed soil and 10 gallons of compost. Create another pile (Pile 2) consisting of 10 gallons of previously mixed soil and 3.3 gallons of compost. Each pile should be mixed in the cement mixer using techniques previously noted. Split each pile in one-half, so there is a Pile 1A, Pile 1B, Pile 2A and Pile 2B. To piles 1A and 2A add 5.0 pounds of active zero valent iron; mix thoroughly. To piles 1B and 2B add 0.5 pounds of active zero valent iron; mix thoroughly. Create 1 foot by 1 foot by 0.5 foot beds of the soil, compost and iron. (The "1" denotes high compost ratio; the A" denotes high iron ratio.) Two beds should be made for each pile. One bed is to be run aerobically. The other bed is to alternate between anaerobic and aerobic. Thus, there will be eight beds. One set (anaerobic) of beds should be covered with plastic and initially left alone. Another set (aerobic) of beds should be thoroughly mixed three times per week. The anaerobic set that is covered with plastic and left alone for one month should then have the plastic removed and the bed	

A-7 @ 2,010,300 CC
– no osm –

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TABLE A (Continued)

PROPOSED CORRECTIVE ACTION ALTERNATIVES AND SUGGESTIONS FOR LABORATORY AND PILOT WORK FOR SOIL CONTAMINATED WITH TOXAPHENE AND DINOSEB

Alternative	Description	Laboratory Work	Pilot/Plan Effort
A-5; In-Situ Composting Plus Iron and A-7; Ex-Situ Composting Plus Iron (Continued)		thoroughly mixed three times per week for one month. The monthly operation of the second set of beds should alternate between anaerobic and aerobic for a total of 6 months. Each of the total of eight beds should be sampled and analyzed every month for dinoseb and toxaphene	
A-6; In-Situ Treatment by Injection of Fenton's Reagent	Inject hydrogen peroxide and ferrous sulfate into surface soil and soil piles.	Obtain 1 five gallon bucket of soil from surface grid 20-F and 1 five gallon bucket of soil from soil pile 20-FF. Dump onto a plastic liner spread atop grid 20-F. Remove, manually or by screening, rock particles greater than ½ inch (½ inch sieve number). Place the screened soil into the cement mixer (1.5 cubic feet capacity), add water and 0.1 pounds of ferrous sulfate to saturate soil, mix for one hour then dump. Place five gallons of the soil into a five gallon bucket. Sample and analyze the soil for toxaphene and dinoseb. (Results might be 77 ppm toxaphene and 131 ppb dinoseb.) Force 0.25 inch tubing through center of soil, then withdraw the tube and replace it with another tube which is sealed on the end but has two small holes drilled into the side. The sparge tube should also go through the top which is placed on the five gallon pail. The pail top should be vented by several holes drilled in it. Carefully sparge 0.5 pound hydrogen peroxide into the pail. Use a peristaltic pump and inject at about 200 ml per hour. During injection, carefully move the injection tube vertically through the entire column of soil. The injection period will last from one-half to one hour.	Inject Fenton's Reagent into soil pile 20-FF. Repeat two times at one day intervals. Obtain a composite sample for toxaphene and dinoseb analysis.

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TABLE A (Continued)

PROPOSED CORRECTIVE ACTION ALTERNATIVES AND SUGGESTIONS FOR LABORATORY AND PILOT WORK FOR SOIL CONTAMINATED WITH TOXAPHENE AND DINOSEB

Alternative	Description	Laboratory Work	Pilot/Plan Effort
A-6; In-Situ Treatment by Injection of Fenton's Reagent (Continued)		Remove the top of the pail. Allow pail to sit overnight. Dump the pail contents onto a plastic tarp, obtain a sample and submit for analysis of toxaphene and dinoseb.	
A-8; Offsite Disposal in Landfill	Explore regulatory aspects of classifying soil as non-hazardous. If non-hazardous, dispose in a commercial industrial waste landfill.	Regulatory deliberation would be required. VCC will not proffer an opinion but will accept the judgment of the U.S. EPA and MSDEQ.	None required.

$462K CC
no O&M

$1,216,000 C
no O&M

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TABLE B

PROPOSED CORRECTIVE ACTION ALTERNATIVES AND SUGGESTIONS FOR LABORATORY AND PILOT WORK AND GROUNDWATER CONTAMINATED WITH DINOSEB, CHLOROFORM, CARBON TETRACHLORIDE AND OTHER VOA'S

Alternative	Description	Laboratory Work	Pilot/Plan Effort
B-1; No Action, Natural Attenuation Monitoring	Continue monitoring.	None required.	None required.
B-2; In-Situ Treatment with Fenton's Reagent B-3; Ex-Situ Treatment with Fenton's Reagent	Inject or mix with Fenton's Reagent (hydrogen peroxide and ferrous sulfate)	Since this process is more costly than alternatives, it will be verified in the laboratory only in the event of failure of the other alternatives.	Since this process is more costly than alternatives, it will be field tested only in the event of failure of all the other alternatives.
B-5; Ex-Situ Treatment with Carbon Adsorption	Pump groundwater to existing wastewater treatment system.	Check carbon usage with vendor.	None required.

$15,000 CC
24,300 O&M

B-2 @ $715K CC
$100 O&M

$109K CC
$156,200 O&M
for 10 yrs

B-3 @ $231K
w/ O&M @
$389K
(10 yrs)

D R A F T

PROGRESS REPORT
CORRECTIVE MEASURES STUDY

Prepared for
Vicksburg Chemical
Vicksburg, Mississippi

March 2002

File No. 35-092B007C.00-03007

URS Corporation
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Table 2-1F Corrective Action Technologies and Process Options Based on Effectiveness, Implementability and Relative Cost – Groundwater Contaminated with Arsenic

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FIGURES

Figure 1-1 SWMU Locations, RFI Soil and Concrete Sample Points, GWA Monitor Well Locations

Figure 2-1 Site Wide Soil Contamination

Figure 2-2 Overview of Site Wide Groundwater Dinoseb Contamination

Figure 2-3 Overview of Site Wide Groundwater VOA Contamination

Figure 2-4 Overview of Site Wide Groundwater Arsenic Contamination

Figure 3-1 Engineered Soil Pile

Figure 3-2 Soil Treatment Pilot Test Locations

Figure 3-3 Composting Biological Treatment Unit

Figure 3-4 Juxtaposition of Creek, Drainage Layer, and Dinoseb and VOA Plumes

Figure 3-5 Recovery Trench for VOA and Dinoseb Contaminated Groundwater

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APPENDICES

Appendix A Laboratory Work – Effect on Composting Plus Iron on Soil Contaminated with Toxaphene and Dinoseb

Appendix B Laboratory Work – Effect of Ladder Brake Ferns (Pteris Vittata) on Groundwater Contaminated with Arsenic

Vicksburg Chemical Company (VCC) retained URS Corporation (URS) to perform activities associated with a RCRA corrective action program. The corrective action program is in response to a Consent Decree which became effective July 1, 1991. The Consent Decree requires that a RCRA Facility Investigation (RFI) be conducted at the Vicksburg, Mississippi manufacturing facility, and that it be followed up by corrective measures as needed.

The purpose of the RFI is to determine the nature and extent of releases of hazardous wastes and/or constituents from regulated units, solid waste management units (SWMUs), and other areas of concern (AOCs) at the facility and to gather all necessary data to support any corrective action required.

The RFI constitutes the second phase of the RCRA corrective action program. The program's first phase consists of the RCRA Facility Assessment (RFA) which is conducted by the EPA and precedes the RFI. The RFI itself is divided into several separate tasks. The tasks include the Preliminary Report, the RFI Work Plan, the Facility Investigation, and the Investigative Analysis Report (RFI Report). Subsequent phases of the RCRA corrective action program concern defining and implementing any needed measures that will protect human health and the environment. In addition, a Groundwater Assessment (GWA) Work Plan, a Closure Plan for SWMU 1 and SWMU 17, and Annual Groundwater Assessment Reports are required by the Consent Decree.

VCC submitted the Preliminary Report and Closure Plan for SWMU 1 and SWMU 17, and subsequently updated the Preliminary Report. The Preliminary Report and Closure Plan for SWMU 1 and SWMU 17 have been approved. VCC submitted the RFI Work Plan and the GWA Work Plan and has updated both plans. The RFI Work Plan was approved, and has been implemented in two phases in the field. The RFI effort is described in the Draft Final RFI Report submitted in August 2001 and the Groundwater Assessment Report submitted in November 2001. Both reports were approved by the U.S. EPA in December 2001.

The following is a summary description of the SWMUs. It is followed by a tabulation of reports which describe SWMU activity at the site. Some of the activity was expedited because of VCC's plans to construct new manufacturing facilities and also utilize some of the SWMU areas for storage and for transportation related activity. The summary discussion of the SWMUs is obtained from the RFI Report. The SWMU locations are depicted on Figure 1-1 "SWMU Locations, RFI Soil and Concrete Sample Points, GWA Monitor Well Locations".

SWMU 1 – Container Drum Storage Area, SWMU 16 – Former Atrazine Production Area, SWMU 17 – Returned Product Storage Area

SWMU 1 is a "less than ninety day hazardous waste drum storage area" that was located at the South Plant adjacent to the Former Atrazine Production Area (SWMU 16) across a walkway from the Returned Product Storage Area (SWMU 17). This area was diked. The roof over the area was destroyed by a windstorm during mid-1990. Spills were collected in a sump common to both this area and the Returned Product Storage Area (SWMU 17). The floor has been cleaned through sweeping, scraping, chipping, and reacting the dinoseb with hydrogen peroxide and a ferrous iron catalyst. A closure plan for the Container (Drum) Storage Area (SWMU 1) and the Returned Production Storage Area (SWMU 17) was developed by URS for VCC. The closure plan is consistent with RCRA rules and regulations. The closure plan was originally submitted in June 1992 as a 60-day deliverable to the EPA and MSDEQ by VCC.

A facility for the manufacture of potassium phosphate has been constructed on the SWMU 1 site.

The Former Atrazine Production Area (SWMU 16) is located adjacent to the Container (Drum) Storage Area (SWMU 1) and the Returned Product Storage Area (SWMU 17). In addition to producing atrazine, this process area manufactured the herbicide cyanazine under the packaged name Bladex. The former atrazine warehouse is located adjacent to the Former Atrazine Production Area (SWMU 16). The warehouse was used to store dinoseb as well as atrazine.

The warehouse continues in service in order to store various fertilizer products manufactured by VCC. The Atrazine Production Area was demolished and was reconstructed for the production of potassium phosphate.

The Returned Products Storage Area (SWMU 17) was located across a walkway from the Container (Drum) Storage Area (SWMU 1). Product formulations returned by consumers and off-spec product were stored here until they could be reblended, re-containerized, and sold or disposed of as a hazardous waste. The floor has been cleaned through sweeping, scraping, chipping, and reacting the dinoseb with hydrogen peroxide and ferrous iron catalyst. A closure plan for the Container (Drum) Storage Area (SWMU 1) and the Returned

Production Storage Area (SWMU 17) was submitted by VCC as a 60-day deliverable pursuant to the Consent Decree.

The SWMU 17 site was part of the site of a potassium phosphate manufacturing facility. As noted above the potassium phosphate groundwater facility encompasses SWMU 1, the production area of SWMU 16 and SWMU 17.

SWMU 2 – Inactive Landfill

SWMU 2 is a hill with a natural elevation approximately 30 feet above immediate surrounding areas. A landfill and four pits or ponds were constructed on the hill and utilized from 1972 to 1975. One pit was constructed to store dinoseb process wastewater. Three pits were used as disposal locations for pallets, empty fiber and steel drums. In 1977 many of the drums in the pits, but not the landfill, were removed and disposed off-site. The location of the closed pits and closed landfill are based on a March, 1979 aerial photograph. The boundary lines of the pits were partially destroyed during regrading efforts in late 1979. In 1979 all the pits were drained, regraded so the hill was flattened and covered with a soil cap. Some of the soil was obtained off-site and placed on the landfill area. In 1983, there was additional grading and capping of the entire area consistent with an engineered plan approved by the MSDNR. In 1988 the SWMU 3 wastewater ponds, which are adjacent to SWMU 2, were lined and a repository for pond sediments (SWACA) was constructed. The SWACA was constructed in a pond location. The sediments from the SWMU 3 wastewater ponds and most of the sediment of the pond are within the SWACA. The pond lining and SWACA construction is consistent with RCRA guidelines.

In the year 2000 a diked area was constructed atop SWMU 2 to settle and dewater the sludge from the wastewater impoundment. The sludge was submitted for TCLP analysis prior to being pumped to the diked area and was determined to be non-hazardous. On September 13 and 14, 2001, two composite samples were obtained by blending grab samples at three locations of the 6- to 12-inch soil depth interval, representing the settled sludge. The entire diked area is covered by dense vegetation. The composite samples were analyzed for toxaphene and dinoseb. One sample contained 3,513.9 ppb toxaphene and 27.4 ppb dinoseb. The other contained 5,170 ppb toxaphene and 100.8 ppb dinoseb.

SWMU 4 – Activated Carbon Unit

The Activated Carbon (Adsorption) Treatment Unit treats wastewater from the Surface Impoundment (SWMU 3) to remove organic materials before the water is pumped to the Mississippi River in accordance with the NPDES permit. Secondary containment for the unit consists of a concrete pad approximately 100 feet long, 20 feet wide with 1-foot tall containment curbs. The concrete containment unit is cracked and stained. There is visual evidence of spillage of carbon on the east side of the containment area. The carbon was sampled, tested by TCLP and found to be non-hazardous.

SWMU 5 – South Plant Drainage System

The South Plant Drainage System was designed to transfer storm water and process water to the Surface Impoundment (SWMU 3) for containment prior to treatment. Sumps exist within the former MSMA, dinoseb and toxaphene production, packaging and shipping areas of the South Plant. At one time, some of the sumps carried water to the Surface Impoundment (SWMU 3); however, due to regulations which became effective in November 1985, sumps in the pesticide process and handling areas were blocked. This precluded the possibility of pesticide spills from entering the Surface Impoundment (SWMU 3) by gravity flow through the Drainage System.

SWMU 6 – Wastewater Storage (Hill) Tanks Area

The Wastewater Storage Tanks were located on the hill in the northern area of the South Plant. They were surrounded by dikes. Three 98-foot diameter storage tanks were once used to store ammonium nitrate. Two of these tanks were emptied, cleaned and used for warehouse storage. The westernmost tank (1,600,000 gallon) was converted to store neutralized process wastewater generated during the production of dinoseb.

The dinoseb process wastewater was originally pretreated by pumping through 2 columns, each containing 20,000 pounds of carbon, in an Activated Carbon System (SWMU 4) and discharged into the Surface Impoundment (SWMU 3). Contents of the Surface Impoundment were additionally treated by pumping through 2 additional columns, each containing 20,000 pounds of carbon, in the Activated Carbon Treatment System prior to discharge to the Mississippi River. The plant increased dinoseb production capacity and increased generation of process wastewater in the early 1980s. This increased production capacity caused the wastewater discharged to the Mississippi River to exceed the NPDES permit levels. As of

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TABLE C

PROPOSED CORRECTIVE ACTION ALTERNATIVES AND SUGGESTIONS FOR LABORATORY AND PILOT WORK FOR GROUNDWATER CONTAMINATED WITH ARSENIC

Alternative	Description	Laboratory Work	Pilot/Plan Effort
C-1; In-Situ Treatment by Injection of Precipitating Agents C-2; Ex-Situ Treatment by Precipitation/Flocculation/Settling	Inject or mix chemicals which will precipitate arsenic and cause it to adhere to the foundation.	This may not be the preferred process. A literature search will suffice for obtaining information.	This is not the preferred process. Will be field tested only if phytoremediation fails or requires excessive residence time.
C-4; Ex-Situ Treatment by Phytoremediation	Discharge groundwater to hydroponic beds of ladder brake ferns (Pteris vittata).	Feasibility is being verified by phytoremediation company that is licensed to provide this particular fern for arsenic recovery in groundwater and soil.	Pump continuously from the small arsenic recovery well at 0.01 gpm to hydroponic beds established on the second floor of the MSMA building. The beds would be established in several horse troughs in series.

January, 1983 the process wastewater was stored in the westernmost storage tank and then sent off-site for deep-well injection, thereby eliminating the cause of the NPDES permit violations. This off-site disposal continued until the dinoseb plant was shut down in December, 1986.

The storage tanks have been demolished and removed from the site. The tank ring foundations still remain in the area. There are no stains on the tank foundations or soil in this area. This diked area was used to settle and dewater the sludge from the wastewater impoundments in 1998. The sludge was submitted for TCLP analysis prior to being pumped to the hill tank area and was determined to be non-hazardous. On September 13, 2001 a composite sample was obtained by blending grab samples at three locations of the 6- to 12-inch depth soil interval, representing the settled sludge. The composite sample was analyzed for toxaphene and dinoseb and was found to contain 1,141.8 ppb toxaphene and 29.8 ppb dinoseb.

SWMU 7 – Former Dinoseb Production Area

The Former Dinoseb Production Area is located near the railroad tracks. The production area and foundation have been demolished and removed and a portion treated in a CAMU. Some discolored soil has been removed. Due to the acid involved in the manufacturing of the herbicide, the concrete and cement in the process area had been badly corroded and etched. The dinoseb manufacturing process consisted of sulfonation and nitration reactors, two formulation blending tanks, and a settling tank. At one time, acidic process wastewater was neutralized with sodium hydroxide or ammonia and then discharged to the Surface Impoundment (SWMU 3) through carbon adsorption beds. Emission from the nitration reactor was controlled by a butane-fired flare. Flare failure required immediate plant shut down; however, the soil in the area surrounding the flare is contaminated. The area is surrounded by the Railroad Area (SWMU 20) and is adjacent to the Toxaphene Area (SWMU 14).

SWMU 8 – Dinoseb Loading/Unloading Area

The Dinoseb Truck Loading/Unloading Area is located in the central section of the South Plant adjacent to the Dinoseb Drumming Area (SWMU 9). It is a concrete pad that used to contain spillage associated with the truck loading/unloading operations at the Former

Dinoseb Drumming Area (SWMU 9). The pad is approximately 25 feet long and 15 feet wide.

The loading/unloading area is now covered with asphalt and within a warehouse/operations area for production of Multi Cote (coated fertilizers for slow release of nutrients). It continues to be used as a loading/unloading area.

SWMU 9 – Dinoseb Drumming Area

Drumming of the dinoseb and toxaphene formulations took place in the south end of a warehouse in the central section of the South Plant. In the drumming operation of the dinoseb and toxaphene, an absorbent was placed on the floor to prevent material reaching the Surface Impoundment from spills. Yellow stains were evident on the floor.

The SWMU 9 site is presently the site on which a facility to coat and then store various fertilizer mixtures has been constructed. Prior to the construction the area was sampled and cleaned up. The entire surface of the concrete in SWMU 9 was treated by grinding off a veneer of concrete then by placing a layer of compost atop it in an attempt to draw contaminants from the surface of the concrete into the compost where biological degradation would occur. The effort was experimental and results were uncertain. Subsequently, concrete and some soil were removed from a section comprising the middle third of SWMU 9. All concrete grindings, concrete debris, and soil removed were taken to the Treatment Unit for eventual biodegradation/composting within the provisions of the CAMU permit.

SWMU 11 – Former MSMA Production Area, SWMU 12 – Former MSMA Salt Unloading Area, SWMU 15 – Former Methyl Parathion Production Area

The Mono Sodium Methane Arsenate (MSMA) Production Area (SWMU 11) was constructed over the remains of the Former Methyl Parathion facility (SWMU 15) in 1983. Subsequently, the MSMA process was shut down and equipment from the area was removed and the concrete foundation of the area was cleaned with high-pressure water equipment.

The MSMA Salt Unloading Unit was an integral part of the MSMA Production Area (SWMU 11). Salts were discharged directly from a centrifuge into containers located within the area.

The original process unit was constructed in the early 1970s to produce methyl parathion. The methyl parathion manufacturing facility was destroyed in an explosion and fire on March 7, 1978.

SWMU 13 – South Plant Drainage Ditch

There is one major Drainage Ditch which runs along the western border of the South Plant and empties into Hennessey's Bayou. No contaminated Drainage System (SWMU 5) water or NPDES permitted discharge is received by the major Drainage Ditch. However, some storm water runoff has discharged into the major Drainage Ditch from the South Plant. Additionally, drainage from a portion of SWMU 34 – The boneyard rainwater drainage discharges into the drainage ditch.

SWMU 14 – Former Toxaphene Production Area

The Former Toxaphene Production Area is adjacent to SWMU 7 - The Dinoseb Production Area and is surrounded by SWMU 20 – The Railroad Area.

Raw material used in the toxaphene manufacturing process included sodium hydroxide, xylene, epichlorohydrin, chlorine, carbon tetrachloride, and camphene. Caustic scrubber water from the toxaphene operation was discharged to the sump adjacent to the Former Dinoseb Processing.

The processing equipment from the Toxaphene plant has all been removed. The foundations and secondary containment concrete structure were in good repair and were not demolished. The foundation presently serves as a repository for soil excavated from various parts of the South Plant during construction activity. The soil is to be treated by a biological degradation composting process.

SWMU 18 – Former Blue Tank Area

The Former Blue Tank Area (SWMU 18) received unneutralized dinoseb process wastewater prior to off-site disposal by deep well injection. The unit was located northwest of the Former Dinoseb Production Area (SWMU 7) and adjacent to the Nitric Acid Production Area in the South Plant. A gravel covered area exists at the location of the Former Blue Tank (SWMU 18). The original 16,000-gallon tank was fiberglass. The fiberglass tank leaked.

Two repair attempts failed in 1983 causing the fiberglass tank to be replaced by a stainless steel tank at the dinoseb plant. The fiberglass tank was demolished and removed from the site.

SWMU 20 – Railroad Area

The Railroad Area (SWMU 20) including the Railroad Car Loading/Unloading Station is located at the eastern boundary of the manufacturing portion of the South Plant. The railcar station was the primary area for the loading/unloading of materials for the various operations conducted at the South Plant. The area spans several hundred feet along the multiple-lane railyard. The ground in the surrounding area has received spillage from the loading/unloading operations. In addition to railyard operations, the flare for the dinoseb production area nitration reactor was located directly across the tracks from the railyard. Incomplete flaring discharged constituents onto the ground in the area surround the flare. The flare area is indistinguishable from the Railroad Area (SWMU 20).

SWMU 20 also surrounds SWMU 7 – The Former Dinoseb Production Area and SWMU 14 – The Former Toxaphene Production Area. SWMU 4 – The Activated Carbon Unit is on the eastern edge of SWMU 20.

SWMU 23 – Equalization/Neutralization Pond

This unlined pond also known as the North Pond was located on the North Plant site and was utilized for neutralization of acidic wastewater from the potassium nitrate production process. The neutralization of the water in the Neutralization Pond was achieved using limestone. The potassium nitrate production wastewater is no longer routed through the equalization and neutralization ponds. The pond at the North Plant is inactive. The pH of the rainwater in the pond has been checked and found to be near neutral. URS conducted an RFI in the North Pond Area in November and December 1993.

SWMU 30 – North Plant Waste Oil Accumulation Area

The Waste Oil Accumulation Area (SWMU 30) is an outdoor drum staging area located in the south section of the North Plant. The unit is downgradient from the Inactive North Plant Surface Impoundment (SWMU 23). The unit consists of a concrete pad with secondary containment in the form of concrete curbing used to stage drums of new and waste lubricant

oils prior to of-site recycling. The area is located within the vicinity of a lubricant storage area. The area is roofed.

SWMU 34 – Surplus Equipment Storage

The Surplus Equipment Storage Areas are located at the western edge of the South Plant alongside the South Plant Drainage Ditch (SWMU 13) and at the western edge of the North Plant. The main storage area is the one located in the South Plant. The storage areas were used for temporary storage of old equipment, and other scrap material.

SWMU 29 – North Plant Oil Collection Unit, SWMU 31 – North Plant No. 6 Fuel Oil Area, SWMU 25 – North Plant Waste Water Pipes, SWMU 22 – North Plant Neutralization System

The four items are grouped together. They were mentioned in the RFA. In the Preliminary Report, it was suggested that inspections of the areas should be made during the field investigations of the RFI prior to determining if field sampling was required. Some cleaning effort was required prior to inspection.

SWMU 29 is a drum that collects oil drips from the potassium nitrate cooling cylinder. The oil collection system has been modified so that oil drips are now directly piped to the drum.

SWMU 31 is a concrete sump that formerly housed pumps to move fuel oil from tanks to boilers. The tanks and pumps had been removed prior to the writing of the Preliminary Report; however, deposits of soil in the sump made it impossible to observe whether there had been cracks in the concrete. The cracks would be potential avenues of escape of fuel oil in the event it leaked from pumps into the sumps.

SWMU 25 is the system of waste water pipes carrying waste water that can be acidic from the North Plant Manufacturing to a sump from which it is pumped to the neutralization system.

SWMU 22 is the sump collecting wastewater as noted above and the neutralization system itself. The neutralization system was not questionable in the Preliminary Report as a source of contamination into the soil and groundwater; however, the integrity of the sump was questioned. The old sump was removed and was replaced with a new sump in March 2001.

The following is a tabulation of published reports on SWMU activity:

TABLE 1-1

REPORT DESCRIBING SWMU ACTIVITY

Report	Date	Status	Comment
RFI Work Plan SWMUs 9 and 16	August 1994	Submitted	--
RFI Report SWMUs 9 and 16	September 1994	Submitted	--
SWMU 23 North Pond RFI Work Plan FRI Report	October 1994	Submitted	14 piezometers were installed.
Closure Plan SWMUs 1 and 17	February 1995 (Modified 10-26-95)	Approved by the U.S. EPA and MSDEQ	--
RFI Work Plan Entire Site	June 1996	Modified 12-16-99 and subsequently approved	Incorporated investigative phase of "Closure Plan SWMUs 1 and 17".
GWA Work Plan Entire Site	June 1996	Modified 12-16-99. To be revised after completion of Final RFI Report	--
RFI Expedited Work Plan SWMUs 12, 11, 15, 16, 1 and 17	January 1997	Submitted	VCC planned to expand manufacturing capability into SWMU 12, 11 and 15 area or SWMU 16, 1 and 17 area.
RFI Report, Corrective Measures Study, RCRA Corrective Measures Implementation Plan SWMUs 16, 1 and 17	June 1997	Approved by the U.S. EPA and MSDEQ	--
Corrective Action Management Unit Application	June 1997	Approved by the U.S. EPA and MSDEQ	--
RFI Report SWMUs 12, 11 and 15	April 1998	Submitted	--
Corrective Measures Implementation Plan SWMUs 12, 11 and 15	April 1998 (as amended July 15,1 998)	Submitted	VCC withdrew plan
Corrective Action Observation Confirmatory Sampling and Analysis SWMUs 1 and 17	July 1998	Submitted	--

TABLE 1-1 (Continued)

REPORT DESCRIBING SWMU ACTIVITY

Report	Date	Status	Comment
Arsenic Data Sets Arsenic Data Sets – Addendum	October 15, 1998 October 26, 1998	Submitted Submitted	Evaluation of arsenic background data.
SWMU 9 Corrective Action Observation	March 11, 1999	Submitted	--
Observations and Sampling of Ditch	September 8, 1999	Submitted	Surficial dinoseb contamination of soil noted during excavation of a ditch for a new water drainage line.
Response to July 3, 1999 Comments by the U.S. EPA on the "Amended and Supplemental Groundwater Assessment Work Plan"	July 31, 2000	Submitted	Summarized previously written description of SWMUs and work accomplished at each SWMU. Additionally *responded to questions.*
RCRA Facility Investigation SWMU 2 – Inactive Landfill Interim Report	October 2000	Submitted	--
Interim Revised Corrective Measures Implementation Plan SWMU 12 – Former MSMA Salt Unloading Area SWMU 11 – Former MSMA Production Area SWMU 15 – Former Methyl Parathion Production Area	November 2000	Submitted	Need agreement of arsenic clean up standards based on background. Need completion of RFI and GWA to completely verify and define problem.
RCRA Facility Investigation Interim Report and Phase II Workplan	December 15, 2000	Submitted (Later revised by VCC)	Contained some analytical laboratory calculation errors.
RCRA Facility Investigation Interim Report and Phase II Workplan	March 16, 2001	Submitted and Approved	Corrected analytical errors and added results of a surface and soil pile sampling program completed on February 16, 2001
Final RFI Report	August, 2001	Submitted and Approved	Contains information on entire RFI program, including the Phase II effort.
Groundwater Assessment Report	November 30, 2001	Submitted and Approved	Emphasizes groundwater aspects of RFI program.

This document is the RCRA Corrective Measures Study (CMS). The purpose of the CMS is to develop and evaluate the corrective action alternatives and recommend the corrective measures to be taken by VCC. The U.S. EPA and MSDEQ have to agree with VCC on the recommendations prior to implementation; therefore, there has been communications during the development of this document. Part of the development of alternatives has included laboratory experiments in the VCC laboratory to ascertain the technical and economic viability of alternatives; the information developed is included in this document.

The CMS consists of three tasks, discussed in the following sections of this document:

2.0 Identification and Development of the CMS Technologies
3.0 Identification and Development of CMS Alternatives
4.0 Evaluation of CMS Alternatives

Based on the results of the RCRA Facility Investigation (RFI) as reported in the RFI Report (August 2001) and the Groundwater Assessment Report (November 2001), technical literature, EPA Guidance Documents, consideration of the Preinvestigation-Evaluation of Corrective Measures Technologies (January 1996), and lab experiments by VCC, VCC has identified, screened, and developed technical alternatives for removal, containment, treatment, and/or other remediation of contamination based on objectives established for the corrective action.

The information is contained in the following subsections:

2.1 Establishment of Corrective Action Objectives
2.2 Description of Current Situation
2.3 Identification and Screening of Technologies

2.1 ESTABLISHMENT OF CORRECTIVE ACTION OBJECTIVES

Soil

VCC has, in conjunction with the U.S. EPA and the MSDEQ, established that the site-specific objectives for corrective action in soil shall consist of not exceeding those concentrations of contaminants listed in the MSDEQ Tier 1 TRG Table for restricted site use in the event that there is an actual or potential pathway for exposure. In the event there is a pathway of exposure to arsenic in soil, the restricted concentration of arsenic shall be the background concentration. The background for arsenic at the VCC site shall be as discussed on pages 4-26 through 4-33 in the Groundwater Assessment Report, November 2001. The concentrations of contaminants in the soil shall be recorded in appropriate legal documents and those legal documents shall specify that the site is useable for industrial use but is not suitable for residential development.

Groundwater

VCC has, in conjunction with the U.S. EPA and the MSDEQ, established that the site-specific objective for corrective action in groundwater shall consist of not exceeding those concentrations of contaminants listed in the MSDEQ Tier 1 TRG Table. The Point of Compliance or Point of Exposure concentrations are to be determined by measurement and/or modeling as the concentration which would enter Stouts or Hennessey's Bayou.

2.2 DESCRIPTION OF CURRENT SITUATION

The following is relevant information summarized from the Preliminary Report, RFI Report and GWA Report that is pertinent to identifying actual or potential exposure pathways.

SOIL CONTAMINATION

Areas of soil contamination that have been detected are depicted on Figure 2-1. The boundaries of the areas investigated are noted on the figure. There was no reason to investigate plant areas outside of the boundaries. On the figure there are five groupings of contaminants:

- Arsenic contamination
- Arsenic and toxaphene contamination
- Volatile organics contamination
- Toxaphene contamination
- Dinoseb and toxaphene contamination

Various cross hatched color codes separate the five groupings.

All the areas noted as being contaminated do not have contamination that exceeds the restricted values listed in the MDEQ Tier 1 TRG Table or for arsenic, the background concentration. Those areas with the "exceedances" are further noted with a double cross hatching and descriptive arrow and note highlighting the SWMU number and the contaminant of concern. The following fall within that category:

- SWMU 20 (including SWMUs 4, 7 and 14) – dinoseb and toxaphene
- SWMU 2 – dinoseb
- SWMU 9 – toxaphene
- SWMU 11, 12, 15 – arsenic
- SWMU 23 – chloroform

The five areas noted above are subject to corrective action for soil, only if corrective action objectives are not met; that is, there must be a pathway for exposure to the contaminants. Each area is discussed below.

SWMU 20 (Including SWMUs 4, 7 and 14) – Dinoseb and Toxaphene in Soil

There are two problem areas, the surface soil and the soil piles. The surface soil is the column of soil from 0 to 18 inches below ground surface (bgs). Soil obtained at depths to groundwater from borings (20-1 through 20-22 with three samples per boring) did meet Corrective Action Objectives. Data is recorded on Tables 13-1 and 13-4 of the RFI Report (August 2001). The boring locations are shown on Figure 1-1. Data on contamination is recorded on Tables 13-2 and 13-3 of the RFI Report (August 2001). Figures, depicting in detail the sample locations are provided as Figure 3 and Figure 4 of the RFI Report (August 2001). Twenty-four composite samples were obtained. The concentration of one sample (20-F with 1,078,068 ppb) exceeded the MDEQ Tier 1 TRG Table restricted value for dinoseb of 204,000 ppb. The concentration of thirteen samples (20-A with 8,240 ppb, 20-B with 18,989 ppb, 20-C with 8,401 ppb, 20-D with 14,200 ppb, 20-F with 10,318 ppb, 20-G with 22,981 ppb, 20-H with 19,052 ppb, 20-I with 110,964 ppb, 20-J with 41,652 ppb, 20-K with 6,098 ppb, 20-N with 9,263 ppb, 20-O with 6,727 ppb and 20-T with 7,617 ppb) exceeded the MDEQ Tier 1 TRG Table restricted value for toxaphene of 5,200 ppb.

The soil piles are accumulations of soil moved during plant construction or in plant clean up efforts that had the potential to be contaminated. Data on contamination is recorded on Table 13-2 of the RFI Report (August 2001). Figures, depicting in detail the sample locations (20-AA through 20-MM) are provided as Figure 3 and Figure 4 of the RFI Report (August 2001). Thirteen composite samples were obtained. In none of the samples did the concentration of dinoseb exceed the MDEQ Tier 1 TRG Table restricted value for dinoseb of 204,000 ppb. The concentration of eight samples (20-BB with 37,036 ppb, 20-CC with 6,852 ppb, 20-DD with 14,691 ppb, 20-EE with 16,815 ppb, 20-FF with 76,683 ppb, 20-II with 17,413 ppb, 20-LL with 14,673 ppb and 20-MM with 11,152 ppb) exceeded the MDEQ Tier 1 TRG Table restricted value for toxaphene of 5,200 ppb.

The soil piles and surface soils noted above and depicted on Figure 2-1 do not meet Corrective Action Objectives. There is approximately 15,000 cubic yards available for corrective action.

SWMU 2 – Dinoseb in Soil

Five borings were advanced to groundwater on the SWMU 2 Hill. Three soil samples were obtained per boring. Data on contamination is recorded on Table 3-4 of the RFI Report

(August 2001). The boring locations were depicted on Figure 1-1. Two samples (LS4-B with 279,000 ppb and LS5-B with 8,282,600 ppb) exceeded the MDEQ Tier 1 TRG Table restricted value for dinoseb of 204,000 ppb.

Sample LS5-B was obtained from the remnants of a corroded drum of solid waste material. Sample LS4-B was obtained from the approximate bottom elevation of a closed out dinoseb wastewater pond. The SWMU-2 Hill is a closed landfill that has an engineered soil cap with good vegetation protection for prevention of soil erosion. There is no evidence of migration of contaminants from the landfill since it was initially closed and capped in 1979.

There is no evident pathway with the potential to harm the environment or health from contamination within the SWMU 2 Landfill. Corrective action is not required.

SWMU 9 – Toxaphene in Soil

Eight shallow borings were advanced through concrete and soil. After in plant clean up of two-thirds of the area (where expansion of manufacturing capability was planned), soil samples were obtained at two locations and one boring was advanced to groundwater. Data on contamination is recorded on Tables 8-1, 8-2 and 8-3 of the RFI Report (August 2001). The boring locations are depicted on Figure 8-1 of the RFI Report (August 2001). Three samples (3S with 19,000, 8S with 250,000 ppb and 8D with 25,000 ppb) exceeded the MDEQ Tier 1 TRG Table restricted value for toxaphene of 5,200 ppb.

The soil from sample location 3S was removed as part of the clean up and forms part of the soil piles in SWMU 20 that requires corrective action. The soil at location 8 remains in place; however, it is beneath a concrete floor in an area refurbished to be a fertilizer coating facility. The concrete floor is well maintained and the entire fertilizer coating facility is under roof.

There is not an evident pathway with the potential to harm the environment or health from contamination underneath the concrete at SWMU 9. Corrective action is not required.

SWMU 11, 12, 15 – Arsenic in Soil

Fifty-eight borings were advanced through concrete and soil. Data on contamination is recorded in Tables 9-3, 9-4 and 9-5 of the RFI Report (August 2001). In addition, results of a

special sample of solids on the bottom of Sump EE are recorded on Table 9-7. The sample locations are depicted on Figures 9-1, 9-2, 9-3 and 9-5 of the RFI Report (August 2001).

Several samples exceed a background concentration proposed by VCC of 20,000 ppb arsenic (see Groundwater Assessment Report [November 2001] Section 4.4, page 4-27 "Background Concentration – Arsenic in Soil and Groundwater"). The area that exceeds 20,000 ppb is double cross hatched at SWMU 11, 12, 15 on Figure 2-1.

The soil is contaminated to 10 feet. A profile of the soil contamination is found as Figure 1-A of the "Interim Revised Corrective Measures Implementation Plan – SWMUs 11, 12, 15, November 2000". (The proposed interim measures were based on the possibility that another manufacturing operation would be constructed on the SWMU 11, 12, 15 site. Those manufacturing operations were constructed elsewhere.)

The contamination is the result of material handling spills, mostly related to transfer of solid hazardous waste from the production of MSMA into roll off boxes prior to being transported to a hazardous waste landfill. That activity took place in the early 1980s. The total area of concern is covered with concrete and underlain with concrete from previous manufacturing operations on the site. Some of the concrete exceeds 55 inches in thickness (at location 4, concrete cores were abandoned at 55 inches – the cores were submitted for analysis). The arsenic has washed and leached beneath the concrete through joints, cracks and leaking drainage systems. There is no potential danger to human health and the environment from contact with surface materials or from erosion. In the event of excavations, there would be potential exposure to arsenic. The pathway for potential exposure to the environment is continued movement of the arsenic groundwater plume to Hennessey's Bayou. If the arsenic plume can then be intercepted the pathway will be incomplete. It is VCC's plan to intercept the arsenic groundwater plume; therefore, corrective action is not required for the soils.

SWMU 11, 12, 15 – Special Consideration – PCDD/PCDF Toxicity in Soil

Sump location EE noted in the RFI Report (August 2001) Figure 9-1 was sampled twice and found to contain about 0.7 gallons of soil that exceeds the restricted value for PCDD/PCDF toxicity of 0.0382 ppb (Table 9-7 RFI Report – August 2001). Even though the quantity is very small there is potential for harm. This small quantity is subject to corrective action by removal from the sump and appropriate disposal offsite.

SWMU 23 – Chloroform in Soil

Thirteen borings were advanced to shallow and deep groundwater zones around SWMU 22 – North Pond (Equalization/Neutralization Pond). The pond is closed; however, a small plume of chloroform developed during operation. Soil in the shallow perched zone near location 22 was analyzed to contain 830 ppb chloroform, which exceeds the restricted MDEQ tier 1 TRG Table value of 478 ppb. In no other soil boring sampled and analyzed was the restricted or unrestricted value exceeded. There is no pathway for potential harm to the environment or health from the contaminated soil. The soil will not be considered for corrective action.

GROUNDWATER CONTAMINATION

The groundwater plumes that have been detected are depicted on the following figures:

- Figure 2-2 – Dinoseb Plume
- Figure 2-3 – VOAs Plume
- Figure 2-4 – Arsenic Plume

The plumes noted above are subject to corrective action. Each plume is discussed below.

Dinoseb Plume

Localized Dinoseb Contamination in Groundwater

There is evidence of localized contamination at MW-1A and MW-11. There are two possible explanations for the localized contamination:

- A break in the line carrying wastewater to the ponds. The break has been repaired.

- The ponds themselves prior to being cleaned out and double lined. MW-1A and MW-11 are upgradient of the ponds now; however, the ponds used to be earthen lined and it is likely that water was mounded underneath the ponds.

The concentration of dinoseb in MW-1A has varied from non-detect to 5,500 ppb. The concentration averages 531 ppb dinoseb. The concentration since 1993 averages 148 ppb.

The concentration since 1997 averages 121 ppb. The most recent (June 2001) concentration is 139.6 ppb. A well, MW-1C, was installed approximately 5 feet from MW-1A in May 2001. The construction of MW-1A and MW-1C are similar, both monitor the shallow zone approximately 10 to 20 feet bgs. Dinoseb in MW-1C and MW-1A are essentially the same.

The concentration of dinoseb in MW-11 varies from non-detect to 29 ppb. The concentration averages 3 ppb. Dinoseb was first detected in 1993; since 1993, the dinoseb concentration averages 5.0 ppb. The concentration in June 2001 was non detect. The concentration since 1997 averages 8 ppb. MW-11 is 150 feet directly downgradient from MW-1A.

It can be inferred that there was localized contamination near MW-1A. The concentration at MW-1A is small in areal extent and in a decreasing trend so it can be further inferred that the original source of the contamination is absent, that is, dinoseb is no longer entering the groundwater at MW-1A. This small area of groundwater contamination does not provide a potential pathway for harm by discharge to Hennessey's Bayou and will not be considered for corrective action.

SWMU 2 Dinoseb Contamination in Groundwater

There is evidence of a plume of dinoseb underneath the SWMU 2 "hill area" landfill. Temporary wells were constructed to groundwater. The groundwater in well LS-5 was 797 ppb dinoseb; the groundwater in well LS-4 was 597 ppb dinoseb; the groundwater in well LS-2 was 8,714 ppb dinoseb. Groundwater in wells LS-1 and LS-3 contained no dinoseb.

The groundwater surrounding the landfill has been monitored by wells MW-5, MW-6 and MW-7 since 1983. The groundwater at MW-5 varies from non-detect to 12.0 ppb dinoseb and averages 0.3 ppb dinoseb. The groundwater at MW-6 varies from non-detect to 75 ppb dinoseb and averages 1.3 ppb dinoseb. The groundwater at MW-7 varies from non-detect to 4.5 ppb dinoseb and averages 0.1 ppb dinoseb.

150 ft/25 yrs

Groundwater in this area is estimated (see Table 3-2 Groundwater Assessment Report – November 2001) to move at 5.8 feet per year. Groundwater is not found, however, at the elevation at which wastes were placed in the landfill. The wastes were placed approximately 30 feet above groundwater. Dinoseb would have to be leached by percolating rainwater downward to the groundwater. That route has been inhibited by soil caps placed in 1979 and 1983. The most likely or most significant source would be a dinoseb process wastewater

pond which was operated from 1972 through 1975. The dinoseb would have begun to enter the groundwater stream prior to the initial cap installation in 1979.

Despite the relatively high dinoseb concentrations found localized in groundwater directly beneath the hill, there is no direct evidence of likely dinoseb impact on Hennessey's Bayou in concentrations in excess of MDEQ Tier 1 TRG Table values. The area is effectively monitored by wells MW-5, MW-6 and MW-7. Despite the scatter of data from dinoseb concentrations in the groundwater at these wells, the overall average is less than one ppb.

Vicksburg Chemical has established in soil treatment units that dinoseb in soil, including moist soil, can be biodegraded aerobically and anaerobically. Neither rates of degradation nor the quantity of dinoseb in the landfill has been established. It can, however, be conjectured, because monitor wells MW-5, MW-6 and MW-7 have not been significantly impacted, that the rate of movement of dinoseb is sufficiently slow and the rate of dinoseb degradation sufficiently fast such that Hennessey's Bayou will not be adversely impacted. The plume has had over 25 years to impact and has not done so. It can be accepted that dinoseb is an electron acceptor. Corrective action will not be considered for this area; however, monitoring will continue at MW-5, MW-6 and MW-7 for dinoseb.

150 ft/25 yrs. @ 5.8 ft/yr.

SWMU 20 Dinoseb Contamination in Groundwater

Results of the May 2001 investigation of groundwater indicate a plume of dinoseb in the vicinity of the Former Dinoseb Manufacturing Area. Concentrations of dinoseb as high as 18,821 ppb were found. Two monitor wells, MW-12C and MW-10C were installed on the boundary of the plume to monitor the shallow zone (10 to 20 feet bgs) of the aquifer. Existing wells MW-12 and MW-10 monitor the deep (20 to 30 feet bgs) of the aquifer. Dinoseb is undetected in MW-12 but present in MW-12C at 277 ppb. Dinoseb is undetected in MW-10 but present in MW-10C at 717 ppb. The plume exists in the shallow zone but not the deep zone. In subsequent sampling and analysis of groundwater from MW-10C and MW-12C by VCC in October 2001, the concentrations of dinoseb are higher than the concentrations obtained in May 2001. The dinoseb concentration reported for MW-10C is 7,000 ppb and the dinoseb concentration for MW-12C is 13,000 ppb. The dinoseb plume on Figure 2-2 reflects the latest concentrations.

It is another observation of conditions in the area of the plume that the top layer of soil (0 to 1 foot bgs) is contaminated with dinoseb, however, deeper soil (1 to 8 feet bgs) is not

contaminated. The RFI Final Report, August 2001, provides a record of the soil contamination. A generalized depiction of soil contamination is presented as Figure 2-1. The corrective action for this plume will be considered during this Corrective Measures Study.

SWMU 11, 12, 15 Dinoseb Contamination in Groundwater

During the September 2001 field investigation, a pre-packed semi-permanent 1-inch diameter well was installed in the center of the arsenic plume to a depth of 15 feet. The purpose of the well was to allow withdrawal of arsenic contaminated water to test compatibility with the brake fern (Pteris vittata). The brake fern is the first plant known to detoxify soils contaminated by arsenic. The fern absorbs large amounts of arsenic into its stems and fronds. Twenty gallons of groundwater was removed. Initially the groundwater was clear; however, after continued pumping it became yellow tinted. During previous investigations, the groundwater appeared clear and was only tested for arsenic. A sample of the twenty gallons was submitted for analysis and, as noted on Table 4-10 contains 1,387 ppb dinoseb, 4,770 ppb 4-nitrophenol, and 244,000 ppb arsenic. The arsenic concentration was as predicted. The dinoseb and 4-nitrophenol and yellow tint was not predicted. At one time, methyl parathion was produced at the SWMU 11, 12, 15 site and 4-nitrophenol was one of the raw materials. The presence of dinoseb must be due to spill of dinoseb stored on the site at some time. SWMU 9, the dinoseb drumming building is downgradient. Groundwater from location TP-1, which is between SWMU 11, 12, 15 and SWMU 9, showed no detection of either dinoseb or 4-nitrophenol. As will be noted in discussion of the arsenic plume, the arsenic plume will have to be intercepted. Consideration of the dinoseb and 4-nitrophenol content will have to be made. The results of the laboratory testing of the adsorption of arsenic by the brake fern show no phytotoxic effects of the dinoseb and 4-nitrophenol.

VOA Plume

The summation of concentrations of various VOAs detected in the groundwater has been made and recorded for each well depicted on Figure 2-3. Isolated values recorded on Figure 2-3 represent localized situations caused by small spills during the many years of operating life at the facility. There are three other areas where there are actual VOA plumes, one is associated with the north pond (SWMU 23), another is associated with the landfill (SWMU 2), and the third is associated with former manufacturing areas in the railroad area (SWMU 20).

SWMU 23 VOA Contamination in Groundwater

There is a zone of perched water associated with former operation of the north pond. The north pond is no longer in operation but at one time served as a neutralization/equalization basin for wastewater effluent from the potassium nitrate plant. The chloroform is a byproduct of the reaction of excess chlorine in the caustics scrubber. The perched zone contains VOAs, mostly as halomethanes.

Modeling the SWMU 23 chloroform plume:

A calculation of chloroform in groundwater that is protective of surface water classified as a non-drinking water supply can be made and then compared to concentrations that exist in the zone of contamination utilizing the following steps:

- Identify the nearest downgradient surface water body that may receive discharge from the impacted zone;
- Determine if the downgradient surface water body (segment or subsegment) is classified as a drinking water or non-drinking water supply;
- Identify the appropriate human health protection criterion based on the use classification (drinking water supply or non-drinking water supply); and
- Calculate a site-specific longitudinal dilution and attenuation factor (DAF) to be applied to groundwater concentrations at the point of exposure (POE) using the Domenico model and site-specific data and/or default parameters as presented below. The site-specific DAF is representative of dilution and attenuation associated with the migration of chloroform from the zone of contamination to the nearest downgradient surface water body (POE).

The appropriate formula is:

$$GW_{3NDW}\,(mg/L) = \frac{TRxBW_a}{SF_o[IRW_{NDW} + (BCFxIRF)]}$$

Where:

GW_{3NDW}	=	Risk-based constituent concentration in water (mg/l)	=	--[a]
TR	=	Target excess individual lifetime cancer risk (unitless)	=	10^{-6}
BW_a	=	Average adult body weight (kg)	=	70 kg
IRF	=	Fish/shellfish ingestion rate (kg/day)	=	0.02 kg/day[b]
SF_o	=	Oral cancer slope factor ((mg/kg-day)$^{-1}$)	=	Chemical-specific[c]
IRW_{NDW}	=	Incidental water ingestion rate (L/day)	=	0.089 L/day[d]
BCF	=	Bioconcentration factor (L/kg)	=	Chemical-specific[e]

[c]The SF used in the calculation is obtained from the following hierarchy of sources: (1) EPA's *Integrated Risk Information System*; (2) EPA's *Health Effects Assessment Summary Tables*; (3) EPA Region VI *Human Health Medium Specific Screening Levels*, EPA Region III *Risk-Based Concentration Tables* or Region IX *Preliminary Remediation Goals*; or (4) other EPA or EPA-recommended reference.

[d]An incidental ingestion rate of 0.089 L/day shall be used for water bodies designated for primary contact recreation. This rate is based on the following assumptions: 250 mL/hr possible ingestion x 5 hrs/week swimming duration x 6 months/12 months swimming season x 1 week/7 days = 0.089 L/day incidental ingestion. The chemical specific parameters used in the calculation shall be obtained from a hierarchy of sources established by the Submitter. If there is potential for a COC to be bioconcentrated by fish and a BCF value is not available for the COC, then a BCF may be estimated using the K_{ow} and the algorithm: Log BCF = 0.76 log K_{ow} – 0.23.

(Fundamentals of Aquatic Toxicology. 1985. Ed. Rand and S. Petrocelli, Washington: Hemisphere Publishing Corp., Chapter 17, Bioaccumulation, A. Ipacie and J.L. Hamelink).

If a K_{ow} is not available in the literature, a K_{ow} value may be estimated from the K_{oc} using Log K_{oc} = 0.0784 + (0.7919 x log K_{ow}).

(Soil Screening Guidance: Technical background Document, EPA, 1996).

For chloroform $SF_o = 6.1(10^{-3})$; $K_{oc} = 52.5$; $K_{ow} = 118.35$; BCF = 22.16

By calculation GW_{3NDW} = 21.6 ppb. Groundwater entering Hennessey's Bayou should not exceed 21.6 ppb or the established MCL. The MCL for chloroform is 100 ppb.

The site-specific DAF is calculated using the following:

$$DAF = \frac{Csi}{C_{(x)i}} = 1/\left(\exp\left(\frac{x}{2\alpha_x}\left[1 - \sqrt{1 + \frac{4\lambda_i \alpha_x R_i}{v}}\right]\right)\left(erf\left[\frac{S_w}{\sqrt[4]{\alpha_y x}}\right]\right)\left(erf\left[\frac{S_d}{\sqrt{\alpha_z x}}\right]\right)\right)$$

Where:

$C_{(x)i}$	=	Concentration of constituent i in groundwater at distance x downstream of source (mg/L) or (mg/m^3)	= --
C_{si}	=	Concentration of constituent i in source zone (mg/L) or mg/m^3)	= --
S_w	=	Source width perpendicular to groundwater flow (ft)	= 150
D_v	=	Groundwater Darcy velocity (K x i) (ft/yr)	= Site-specific (30)[b]
n	=	Soil porosity (dimensionless)	= Site-specific (0.36)[b]
λ_i	=	First-order degradation rate for constituent i	= 0.1[c]
R_i	=	Constituent retardation factor (dimensionless)	= 1.4[d]
i	=	Hydraulic gradient (ft/ft)	= Site-specific
v	=	Groundwater seepage velocity or $K_{i/n}$	= 4.3
x	=	Distance downgradient from source (ft)	= 450
S_d	=	Source thickness (e.g., the thickness of the impacted groundwater within the permeable zone) (ft)	= 10
K	=	Hydraulic conductivity (ft/yr)	= 4.3
α_x	=	Longitudinal groundwater dispersivity (ft) or 0.1X	= 45
α_y	=	Transverse groundwater dispersivity (ft) or $\frac{\alpha_x}{3}$	= 15
α_z	=	Vertical groundwater dispersivity (ft) or $\frac{\alpha_x}{20}$	= 2.25
erf	=	Error function; $\text{erf}\chi = \frac{2}{\sqrt{\pi}}\int_o^x e^{-1^2} dt$	= --[e]

[a] Domenico, P.A. and F.W. Schwartz, 1990. *Physical and Chemical Hydrogeology*, John Wiley and Sons, New York, N.Y.

[b] LDEQ

[c] Degradation and/or retardation shall only be included in the model when site-specific quantitative data document occurrence. Derivation of constants for these process shall be included with the model input data. Degradation and retardation data are by definition monitored natural attenuation processes. The first order degradation constant for chloroform was estimated from "Proceedings of the Symposium on Natural Attenuation of Chlorinated Organics in Ground Water EPA/540/R-97/504 May 1997". The presentation "Biotic and Abiotic Transformations of Chlorinated Solvents in Groundwater" by Perry L. McCarty contains the following information:

> "The major chlorinated solvents are carbon tetrachloride (CT), tetrachloroethene (PCE), trichloroethene (TCE), and 1,1,1-trichloroethane (TCA). These compounds can be transformed by chemical and biological processes in soils to form a variety of other chlorinated aliphatic hydrocarbons (CAHs), including chloroform (CF), methylene chloride (MC), cis- and trans-1,2-dichloroethene (cis-DCE, t-DCE), 1,1-dichloroethene (1,1-DCE), vinyl chloride (VC), 1,1-dichloroethane (DCA), and chloroethane (CA). Abiotic or chemical transformations of some CAHs can occur within the time frame of interest in groundwater. CAHs can also be transformed through the action of aerobic or anaerobic microorganisms. In some cases, such transformations may be co-metabolic, that is, fortuitous transformation brought about by enzymes that microorganisms are using for other purposes. In such cases, the transforming microorganisms must be actively growing, which requires the presence of primary substrates. In other cases, the microorganisms may be using the CAHs in energy metabolism, a condition now being commonly found under anaerobic conditions. These are unique reactions, because the microorganisms use CAHs as electron acceptors just as aerobic organisms use oxygen. This in turn requires a suitable electron donor such as hydrogen or organic compounds."

Within the same presentation data on the degradation of TCA at 20 degrees centigrade indicated degradation constants from 0.31 to 0.34. Another presentation "Extraction of Degradation Rate Constants from the St. Joseph, Michigan Trichloroethene Site" by J.W. Weaver, D.H. Kampbell, and J.T. Wilson presents degradation acts constants from 0.3 to 1.7 for TCE, from 0.26 to 3.3 for cis-DCE, and 0.15 to 2.6 for vinyl chloride. Although data on chloroform and/or carbon tetrachloride has not been found, a value of 0.1 is conservative and credible.

[d] The retardation factor, R, is the ratio of seepage velocity to contaminant migration velocity due to linear adsorption. For the unsaturated zone, R can be approximated as:

$$R = 1 + \frac{\rho_b K_d}{\theta_w} + \frac{(\theta - \theta_w) H'}{\theta_w}$$

Where:

ρ_b	=	the bulk density of the soil (g/cc)
K_d	=	the sorption coefficient (g/g/g/cc)
θ	=	saturated water content (total porosity) (cc/cc)
θ_w	=	the volumetric water content (cc/cc)
H'	=	the dimensionless Henry's Law Constant

Note when the soil is saturated, the saturated water content $\theta = \theta_w$ and the above equation reduces to:

$$R = 1 + \rho_b K_d / \theta$$

For organic constituents the sorption coefficient, K_d, was estimated by using the expression provided in U.S. EPA (1989):

$$K_d = K_{oc}\, f_{oc}$$

Where:

f_{oc}	=	the fractional organic carbon content of the soil (unitless) = 0.02[b]
K_{oc}	=	the normalized chemical-specific organic carbon partition coefficient (L/kg) = 39.8 per Risk Assessment Information System, current as of October 2001.

[e] The solution to the error function is presented below:

χ	erf χ
0.00	0.000 000
0.05	0.056 372
0.10	0.112 463
0.15	0.167 996
0.20	0.222 703
0.25	0.276 326
0.30	0.328 627
0.35	0.379 382
0.40	0.428 392
0.45	0.475 482
0.50	0.520 500
0.55	0.563 323
0.60	0.603 856
0.65	0.642 029

χ	erf χ
0.70	0.677 801
0.75	0.711 156
0.80	0.742 101
0.85	0.770 668
0.90	0.796 908
0.95	0.820 891
1.00	0.842 701
1.1	0.880 205
1.2	0.910 314
1.3	0.934 008
1.4	0.952 285
1.5	0.966 105
1.6	0.976 348
1.7	0.983 790

χ	erf χ
1.8	0.989 091
1.9	0.992 790
2.0	0.995 322
2.2	0.998 137
2.4	0.999 311
2.6	0.999 764
2.8	0.999 925
3.0	0.999 978
3.2	0.999 994
3.4	0.999 998
3.6	1.000 000
3.8	1.000 000
≥ 4.0	1.000 000

S_d is defined as the thickness of the contaminated groundwater within the permeable zone.

Developing a DAF for GW_3 requires that the S_d be estimated as below: (If the estimated S_d value exceeds the aquifer thickness, S_d should be set to the thickness of the aquifer.)

$S_d = h_{adv} + h_{disp}$

h_{adv} = Advective component of the plume depth (ft) or $B\left[1-\exp\left(\frac{(-I \times L)}{(B \times D_v)}\right)\right]$ = Site-specific

I = Infiltration rate (ft/yr) = (0.33)[b]

D_v = Darcy horizontal velocity (ft/yr) = 4.3 ft/yr

B = Thickness of the shallow water bearing zone (ft) = 10

L = Length of the source parallel to the groundwater flow at the water table = 150

α_z = Vertical dispersivity (ft) or L/200 = 0.75

h_{disp} = Dispersive component of the plume depth (ft) or $(2 \times \alpha_z \times L)^{1/2}$ = 15

By calculation:

h_{adv} = 6.8
h_{disp} = 15
S_d = 21.8 ft which is larger than aquifer thickness; therefore, use S_d = 10 ft
x = 450 feet
λ_i = degradation rate constant = 0.1
Ri = retardation factor = $1+\frac{P_B K_d}{\theta_w}$
v = 4.3 ft/year
S_w = source width at 1,000 ppb isopleth = 150
K_{oc} = 39.8
f_{oc} = 0.02
θ_w = 0.6
P_G = 0.3
R = 1.4 (by calculation)

$$DAF = \frac{1}{\exp\left[\frac{450}{2(45)}\left(1-\sqrt{1+\frac{4(0.1)45(1.4)}{4.3}}\right)\right] \text{erf A} \quad \text{erf B}}$$

$$A = \frac{150}{4\sqrt{15(450)}}$$

$$B = \frac{10}{\sqrt{\frac{45}{20}(450)}}$$

DAF = 9467

It can be concluded:

- In order to keep the chloroform concentration at the point of exposure (the creek) below the MDEQ Tier 1 TRG Table, the zone of contamination should be kept below 9467 (0.152) = 1,460 ppb.

- In order to keep the chloroform concentration at the point of exposure (the creek) below the MCL, the zone of contamination should be kept below 9467 (100) = 946,700 ppb.

- In order to keep the chloroform concentration at the point of exposure (the creek) below the risk based number calculated in this section for non drinking water, the zone of contamination should be kept below 9467 (21.6) = 204,500 ppb.

Therefore, this chloroform plume need not be considered for corrective action. Continued monitoring is required.

SWMU 2 VOA Contamination in Groundwater

The groundwater underneath the landfill (SWMU 2) does contain various VOAs that are present in concentrations in excess of MDEQ Tier 1 TRG Table values. The contaminants are chloroform, carbon tetrachloride, acetaphenone, 4-nitrophenol, and bis-(2-ethyl)hexyl phthalate.

Figure 2-3 is a presentation of the summation of all the VOAs. The summations are misleadingly high; for example, a big contributor was caprolactam (MDEQ Tier 1 TRG value of 18,300 ppb) with a concentration as high as 12,200 ppb. The individual concentrations detected are tabulated in Table 4-5 and are listed on Figure 4-4K of the Groundwater Assessment Report (November 2001). There are no patterns that indicate interconnection of the VOA plumes within the landfill. The borings and temporary wells were advanced through the boundaries of former ponds or burial areas. The VOAs are indicative of what was buried or dumped into a particular pond or burial area.

The landfill area (SWMU 2) is monitored by permanent monitoring wells MW-5, MW-6 and MW-7. None of the compounds noted above have been detected in these monitor wells. Trichloroethene was detected in MW-5 and MW-6 in March 1996; laboratory or sampling error is suspected since it has been detected at no other time in both wells.

Modeling the SWMU 2 chloroform plume at LS2-W:

In order to check the potential difficulty at SWMU 2, chloroform from LS2-W was modeled similarly to the modeling at SWMU 23. With the only change to the previous calculation of

3.525 feet and SW = 100 feet, a DAF of $2.5(10^6)$ is calculated. Using the MSDEQ Tier 1 TRG Table value of 0.152 ppb as the objective to not exceed at the creek, the chloroform at LS2-W could be as high as 380,000 ppb. The calculations utilize degradation rate constants (λ) and retardation factors (R) are calculated from the literature. A field check is provided at SWMU 2 in that chloroform concentration drops from 221 ppb at LS2 to 17.3 ppb at LS4 which is 200 feet distant and directly in line with groundwater flow. At LS2, which is another 150 feet distant and also in line with groundwater flow, the chloroform concentration is non-detect.

Therefore, this chloroform plume need not be considered for corrective action.

SWMU 20 VOA Contamination in Groundwater

Solvents were used in the manufacturing processes for toxaphene. There is ample evidence of subsurface contamination of groundwater by these solvents. The concentration of VOAs in groundwater at temporary well location 20-2 is 401,112 ppb. Monitor wells MW-10C and MW-12C were installed at the boundaries of the VOA plumes. The concentration of VOAs in MW-12C is 27,837 ppb. The concentration of VOAs in Mw-10C is 2,568 ppb. VOAs are virtually non-detected in MW-12 and MW-10; therefore, the plume exists in the shallow zone of the aquifer.

The toxaphene manufacturing area was south of and adjacent to the dinoseb manufacturing area. Not surprisingly, the VOA plume is south of and adjacent to the dinoseb plume.

Various of the VOA components are presented in the groundwater in concentrations in excess of MDEQ Tier 1 TRG Table values. The contaminants are chloromethane, methylene chloride, 1,1-dichloroethene, 1,2, dichloroethene (total), chloroform, carbon tetrachloride, trichloroethene, benzene, 1,1,2-trichloroethane, and tetrachloroethene. Individual plumes of the contaminants are mapped on Figures 4-4A through 4-4J of the Groundwater Assessment Report (November 2001).

The corrective action for this plume will be considered during the Corrective Measures Study. There is, however, an important feature of the construction of the lining of the Surface Impoundments that may impact the transport of the VOA plume. A "blanket drain" was constructed along the western edge of the impoundment from the intake structure of the impoundment to the pump outlet structures. The blanket drain is a permeable layer that is

connected to the impoundment subsurface sumps. The blanket drain is depicted on Figure 2-5. The blanket drain and compacted soil placed atop the drain were installed to dewater the general area and provide support for the surface impoundment double liner system. The blanket drain now functions as an intercept trench between the dinoseb plume and Hennessey's Bayou and does influence the VOA plume.

ARSENIC PLUME

SWMU 11, 12, 15 – Arsenic Plume

Thirteen temporary wells advanced to the shallow zone and two permanent sets of permanent wells (MW-17A, MW-17B, MW-18A, MW-18B) advanced to the shallow and deep zones define the arsenic plume. The plume is depicted on Figure 2-4. Concentrations of arsenic as high as 288,000 ppb were detected in the shallow zone underneath the MSMA hazardous waste coke unloading area. A permanent 1-inch diameter well was installed in the area to allow a twenty gallon sample to be obtained for treatability testing. The sample analyzed 244,000 ppb arsenic.

The arsenic plume can be modeled similarly to the chloroform plume. Since arsenic is inorganic, there are significant differences. The degradation rate constant (λ) is zero; that is, there is no degradation. The retardation factor (R) is one; that is, the arsenic moves at the same velocity as the groundwater. Other parameters are (there is additional detail in the Groundwater Assessment Report [November 2001] beginning on page 4-33):

- x = 600 feet (Figure 2-4 distance from 300 ppb isopleth to Hennessey's Bayou)
- λ_i = 0 for inorganics
- R_i = 1 for inorganics
- v = 4.3 ft/year (Table 3-5)
- S_w = 20 ft (source depth at 300 ppb isopleth) is 20
- S_a = 300 ft (source thickness from 300 ppb isopleth to center of highest arsenic concentration)

The DAF is calculated as equal to 6.3.

The zone of contamination should be kept below (DAF)(MCL) = 6.3 (10) = 63 ppb in order that the arsenic concentration at the point of exposure is below 10 ppb.

The arsenic plume at SWMU 11, 12, 15 is subject to corrective action measures.

SUMMARY

From the description of the current situation it can be concluded that the following are to be considered for corrective action:

- Soil piles and surface soil in SWMU 20. Contamination is toxaphene and dinoseb as defined on Figure 2-1. The toxaphene is the most significant contaminant.

- The groundwater plume in SWMU 20. Contamination is VOAs and dinoseb. The VOA consists of ten organic compounds, each in concentrations that exceed MDEQ Tier 1 TRG Table value; the most significant VOAs are chloroform and carbon tetrachloride. The plumes are defined on Figures 2-2 and 2-3. Both VOA and dinoseb plumes are located in the source area.

- The groundwater plume in SWMU 11, 12, 15. Contamination is arsenic.

2.3 SCREENING OF CORRECTIVE MEASURES TECHNOLOGIES AND PROCESS OPTIONS

VCC has reviewed the results of the RFI and identified technologies which are applicable for corrective measures at the facility. In this section the preliminary corrective measures technologies are screened and supplemental technologies added to eliminate those that prove infeasible to implement, that rely on technologies unlikely to perform satisfactorily or reliably, or that do not achieve the corrective measures objectives. Those technologies which have severe limitations for a given set of waste and site-specific conditions are eliminated.

Potential corrective action technologies and process options that will be used to assemble the corrective action alternatives described in Section 3.0 were selected based on the site characterization data. Corrective action alternatives may consist of a combination of many technologies. The term corrective action technology refers to general categories of technology types, such as biological treatment, chemical treatment, and thermal destruction. The term process option refers to specific processes within each technology category. For

example, under the technology category of biological treatment, there may be aerobic and anaerobic treatment process options.

The screening and evaluation of corrective action technologies and process options were conducted for the following:

A. Soil contaminated with toxaphene. Dinoseb may also be present.

B. Groundwater contaminated with dinoseb, chloroform, carbon tetrachloride and other VOA.

C. Groundwater contaminated with arsenic.

IDENTIFICATION AND INITIAL SCREENING

The screening and evaluation of corrective action technologies and process options were conducted by going through the following steps:

- Identification and initial screening of corrective action technologies and process options.
- Evaluation of process options based on effectiveness, implementability, and relative cost.
- Selection of corrective action technologies and process options based on effectiveness and implementability.

The technologies and process options were assembled based on a review of the following:

- EPA guidance documents.
- EPA's Alternative Treatment Technology Information Center (ATTIC) database.
- Pertinent technical journals and seminar/conference proceedings.

- EPA's Vendor Information System for Innovative Treatment Technologies (VISITT).
- EPA's Cleanup Information Bulletin Board (CLU-IN).
- Information provided by equipment/process vendors and remediation contractors.
- URS' past experience in the hazardous waste remediation area.

The screening is presented in Tables 2-1A through 2-1I.

TABLE 2-1A

IDENTIFICATION AND INITIAL SCREENING OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

A. Soil Contaminated with Toxaphene and Dinoseb

General Response Action	Corrective Action Technology	Process Option	Status	Screening Comments
No Action	None	Continue observing for erosion potential.	Retained	Potentially applicable. Eroded contaminated soil ends up in rainwater impoundment.
Institutional Action	Access restrictions	Restrict access by Vicksburg Chemical employees to railroad area.	Screened out	Access to the railroad area is needed to operate the facility. It is a major transportation path for rail, car, and truck traffic.
Institutional and Removal Action	Move contaminated soil and provide access restrictions	Move contaminated soil piles and railroad area surface soil, then restrict access by Vicksburg Chemical employees.	Retained	Potentially applicable as long as erosion can be controlled.
Containment Action	Soil cap	Move contaminated soil piles and railroad area surface soil, then provide a clean soil cap.	Retained	Potentially applicable.
Containment Action	Geosynthetic liner and soil cap	Move contaminated soil piles and railroad area surface soil, then provide a geosynthetic liner and a clean soil cap.	Retained	Potentially applicable.
Containment Action	Landfill	Move contaminated soil piles and railroad area surface soil into an onsite landfill with a geosynthetic lined bottom, sides and cap and a clean soil cap.	Retained	Potentially applicable.
In-Situ Treatment	Bioremediation by composting	Mix compost (a mixture of gin trash, chicken manure, fertilizer and iron) with surface soil utilizing a rototiller. When degradation is complete, push soil piles onto same area, add compost and rototill.	Retained	Potentially applicable. Pilot testing required. It is likely that alternating anaerobic and aerobic cycles would be required. Addition of iron with compost shows a lot of promise.

TABLE 2-1A (Continued)

IDENTIFICATION AND INITIAL SCREENING OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

A. Soil Contaminated with Toxaphene and Dinoseb

General Response Action	Corrective Action Technology	Process Option	Status	Screening Comments
In-Situ Treatment	Solidification/ stabilization	Contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility.	Retained	Potentially applicable. Will reduce erosion and leaching potential.
In-Situ Treatment	Solidification/ stabilization plus soil cap	Contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility. A cap of clean soil is then added.	Retained	Potentially applicable. Will reduce erosion and leaching potential and potential for human exposure.
In-Situ Treatment	Solidification/ stabilization plus geosynthetic liner and soil cap	Contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility. A geosynthetic liner and cap of clean soil is then added.	Retained	Potentially applicable. Will reduce erosion and leaching potential and potential for human exposure.
In-Situ Treatment	Chemical treatment – oxidation	Inject Fenton's Reagent (solutions of hydrogen peroxide and ferrous chloride) into surface soil and into soil piles.	Retained	Potentially applicable. Pilot testing required.
In-Situ Treatment	Chemical treatment – dehalogenation	Inject potassium ethyl glycolate to replace halogen modules and under soil non-toxic.	Retained	Potentially applicable. Pilot testing required.
Ex-Situ Treatment	Bioremediation by composting	Move soil piles and surface soils into a Biological Treatment Unit (lined landfarm). Mix compost (a mixture of gin trash, chicken manure, fertilizer and iron) and rototill every three days. May have to alternate aerobic and anaerobic cycles.	Retained	Potentially applicable. Pilot testing required. Mixing of finely sized iron with compost shows a lot of promise.
Ex-Situ Treatment	Solidification/ stabilization	Move soil piles and surface soils and mix with solidification/ stabilization chemicals so that contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility.	Retained	Potentially applicable.

TABLE 2-1A (Continued)

IDENTIFICATION AND INITIAL SCREENING OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

A. Soil Contaminated with Toxaphene and Dinoseb

General Response Action	Corrective Action Technology	Process Option	Status	Screening Comments
Ex-Situ Treatment	Solidification/ stabilization plus soil cap	Move soil piles and surface soils and mix with solidification/ stabilization chemicals so that contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility. A clean soil cap is then added.	Retained	Potentially applicable.
Ex-Situ Treatment	Solidification/ stabilization plus geosynthetic liner and soil cap	Move soil piles and mix with solidification/ stabilization chemicals so that contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility. A geosynthetic liner and clean soil cap is then added.	Retained	Potentially applicable.
Ex-Situ Treatment	Solidification/ stabilization plus on-site landfill	Move soil piles and mix with solidification/ stabilization chemicals so that contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility. The material is then placed in a landfill with geosynthetic bottom, sides and top plus a clean soil cap.	Retained	Potentially applicable.
Ex-Situ Treatment	Soil washing	Contaminants sorbed onto soil particles are separated from soil in an aqueous-based system. The wash water may be augmented by pH adjustment, surfactant or chelating agent.	Screened out	Toxaphene tenaciously adsorbs to soil. There are no obvious solvents that would work and would not create a more difficult problem.
Ex-Situ Treatment	Incineration	Soil would be excavated and treated in an on-site incinerator.	Screened out	Public perception of incineration would not allow permitting to proceed.

TABLE 2-1A (Continued)

IDENTIFICATION AND INITIAL SCREENING OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

A. Soil Contaminated with Toxaphene and Dinoseb

General Response Action	Corrective Action Technology	Process Option	Status	Screening Comments
Ex-Situ Treatment	Vacuum assisted, indirect electrically treated thermal desorption unit	Soil would be excavated and treated in a thermal desorber. Contaminants would be desorbed from soil and condensed from the vapor stream.	Screened out	Even though it is not incineration, the public perceives it to be.
Ex-Situ Treatment	Biological treatment in a slurry reactor	Soil is mixed with water to a 25% slurry pumped to a reactor where it is mixed and biodegradation occurs. There may have to be alternating anaerobic and aerobic cycles.	Retained	Potentially applicable. Pilot effort would be required.
Ex-Situ Treatment	Chemical treatment – dehalogenation	Soil is mixed with a solution of potassium ethyl glycolate to replace to replace halogen molecules and render soil non-toxic.	Retained	Potentially applicable. Pilot effort would be required.
Ex-Situ Treatment	Chemical treatment – oxidation	Soil mixed with a solution of Fenton's Reagent (hydrogen peroxide and ferrous chloride) to destroy organic constituents.	Retained	Potentially applicable. Pilot effort would be required.
Off-Site	Excavation and off-site disposal	Dispose in a commercial waste landfill.	Retained	Potentially applicable. Soil may not be a characteristic or listed hazardous waste so land disposal restrictions would not apply.

TABLE 2-1B

IDENTIFICATION AND INITIAL SCREENING OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

B. Groundwater Contaminated with Dinoseb, Chloroform, Carbon Tetrachloride, and Other VOAs

General Response Action	Corrective Action Technology	Process Option	Status	Screening Comments
No Action	Monitoring	Continue monitoring program.	Retained	Will occur but in combination with other *corrective action technologies.*
Natural Attenuation	Monitoring	Monitor groundwater to evaluate progress of natural biodegradation and other attenuation mechanisms.	Retained	Applicable as part of the monitoring program and in combination with other corrective action technologies.
Institutional Action	Access restrictions	Deed restrictions in area of influence to restrict use of wells	Retained for the future	Contamination is on-site. Site will remain strictly industrial.
Containment Action	Vertical barriers – slurry wall	Slurry walls. Soil-bentonite slurry walls act as low permeability subsurface barrier walls that either contain, capture, or redirect groundwater flow at the site.	Screened out	Existing soil is quite impermeable. An engineered vertical barrier would have to tie into mari which is 60 feed bgs; that is not practical.
Containment Action	Vertical barriers – grouting	Grouting is a process by which grout is injected into the aquifer where it is set to reduce permeability of the aquifer and reduce flow.	Screened out	Effectiveness of grout barriers is uncertain for the depths involved and the compatibility with contaminants.
Removal Action	French drain	Installation of subsurface interceptor drains to collect and convey groundwater by gravity flow to sumps fitted with a pump.	Retained	Potentially very effective.
Removal Action	Extraction wells	Installation and operation of vertical extraction wells to remove contaminants and control hydraulic gradient,	Retained	Potentially applicable.
Removal Action	Extraction – horizontal wells	Wells are installed horizontally.	Screened out	For the transmissivity of the aquifer, horizontal wells are less applicable than vertical wells.

TABLE 2-1B (Continued)

IDENTIFICATION AND INITIAL SCREENING OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

B. Groundwater Contaminated with Dinoseb, Chloroform, Carbon Tetrachloride, and Other VOAs

General Response Action	Corrective Action Technology	Process Option	Status	Screening Comments
Removal Action	Extraction assisted by steam injection	Steam is injected into the subsurface soils to enhance the removal of organics. Extraction wells pump groundwater and transport vaporized contaminants under vacuum to the surface.	Screened out	Would disperse and spread contaminants. Vadose zone soil (except for 18-inch surface soil) is relatively free of contaminants.
Removal Action	Extraction assisted by solvent extraction	Solvents are injected into the groundwater to dissolve and mobilize the organic contaminants.	Screened out	The VOAs being extracted are solvents. Adding more would exacerbate the problem.
Removal Action	Extraction assisted by air sparging	Air is injected into groundwater to strip volatile organics from the groundwater into vapor in the vadose zone. Vapor extraction from the vadose zone in then used to remove the volatile organics from the vadose zone.	Screened out	Would disperse and spread contaminants. Vadose zone soil (except for 18-inch surface soil) is relatively free of contaminants.
Treatment Action – In-Situ	Chemical treatment – oxidation	Fenton's Reagent (hydrogen peroxide and ferrous chloride) is injected into groundwater utilizing a special high pressure sparging probe.	Retained	Potentially applicable.
Treatment Action – In-Situ	Biological treatment – bioplugs	System to introduce bacteria and nutrients subsurface to enhance the natural degradation of contamination. Bioplugs are inserted into vadose zone and groundwater and air trickled through bioplugs.	Screened out	Bioplugs are aerobic systems. It is likely that anaerobic then aerobic cycles would be required.
Treatment Action – Recovered Groundwater	Physical/chemical treatment – filtration	Remove suspended solids from recovered groundwater.	Retained	Potentially applicable as first treatment step.

TABLE 2-1B (Continued)

IDENTIFICATION AND INITIAL SCREENING OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

B. Groundwater Contaminated with Dinoseb, Chloroform, Carbon Tetrachloride, and Other VOAs

General Response Action	Corrective Action Technology	Process Option	Status	Screening Comments
Treatment Action – Recovered Groundwater	Physical/chemical treatment – precipitation/flocculation/ sedimentation	A combination of technologies used to remove inorganics from solution by precipitation, conglomeration, and gravity settling.	Screened out	Primarily for inorganics.
Treatment Action – Recovered Groundwater	Physical/chemical treatment – membrane technology	Reverse osmosis, ultrafiltration, hyperfiltration and electrodialysis are used to separate dissolved and suspended material from water.	Screened out	Each of these process has a concentrate stream which requires treatment
Treatment Action – Recovered Groundwater	Physical/chemical treatment – ion exchange	Anions and cations in dilute aqueous waste are removed from solution through the process of ion exchange.	Screened out	Chiefly of value when metals are the contaminants.
Treatment Action – Recovered Groundwater	Physical/chemical treatment – air stripping	A means of treating contaminated water by pumping through a packed column counter current to a stream of air injected with a compressor. Transfers volatile components to the air.	Screened out	Would not be effective for dinoseb. Chloroform and carbon tetrachloride would be stripped out but would need to be destroyed in a vapor phase catalytic incinerator.
Treatment Action – Recovered Groundwater	Physical/chemical treatment – steam stripping	Similar to air stripping except steam is injected rather than air. Used if volatility of the contaminant is too low for air stripping.	Screened out	Effective for dinoseb and VOAs. Contaminants and steam would have to be condensed in the air stream leaving a concentrated water stream to treat.
Treatment Action – Recovered Groundwater	Physical/chemical treatment – carbon adsorption	Soluble molecules of dinoseb and VOAs would be bonded onto activated carbon.	Retained	Very effective. An activated carbon system exists for treatment of water flowing to the surface impoundments. Groundwater could be pumped to these impoundments.

TABLE 2-1B (Continued)

IDENTIFICATION AND INITIAL SCREENING OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

B. Groundwater Contaminated with Dinoseb, Chloroform, Carbon Tetrachloride, and Other VOAs

General Response Action	Corrective Action Technology	Process Option	Status	Screening Comments
Treatment Action – Recovered Groundwater	Physical/chemical treatment – distillation	This unit process separates components of a liquid by partially vaporizing the mixture and separately recovering the vapors and residue.	Screened out	Primarily applicable to the recovery of concentrated spent solvents.
Treatment Action – Recovered Groundwater	Physical/chemical treatment – oxidation	Fenton's Reagent (hydrogen peroxide and ferrous chloride) is added to destroy organics.	Retained	Very effective.
Treatment Action – Recovered Groundwater	Treatment with iron filings	Iron filings are mixed with groundwater in a reactor to destroy the organics. The filings are filtered out and reused.	Retained	Potentially effective. Must be verified in the laboratory and then a pilot plant.
Treatment Action – Recovered Groundwater	Biological treatment – anaerobic and aerobic	An anaerobic flow through cycle would be followed by an aerobic cycle.	Screened out	The anaerobic cycle to dechlorinate the chloroform and carbon tetrachloride would be difficult to operate.
Disposal Action	Discharge – NPDES outfall	Discharge, after treatment, to Mississippi River in compliance with NPDES permit.	Retained	Applicable when used in conjunction with treatment technologies.
Disposal Action	Discharge – subsurface	Inject into subsurface zones.	Screened out	Injection could spread contaminants.

TABLE 2-1C

IDENTIFICATION AND INITIAL SCREENING OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

C. Groundwater Contaminated with Arsenic

General Response Action	*Corrective Action* Technology	Process Option	Status	Screening Comments
No Action	Monitoring	Continue monitoring program.	Retained	Will occur but in combination with other corrective action technologies
Natural Attenuation	Monitoring	Monitor groundwater to evaluate progress of natural biodegradation and other attenuation mechanisms.	Screened out	Arsenic will not degrade and is not retarded in groundwater flow.
Institutional Actions	Access Restrictions	Deed restrictions in area of influence to restrict use of wells.	Retained for the future	Contamination in on-site. Site will remain strictly industrial.
Containment Actions	Vertical barriers – slurry wall	Slurry walls. Soil-bentonite slurry walls act as low permeability subsurface barrier walls that either contain, capture, or redirect groundwater flow at the site.	Screened out	Existing soil is quite impermeable. An engineered vertical barrier would have to tie into marl which is 60 feet bgs; that is not practical.
Containment Action	Vertical barriers – grouting	Grouting is a process by which grout is injected into the aquifer where it is set to reduce permeability of the aquifer and reduce flow.	Screened out	Effectiveness of grout barriers is uncertain for the depths involved and the compatibility with contaminants.
Removal Action	French drain	Installation of subsurface interceptor chains to collect and convey groundwater by gravity flow to sumps fitted with a pump.	Retained	Potentially very effective.
Removal Action	Extraction wells	Installation and operation of vertical extraction wells to remove contaminants and control hydraulic gradient,	Retained	Potentially applicable.
Removal Action	Extraction – horizontal wells	Wells are installed horizontally.	Screened out	For the transmissivity of the aquifer, horizontal wells are less applicable than vertical wells.

TABLE 2-1C (Continued)

IDENTIFICATION AND INITIAL SCREENING OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

C. Groundwater Contaminated with Arsenic

General Response Action	Corrective Action Technology	Process Option	Status	Screening Comments
Removal Action	Extraction assisted by steam injection	Steam is injected into the subsurface soils to enhance the removal of organics. Extraction wells pump groundwater and transport vaporized contaminants under vacuum to the surface.	Screened out	Applicable to organics only.
Removal Action	Extraction assisted by solvent extraction	Solvents are injected into the groundwater to dissolve and mobilize the organic contaminants.	Screened out	Mainly applicable to organics.
Removal Action	Extraction assisted by air sparging	Air is injected into groundwater to strip volatile organics from the groundwater into vapor in the vadose zone. Vapor extraction from the vadose zone in then used to remove the volatile organics from the vadose zone.	Screened out	Applicable to organics only.
Treatment Action – In-Situ	Chemical treatment – oxidation	Fenton's Reagent (hydrogen peroxide and ferrous chloride) is injected into groundwater utilizing a special high pressure sparging probe.	Retained	Potentially applicable since it will form a precipitate with iron and adhere to the iron and soil subsurface.
Treatment Action – In-Situ	Biological treatment – bioplugs	System to introduce bacteria and nutrients subsurface to enhance the natural degradation of contamination. Bioplugs are inserted into vadose zone and groundwater and air trickled through bioplugs.	Screened out	Applicable to organics only.
Treatment Action – Recovered Groundwater	Physical/chemical treatment – filtration	Remove suspended solids from recovered groundwater.	Retained	Potentially applicable as first treatment step.

TABLE 2-1C (Continued)

IDENTIFICATION AND INITIAL SCREENING OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

C. Groundwater Contaminated with Arsenic

General Response Action	Corrective Action Technology	Process Option	Status	Screening Comments
Treatment Action – Recovered Groundwater	Physical/chemical treatment – precipitation/flocculation/ sedimentation	A combination of technologies used to remove inorganics from solution by precipitation, conglomeration, and gravity settling.	Retained	A precipitate is formed with arsenic and it is settled out or filtered.
Treatment Action – Recovered Groundwater	Physical/chemical treatment – membrane technology	Reverse osmosis, ultrafiltration, hyperfiltration and electrodialysis are used to separate dissolved and suspended material from water.	Screened out	Each of these process has a concentrate stream which requires treatment
Treatment Action – Recovered Groundwater	Physical/chemical treatment – ion exchange	Anions and cations in dilute aqueous waste are removed from solution through the process of ion exchange.	Retained	Potentially applicable.
Treatment Action – Recovered Groundwater	Physical/chemical treatment – air stripping	A means of treating contaminated water by pumping through a packed column counter current to a stream of air injected with a compressor. Transfers volatile components to the air.	Screened out	Only applicable for organics.
Treatment Action – Recovered Groundwater	Physical/chemical treatment – steam stripping	Similar to air stripping except steam is injected rather than air. Used if volatility of the contaminant is too low for air stripping.	Screened out	Only applicable for organics.
Treatment Action – Recovered Groundwater	Physical/chemical treatment – carbon adsorption	Soluble molecules of dinoseb and VOAs would be bonded onto activated carbon.	Screened out	Would cause difficulties with Calgon when they regenerate carbon. Regeneration is by thermal desorption in a non-oxidizing atmosphere. Arsenic would get into the air stream.
Treatment Action – Recovered Groundwater	Physical/chemical treatment – distillation	This unit process separates components of a liquid by partially vaporizing the mixture and separately recovering the vapors and residue.	Screened out	Only applicable to organics.

TABLE 2-1C (Continued)

IDENTIFICATION AND INITIAL SCREENING OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

C. Groundwater Contaminated with Arsenic

General Response Action	Corrective Action Technology	Process Option	Status	Screening Comments
Treatment Action – Recovered Groundwater	Physical/chemical treatment – oxidation	Fenton's Reagent (hydrogen peroxide and ferrous chloride) is added to precipitate arsenic.	Screened out	Subset of precipitation/flocculation/settling.
Treatment Action – Recovered Groundwater	Biological treatment – anaerobic and aerobic	An anaerobic flow through cycle would be followed by an aerobic cycle.	Screened out	Only applicable to organics.
Treatment Action – Recovered Groundwater	Phytoremediation	Use brake ferns to assimilate arsenic from groundwater. Fern fronds are harvested, dried, and disposed in hazardous waste landfill.	Retained	Potentially very effective.
Disposal Action	Discharge – NPDES outfall	Discharge, after treatment, to Mississippi River in compliance with NPDES permit.	Retained	Applicable when used in conjunction with treatment technologies.
Disposal Action	Discharge – subsurface	Inject into subsurface zones.	Screened out	Injection could spread contaminants.

Evaluation of Corrective Action Technologies and Process Options Based on Effectiveness, Implementability and Cost

This section describes the basis for evaluation of corrective action technologies and process options that were retained as potentially applicable after the identification and initial screening described in Tables 2-1A, 2-1B and 2-1C. The process options were evaluated based on effectiveness, implementability, and relative cost. The detailed evaluation is found in Tables 2-1D, 2-1E and 2-1F presented after the following discussion of effectiveness, implementability, and relative cost.

Effectiveness

The effectiveness evaluation focused on three primary considerations:

- The potential effectiveness of process options in handling each medium and meeting the goals identified in the general response actions. A process option that would not help to achieve the goals is generally precluded from further consideration.

- The effectiveness of the process options in protecting human health and the environment during the construction and implementation phases.

- The proven history and reliability of the process options with respect to contaminants and conditions such at hose at the site.

Implementability

The implementability evaluation considered both the technical and the administrative feasibility of constructing, operating and maintaining a particular process option. The determination that a process option is not technically feasible would generally preclude it from further consideration unless steps could be taken to change the conditions responsible for the determination.

Relative Cost

The relative cost included a qualitative (e.g., very high, high, moderate, etc.) estimation of the relative capital and operation and maintenance (O&M) costs associated with the process options. The cost analysis was made based on engineering judgment. Each process option was evaluated as to whether costs are high, medium, or low compared to other process options within the technology type.

TABLE 2-1D

EVALUATION OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

A. Soil Contaminated with Toxaphene and Dinoseb

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost	Status
No Action	None	Continue observing for erosion potential.	Not effective	Easy	Low	Screened out
Institutional and Removal Action	Move contaminated soil and provide access restrictions	Move contaminated soil piles and railroad area surface soil, then restrict access by Vicksburg Chemical employees.	Somewhat effective	Easy	Low	Retained
Containment Action	Soil cap	Move contaminated soil piles and railroad area surface soil, then provide a clean soil cap.	Somewhat effective	Easy	Low	Retained
Containment Action	Geosynthetic liner and soil cap	Move contaminated soil piles and railroad area surface soil, then provide a geosynthetic liner and a clean soil cap.	Reasonably effective	Relatively easy	Low to moderate	Retained
Containment Action	Landfill	Move contaminated soil piles and railroad area surface soil into an onsite landfill with a geosynthetic lined bottom, sides and cap and a clean soil cap.	Effective	Moderate	Moderate	Retained
In-Situ Treatment	Bioremediation by composting	Mix compost (a mixture of gin trash, chicken manure, fertilizer and iron) with surface soil utilizing a rototiller. When degradation is complete, push soil piles onto same area, add compost and rototill.	Very effective. Needs to be tested first by pilot effort.	Moderate	Moderate	Retained

TABLE 2-1D (Continued)

EVALUATION OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

A. Soil Contaminated with Toxaphene and Dinoseb

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost	Status
In-Situ Treatment	Solidification/ stabilization	Contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility.	Somewhat effective, although toxaphene is already well bound to soil.	Relatively easy	Moderate	Screened out. Insufficient increase in effectiveness.
In-Situ Treatment	Solidification/ stabilization plus soil cap	Contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility. A cap of clean soil is then added.	Effective, although toxaphene is already well bound to soil.	Moderate	Moderate	Screened out. Insufficient increase in effectiveness over alternative with soil cap only.
In-Situ Treatment	Solidification/ stabilization plus geosynthetic liner and soil cap	Contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility. A geosynthetic liner and clean soil cap is then added.	Effective, although toxaphene is already well bound to soil.	Moderate	Moderate	Screened out. Insufficient increase in effectiveness over alternative with geosynthetic liner and soil cap.
In-Situ Treatment	Chemical treatment – oxidation	Inject Fenton's Reagent (solutions of hydrogen peroxide and ferrous chloride) into surface soil and into soil piles.	Effective. Pilot effort would be required.	Many injections would be required.	High	Retained

TABLE 2-1D (Continued)

EVALUATION OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

A. Soil Contaminated with Toxaphene and Dinoseb

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost	Status
In-Situ Treatment	Chemical treatment – dehalogenation	Inject potassium ethyl glycolate to replace halogen modules and under soil non-toxic.	Somewhat effective on toxaphene but would not degrade dinoseb.	Moderate	Very high	Screened out on effectiveness.
Ex-Situ Treatment	Bioremediation by composting	Move soil piles and surface soils into a Biological Treatment Unit (lined landfarm). Mix compost (a mixture of gin trash, chicken manure, fertilizer and iron) and rototill every three days. May have to alternate aerobic and anaerobic cycles.	Effective. Pilot effort would be required.	Moderate	Moderate	Retained
Ex-Situ Treatment	Solidification/ stabilization	Move soil piles and surface soils and mix with solidification/ stabilization chemicals so that contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility.	Somewhat effective, but toxaphene is already well bound to soil.	Moderately easy	Moderate to high	Screened out. Insufficient increase in effectiveness.
Ex-Situ Treatment	Solidification/ stabilization plus soil cap	Move soil piles and surface soils and mix with solidification/ stabilization chemicals so that contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility. A clean soil cap is then added.	Reasonable effective, but toxaphene is already well bound to soil.	Moderately easy	Moderate to high	Screened out. Insufficient increase in effectiveness over alternative with soil cap.

TABLE 2-1D (Continued)

EVALUATION OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

A. Soil Contaminated with Toxaphene and Dinoseb

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost	Status
Ex-Situ Treatment	Solidification/ stabilization plus geosynthetic liner and soil cap	Move soil piles and mix with solidification/ stabilization chemicals so that contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility. A geosynthetic liner and clean soil cap is then added.	Effective, but toxaphene is already well bound to soil.	Moderate	Moderate to high	Screened out. Insufficient increase in effectiveness over alternative with geosynthetic liner and soil cap.
Ex-Situ Treatment	Solidification/ stabilization plus on-site landfill	Move soil piles and mix with solidification/ stabilization chemicals so that contaminants are physically bound and chemical reactions are induced to reduce contaminant mobility. The material is then placed in a landfill with geosynthetic bottom, sides and top plus a clean soil cap.	Effective, but toxaphene is already well bound to soil.	Moderate	Moderate to high	Screened out. Insufficient increase in effectiveness over landfill alternatives.
Ex-Situ Treatment	Biological treatment in a slurry reactor	Soil is mixed with water to a 25% slurry pumped to a reactor where it is mixed and biodegradation occurs. There may have to be alternating anaerobic and aerobic cycles.	Effective, but no more effective than composting.	Difficult	Very high	Screened out on lack of increase in effectiveness over composting and very high cost.

TABLE 2-1D (Continued)

EVALUATION OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

A. Soil Contaminated with Toxaphene and Dinoseb

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost	Status
Ex-Situ Treatment	Chemical treatment – dehalogenation	Soil is mixed with a solution of potassium ethyl glycolate to replace to replace halogen molecules and render soil non-toxic.	Somewhat effective on toxaphene but would not degrade dinoseb.	Moderate	Very high	Screened out on effectiveness.
Ex-Situ Treatment	Chemical treatment – oxidation	Soil mixed with a solution of Fenton's Reagent (hydrogen peroxide and ferrous chloride) to destroy organic constituents.	Effective. Pilot effort would be required.	Moderate	High	Retained
Off-Site	Excavation and off-site disposal	Dispose in a commercial waste landfill.	Effective	Easy	The cost depends on whether the soil is classified hazardous or not. If LDR conditions apply, off-site treatment would drive costs to "extremely high".	Retained for evaluation of classification of waste.

TABLE 2-1E

EVALUATION OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

B. Groundwater Contaminated with Dinoseb, Chloroform Carbon Tetrachloride and Other VOAs

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost	Status
No Action	Monitoring	Continue monitoring program.	Not effective	Easy	Low	Screened out
Natural Attenuation	Monitoring	Monitor groundwater to evaluate progress of natural biodegradation and other attenuation mechanisms.	Somewhat effective	Easy	Low	Retained
Institutional Action	Access restrictions	Deed restrictions in area of influence to restrict use of wells	Not effective	Easy	Low	Screened out. Site will remain industrial.
Removal Action	French drain	Installation of subsurface interceptor drains to collect and convey groundwater by gravity flow to sumps fitted with a pump.	Effective	Relatively easy. Watch for subsurface lines in old facility.	Relatively low	Retained
Removal Action	Extraction wells	Installation and operation of vertical extraction wells to remove contaminants and control hydraulic gradient,	Effective if many wells are installed	Relatively easy	Relatively low	Retained
Treatment Action – In-Situ	Chemical treatment – oxidation	Fenton's Reagent (hydrogen peroxide and ferrous chloride) is injected into groundwater utilizing a special high pressure sparging probe.	Effective, but many injections would be required	Easy	High	Retained
Treatment Action – Recovered Groundwater	Physical/chemical treatment – filtration	Remove suspended solids from recovered groundwater.	Effective	Easy	Low	Retained as one step in treatment train.

TABLE 2-1E (Continued)

EVALUATION OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

B. Groundwater Contaminated with Dinoseb, Chloroform Carbon Tetrachloride and Other VOAs

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost	Status
Treatment Action – Recovered Groundwater	Physical/chemical treatment – carbon adsorption	Soluble molecules of dinoseb and VOAs would be bonded onto activated carbon.	Effective	Easy	Low	Retained
Treatment Action – Recovered Groundwater	Physical/chemical treatment – oxidation	Fenton's Reagent (hydrogen peroxide and ferrous chloride) is added to destroy organics.	Effective	Easy	High	Retained
Treatment Action – Recovered Groundwater	Mix groundwater with iron filings	Iron fillings and groundwater would be mixed in a reactor. The iron filings would be filtered out and reused.	Potentially effective	Moderate	Moderate	Retained
Disposal Action	Discharge – NPDES outfall	Discharge, after treatment, to Mississippi River in compliance with NPDES permit.	Effective	Easy	Low	Retained in conjunction with treatment technologies.

TABLE 2-1F

EVALUATION OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

Groundwater Contaminated with Arsenic

General Response Action	Corrective Action *Technology*	Process Option	Effectiveness	Implementability	Relative Cost	Status
No Action	Monitoring	Continue monitoring program.	Not effective	Easy	Low	Screened out effectiveness
Institutional Actions	Access Restrictions	Deed restrictions in area of influence to restrict use of wells.	Not needed. Site will remain industrial.	Easy	Low	Screened out
Removal Action	French drain	Installation of subsurface interceptor chains to collect and convey groundwater by gravity flow to sumps fitted with a pump.	Effective	Relatively easy	Low	Retained
Removal Action	Extraction wells	Installation and operation of vertical extraction wells to remove contaminants and control hydraulic gradient,	Effective. Many wells would be required.	Easy	Low	Retained
Treatment Action – In-Situ	Chemical treatment – oxidation	Fenton's Reagent (hydrogen peroxide and ferrous chloride) is injected into groundwater utilizing a special high pressure sparging *probe.*	Effective	Moderate	High	Retained
Treatment Action – Recovered Groundwater	Physical/chemical treatment – filtration	Remove suspended solids from recovered groundwater.	Effective	Easy	Low	Retained

TABLE 2-1F (Continued)

EVALUATION OF CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

Groundwater Contaminated with Arsenic

General Response Action	Corrective Action Technology	Process Option	*Effectiveness*	Implementability	Relative Cost	Status
Treatment Action – Recovered Groundwater	Physical/chemical treatment – precipitation/ flocculation/ sedimentation	A combination of technologies used to remove inorganics from solution by precipitation, conglomeration, and gravity settling.	Effective	Moderate	Moderate	Retained
Treatment Action – Recovered Groundwater	Physical/chemical treatment – ion exchange	Anions and cations in dilute aqueous waste are removed from solution through the process of ion exchange.	Effective	Easy	High	Retained
Treatment Action – Recovered Groundwater	Phytoremediation	Use brake ferns to assimilate arsenic from groundwater. Fern fronds are harvested, dried, and disposed in hazardous waste landfill.	Effective	Relatively easy	Relatively low	Retained
Disposal Action	Discharge – NPDES outfall	Discharge, after treatment, to Mississippi River in compliance with NPDES permit.	Effective	Moderate. May have to bypass carbon units.	Low	Retained

RETAINED CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS

Those corrective action technologies and process options which have been retained are resummarized in tables 2-1G, 2-1H, and 2-1I. The retained corrective action technologies and process options are used as building blocks to form remedial action alternatives for the entire Vicksburg Chemical site. Section 3.0 is the Identification and Development of Corrective Measures Study Alternatives. Some of that development involves laboratory experiments conducted by Vicksburg Chemical. Section 4.0 is the Evaluation of Corrective Measures Study Alternatives, which lead to the final selection of recommended corrective action alternatives for the Vicksburg Chemical site. Various assumption on treatment effectiveness and cost will be made which have to be verified in the field; therefore, each corrective action alternative will set out a pilot evaluation as the first step.

TABLE 2-1G (Continued)

CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS RETAINED BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

A. Soil Contaminated with Toxaphene and Dinoseb

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost
Ex-Situ Treatment	Bioremediation by composting	Move soil piles and surface soils into a Biological Treatment Unit (lined landfarm). Mix compost (a mixture of gin trash, chicken manure, fertilizer and iron) and rototill every three days. May have to alternate aerobic and anaerobic cycles.	Effective. Pilot effort would be required.	Moderate	Moderate
Ex-Situ Treatment	Chemical treatment – oxidation	Soil mixed with a solution of Fenton's Reagent (hydrogen peroxide and ferrous chloride) to destroy organic constituents.	Effective. Pilot effort would be required.	Moderate	High
Off-Site	Excavation and off-site disposal	Dispose in a hazardous waste landfill.	Effective	Easy	The cost depends on whether the soil is classified hazardous or not. If LDR conditions apply, off-site treatment would drive costs to "extremely high".

TABLE 2-1H

CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS RETAINED BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

B. Groundwater Contaminated with Dinoseb, Chloroform Carbon Tetrachloride and Other VOAs

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost
Natural Attenuation	Monitoring	Monitor groundwater to evaluate progress of natural biodegradation and other attenuation mechanisms.	Somewhat effective	Easy	Low
Removal Action	French drain	Installation of subsurface interceptor drains to collect and convey groundwater by gravity flow to sumps fitted with a pump.	Effective	Relatively easy. Watch for subsurface lines in old facility.	Relatively low
Removal Action	Extraction wells	Installation and operation of vertical extraction wells to remove contaminants and control hydraulic gradient.	Effective if many wells are installed	Relatively easy	Relatively low
Treatment Action – In-Situ	Chemical treatment – oxidation	Fenton's Reagent (hydrogen peroxide and ferrous chloride) is injected into groundwater utilizing a special high pressure sparging probe.	Effective, but many injections would be required	Easy	High
Treatment Action – Recovered Groundwater	Physical/chemical treatment – filtration	Remove suspended solids from recovered groundwater.	Effective	Easy	Low
Treatment Action – Recovered Groundwater	Physical/chemical treatment – oxidation	Fenton's Reagent (hydrogen peroxide and ferrous chloride) is added to destroy organics.	Effective	Easy	High
Treatment Action – Recovered Groundwater	Mix groundwater with iron filings	Iron filings and groundwater would be mixed in a reactor. The iron filings would be filtered out and reused.	Potentially effective	Moderate	Moderate

TABLE 2-1H (Continued)

CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS RETAINED BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

B. Groundwater Contaminated with Dinoseb, Chloroform Carbon Tetrachloride and Other VOAs

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost
Treatment Action – Recovered Groundwater	Physical/chemical treatment – carbon adsorption	Soluble molecules of dinoseb and VOAs would be bonded onto activated carbon.	Effective	Easy	Low
Disposal Action	Discharge – NPDES outfall	Discharge, after treatment, to Mississippi River in compliance with NPDES permit.	Effective	Easy	Low

TABLE 2-1I

CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS RETAINED BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

Groundwater Contaminated with Arsenic

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost
Removal Action	French drain	Installation of subsurface interceptor drains to collect and convey groundwater by gravity flow to sumps fitted with a pump.	Effective	Relatively easy	Low
Removal Action	Extraction wells	Installation and operation of vertical extraction wells to remove contaminants and control hydraulic gradient,	Effective. Many wells would be required.	Easy	Low
Treatment Action – In-Situ	Chemical treatment – oxidation	Fenton's Reagent (hydrogen peroxide and ferrous chloride) is injected into groundwater utilizing a special high pressure sparging probe.	Effective	Moderate	High
Treatment Action – Recovered Groundwater	Physical/chemical treatment – filtration	Remove suspended solids from recovered groundwater.	Effective	Easy	Low
Treatment Action – Recovered Groundwater	Physical/chemical treatment – precipitation/ flocculation/ sedimentation	A combination of technologies used to remove inorganics from solution by precipitation, conglomeration, and gravity settling.	Effective	Moderate	Moderate
Treatment Action – Recovered Groundwater	Physical/chemical treatment – ion exchange	Anions and cations in dilute aqueous waste are removed from solution through the process of ion exchange.	Effective	Easy	High

TABLE 2-1I (Continued)

CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS RETAINED BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

Groundwater Contaminated with Arsenic

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost
Treatment Action – Recovered Groundwater	Phytoremediation	Use brake ferns to assimilate arsenic from groundwater. Fern fronds are harvested, dried, and disposed in hazardous waste landfill.	Effective	Relatively easy	Relatively low
Disposal Action	Discharge – NPDES outfall	Discharge, after treatment, to Mississippi River in compliance with NPDES permit.	Effective	Moderate. May have to bypass carbon units.	Low

Corrective action alternatives are identified and developed in this section to provide a range of cleanup options to address the corrective action objectives for soil and groundwater. These alternatives are identified from the retained technology types and process options described in Section 2.0. The identified alternatives (Subsections 3.1, 3.2, and 3.3) are developed by screening (Subsections 3.4, 3.5, and 3.6) on the basis of the following:

- Effectiveness – Evaluated by considering each alternative's ability to protect human health and the environment and reduce the toxicity, mobility and volume of contaminants.

- Implementability – Evaluated by considering both the operational and technical feasibility of constructing, maintaining and operating the alternatives.

- Cost – Evaluated on a relative basis for making comparisons among the alternatives. No alternatives are screened out on the basis of cost. Detailed cost analysis is found in Section 4.0.

The following retained technologies and process options were identified and screened in the previous Section Two for each of the three problem areas requiring corrective action.

A. Soil Contaminated with Toxaphene and Dinoseb

Removal and Institutional Action
- Move contaminated soil and restrict access

Contaminant Action
- Move contaminated soil and provide a soil cap
- Move contaminated soil and provide a geosynthetic liner and a soil cap
- Move contaminated soil into onsite landfill with a geosynthetic lined bottom, side, and cap plus a soil cap

In-Situ Treatment
- Bioremediation by composting
- Oxidation with Fenton's Reagent

Ex-Situ Treatment

- Bioremediation by composting with iron addition
- Oxidation with Fenton's Reagent

Off-Site

- Dispose in commercial waste landfill, if soil can be classified non-hazardous and subjected to Land Disposal Restrictions

B. Groundwater Contaminated with Dinoseb, Chloroform, Carbon Tetrachloride and Other VOAs

No Action – In-Situ Treatment

- Oxidation with Fenton's Reagent

Removal Action

- French drains
- Extraction wells

Ex-Situ Treatment

- Filtration
- Oxidation with Fenton's Reagent
- Iron filings
- Carbon adsorption

Disposal Action

- Discharge, after treatment, through NPDES permit

C. Groundwater Contaminated with Arsenic

In-Situ Treatment

- Fenton's Reagent – Precipitate arsenic/iron complex on Formation Soil

Removal Action

- French drains
- Extraction wells

Ex-Situ Treatment
- Filtration
- Precipitation/flocculation/settling
- Ion exchange
- Phytoremediation

Disposal Action
- Discharge, after treatment, through NPDES permit

There are 9 technologies for "A. Soil Contaminated with Toxaphene and Dinoseb", 9 technologies for "B. Groundwater Contaminated with Dinoseb, Chloroform, Carbon Tetrachloride and Other VOAs" and 8 technologies for "C. Groundwater Contaminated with Arsenic." Assuming that one technology chosen is chosen from each of "A", "B", or "C" to constitute a site-wide Corrective Action Alternative, that would result in a potential study of 720 alternatives. Since more than one technology alternative may be chosen for each of "A", "B", and "C", it is possible to create more than 720 site-wide corrective action alternatives. It is more logical to separately identify corrective action alternatives for each of "A", "B", and "C"; therefore, that will be the format in each of the following subsections:

3.1 Identification of Corrective Action Alternatives for Soil Contaminated with Toxaphene and Dinoseb

3.2 Identification of Corrective Action Alternatives for Groundwater Contaminated with Dinoseb, Chloroform, Carbon Tetrachloride and Other VOAs

3.3 Identification of Corrective Action Alternatives for Groundwater Contaminated with Arsenic

3.1 IDENTIFICATION OF CORRECTIVE ACTION ALTERNATIVES FOR SOIL CONTAMINATED WITH TOXAPHENE AND DINOSEB

The following are the corrective action alternatives that have been identified:

Alternative A-1; Removal and Institutional Action

This alternative involves the construction of an uncovered soil pile immediately to the southwest of the atrazine warehouse. The soil piles located there now would form the western boundary and the southern boundary of the new soil pile. The soil pile and surface soil in SWMU 20 that is contaminated with toxaphene or dinoseb in excess of the MDEQ Tier 1 TRE Table restricted values would be excavated and moved to the new soil pile. Signs would be posted around the pile to prohibit entrance. Silt fences would be constructed down slope to trap soil eroding during rainstorms.

Alternative A-2; Removal Action with Containing Soil Cap

This alternative involves construction of the soil pile noted in Alternative A-1; however, a cap would be constructed atop the soil and would consist of 6 inches of clay and 6 inches of top soil. Grassy vegetation would be established to inhibit erosion.

Alternative A-3; Removal Action with Containing Geosynthetic Liner and Soil Cap

This alternative involves construction of the soil pile noted in Alternative A-1; however, a cap would be constructed atop the soil and would consist of a geosynthetic liner and drainage layer, 6 inches of clay and 6 inches of top soil. Grassy vegetation would be established to inhibit erosion.

Alternative A-4; Removal Action with Containing Geosynthetic Liner on Bottom, Sides and Top with Appropriate Drainage Layers Plus Soil Cap

The alternative involves removal of the soil pile noted in Alternative A-1; however, the soil would be placed inside a landfill constructed on-site. The landfill would have a geosynthetic liner and drainage layer on the bottom, sides and top. The cap would additionally consist of 6 inches of clay and 6 inches of top soil. Grassy vegetation would be established to inhibit erosion.

TABLE 2-1G

CORRECTIVE ACTION TECHNOLOGIES AND PROCESS OPTIONS RETAINED BASED ON EFFECTIVENESS, IMPLEMENTABILITY AND RELATIVE COST

A. Soil Contaminated with Toxaphene and Dinoseb

General Response Action	Corrective Action Technology	Process Option	Effectiveness	Implementability	Relative Cost
Removal and Institutional Action	Move contaminated soil and provide access restrictions	Move contaminated soil piles and railroad area surface soil, then restrict access by Vicksburg Chemical employees.	Somewhat effective	Easy	Low
Containment Action	Soil cap	Move contaminated soil piles and railroad area surface soil, then provide a clean soil cap.	Effective	Easy	Low
Containment Action	Geosynthetic liner and soil cap	Move contaminated soil piles and railroad area surface soil, then provide a geosynthetic liner and a clean soil cap.	Effective	Relatively easy	Low to moderate
Containment Action	Landfill	Move contaminated soil piles and railroad area surface soil into an onsite landfill with a geosynthetic lined bottom, sides and cap and a clean soil cap.	Effective	Moderate	Moderate
In-Situ Treatment	Bioremediation by composting	Mix compost (a mixture of gin trash, chicken manure, fertilizer and iron) with surface soil utilizing a rototiller. When degradation is complete, push soil piles onto same area, add compost and rototill.	Very effective. Needs to be tested first by pilot effort.	Moderate	Moderate
In-Situ Treatment	Chemical treatment – oxidation	Inject Fenton's Reagent (solutions of hydrogen peroxide and ferrous chloride) into surface soil and into soil piles.	Effective. Pilot effort would be required.	Many injections will be required.	High

Alternative A-5; In-Situ Treatment by Composting Plus Iron Addition

With this alternative a composting bed would first be established by rotatilling compost and iron into the top 18 inches of surface soil of interest in SWMU 20. The compost would consist of gin trash, chicken manure, and fertilizer. After sufficient degradation of toxaphene and dinoseb, the soil piles would be placed atop the bed in a 6 inch lift. Compost and iron would be added and the bed would be rotatilled. After adequate degradation of the contaminants in the lift another 6 inches of soil would be added with compost and iron. After sufficient iterations the soil pile would be completely treated. Treated soil could remain in place or be moved anywhere within CAMU boundaries. Erosion control would have to be maintained.

Alternative A-6; In-Situ Treatment By Injection of Fenton's Reagent

This alternative involves injection of Fenton's Reagent (hydrogen peroxide and ferrous sulfate) directly into the soil piles and the pertinent 18 inches of surface soil depth. The injection tool is a wand with multiple injection jets at the end. Upwards of 20,000 psi can be generated at the jet tips to allow horizontal penetration of the soil as the wand is moved vertically. Injections might have to be made at 4-foot-intervals. Injections would have to be repeated as many as six times. Treated soil could remain in place or be moved anywhere within CAMU boundaries. Erosion control would have to be maintained.

Alternative A-7; Ex-Situ Treatment by Composting Plus Iron Addition

This alternative is similar to Alternative A-5; however, all the soil to be treated would be moved to one location on-site where treatment beds would be established. Treated soil could remain in place or be moved anywhere within CAMU boundaries. Erosion control would have to be maintained.

Alternative A-8; Off-Site Disposal in Landfill

This alternative involves movement of soil piles and surface soil to an off-site commercial landfill. Exploration of this alternative is a regulatory study and site history study to determine if the soil of interest is hazardous. The soil meets TCLP requirements and is, therefore, not hazardous by characteristic.

3.2 IDENTIFICATION OF CORRECTIVE ACTION ALTERNATIVES FOR GROUNDWATER CONTAMINATED WITH DINOSEB, CHLOROFORM, CARBON TETRACHLORIDE AND OTHER VOAs

The following are the corrective action alternatives that have been identified.

Alternative B-1; No Action, Natural Attenuation Monitoring

As the name implies, this alternative involves no corrective action but does require continued monitoring. Groundwater would be evaluated for progress of natural biodegradation and other attenuation mechanisms.

Alternative B-2; In-Situ Treatment with Fenton's Reagent

This alternative involves injection of Fenton's Reagent (hydrogen peroxide and ferrous sulfate) directly into the shallow zone of the groundwater aquifer. The injection tool is a wand with multiple injection jets at the end. Upwards of 20,000 psi can be generated at the jet tips to allow horizontal penetration throughout the zone as the wand is moved vertically from 10 feet bgs to 20 feet bgs. Injections might have to be made at 4-foot intervals. Injections would have to be repeated as many as six times.

Alternative B-3; Ex-Situ Treatment with Fenton's Reagent

This alternative involves capture of the plume with a French drain, extraction wells or some combination thereof. The recovered groundwater would be treated by addition of Fenton's Reagent (hydrogen peroxide and ferrous sulfate) in a reactor. The reactor contents would be discharged into the surface impoundment. Contents of the surface impoundment are discharged through activated carbon columns and into the Mississippi River via an NPDES Permit.

Alternative B-4; Ex-Situ Treatment with Iron Filings

This alternative involves capture of the plume with a French drain, extraction wells or some combination thereof. The recovered groundwater would be treated by addition of iron filings in a reactor. The reactor contents would be pumped through a settling tank then a polishing filter and into the surface impoundment. The iron filings would drop to the bottom of the

settling tank and would be recycled to the reactor for reuse. Contents of the surface impoundment are discharged through activated carbon columns and into the Mississippi River via an NPDES Permit.

Alternative B-5; Ex-Situ Treatment with Carbon Adsorption

This alternative involves capture of the plume with a French drain, extraction wells or some combination thereof. The recovered groundwater would be discharged directly into the surface impoundment. Contents of the surface impoundment are discharged through activated carbon columns and into the Mississippi River via an NPDES Permit.

3.3 IDENTIFICATION OF CORRECTIVE ACTION ALTERNATIVES FOR GROUNDWATER CONTAMINATED WITH ARSENIC

The following are corrective action alternatives that have been identified.

Alternative C-1; In-Situ Treatment with Injection of Precipitating Agents

This alternative involves injection of chemicals directly into the shallow zone of the groundwater aquifer. The objective is to cause precipitation of arsenic and adherence of that arsenic to subsurface media. Fenton's Reagent (hydrogen peroxide and ferrous sulfate) is an example of chemicals that will achieve the desired objective. The injection tool is a wand with multiple injection jets at the end. Upwards of 20,000 psi can be generated at the jet tips to allow horizontal penetration throughout the zone as the wand is moved vertically from 10 feet bgs to 20 feet bgs. Injections might have to be made at 4-foot intervals. Injections would have to be repeated as many as six times.

Alternative C-2; Ex-Situ Treatment By Precipitation/Flocculating/Settling

This alternative involves capture of the plume with a French drain, extraction wells or some combination thereof. The recovered groundwater would be discharged to a reactor where a precipitation chemical would be added. Reactor contents would be pumped to a clarifier where flocculants would be added and the arsenic bearing precipitant would be separated out. The arsenic bearing stream would be pumped through a filter for accumulation of the arsenic precipitant then through a polish filter into the surface impoundment. The clarified stream would be pumped through a separate polish filter into the surface impoundment. The

accumulated arsenic would be disposed at a commercial waste landfill. The surface impoundment is discharged through activated carbon columns into the Mississippi River via an NPDES permit.

Alternative C-3; Ex-Situ Treatment By Ion Exchange

This alternative involves capture of the plume with a French drain, extraction wells or some combination thereof. The recovered groundwater would be discharged through ion exchange columns where arsenic would be exchanged for a non-toxic ion to the surface impoundment. The surface impoundment is discharged through activated carbon columns into the Mississippi River via an NPDES permit. Spent ion-exchange columns would be disposed in a hazardous waste landfill.

Alternative C-4; Ex-Situ Treatment By Phytoremediation

This alternative involves capture of the plume with a French drain, extraction wells or some combination thereof. The recovered groundwater would be discharged to a hydroponic bed of cane brake ferns. Overflow from the hydroponic bed would be pumped to the surface impoundment. Contents of the surface impoundment would be discharged to the Mississippi River through activated carbon columns via an NPDES permit. Fern fronds would be periodically harvested, dried and disposed in a hazardous waste landfill.

3.4 DEVELOPMENT OF CORRECTIVE ACTION ALTERNATIVES FOR SOIL CONTAMINATED WITH TOXAPHENE AND DINOSEB

Alternative A-1; Removal and Institutional Action

This solution involves the construction of one soil pile which is a consolidation of contaminated soil not meeting Corrective Action Objectives. The soil pile would be constructed immediately to the southwest of the atrazine warehouse. A depiction of the soil pile is presented in Figure 3-1. The footprint of the soil pile is 650 feet by 75 feet by 15 feet high. Sides would be sloped 2:1. In order to obtain the footprint noted a portion of the south plant drainage ditch would be rerouted.

Access to the soil pile would be restricted. Grass would be grown on the soil pile to control erosion. Silt fences would be placed in erosional pathways.

Effectiveness

If equal weight is given to each of the toxaphene and dinoseb analytical results of the contaminated soil to be moved to the engineered soil pile, the average for the soil pile is 23,610 ppb toxaphene and 88,445 ppb dinoseb. The restricted values from the MDEQ Tier 1 TRG Table is 5,200 ppb toxaphene and 204,000 ppb dinoseb.

In order for this alternative to be effective, the pathways of exposure for toxaphene have to be closed. The absence of leaching of the toxaphene by rainwater has been demonstrated by the data in the RFI Report and the Groundwater Assessment Report. Mobility of toxaphene is accomplished by water and wind erosional mechanisms; therefore, both have to be controlled. Direct contact with the soil is an exposure mechanism to be controlled.

Erosion by water and wind can be controlled by establishing vegetation on the soil piles. While the vegetation is being established, silt fences will be placed in erosion pathways.

Direct contact exposure will be controlled by restricting access to the soil pile. Since the vegetation on the soil pile will have to be established and then mowed when established, avoidance of direct contact may be a problem. Wind erosion will be controlled by keeping the soil pile moist as vegetation is established.

Implementability

This alternative would be implemented by first rerouting a portion of the South Plant Drainage Ditch. A section, approximately 300 feet long, would have to be excavated. The excavated soil would be placed in the existing ditch to help form a base for the soil pile. Then the relatively uncontaminated adjacent soil piles would be used to form a 700 feet by 90 feet by 0.5 feet base.

The first step is to move the adjacent contaminated soil piles atop the base. Next the soil piles atop the former toxaphene and dinoseb manufacturing areas would be moved to the engineered soil pile. Then the shallow surface soil would be excavated and moved to the new soil pile location. Approximately 5,400 cubic yards of clean fill would be placed in the excavations.

As the soil pile is constructed, large chunks of concrete are removed and set aside to be used to cover the bottom slopes of the soil pile as a rip rap for erosion control.

Relative Cost

There are no difficult or complex steps required with this alternative. The relative cost is low.

Screening Comments

Even though this alternative is somewhat effective, the potential for mobility of toxaphene and direct contact of workers with toxaphene remains. This alternative is screened out.

Alternative A-2; Removal Action with Containing Soil Cap

This alternative involves the construction of one soil pile which is a consolidation of contaminated soil not meeting Corrective Action Objectives. The soil pile would be constructed immediately to the southwest of the atrazine warehouse. A depiction of the soil pile is presented as Figure 3-1. The footprint of the soil pile is 650 feet by 75 feet by 15 feet high. Sides would be sloped 2:1. In order to obtain the footprint noted, a portion of the south plant drainage ditch would be rerouted.

The soil pile would be covered with a soil cap consisting of six inches of clay and six inches of top soil. Grassy vegetation would be established to inhibit erosion.

Effectiveness

If equal weight is given to each of the toxaphene and dinoseb analytical results of the contaminated soil to be moved to the engineered soil pile, the average for the soil pile is 23,610 ppb toxaphene and 88,445 ppb dinoseb. The restricted values from the MDEQ Tier 1 TRG Table are 5,200 ppb toxaphene and 204,000 ppb dinoseb.

In order for this alternative to be effective, the pathways of exposure for toxaphene have to be closed. The absence of leaching of the toxaphene by rainwater has been demonstrated by the data in the RFI Report and the Groundwater Assessment Report. Mobility of toxaphene is

accomplished by water and wind erosional mechanisms; therefore, both have to be controlled. Direct contact with the soil is an exposure mechanism to be controlled.

Erosion of toxaphene contaminated soil can be controlled by constructing the soil cap and establishing grassy vegetation on the cap.

Implementability

This alternative would be implemented by first rerouting a portion of the South Plant Drainage Ditch. A section, approximately 300 feet long, would have to be excavated. The excavated soil would be placed in the existing ditch to help form a base for the soil pile. The relatively uncontaminated adjacent soil piles would be used to form a 700 feet by 90 feet by 0.5 feet base.

The first step is to move the adjacent contaminated soil piles atop the base. Next the soil piles atop the former toxaphene and dinoseb manufacturing areas would be moved to the engineered soil pile. Then the shallow surface soil would be excavated and moved to the new soil pile location. Approximately 5,400 cubic yards of clean fill would be placed in the excavations.

A soil cap would be constructed atop the soil pile. Approximately 1,400 cubic yards of clay would be placed and compacted to provide a six-inch clay cap. Then six inches of top soil would be established with 1,100 cubic yards of fill material.

As the soil pile is constructed, large chunks of concrete are removed and set aside to be used to cover the bottom slopes of the soil pile as a rip rap for erosion control.

Relative Cost

There are no difficult or complex steps required with this alternative. The relative cost is low.

Screening Comments

This alternative is effective. The potential for mobility of toxaphene and direct contact of workers with toxaphene is successfully addressed. This alternative remains.

Alternative A-3; Removal Action with Containing Geosynthetic Liner and Soil Cap

This alternative involves the construction of one soil pile which is a consolidation of contaminated soil not meeting Corrective Action Objectives. The soil pile would be constructed immediately to the southwest of the atrazine warehouse. A depiction of the soil pile is presented as Figure 3-1. The footprint of the soil pile is 650 feet by 75 feet by 15 feet high. Sides would be sloped 2:1. In order to obtain the footprint noted, a portion of the south plant drainage ditch would be rerouted.

The soil pile would be covered with a soil cap consisting of six inches of clay. Then a geosynthetic liner with composite drainage layer would be installed. Then six inches of top soil would be added and grassy vegetation established.

Effectiveness

If equal weight is given to each of the toxaphene and dinoseb analytical results for the contaminated soil to be moved to the engineered soil pile, the average for the soil pile is 23,610 ppb toxaphene and 88,445 ppb dinoseb. The restricted values from the MDEQ Tier 1 TRG Table are 5,200 ppb toxaphene and 204,000 ppb dinoseb.

In order for this alternative to be effective, the pathways of exposure for toxaphene have to be closed. The absence of leaching of the toxaphene by rainwater has been demonstrated by the data in the RFI Report and the Groundwater Assessment Report. Mobility of toxaphene is accomplished by water and wind erosional mechanisms; therefore, both have to be controlled. Direct contact with the soil is an exposure mechanism to be controlled.

Erosion of toxaphene contaminated soil by water and wind can be controlled by constructing the cap consisting of clay, geosynthetic liner and drainage layer, and top soil plus grassy vegetation.

Implementability

This alternative would be implemented by first rerouting a portion of the South Plant Drainage Ditch. A section, approximately 300 feet long, would have to be excavated. The excavated soil would be placed in the existing ditch to help form a base for the soil pile. The

relatively uncontaminated adjacent soil piles would be used to form a 700 feet by 90 feet by 0.5 feet base.

The first step is to move the adjacent contaminated soil piles atop the base. Next the soil piles atop the former toxaphene and dinoseb manufacturing areas would be moved to the engineered soil pile. Then the shallow surface soil would be excavated and moved to the new soil pile location. Approximately 5,400 cubic yards of clean fill would be placed in the excavations.

A cap would be constructed atop the soil pile. Approximately 1,400 cubic yards of clay would be placed and compacted to provide a six-inch clay cap. Next a geosynthetic liner and drainage layer would be placed. Then six inches of top soil would be established with 1,100 cubic yards of fill material.

As the soil pile is constructed, large chunks of concrete are removed and set aside to be used to cover the bottom slopes of the soil pile as a rip rap for erosion control.

Relative Cost

There are no extremely complex steps required with this alternative. The relative cost is moderate to low.

Screening Comments

This alternative is effective. The potential for mobility of toxaphene and direct contact of workers with toxaphene is successfully addressed. This alternative remains.

Alternative A-4; Removal Action with Containing Geosynthetic Liner on Bottom, Sides and Top with Appropriate Drainage Layers Plus Soil Cap

This alternative involves the construction of one soil pile which is a consolidation of contaminated soil not meeting Corrective Action Objectives. The soil pile would be constructed immediately to the southwest of the atrazine warehouse. A depiction of the soil pile is presented as Figure 3-1. The footprint of the soil pile is 650 feet by 75 feet by 15 feet high. Sides would be sloped 2:1. In order to obtain the footprint noted, a portion of the south plant drainage ditch would be rerouted.

The soil pile would be constructed atop a liner consisting of six inches of fill then a geosynthetic liner and drainage layer. Then a liner system identical to that in Alternative A-3 would be constructed; that is, six inches of clay, a geosynthetic liner and drainage layer, six inches of top soil and vegetation would be constructed.

Effectiveness

If equal weight is given to each of the toxaphene and dinoseb analytical results for the contaminated soil to be moved to the engineered soil pile, the average for the soil pile is 23,610 ppb toxaphene and 88,445 ppb dinoseb. The restricted values from the MDEQ Tier 1 TRG Table are 5,200 ppb toxaphene and 204,000 ppb dinoseb.

In order for this alternative to be effective, the pathways of exposure for toxaphene have to be closed. The absence of leaching of the toxaphene by rainwater has been demonstrated by the data in the RFI Report and the Groundwater Assessment Report. Mobility of toxaphene is accomplished by water and wind erosional mechanisms; therefore, both have to be controlled. Direct contact with the soil is an exposure mechanism to be controlled.

Erosion of toxaphene contaminated soil by water and wind can be controlled by constructing the bottom, sides and cap consisting of clay, geosynthetic liner and drainage layer, and top soil plus grassy vegetation.

Implementability

This alternative would be implemented by first rerouting a portion of the South Plant Drainage Ditch. A section, approximately 300 feet long, would have to be excavated. The excavated soil would be placed in the existing ditch to help form a base for the soil pile. The relatively uncontaminated adjacent soil piles would be used to form a 700 feet by 90 feet by 0.5 feet base.

Next a geosynthetic liner and drainage layer would be placed followed by six inches of fill would then be constructed.

The first step is to move the adjacent contaminated soil piles atop the base. Then the soil piles atop the former toxaphene and dinoseb manufacturing areas would be moved to the engineered soil pile. The shallow surface soil would be excavated and moved to the new soil

pile location. Approximately 5,400 cubic yards of clean fill would be placed in the excavations.

The sides and top (the cap) would be constructed by placing six inches of compact clay, a geosynthetic liner and drainage layer, and six inches of top soil. Grassy vegetation would then be established.

Relative Cost

Placing geosynthetics completely entombing the soil pile requires skill and expertise. The relative cost of this alternative is moderate.

Alternative A-5; In-Situ Treatment by Composting Plus Iron Addition

This is a bioremediation alternative. VCC has established in field testing that dinoseb will readily biodegrade when mixed with compost and allowed time to react. The evidence on toxaphene biodegradation is less certain; although, with adequate passage of time it will biodegrade.

Composting is a controlled biological process by which organic contaminants are converted by microorganisms (under aerobic and anaerobic conditions) to innocuous, stabilized byproducts. Typically, thermophilic conditions (54 to 65 °C) must be maintained to properly compost soil contaminated with hazardous organic contaminants. The increased temperatures result from heat produced by microorganisms during the degradation of the organic material in the waste and the compost. In most cases, this is achieved by the use of indigenous microorganisms. Soils are excavated and mixed with bulking agents and organic amendments, such as wood chips, gin trash, animal, and vegetative wastes to enhance the porosity of the mixture to be decomposed. Degradation is achieved through using alternating aerobic and anaerobic cycles. During the aerobic cycle the optimum rate of degradation is achieved through maintaining oxygenation, irrigation as necessary, and closely monitoring moisture content, and temperature.

There are three process designs used in composting; aerated static pile composting (compost is formed into piles and aerated with blowers or vacuum pumps), mechanically agitated in-vessel composting (compost is placed in a reactor vessel where it is mixed and aerated), and windrow composting (compost is placed in long piles known as windrows and periodically

mixed by rototilling). Windrow composting is usually considered to be the most cost-effective composting alternative. Windrow composting has been demonstrated as an effective technology for treatment of Nitro-contaminated soil. During a field demonstration conducted by USAEC and the Umatilla Depot Activity, TNT reductions were as high as 99.7% in 40 days of operation, with the majority of removal occurring in the first 20 days of operation. Maximum removal efficiencies for RDX and HMX were 99.8% and 96.8%, respectively. The relatively simple equipment requirements combined with these performance results make windrow composting economically and technically attractive.
As previously noted, the average for the soil not meeting Corrective Action Objectives is 88,445 ppb dinoseb and 23,610 ppb toxaphene. The restricted values from the MDEQ Tier 1 TRG Table are 204,000 ppb dinoseb and 5,200 ppb toxaphene. Toxaphene is, therefore, the predominant contaminant of concern. Toxaphene is also the most refractory compound.

There are studies from the U.S. EPA Experimental Lab in Athens, Georgia that demonstrate toxaphene can be dechlorinated in the presence of iron filings. The reductive dechlorination of toxaphene in the presence of zero valent iron accomplishes the same purpose through different mechanism as the anaerobic cycle. As explained in "Pilot Scale Reductive Dechlorination Treatability Study, Helene Chemical Company, Tampa, Florida" by Carlton, Jackson and Wolfe, USEPA December 2001: "Zero-Valent Iron (Fe^0) is an effective electron donor. The theory of electron transfer is best illustrated in the following reaction equation for the compound RCL (where "R" is an aliphatic carbon):

$$Fe^0 + RCL + H^+ = Fe^{+2} + RH + CL^- \text{ or}$$
$$2Fe^{2+} + RCL + H^+ = 2FE^{+3} + RH + CL^-$$

In aqueous media hydrogen ions are consumed to form ferrous hydroxide which coats the surface of the iron and blocks activity. By adding an acid the iron remains active; the addition of pyrite (iron sulfide) prevents the formation of ferrous hydroxide on the surface of the iron."

The reductive dechlorination of toxaphene is a three step process, with the electron transfer noted above as the third step. First the toxaphene must be desorbed from the soil particle into the aqueous phase. The desorption can be done mechanically with mixing or can be enhanced chemically with the addition of isopropyl alcohol. Desorption is likely the limiting step in the mass transfer. In order for the zero valent iron to react with the desorbed toxaphene, it must come into contact with the compound at the molecular level.

Although this process could be enhanced mechanically, it occurs more rapidly if the pesticide is in the aqueous phase.

The EPA established in their work that toxaphene will dechlorinate in the presence of zero valent iron. If a mixture of toxaphene contaminated soil saturated with water, zero valent iron and isopropyl alcohol is continuously mixed, the one-half life of toxaphene is three days. (The amount of iron and isopropyl alcohol is not disclosed.) If a plot of toxaphene contaminated soil saturated with water has zero valent iron and isopropyl alcohol added and is rototilled daily for two weeks, then twice per week, then the one-half life of toxaphene is between 365 and 433 days.

VCC is of the opinion that addition of zero valent iron to anaerobic/aerobic composting cycles will enhance overall rate of degradation of toxaphene.

Effectiveness

The effectiveness of the technology in meeting Corrective Action Objectives has been established in the laboratory under controlled conditions. The first steps in the implementation of this alternative involve field verification and establishment of conditions that allow Corrective Action Objectives to be met.

Implementability

The field verification testing will take place on grid location 20-F on Figure 3-2. The soil tested will be mixed 1:1 with soil from soil pile location 20-FF. The composite analysis of location 20-F is 1,078,018 ppb dinoseb and 10,318 ppb toxaphene. The composite analysis of location 20-FF is 130,675 ppb dinoseb and 76,683 ppb toxaphene. The 1:1 mixture will then be about 600,000 ppb dinoseb and 44,000 ppb toxaphene.

In order to implement the field test, four plots of soil, each 8 feet by 100 feet, are rototilled thoroughly to six inches on location 20-F. To each plot 15 cubic yards of soil (six inch lift) from location 20-FF are spread as evenly as possible. Each of the plots is then rototilled thoroughly to a depth of 12 inches.

Once the soil from both sources is thoroughly mixed, the compost is added. The compost will consist of gin trash, 5% chicken manure, 5% fertilizer, and iron. The ratio of soil to

compost and the optimum operating conditions are obtained from the laboratory experimental results attached as Appendix A.

The full scale operation would be operated similarly to the pilot field test. There are 12 surface area grids (100' by 100') that require corrective action. In each of the grid areas soil would be rototilled to 18 inches deep in four beds 10 feet by 100 feet. Premixed compost would be added in an amount determined by optimization studies presented in Appendix A. The soil would be biodegraded to Corrective Action Objectives. The first episode will have treated 2,500 cubic yards. The second episode would commence by removing the treated soil and compost to 18 inches then adding new compost and 2,500 cubic yards of soil requiring treatment. Up to four more iterations of the same scenario would be required. The last soil to be treated would be left in place.

Relative Cost

The cost of in-situ treatment is moderate. The significant elements of cost are related to the operation and monitoring of biodegradation over a long period of time. The use of iron is thought to decrease the length of time by assisting in the dechlorination of toxaphene.

Screening Comments

This alternative will be retained.

Alternative A-6; In-Situ Treatment by Injection of Fenton's Reagent

This is an in-situ chemical treatment alternative. Fenton's reagent would be injected directly into the soil by high pressure jetting.

Chemical treatment has been used extensively to treat a variety of toxic wastes, primarily in wastewater treatment systems. In-situ chemical treatment (ISCT) is a treatment for contaminated soils and groundwater at many waste sites, and employs chemical oxidation, either as a stand alone technology or in tandem with bioremediation or other technology. ISCT has been used to treat a variety of contaminants, primarily in groundwater, and to a lesser extent in soils. Success has varied among sites and contaminants, with the primary limiting factor being the effectiveness and efficiency of contact between the remediation agents and the contaminants.

A variety of ISCT chemical oxidation processes have been used to remediate hydrocarbons, chlorinated hydrocarbons, and other contaminants in both soil and groundwater matrixes. Several oxidizers are commonly used, such as hydrogen peroxide (H_2O_2), Fenton's Reagent ($FeSO_4 + H_2O_2$) sodium permanganate ($NaMnO_4$), potassium permanganate ($KMNO_4$), and others. Fenton's Reagent is a preferred choice due to its versatility and strong oxidizing potential.

In Fenton's Reagent, the enhanced power of hydrogen peroxide can be obtained by using it in conjunction with ferrous iron as a catalyst, due to the increased generation of hydroxyl radicals, which are potent oxidizing agents. J.J.H. Fenton first reported the rapid oxidative properties of hydrogen peroxide in the presence of ferrous iron in 1894. Fenton's Reagent has been used extensively in a wider variety of applications in the United States, Europe, and elsewhere.

In Fenton's Reagent, the free hydroxyl radical (OH) is formed by the reaction:

$$H_2O_2 + Fe \rightarrow Fe + OH$$

The hydroxyl radicals produced by the Fenton's Reagent provide rapid, exothermic, and non-selective chemical reactions, with both contaminants and indigenous hydrocarbons and other substances, in the remediating of contaminated sites.

Fenton's Reagent oxidation of hydrocarbons produces a number of intermediate products that are short-lived and readily oxidized, ultimately to carbon dioxide and water. Complete mineralization of organic molecules (i.e., transformation of an organic contaminant molecule into its components of carbon dioxide, water, methane, and/or halides) is generally completed in minutes to a few hours:

$$HC + H_2O_2 \rightarrow CO_2 + H_2O$$
$$CHC + H_2O_2 \rightarrow CO_2 + H_2O + \text{Chlorides}$$

Hydrogen peroxide is unstable and naturally decomposes very rapidly into water and oxygen. Thus, residual hydrogen peroxide in the environmental media is not a concern. Laboratory and field studies have indicated that hydrogen peroxide is generally not detectable within hours after use.

In the case of chlorinated hydrocarbons, chlorides and nitrates can be generated. Naturally occurring carboxylic acids are the only significant intermediate oxidation products of Fenton's Reagent. Remediation byproducts are, therefore, not a significant concern.

Consecutive field treatment cycles may be required to fully remediate the site, depending on the nature and extent of contamination. For complete mineralization of hydrocarbon, the Theoretical Weight Ratio can range form 1-100 pounds of hydrogen peroxide per pound of hydrocarbon, and is highly variable due to the environmental matrix of the contaminant.

Trailer-mounted remediation systems that use high-pressure, low-volume jetting systems to jet remediation agents into the subsurface for purposes of remediating contaminated soil or groundwater are required.

Jetting of remediation agents can be accomplished at many sites to depth of 30 feet. Jetting is usually performed under high pressure and at low volume using specially designed jetting lances and tips that can jet remediation agents at pressures ranging from 500 to up to 20,000 psi. Flow rates can range from 1 to 20 gpm. The high pressure can be sufficient to fracture soils even with low permeability, and to overcome ground pressures in the areas of treatment of up to several feet from the vertical point of jetting. Once the soil is fractured, the remediation agents are effectively dispersed into the contaminated soil and/or water matrix.

Since jetting systems use high pressure, there is typically no need for pre-drilling, pushing, or installation of temporary or permanent well points at most sites. In many subsurface soils, jetting to 20 feet bgs can be accomplished in a matter of only a few minutes. After the jetting lance reaches the desired depth, the remediation agents are jetted into the treatment zone via a variety of specially-designed tips that distribute the remediation agents both radially and/or vertically. Sufficient jetting pressure can force the remediation agents outward into the soil or groundwater up to several feet from the point of jetting.

In jetting systems, the remediation agents, such as hydrogen peroxide and catalysts, are delivered to the site and then transferred from the product storage tanks into mixing tanks according to a pre-determined remediation "recipe". A gasoline-powered compressor powers the jetting system which jets the remediation solution into the subsurface soil and/or groundwater under high pressure through a specially designed jetting lance and tip system. The jetting lances come in various lengths, and can be connected in a series for deeper jetting.

The jetting lance is designed to rapidly jet through subsurface soils, including clays. The lance is less than one inch in diameter, with specially designed jetting tips. Jetting ports on the tip allow high pressure (up to 20,000 psi), low volume (up to 20 gpm) jetting of remediation agents into the treatment zone. Depending on the application, tips with up to nine jetting ports can be used to inject remediation agents both vertically (downward) and radially in up to eight compass directions, effecting uniform distribution of remediation agents throughout the treatment zone.

Jetting to the top of the treatment zone is typically accomplished using fresh water (or remediation agents if the treatment zone is near the surface). Once the top of the treatment zone is encountered, jetting is accomplished with remediation agents. As the jetting lance jets downward from the top of the treatment zone to the terminal depth of the treatment zone, remediation agents are jetted laterally, thereby treating a cylindrically-shaped area. Typical radius of influence is on the order of two to ten feet, depending on the subsurface stratigraphy, jetting pressure, jetting volume, residence time, and other factors. Tightly-spaced and overlapping treatment "cylinders" result in effective remediation of the treatment zone with minimal "cold spots". Multiple treatment cycles are frequently used to effect remediation.

In the case of using Fenton's Reagent, jetting occurs in two steps. The first step involves the jetting of the ferrous sulfate catalyst, and if necessary, surfactant. At many sites, the surfactant solution will help increase the porosity of the treatment zone and help loosen any adsorbed contaminant within the soil or groundwater matrix. The second step involves the jetting of hydrogen peroxide through the same jetting holes into the treatment zone.

The quantity of ISCT remediation agents required to oxidize a specific contaminant is dependent upon the chemical and physical properties of the contaminant, remediation criteria, remediation schedule, subsurface conditions, and other factors. The stoichiometric ratios for successful remediation can be determined by:

- Theoretical stoichiometric calculations
- Laboratory bench-scale studies
- Field pilot studies
- Field experience on other projects

Theoretical stoichiometric calculations can be made; however, site specific factors which lead to collateral oxidation can greatly affect the theoretical quantities of remediation agents required.

Laboratory bench-scale studies can be used to simulate the oxidation process to help guide the field application. While laboratory bench-scale studies can provide guidance, they may not always provide exact answers since actual field conditions are difficult to simulate in the laboratory, especially contact phenomena.

Field pilot studies are beneficial, especially at those sites with unique or difficult subsurface conditions. Such studies would involve establishing a test plot on the order of 20 feet by 20 feet. Remediation agents would be jetted into the test plot, and observations would be made.

One of the main observations to be made is that "cross-communication" is apparent. Cross-communication is defined as the physical evidence (i.e., observation) that the jetting of remediation agents at one location is extending sufficiently in a lateral direction in the subsurface so as to intersect the adjacent jetting points. Cross-communication is a function of site stratigraphy, hydrogeology, spacing of jetting points, jetting pressure, and other factors. For most sites, cross-communication between points can be easily observed at the surface by noting "bubbling" or "vapors" or "surface liquids" as a result of the pressurized jetting of remediation agents. For example, if hydrogen peroxide is used, a one-pound mass of 30% H_2O_2 will generate approximately 8.7 cubic feet of vapor, which equates to a rapid 600-fold volume expansion. Lower concentrations and/or volumes of hydrogen peroxide will yield corresponding small volumes of vapors. The "vapors" are carbon dioxide, water vapor, and perhaps some oxygen that result from the chemical reaction of hydrogen peroxide with organic matter, and the "bubbling" and "surface liquids" are displaced liquids and air from the jetting process.

Effectiveness

The effectiveness of the technology can be controlled by the number of injections made; that is, injections can be made until Corrective Action Objectives are met.

Implementability

Field verification testing would have to precede full scale operation in order to verify the number of injections required. Based on experience with refractory chlorinated organics, as many as six separate injection episodes may be required.

Relative Cost

Unless field verification experiments demonstrated otherwise, high costs would be anticipated. The elements of cost expected to be high would be the cost of manpower for injections, multiple mobilizations and the cost of hydrogen peroxide and ferrous sulfate.

Screening Comments

This alternative will be retained.

Alternative A-7; Ex-Situ Treatment by Composting Plus Iron Addition

This is a bioremediation alternative. It is very similar to Alternative A-5, In-Situ Treatment by Composting Plus Iron Addition. The main variation presented by Alternative A-7 is that the surface soil and soil piles are both moved to a separate location where biotreatment cells are established.

VCC has established in field testing that dinoseb will readily biodegrade when mixed with compost and allowed time to react. The evidence on toxaphene biodegradation is less certain; although, with adequate passage of time it will biodegrade.

Composting is a controlled biological process by which organic contaminants are converted by microorganisms (under aerobic and anaerobic conditions) to innocuous, stabilized byproducts. Typically, thermophilic conditions (54 to 65 °C) must be maintained to properly compost soil contaminated with hazardous organic contaminants. The increased temperatures result from heat produced by microorganisms during the degradation of the organic material in the waste and the compost. In most cases, this is achieved by the use of indigenous microorganisms. Soils are excavated and mixed with bulking agents and organic amendments, such as wood chips, gin trash, animal, and vegetative wastes, to enhance the porosity of the mixture to be decomposed. Degradation is achieved through using alternating

aerobic and anaerobic cycles. During the aerobic cycle, the optimum rate of degradation is achieved through maintaining oxygenation, irrigation as necessary, and closely monitoring moisture content, and temperature.

There are three process designs used in composting; aerated static pile composting (compost is formed into piles and aerated with blowers or vacuum pumps), mechanically agitated in-vessel composting (compost is placed in a reactor vessel where it is mixed and aerated), and windrow composting (compost is placed in long piles known as windrows and periodically mixed by rototilling). Windrow composting is usually considered to be the most cost-effective composting alternative. Windrow composting has been demonstrated as an effective technology for treatment of Nitro-contaminated soil. During a field demonstration conducted by USAEC and the Umatilla Depot Activity, TNT reductions were as high as 99.7% in 40 days of operation, with the majority of removal occurring in the first 20 days of operation. Maximum removal efficiencies for RDX and HMX were 99.8% and 96.8%, respectively. The relatively simple equipment requirements combined with these performance results make windrow composting economically and technically attractive.

As previously noted, the average for the soil not meeting Corrective Action Objectives is 88,445 ppb dinoseb and 23,610 ppb toxaphene. The restricted values from the MDEQ Tier 1 TRG Table are 204,000 ppb dinoseb and 5,200 ppb toxaphene. Toxaphene is, therefore, the predominant contaminant of concern. Toxaphene is also the most refractory compound.

There are studies from the U.S. EPA Experimental Lab in Athens, Georgia that demonstrate toxaphene can be dechlorinated in the presence of iron filings. The reductive dechlorination of toxaphene in the presence of zero valent iron accomplishes the same purpose through different mechanism as the anaerobic cycle. As explained in "Pilot Scale Reductive Dechlorination Treatability Study, Helene Chemical Company, Tampa, Florida" by Carlton, Jackson and Wolfe, USEPA December 2001: "Zero-Valent Iron (Fe^0) is an effective electron donor. The theory of electron transfer is best illustrated in the following reaction equation for the compound RCL (where "R" is an aliphatic carbon):

$$Fe^0 + RCL + H^+ = Fe^{+2} + RH + CL^- \text{ or}$$
$$2Fe^{2+} + RCL + H^+ = 2FE^{+3} + RH + CL^-$$

In aqueous media hydrogen ions are consumed to form ferrous hydroxide which coats the surface of the iron and blocks activity. By adding an acid the iron remains active; the

addition of pyrite (iron sulfide) prevents the formation of ferrous hydroxide on the surface of the iron."

The reductive dechlorination of toxaphene is a three step process, with the electron transfer noted above as the third step. First the toxaphene must be desorbed from the soil particle into the aqueous phase. The desorption can be done mechanically with mixing or can be enhanced chemically with the addition of isopropyl alcohol. Desorption is likely the limiting step in the mass transfer. In order for the zero valent iron to react with the desorbed toxaphene, it must come into contact with the compound at the molecular level.
Although this process could be enhanced mechanically, it occurs more rapidly if the pesticide is in the aqueous phase.

The EPA established in their work that toxaphene will dechlorinate in the presence of zero valent iron. If a mixture of toxaphene contaminated soil saturated with water, zero valent iron and isopropyl alcohol is continuously mixed, the one-half life of toxaphene is three days. (The amount of iron and isopropyl alcohol is not disclosed.) If a plot of toxaphene contaminated soil saturated with water has zero valent iron and isopropyl alcohol added and is rototilled daily for two weeks, then twice per week, then the one-half life of toxaphene is between 365 and 433 days.

VCC is of the opinion that addition of zero valent iron to anaerobic/aerobic composting cycles will enhance overall rate of degradation of toxaphene.

Effectiveness

The effectiveness of the technology in meeting Corrective Action Objectives has been established in the laboratory under controlled conditions. The first steps in the implementation of this alternative involve field verification and establishment of conditions that allow Corrective Action Objectives to be met.

Implementability

The field verification testing will take place on grid location 20-F on Figure 3-2. The soil tested will be mixed 1:1 with soil from soil pile location 20-FF. The composite analysis of location 20-F is 1,078,018 ppb dinoseb and 10,318 ppb toxaphene. The composite analysis

of location 20-FF is 130,675 ppb dinoseb and 76,683 ppb toxaphene. The 1:1 mixture will then be about 600,000 ppb dinoseb and 44,000 ppb toxaphene.

In order to implement the field test, four plots of soil, each 8 feet by 100 feet, are rototilled thoroughly to six inches on location 20-F. To each plot 15 cubic yards of soil (six inch lift) from location 20-FF are spread as evenly as possible. Each of the plots is then rototilled thoroughly to a depth of 12 inches.

Once the soil from both sources is thoroughly mixed, the compost is added. The compost will consist of gin trash, 5% chicken manure, 5% fertilizer, and iron. The ratio of soil to compost and the optimum operating conditions are obtained from the laboratory experimental results attached as Appendix A.

The full scale operation would be set up by utilizing the bermed area atop the "Hill Area" of SWMU 2. The bermed area is depicted on Figure 3-3. The bottom surface are of the bermed area is 58,500 square feet. The entire quantity of soil not meeting Corrective Action Objectives could fit within the berms, if piled to a depth of 6.9 feet; however, the preferred method of treatment will be to treat soil in lifts of 18 inches. There will be five separate episodes of treatment. The first episode will begin by adding compost spread evenly into the bermed area. A lift of 18 inches of soil would be added and mixed thoroughly by rototilling with the compost. After degradation to Corrective Action Objectives, additional compost and another lift of contaminated soil would be added and rototilled. The same scenario would be carried out for a total of four to five iterations. When the last lift has degraded, the soil would be smoothed out and grassy vegetation would be established.

Relative Cost

The cost of ex-situ treatment is moderate. The significant elements of cost are related to the operation and monitoring of biodegradation over a long period of time.

Screening Comments

This alternative will be retained.

Alternative A-8; Off-Site Disposal in Landfill

This alternative involves movement of soil piles and surface soil to an off-site commercial landfill in Mississippi. The soil meets TCLP requirements as is, therefore, not hazardous by characteristic. The specific source of contaminants or specific incidents causing the contamination remains unknown. Although there can be speculation on the source or sources, there is no documentary evidence or incidence reports. The soil does contain hazardous constituents.

Effectiveness

As previously noted, the average for the soil not meeting Corrective Action Objectives is 88,445 ppb dinoseb and 23,610 ppb toxaphene. The restricted values from the MDEQ Tier 1 TRG Table are 204,000 ppb dinoseb and 5,200 ppb toxaphene. Toxaphene is, therefore, the predominant contaminant of concern.

Toxaphene adheres well to soil. It is not a mobile contaminant except by wind swept or water erosion. As long as these mechanisms are controlled during excavation, transportation and placement in the commercial landfill, then this alternative is effective.

Implementability

This alternative involves excavation, loading, transportation, unloading and placement of soils. Backfilling of excavated shallow soil areas would be involved.

Dusting and spillage of contaminated soil must be avoided. All activities are routine soil handling operations.

Relative Cost

The key to determining the viability of this alternative is agreement by the U.S. EPA and MSDEQ that the soil is not RCRA hazardous. If the soil is not RCRA hazardous, it is not subject to Land Disposal Restrictions (LDR) and treatment standards dictated by LDR. Then, and only the, would off-site disposal have economical viability.

Screening Comments

This alternative is retained for discussion with regulatory agencies.

3.5 DEVELOPMENT OF CORRECTIVE ACTION ALTERNATIVES FOR GROUNDWATER CONTAMINATED WITH DINOSEB, CHLOROFORM, CARBON TETRACHLORIDE AND OTHER VOAS

Alternative B-1; No Action, Natural Attenuation Monitoring

This alternative involves no corrective action but does required continued monitoring. The plumes of interest are approximately 600 feet from the nearest point of the creek. There is a drainage layer or drainage trench constructed for dewatering during the lining of the surface impoundments. The drainage trench is located directly between the plumes and nearest point of the of the creek. It is depicted on Figure 3-4. The drainage trench does capture groundwater. The groundwater is pumped to the body of the surface impoundment and is treated directly by adsorption on carbon prior to discharge to the Mississippi River via a NPDES permit. Therefore, there is ongoing corrective action.

A portion of the plume will travel south towards Hennessey's Bayou. The portion of the lined surface impoundment that does not have the built-in drainage layer will serve to divert groundwater flow toward Hennessey's Bayou toward the span covered by MW-6, MW-7, and temporary well 2-15.

Effectiveness

The effectiveness of natural attenuation can be determined by monitoring and modeling. Referring to Figure 2-2 and 2-3 and analytical results from MW-6, MW-7 and temporary wells 20-19, 20-18 and 2-15, natural attenuation of the dinoseb and VOA plumes is effective.

Modeling the VOA plume as if it were all chloroform provides additional useful information. Chloroform has the most stringent MDEQ Tier 1 TRG Table values (0.152 ppb) of the 10 individual VOAs found. Calculating the Dilution and Attenuation Factor (DAF) following formulas noted on pages 2-12 through 2-15 and changing values of only the following:

S_w = 200 feet
x = 750 feet
α_x = 75
α_y = 25
α_z = 3.75,

a DAF of 4.7 (10^5) is calculated. Therefore, the VOA plume needs to remain below (0.152) (4.7) 10^5 = 71,000. The reference plume modeled is the 10,000 ppb isopleth that is approximately 200 feet wide.

Retardation and degradation factors for dinoseb have not been found in the literature. The VCC experience is that it can easily be biodegraded. A monitoring program will have to verify natural attenuation effectiveness.

Implementability

The corrective action through collection of groundwater by the drainage layer will continue. In order to monitor natural attenuation two new permanent monitor wells will be constructed. Locations are provided on Figure 2-2 and Figure 2-3. The proposed locations are difficult to reach with a full-sized drilling rig without major preparatory bulldozer work; therefore, installation of one-inch diameter prepacked wells installed with a geoprobe are proposed.

Relative Cost

The cost is low.

Screening Comments

This alternative is retained.

Alternative B-2; In-Situ Treatment by Injection of Fenton's Reagent

This is an in-situ chemical treatment alternative. Fenton's reagent would be injected directly into the groundwater by high pressure jetting.

Chemical treatment has been used extensively to treat a variety of toxic wastes, primarily in wastewater treatment systems. In-situ chemical treatment (ISCT) is a treatment for

contaminated soils and groundwater at many waste sites, and employs chemical oxidation, either as a stand alone technology or in tandem with bioremediation or other technology. ISCT has been used to treat a variety of contaminants, primarily in groundwater, and to a lesser extent in soils. Success has varied among sites and contaminants, with the primary limiting factor being the effectiveness and efficiency of contact between the remediation agents and the contaminants.

A variety of ISCT chemical oxidation processes have been used to remediate hydrocarbons, chlorinated hydrocarbons, and other contaminants in both soil and groundwater matrixes. Several oxidizers are commonly used, such as hydrogen peroxide (H_2O_2), Fenton's Reagent ($FeSO_4 + H_2O_2$) sodium permanganate ($NaMnO_4$), potassium permanganate ($KMNO_4$), and others. Fenton's Reagent is a preferred choice due to its versatility and strong oxidizing potential.

In Fenton's Reagent, the enhanced power of hydrogen peroxide can be obtained by using it in conjunction with ferrous iron as a catalyst, due to the increased generation of hydroxyl radicals, which are potent oxidizing agents. J.J.H. Fenton first reported the rapid oxidative properties of hydrogen peroxide in the presence of ferrous iron in 1894. .

In Fenton's Reagent, the free hydroxyl radical (OH) is formed by the reaction:

$$H_2O_2 + Fe \rightarrow Fe + OH$$

The hydroxyl radicals produced by the Fenton's Reagent provide rapid, exothermic, and non-selective chemical reactions, with both contaminants and indigenous hydrocarbons and other substances, in the remediating of contaminated sites.

Fenton's Reagent oxidation of hydrocarbons produces a number of intermediate products that are short-lived and readily oxidized, ultimately to carbon dioxide and water. Complete mineralization of organic molecules (i.e., transformation of an organic contaminant molecule into its components of carbon dioxide, water, methane, and/or halides) is generally completed in minutes to a few hours:

$$HC + H_2O_2 \rightarrow CO_2 + H_2O$$
$$CHC + H_2O_2 \rightarrow CO_2 + H_2O + \text{Chlorides}$$

Hydrogen peroxide is unstable and naturally decomposes very rapidly into water and oxygen. Thus, residual hydrogen peroxide in the environmental media is not a concern. Laboratory and field studies have indicated that hydrogen peroxide is generally not detectable within hours after use.

In the case of chlorinated hydrocarbons, chlorides and nitrates can be generated. Naturally occurring carboxylic acids are the only significant intermediate oxidation products of Fenton's Reagent. Remediation byproducts are, therefore, not a significant concern.

Consecutive field treatment cycles may be required to fully remediate the site, depending on the nature and extent of contamination. For complete mineralization of hydrocarbon, the Theoretical Weight Ration can range form 1-100 pounds of hydrogen peroxide per pound of hydrocarbon, and is highly variable due to the environmental matrix of the contaminant.

Trailer-mounted remediation systems that use high-pressure, low-volume jetting systems to jet remediation agents into the subsurface for purposes of remediating contaminated soil or groundwater are required.

Jetting of remediation agents can be accomplished at many sites to depth of 30 feet. Jetting is usually performed under high pressure and at low volume using specially designed jetting lances and tips that can jet remediation agents at pressures ranging from 500 to up to 20,000 psi. Flow rates can range from 1 to 20 gpm. The high pressure can be sufficient to fracture soils even with low permeability, and to overcome ground pressures in the areas of treatment of up to several feet from the vertical point of jetting. Once the soil is fractured, the remediation agents are effectively dispersed into the contaminated soil and/or water matrix.

Since jetting systems use high pressure, there is typically no need for pre-drilling, pushing, or installation of temporary or permanent well points at most sites. In many subsurface soils, jetting to 20 feet bgs can be accomplished in a matter of only a few minutes. After the jetting lance reaches the desired depth, the remediation agents are jetted into the treatment zone via a variety of specially-designed tips that distribute the remediation agents both radially and/or vertically. Sufficient jetting pressure can force the remediation agents outward into the soil or groundwater up to several feet from the point of jetting.

In jetting systems, the remediation agents, such as hydrogen peroxide and catalysts, are delivered to the site and then transferred from the product storage tanks into mixing tanks

according to a pre-determined remediation "recipe". A gasoline-powered compressor powers the jetting system which jets the remediation solution into the subsurface soil and/or groundwater under high pressure through a specially designed jetting lance and tip system. The jetting lances come in various lengths, and can be connected in a series for deeper jetting.

The jetting lance is designed to rapidly jet through subsurface soils, including clays. The lance is less than one inch in diameter, with specially designed jetting tips. Jetting ports on the tip allow high pressure (up to 20,000 psi), low volume (up to 20 gpm) jetting of remediation agents into the treatment zone. Depending on the application, tips with up to nine jetting ports can be used to inject remediation agents both vertically (downward) and radially in up to eight compass directions, effecting uniform distribution of remediation agents throughout the treatment zone.

Jetting to the top of the treatment zone is typically accomplished using fresh water (or remediation agents if the treatment zone is near the surface). Once the top of the treatment zone is encountered, jetting is accomplished with remediation agents. As the jetting lance jets downward from the top of the treatment zone to the terminal depth of the treatment zone, remediation agents are jetted laterally, thereby treating a cylindrically-shaped area. Typical radius of influence is on the order of two to ten feet, depending on the subsurface stratigraphy, jetting pressure, jetting volume, residence time, and other factors. Tightly-spaced and overlapping treatment "cylinders" result in effective remediation of the treatment zone with minimal "cold spots". Multiple treatment cycles are frequently used to effect remediation.

In the case of using Fenton's Reagent, jetting occurs in two steps. The first step involves the jetting of the ferrous sulfate catalyst, and if necessary, surfactant. At many sites, the surfactant solution will help increase the porosity of the treatment zone and help loosen any adsorbed contaminant within the soil or groundwater matrix. The second step involves the jetting of hydrogen peroxide through the same jetting holes into the treatment zone.

The quantity of ISCT remediation agents required to oxidize a specific contaminant is dependent upon the chemical and physical properties of the contaminant, remediation criteria, remediation schedule, subsurface conditions, and other factors. The stoichiometric ratios for successful remediation can be determined by:

- Theoretical stoichiometric calculations

- Laboratory bench-scale studies
- Field pilot studies
- Field experience on other projects

Theoretical stoichiometric calculations can be made; however, site specific factors which lead to collateral oxidation can greatly affect the theoretical quantities of remediation agents required.

Laboratory bench-scale studies can be used to simulate the oxidation process to help guide the field application. While laboratory bench-scale studies can provide guidance, they may not always provide exact answers since actual field conditions are difficult to simulate in the laboratory, especially contact phenomena.

Field pilot studies are beneficial, especially at those sites with unique or difficult subsurface conditions. Such studies would involve establishing a test plot on the order of 20 feet by 20 feet. Remediation agents would be jetted into the test plot, and observations would be made.

One of the main observations to be made is that "cross-communication" is apparent. Cross-communication is defined as the physical evidence (i.e., observation) that the jetting of remediation agents at one location is extending sufficiently in a lateral direction in the subsurface so as to intersect the adjacent jetting points. Cross-communication is a function of site stratigraphy, hydrogeology, spacing of jetting points, jetting pressure, and other factors. For most sites, cross-communication between points can be easily observed at the surface by noting "bubbling" or "vapors" or "surface liquids" as a result of the pressurized jetting of remediation agents. For example, if hydrogen peroxide is used, a one-pound mass of 30% H_2O_2 will generate approximately 8.7 cubic feet of vapor, which equates to a rapid 600-fold volume expansion. Lower concentrations and/or volumes of hydrogen peroxide will yield corresponding small volumes of vapors. The "vapors" are carbon dioxide, water vapor, and perhaps some oxygen that result from the chemical reaction of hydrogen peroxide with organic matter, and the "bubbling" and "surface liquids" are displaced liquids and air from the jetting process.

Effectiveness

The effectiveness of the technology can be controlled by the number of injections made; that is, injections can be made until Corrective Action Objectives are met.

Implementability

Field verification testing would have to precede full scale operation in order to verify the number of injections required. Based on experience with refractory chlorinated organics, as many as six separate injection episodes may be required.

Relative Cost

Unless field verification experiments demonstrated otherwise, high costs would be anticipated. The elements of cost expected to be high would be the cost of manpower for injections, multiple mobilizations and the cost of hydrogen peroxide and ferrous sulfate.

Screening Comments

Retained.

Alternative B-3; Ex-Situ Treatment with Fenton's Reagent or Other Oxidation Technologies

This alternative involves capture and recovery of the plume with a trench drain. The recovered groundwater would be pumped to a vessel where it can be oxidized by addition of Fenton's Reagent or other oxidation technologies. The recovery and oxidation are discussed separately below:

Effectiveness of Recovery

The two most popular methods for the recovery of shallow contaminated groundwater are the use of wells and infiltration trenches. Groundwater recovery trenches typically consist of a narrow sand-filled trench, often with a collection lateral used to convey the water infiltrated to a sump where it is pumped to a treatment unit. Although the use of wells is more common, there are many situations where trenches would provide a more effective and economical means for recovering contaminated groundwater.

In hydrogeologic settings where trenches are feasible, i.e., groundwater is relatively shallow, trenches have several advantages over recovery wells including:

- A much larger surface infiltration area providing lower groundwater entrance velocities which extends the life of the recovery system in environments where plugging of the filter pack with fines may be a factor.

- A more contiguous capture area compared to wells which rely upon the proper spacing for capture of migrating groundwater.

- Lower operation and maintenance cost of pumping equipment since a single sump pump can be utilized to recover groundwater for hundreds of linear feet.

Implementability of Recovery

The groundwater capture effectiveness of a trench is directly related to the ratio of saturated zone dewatered compared to the total thickness of the water table aquifer. At a minimum, a trench must be capable of lowering the water table 50 percent of the saturated thickness of the uppermost water bearing unit. Therefore, the minimum trench depth should be at least the depth to the water table plus one-half the saturated thickness of the upper water bearing zone. Generally, the practical depth limitations for trenches are static water levels of 15 feet or less and depth to base of the aquifer of 40 feet or less.

The volume of water (Q) passing through an aquifer for a given length perpendicular to the flow direction (L_a) is equal to:

$$Q = T \times i \times L$$

Where:

Q = volume of water flowing between two given points (gallons per day)
T = transmissivity (gallons per day per foot)
i = natural groundwater gradient (dimensionless)
L = length perpendicular to flow direction (feet)

During the initial start-up of the trench there will be an initial volume of water in storage which will need to be removed to create the cone or envelope of depression. The volume is equal to the effective pore volume of the area dewatered. This excess water must be accounted for in determining the initial pumping rates.

The most important factor to groundwater capture effectiveness and life of the trench is the selection of the material selected for use in the filter pack placed between the natural sediments and the collection lateral. A common mistake is to use too large of a filter pack material such as crushed rock or gravel. Fine grained sediments of the formation will tend to migrate between the "large" filter material and plug the filter pack.

Since the rate of groundwater flow into a trench is relatively slow, commonly less than a few feet per day, the limiting factor is usually the hydraulic conductivity of the formation.

Selection of a filter pack material comprised of a clean washed fine quartz sand close to the mean grain size of the formation material or slightly larger is recommended. The permeability of any clean fine quartz sand will usually be many times greater than the formation. A minimum of 6 inches of filter pack material are recommended below and beside the lateral to separate the formation from the collection lateral. The height of the sand pack may extend any length above the lateral, however, the depressed water level at steady state will most likely be only a few feet above the lateral. Extending the filter pack to the static water level is generally not necessary. The use of geomembranes is generally not necessary and may cause plugging if not selected or installed properly.

Although it is not absolutely necessary to install a collection lateral in the filter pack material, it is highly recommended for a number of reasons. The lateral is much less likely to "plug" as compared to the filter pack without the lateral.

Another advantage of a collection lateral is the installation of an "S" trap to keep the lateral constantly saturated. It is important not to entirely dewater the filter pack in order to minimize the potential for bacterial (algae) growth in the filter pack.

Very little maintenance is required for a properly constructed infiltration trench system. A large diameter sump is recommended to provide ample storage of water to minimize cycling of the sump pump. A 3- or 4-foot diameter reinforced concrete pipe with manhole cover and built-in ladder has proven to be useful. On-off levels for the pump can be set with float switches or transducers calibrated to measure water levels.

Relative Cost of Recovery

Groundwater recovery trenches have proven to be a highly effective and cost-efficient method for recovering a wide range of dissolved and LNAPL contaminants from the subsurface. Trenches are particularly applicable in shallow aquifers where water tables are generally less than 15 feet and base of the aquifer is less than 40 feet. Trenches are easily maintained and operational costs are generally lower than using multiple wells for groundwater recovery.

Effectiveness of Chemical Oxidation

Per the Calgon Handbook of Advanced Oxidation Technologies, the overall rate of oxidation of a contaminant can be greatly increased over that obtained by the simple addition of oxidizing agents if highly reactive initiators (radicals) such as the hydroxyl radical (•OH) can be created. "Table 3-1 compares the reaction rates of various organic contaminants with ozone and hydroxyl radical. The hydroxyl radical reacts typically a million to a billion times faster than ozone and hydrogen peroxide, resulting in greatly reduced treatment costs and system size.

TABLE 3-1

REACTION RATE CONSTANTS (k, in L mole^{-1} s^{-1}) OF OZONE VS. HYDROXYL RADICAL

Compound	O_3	•OH
Chlorinated Alkenes	10^{-1} to 10^{3}	10^{9} to 10^{11}
Phenols	10^{3}	10^{9} to 10^{10}
N-containing Organics	10 to 10^{2}	10^{8} to 10^{10}
Aromatics	1 to 10^{2}	10^{8} to 10^{10}
Ketones	1	10^{9} to 10^{10}
Alcohols	10^{-2} to 1	10^{8} to 10^{9}
Alkanes	10^{-1}	10^{6} to 10^{9}

Once generated, the hydroxyl radicals aggressively attack virtually all organic compounds."

There are well-known methods for generating hydroxyl radicals without using light energy. Two of the methods involve the reaction of ozone, one uses the Fe^{+2} ion, and two uses ultraviolet light.

- Ozone at high pH

$$2\,O_3 + H_2O \xrightarrow{OH^-} \bullet OH + O_2 + HO_2$$

- Ozone + Hydrogen Peroxide

$$O_3 + H_2O_2 \rightarrow \bullet OH + O_2 + HO_2$$

- Fenton's Reaction

$$Fe^{+2} + H_2O_2 \rightarrow Fe^{+3} + OH^- + \bullet OH$$

- Photolysis of Ozone

$$O_3 + hv \rightarrow O_2 + O(^1D)$$
$$O(^1D) + H_2O \rightarrow (2\ \bullet OH) \rightarrow H_2O_2$$

- Photolysis of Hydrogen Peroxide

$$H_2O_2 + hv \rightarrow 2\ \bullet OH$$

The following equation represents the simplified statement of the oxidation process:

Chlorinated Organic Molecule	$\xrightarrow{O_2\ \bullet OH}$	Intermediates (aldehydes /carbon acids)	$\xrightarrow{O_2\ \bullet OH}$	$CO_2 + H_2O + Cl$

In drinking water systems there are advantages to using UV light. In this waste water treatment, there is no disadvantage to utilizing Fenton's Reagent and there is a definite cost advantage. Use of ozone increases capital costs, complexity, and health and environmental concerns. For this particular industrial use, Fenton's Reagent is chosen for effectiveness and industrial simplicity.

Implementability of Chemical Oxidation by Fenton's Reagent

The recovered groundwater would be continuously pumped to a stirred vessel. Hydrogen peroxide and ferrous sulfate would be added continuously. The contents would overflow into the existing surface impoundments.

An advantage of ex-situ use of Fenton's Reagent as opposed to in-situ injection is that mixing and stoichiometry can be reliably determined and predicted. The theoretical considerations should be verified in the laboratory. Once determined, the results will be reproducible.

Relative Cost

Hydrogen peroxide costs are high.

Screening Comments

Use of a trench drain for recovery and Fenton's Reagent for chemical treatment is retained.

Alternative B-4; Ex-Situ Treatment with Iron Filings

This alternative involves capture of the plume with a trench drain and pumping the groundwater to treatment by contact with iron filings. The recovery and iron treatment are discussed separately below:

Effectiveness of Recovery

The two most popular methods for the recovery of shallow contaminated groundwater are the use of wells and infiltration trenches. Groundwater recovery trenches typically consist of a narrow sand-filled trench, often with a collection lateral used to convey the water infiltrated to a sump where it is pumped to a treatment unit. Although the use of wells is more common, there are many situations where trenches would provide a more effective and economical means for recovering contaminated groundwater.

In hydrogeologic settings where trenches are feasible, i.e., groundwater is relatively shallow, trenches have several advantages over recovery wells including:

- A much larger surface infiltration area providing lower groundwater entrance velocities which extends the life of the recovery system in environments where plugging of the filter pack with fines may be a factor.

- A more contiguous capture area compared to wells which rely upon the proper spacing for capture of migrating groundwater.

- Lower operation and maintenance cost of pumping equipment since a single sump pump can be utilized to recover groundwater for hundreds of linear feet.

Implementability of Recovery

The groundwater capture effectiveness of a trench is directly related to the ratio of saturated zone dewatered compared to the total thickness of the water table aquifer. At a minimum, a trench must be capable of lowering the water table 50 percent of the saturated thickness of the uppermost water bearing unit. Therefore, the minimum trench depth should be at least the depth to the water table plus one-half the saturated thickness of the upper water bearing zone. Generally, the practical depth limitations for trenches are static water levels of 15 feet or less and depth to base of the aquifer of 40 feet or less.

The volume of water (Q) passing through an aquifer for a given length perpendicular to the flow direction (L_a) is equal to:

$$Q = T \times i \times L$$

Where:

Q = volume of water flowing between two given points (gallons per day)
T = transmissivity (gallons per day per foot)
i = natural groundwater gradient (dimensionless)
L = length perpendicular to flow direction (feet)

During the initial start-up of the trench there will be an initial volume of water in storage which will need to be removed to create the cone or envelope of depression. The volume is equal to the effective pore volume of the area dewatered. This excess water must be accounted for in determining the initial pumping rates.

The most important factor to groundwater capture effectiveness and life of the trench is the selection of the material selected for use in the filter pack placed between the natural sediments and the collection lateral. A common mistake is to use too large of a filter pack material such as crushed rock or gravel. Fine grained sediments of the formation will tend to migrate between the "large" filter material and plug the filter pack.

Since the rate of groundwater flow into a trench is relatively slow, commonly less than a few feet per day, the limiting factor is usually the hydraulic conductivity of the formation.

Selection of a filter pack material comprised of a clean washed fine quartz sand close to the mean grain size of the formation material or slightly larger is recommended. The permeability of any clean fine quartz sand will usually be many times greater than the formation. A minimum of 6 inches of filter pack material are recommended below and beside the lateral to separate the formation from the collection lateral. The height of the sand pack may extend any length above the lateral, however, the depressed water level at steady state will most likely be only a few feet above the lateral. Extending the filter pack to the static water level is generally not necessary. The use of geomembranes is generally not necessary and may cause plugging if not selected or installed properly.

Although it is not absolutely necessary to install a collection lateral in the filter pack material, it is highly recommended for a number of reasons. The lateral is much less likely to "plug" as compared to the filter pack without the lateral.

Another advantage of a collection lateral is the installation of an "S" trap to keep the lateral constantly saturated. It is important not to entirely dewater the filter pack in order to minimize the potential for bacterial (algae) growth in the filter pack.

Very little maintenance is required for a properly constructed infiltration trench system. A large diameter sump is recommended to provide ample storage of water to minimize cycling of the sump pump. A 3- or 4-foot diameter reinforced concrete pipe with manhole cover and built-in ladder has proven to be useful. On-off levels for the pump can be set with float switches or transducers calibrated to measure water levels.

Relative Cost of Recovery

Groundwater recovery trenches have proven to be a highly effective and cost-efficient method for recovering a wide range of dissolved and LNAPL contaminants from the subsurface. Trenches are particularly applicable in shallow aquifers where water tables are generally less than 15 feet and base of the aquifer is less than 40 feet. Trenches are easily maintained and operational costs are generally lower than using multiple wells for groundwater recovery.

Effectiveness of Treatment with Iron Filings

Iron corrosion processes in aqueous systems have been studied extensively ("Permeable Reaction Barrier Technologies for Contaminant Reduction", EPA/600/R-98/125). Until recently, the fate of corrosion processes in dilute aqueous concentrations of chlorinated solvents acting as the oxidizing agents have not been investigated. The net reductive dechlorination reaction promoted by Fe(0) may be viewed as the sum of anodic and cathodic reactions occurring at the iron metal surface, resulting in hydrocarbon products if the dechlorination proceeds to completion.

$Fe^0 \rightarrow Fe^{2+} + 2e^-$	Anodic Reaction
$RCl + 2e^- + H^+ \rightarrow RH + Cl$	Cathodic Reaction
$Fe^0 + RCl + H^+ \rightarrow Fe^{2+} + RH + Cl$	Net Reaction

Under aerobic conditions, dissolved oxygen is usually the preferred electron acceptor and can compete with the chlorinated hydrocarbon as the favored oxidant. When sufficient oxygen is present, the Fe^{2+} generated further oxidizes to Fe^{3+} and can precipitate as ferric hydroxide.

$$2Fe^0 + O_2 + 2H_2O \rightarrow 2Fe^{2+} + 4OH^-$$
$$4Fe^{2+} + 4H^+ + O_2 \rightarrow 4Fe^{3+} + 2H_2O$$
$$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_{3(s)}$$

Anaerobic corrosion of iron by water proceeds slowly resulting in an increased pH in weakly buffered systems, yielding ferrous hydroxides in anaerobic systems.

$$Fe^0 + 2H_2O \rightarrow Fe^{2+} + H_2 + 2OH^-$$
$$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_{2(s)}$$

Laboratory experiments by VCC using iron demonstrated that the iron is cemented together by the hydroxide precipitates fairly rapidly. A permeable reactive barrier using iron would not be effective. A stirred reactor using iron can, however, be effective.

Zero-valent iron is a mild reductant, and consequently the dehalogenation rates vary for the various chlorinated solvents of environmental interest. Carbon tetrachloride has been shown to undergo sequential hydrogenolysis to chloroform and methylene chloride. The formation of chloroform accounted for about 70% of the carbon tetrachloride lost. Methylene chloride

appeared, after carbon tetrachloride decreased to the detection limit, and typically accounted for about 50% of the chloroform lost. No further reaction of methylene chloride has been detected in an unamended zero-valent iron system.

$$\begin{array}{cc} 2e^- + H^+ & 2e^- + H^+ \\ CCl_4 \rightarrow CHCl_3 + Cl^- & \rightarrow CH_2Cl_2 + 2Cl^- \end{array}$$

Carbon tetrachloride has an MCL of 5 ppb, chloroform 0.152 ppb, and methylene chloride 5 ppb; therefore, the net positive effect of iron treatment on VOAs that are chiefly carbon tetrachloride and chloroform is not significant.

Reduction of NO_3^- by Fe(0) has been observed to proceed rapidly, resulting in production of NO_2^-, and subsequently ammonium ion. The proposed pathway for the overall reaction is:

$$4Fe(0) + NO^{3-} + 10H^+ \rightarrow 4Fe^{2+} + NH_4^+ + 3H_2O$$

During laboratory studies, NO_3^- reduction was observed to proceed through NO_2^- to NH_4^+ formation. The rate of reduction was observed to be first order with respect to the Fe^0 substrate. In addition, the rate was observed to decline with increasing duration, particularly in the presence of chloride. However, NH_4^+ formation is not desirable since its MCL is lower than that of NO_3^-.

The effectiveness of iron treatment alone is limited.

Implementability of Iron Treatment

The groundwater would be treated by finely ground iron in well stirred reactor. Contents of the reactor would be pumped to a clarifier where the iron and hydroxides of iron would settle out and be pumped back to the treatment reactor. Vigorous agitation would have to be maintained to keep the iron hydroxide from coating the surface of the reactant iron. The treated groundwater would be discharged through a polish filter into the surface impoundments.

Relative Cost

The capital and operating cost is moderate to high.

Screening Comments

This alternative is screened out on effectiveness and also operation of the iron treating unit.

Alternative B-5; Ex-Situ Treatment with Carbon Adsorption

This alternative involves capture of the plume with a trench drain and pumping the groundwater to the surface impoundment. Water from the surface impoundment is treated by pumping through columns of activated carbon prior to discharge to the Mississippi River via an NPDES permit.

As previously noted, there is a drainage layer or drainage trench constructed for dewatering during the lining of the surface impoundments. The drainage trench is located directly between the plumes and the nearest point of the creek. It is depicted on Figure 3-4. The drainage trench does capture groundwater. The groundwater is pumped to the body of the surface impoundment and is treated directly by adsorption on carbon prior to discharge to the Mississippi River via a NPDES permit. Therefore, there is ongoing corrective action.

The portion of the plume that flows south towards Hennessey's Bayou will be captured in a trench drain. The trench drain is depicted in Figure 3-5. The captured groundwater will be pumped to the surface impoundment.

Effectiveness of Recovery

The two most popular methods for the recovery of shallow contaminated groundwater are the use of wells and infiltration trenches. Groundwater recovery trenches typically consist of a narrow sand-filled trench, often with a collection lateral used to convey the water infiltrated to a sump where it is pumped to a treatment unit. Although the use of wells is more common, there are many situations where trenches would provide a more effective and economical means for recovering contaminated groundwater.

In hydrogeologic settings where trenches are feasible, i.e., groundwater is relatively shallow, trenches have several advantages over recovery wells including:

- A much larger surface infiltration area providing lower groundwater entrance velocities which extends the life of the recovery system in environments where plugging of the filter pack with fines may be a factor.

- A more contiguous capture area compared to wells which rely upon the proper spacing for capture of migrating groundwater.

- Lower operation and maintenance cost of pumping equipment since a single sump pump can be utilized to recover groundwater for hundreds of linear feet.

Implementability of Recovery

The groundwater capture effectiveness of a trench is directly related to the ratio of saturated zone dewatered compared to the total thickness of the water table aquifer. At a minimum, a trench must be capable of lowering the water table 50 percent of the saturated thickness of the uppermost water bearing unit. Therefore, the minimum trench depth should be at least the depth to the water table plus one-half the saturated thickness of the upper water bearing zone. Generally, the practical depth limitations for trenches are static water levels of 15 feet or less and depth to base of the aquifer of 40 feet or less.

The volume of water (Q) passing through an aquifer for a given length perpendicular to the flow direction (L_a) is equal to:

$$Q = T \times i \times L$$

Where:

Q = volume of water flowing between two given points (gallons per day)
T = transmissivity (gallons per day per foot)
i = natural groundwater gradient (dimensionless)
L = length perpendicular to flow direction (feet)

During the initial start-up of the trench there will be an initial volume of water in storage which will need to be removed to create the cone or envelope of depression. The volume is equal to the effective pore volume of the area dewatered. This excess water must be accounted for in determining the initial pumping rates.

The most important factor to groundwater capture effectiveness and life of the trench is the selection of the material selected for use in the filter pack placed between the natural sediments and the collection lateral. A common mistake is to use too large of a filter pack material such as crushed rock or gravel. Fine grained sediments of the formation will tend to migrate between the "large" filter material and plug the filter pack.

Since the rate of groundwater flow into a trench is relatively slow, commonly less than a few feet per day, the limiting factor is usually the hydraulic conductivity of the formation.

Selection of a filter pack material comprised of a clean washed fine quartz sand close to the mean grain size of the formation material or slightly larger is recommended. The permeability of any clean fine quartz sand will usually be many times greater than the formation. A minimum of 6 inches of filter pack material are recommended below and beside the lateral to separate the formation from the collection lateral. The height of the sand pack may extend any length above the lateral, however, the depressed water level at steady state will most likely be only a few feet above the lateral. Extending the filter pack to the static water level is generally not necessary. The use of geomembranes is generally not necessary and may cause plugging if not selected or installed properly.

Although it is not absolutely necessary to install a collection lateral in the filter pack material, it is highly recommended for a number of reasons. The lateral is much less likely to "plug" as compared to the filter pack without the lateral.

Another advantage of a collection lateral is the installation of an "S" trap to keep the lateral constantly saturated. It is important not to entirely dewater the filter pack in order to minimize the potential for bacterial (algae) growth in the filter pack.

Very little maintenance is required for a properly constructed infiltration trench system. A large diameter sump is recommended to provide ample storage of water to minimize cycling of the sump pump. A 3- or 4-foot diameter reinforced concrete pipe with manhole cover and built-in ladder has proven to be useful. On-off levels for the pump can be set with float switches or transducers calibrated to measure water levels.

Relative Cost of Recovery

Groundwater recovery trenches have proven o be a highly effective and cost-efficient method for recovering a wide range of dissolved and LNAPL contaminants from the subsurface. Trenches are particularly applicable in shallow aquifers where water tables are generally less than 15 feet and base of the aquifer is less than 40 feet. Trenches are easily maintained and operational costs are generally lower than using multiple wells for groundwater recovery.

Effectiveness of Treatment by Adsorption by Activated Carbon

The existing drainage layer is capable of capturing about 3,000 gallons per day. It is about 300 feet in length. The new trench will likewise capture about 3,000 gallons per day. The drainage layer contents are discharged to the surface impoundment and treated by passage through a carbon adsorption system prior to discharge to the Mississippi Rive via an NPDES permit. The contents of the drainage layer system have had no adverse impact on the effluent.

The discharge from the new trench to the surface impoundment will have a higher concentration of dinoseb and VOAs than are discharged from the drainage layer. If 3,000 gallons is discharged per day and the concentration of dinoseb plus VOAs is 20,000 ppb, that would result in a discharge of about one-half pound organics per day. The consumption of carbon would, therefore, increase by 5 to 10 pounds per day.

Another variation of this alternative would be to pretreat the discharge in a smaller carbon adsorption unit. Prepackaged adsorption units are available from vendors (e.g. ASC-200 from U.S. Filter) containing 200 pounds of carbon and can accommodate low rates of flow while maintaining good groundwater to activated carbon distribution.

Treatment of water by activated carbon has a proven record and history of effectiveness at the VCC site.

Implementability of Treatment B, Adsorption by Activated Carbon

A wastewater treatment system consisting of six vessels of activated carbon exists at VCC for wastewater treatment. Each vessel contains 20,000 pounds of activated carbon. The vessels are hydraulically too large for direct treatment of groundwater but if the groundwater is

pumped to the surface impoundment, it will be treated by activated carbon prior to discharge to the Mississippi River.

It is almost equal in simplicity to purchase prepackaged containers of carbon for pretreatment of groundwater being pumped to the surface impoundment.

Relative Cost

This alternative is low cost.

Screening Comments

This alternative will be retained.

3.6 DEVELOPMENT OF CORRECTIVE ACTION ALTERNATIVES FOR GROUNDWATER CONTAMINATED WITH ARSENIC

Alternative C-1; In-Situ Treatment with Injection of Precipitating Agents

This alternative involves injection of chemicals directly into the shallow zone of the groundwater aquifer. The objective is to cause precipitation of arsenic and adherence of that arsenic to subsurface media. Injection of a slurry of zero valent iron or injection of Fenton's Reagent (hydrogen peroxide and ferrous sulfate) is intended to achieve that objective. The injection tool is a wand with multiple injection jets at the end. The jets can be modified to accommodate the particular innoculant. Upwards of 20,000 psi can be generated at the jet tips to allow horizontal penetration by jetting fissures in the formation as the wand is moved vertically from 10 feet bgs to 20 feet bgs.

Effectiveness

Reduction and precipitation of anion-forming elements by elemental iron have been investigated at the laboratory scale. Arsenic commonly occurs as a dissolved species in two oxidation states, As(V) and As(III), and less commonly in other oxidation states, including As(0), AS(-I) and As(-II). The As(V) oxidation state occurs as H_3AsO_4 and its dissociation products. The As(III) oxidation state occurs as H_3AsO_3 and its dissociation products. Although As(III), which has greater health effects, is considered to be potentially more

mobile in groundwater systems, As(V) is also observed to be mobile in natural systems. In addition, the rate of arsenic transformation between the AS(III) and As(V) oxidation states occurs rapidly in response to changing environmental conditions. Arsenic reduction to the As(0) oxidation state and precipitation of native arsenic, or incorporation into a secondary arsenic sulfide, has been proposed as a potential treatment technique. In batch tests conducted using elemental iron, rapid removal of As(V) is observed from concentrations of 1,000 µg/L to <3 µg/L over a two-hour period. Similar experiments using As(III) and mixtures of As(III) and AS(V) indicated equally rapid removal rates. The mechanisms resulting in arsenic attenuation, and the potential duration of treatment need to be evaluated by experiments.

The effectiveness of the above is a formation of the ability to evenly distribute a slurry of finely ground zero valent iron into the formation. The probability of an effective distribution into the tight formation is remote. As precipitation of arsenic or arsenic salt occurs effective contact would become more remote.

A variation of the above is to construct a Permeable Reaction Barrier (PRB) of zero valent iron through which the groundwater must pass. The effectiveness of the PRB would diminish as both permeability and iron contact decreased as arsenic or arsenic salts precipitated.

Another variation is to use Fenton's Reagent (hydrogen peroxide and ferrous sulfate). The complex mechanism is from "A Treatment Process for Removal of Mixed Inorganic and Organic Arsenic Species from Groundwater" by K. Banerjer, R.P. Helwick and S. Gupter, Environmental Progress, Volume 18, No. 4, 1999. Arsenate ions and organoarsenicals are oxidized to arsenate ions, which are highly soluble in water at pH between 6 and 8. The ferric ions generated in the oxidation process precipitate As(V) as a ferric-arsenate complex. The remaining arsenate ions ($As\ 0_4^{-3}$) are then adsorbed into amorphous iron oxyhydroxide ($Fe_2\ O_3 \cdot H_2O$).

The Fenton's Reagent variation has been successfully used ex-situ. Its effectiveness in-situ is dependent on good contact and then on precipitation and/or adherence of the arsenic onto the subsurface media.

Implementability

Jetting of remediation agents can be accomplished at many sites to depth of 30 feet. Jetting is usually performed under high pressure and at low volume using specially designed jetting lances and tips that can jet remediation agents at pressures ranging from 500 to up to 20,000 psi. Flow rates can range from 1 to 20 gpm. The high pressure can be sufficient to fracture soils even with low permeability, and to overcome ground pressures in the areas of treatment of up to several feet from the vertical point of jetting. Once the soil is fractured, the remediation agents are effectively dispersed into the contaminated soil and/or water matrix.

In many subsurface soils, jetting to 20 feet bgs can be accomplished in a matter of only a few minutes. After the jetting lance reaches the desired depth, the remediation agents are jetted into the treatment zone via a variety of specially-designed tips that distribute the remediation agents both radially and/or vertically. Sufficient jetting pressure can force the remediation agents outward into the soil or groundwater up to several feet from the point of jetting. At the source of the arsenic plume there will be a need to predrill through concrete areas and install temporary well points.

In jetting systems, the remediation agents, such as hydrogen peroxide and catalysts, are delivered to the site and then transferred from the product storage tanks into mixing tanks according to a pre-determined remediation "recipe". A gasoline-powered compressor powers the jetting system which jets the remediation solution into the subsurface soil and/or groundwater under high pressure through a specially designed jetting lance and tip system. The jetting lances come in various lengths, and can be connected in a series for deeper jetting.

The jetting lance is designed to rapidly jet through subsurface soils, including clays. The lance is less than one inch in diameter, with specially designed jetting tips. Jetting ports on the tip allow high pressure (up to 20,000 psi), low volume (up to 20 gpm) jetting of remediation agents into the treatment zone. Depending on the application, tips with up to nine jetting ports can be used to inject remediation agents both vertically (downward) and radially n up to eight compass directions, effecting uniform distribution of remediation agents throughout the treatment zone.

Jetting to the top of the treatment zone is typically accomplished using fresh water (or remediation agents if the treatment zone is near the surface). Once the top of the treatment zone is encountered, jetting is accomplished with remediation agents. As the jetting lance

jets downward from the top of the treatment zone to the terminal depth of the treatment zone, remediation agents are jetted laterally, thereby treating a cylindrically-shaped area. Typical radius of influence is on the order of two to ten feet, depending on the subsurface stratigraphy, jetting pressure, jetting volume, residence time, and other factors. Tightly-spaced and overlapping treatment "cylinders" result in effective remediation of the treatment zone with minimal "cold spots". Multiple treatment cycles are frequently used to effect remediation.

In the case of using Fenton's Reagent, jetting occurs in two steps. The first step involves the jetting of the ferrous sulfate catalyst, and if necessary, surfactant. At many sites, the surfactant solution will help increase the porosity of the treatment zone and help loosen any adsorbed contaminant within the soil or groundwater matrix. The second step involves the jetting of hydrogen peroxide through the same jetting holes into the treatment zone.

The quantity of ISCT remediation agents required to oxidize a specific contaminant is dependent upon the chemical and physical properties of the contaminant, remediation criteria, remediation schedule, subsurface conditions, and other factors. The stoichiometric ratios for successful remediation can be determined by:

- Theoretical stoichiometric calculations
- Laboratory bench-scale studies
- Field pilot studies
- Field experience on other projects

Theoretical stoichiometric calculations can be made; however, site specific factors which lead to collateral oxidation can greatly affect the theoretical quantities of remediation agents required.

Laboratory bench-scale studies can be sued to simulate the oxidation process to help guide the field application. While laboratory bench-scale studies can provide guidance, they may not always provide exact answers since actual field conditions are difficult to simulate in the laboratory, especially contact phenomena.

Field studies would prove mandatory at this site. The proposed mechanism has not been proved by in-situ injection.

Relative Cost

Unless field verification experiments demonstrated otherwise, high costs would be anticipated. The elements of cost expected to be high would be the cost of manpower for injections, multiple mobilizations and the cost of hydrogen peroxide and ferrous sulfate.

Screening Comments

This alternative is screened out on effectiveness and implementability. While the ideas have certain merit they are largely unproven. There would be considerably difficulty in proving the mechanism in the field without treating the site one full scale basis and then determining its efficacy.

Alternative C-2; Ex-Situ Treatment by Precipitation/Flocculation/Settlement

This alternative involves capture of the plume with a trench drain. The recovered groundwater would be discharge to a reactor where a precipitation chemical would be added. Reactor contents would be pumped to a clarifier where flocculants would be added and the arsenic precipitant then through a polish filter into the surface impoundment. The clarified stream would be pumped through a separate polish filter into the surface impoundment. The accumulated arsenic would be disposed at a commercial waste landfill. The surface impoundment is discharged through activated carbon columns into the Mississippi River via an NPDES permit.

A variety of methods have been developed for removal of inorganic arsenic compounds from water and wastewater. EPA publication 815-R-00-028 December 2000 "Technologies and Costs for Removal of Arsenic from Drinking Water" lists several categories of precipitation processes, adsorptive processes, ion exchange, and membrane processes.

Alternative C-2 is based on "A Treatment Process for Removal of Mixed Inorganic and Organic Arsenic Species from Groundwater" by Banerjer, Helwick and Gupter, Environmental Progress, writer 1999. It is chosen because it will treat the arsenic and also any residual organic compounds.

Effectiveness of Recovery

The two most popular methods for the recovery of shallow contaminated groundwater are the use of wells and infiltration trenches. Groundwater recovery trenches typically consist of a narrow sand-filled trench, often with a collection lateral used to convey the water infiltrated to a sump where it is pumped to a treatment unit. Although the use of wells is more common, there are many situations where trenches would provide a more effective and economical means for recovering contaminated groundwater.

In hydrogeologic settings where trenches are feasible, i.e., groundwater is relatively shallow, trenches have several advantages over recovery wells including:

- A much larger surface infiltration area providing lower groundwater entrance velocities which extends the life of the recovery system in environments where plugging of the filter pack with fines may be a factor.

- A more contiguous capture area compared to wells which rely upon the proper spacing for capture of migrating groundwater.

- Lower operation and maintenance cost of pumping equipment since a single sump pump can be utilized to recover groundwater for hundreds of linear feet.

Implementability of Recovery

The groundwater capture effectiveness of a trench is directly related to the ratio of saturated zone dewatered compared to the total thickness of the water table aquifer. At a minimum, a trench must be capable of lowering the water table 50 percent of the saturated thickness of the uppermost water bearing unit. Therefore, the minimum trench depth should be at least the depth to the water table plus one-half the saturated thickness of the upper water bearing zone. Generally, the practical depth limitations for trenches are static water levels of 15 feet or less and depth to base of the aquifer of 40 feet or less.

The volume of water (Q) passing through an aquifer for a given length perpendicular to the flow direction (L_a) is equal to:

$$Q = T \times i \times L$$

Where:

Q = volume of water flowing between two given points (gallons per day)
T = transmissivity (gallons per day per foot)
i = natural groundwater gradient (dimensionless)
L = length perpendicular to flow direction (feet)

During the initial start-up of the trench there will be an initial volume of water in storage which will need to be removed to create the cone or envelope of depression. The volume is equal to the effective pore volume of the area dewatered. This excess water must be accounted for in determining the initial pumping rates.

The most important factor to groundwater capture effectiveness and life of the trench is the selection of the material selected for use in the filter pack placed between the natural sediments and the collection lateral. A common mistake is to use too large of a filter pack material such as crushed rock or gravel. Fine grained sediments of the formation will tend to migrate between the "large" filter material and plug the filter pack.

Since the rate of groundwater flow into a trench is relatively slow, commonly less than a few feet per day, the limiting factor is usually the hydraulic conductivity of the formation.

Selection of a filter pack material comprised of a clean washed fine quartz sand close to the mean grain size of the formation material or slightly larger is recommended. The permeability of any clean fine quartz sand will usually be many times greater than the formation. A minimum of 6 inches of filter pack material are recommended below and beside the lateral to separate the formation from the collection lateral. The height of the sand pack may extend any length above the lateral, however, the depressed water level at steady state will most likely be only a few feet above the lateral. Extending the filter pack to the static water level is generally not necessary. The use of geomembranes is generally not necessary and may cause plugging if not selected or installed properly.

Although it is not absolutely necessary to install a collection lateral in the filter pack material, it is highly recommended for a number of reasons. The lateral is much less likely to "plug" as compared to the filter pack without the lateral.

Another advantage of a collection lateral is the installation of an "S" trap to keep the lateral constantly saturated. It is important not to entirely dewater the filter pack in order to minimize the potential for bacterial (algae) growth in the filter pack.

Very little maintenance is required for a properly constructed infiltration trench system. A large diameter sump is recommended to provide ample storage of water to minimize cycling of the sump pump. A 3- or 4-foot diameter reinforced concrete pipe with manhole cover and built-in ladder has proven to be useful. On-off levels for the pump can be set with float switches or transducers calibrated to measure water levels.

Effectiveness of Recovery

Groundwater recovery trenches have proven o be a highly effective and cost-efficient method for recovering a wide range of dissolved and LNAPL contaminants from the subsurface. Trenches are particularly applicable in shallow aquifers where water tables are generally less than 15 feet and base of the aquifer is less than 40 feet. Trenches are easily maintained and operational costs are generally lower than using multiple wells for groundwater recovery.

Effectiveness of Treatment by Precipitation/Flocculation /Settlement

The reference article has provided data that indicates the treatment should be effective. There would have to be laboratory and pilot plant verification prior to proceeding with this alternative on a field scale.

Implementability of Treatment

Groundwater would be continuously removed from the interceptor trench at a rate of 0.1 gpm and pumped to a continuously stirred 10 gallon reactor. There would additionally be pumped to the reactor 0.0015 gph of 22% caustic, 0.21 gph of pickle liquor (by-product of steel mills with 87,000 ppm iron content), and 0.18 gph of 5% hydrogen peroxide. Residence time for oxidation of arsenic (III) and organoarsenicals to arsenic (V) is 30 minutes at pH 2.5.

The reactor contents are continuously removed on level control to an aeration reactor where the precipitation, adsorption and coprecipitation of oxidized arsenic is completed by aerating for another 30 minutes with an air sparge under a pH of 7.5. The pH of 7.5 is achieved by continuous addition of another 0.0015 gph caustic.

The aerator contents are continuously removed on level control to a 20 gallon settling tank. Anionic polymeric flocculant is metered into the tank at 0.01 cc per hour. Settling residence time in the tank is 120 minutes. The insoluble ferric-arsenate precipitant adsorbed onto the iron settles out in the floc. Solids are removed in a filter via a circulation loop with the pump suction at the bottom of the settling tank. Filtered water is discharged back to the settling tank. Clean water is continuously removed under level control and pumped to the wastewater pond to eventually be discharged to the Mississippi River via the site NPDES permit. The clean water will contain less than 10 ppb arsenic. Contents of the filter are removed once per month and placed in two 55 gallon drums for disposal in an offsite commercial landfill.

The following are the key parameters for the design:

- Fe/As ration = 10/1
- Hydrogen peroxide/Fe ration = 1/2
- Residence time for initial oxidation at pH 2.5 = 30 minutes
- Residence time for aeration at pH 7.5 = 30 minutes
- Residence time for settling = 120 minutes

A process flow diagram is presented as Figure 3-6.

Relative Cost

The relative cost of this alternative is low to moderate.

Screening Comments

This alternative will be retained.

Alternative C-3; Ex-Situ Treatment by Ion Exchange

This alternative involves capture of the plume with a trench drain. The recovered groundwater would be discharged through ion exchange columns where arsenic would be exchanged for a non-toxic ion to the surface impoundment. The surface impoundment is discharged through activated carbon columns into the Mississippi River via an NPDES permit. Beds are regenerated after breakthrough until they become spent. Spent ion-exchange columns would be disposed in a commercial waste landfill.

Effectiveness of Recovery

The two most popular methods for the recovery of shallow contaminated groundwater are the use of wells and infiltration trenches. Groundwater recovery trenches typically consist of a narrow sand-filled trench, often with a collection lateral used to convey the water infiltrated to a sump where it is pumped to a treatment unit. Although the use of wells is more common, there are many situations where trenches would provide a more effective and economical means for recovering contaminated groundwater.

In hydrogeologic settings where trenches are feasible, i.e., groundwater is relatively shallow, trenches have several advantages over recovery wells including:

- A much larger surface infiltration area providing lower groundwater entrance velocities which extends the life of the recovery system in environments where plugging of the filter pack with fines may be a factor.

- A more contiguous capture area compared to wells which rely upon the proper spacing for capture of migrating groundwater.

- Lower operation and maintenance cost of pumping equipment since a single sump pump can be utilized to recover groundwater for hundreds of linear feet.

Implementability of Recovery

The groundwater capture effectiveness of a trench is directly related to the ratio of saturated zone dewatered compared to the total thickness of the water table aquifer. At a minimum, a trench must be capable of lowering the water table 50 percent of the saturated thickness of the uppermost water bearing unit. Therefore, the minimum trench depth should be at least the depth to the water table plus one-half the saturated thickness of the upper water bearing zone. Generally, the practical depth limitations for trenches are static water levels of 15 feet or less and depth to base of the aquifer of 40 feet or less.

The volume of water (Q) passing through an aquifer for a given length perpendicular to the flow direction (L_a) is equal to:

$$Q = T \times i \times L$$

Where:

Q = volume of water flowing between two given points (gallons per day)
T = transmissivity (gallons per day per foot)
i = natural groundwater gradient (dimensionless)
L = length perpendicular to flow direction (feet)

During the initial start-up of the trench there will be an initial volume of water in storage which will need to be removed to create the cone or envelope of depression. The volume is equal to the effective pore volume of the area dewatered. This excess water must be accounted for in determining the initial pumping rates.

The most important factor to groundwater capture effectiveness and life of the trench is the selection of the material selected for use in the filter pack placed between the natural sediments and the collection lateral. A common mistake is to use too large of a filter pack material such as crushed rock or gravel. Fine grained sediments of the formation will tend to migrate between the "large" filter material and plug the filter pack.

Since the rate of groundwater flow into a trench is relatively slow, commonly less than a few feet per day, the limiting factor is usually the hydraulic conductivity of the formation.

Selection of a filter pack material comprised of a clean washed fine quartz sand close to the mean grain size of the formation material or slightly larger is recommended. The permeability of any clean fine quartz sand will usually be many times greater than the formation. A *minimum* of 6 inches of filter pack material are recommended below and beside the lateral to separate the formation from the collection lateral. The height of the sand pack may extend any length above the lateral, however, the depressed water level at steady state will most likely be only a few feet above the lateral. Extending the filter pack to the static water level is generally not necessary. The use of geomembranes is generally not necessary and may cause plugging if not selected or installed properly.

Although it is not absolutely necessary to install a collection lateral in the filter pack material, it is highly recommended for a number of reasons. The lateral is much less likely to "plug" as compared to the filter pack without the lateral.

Another advantage of a collection lateral is the installation of an "S" trap to keep the lateral constantly saturated. It is important not to entirely dewater the filter pack in order to minimize the potential for bacterial (algae) growth in the filter pack.

Very little maintenance is required for a properly constructed infiltration trench system. A large diameter sump is recommended to provide ample storage of water to minimize cycling of the sump pump. A 3- or 4-foot diameter reinforced concrete pipe with manhole cover and built-in ladder has proven to be useful. On-off levels for the pump can be set with float switches or transducers calibrated to measure water levels.

Groundwater recovery trenches have proven o be a highly effective and cost-efficient method for recovering a wide range of dissolved and LNAPL contaminants from the subsurface. Trenches are particularly applicable in shallow aquifers where water tables are generally less than 15 feet and base of the aquifer is less than 40 feet. Trenches are easily maintained and operational costs are generally lower than using multiple wells for groundwater recovery.

Effectiveness of Treatment by Ion Exchange

The following discussion is abstracted from "Technologies and Costs for Removal of Arsenic from Drinking Water", EPA815-R-00-028, December 2000.

Ion exchange (IX) is a physical/chemical process by which an ion on the solid phase, typically a synthetic resin, is exchanged for an ion in the feed water. To accomplish this exchange of ions, feed water is continuously passed through a bed of ion exchange resin beads until the resin is exhausted. It is difficult to reduce effluent arsenic concentrations to below 3 ppm. At this point, the bed is regenerated by rinsing the IX column with a regenerant – a concentrated solution of ions initially exchanged from the resin. The number of bed volumes that can be treated before exhaustion varies with resin type and influent water quality, particularly arsenic concentration. Studies suggest that from 200 to 4,940 bed volumes can be treated before regeneration is required. Regeneration of the bed can be accomplished with only 1 to 5 bed volumes of regenerant followed by 2 to 20 bed volumes of rinse water. The regenerant would be laden with arsenic and would have to be treated by precipitation/flocculation/settlement (see Alternative C-2) prior to discharge.

Competition from background ions for IX sites can greatly affect the efficiency, as well as the economics, of IX systems. The level of these background contaminants may determine the

applicability of IX at a particular site. Typically, strong-base anion exchange resins are used in arsenic removal. Strong-base anion resins tend to be more effective over a larger rang of pH than weak-base resins. The order of exchange for most strong-base resins is given below, with the adsorption preference being greater for the constituents on the far left.

$$HCrO_4^- > CrO_4^{2-} > ClO_4^- > SeO_4^{2-} > NO_3^- > Br^- > (HPO_4^{2-}, HAsO_4^{2-}, SeO_3^{2-}, CO_3^{2-}) > CN^- > NO_2^- > Cl^- > (H_{2PO}^{4-}, H_2AsO_4^-, HCO_3^-) > OH^- > CH_3COO^- > F^-$$

These resins have a relatively high affinity for arsenic in the arsenate form ($HAsO_4^{2-}$).

Properly configuring IX columns can improve arsenic removal and help minimize regeneration frequency. This is because "leakage" often occurs in IX columns. Series operation and implementation of certain operating methods are needed to achieve lowest arsenic levels. Series operation uses three beds: two in production and one in regeneration mode at a given time. When exchange capacity of the first bed in series is exhausted, the first bed is removed from service to be regenerated. The second bed in series then becomes the first and a freshly-regenerated bed is brought on-line to become the second. This allows the maximum exchange capacity of beds to be used and prevents leakage since a fresh bed is always last in line. This also helps minimize regeneration frequency.

Many resins are available for arsenic removal. Some of the commercially available resins which have been used in relevant IX studies are summarized in Table 3-2. Data in the table represent bed volume to exhaustion using virgin IX resins. The capacity of the bed may decrease slightly over time. Choice of resin will ultimately be site-specific, making preliminary studies a necessity to determine resin type and the number of bed volumes with throughput prior to exhaustion.

TABLE 3-2

TYPICAL ION EXCHANGE RESINS FOR ARSENIC REMOVAL

Resin	Operating Parameters	Bed volumes to Exhaustion
Dowex 11	Bed Volume: 0.8 cu ft Flowrate: 1 gpm Depth: 2.5-5 ft Sulfate/As Ratio: 60:1 TDS/As Ratio: 2500:1	4,200

TABLE 3-2 (continued)

TYPICAL ION EXCHANGE RESINS FOR ARSENIC REMOVAL

Resin	Operating Parameters	Bed volumes to Exhaustion
Ionac ASB-2	Bed Volume: 0.8 cu ft Flowrate: 1 gpm Depth: 2.5-5 ft Sulfate/As Ratio: 60:1 TDS/As Ratio: 2500:1	4,940
Dowex SBR-1	Bed Volume: 1.0 cu ft Flowrate: 1 gpm Depth: 3.8 ft Sulfate/As Ratio: Not Reported TDS/As Ratio: Not Reported	2,800
Ionac ASB-1 - and - Dowex 11	Bed Volume: 0.014 cu ft Flowrate: Not Reported Depth: Not Reported Sulfate/As Ratio: 420:1 TDS/As Ratio: 9200:1	• 200 • 400-500 [projected if As(III) is oxidized to As(V)]

Relative Cost

Treatment costs and cost of resins can be high.

Screening Comments

This alternative will be screened out on effectiveness. Desired effluent concentrations will be difficult to obtain. Also the regenerant will be laden with arsenic and must be treated by precipitation/flocculation/settlement process such as that presented as Alternative C-2.

Alternative C-4; Ex-Situ Treatment by Phytoremediation

This alternative involves capture of the plume with a trench drain. The recovered groundwater would be discharged to a hydroponic bed of ladder brake ferns. Overflow from the hydroponic bed would be pumped to the surface impoundment. Contents of the surface impoundment would be discharged to the Mississippi River through activated carbon columns via an NPDES permit. Fern fronds would be periodically harvested, dried and disposed in a hazardous waste landfill.

Where:

Q = volume of water flowing between two given points (gallons per day)
T = transmissivity (gallons per day per foot)
i = natural groundwater gradient (dimensionless)
L = length perpendicular to flow direction (feet)

During the initial start-up of the trench there will be an initial volume of water in storage which will need to be removed to create the cone or envelope of depression. The volume is equal to the effective pore volume of the area dewatered. This excess water must be accounted for in determining the initial pumping rates.
The most important factor to groundwater capture effectiveness and life of the trench is the selection of the material selected for use in the filter pack placed between the natural sediments and the collection lateral. A common mistake is to use too large of a filter pack material such as crushed rock or gravel. Fine grained sediments of the formation will tend to migrate between the "large" filter material and plug the filter pack.

Since the rate of groundwater flow into a trench is relatively slow, commonly less than a few feet per day, the limiting factor is usually the hydraulic conductivity of the formation.

Selection of a filter pack material comprised of a clean washed fine quartz sand close to the mean grain size of the formation material or slightly larger is recommended. The permeability of any clean fine quartz sand will usually be many times greater than the formation. A minimum of 6 inches of filter pack material are recommended below and beside the lateral to separate the formation from the collection lateral. The height of the sand pack may extend any length above the lateral, however, the depressed water level at steady state will most likely be only a few feet above the lateral. Extending the filter pack to the static water level is generally not necessary. The use of geomembranes is generally not necessary and may cause plugging if not selected or installed properly.

Although it is not absolutely necessary to install a collection lateral in the filter pack material, it is highly recommended for a number of reasons. The lateral is much less likely to "plug" as compared to the filter pack without the lateral.

Another advantage of a collection lateral is the installation of an "S" trap to keep the lateral constantly saturated. It is important not to entirely dewater the filter pack in order to minimize the potential for bacterial (algae) growth in the filter pack.

Very little maintenance is required for a properly constructed infiltration trench system. A large diameter sump is recommended to provide ample storage of water to minimize cycling of the sump pump. A 3- or 4-foot diameter reinforced concrete pipe with manhole cover and built-in ladder has proven to be useful. On-off levels for the pump can be set with float switches or transducers calibrated to measure water levels.

Relative Cost of Recovery

Groundwater recovery trenches have proven o be a highly effective and cost-efficient method for recovering a wide range of dissolved and LNAPL contaminants from the subsurface. Trenches are particularly applicable in shallow aquifers where water tables are generally less than 15 feet and base of the aquifer is less than 40 feet. Trenches are easily maintained and operational costs are generally lower than using multiple wells for groundwater recovery.

Effectiveness of Treatment by Phytoremediation

Phytoremediation is defined as the use of green plants to remove pollutants from the environment or to render them harmless. This cost-effective plant based approach to remediation takes advantage of the remarkable ability of plants to concentrate elements from the environment.

In recent years, knowledge of the physiological and molecular mechanisms of phytoremediation has begun to emerge together with biological and engineering strategies designed to optimize and improve the phytoremediation process. In addition, several field trials confirmed the feasibility of using plants for environmental clean-up of toxic heavy metals and organic pollutants.

Phytoremediation is currently divided into the following areas:

- Phytoextraction: the use of pollutant-accumulating plants to remove metals or organics from soil by concentrating them in the harvestable parts.

- Phytodegradation: the use of plants and associated microorganisms to degrade organic pollutants.
- Rhizofiltration: the use of plant roots to ab/adsorb pollutants, mainly metals, from aqueous waste streams.
- Phytostabilization: the use of plants to reduce the bioavailability of pollutants in the environment.
- Phytovolatilization: the use of plants to volatilize pollutants.

At VCC the mechanism proposed is rhizofiltration. Laboratory experiments by Edenspace System Corporation on arsenic contaminated groundwater have shown 50% reduction from 250,000 ppb in 3 to 4 weeks and a projected reduction to MCL in 10 weeks.

Implementability of Ferns

A trench drain would be constructed approximately the feet long in the most constructed portion of the arsenic plume. It would be 15 feet deep and filled with sad to 10 feet below ground surface. A collector pipe would be installed and drain to a collection sump. Water would be continuously pumped at 0.1 gpm to hydroponic stands of ladder brake ferns.

With the following assumptions:

- The soil of interest contains 600 pounds arsenic which can leak into the groundwater.
- The groundwater of interest presently contains 150 pounds of arsenic.
- 144 gallons of groundwater is pumped per day; the groundwater contains 0.24 pounds arsenic.
- Each plant weighs one pound (plants grow to have five foot fronds).
- Each plant can absorb to 20,000 ppm arsenic; 0.02 pounds arsenic is removed per plant in 70 days.

Then it can be calculated that:

- 144 (70) = 10,080 gallons of troughs are required; construct 20' x 5' x 2.0' and operate at 1.5' depth, so 8 troughs are required. The troughs would be covered by a greenhouse type roof and walls. Heating would be provided for the winter.

- 750/0.24 = 3125 days (8.6 years) of operation are required.

- 750/0.02 = 37,500 plants would be required over the 8.6 years of operation, assuming that the entire plant is replaced when fronds are harvested. Factually, the ferns will regenerate fronds as the fronds are harvested. Assuming a six inch spacing of ferns or 4 ferns per square feet, the starting number of ferns would be 3,200. If all the ferns continue to regenerate then only 3,200 ferns may be required.

The method of operation can be explained by reference to Figure 3-7. The groundwater is continuously pumped to the system consisting of eight cells in series. At start up the fist cell would be filled with 1,000 gallons of arsenic groundwater and the other cells would each be filled with 1,000 gallons of potable water. Each cell would contain 400 ferns and appropriate fertilizer. Water from cell 8 would be discharged to the drainage system leading to the surface impoundment.

On a monthly basis, a sample of fronds in cell 1 and water discharge from cell 8 would be analyzed for arsenic. The water discharge would have to remain below 10 ppb. The fronds in cell 1 would increase in arsenic concentration.

When the arsenic concentration of the fronds in cell 1 has increased to 20,000 ppm, they are ready for harvesting. At this time the supply stream of 0.1 gpm arsenic contaminated groundwater is diverted to cell 2. When fronds are harvested in cell 1 the water in cell 1 is pumped with a temporary pump to cell 2. Potable water is introduced to cell 1. Then the discharge form cell 8 is diverted to the drainage system. The fronds in cell 2 and discharge of water from cell 1 would be monitored on a monthly basis. This same pattern would be continued for about 8.6 years.

Relative Costs

Costs would be low to moderate.

Screening Comments

This alternative will be retained.

APPENDIX A

LABORATORY WORK – EFFECT OF COMPOSTING PLUS IRON ON SOIL CONTAMINATED WITH TOXAPHENE AND DINOSEB

APPENDIX B

LABORATORY WORK – EFFECT OF LADDER BRAKE FERNS (Pteris Vittata) ON GROUNDWATER CONTAMINATED WITH ARSENIC

Effectiveness of Recovery

The two most popular methods for the recovery of shallow contaminated groundwater are the use of wells and infiltration trenches. Groundwater recovery trenches typically consist of a narrow sand-filled trench, often with a collection lateral used to convey the water infiltrated to a sump where it is pumped to a treatment unit. Although the use of wells is more common, there are many situations where trenches would provide a more effective and economical means for recovering contaminated groundwater.

In hydrogeologic settings where trenches are feasible, i.e., groundwater is relatively shallow, trenches have several advantages over recovery wells including:

- A much larger surface infiltration area providing lower groundwater entrance velocities which extends the life of the recovery system in environments where plugging of the filter pack with fines may be a factor.

- A more contiguous capture area compared to wells which rely upon the proper spacing for capture of migrating groundwater.

- Lower operation and maintenance cost of pumping equipment since a single sump pump can be utilized to recover groundwater for hundreds of linear feet.

Implementability of Recovery

The groundwater capture effectiveness of a trench is directly related to the ratio of saturated zone dewatered compared to the total thickness of the water table aquifer. At a minimum, a trench must be capable of lowering the water table 50 percent of the saturated thickness of the uppermost water bearing unit. Therefore, the minimum trench depth should be at least the depth to the water table plus one-half the saturated thickness of the upper water bearing zone. Generally, the practical depth limitations for trenches are static water levels of 15 feet or less and depth to base of the aquifer of 40 feet or less.

The volume of water (Q) passing through an aquifer for a given length perpendicular to the flow direction (L_a) is equal to:

$$Q = T \times i \times L$$

DRAFT

CORRECTIVE MEASURES STUDY

Prepared for:
Harcros Chemical Inc.

Re:
Vicksburg Chemical Site
Vicksburg, Mississippi

October 2002

Prepared by:
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4.1 INTRODUCTION

The purpose of the following detailed analysis is to evaluate the retained alternatives and provide a basis for selection of the most appropriate alternative. The analysis was performed using the following evaluation criteria:

- Overall protection of human health and the environment
- Institutional
- Performance
- Reliability
- Safety
- Implementability
- Cost

The first two criteria (overall protection of human health and the environment and compliance with institutional needs) are designated as threshold criteria because in most cases, these criteria must be met by the selected alternative. After evaluating compliance with the threshold criteria, the alternatives were analyzed using the next criteria to determine how they compare to one another and to identify possible compromises between them.

Overall Protection of Human Health and the Environment

This criterion addresses whether the remedy is protective of human health and the environment considering the site's characteristics. The corrective action's long-term effectiveness and permanence, short-term effectiveness, and reduction of toxicity, mobility, and volume affect the overall protection of human health and the environment. How each alternative achieves protection over time and whether site risks are eliminated, reduced, or controlled are also analyzed.

Institutional

This criteria evaluates the effects of Federal, state, and local environmental and public health standards, regulations, guidance, advisories, ordinances or community relations on the design, operation, and timing of each alternative.

Performance

This criterion relates to the effectiveness and useful life of the alternative in maintaining protection of human health and the environment after corrective action objectives have been met. The focus is on any residual risk remaining at the site after completion of the corrective action and the reliability of engineering and institutional controls and monitoring to manage hazardous substances remaining at the site.

Reliability

This evaluation criterion addresses the general preference for treatment methods that would reliably result in the reduction of toxicity, mobility, or volume of a waste. The specific factors to be considered are the frequency and complexity of operations and maintenance; the expected degree of reduction in toxicity, mobility, or volume; the degree to which the remediation would be irreversible; and the nature and quantity of treatment residuals that would remain on-site.

Safety

This criterion relates to the potential for adverse effects to the community or environment during construction and implementation of the corrective action. The length of time required to achieve protection, the short-term reliability of the technology, and protection of the community and of workers during corrective action are considered.

Implementability

This criterion relates to the technical and administrative feasibility of the corrective action alternative. The specific factors to be considered are ability to construct, operate, and maintain the technology; ability to monitor the effectiveness of the corrective action; and the ability to obtain approvals from other agencies.

Cost

The cost estimates presented in this report are typically in the +50 percent to -30 percent accuracy range. The estimates are based on a variety of information, including estimates from technology vendors, generic unit costs, conventional cost estimating guides, prior

experience, and information from other sites. The estimates have been prepared for guidance in the alternative evaluation from the information available at the time of the estimate. The actual costs of the project would depend on the negotiated labor and material costs, actual site conditions, final project scope, the implementation schedule, competitive market conditions, and other variable factors.

Capital and operation maintenance (O&M) costs are estimated for each alternative and used to calculate present net worth. Capital costs include the direct and indirect expenditures required to implement a corrective action. Direct costs include construction costs or expenditures for equipment, labor, and materials required to implement a corrective action. Indirect costs include those associated with engineering services, permitting, legal services, construction services, and other services necessary to carry out a corrective action.

Annual O&M costs include operation labor, maintenance materials, maintenance labor, energy, and other costs needed for continued post-construction operation and maintenance. For purposes of comparing the long-term corrective actions, typically 30 years of operation, maintenance and monitoring were utilized in the present net worth calculations at a five percent discount rate.

4.2 INDIVIDUAL ANALYSIS OF ALTERNATIVES FOR SOIL CONTAMINATED WITH TOXAPHENE AND DINOSEB

Alternative A-2; Removal Action with Containing Soil Cap

This alternative involves consolidation of contaminated soil not meeting Corrective Action Objectives into one soil pile. The soil pile would be covered with a soil cap consisting of six inches of clay and six inches of topsoil. The soil pile, which is depicted on Figure 3-1, would be constructed immediately to the southwest of the atrazine warehouse. The footprint of the soil pile is 650 feet by 75 feet by 15 feet high. Sides would be sloped 2:1. grass would be grown on the soil pile. The location would be graded such that rainwater runoff would flow to the east. Silt fences would be placed in erosional pathways. A portion of the south plant drainage ditch would be re-routed. Access to the soil pile would be restricted.

Overall Protection of Human Health and the Environment

Alternative A-2 is somewhat protective of human health and the environment. The average concentration of toxaphene is 23,610 ppb and the average concentration of dinoseb is 88,445 ppb. The pathways of exposure to toxaphene are closed. Movement by erosion is controlled and leaching by rainwater is controlled. Even though the dinoseb concentration is below the MDEQ Tier I TRG Table value of 204,000 ppb, the dinoseb can be leached out.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations. Since the South Plant Drainage Ditch drains into Hennessey's Bayou, some Corps of Engineers permitting may be required. A meeting would be held with the Vicksburg Corps of Engineers to review appropriate maps and drawings and a decision will be requested as to their jurisdictional interest. If they have interest, a permit would be obtained.

Since the waste pile is a permanent repository, restrictions on land use would have to be placed on the deed of the property.

Performance

This alternative offers protection for the spread of toxaphene and dinoseb contamination. It would be a permanent repository. Additional monitor wells would have to be placed around the pile. The vegetation on the cap would have to be established and maintained by mowing and filling in any erosional areas.

Reliability

Slow release of dinoseb plus naturally occurring biodegradation in the vadose zone and within the waste pile itself will in time reduce the toxicity and volume of that contaminant.

The mobility of the toxaphene contaminant will be significantly reduced by consolidating contaminated soil in one waste pile and containing it by covering it with clean soil and vegetation.

Safety

This alternative can be constructed in a span of two months. One month is required for site preparation and one month for completion of the waste pile. It is during the completion of the waste pile that care will have to be taken to prevent dusting and airborne transport of the toxaphene. There is a potential for exposure to plant workers in the south plant of VCC. There is very little chance that the dust could move off site. Dusting will be prevented by wetting the soil.

Implementability

This alternative would be implemented by first rerouting a portion of the South Plant Drainage Ditch. A section approximately 300 feet long would have to be excavated. The excavated soil would be placed in the existing ditch to help form a base for the soil pile. Then the relatively uncontaminated adjacent soil piles would be used to form a 700 foot by 90 foot by 0.5 foot base. The base and surrounding area would be sloped such that rainwater runoff would be diverted to the east. Drainage ditches and swales would be provided as necessary.

The first step is to move the adjacent contaminated soil piles atop the base. Next the soil piles atop the former toxaphene and dinoseb manufacturing areas would be moved to the engineered soil pile. Then the shallow surface soil would be excavated and moved to the new soil pile location. Approximately 5,400 cubic yards of clean fill would be placed in the excavations.

A soil cap would be constructed atop the soil pile. Approximately 1,400 cubic yards of clay would be placed and compacted to provide a six-inch clay cap. Then six inches of top soil would be established with 1,100 cubic yards of fill material.

As the soil pile is constructed, large chunks of concrete are removed and set aside to be used to cover the bottom slopes of the soil pile as a rip rap for erosion control.

Four monitor wells would be installed, one upflow and three downflow.

Cost

The capital cost of this alternative is $227,000. Details are presented in Table 4-1. The Present Value of the operating and maintenance costs for 30 years is $48,600. Details are presented in Table 4-2.

TABLE 4-1

CAPITAL COST ESTIMATE FOR ALTERNATIVE A-2 REMOVAL ACTION WITH CONTAINING SOIL CAP

• Mobilization	$5,000
• Clear and Grub 300' x 100' area for rerouting drainage ditch; (3,300 yd^2 @ $1.50/$yd^2$)	$4,950
• Excavate 300' x 10' x 5' new drainage ditch. Use soil excavated to fill old ditch; (560 yd^3 @ $2.50/$yd^3$)	$1,400
• Prepare 700' x 90' x 0.5' base of soil pile by using uncontaminated sections 20-GG, 20-HH, 20-JJ and 20-KK of existing piles; (1,200 yd^3 @ $1.50/$yd^3$)	$1,800
• Grade such that rainwater runoff will flow to the east (1,200 yd^3 @ $1.00/$yd^3$)	$1,200
• Move contaminated soil pile sections 20-II, 20-CC and 20-MM to soil pile; (1,000 yd^3 @ $1.50/$yd^3$)	$1,500
• Move contaminated soil pile sections 20-AA, 20-BB, 20-CC, 20-DD, 20-EE and 20-FF to soil pile by excavating, trucking, dumping and bulldozing; (1,800 yd^3 @ $3.50/$yd^3$)	$6,300
• Excavate contaminated soil areas surrounding former dinoseb and toxaphene manufacturing areas of SWMU 20 to 1.5 feet. Move by truck to soil pile, dump and bulldoze; (5,500 yd^3 @ $6.00/$yd^3$)	$33,000
• Separate all construction debris and utilize as rip rap on slopes of pile	$10,000
• Excavate fill material from Vicksburg site, truck to railroad area and use as compacted fill; (5,500 yd^3 @ $8.00/$yd^3$)	$44,000
• Excavate fill material from Vicksburg Site, truck to soil pile and use as soil cap; (1,400 yd^3 @ $8.00/$yd^3$)	$11,200
• Excavate top soil from Vicksburg Site, truck to soil pile and place atop cap to establish vegetation; (1,100 yd^3 @ $8.00/$yd^3$)	$8,800
• Establish vegetation; (6,400 yd^2 @ $1.00/$yd^2$)	$6,400
• Install four monitor wells	$10,000
• Engineering and construction management services @ 20%	$29,100
• Contingency @ 30%	$52,400
Total	**$227,000**

TABLE 4-2 PRESENT VALUE OF OPERATING AND MAINTENANCE COSTS OF ALTERNATIVE A-2 FOR THIRTY YEARS	
• Sample wells semi-annually	$2,000
• Analyze four samples for toxaphene and dinoseb semi-annually	$2,000
• Inspect the soil cap monthly	$1,200
• Mow the grass 20 times	$2,000
• Annual cost	$7,000
Present Value @ 30 Years and 5% Interest = 7,000 (30)(0.2314)	**$48,600**

Alternative A-3; Removal Action with Containing Geosynthethic Liner and Soil Cap

This alternative involves consolidation of contaminated soil not meeting Corrective Action Objectives into one soil pile. The soil pile would be covered with a soil cap consisting of six inches of clay. Then a geosynthetic liner with composite drainage layer would be installed. Then six inches of topsoil would be added. The soil pile, which is depicted on Figure 3-1, would be constructed immediately to the southwest of the atrazine warehouse. The footprint of the soil pile is 650 feet by 75 feet by 15 feet high. Sides would be sloped 2:1. Grass would be grown on the soil pile. The location would be graded such that rainwater runoff would flow to the east. Silt fences would be placed in erosional pathways. A portion of the south plant drainage ditch would be rerouted. Access to the soil pile would be restricted.

Overall Protection of Human Health and the Environment

Alternative A-3 is protective of human health and the environment. The average concentration of toxaphene is 23,610 ppb and the average concentration of dinoseb is 88,445 ppb. The pathways of exposure to toxaphene are closed. Movement by erosion is controlled and leaching by rainwater is controlled. Even though the dinoseb concentration is below the MDEQ Tier I TRG Table value of 204,000 ppb, the dinoseb has potential to be leached out. The addition of the geosynthetic liner effectively seals off that potential.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations. Since the South Plant Drainage Ditch drains into Hennessey's Bayou, some Corps of Engineers permitting may be required. A meeting would be held with the Vicksburg Corps of Engineers to review appropriate maps and drawings and a decision will be requested as to their jurisdictional interest. If they have interest, a permit would be obtained.

Since the waste pile is a permanent repository, restrictions on land use would have to be placed on the deed of the property.

Performance

This alternative offers protection for the spread of toxaphene and dinoseb contamination. It would be a permanent repository. Additional monitor wells would have to be placed around the pile. The vegetation on the cap would have to be established and maintained by mowing and filling in any erosional areas.

Reliability

Slow release of dinoseb, if there is any release, plus naturally occurring biodegradation in the vadose zone and within the waste pile itself will in time reduce the toxicity and volume of that contaminant.

The mobility of the toxaphene contaminant will be significantly eliminated by consolidating contaminated soil in one waste pile and containing it by covering it with clay, a geosynthetic cap, clean soil and vegetation.

Safety

This alternative can be constructed in a span of three months. One month is required for site preparation and two months for completion of the waste pile. It is during the completion of the waste pile that care will have to be taken to prevent dusting and airborne transport of the toxaphene. There is a potential for exposure to plant workers in the south plant of VCC.

There is very little chance that the dust could move off site. Dusting will be prevented by wetting the soil.

Implementability

This alternative would be implemented by first rerouting a portion of the South Plant Drainage Ditch. A section approximately 300 feet long would have to be excavated. The excavated soil would be placed in the existing ditch to help form a base for the soil pile. Then the relatively uncontaminated adjacent soil piles would be used to form a 700 foot by 90 foot by 0.5 foot base. The base and surrounding area would be sloped such that rainwater runoff would be diverted to the east. Drainage ditches and swales would be provided as necessary.

The first step is to move the adjacent contaminated oil piles atop the base. Next the soil piles atop the former toxaphene and dinoseb manufacturing areas would be moved to the engineered soil pile. Then the shallow surface soil would be excavated and moved to the new soil pile location. Approximately 5,400 cubic yards of clean fill would be placed in the excavations.

A soil cap would be constructed atop the soil pile. Approximately 1,400 cubic yards of clay would be placed and compacted to provide a six-inch clay cap. Next a geosynthetic liner and drainage layer would be placed. Then six inches of top soil would be established with 1,100 cubic yards of fill material.

As the soil pile is constructed, large chunks of concrete are removed and set aside to be used to cover the bottom slopes of the soil pile as a rip rap for erosion control.

Four monitor wells would be installed, one upflow and three downflow.

Cost

The capital cost of this alternative is $370,900. Details are presented in Table 4-3. The Present Value of the operating and maintenance costs for 30 years is $48,600. Details are presented in Table 4-4.

TABLE 4-3 COST ESTIMATE FOR ALTERNATIVE A-3 REMOVAL ACTION WITH CONTAINING GEOSYNTHETIC LINER AND SOIL CAP	
• Mobilization	$5,000
• Clear and Grub 300' x 100' area for rerouting drainage ditch; (2,300 yd^2 @ $1.50/$yd^2$)	$4,950
• Excavate 300' x 10' x 5' new drainage ditch. Use soil excavated to fill old ditch; (560 yd^3 @ $2.50/$yd^3$)	$1,400
• Prepare 700' x 90' x 0.5' base of soil pile by using uncontaminated sections 20-GG, 20-HH, 20-JJ and 20-KK of existing piles; (1,200 yd^3 @ $1.50/$yd^3$)	$1,800
• Grade such that rainwater runoff will flow to the east (120 yd^3 @ $1.00/$yd^3$)	$1,200
• Move contaminated soil pile sections 20-II, 20-CC and 20-MM to soil pile; (1,000 yd^3 @ $1.50/$yd^3$)	$1,500
• Move contaminated soil pile sections 20-AA, 20-BB, 20-CC, 20-DD, 20-EE and 20-FF to soil pile by excavating, trucking, dumping and bulldozing; (1,800 yd^3 @ $3.50/$yd^3$)	$6,300
• Excavate contaminated soil areas surrounding former dinoseb and toxaphene manufacturing areas of SWMU 20 to 1.5 feet. Move by truck to soil pile, dump and bulldoze; (5,500 yd^3 @ $6.00/$yd^3$)	$33,000
• Separate all construction debris for utilization as rip rap on slope of pile after cap is constructed.	$10,000
• Excavate fill material from Vicksburg Site, truck to railroad area and use as compacted fill; (5,500 yd^3 @ $8.00/$yd^3$)	$44,000
• Install 60 mil HDPE liner with composite geonet drainage layer; (57,600 ft^2 @ $1.60/$ft^2$)	92,200
• Excavate fill material from Vicksburg Site, truck to soil pile and use as soil cap; (1,400 yd^3 @ $8.00/$yd^3$)	$11,200
• Excavate top soil from Vicksburg Site, truck to soil pile and place atop cap to establish vegetation; (1,100 yd^2 @ $8.00/$yd^3$)	$8,800
• Establish vegetation; (6,400 yd^2 @ $1.00/$yd^3$)	$6,400
• Install four monitor wells	$10,000
• Engineering and construction management services @ 20%	$47,550
• Contingency @ 30%	$85,600
Total	**$370,900**

TABLE 4-4 PRESENT VALUE OF OPERATING AND MAINTENANCE COSTS OF ALTERNATIVE A-3 FOR THIRTY YEARS	
• Sample wells semi-annually	$2,000
• Analyze four samples for toxaphene and dinoseb semi-annually	$2,000
• Inspect the soil cap monthly	$1,200
• Mow the grass 20 times	$2,000
• Annual cost	$7,000
Present Value @ 30 Years and 5% Interest = 7,000 (30)(0.2314)	**$48,600**

Alternative A-4; Removal Action with Complete Geosynthetic Liner and Soil Cap

This alternative involves consolidation of contaminated soil not meeting Corrective Action Objectives into one soil pile. The soil pile would be covered with a soil cap consisting of six inches of clay and a complete geosynthetic liner system with composite drainage layer would be installed to surround the pile. Six inches of topsoil would be added. The soil pile, which is depicted on Figure 3-1, would be constructed immediately to the southwest of the atrazine warehouse. The footprint of the soil pile is 650 feet by 75 feet by 15 feet high. Sides would be sloped 2:1. Grass would be grown n the soil pile. The location would be graded such that rainwater runoff would flow to the east. Silt fences would be placed in erosional pathways. A portion of the south plant drainage ditch would be re-routed. Access to the soil pile would be restricted.

Overall Protection of Human Health and the Environment

Alternative A-4 is protective of human health and the environment. The average concentration of toxaphene is 23,610 ppb and the average concentration of dinoseb is 88,445 ppb. The pathways of exposure to toxaphene are closed. Movement by erosion is controlled and leaching by rainwater is controlled. Even though the dinoseb concentration is below the MDEQ Tier I TRG Table value of 204,000 ppb, the dinoseb can be leached out. The addition of the complete geosynthetic liner system on the bottom, sides, and top seals off that potential.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations. Since the South Plant Drainage Ditch drains into Hennessey's Bayou, some Corps of Engineers permitting may be required. A meeting would be held with the Vicksburg Corps of Engineers to review appropriate maps and drawings and a decision will be requested as to their jurisdictional interest. If they have interest, a permit would be obtained.

Since the waste pile is a permanent repository, restrictions on land use would have to be placed on the deed of the property.

Performance

This alternative offers protection for the spread of toxaphene and dinoseb contamination. It would be a permanent repository. Additional monitor wells would have to be placed around the pile. The vegetation on the cap would have to be established and maintained by mowing and filling in any erosional areas.

Reliability

Slow dinoseb biodegradation within the waste pile itself will in time reduce the toxicity and volume of that contaminant.

The mobility of the toxaphene contaminant will be reduced by consolidating contaminated soil in one waste pile and containing it by enclosing it with clay, geosynthetic systems, and clean soil and vegetation.

Safety

This alternative can be constructed in a span of three months. One month is required for site preparation and two months for completion of the waste pile. It is during the completion of the waste pile that care will have to be taken to prevent dusting and airborne transport of the toxaphene. There is a potential for exposure to plant workers in the south plant of VCC.

There is very little chance that the dust could move off site. Dusting will be prevented by wetting the soil.

Implementability

This alternative would be implemented by first rerouting a portion of the South Plant Drainage Ditch. A section approximately 300 feet long would have to be excavated. The excavated soil would be placed in the existing ditch to help form a base for the soil pile. Then the relatively uncontaminated adjacent soil piles would be used to form a 700 foot by 90 foot by 0.5 foot base. The base and surrounding area would be sloped such that rainwater runoff would be diverted to the east. Drainage ditches and swales would be provided as necessary. A geosynthetic liner, drainage system, and clean fill would be placed as the bottom protection.

The next step is to move the adjacent contaminated oil piles atop the base. Next the soil piles atop the former toxaphene and dinoseb manufacturing areas would be moved to the engineered soil pile. Then the shallow surface soil would be excavated and moved to the new soil pile location. Approximately 5,400 cubic yards of clean fill would be placed in the excavations.

A soil cap would be constructed atop the soil pile. Approximately 1,400 cubic yards of clay would be placed and compacted to provide a six-inch clay cap. Next, a geosynthetic liner and drainage layer would be placed. Then six inches of top soil would be established with 1,100 cubic yards of fill material.

As the soil pile is constructed, large chunks of concrete are removed and set aside to be used to cover the bottom slopes of the soil pile as a rip rap for erosion control.

Four monitor wells would be installed, one upflow and three downflow.

Cost

The capital cost of this alternative is $397,700. Details are presented in Table 4-1. The Present Value of the operating and maintenance costs for 30 years is $48,600. Details are presented in Table 4-6.

TABLE 4-5

COST ESTIMATE FOR ALTERNATIVE A-4
REMOVAL ACTION WITH CONTAINING GEOSYNTHETIC LINER
ON BOTTOM AND TOP AND SOIL CAP

• Mobilization	$5,000
• Clear and Grub 300' x 100' area for rerouting drainage ditch; (2,300 yd^2 @ $1.50/$yd^2$)	$4,950
• Excavate 300' x 10' x 5' new drainage ditch. Use soil excavated to fill old ditch; (560 yd^3 @ $2.50/$yd^3$)	$1,400
• Prepare 700' x 90' x 0.5' base of soil pile by using uncontaminated sections 20-GG, 20-HH, 20-JJ and 20-KK of existing piles; (1,200 yd^3 @ $1.50/$yd^3$)	$1,800
• Grade such that rainwater runoff will flow to the east (1,200 yd^3 @ $1.00/$yd^3$)	$1,200
• Move contaminated soil pile sections 20-II, 20-CC and 20-MM to soil pile; (1,000 yd^3 @ $1.50/$yd^3$)	$1,500
• Move contaminated soil pile sections 20-AA, 20-BB, 20-CC, 20-DD, 20-EE and 20-FF to soil pile by excavating, trucking, dumping and bulldozing; (1,800 yd^3 @ $3.50/$yd^3$)	$6,300
• Excavate contaminated soil areas surrounding former dinoseb and toxaphene manufacturing areas of SWMU 20 to 1.5 feet. Move by truck to soil pile, dump and bulldoze; (5,500 yd^3 @ $6.00/$yd^3$)	$33,000
• Separate all construction debris for utilization as rip rap on slope of pile after cap is constructed	$10,000
• Excavate fill material from Vicksburg Site, truck to railroad area and use as compacted fill; (5,500 yd^3 @ $8.00/$yd^3$)	$44,000
• Install 60 mil HDPE liner with composite geonet drainage layer on bottom and top; (68,400 ft^2 @ $1.60/$ft^2$)	109,400
• Excavate fill material from Vicksburg Site, truck to soil pile and use as soil cap; (1,400 yd^3 @ $8.00/$yd^3$)	$11,200
• Excavate top soil from Vicksburg Site, truck to soil pile and place atop cap to establish vegetation; (1,100 yd^2 @ $8.00/$yd^3$)	$8,800
• Establish vegetation; (6,400 yd^2 @ $1.00/$yd^3$)	$6,400
• Install four monitor wells	$10,000
• Engineering and construction management services @ 20%	$50,990
• Contingency @ 30%	$91,780
Total	**$397,700**

TABLE 4-6 PRESENT VALUE OF OPERATING AND MAINTENANCE COSTS OF ALTERNATIVE A-4 FOR THIRTY YEARS	
• Sample wells semi-annually	$2,000
• Analyze four samples for toxaphene and dinoseb semi-annually	$2,000
• Inspect the soil cap monthly	$1,200
• Mow the grass 20 times	$2,000
• Annual cost	$7,000
Present Value @ 30 Years and 5% Interest = 7,000 (30)(0.2314)	**$48,600**

Alternative A-5; In-Situ Treatment by Composting Plus Iron Addition

This alternative consists of in-situ biodegradation. The contaminated soil exists in portions of the railroad area (SWMU 20) and in soil piles. With this alternative, biodegradation would be initiated by composting within the contaminated railroad areas. Contamination exists only to a depth of about 18 inches in the railroad area. When the contamination has met Corrective Action Objectives, then the same area will continue to be used as composting beds. The soil piles will be mixed with compost and placed atop the composting beds.

Overall Protection of Human Health and the Environment

Alternative A-5 is protective of human health and the environment. The concentration of toxaphene in the soil would be reduced until Corrective Action Objectives are met. The average concentration of dinoseb in the soil already meets Corrective Action Objectives. The long-term protection with this alternative is, therefore, excellent. In the short-term, during project execution, care will have to be taken to inhibit erosion, dusting, and leaching.

Silt fences will have to be installed to control erosion potential. The compost piles will have to be maintained in a moist condition to prevent dusting. During rainstorms there will be some leaching of dinoseb into rainwater runoff. Rainwater at the site is captured and pumped to the water impoundments. Water in the impoundments is pumped through activated carbon columns prior to discharges, under an NPDES permit, to the Mississippi River.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations. There is an existing Corrective Action Management Unit (CAMU) permit that allows for treatment by composting.

Performance

This alternative offers protection for the spread of toxaphene and dinoseb contamination by eliminating it. The solution would be permanent.

Reliability

The composting technology employed has been demonstrated in the literature and by VCC experience. It will be enhanced by the addition of zero valent iron and sodium lactate. Ultimately this alternative is very reliable in that toxaphene and dinoseb will be destroyed. The element of time is the potential "Achilles heel" of this alternative. Working through all the soil will take approximately three years.

During the three year time period diligent care will be have to be taken with regard to operation of the composting beds and short-term environmental concerns. The beds will have to be disced three times a week during aerobic cycles. During anaerobic cycles a tarpaulin will have to be placed and kept atop the composting beds. Silt fences will have to be maintained in place and drainage will have to be monitored.

Safety

This alternative will require three years to execute. During the entire three year period care will have to be taken to prevent dusting and airborne transport of the toxaphene. There is a potential for exposure to plant workers in the south plant of VCC. There is very little chance that the dust could move off site. Dusting will be prevented by monitoring and maintaining the moisture content of soil.

Implementability

There are no difficult operations associated with this alternative. What can, however, prove to be difficult is the element of time. Diligent effort to operate the composting beds will have to be made over a three year period.

The field verification testing will take place on grid location 20-F on Figure 3-2. The soil tested will be mixed 1:1 with soil from soil pile location 20-FF. The composite analysis of location 20-F is 1,078,018 ppb dinoseb and 10,318 ppb toxaphene. The composite analysis of location 20-FF is 130,675 ppb dinoseb and 76,683 ppb toxaphene. The 1:1 mixture will then be about 600,000 ppb dinoseb and 44,000 ppb toxaphene.

In order to implement the field test, four plots of soil, each 8 feet by 100 feet, are rototilled thoroughly to six inches on location 20-F. To each plot 15 cubic yards of soil (six-inch lift) from location 20-FF are spread as evenly as possible. Each of the plots is then rototilled thoroughly to a depth of 12 inches.

Once the soil from both sources is thoroughly mixed, the compost is added. The compost will consist of gin trash, 5% chicken manure, 5% fertilizer, and iron. A 6% solution of sodium lactate would be added. The ratio of soil to compost and the optimum operating conditions are obtained from the laboratory experimental results attached as Appendix A.

The full scale operation would be operated similarly to the pilot field test. There are 12 surface area grids (100' by 100') that require corrective action. In each of the grid areas soil would be rototilled to 18 inches deep in four beds 10 feet by 100 feet. Premixed compost would be added in an amount determined by optimization studies presented in Appendix A. The soil would be biodegraded to Corrective Action Objectives. The first episode will have treated 2,500 cubic yards. The second episode would commence by removing the treated soil and compost to 18 inches then adding new compost and 1,500 cubic yards of soil requiring treatment. Up to four more iterations of the same scenario would be required. The last soil to be treated would be left in place.

Cost

The capital cost of this alternative is $2,268,200. Details are presented in Table 4-7. There are no continuing operating and maintenance costs.

TABLE 4-7 COST ESTIMATE FOR ALTERNATIVE A-5 IN-SITU TREATMENT BY COMPOSTING PLUS IRON ADDITION	
• Mobilization	$5,000
• Excavate in sections the contaminated surface soil areas surrounding former dinoseb and toxaphene manufacturing areas of SWMU 20 to 1.5 feet. Set to one side; (5,500 yd^3 @ $2.00/$yd^3$)	$11,000
• Purchase and prepare 11,000 yd^3 of compost plus iron; (11,000 yd^3 @ $35.00/$yd^3$)	$385,000
• Add compost and previously excavated contaminated soil to excavation space. Mix during addition; (16,500 yd^3 @ $2.00/$yd^3$)	$33,000
• Rototill 48 plots, each plot is 10' x 100'; (10 minutes/plot, 8 hours/day, 3 days/week, 26 weeks, $25.00/hour)	$15,600
• Excavate the plots to ground level only and truck to area needing fill; (11,000 yd^3 @ $4.00/$yd^3$)	$44,000
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and 2,500 yd^3 contaminated soil from soil piles. Mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill 48 plots, each plot is 10' x 100'; (10 minutes/plot, 8 hours/day, 3 days/week, 26 weeks, $25.00/hour)	$15,600
• Excavate the plots to ground level only and truck to area needing fill; (7,500 yd^3 @ $4.00/$yd^3$)	$30,000
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and second 2,500 yd^3 contaminated soil from soil piles. Mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill 48 plots, each plot is 10' x 100'; (10 minutes/plot, 8 hours/day, 3 days/week, 26 weeks, $25.00/hour)	$15,600
• Excavate the plots to ground level only and truck to area needing fill; (7,500 yd^3 @ $4.00 yd^3)	$30,000
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and third 2,500 yd^3 contaminated soil from soil piles. Mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill 48 plots, each plot is 10' x 100'; (10 minutes/plot, 8 hours/day, 3 days/week, 26 weeks, $25.00/hour)	$15,600
• Excavate the plots to ground level only and truck to area needing fill; (7,500 yd^3 @ $4.00/$yd^3$)	$30,000
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and third 2,500 yd^3 contaminated soil from soil piles. Mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill 48 plots, each plot is 10' x 100'; (10 minutes/plot, 8 hours/day, 3 days/week, 26 weeks, $25.00/hour)	$15,600
• Analysis for toxaphene; (48 plots, 2 analyses/plot, 5 episodes, $100.00/analysis)	$48,000
• Engineering and construction management services @ 20%	$290,800
• Contingency @ 30%	$523,400
Total	**$2,268,200**

Alternative A-6; In-Situ Treatment by Insertion of Fenton's Reagent

This alternative consists of in-situ chemical treatment. The contaminated soil exists in portions of the railroad area (SWMU 20) and in soil piles. With this alternative chemical treatment would be initiated by injecting Fenton's Reagent within the contaminated railroad areas and the soil piles. Contamination exists only to a depth of about 18 inches in the railroad area. Injections would continue until Corrective Action Objectives are met.

Overall Protection of Human Health and the Environment

Alternative A-6 is potentially protective of human health and the environment. The concentration of toxaphene in the soil would be reduced until Corrective Action Objectives are met. The average concentration of dinoseb in the soil already meets Corrective Action Objectives. During project execution, care will have to be taken to inhibit erosion, dusting, and runoff.

Silt fences will have to be installed to control erosion potential. The soil piles will be maintained in a moist condition to promote reaction and to prevent dusting. During rainstorms there will be some leaching of dinoseb into rainwater runoff. Rainwater at the site is captured and pumped to the water impoundments. Water in the impoundments is pumped through activated carbon columns prior to discharge, under an NPDES permit, to the Mississippi River.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations. There is an existing Corrective Action Management Unit (CAMU) permit that allows for treatment. The CAMU permit may have to be amended to specifically note the use of Fenton's Reagent (hydrogen peroxide and ferrous sulfate).

Performance

The effectiveness of Fenton's Reagent on toxaphene has not been established. It can be effective on chlorinated compounds but there is no data on toxaphene.

Reliability

The oxidation technology employed has been demonstrated in the literature. Its effectiveness of toxaphene has not been demonstrated.

The element of time is what is potentially attractive for this alternative. Previous experience (but not on toxaphene) indicates that treatment can be complete at three to six episodes of injections of Fenton's Reagent. The project would, therefore, be completed in a two- to three-month time frame.

Safety

This alternative will only require three months to implement. During that time period, problems of erosion and dusting can be dealt with.

Silt fences will have to be installed to control erosion potential. The compost piles will have to be maintained in a moist condition to prevent dusting. During rainstorms there will be some leaching of dinoseb into rainwater runoff. Rainwater at the site is captured and pumped to the water impoundments. Water in the impoundments is pumped through activated carbon columns prior to discharge, under an NPDES permit, to the Mississippi River.

During implementation of treatment by injection, great care will have to be taken that there is no direct exposure of hydrogen peroxide to anyone. The technicians handling the injection equipment will be properly protected to avoid potential direct exposure to hydrogen peroxide to any skin areas. Others there will be protected by roping off the areas and keeping everyone distant.

Implementability

Trailer-mounted remediation systems that use high-pressure, low-volume jetting systems to jet remediation agents into the subsurface for purposes of remediating contaminated soil or groundwater are recommended. In this alternative high pressure is not needed. The surface soil need only be treated to 18 inches and the soil piles have not been compacted.

Since jetting systems can use high pressure, there is typically no need for pre-drilling, pushing, or installation of temporary or permanent well points at most sites. In many

subsurface soils, jetting to 20 feet bgs can be accomplished in a matter of only a few minutes. After the jetting lance reaches the desired depth, the remediation agents are jetting into the treatment zone via a variety of specially-designed tips that distribute the remediation agents both radially and/or vertically. Sufficient jetting pressure can force the remediation agents outward into the soil or groundwater up to several feet from the point of jetting.

In jetting systems, the remediation agents, such as hydrogen peroxide and catalysts, are delivered to the site and then transferred from the product storage tanks into mixing tanks according to a pre-determined remediation "recipe." A gasoline-powered compressor powers the jetting system which jets the remediation solution into the subsurface soil and/or groundwater under high pressure through a specially designed jetting lance and tip system. The jetting lances come in various lengths, and can be connected in a series for deeper jetting.

The jetting lance is designed to rapidly jet through soils, including clays. The lance is less than one-inch in diameter, with specially designed jetting tips. Jetting ports on the tip allow high pressure (up to 20,000 psi), low volume (up to 20 gpm) jetting of remediation agents into the treatment zone. Depending on the application, tips with up to nine jetting ports can be used to inject remediation agents both vertically (downward) and radially in up to eight compass directions, effecting uniform distribution of remediation agents throughout the treatment zone. As the jetting lance jets downward from the top of the treatment zone to the terminal depth of the treatment zone, remediation agents are jetted laterally, thereby treating a cylindrically-shaped area. Typical radius of influence is on the order of two to ten feet, depending on the subsurface stratigraphy, jetting pressure, jetting volume, residence time, and other factors. Tightly-spaced and overlapping treatment "cylinders" result in effective remediation of the treatment zone with minimal "cold spots." Multiple treatment cycles are frequently used to effect remediation.

In the case of using Fenton's Reagent, jetting occurs in two steps. The first step involves the jetting of the ferrous sulfate catalyst, and if necessary, surfactant. At many sites, the surfactant solution will help increase the porosity of the treatment zone and help loosen any adsorbed contaminant within the soil or groundwater matrix. The second step involves the jetting of hydrogen peroxide through the same jetting holes into the treatment zone.

Cost

The capital cost of this alternative is $462,300. Details are presented on Table 4-8. There are no continuing operating and maintenance costs.

TABLE 4-8

COST ESTIMATE FOR ALTERNATIVE A-6
IN-SITU TREATMENT BY INJECTION OF FENTON'S REAGENT

• Mobilization of injection equipment; ($2,500.00/injection event)	$7,500
• High pressure jetting equipment; ($1,500.00/day, 5 days/event, 6 events)	$45,000
• Labor – field supervisor and 3 field technicians; ($1,750.00/day, 5 days/event, 6 events)	$52,500
• Labor – per diem and vehicle; ($450.00/day, 5 days/event, 6 events)	$13,500
• Personal protective equipment and expendable job materials	$6,800
• Inoculant costs; (4,500 gallons Ferrous Sulfate @ $6.00/gallon, 36,000 gallons hydrogen peroxide @ $4.00 gallon)	$171,000
• Engineering @ 20%	$59,300
• Contingency @ 30%	$106,700
Total	**$462,300**

Alternative A-7; Ex-Situ Treatment by Composting Plus Iron Addition

This alternative consists of ex-situ biodegradation. The contaminated soil exists in portions of the railroad area (SWMU 20) and in soil piles. With this alternative the soil would be moved to a separate location where biotreatment cells are established.

Overall Protection of Human Health and the Environment

Alternative A-7 is protective of human health and the environment. The concentration of toxaphene in the soil would be reduced until Corrective Action Objectives are met. The average concentration of dinoseb in the soil already meets Corrective Action Objectives. The long-term protection with this alternative is, therefore, excellent. In the short-term, during project execution, care will have to be taken to inhibit erosion, dusting, and leaching.

Silt fences will have to be installed to control erosion potential. The compost piles will have to be maintained in a moist condition to prevent dusting. During rainstorms there will be

some leaching of dinoseb into rainwater runoff. Rainwater at the site is captured and pumped to the water impoundments. Water in the impoundments is pumped through activated carbon columns prior to discharge, under an NPDES permit, to the Mississippi River.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations. There is an existing Corrective Action Management Unit (CAMU) permit that allows for treatment by composting.

Performance

This alternative offers protection for the spread of toxaphene and dinoseb contamination by eliminating it. The solution will be permanent.

Reliability

The composting technology employed has been demonstrated in the literature and by VCC experience. It will be enhanced by the addition of zero valent iron and sodium lactate. Ultimately this alternative is very reliable in that toxaphene and dinoseb will be destroyed. The element of time is the potential "Achilles heel" of this alternative. Working through all the soil will take approximately three years.

During the three year time period diligent care will be have to be taken with regard to operation of the composting beds and short-term environmental concerns. The beds will have to be disced three times a week during aerobic cycles. During anaerobic cycles a tarpaulin will have to be placed and kept atop the composting beds. Silt fences will have to be maintained in place and drainage will have to be monitored.

Safety

This alternative will require three years to execute. During the entire three year period care will have to be taken to prevent dusting and airborne transport of the toxaphene. There is a potential for exposure to plant workers in the south plant of VCC. There is very little chance that the dust could move off site. Dusting will be prevented by monitoring and maintaining the moisture content of soil.

Implementability

There are no difficult operations associated with this alternative. What can, however, prove to be difficult is the element of time. Diligent effort to operate the composting beds will have to be made over a three year period.

The field verification testing will take place on grid location 20-F on Figure 3-2. The soil tested will be mixed 1:1 with soil from soil pile location 20-FF. The composite analysis of location 20-F is 1,078,018 ppb dinoseb and 10,318 ppb toxaphene. The composite analysis of location 20-FF is 130,675 ppb dinoseb and 76,683 ppb toxaphene. The 1:1 mixture will then be about 600,000 ppb dinoseb and 44,000 ppb toxaphene.

In order to implement the field test, four plots of soil, each 8 feet by 100 feet, are rototilled thoroughly to six inches on location 20-F. To each plot 15 cubic yards of soil (six-inch lift) from location 20-FF are spread as evenly as possible. Each of the plots is then rototilled thoroughly to a depth of 12 inches.

Once the soil from both sources is thoroughly mixed, the compost is added. The compost will consist of gin trash, 5% chicken manure, 5% fertilizer, and iron. A 6% solution of sodium lactate would be added. The ratio of soil to compost and the optimum operating conditions are obtained from the laboratory experimental results attached as Appendix A.

The full scale operation would be set up by utilizing the bermed area atop the "Hill Area" of SWMU 2. The bermed area is depicted on Figure 3-3. The bottom surface area of the bermed area is 58,500 square feet. The entire quantity of soil not meeting Corrective Action Objectives could fit within the berms, if piled to a depth of 6.9 feet; however, the preferred method of treatment will be to treat soil in lifts of 18 inches. There will be five separate episodes of treatment. The first episode will begin by adding compost spread evenly into the bermed area. A lift of 18 inches of soil would be added and mixed thoroughly by rototilling with the compost. After degradation to Corrective Action Objectives, additional compost and another lift of contaminated soil would be added and rototilled. The same scenario would be carried out for a total of four to five iterations. When the last lift has degraded, the soil would be smoothed out and grassing vegetation would be established.

Cost

The capital cost of this alternative is $2,010,800. Details are presented in Table 4-8. There are no continuing operating and maintenance costs.

TABLE 4-9

COST ESTIMATE FOR ALTERNATIVE A-7
EX-SITU TREATMENT BY COMPOSTING PLUS IRON ADDITION

• Mobilization	$5,000
• Purchase and prepare 11,000 yd^3 of compost plus iron; (11,000 yd^3 @ $35.00/$yd^3$)	$385,000
• Add compost to bermed area atop the "Hill Area" of SWMU 2; (11,000 yd^3 @ $2.00/$yd^3$)	$22,000
• Excavate the contaminated surface: soil areas surrounding former dinoseb and toxaphene manufacturing areas of SWMU 20 to 1.5 feet. Truck to bermed area, mix with compost; (5,500 yd^3 @ $6.00/$yd^3$)	$33,000
• Excavate fill from Vicksburg Site, truck to railroad area and use as compacted fill (5,500 yd^3; @ $8.00/$yd^3$)	$44,000
• Rototill, 58,000 ft^2; (4 hours, 3 days/week, 26 weeks, $25.00/hour)	$7,800
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and 2,500 yd^3 contaminated soil from soil piles, mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill, 58,000 ft^2; (4 hours, 3 days/week, 26 weeks, $25.00/hour)	$7,800
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and second 2,500 yd^3 of contaminated soil from soil piles; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill, 58,000 ft^2; (4 hours, 3 days/week, 26 weeks, $25.00/hour)	$7,800
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and third 2,500 yd^3 of contaminated soil from soil piles. Mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill, 58,000 ft^2; (4 hours, 3 days/week, 26 weeks, $25.00/hour)	$7,800
• Purchase and prepare 5,000 yd^3 of compost plus iron; (5,000 yd^3 @ $35.00/$yd^3$)	$175,000
• Add compost and fourth 2,500 yd^3 of contaminated soil from soil piles. Mix during addition; (7,500 yd^3 @ $2.00/$yd^3$)	$15,000
• Rototill, 58,000 ft^2; (4 hours, 3 days/week, 26 weeks, $25.00/hour)	$7,800
• Analyses for toxaphene (1 plot, 2 analyses/plot, 5 episodes, $100.00/analysis)	$1,000
• Engineering and Construction Management Services @ 20%q	$257,800
• Contingency @ 30%	$464,040
Total	**$2,010,800**

Alternative A-8; Off-Site Disposal in Landfill

This alternative involves movement of soil piles and surface soil to an off-site commercial landfill in Mississippi as a non-hazardous waste. The soil meets TCLP requirements as is, and is, therefore, not hazardous by characteristic. The specific source of contamination remains unknown. Although there can be speculation on the source or sources, there is no documentary evidence or incidence reports. The soil does contain hazardous constituents but may not be a listed hazardous waste. That decision, under this alternative, is left up to the USEPA and MSDEQ.

Overall Protection of Human Health and the Environment

Alternative A-8 is protective of human health and the environment. If this alternative is acceptable and could be implemented, it is protective of human health and the environment. Toxaphene is tightly bound to the soil. The average concentration of dinoseb in the soil already meets Corrective Action Objectives. The long-term protection with this alternative is, therefore, good. In the short-term, during project execution, care will have to be taken during the truck loading and transportation stage of work. Dusting and spillage are to be avoided.

As the soil is loaded into trucks or "tote bins" to be transported to the commercial landfill it will need to be kept moist to avoid dusting. During transportation the soil must be covered by a tarpaulin or other enclosing device.

Institutional

In order to exercise this alternative the USEPA and MSDEQ would have to make a determination that the contaminated soil is non-hazardous.

Performance

This alternative offers protection for the spread of toxaphene and dinoseb contamination. It would be a permanent repository. The commercial landfill facility would have a monitoring and maintenance program.

Reliability

The slow dinoseb biodegradation within the landfill itself will in time reduce the toxicity and volume of that contaminant. The mobility of the toxaphene contaminant will be substantially eliminated by consolidating the contaminated soil in one landfill as a permanent off-site repository.

Safety

This alternative can be implemented in a span of one month. During the excavation and loading and transportation, care will have to be taken to prevent dusting and airborne transport of the toxaphene. Dusting will be inhibited by wetting the soil during excavation. During transportation a tarpaulin or other enclosure will be placed atop the soil.

Implementability

This alternative involves excavation, loading, transportation, unloading and placement of soils. Backfilling of excavated shallow soil areas would be involved.

Dusting and spillage of contaminated soil must be avoided. All activities are routine soil handling operations.

Cost

The capital cost of this alternative is $1,216,000. See Table 4-10 for details. There would be no continuing maintenance and operating costs.

TABLE 4-10

COST ESTIMATE FOR ALTERNATIVE A-8
OFF-SITE DISPOSAL AND COMMERCIAL LANDFILL

• Mobilization	$5,000
• Excavate the contaminated surface soil areas surrounding former dinoseb and toxaphene manufacturing areas of SWMU 20 to 1.5 feet. Load onto 40 yd^3 waste bins; (5,500 yd^3 @ $6.00/$yd^3$)	$33,000
• Excavate fill from Vicksburg Site, truck to railroad area and use as compacted fill;	$44,000

TABLE 4-10 COST ESTIMATE FOR ALTERNATIVE A-8 OFF-SITE DISPOSAL AND COMMERCIAL LANDFILL	
($5,500 yd^3$ @ $8.00/yd^3$)	
• Transport contaminated surface soil and soil piles to a commercial waste landfill. Note that the soil must not be considered to be a hazardous waste and the EPA and MSDEQ must agree; (15,500 yd^3 @ $45.00/$yd^3$)	$697,500
• Engineering and Construction Management Services @ 20%	$155,900
• Contingency @ 30%	$280,600
Total	**$1,216,000**

4.3 COMPARATIVE ANALYSIS OF ALTERNATIVES FOR SOIL CONTAMINATED WITH TOXAPHENE AND DINOSEB

The comparative analysis of all the factors noted in Section 4.2 is presented as Table 4-11.

TABLE 4-11

COMPARATIVE ANALYSIS OF ALTERNATIVES FOR SOIL CONTAMINATED WITH TOXAPHENE AND DINOSEB

Alternative	Overall Protection of Human Health & the Environment	Institutional	Performance	Reliability	Safety	Implementability	Cost	Total
A-2 Removal of Soil Cap	3	3	1	2	4	5	5	23
A-3 Removal with Cap of Geosynthetic & Soil	4	3	2	3	4	4	4	24
A-4 Removal with Complete Geosynthetic Liner & Soil Cap	4	3	2	3	4	4	4	24
A-5 In-Situ Treatment by Composting	5	4	5	4	3	3	3	27
A-6 In-Situ Treatment by Injection of Fenton's Reagent	5	3	2	4	4	4	4	26
A-7 Ex-Situ Treatment by Composting	5	4	5	4	3	3	3	27
A-8 Off-Site Disposal in Landfill	4	3	2	3	4	5	3	24

Legend: 5 = Highest Ranking
1 = Lowest Ranking

4.4 INDIVIDUAL ANALYSIS OF CORRECTIVE ACTION ALTERNATIVES FOR GROUNDWATER CONTAMINATED WITH DINOSEB, CHLOROFORM, CARBON TETRACHLORIDE, AND OTHER VOAs

Alternative B-1; No Action; Natural Attenuation Monitoring

This alternative involves no further corrective action. It does require continued monitoring and continued operation of the impoundment drainage trench. The plumes of interest are approximately 600 feet from the nearest point of the creek. There is a drainage layer or drainage trench constructed for dewatering during the lining of the surface impoundments. The drainage trench is located directly between the plumes and nearest point of the creek. It is depicted on Figure 3-4. The drainage trench does capture groundwater. The groundwater is pumped to the body of the surface impoundment and is treated directly by adsorption on carbon prior to discharge to the Mississippi River via an NPDES permit. Therefore, there is ongoing corrective action.

Overall Protection of Human Health and the Environment

This alternative provides for protection of human health and the environment. A portion of the dinoseb and VOA plume will not be picked up by the existing drainage trench; it will flow south toward Hennessey's Bayou. Modeling indicates that VOAs will not reach Hennessey's Bayou but will be retarded and degraded naturally. VCC experience indicates that dinoseb will also biodegrade. Two additional monitor wells will be used to verify natural attenuation assumptions.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations.

Performance

This alternative offers control of the dinoseb and VOA plumes and verification of the natural attenuation mechanism by monitoring. Continued operation of the existing drainage trench is a necessary part of adequate control.

Reliability

The slow biodegradation of dinoseb and VOAs moving toward Hennessey's Bayou will in time reduce the toxicity and volume. Continued operation of the trench drain will also reduce the toxicity and volume of dinoseb and VOAs. The captured groundwater is pumped to the surface impoundments. Water in the surface impoundments is pumped through activated carbon columns prior to discharge to the Mississippi River via an NPDES permit.

Safety

This alternative requires a minimum of corrective action effort. There is inherent safety associated with this alternative.

Implementability

The corrective action through collection of groundwater by the drainage layer will continue. In order to monitor natural attenuation two new permanent monitor wells will be constructed. Locations are provided on Figure 2-2 and Figure 2-3. The proposed locations are difficult to reach with a full-sized drilling rig without major preparatory bulldozer work; therefore, installation of one-inch diameter prepacked wells installed with a geoprobe are proposed.

Cost

The capital cost of this alternative is $15,000. See Table 4-13 for details. The present value of incremental operation and maintenance costs for 30 years is $24,300. See Table 4-13 for details. Continued operation of the drainage trench, surface impoundments, and activated carbon unit is not included since it would continue irrespective of this alternative.

TABLE 4-12

COST ESTIMATE FOR ALTERNATIVE B-1
NO ACTION, NATURAL ATTENUATION MONITORING

• Install two groundwater monitoring wells	$10,000
• Engineering @ 20%	$2,000
• Contingency @ 30%	$3,000
Total	**$15,000**

TABLE 4-13

PRESENT VALUE OF INCREMENTAL OPERATION AND MAINTENANCE COSTS OF ALTERNATIVE B-1 FOR 30 YEARS

• Sample wells semi-annually	$1,500
• Analyze two samples for dinoseb and VOAs semi-annually	$1,500
• Maintain wells	$500
• Annual cost	$3,500
Present Value @ 30 Years and 5% Interest = $3,500(3)(0.2314)	**$24,300**

Alternative B-2; In-Situ Treatment by Injection of Fenton's Reagent

This is an in-situ chemical treatment alternative. Fenton's reagent would be injected directly into the groundwater by high pressure jetting.

Overall Protection of Human Health and the Environment

This alternative provides for overall protection of human health and the environment. The dinoseb and VOAs are chemically destroyed by the free hydroxyl radical. The organic contaminant molecules are transformed to carbon dioxide, water, methane, and chloride salts.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations.

Performance

If sufficient number of injections are made, the dinoseb and VOAs will be destroyed. Another observation to be made is that "cross-communication" must be apparent. Cross-

communication is defined as the physical evidence (i.e., observation) that the jetting of remediation agents at one location is extending sufficiently in a lateral direction in the subsurface so as to intersect the adjacent jetting points.

Reliability

If sufficient injections are made and there is clearly observable overlap or cross-communication, then the treatment should be reliable. The problem associated with this type of system is that there is no way to reliably predict the number of injections or spacing of injections short of a full scale field trial.

Safety

This alternative would be implemented by a minimum of six episodes of injections spanning a probable period of at least three months. The key safety issue is avoidance of skin contact of hydrogen peroxide by technicians performing the injections. The skin contact can be avoided by careful selection of person protective equipment and by using only technicians with previous experience in the injection techniques.

Implementability

In jetting systems, the remediation agents, such as hydrogen peroxide and catalysts, are delivered to the site and then transferred from the product storage tanks into mixing tanks according to a predetermined remediation "recipe." A gasoline-powered compressor powers the jetting system which jets the remediation solution into the subsurface soil and/or groundwater under high pressure through a specially designed jetting lance and tip system. The jetting lances come in various lengths, and can be connected in a series for deeper jetting.

The jetting lance is designed to rapidly jet through subsurface soils, including clays. The lance is less than one inch in diameter, with specially designed jetting tips. Jetting ports on the tip allow high pressure (up to 20,000 psi), low volume (up to 20 gpm) jetting of remediation agents into the treatment zone. Depending on the application, tips with up to nine jetting ports can be used to inject remediation agents both vertically (downward) and radially in up to eight compass directions, effecting uniform distribution of remediation agents throughout the treatment zone.

Jetting to the top of the treatment zone is typically accomplished using fresh water (or remediation agents if the treatment zone is near the surface). Once the top of the treatment zone is encountered, jetting is accomplished with remediation agents. As the jetting lance jets downward from the top of the treatment zone to the terminal depth of the treatment zone, remediation agents are jetted laterally, thereby treating a cylindrically-shaped area. Typical radius of influence is on the order of two to ten feet, depending on the subsurface stratigraphy, jetting pressure, jetting volume, residence time, and other factors. Tightly-spaced and overlapping treatment "cylinders" result in effective remediation of the treatment zone with minimal "cold spots." Multiple treatment cycles are necessary to effect remediation.

In the case of using Fenton's Reagent, jetting occurs in two steps. The first step involves the jetting of the ferrous sulfate catalyst, and if necessary, surfactant. At many sites, the surfactant solution will help increase the porosity of the treatment zone and help loosen any adsorbed contaminant within the soil or groundwater matrix. The second step involves the jetting of hydrogen peroxide through the same jetting holes into the treatment zone.

Cost

The capital cost of this alternative with six treatment cycles is $715,000. Details are provided in Table 4-14. There are no continuing operation and maintenance costs.

TABLE 4-14

COST ESTIMATE FOR ALTERNATIVE B-2
IN-SITU TREATMENT BY INJECTION OF FENTON'S REAGENT

• Mobilization; (six times @ $2,500)	$15,000
• High pressure jetting equipment; (30,000 ft^2 treatment area, $1,500/day, 14 days/event, 6 events, 300 injections/event)	$126,000
• Labor – Field Supervisor and 3 Field Technicians; ($1,750/day, 14 days/event, 6 events)	$147,000
• Labor – per diem and vehicle; ($450/day, 14 days/event, 6 events)	$37,800
• Personal protective equipment and expendable job materials	$6,800
• Inoculant costs; (2,250 gallon ferrous sulfate @ $6.00/gallon, 18,000 gallons hydrogen peroxide @ $4.00/gallon)	$85,500
• Laboratory sampling and analytical costs – Install six prepackaged monitor wells for $20,000. Sample and analyze seven times for dinoseb and VOAs for $20,000	$40,000

• Engineering @ 20%	$91,600
• Contingency @ 30%	$165,000
Total	**$715,000**

Alternative B-3; Ex-Situ Treatment with Fenton's Reagent or Other Oxidation Technologies

This alternative involves capture and recovery of the plume with a trench drain. The recovered groundwater would be pumped to a vessel where it can be oxidized by addition of Fenton's Reagent or other oxidation technologies.

Overall Protection of Human Health and the Environment

This alternative provides for interception of the contaminant plume and chemical destruction of the contaminants prior to discharge to the surface impoundments. Water in the surface impoundments is again treated by pumping through activated carbon columns prior to discharge to the Mississippi River via an NPDES permit.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations.

Performance

This method of capture and treatment of contaminants is superior to in-situ injection of the same oxidation chemicals. The mixing of contaminants and oxidizing chemicals is more rigorous than relying on in-situ injection and mixing as in Alternative B-2. The disadvantage is that the interception of groundwater will take more time than a direct attack on the plume. On the other hand, this alternative would be completed more quickly than Alternative B-1, Natural Attenuation.

Reliability

The capture of groundwater in the trench over the prescribed area is routine and reliable technology. Continuing operation of the system plus the existing impoundment trench must also be assured in order to capture the entire contaminant plume.

The treatment itself can be counted on to be reliable. The oxidation of dinoseb and VOAs by the hydroxyl radical is proven technology. Mixing in an ex-situ reaction can assure good contact between oxidizing chemicals and contaminants.

Safety

This alternative employs well known techniques and can be safely implemented. A key safety concern is the storage, continuous pumping and reaction of hydrogen peroxides and the maintenance of the system.

Implementability

Groundwater recovery trenches have proven to be a highly effective, easy to implement, and cost-efficient method for recovering a wide range of dissolved and LNAPL contaminants from the subsurface. Trenches are particularly applicable in shallow aquifers where water tables are generally less than 15 feet and base of the aquifer is less than 40 feet. Trenches are also easily maintained and operational costs are generally lower than using multiple wells for groundwater recovery.

The recovered groundwater would be continuously pumped to a stirred vessel. Hydrogen peroxide and a solution of ferrous sulfate would be stored in 55-gallon drums. Metering pumps would pump hydrogen peroxide and ferrous sulfate to the stirred vessel. The vessel would continuously overflow to the surface impoundment.

Cost

The capital cost of this alternative is $231,000. Details are provided in Table 4-15. The present worth of operation and maintenance costs over a ten-year period is $389,000. Details are presented in Table 4-16.

TABLE 4-15

COST ESTIMATE FOR ALTERNATIVE B-3
EX-SITU TREATMENT WITH FENTON'S REAGENT OR OTHER OXIDATION TECHNOLOGIES

• Mobilization		$5,000
• Excavation for trench drain; 300' x 15' x 1.5'		$45,000
• Collection pipe; 300'		$6,000
• Collection sump; 15' x 3' diameter		$4,000
• Pump, piping and level control system		$6,000
• Backfill, including drainage sand		$4,000
• Treatment system		
- 100 gallon stainless steel reactor with agitator	$20,000	
- ferrous sulfate metering pump	$3,000	
- hydrogen peroxide metering pump	$3,000	
- foundation, electrical, instruments, piping	$52,000	$78,000
• Engineering @ 20%		$30,000
• Contingency @ 30%		$53,000
Total		**$231,000**

TABLE 4-16

PRESENT VALUE OF
OPERATION AND MAINTENANCE COSTS
OF ALTERNATIVE B-3
FOR 10 YEARS

• Chemical costs required over a ten-year treatment cycle; 4,500 gallons ferrous sulfate @ $6.00/gallon; 36,000 gallons hydrogen peroxide @ $4.00/gallon	$171,000
• Maintenance @ 10% capital each year for 10 years	$231,000
• Operation at 10% capital each year for 10 years	$231,000
Total	$633,000
Present Value @ 10 Years and 5% Interest = $633,000(0.6139)	**$389,000**

Alternative B-5; Ex-Situ Treatment with Carbon Adsorption

This alternative involves capture of the plume with a trench drain and pumping the groundwater to the surface impoundment. Water from the surface impoundment is treated by pumping through columns of activated carbon prior to discharge to the Mississippi River via an NPDES permit.

As previously noted, there is a drainage layer or drainage trench constructed for dewatering during the lining of the surface impoundments. The drainage trench is located directly between the plumes and the nearest point of the creek. It is depicted on Figure 3-4. The drainage trench does capture groundwater. The groundwater is pumped to the body of the surface impoundment and is treated directly by adsorption on carbon prior to discharge to the Mississippi River via an NPDES permit. This ongoing corrective action needs to be continued as part of the overall remedy.

The portion of the plume that flows south towards Hennessey's Bayou will be captured in a trench drain. The trench drain is depicted in Figure 3-5. The captured groundwater will be pumped to the surface impoundment.

Overall Protection of Human Health and the Environment

This alternative provides for interception of the contaminant plume and discharge to the surface impoundments. Water in the surface impoundments is again treated by pumping through activated carbon prior to discharge to the Mississippi River via an NPDES permit.

Institutional

This activity will be carried out under existing permit conditions and in compliance with appropriate regulations.

Performance

This method of capture and pumping to the surface impoundment for treatment by flowing through columns of activated carbon prior to discharge to the Mississippi River via an NPDES permit takes advantage of existing treatment systems and proven technology. A disadvantage is that the interception of groundwater will take time. On the other hand, this alternative would be completed more quickly than Alternative B-1, Natural Attenuation.

Reliability

The capture of groundwater in the trench over the prescribed area is routine and reliable technology. Continuing operation of the system plus the existing impoundment trench must also be assured in order to capture the entire contaminant plume.

The treatment itself can be counted on to be reliable. The wastewater treatment system consists of six vessels of activated carbon. The vessels are hydraulically too large for direct treatment of the groundwater but by pumping to the surface impoundment, it will be adequately treated prior to discharge to the Mississippi River.

Safety

This alternative employs well known techniques and an existing wastewater treatment system. There are no particular safety problems which would cause concern.

Implementability

Groundwater recovery trenches have proven to be a highly effective, easy to implement, and cost-efficient method for recovering a wide range of dissolved and LNAPL contaminants from the subsurface. Trenches are particularly applicable in shallow aquifers where water tables are generally less than 15 feet and the base of the aquifer is less than 40 feet. Trenches are also easily maintained and operational costs are generally lower than using multiple wells for groundwater recovery.

The recovered groundwater would be pumped to the surface impoundment and wastewater treatment system, both of which already exist.

Cost

The capital cost of this alternative is $109,000. Details are provided in Table 4-17. The present worth of operation and maintenance costs over a ten-year period is $156,200. Details are presented in Table 4-18.

TABLE 4-17 COST ESTIMATE FOR ALTERNATIVE B-5 EX-SITU TREATMENT WITH CARBON ADSORPTION	
• Mobilization	$5,000
• Excavation for trench drain; 300' x 15' x 1.5'	$45,000
• Collection pipe; 300'	$6,000
• Collection sump; 15' x 3' diameter	$4,000
• Pump, piping and level control system	$6,000
• Backfill, including drainage sand	$4,000
• Engineering @ 20%	$14,000
• Contingency @ 30%	$25,000
Total	**$109,000**

TABLE 4-18 PRESENT VALUE OF INCREMENTAL OPERATION AND MAINTENANCE COSTS OF ALTERNATIVE B-5 FOR 10 YEARS	
• Carbon consumed over a ten-year period; 10 pounds per day @ $1.00/pound	$36,500
• Maintenance @ 10% capital each year for 10 years	$109,000
• Operation at 10% capital each year for 10 years	$109,000
Total	**$254,500**
Present Value @ 10 Years and 5% Interest = $254,500(0.6139)	**$156,200**

4.5 COMPARATIVE ANALYSIS OF ALTERNATIVES FOR GROUNDWATER CONTAMINATED WITH DINOSEB AND VOAs

The comparative analysis of all the factors noted in Section 4.4 is presented as Table 4-19.

TABLE 4-19

COMPARATIVE ANALYSIS OF ALTERNATIVES FOR GROUNDWATER CONTAMINATED WITH DINOSEB AND VOAs

Alternative	Overall Protection of Human Health & the Environment	Institutional	Performance	Reliability	Safety	Implementability	Cost	Total
B-1 No Action; Natural Attenuation	4	4	3	4	5	5	5	30
B-2 In-Situ Treatment with Fenton's Reagent	4	3	4	4	3	3	3	24
B-3 Ex-Situ Treatment with Fenton's Reagent	5	4	5	4	3	4	3	28
B-5 Ex-Situ Treatment with Carbon Adsorption	5	5	5	5	5	4	4	33

Legend: 5 = Highest Ranking
1 = Lowest Ranking

Groundwater Contaminated with Arsenic

Alternative C-1; In-Situ Treatment with Injection of Precipitating Agents

This alternative involves injection of chemicals directly into the shallow zone of the groundwater aquifer. The objective is to cause precipitation of arsenic and adherence of that arsenic to subsurface media. Injection of a slurry of zero valent iron or injection of Fenton's Reagent (hydrogen peroxide and ferrous sulfate) is intended to achieve that objective. The injection tool is a wand with multiple injection jets at the end. The jets can be modified to accommodate the particular innoculant. Upwards of 20,000 psi can be generated at the jet tips to allow horizontal penetration by jetting fissures in the formation as the wand is moved vertically from 10 feet bgs to 20 feet bgs.

Overall Protection of Human Health and the Environment

This alternative provides for protection of human health and the environment. The chemistry of the process is that the arsenic will precipitate subsurface as ferric-arsenate complex and/or are adsorbed onto an amorphous iron oxyhydroxide. The effectiveness of overall protection

is initially dependent on good contact subsurface during injection and resultant precipitation and/or adherence of the arsenic onto the subsurface media. While in the short term this alternative may work as intended by multiple injections and multiple injection events, there is no projection of effectiveness in the long term as fresh groundwater slowly intrudes into the formation. Arsenic may resolubilize.

Institutional

The activity will be carried out under existing permit conditions and in compliance with appropriate regulations.

Performance

The merit of this alternative is the potential that it will be a "fix" in a short period of time, that is, a few months. As noted previously, long term performance is questionable. There is potential for arsenic to resolubilize into the groundwater stream.

Reliability

The intent of this alternative is to reduce the mobility of arsenic. There is no reduction in volume or toxicity. While the mobility can effectively be reduced in the short term, the reduction may in time be reversible.

Safety

This alternative would be safe to implement. The technicians implementing the injections would be adequately prepared with personal protective equipment such that all contact of hydrogen peroxide with skin is avoided. The technicians would all have previous experience with the injection equipment.

Implementability

Jetting of remediation agents can be accomplished at many sites to depths of 30 feet. Jetting is usually performed under high pressure and at low volume using specially designed jetting lances and tips that can jet remediation agents at pressures ranging from 500 to up to 20,000 psi. Flow rates can range from 1 to 20 gpm. The high pressure can be sufficient to fracture

soils event with low permeability, and to overcome ground pressures in the areas of treatment of up to several feet from the vertical point of jetting. Once the soil is fractured, the remediation agents are effectively dispersed into the contaminated soil and/or water matrix.

In many subsurface soils, jetting to 20 feet bgs can be accomplished in a matter of only a few minutes. After the jetting lance reaches the desired depth, the remediation agents are jetting into the treatment zone via a variety of specially-designed tips that distribute the remediation agents both radially and/or vertically. Sufficient jetting pressure can force the remediation agents outward into the soil or groundwater up to several feet from the point of jetting. At the source of the arsenic plume there will be a need to predrill through concrete areas and install temporary well points. A gasoline-powered compressor powers the jetting system which jets the remediation solution into the subsurface soil and/or groundwater under high pressure through a specially designed jetting lance and tip system. The jetting lance is designed to rapidly jet through subsurface soils, including clays. The lance is less than one inch in diameter, with specially designed jetting tips. Jetting ports on the tip allow high pressure (up to 20,000 psi), low volume (up to 20 gpm) jetting of remediation agents into the treatment zone. Tips with up to nine jetting ports can be used to inject remediation agents both vertically (downward) and radially in up to eight compass directions, effecting uniform distribution of remediation agents throughout the treatment zone.

In the case of using Fenton's Reagent, jetting occurs in two steps. The first step involves the jetting of the ferrous sulfate catalyst, and if necessary, surfactant. At many sites, the surfactant solution will help increase the porosity of the treatment zone and help loosen any adsorbed contaminant within the soil or groundwater matrix. The second step involves the jetting of hydrogen peroxide through the same jetting holes into the treatment zone.

Jetting to the top of the treatment zone is typically accomplished using fresh water (or remediation agents if the treatment zone is near the surface). Once the top of the treatment zone is encountered, jetting is accomplished with remediation agents. As the jetting lance jets downward from the top of the treatment zone to the terminal depth of the treatment zone, remediation agents are jetted laterally, thereby treating a cylindrically-shaped area. Typical radius of influence is on the order of two to ten feet, depending on the subsurface stratigraphy, jetting pressure, jetting volume, residence time, and other factors. Tightly-spaced and overlapping treatment "cylinders" result in effective remediation of the treatment zone with minimal "cold spots." Multiple treatment cycles are necessary to effect remediation.

Cost

The capital cost of this alternative is $1,335,000. Details are presented in Table 4-20. There are no continuing operation and maintenance costs.

TABLE 4-20

COST ESTIMATE FOR ALTERNATIVE C-1
IN-SITU TREATMENT WITH INJECTION OF PRECIPITATING AGENTS

• Mobilization; (six times @ $2,500)	$15,000
• High pressure jetting equipment; (84,000 ft^2 treatment area, $1,500.00/day, 28 *days/event, 6 events, 600 injections/event*)	$252,000
• Labor – Field Supervisor and 3 Field Technicians; ($1,750.00/day, 28 days/event, 6 events)	$294,000
• Labor – Per diem and vehicle; ($450.00/day, 28 days/event, 6 events)	$75,600
• Personal protective equipment and expendable job materials	$13,600
• Innoculant cost; (6,300 gallons ferrous sulfate @ $6.00/gallon, 50,400 gallons hydrogen peroxide @ $4.00/gallon)	$239,400
• Engineering @ 20%	$178,000
• Contingency @ 30%	$267,000
Total	**$1,335,000**

Alternative C-2; Ex-Situ Treatment by Precipitation/Flocculation/Settlement

This alternative involves capture of the plume with a trench drain. The recovered groundwater would be discharged to a reactor where a precipitation chemical would be added. Reactor contents would be pumped to a clarifier where flocculants would be added and the arsenic precipitant then through a polish filter into the surface impoundment. The clarified stream would be pumped through a separate polish filter into the surface impoundment. The accumulated arsenic would be disposed at a commercial waste landfill. The surface impoundment is discharged through activated carbon columns into the Mississippi River via an NPDES permit.

Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment. Movement of the arsenic plume is stopped by construction of the trench drain to intercept the groundwater. The pathway to the environment is, therefore, broken.

Once the groundwater is intercepted it has to be adequately treated so as not to open up another pathway caused by discharge of the groundwater. The pathway is kept closed by precipitating the arsenic and removing the filter cake. The filter cake is properly disposed at a hazardous waste landfill.

Institutional

This alternative will be implemented under existing permit conditions and in compliance with appropriate regulations. One permit of particular applicability is the NPDES permit. The groundwater will be treated to MCL levels prior to discharge to the surface impoundments. Water in the surface impoundments is treated by pumping through activated carbon columns prior to discharge to the Mississippi River via an NPDES permit.

Performance

The trench drain will effectively intercept the flow of the arsenic plume. The trench will be constructed at the source of the plume where apparent historic arsenic spillage occurred. The intent is not only to block and intercept arsenic plume flow but also to remove the arsenic at the source. The alternative will have to be maintained and operated for several years.

The treatment of the intercepted groundwater is also implemented with proven technology. The long-term performance is expected to be good.

Reliability

Implementation of this alternative results in the reduction of the mobility and volume of arsenic. The solution is permanent. The arsenic is removed from the environment, stabilized, and placed in a permitted, secure hazardous waste landfill.

Safety

Construction of this alternative will have to proceed by paying attention to and adhering to standard safety precautions. The trenching will be done in a former process area. Probing for obstructions will have to precede the excavation. When the trench is excavated any

necessity to enter the trench to construct the collection piping or collection sump will have to be done in adherence to shoring requirements of OSHA.

Construction of the treatment system itself is standard process plant construction to be carried out by experienced craftsmen.

Implementability

A trench must be capable of lowering the water table 50 percent of the saturated thickness of the uppermost water bearing unit. Therefore, the minimum trench depth should be at least the depth to the water table plus one-half the saturated thickness of the upper water bearing zone. Generally, the practical depth limitations for trenches are static water levels of 15 feet or less and depth to base of the aquifer of 40 feet or less.

The most important factor to life of the trench is the selection of the material selected for use in the filter pack placed between the natural sediments and the collection lateral. A common mistake is to use too large of a filter pack material such as crushed rock or gravel. Fine grained sediments of the formation will tend to migrate between the "large" filter material and plug the filter pack.

Selection of a filter pack material comprised of a clean washed fine quartz sand close to the mean grain size of the formation material or slightly larger is recommended. The permeability of any clean fine quartz sand will usually be many times greater than the formation. A minimum of six inches of filter pack material is recommended below and beside the lateral to separate the formation from the collection lateral. The height of the sand pack may extend any length above the lateral, however, the depressed water level at steady state will most likely be only a few feet above the lateral. Extending the filter pack to the static water level is generally not necessary. The use of geomembranes is generally not necessary and may cause plugging if not selected or installed properly.

Although it is not absolutely necessary to install a collection lateral in the filter pack material, it is highly recommended for a number of reasons. The lateral is much less likely to "plug" as compared to the filter pack without the lateral.

Another advantage of a collection lateral is the installation of an "S" trap to keep the lateral constantly saturated. It is important not to entirely dewater the filter pack in order to minimize the potential for bacterial (algae) growth in the filter pack.

Very little maintenance is required for a properly constructed infiltration trench system. A large diameter sump is recommended to provide ample storage of water to minimize cycling of the sump pump. A 3- or 4-foot diameter reinforced concrete pipe with manhole cover and built-in ladder has proven to be useful. On-off levels for the pump can be set with float switches or transducers calibrated to measure water levels.

Groundwater would be continuously removed from the interceptor trench at a rate of 0.1 gpm and pumped to a continuously stirred 10-gallon reactor. There would additionally be pumped to the reactor 0.0015 gph of 22% caustic, 0.21 gph of pickle liquor (byproduct of steel mills with 87,000 ppm iron content), and 0.18 gph of 5% hydrogen peroxide. Residence time for oxidation of arsenic (III) and organoarsenicals to arsenic (V) is 30 minutes at pH 2.5.

The reactor contents are continuously removed on level control to an aeration reactor where the precipitation, adsorption, and coprecipitation of oxidized arsenic is completed by aerating for another 30 minutes with an air sparge under a pH of 7.5. The pH of 7.5 is achieved by continuous addition of another 0.0015 gph caustic.

The aerator contents are continuously removed on level control to a 20-gallon settling tank. Anionic polymeric flocculant is metered into the tank at 0.01 cc per hour. Settling residence time in the tank is 120 minutes. The insoluble ferric-arsenate precipitant adsorbed onto the iron settles out in the floc. Solids are removed in a filter via a circulation loop with the pump suction at the bottom of the settling tank. Filtered water is discharged back to the settling tank. Clean water is continuously removed under level control and pumped to the wastewater pond to eventually be discharged to the Mississippi River via the site NPDES permit. The clean water will contain less than 10 ppb arsenic. Contents of the filter are removed once per month and placed in two 55-gallon drums for disposal in an offsite commercial landfill.

The following are the key parameters for the design:

- Fe/As ratio – 10/1
- Hydrogen peroxide/Fe ratio – 1/2

- Residence time for initial oxidation at pH 2.5 = 30 minutes
- Residence time for aeration at pH 7.5 – 30 minutes
- Residence time for settling – 120 minutes

Cost

The capital cost of this alternative is $242,000. Details are presented in Table 4-21. The present value of operation and maintenance costs for 10 years at 5% interest is $445,300. Details are presented in Table 4-22.

TABLE 4-21

COST ESTIMATE FOR ALTERNATIVE C-2
EX-SITU TREATMENT BY PRECIPITATION/FLOCCULATION/SETTLEMENT

• Mobilization		$5,000
• Concrete removal in trench drain area		$5,000
• Excavation for trench drain; (30' x 15' x 1.5')		$4,500
• Collection pipe; 30'		$1,000
• Collection sump; 15' x 3' diameter		$4,000
• Pump, piping and level control system		$6,000
• Backfill, including drainage sand		$500
• Treatment system		
- 10 gallon stainless steel reactor with agitator	$6,000	
- 10 gallon stainless steel aeration tank with aeration style agitator	$6,000	
- 50 gallon settling tank	$5,000	
- filter, 8 ft^2 filtering area, 4" cake	$11,000	
- ferrous sulfate metering pump	$2,500	
- Hydrogen peroxide metering pump	$2,500	
- Caustic metering pump	$2,500	
- A__ polymeric flocculant metering pump	$2,500	
- F___ co_____ pumps	$5,000	
- Foundation, electrical, instruments, piping	$86,000	$129,000
• Engineering @ 20%		$31,000
• Contingency @ 30%		$56,000
Total		**$242,000**

TABLE 4-22 PRESENT VALUE OF OPERATION AND MAINTENANCE COSTS OF ALTERNATIVE C-2 FOR 10 YEARS	
• Chemical cost over 10 years; 6,300 gallons ferrous sulfate @ $6.00/gallon, 50,400 gallons hydrogen peroxide @ $4.00/gallon	$239,400
• Transportation and disposal of arsenic	$2,000
• Operation at 10% capital for 10 years	$242,00
• Maintenance at 10% maintenance for 10 years	$242,00
Total	**$725,400**
Present Value @ 10 Years and 5% Interest = $725,400(0.6139)	**$445,300**

Alternative C-4; Ex-Situ Treatment by Phytoremediation

This alternative involves capture of the plume with a trench drain. The recovered groundwater would be discharged to a hydroponic bed of ladder brake ferns. Overflow from the hydroponic bed would be pumped to the surface impoundment. Contents of the surface impoundment would be discharged to the Mississippi River through activated carbon columns via an NPDES permit. Fern fronds would be periodically harvested, dried, and disposed in a hazardous waste landfill.

Overall Protection of Human Health and the Environment

This alternative is protective of human health and the environment. Movement of the arsenic plume is stopped by construction of the trench drain to intercept the groundwater. The pathway to the environment is, therefore, broken.

Once the groundwater is intercepted it has to be handled and in a manner that will not open up another pathway of potential exposure. In this alternative the pathway is kept closed by pumping the captured groundwater to several hydroponic beds of ladder break ferns. The ferns hyperaccumulate arsenic. The treated groundwater would flow to the surface impoundments and would be pumped through activated carbon beds prior to discharge to the Mississippi River via an NPDES permitted outfall. There is, of course, potential exposure to

arsenic in the hydroponic bed areas. Care will have to be taken by those who maintain the beds.

Reliability

Implementation of this alternative results in the reduction of the mobility and volume of arsenic. The solution is permanent. The arsenic is removed from the environment with the ferns, the ferns are dried, stabilized, and placed in a permitted, secure hazardous waste landfill.

Safety

Construction of this alternative will have to proceed by paying attention to and adhering to standard safety precautions. The trenching will be done in a former process area. Probing for obstructions will have to precede the excavation. When the trench is excavated any necessity to enter the trench to construct the collection piping or collection sump will have to be done in adherence to shoring requirements of OSHA.

Construction of the treatment system itself involves standard process plant construction to be carried out by experienced craftsmen.

Operation of the treatment system will require care in order to avoid potential skin contact with arsenic. Both the water and the fern fronds will contain high concentrations of arsenic.

Institutional

This alternative will be implemented under existing permit conditions and in compliance with appropriate regulations. One permit of particular applicability is the NPDES permit. The groundwater will be treated to MCL levels prior to discharge to the surface impoundments. Water in the surface impoundments is treated by pumping through activated carbon columns prior to discharge to the Mississippi River via an NPDES permit.

Performance

The trench drain will effectively intercept the flow the arsenic plume. The trench will be constructed at the source of the plume where apparent historic arsenic spillage occurred. The

intent is not only to block and intercept arsenic plume flow but also to remove the arsenic at the source. The alternative will have to be maintained and operated for several years.

The treatment of the intercepted groundwater by phytoremediation; that is, pumping the groundwater to hydroponic beds of ladder brake ferns has been tested in the laboratory. Extrapolation of the available data lead to the conclusion that with enough time and enough ferns the MCL for arsenic in groundwater can be met. The residence time is 140 days. After 140 days exposure, 72 pounds of ferns is required per pound of arsenic accumulated.

A trench must be capable of lowering the water table 50 percent of the saturated thickness of the uppermost water bearing unit. Therefore, the minimum trench depth should be at least the depth to the water table plus one-half the saturated thickness of the upper water bearing zone. Generally, the practical depth limitations for trenches are static water levels of 15 feet or less and depth to base of the aquifer of 40 feet or less.

The most important factor to life of the trench is the selection of the material selected for use in the filter pack placed between the natural sediments and the collection lateral. A common mistake is to use too large of a filter pack material such as crushed rock or gravel. Fine grained sediments of the formation will tend to migrate between the "large" filter material and plug the filter pack.

Selection of a filter pack material comprised of a clean washed fine quartz sand close to the mean grain size of the formation material or slightly larger is recommended. The permeability of any clean fine quartz sand will usually be many times greater than the formation. A minimum of 6 inches of filter pack material are recommended below and beside the lateral to separate the formation from the collection lateral. The height of the sand pack may extend any length above the lateral, however, the depressed water level at steady state will most likely be only a few feet above the lateral. Extending the filter pack to the static water level is generally not necessary. The use of geomembranes is generally not necessary and may cause plugging if not selected or installed properly.

Although it is not absolutely necessary to install a collection lateral in the filter pack material, it is highly recommended for a number of reasons. The lateral is much less likely to "plug" as compared to the filter pack without the lateral.

Another advantage of a collection lateral is the installation of an "S" trap to keep the lateral constantly saturated. It is important not to entirely dewater the filter pack in order to minimize the potential for bacterial (algae) growth in the filter pack.

Very little maintenance is required for a properly constructed infiltration trench system. A large diameter sump is recommended to provide ample storage of water to minimize cycling of the sump pump. A 3- or 4-foot diameter reinforced concrete pipe with manhole cover and built-in ladder has proven to be useful. On-off levels for the pump can be set with float switches or transducers calibrated to measure water levels.

Groundwater would be continuously removed from the interceptor trench at a rate of 0.1 gpm and pumped to the system consisting of 21 cells in series.

At start-up, the first cell would be filled with 1,000 gallons of arsenic groundwater and the other cells would each be filled with 1,000 gallons of potable water. Each cell would contain 400 ferns and appropriate fertilizer. Water from cell 21 would be discharged to the drainage system leading to the surface impoundment.

On a monthly basis, a sample of fronds in cell 1 and water discharge from cell 21 would be analyzed for arsenic. The water discharge would have to remain below 10 ppb. The fronds in cell 1 would increase in arsenic concentration.

When the arsenic concentration of the fronds in cell 1 has increased to 7,500 ppm, they are ready for harvesting. At this time, the supply stream of 0.1 gpm arsenic contaminated groundwater is diverted to cell 2. When fronds are harvested in cell 1, the water in cell 1 is pumped with a temporary pump to cell 2. Potable water is introduced to cell 1. Then the discharge from cell 21 is diverted to the drainage system. The fronds in cell 2 and discharge of water from cell 1 would be monitored on a monthly basis. This same pattern would be continued for about 8.6 to 10 years.

Cost

The capital cost of this alternative is $1,307,000. Details are presented in Table 4-23. The present value of operation and maintenance costs for 10 years at 5% interest is $802,000. Details are presented in Table 4-24.

TABLE 4-23

COST ESTIMATE FOR ALTERNATIVE C-4
EX-SITU TREATEMENT BY PHYTOREMEDIATION

• Mobilization		$5,000
• Concrete removal in trench drain area		$5,000
• Excavation for trench drain; (30' x 15' x 1.5')		$4,500
• Collection pipe; 30'		$1,000
• Collection sump; 15' x 3' diameter		$4,000
• Pump, piping and level control system		$6,000
• Backfill, including drainage sand		$500
• Treatment system		
- 21 troughs, plastic construction 1,400 gallons each	$105,000	
- Foundation, electrical, instruments, piping, green house roof and walls. Constructed on former MSMA plant structures	$210,000	$315,000
• Engineering @ 20%		$68,000
• Contingency @ 30%		$123,000
Total		**$532,000**

TABLE 4-24

PRESENT VALUE OF OPERATION AND MAINTENANCE COSTS
OF ALTERNATIVE C-4
FOR 10 YEARS

• Cost of 54,00 plants at $4.50/plant	$243,000
• Operation at 10% capital for 10 years	$532,000
• Maintenance at 10% capital for 10 years	$532,000
Total	**$1,307,000**
Present Value @ 10 Years and 5% Interest = $1,307,000(0.6139)	**$802,000**

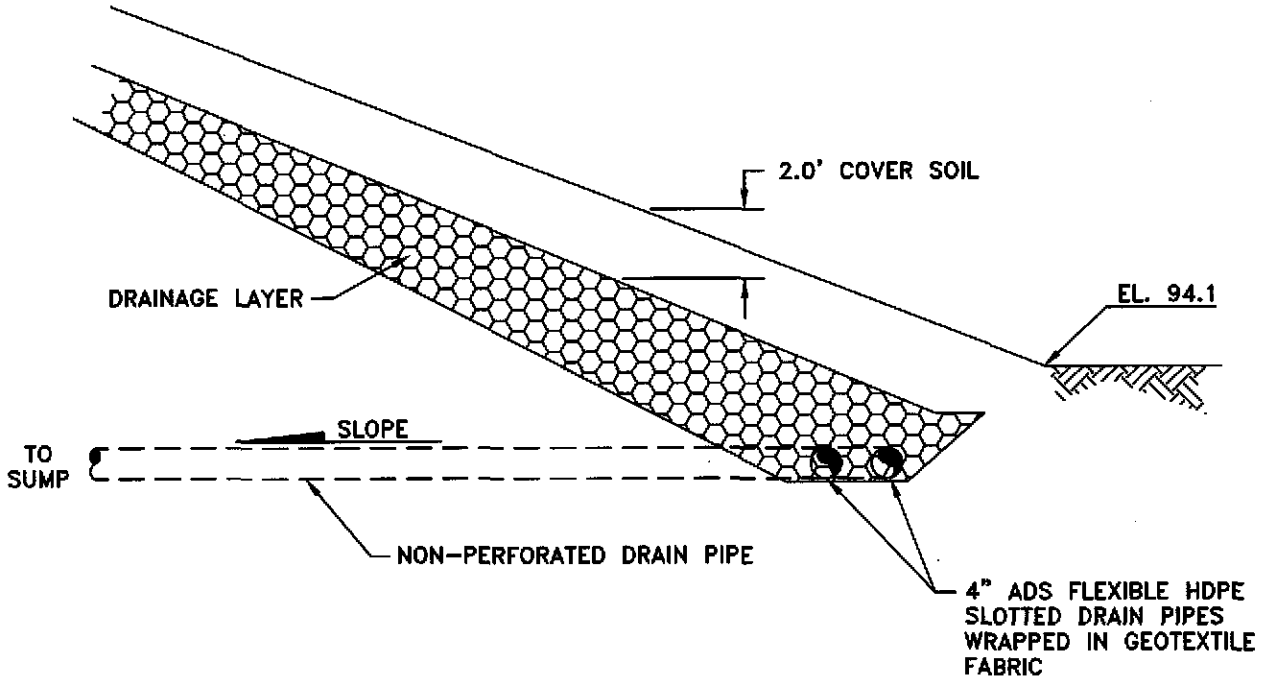
4.6 COMPARATIVE ANALYSIS OF ALTERNATIVES FOR GROUNDWATER CONTAMINATED WITH ARSENIC

The comparative analysis of all the factors noted in Section 4.6 is presented as Table 4-25.

TABLE 4-25
COMPARATIVE ANALYSIS OF ALTERNATIVES
FOR GROUNDWATER CONTAMINATED WITH ARSENIC

Alternative	Overall Protection of Human Health & the Environment	Institutional	Performance	Reliability	Safety	Implementability	Cost	Total
C-1 In-Situ Treatment with Injection of Precipitating Agents	3	3	3	2	3	4	3	21
C-2 Ex-Situ Treatment by Precipitation/Flocculation/ Settling	5	5	5	5	4	3	4	31
C-4 Ex-Situ Treatment by Phytoremediation	4	4	4	3	3	3	3	24

Legend: 5 = Highest Ranking
1 = Lowest Ranking



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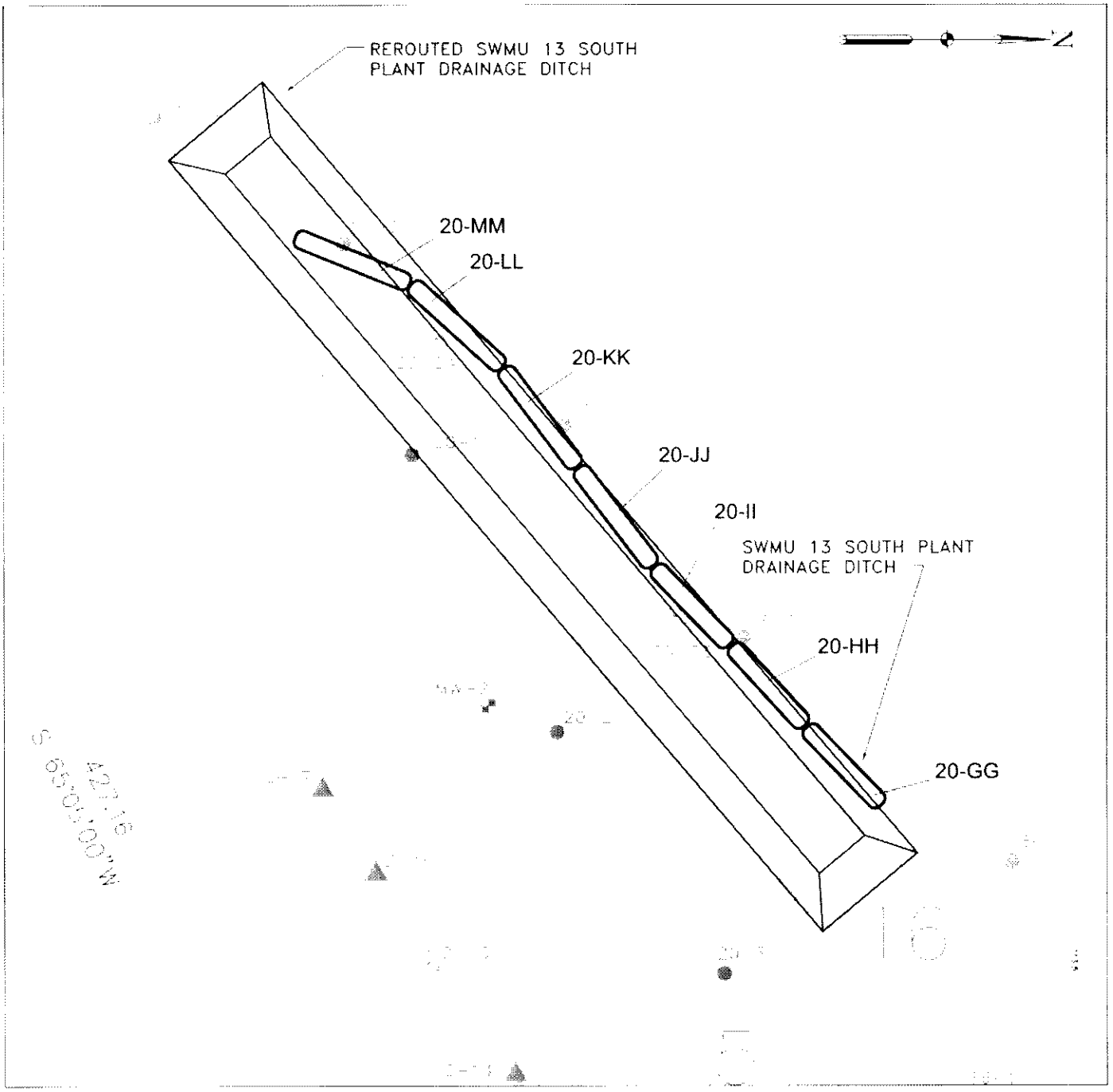
VICKSBURG CHEMICAL CORPORATION VICKSBURG, MISSISSIPPI	**URS** 2822 O'Neal Lane Baton Rouge, Louisiana 70616 225/751-1873	CORRECTIVE MEASURES STUDY	PROJ. NO. 92B007C
	SCALE: N.T.S. / DRAWN BY: GAT / DATE: 8/21/01 CHKD. BY: RDK / DATE: 2/6/02	BLANKET DRAIN AND SOIL CONSTRUCTED TO SUPPORT SURFACE IMPOUNDMENT LINING	FIG. NO. 2-5



LEGEND

- BORINGS FOR SOIL SAMPLES AND CHEMICAL ANALYSIS
- EXISTING MONITOR WELLS
- PHASE II BORINGS TO GROUNDWATER
- PHASE II SOIL SAMPLE
- SOIL PILE SECTIONS

SCALE 1 INCH=100 FEET

100' 0 100'

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VICKSBURG CHEMICAL
VICKSBURG, MISSISSIPPI

URS
2822 O'Neal Lane
Baton Rouge, Louisiana 70816
225/751-1873

SCALE:	DRAWN BY: PCG	DATE: 2/6/02
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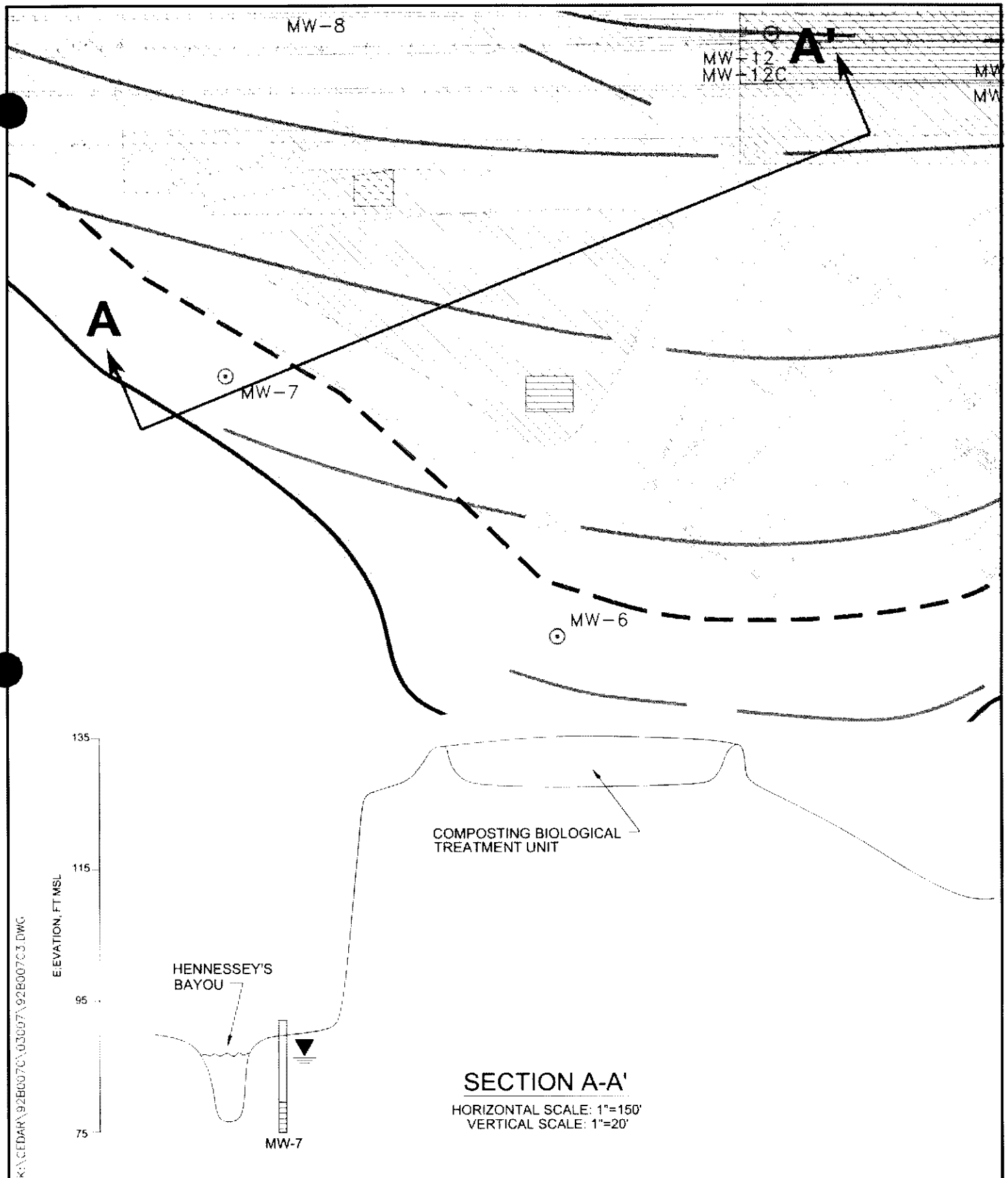
CORRECTIVE MEASURES STUDY

ENGINEERED SOIL PILE

PROJ. NO. 92B007C

FIG. NO. 3-1



SECTION A-A'

HORIZONTAL SCALE: 1"=150'
VERTICAL SCALE: 1"=20'

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VICKSBURG, MISSISSIPPI

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Baton Rouge, Louisiana 70816
225/751-1873

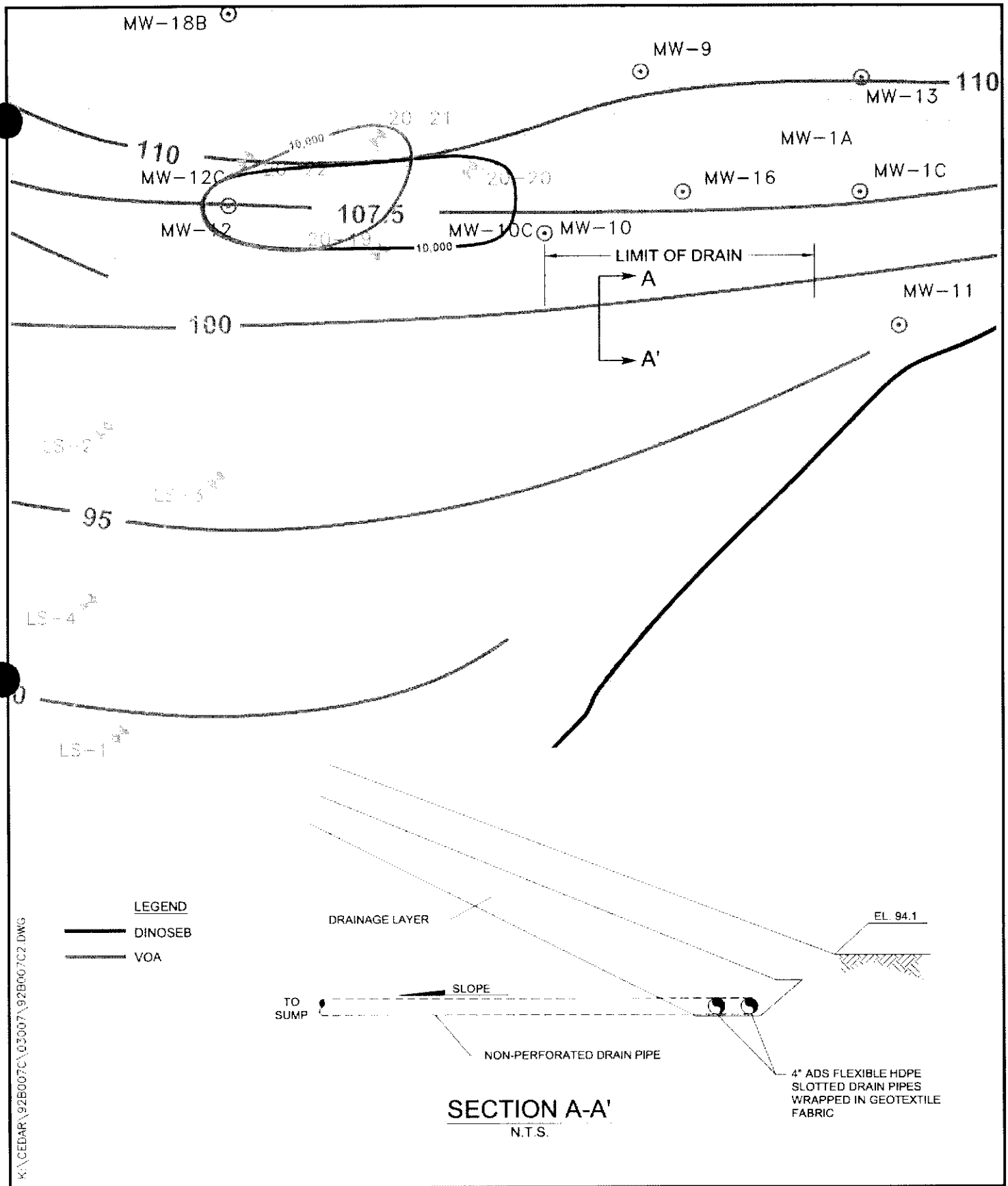
SCALE:	DRAWN BY: PCG	DATE: 2/5/02
AS SHOWN	CHKD. BY:	DATE:

CORRECTIVE MEASURES STUDY

COMPOSTING BIOLOGICAL TREATMENT UNIT

PROJ. NO. 92B007C

FIG. NO. 3-3



SECTION A-A'
N.T.S.

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VICKSBURG CHEMICAL CORPORATION
VICKSBURG, MISSISSIPPI

URS
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Baton Rouge, Louisiana 70816
225/751-1873

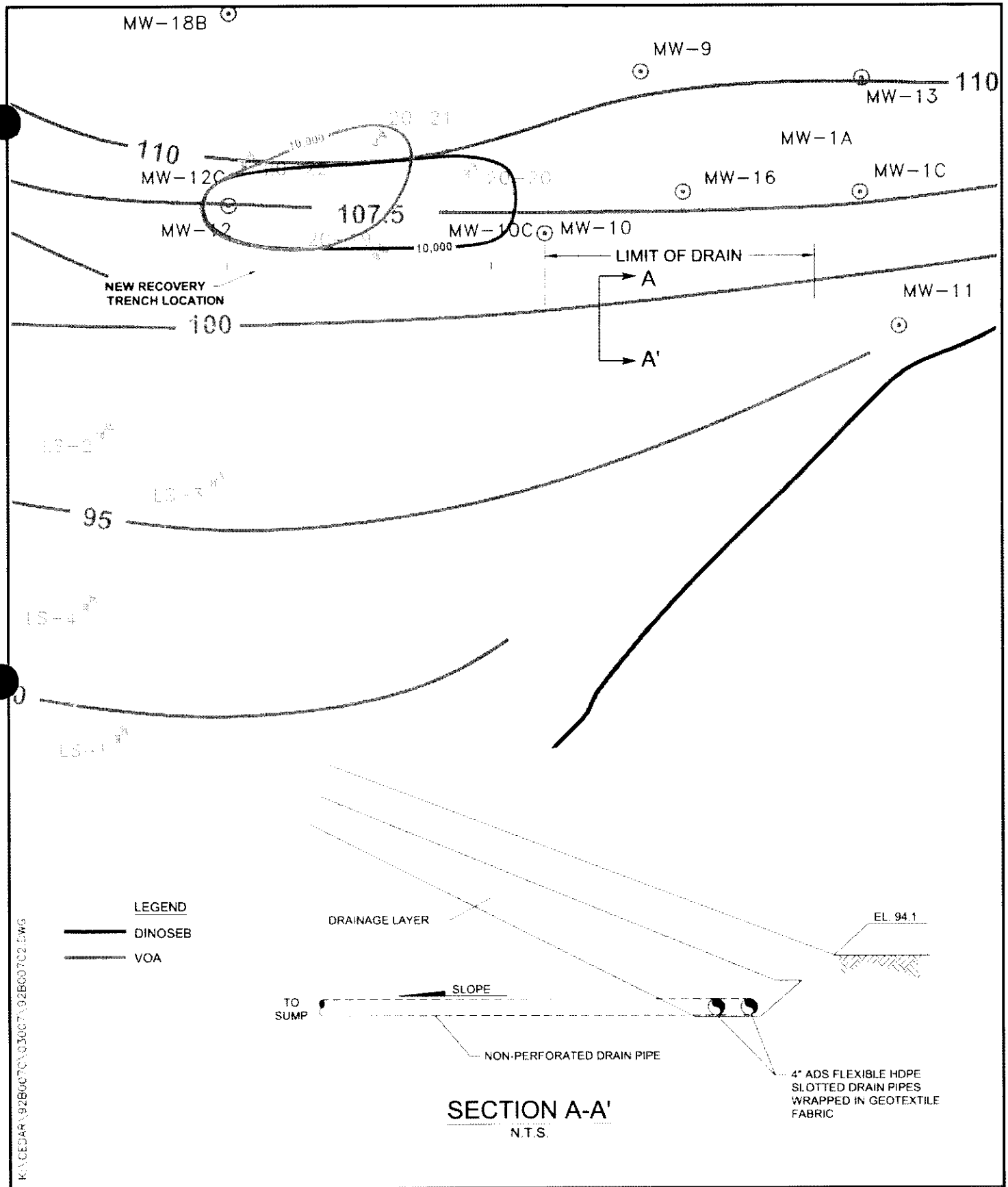
SCALE:	DRAWN BY: PCG	DATE: 2/5/02
1"=150'	CHKD. BY:	DATE:

CORRECTIVE MEASURES STUDY

JUXTAPOSITION OF CREEK, DRAINAGE LAYER AND AND DINOSEB AND VOA PLUMES

PROJ. NO. 92B007C

FIG. NO. 3-4



SECTION A-A'

N.T.S.

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VICKSBURG CHEMICAL CORPORATION
VICKSBURG, MISSISSIPPI

URS
2822 O'Neal Lane
Baton Rouge, Louisiana 70816
225/751-1873

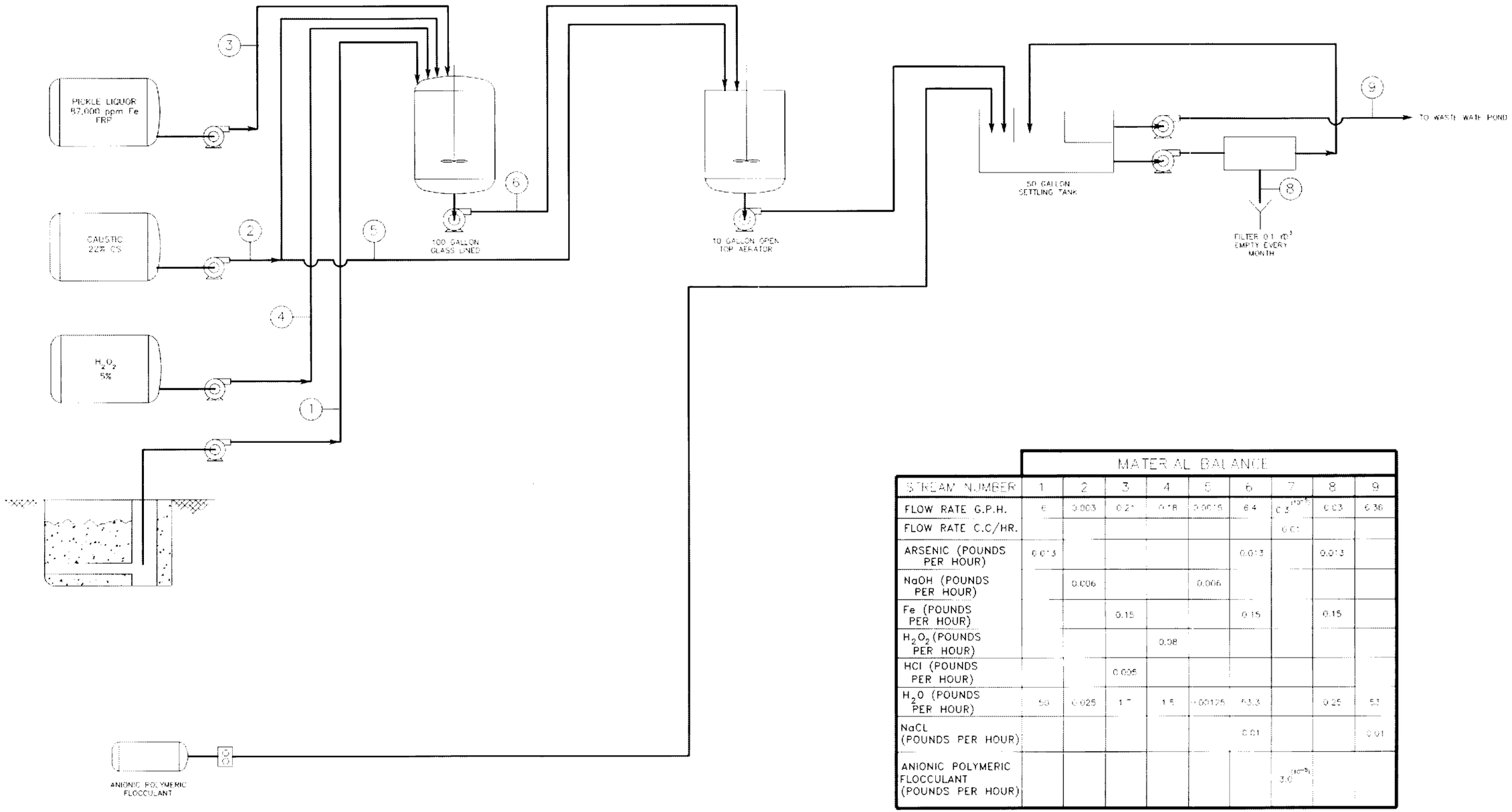
SCALE:	DRAWN BY: PCG	DATE: 2/15/02
1"=150'	CHKD. BY:	DATE:

CORRECTIVE MEASURES STUDY

RECOVERY TRENCH FOR VOA & DINOSEB CONTAMINATED GROUNDWATER

PROJ. NO 92B007C

FIG. NO 3-5



	MATERIAL BALANCE								
STREAM NUMBER	1	2	3	4	5	6	7	8	9
FLOW RATE G.P.H.	6	0.003	0.21	0.18	0.0015	6.4	0.3 (10^{-3})	0.03	6.36
FLOW RATE C.C/HR.							0.01		
ARSENIC (POUNDS PER HOUR)	0.013					0.013		0.013	
NaOH (POUNDS PER HOUR)		0.006			0.006				
Fe (POUNDS PER HOUR)			0.15			0.15		0.15	
H_2O_2 (POUNDS PER HOUR)				0.08					
HCl (POUNDS PER HOUR)			0.005						
H_2O (POUNDS PER HOUR)	50	0.025	1.7	1.5	0.00125	53.3		0.25	53
NaCL (POUNDS PER HOUR)						0.01			0.01
ANIONIC POLYMERIC FLOCCULANT (POUNDS PER HOUR)							3.0 (10^{-3})		

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REV	DESCRIPTION OF REVISION	BY	DATE
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VICKSBURG CHEMICAL
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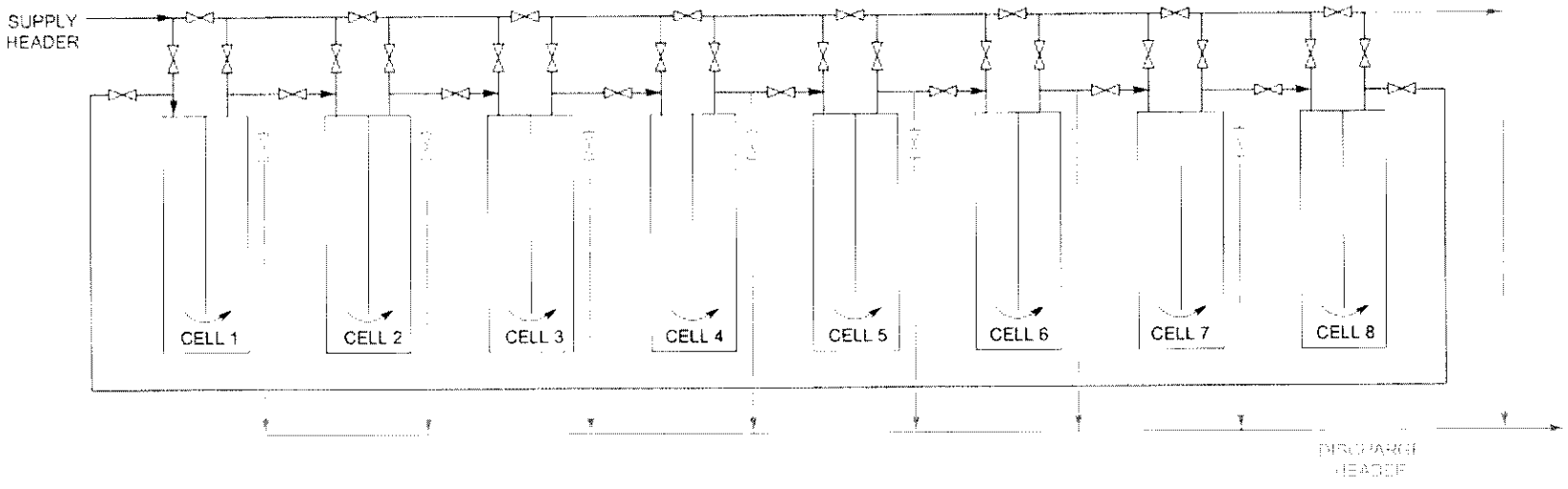
REFERENCE DRAWINGS

SCALE N.T.S.
DESIGNED
DRAWN PCG
CHECKED
PEER REVIEWED
DATE

CORRECTIVE MEASURES STYUDY

PROCESS FLOW DIAGRAM

REVISION △
PROJECT 92B007C
FIGURE 3-6



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CORRECTIVE MEASURES STUDY

SCHEMATIC OPERATIONAL FLOW
OF HYDROPONIC CELL SYSTEM

PROJ. NO.
92B007C

F.G. NO.
3-7

F I N A L

MAR 3 0 1999

CORRECTIVE ACTION OBSERVATION CONFIRMATORY SAMPLING AND ANALYSIS

Prepared for
Vicksburg Chemical
Vicksburg, Mississippi

March 11, 1999

File No. 35092B007C.00.03004

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Offices Worldwide

March 11, 1999

Mr. Steve Boswell
Vicksburg Chemical Company
P.O. Box 821003
Vicksburg, Mississippi 39182-1003

Re: SWMU 9
Corrective Action Observation
Confirmatory Sampling and Analysis
Project No. 35092B007C.00.03004

Dear Steve:

This is written as documentary record of the confirmation soil sampling that was performed by me on November 4, 1998, subsequent sampling of the groundwater the following week by ETS, and the analytical results from both efforts. The following topics are covered in this letter:

- History of the corrective action program including SWMU 9
- Results summarized from RFI Report
- Summary of Corrective Measures
- Documentation of the sampling effort
- Analytical results
- Conclusions

HISTORY

Vicksburg Chemical Company (VCC) retained URS Greiner Woodward Clyde (URSGWC) to perform activities associated with a RCRA corrective action program. The corrective action program is in response to a Consent Decree effective July 1, 1991. The Consent Decree requires that a RCRA Facility Investigation (RFI) be conducted at the Vicksburg, Mississippi manufacturing facility.

The purpose of the RFI is to determine the nature and extent of releases of hazardous wastes and/or constituents from regulated units, solid waste management units (SWMUs), and other areas of concern (AOCs) at the facility and to gather all necessary data to support any corrective action required.

The RFI constitutes the second phase of the RCRA corrective action program. The program's initial phase consists of the RCRA Facility Assessment (RFA) which is conducted by the EPA and precedes the RFI. The RFI itself is divided into several separate tasks which includes the Preliminary Report (Report of Current Conditions, submitted previously by VCC then resubmitted as the Amended and Restated Preliminary Report and subsequently approved by the U.S. EPA), the RFI Work Plan (submitted in June 1996), the Facility Investigation, and the Investigative Analysis

Reports (RFI Report). In addition to these phases, a Groundwater Assessment Work Plan (submitted in June 1996), a Closure Plan for SWMU 1 and SWMU 17 (submitted and subsequently approved by the U.S. EPA) and Annual Groundwater Assessment Reports are required by the Consent Decree.

The following is a tabulation of additional SWMU activity at the site which was expedited because of VCC's plans to construct new manufacturing facilities in the South Plant and also utilize some of the areas for storage and transportation:

Report	Date	Status	Comment
RFI Work Plan SWMUs 9 and 16	August 1994	Submitted	--
RFI Report SWMUs 9 and 16	September 1994	Submitted	--
Closure Plan SWMUs 1 and 17	February 1995 (Modified 10-26-95)	Approved by the U.S. EPA and MSDEQ	--
RFI Work Plan Entire Site	June 1996	Under review	Incorporated investigative phase of "Closure Plan SWMUs 1 and 17".
RFI Expedited Work Plan SWMUs 12, 11, 15, 16, 1 and 17	January 1997	Submitted	VCC planned to expand manufacturing capability into SWMU 12, 11 and 15 area or SWMU 16, 1 and 17 area.
RFI Report, Corrective Measures Study, RCRA Corrective Measures Implementation Plan SWMUs 16, 1 and 17	June 1997	Approved by U.S. EPA and MSDEQ	--
Corrective Management Unit Application	June 1997	Approved by U.S. EPA and MSDEQ	--
RFI Report SWMUs 12, 11 and 15	April 1998	Submitted	--
Corrective Measures Implementation Plan SWMUs 12, 11 and 15	April 1998 (as amended July 15, 1998)	Submitted	--
Corrective Action Observation Confirmatory Sampling and Analysis SWMUs 1 and 17	July 1998	Submitted	--
Arsenic Data Sets Arsenic Data Sets - Addendum	October 15, 1998 October 26, 1998	Submitted Submitted	Evaluation of arsenic background data.

RESULTS SUMMARIZED FROM THE RFI REPORT - SWMUs 9 AND 16 SEPTEMBER 1994

The specific sample locations for SWMU 9 are depicted on Figure 1. For each sample point there were two or three samples taken:

- A core of the concrete.
- A composite sample of the first 0 to 12 inches of soil beneath the concrete referred to as the shallow sample.
- A sample of soil generally 12 to 24 inches beneath the concrete referred to as the deep sample.

The results of the analyses for SWMU 9 samples in September 1994 are recorded in the following table:

TABLE 1

Sample No.	Concentration in mg/kg					
	BTEX	Arsenic	Toxaphene	Cyanazine	Dinoseb	Atrazine
1S	--	8.2	ND	ND	ND	ND
2S	--	30.0	0.85	ND	ND	ND
2D	--	14.0	1.3	ND	ND	ND
3S	--	4.1	19.0	ND	ND	ND
4S	ND	5.9	ND	0.9	ND	ND
4D	ND	7.7	ND	ND	ND	ND
4C	--	24.0	ND	ND	ND	ND
5S	0.002	6.2	1.2	ND	ND	ND
5D	--	7.1	ND	ND	ND	ND
5C	--	4.8	0.1	ND	ND	ND
6S	ND	8.5	ND	ND	ND	ND
6C	--	3.8	ND	ND	ND	ND
7S	--	12.0	0.8	ND	ND	0.039
8S	ND	61.0	250.0	8.7	ND	21.0
8D	0.308	60.0	25.0	0.57	ND	0.39
8C	--	58.0	4.2	0.12	ND	0.061
*	--	3.0	2.6	--	61.0	--
**	--	100.0	34.0	--	0.14	--
***	--	9.7/11.8	--	--	--	--

NOTES:

S	Shallow sample	D	Deep sample
C	Concrete sample	ND	Not detected
--	Sample not analyzed, or no value reported		
*	Soil Screening Level - Industrial		
**	Soil Screening Level Protective of Groundwater		
***	Background Construction arithmetic mean 95% Upper Confidence Limit		

Notice that the concentrations detected can be compared to risk based or background levels presented in the last three rows of Table 1. The risk based numbers have been obtained from the Louisiana Department of Environmental Quality (LDEQ) Risk Evaluation Corrective Action Program (RECAP) dated December 20, 1998. The LDEQ has, of course, no jurisdictional authority at the VCC site. RECAP is based on EPA's Risk Assessment Guidance for Superfund in addition to subsequent EPA guidance and memoranda. A preamble from RECAP is attached in Appendix A in order to further identify the source of the document and to, therefore, establish its relevance. The background concentration number, relevant for arsenic, is further discussed in two memoranda, dated October 15, 1998 and October 26, 1998, copies of which were submitted to the U.S. EPA and Mississippi Department of Environmental Quality (MSDEQ).

SUMMARY OF CORRECTIVE MEASURES

Corrective Measures Implementation Plans (CMIPs) were written to describe remediation work at SWMUs 12, 11, 15, 16, 1 and 17. Remediation proposed for SWMU 9 was not written into any of the CMIPs; however, the area is very similar to the other SWMUs specifically noted in those plans and the remediation activity is also very similar.

The required activity specified in the CMIPs was to permanently deal with corrective measures by incorporating elements of the following for each remediation area, as necessary and appropriate:

- Busting out certain sections of concrete, reducing the size of the concrete to gravel size and treating onsite by biodegradation/composting.
- Excavating certain sections of soil and treating onsite by biodegradation/composting.
- Grinding the surface of certain sections and treating onsite by biodegradation/composting.
- Resurfacing and sealing existing concrete where appropriate.
- Disposing of treated and/or untreated soil and/or concrete either offsite or onsite. The onsite option would be a non-RCRA solid waste disposal option.

VCC did carry out corrective measures with respect to the area north of the inner wall in SWMU 9. The sample numbers 3, 4, 5, and 6 depicted in Figure 1, are from that area.

The entire surface of the concrete was treated by grinding off a veneer of concrete then by placing a layer of compost atop it in an attempt to draw contaminants from the surface of the concrete into the compost where biological degradation would occur. The effort was experimental and results were uncertain. Subsequently concrete and some soil were removed from a section comprising the middle third of SWMU 9. The section is depicted on Figure 1. All concrete grindings, concrete

debris and soil removed were taken to the Treatment Unit for biodegradation/composting within the provisions of the CAMU permit.

Subsequent to the remediation effort, samples A-1, B-2 and B-4 and groundwater sample TP-1 were obtained. The following is a discussion of that sampling effort and the analytical results.

DOCUMENTATION OF THE CONFIRMATION SAMPLING EFFORT

The locations of the confirmation samples are noted on Figure 1. At location "A", a sample was obtained at the surface of remaining soil; since the concrete had been removed, the sample was obtained approximately 1-foot below the original surface. At location "B", a shallow trench had been excavated to remove various construction debris. Two samples were taken at location "B" (the trench sidewall), one approximately 2 feet below the original surface and the other approximately 4 feet below the original surface.

The documentation of the sampling effort is provided in Appendix 2. The contents of Appendix 2 are:

- Photographs.
- Chain-of-custody record for soil samples and groundwater sample.
- Boring logs and sampling procedures for temporary well groundwater monitoring point.

ANALYTICAL RESULTS

The total analytical results and laboratory report are presented in Appendix 3. Soil and groundwater were analyzed for the Target Compound List (TCL) and Target Analyte List (TAL). The contents of Appendix 3 are:

- Analytical reports
- Holding time report
- Inorganics Q C
- Organics Q C

SOIL

The constituents above detection limits recorded for the soil samples are noted in Table 2 for inorganics and Table 3 for organics (Atrazine, Toxaphene and Dinoseb are listed for emphasis despite the reported result of non-detect). Risk based screening levels from the LDEQ RECAP are listed along side the reported values. Values lower than the listed screening levels are considered low enough to warrant no further remedial action.

TABLE 2

INORGANICS IN SOIL

	A-1 Result (mg/kg)	B-2 Result (mg/kg)	B-4 Result (mg/kg)	Soil Screening Level Industrial (mg/kg)	Soil Screening Level Protective of Groundwater (mg/kg)
Antimony	ND	ND	ND	75	12
Arsenic	9.06	7.32	9.57	3.0[1]	100
Barium	59.7	85.9	72.1	13,000	2,000
Beryllium	0.896	0.705	0.530	370	8
Cadium	0.874	0.610	0.398	94	20
Chromium	245.3	45.60	11.21	940[2]	100
Cobalt	7.91	8.52	8.28	11,000	4,400
Copper	29.11	13.73	13.52	660,000	1,500
Lead	46.09	14.38	12.18	1,700	100
Mercury	0.144	ND	ND	56	4
Nickel	21.09	19.15	17.70	3,700	200
Selenium	ND	ND	ND	940	20
Silver	ND	ND	ND	940	100
Thallium	8.04	6.85	5.39	15	4
Vanadium	23.50	22.0	16.77	1,300	2,000
Zing	82.04	48.9	49.79	56,000	2,800
Cyanide	ND	ND	ND	3,700	400

NOTES:

[1] Superceded at the Vicksburg site by high levels of arsenic in the background. 9.7 mg/kg arithmetic mean and 11.8 mg/kg 95% upper confidence limit.

[2] Screening level for Chromium VI; for chromium III it is 190,000.

TABLE 3

ORGANICS IN SOIL

	A-1 Result (mg/kg)	B-2 Result (mg/kg)	B-4 Result (mg/kg	Soil Screening Level Industrial (mg/kg)	Soil Screening Level Protective of Ground Water (mg/kg)
Atrazine	ND	ND	ND	--	--
Dinoseb	ND	ND	ND	61	0.14
Toxaphene	ND	ND	ND	2.6	34.0

TABLE 3

ORGANICS IN SOIL

	A-1 Result (mg/kg)	B-2 Result (mg/kg)	B-4 Result (mg/kg	Soil Screening Level Industrial (mg/kg)	Soil Screening Level Protective of Ground Water (mg/kg)
Benzo(a)athracene	1.11	ND	ND	3.6	8.6
Benzo(a)pyrene	1.16	ND	ND	0.36	23
Benzo(b)fluoranthene	0.977	D	ND	3.6	30
Benzo(g,h,i)perylene	0.551	ND	ND	--	--
Benzo(k)fluoranthene	1.15	ND	ND	35	120
Chrysene	1.34	ND	ND	400	76
Fluoranthene	1.35	ND	ND	3,600	1,200
Phenanthene	0.338	ND	ND	--	--
4-4'-DDE	0.011	ND	ND	12	2
PCB-1254	0.527	ND	ND	1.1	19

GROUNDWATER

The constituents above detection limits recorded for the groundwater samples are noted in Table 4 for inorganics and Table 5 for organics (Atrazine, Toxaphene and Dinoseb are listed for emphasis despite the reported result of non-detect). Risk based screening levels from the LDEQ RECAP are listed alongside the reported values. Values lower than the listed screening levels are considered low enough to warrant no further remedial action.

TABLE 4

INORGANICS IN GROUNDWATER

	Groundwater Sample TP-1 (mg/l)	Groundwater Screening Level (mg/l)
Antimony	0.012	0.006
Arsenic	0.378	0.05[1]
Barium	0.22	2
Beryllium	ND	0.004
Cadonium	ND	0.005
Chromium	ND	0.18[2]
Cobalt	0.06	0.22
Copper	ND	1.3

TABLE 4

INORGANICS IN GROUNDWATER

	Groundwater Sample TP-1 (mg/l)	Groundwater Screening Level (mg/l)
Lead	ND	0.015
Mercury	ND	0.002
Nickel	0.09	0.1
Selenium	ND	0.05
Silver	ND	0.018
Thallium	ND	0.002
Vanadium	ND	0.026
Zinc	0.07	1.1
Cyanide	ND	0.2

TABLE 5

ORGANICS IN GROUNDWATER

	Groundwater Sample TP-1 (mg/l)	Groundwater Screening Level (mg/l)
1,2-Dichlorobenzene	0.011	0.6
Cis-1,2-Dichloroethene	0.026	0.07
Trans-1,2-Dichloroethene	0.006	0.1
Trichloroethene	0.068	0.005
Xylenes	0.014	10
1,2-Dichlorobenzene	0.004	0.6
m-Nitrosodiphenylamine	0.002	0.014
Atrazine	ND	--
Dinoseb	ND	0.007
Toxophene	ND	0.003

CONCLUSIONS

The constituents listed in Table 6 exceeded the screening levels or background levels.

TABLE 6

SOIL

Sample Number and Parameter	Result (mg/l)	Soil Screening Level (mg/l)	Soil Screening Level Protective of Groundwater (mg/l)
Sample A-1			
Chromium	245.3	940	100
Thallium	8.04	15	4
Sample B-2			
thallium	6.85	15	4
Sample B-4			
thallium	5.39	15	4

The constituents listed in Table 7 exceeded the screening levels for groundwater.

TABLE 7

GROUNDWATER

Parameter	Result (mg/l)	Groundwater Screening Level (mg/l)
Sample TP-1		
Antimony	0.012	0.006
Arsenic	0.378	0.05
Trichloroethene	0.068	0.005

The following conclusions can be made:

- The only excursions in the soil in the area comprising one-third of SWMU 9 are minor deviations for chromium and thallium. The deviation is because of values protective of groundwater. In as much as the area will continue to be roofed and a new concrete pad poured there is no mechanism available to transport these contaminants into groundwater.

- The only excursions in the groundwater are minor deviations for antimony, arsenic and trichloroethene. SWMU 9 is adjacent to SWMU 12, which is the likely source of arsenic. Discussion of the remediation of SWMU 12 is found in the Corrective Measures Implementation Plan SWMUs 12, 11 and 15 as amended July 15, 1998. The source of antimony and trichloroethene is unknown at this time. The site wide groundwater Assessment will further examine the presence of these constituents.

There is no reason to delay construction of facilities above the remediated area comprising one-third of SWMU 9. Taking into account the results of the original sampling in September 1994, there is no reason to delay construction on the entire SWMU 9 area north of the inner wall.

Sincerely,

URS Greiner Woodward Clyde, Inc.

Richard D. Karkkainen

Attachments

RDK:cgb

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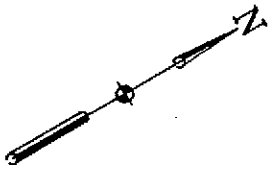

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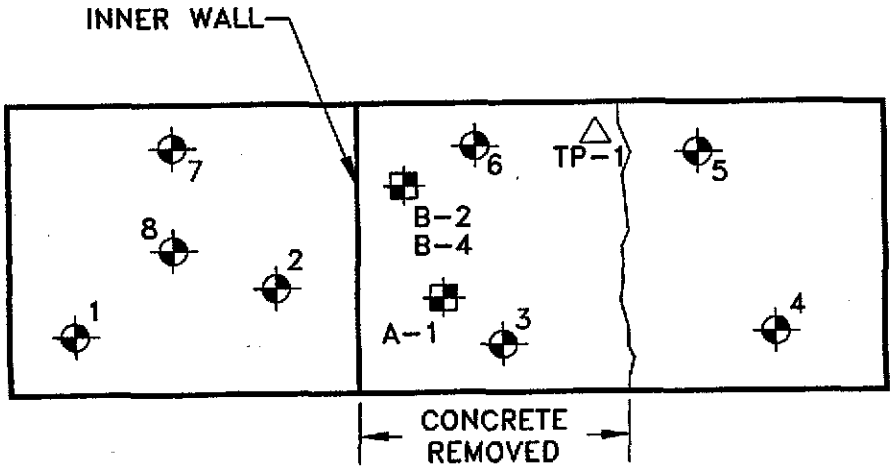


LEGEND

- SAMPLE LOCATIONS SEPTEMBER, 1994
- SAMPLE LOCATIONS NOVEMBER, 1998
- GROUNDWATER SAMPLE LOCATION NOVEMBER, 1998

VICKSBURG CHEMICAL	URS Greiner Woodward Clyde 2822 O'Neal Lane Baton Rouge, Louisiana 70816 225/751-1673	SWMU 9 SAMPLING LOCATIONS	FILE NO. 350928007C 03004 FIG. NO. 1

SCALE: AS SHOWN	DRAWN BY: PCG	DATE: 11/17/98
	CHKD. BY:	DATE: 3/10/99

APPENDIX 1

PREAMBLE FROM LDEQ-RECAP

Preamble

The Louisiana Department of Environmental Quality (LDEQ) has developed a Risk Evaluation/Corrective Action Program (RECAP) to address risks to human health and the environment posed by the release of chemical constituents to the environment. This is LDEQ's primary statutory mandate for remediation activities. It is clear in Louisiana's Environmental Quality Act that risk to human health and the environment must be evaluated in the remedial decision-making process.

RECAP uses risk evaluation to: (1) determine if corrective action is necessary for the protection of human health and the environment, and (2) identify constituent levels in impacted media that do not pose unacceptable risks to human health or the environment, i.e. RECAP Standards.

RECAP consists of a tiered framework composed of a Screening Option and three Management Options. This tiered approach allows site evaluation and corrective action efforts to be tailored to site conditions and risks. As the Management Option level increases, the approach becomes more site-specific and, hence, the level of effort required to meet the objectives of the Option increases. Although the level of effort required for each Option varies, each Option achieves a common goal: protection of human health and the environment.

There are numerous reasons for establishing RECAP; chief among them is the necessity to ensure that risks are properly evaluated to protect human health and the environment. Absent the establishment of such a program, the Department will expend considerably more resources to ensure that risk is evaluated properly, the regulated community will not have a clear understanding of the Department's requirements, and the general public will be uncertain as to the criteria used by the Department for remedial decisions.

In addition, LDEQ finds it necessary to establish clear and consistent guidelines across media-based program lines for the remediation of releases to air, land, and water. Remediation in Louisiana has not always been performed consistently over the years; various programs have used different standards for remediation. The broad array of clean up criteria being used across programs is not unique to Louisiana, as most environmental agencies have been struggling with this issue. RECAP will ensure that remediation standards are developed consistently, that all parties are treated equally, and that risk to human health and the environment is the primary consideration when remedial decisions are made.

The Department has reviewed risk assessments for a number of years. These risk assessments have, in general, been prepared in accordance with the Environmental Protection Agency's (EPA's) Risk Assessment Guidance for Superfund in addition to subsequent guidance and memoranda from that agency. Policy decisions using EPA's guidance documents have not previously been clarified by LDEQ. Rather, they have been negotiated on a site-by-site basis. These policy issues include appropriate risk level, exposure concentration, ground water use, land use, points of exposure, and points of

compliance. The previously mentioned EPA documents were used to develop the RECAP regulation, and necessary policy decisions have been made in the regulation. The written establishment of the Department's position on these issues will reduce transaction costs, not only for the regulated community, but also the Department. In addition, by clearly establishing the submittal requirements for a Risk Evaluation, LDEQ will be able to ensure that all documents received contain the information required for remedial decision making. RECAP regulation serves as LDEQ's policy statement on the performance of risk evaluations to determine if corrective action is warranted and the level of remediation required. Without RECAP regulation, risk evaluation would not be performed consistently in Louisiana.

The Louisiana Legislature has mandated in La. R.S. 30:2272 (Act 1092 of the 1995 Regular Session) that LDEQ develop Minimum Remediation Standards. The RECAP regulation is the Department's response to that mandate. RECAP's tiered approach to risk evaluation and corrective action establishes not only across the board numerical standards for most media, but also allows for the development of more site-specific numerical standards when warranted. It is anticipated that regulations for the Voluntary Cleanup Program (VCP) required to be established pursuant to this statute, will be proposed subsequent to the finalization of RECAP.

The difficulty in identifying appropriate remedial criteria has been an additional driving force behind the development of this program. Often, regardless of the resources spent, remediating to pristine conditions has been unachievable and risk is not reduced. The time and effort expended in making these sometimes futile efforts can be better spent on projects that provide greater reduction in risk to human health and the environment. RECAP regulation will assist the Department in prioritizing sites that require remediation. As a result, LDEQ remediation staff will better focus their efforts on sites posing the greatest risk.

The Department has also observed the national trend in using risk evaluation to establish remedial criteria. LDEQ has modeled its program along the lines of programs established by Texas, Massachusetts, and Washington, who all have successful programs in place, as well as EPA Regions III, VI, and IX. The framework for Risk-Based Corrective Action (RBCA) established by the American Society of Testing and Materials (ASTM) has also been used to develop this regulation. LDEQ has worked closely with many of the aforementioned organizations to develop the RECAP regulation.

The proposed RECAP regulation includes an example of a site-specific MO-2 analysis that may be used for typical Underground Storage Tank Sites (Appendix J). This analysis has been performed to exhibit the use of site-specific information to develop remedial standards. The Department will continue to encourage site-specific evaluations while working to achieve additional consistency and uniformity in its submittals. This will be accomplished by the continued evaluation of risk assessment tools such as computer programs and computer models to ensure that wide spread use of the proper tools is encouraged.

The RECAP document will be a "living" document that will be revised through rulemaking on an as needed basis to incorporate changes in the science of risk evaluation and revisions to toxicological data. Such revisions will also allow the Department to modify the regulation based on its work experience.

The Department has expended a great deal of time, effort, and resources to develop the RECAP regulation. The regulation has been developed with public input during three public comment periods that have taken place. The Department values any additional comments on the program subsequent to the rule becoming final.

All comments, questions, and requests for copies of this document should be directed to the Investigations and Regulation Development Division (IRDD) of the LDEQ. The IRDD may be contacted as follows:

Investigations and Regulation Development Division
Post Office Box 82282
Baton Rouge, Louisiana 70884-2282
(225) 765-0399

The document will also be available on the Internet on LDEQ's home page at:

http://www.deq.state.la.us/olae/irdd/recap/

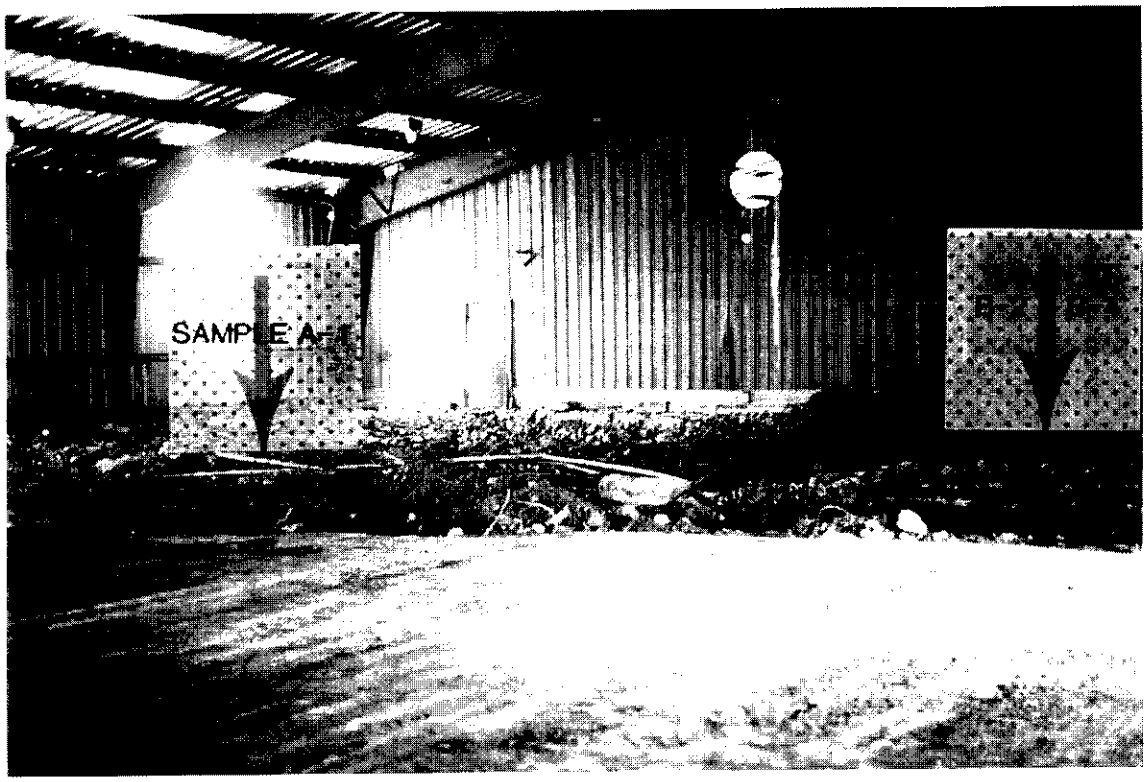
Thank you for your interest in LDEQ's Risk Evaluation/Corrective Action Program.

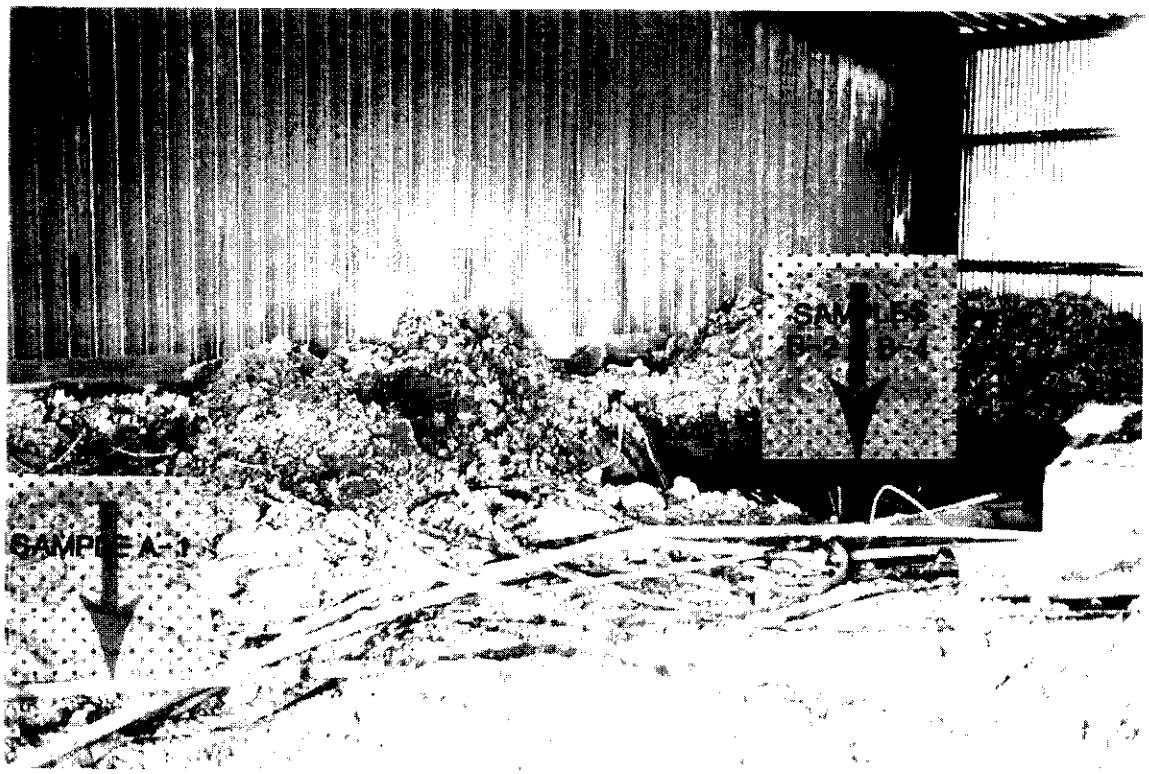
APPENDIX 2

DOCUMENTATION OF SAMPLING EFFORT

- Photographs
- Chain-of custody records
- Boring logs and sampling procedures for temporary groundwater monitoring point

PHOTOGRAPHS





PHOTOGRAPHS

PHOTOGRAPH

CHAIN-OF-CUSTODY RECORDS

ARGUS ANALYTICAL, INC
235 Highpoint Drive
Ridgeland, MS 39157
Telephone: 601/957-2676 FAX: 601/957-1887

I / MI

Argus Cooler # 150

CHAIN-OF-CUSTODY

Client Name: Vicksburg Chemical	Project Name/Location: SWMU 9	Project Number: 523007C
Address: Rifle Range Road, Vicksburg Mississippi	Sampler (print/signature): Dick Karkkainen 11-4-98	H/M/S (lab use)

Item #	Field Number	Sample Description	Collection Date	Time	Initials	G/C	#	Analysis Required	Lab Number (for lab use only)
1	A-A-1	Location A Soil 1' Depth	11/4/98	1115	DK			TCL/TAL *TCLP Metals	AA66497
2	A-B-1	Location A Soil 1' Depth	11/4/98	1210	DK			Atrazine/Dinoseb	↓
3	B-A-2	Location B Soil 2' Depth	11/4/98	1310	DK			TCL/TAL	AA66498
4	B-B-2	Location B Soil 2' Depth	11/4/98	1310	DK			Atrazine/Dinoseb	↓
5	B-A-4	Location B Soil 4' Depth	11/4/98	1315	DK			TCL/TAL	AA66499
6	B-B-4	Location B Soil 4' Depth	11/4/98	1315	DK			Atrazine/Dinoseb	↓

11/11/98 * Added TCLP Metals to AA66497 per Steve Boswell's instructions (Routine Turnaround).

see # AA66725

Relinquished by:	Date/time:	Accepted by:	Date/time	Relinquished by:	Date/time:	Accepted by:	Date/time
Dick Karkkainen	11/4/98 2145	Steven I. Boswell	11/4/98 1445	Steven I. Boswell	11/5/98 0750		
SB		Kelly Kuiper	11-5-98 15:40	Leonardo	11/5/98 7:50		

f:\users\public\forms\coc_r05.wk1 *faxed pending report 11-10-98 WK

Rev 11/98

Work order # 01-115220 (as per Soil work)

ARGUS ANALYTICAL, INC
235 Highpoint Drive
Ridgeland, MS 39157
Telephone: 601/957-2676 FAX: 601/957-1887

1 / MI

1 of 1 ES1

Argus Cooler #

CHAIN-OF-CUSTODY

Client Name: Vicksburg Chemical Address: 4280 Rifle Range Rd. Vicksburg, MS	Project Name/Location: SWMU #9 Grab Sampling Sampler (print/signature): [signature] John M. Ryan	Project Number: H/M/S (lab use)

Item #	Field Number	Sample Description	Collection Date	Collection Time	Collection Initials	Collection G/C	Collection #	Analysis Required	Lab Number (for lab use only)
		VCC-SWMU9-GW-TP1-01	11-11-98	1300	JZ	G	6	TAL Metals + CN, TCL Voas/Semivoas	AA66724
								+ TCL Pesticides / PCBs.	
								~~Atrazine & Dinoseb*~~ *	
								*added per Steve Boswell	
								11-12-98 (LNK) See	
								Sample AA66928 for	
								Atrazine & Dinoseb.	

Relinquished by:	Date/time:	Accepted by:	Date/time	Relinquished by:	Date/time:	Accepted by:	Date/time
David Kaen	1340 11/11/98	[signature] ES1	1340 11-11-98	[signature]	11-11-98 1438	Nicky Kuiper	11-11-98 14:38
Relinquished by:	Date/time:	Accepted by:	Date/time	Relinquished by:	Date/time:	Accepted by:	Date/time

f:\users\public\forms\coc_r05.wk1 *results faxed 11-12-98 (LNK)
AA66928 Faxed 11/15/98 @ 12:10 TJ

Rev 1196

235 Highpoint Drive
Jackson, MS 39213
Telephone: 601/957-2676 FAX: 601/957-1887

Argus Cooler #

CHAIN-OF-CUSTODY

Client Name: Vicksburg Chemical	Project Name/Location: SWMU 9	Project Number:
Address: P.O. Box 821003 Vicksburg, MS 39182 Attn: Steve Boswell	Sampler (print/signature): Blush, Eric Eric Blush	CFS (lab use)

Rush

Item #	Field Number	Sample Description	Collection Date	Time	Initials	G/C	#	Analysis Required	Lab Number (for lab use only)
1		TP-1	11/12/98	1400	EB	G	1	Dinoseb	AA66924
2		TP-2	11/12/98	1400	EB	G	1	Atrazine	↓
								PO # 01-115220	

Relinquished by:	Date/Time:	Accepted by:	Date/Time	Relinquished by:	Date/Time:	Accepted by:	Date/Time
Eric Blush	11-16-98 3:45	Vicky Kuper	11-16-98 15:45				
Relinquished by:	Date/Time:	Accepted by:	Date/Time	Relinquished by:	Date/Time:	Accepted by:	Date/Time

I:\users\lisa\forms\lotus\coc_r02.wk1

Refer to AA66724 for the balance of testing on this sample description

FAXed 11/19/98 17:15 JH

Rev 02/94

BORING LOGS AND SAMPLING PROCEDURES FOR TEMPORARY GROUNDWATER MONITORING POINT

Eco·Systems, Inc.
Consultants, Engineers and Scientists

February 15, 1999

Mr. Steve Boswell
Vicksburg Chemical Company
Vicksburg Mississippi, 39182-1003

RE: ***SWMU #9 Field Activities Letter Report***
South Plant, Vicksburg Chemical Company
Vicksburg, Mississippi

Dear Mr. Boswell:

Eco·Systems, Inc. (*Eco·Systems*) is pleased to present the following report summarizing field activities completed at Vicksburg Chemical Company's (Vicksburg Chemical) South Plant in Vicksburg, Mississippi (the Site). *Eco·Systems* was contracted to provide environmental quality control oversight during the completion of geotechnical borings in the vicinity of the solid waste management unit (SWMU) number nine (#9) and the collection of groundwater samples from the borings for laboratory analysis. The following provides a summary of the work completed, quality assurance/quality control (QA/QC) review of the analytical data, and a brief summary of the results.

Scope of Work

The area of concern, SWMU #9, is a former drumming and storage area for dinitro-butylphenol (DNBP) located on the Vicksburg Chemical property (Figure 1). This area is located south of the former mono-sodium methylarsenate (MSMA) storage area and is comprised of a steel frame building, concrete floor, and steel panels. A portion of the concrete floor was removed in the recent past due to construction and/or remedial investigation considerations. *Eco·Systems* understands that geotechnical borings were completed by Burns-Cooley-Dennis, Inc. (BCD) to support construction of a new facility in the vicinity of SWMU #9. Groundwater sampling was attempted at select intervals following completion of the geotechnical borings to provide supplemental information for an ongoing RCRA Facility Investigation (RFI) being completed by Woodward-Clyde Consultants for Vicksburg Chemical. Specifically, groundwater sampling was planned for the two (2) uppermost water-bearing zones initially anticipated to be encountered during boring advancement at the Site.

Field Activities

All field activities and/or oversight completed by *Eco·Systems* followed the methods and procedures set forth in Attachment A. One (1) geotechnical boring had been completed around SWMU #9 prior to *Eco·Systems'* arrival on November 10, 1998. Walker-Hill Environmental (WHE) was subcontracted by BCD to complete borings and install temporary groundwater

monitoring points (TPs) using a Geoprobe™. Soil sampling was conducted at several intervals for the purpose of geotechnical evaluation and selection of groundwater sampling intervals. Soil cores were prepared and shipped to BCD for further analysis. Three (3) borings were attempted for evaluation of both geotechnical characteristics and groundwater quality. Two (2) of three (3) were planned to be advanced to the top of the limestone underlying the Site (believed to be approximately 60 feet below land surface (bls). Boring logs detailing the lithology encountered can be found in Attachment B.

The first boring completed by WHE, GP-1, was located in the northern side of the former warehouse (Figure 1) and was advanced to 17 feet bls in continuous 4-foot intervals. Prior to installing a TP, a grab groundwater sample was collected by advancing a stainless steel well point (GSP) into the water-bearing zone. The grab groundwater sample was collected with a peristaltic pump and polyethylene tubing and was analyzed for total Arsenic utilizing the Vicksburg Chemical's onsite laboratory. Following removal of the GSP, boring GP-1 was converted to temporary groundwater monitoring point TP-1 to allow for short-term collection of grab groundwater samples. As illustrated in Attachment C, the temporary well was screened from six (6) to 16 feet bls with a filter sock covering the screen for secondary filtering. A sand pack consisting of 20/40 silica sand was placed around the temporary well to within three (3) feet bls and a seal of hydrated bentonite pellets was added to the surface. Boring GP-2 was attempted approximately 20 feet south of GP-1 in the former warehouse. A continuous subsurface obstruction (< 2 feet bls) prevented the boring from being advanced and after several offset attempts, the hole was aborted. The third boring, GP-3, was completed approximately 45 feet southeast of GP-1 to a depth of 61 feet bls through continuous sampling on 5-foot centers. The second water-bearing zone was not encountered at this point so a decision was made to terminate the boring at that depth. No groundwater sampling was completed at this location.

As presented in Attachment D, a grab groundwater sample was collected from TP-1 after the screened portion of the temporary well was "developed" by purging approximately one (1) gallon of water with a peristaltic pump until the particulates were minimized based on visual estimation. Following adequate purging, samples were collected for laboratory analysis of the full Target Analyte/Compound List (TAL/TCL) scan plus Atrazine and Dinoseb. Samples were placed on ice and delivered under proper chain of custody to Vicksburg Chemical's subcontract laboratory, Argus Analytical, Inc., of Jackson, Mississippi. Analytical data sheets can be found in Attachment E. Specific sample collection/handling methods and procedures are further described in Attachment A.

Eco·Systems performed a QA/QC review on all analytical data collected during this sampling event. *Eco·Systems* concluded that the analyses were conducted under well-controlled conditions, and with sufficient precision and accuracy to provide accurate analytical results with no qualifiers. After review of the analytical results (Attachment D) and the QA/QC procedures, elevated levels of the following compounds were observed above their respective Maximum Contaminant Level (MCL) and/or risk-based action levels (Risk-Based Concentration Table, EPA Region III, January-June, 1996) in the groundwater sample collected from TP-1:

TAL Metals

- Antimony at 0.012 milligrams per liter (milligrams per liter, or mg/L),
- Arsenic at 0.378 mg/L,
- Iron at 0.63 mg/L,
- Manganese at 3.66 mg/L,

TCL Volatiles

- 1,2 Dichlorobenzene at 0.011 mg/L, and
- Trichloroethene at 0.068 mg/L.

The data review indicated that the laboratory may have used practical quantitation limits (PQLs) which were greater than possible regulatory action levels (MCLs and/or risk-based standards) in effect potentially masking elevated concentrations of a few parameters of concern including Lead (non-detect at a PQL of 0.05 mg/L) and Atrazine and Dinoseb (non-detect at a PQL of 0.01 mg/L). Vicksburg Chemical notified their laboratory of these elevated PQLs and authorized re-analysis. The laboratory could only re-analyze the sample for total Lead and resulted in continued non-detect concentrations of total Lead except at a lowered PQL of 0.001 mg/L. Atrazine and Dinoseb could not be re-analyzed due to volume and holding time considerations and therefore the data is only adequate for gross screening-level purposes of the groundwater.

Closing

Eco·Systems appreciates the opportunity to assist Vicksburg Chemical Company with its environmental consulting needs. Please call me or Caleb Dana at (601) 936-4440 if you have any comments or require additional support in this process.

Sincerely,
Eco·Systems, Inc.

John Ryan
Project Geologist

Caleb H. Dana, Jr., P.E., CHHM
Principal Engineer

Attachments

TABLES

ESI

TABLE 1
TAL/TCL GROUNDWATER ANALYTICAL RESULTS
SWMU #9 GROUNDWATER SCREENING INVESTIGATION
VICKSBURG CHEMICAL COMPANY
VICKSBURG, MISSISSIPPI

PARAMETER[1]	PQL (mg/L)[2]	TP-1 CONCENTRATION (mg/L)[3]
TARGET ANALYTE LIST METALS (METHOD 200/300 SERIES)		
Aluminum	0.10	0.38
Antimony	0.001	0.012
Arsenic	0.005	0.378
Barium	0.10	0.22
Calcium	5.0	87.6
Chromium	0.05	ND[4]
Cobalt	0.05	0.06
Iron	0.03	0.63
Lead	0.05 / 0.001	ND / ND[5]
Magnesium	0.001	50.7
Manganese	0.10	3.66
Nickel	0.04	0.09
Potassium	0.10	3.02
Sodium	2.0	329
Zinc	0.02	0.07
All Others Not Listed	0.0002 - 0.1	ND

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TABLE 1 (Continued)
TAL/TCL GROUNDWATER ANALYTICAL RESULTS
SWMU #9 GROUNDWATER SCREENING INVESTIGATION
VICKSBURG CHEMICAL COMPANY
VICKSBURG, MISSISSIPPI

PARAMETER[1]	PQL (mg/L)[2]	TP-1 CONCENTRATION (mg/L)[3]
TARGET COMPOUND LIST VOLATILES (METHOD 8260)		
1,2 Dichlorobenzene	0.005	0.011
cis - 1,2-Dichloroethene	0.005	0.026
trans - 1,2-Dichloroethene	0.005	0.006
Trichloroethene	0.005	0.068
Xylenes (total)	0.005	0.014
All Others Not Listed	0.002 - 0.005	ND[4]
TARGET COMPOUND LIST SEMI-VOLATILES (METHOD 8270)		
1,2 Dichlorobenzene	0.002	0.004
n - Nitrosodiphenylamine	0.002	0.002
All Others Not Listed	0.002 - 0.005	ND
TARGET COMPOUND LIST PESTICIDES/PCBs (METHOD 8081)		
All	0.00005 - 0.002	ND
OTHER COMPOUNDS OF CONCERN		
Atrazine (Method 8141)	0.01	ND
Dinoseb (Method 8270)	0.01	ND

[1] Groundwater collected from TP-1 was analyzed for the entire Target Analyte/Compound List as well as select compounds not included in this suite.

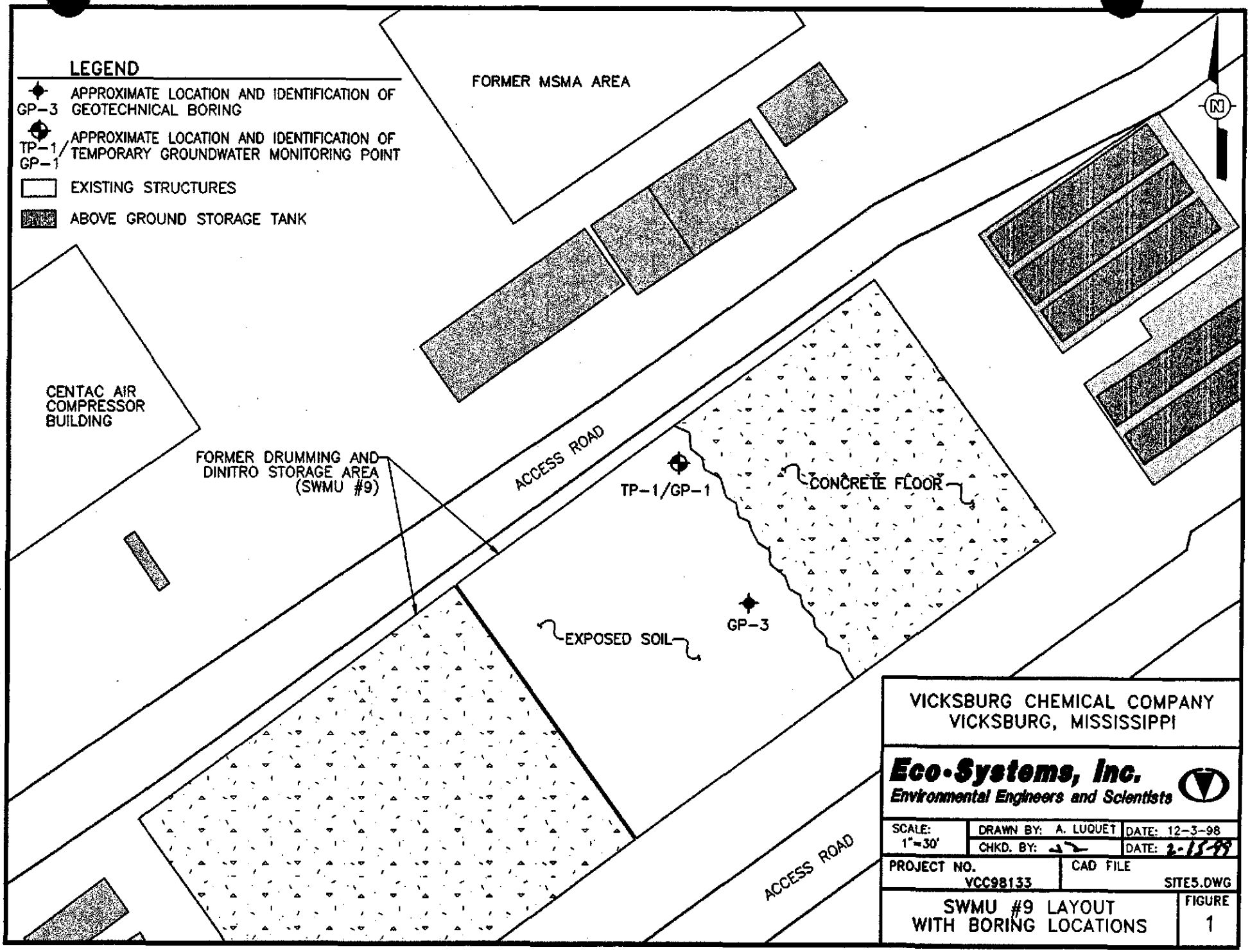
[2] PQL = Practical quantitation limit, or detection limit, for the individual analyses.

[3] Result concentrations are reported in milligrams per liter (mg/L), equivalent to parts per million (ppm).

[4] Result was below the PQL, or "Non-Detect".

[5] Due to the initially-elevated PQL (0.05 mg/L), the sample was re-analyzed at the lower PQL (0.001 mg/L) within holding times.

FIGURES


LEGEND
GP-3 APPROXIMATE LOCATION AND IDENTIFICATION OF GEOTECHNICAL BORING
TP-1/GP-1 APPROXIMATE LOCATION AND IDENTIFICATION OF TEMPORARY GROUNDWATER MONITORING POINT
EXISTING STRUCTURES
ABOVE GROUND STORAGE TANK
FORMER MSMA AREA
CENTAC AIR COMPRESSOR BUILDING
FORMER DRUMMING AND DINITRO STORAGE AREA (SWMU #9)
ACCESS ROAD
TP-1/GP-1
CONCRETE FLOOR
GP-3
EXPOSED SOIL
ACCESS ROAD
N
VICKSBURG CHEMICAL COMPANY
VICKSBURG, MISSISSIPPI
Eco-Systems, Inc.
Environmental Engineers and Scientists
SCALE: 1"=30'
DRAWN BY: A. LUQUET
DATE: 12-3-98
CHKD. BY:
DATE: 2-15-99
PROJECT NO. VCC98133
CAD FILE SITE5.DWG
SWMU #9 LAYOUT WITH BORING LOCATIONS
FIGURE 1
A.L. 12/07/1998 16:23 D:\DRWG\VICKCHEM\SITE5

ESI

ATTACHMENT A

METHODS AND PROCEDURES

METHODS AND PROCEDURES

SOIL SAMPLING PROCEDURES

Drilling and sampling was accomplished with a hydraulic probing apparatus (GeoProbe™) designed to expedite boring advancement and sample collection as well as to minimize the generation of soil cuttings. Samples were collected from each interval for field screening and lithologic description. Following examination of a portion of the cored interval, the core was properly labeled, sealed, and shipped to a geotechnical laboratory for further examination.

GROUNDWATER ASSESSMENT PROCEDURES

Temporary Groundwater Monitoring Point Installation

Groundwater quality was monitored through the installation of temporary groundwater monitoring points (TPs). Immediately following the completion the boring, a TP was installed into the open borehole. TPs were completed by installing a 3/4-inch (I.D.) PVC screen and riser into the anticipated water-bearing interval. A filter sock was applied and secured to the screened interval prior to installation into the borehole. 20/40 silica sand was added around the screen to a depth of approximately two feet above the top of the screen. A bentonite seal was placed within the remaining portion of the open hole.

For GSP installation, a special stainless-steel rod with inner stainless steel screen (0.01-inch slots) was hydraulically pushed to the desired depth. Upon reaching the desired sampling interval, a release mechanism allowed the protective sleeve to be removed exposing the screened portion of the device to the water-bearing zone. This temporary screen allowed for effective filtration of fines to produce a relatively low turbidity sample without installation of excessive well construction materials.

Groundwater Sampling

Prior to collecting a groundwater sample, the TPs and the GSPs were purged using a low-flow/low-stress technique. This technique consisted of slowly lowering dedicated tubing connected to a peristaltic pump (if groundwater is encountered less than 26 feet bls) into a region of adequate permeability within the water-bearing zone. Purging began with withdrawal of water at a rate that created an equilibrium with recharge (e.g., stabilized water table). Following adequate purging, the low permeability of the site soils prevented attempts at establishing the necessary "equilibrium". Therefore, the borehole was successively purged dry at a low rate and allowed to recharge until particulates were minimized.

Following adequate purging, groundwater to be analyzed was sampled by collecting water from the discharge stream directly into the laboratory-supplied sample containers for subsequent laboratory analysis. Groundwater samples to be analyzed for volatile analysis were

collected from water in the influent tubing (e.g., prior to entering the pump head) in order to avoid concerns for volatilization inherent to the pumping mechanism (suction lift techniques). Tubing used during purging and sampling was disposed of after use. Subsequent to sampling, sample containers were placed in an ice chest and shipped under chain of custody via ground courier to the designated laboratory. Personnel involved in sampling wore latex gloves which were changed between each sample collection. All non-disposable sampling equipment were decontaminated as outlined below.

SAMPLE IDENTIFICATION

The sample collected was identified by a unique alpha-numeric code. The first three digits of each sample code denoted the Vicksburg Chemical Company (VCC) site. This portion of the code was following by a hyphen (-) and the indication of the area of concern the sample was taken (SWMU9). A hyphen and "GW" followed this portion indicating that this was a groundwater sample. This portion was followed by a hyphen and the identification of the temporary well the sample was collected from (TP-1) and the subsequent sampling event (01).

Subsequent to sampling, a waterproof paper label was attached to each sample container containing the following information:

- Project number,
- Site/project name,
- Sample identification code,
- Sampler's name,
- Date and time the sample was collected, and
- Parameters for analysis.

DECONTAMINATION

All drilling equipment used to collect subsurface soil and groundwater samples (drill rods and samplers, screens points (stainless and PVC)) were decontaminated initially by high-pressure steam cleaning. Decontamination between sampling intervals was also performed to preclude vertical cross-contamination between sample intervals/locations. For stainless-steel sampling equipment specifically used for collecting soil samples (e.g., trowels, bowls, etc.), decontamination was accomplished by the following procedure:

1) Phosphate-free detergent wash.
2) Potable water rinse.
3) Deionized water rinse.
4) Isopropanol rinse.
5) Organic-free water rinse or air dry.
6) Individual tin foil wrap.

For boring activities, separate decontaminated samplers was used between sample intervals within the same boring, thereby requiring decontamination between boring locations only.

ANALYTICAL METHODS

Groundwater samples were analyzed by Argus Analytical, Inc. of Jackson, Mississippi using EPA-approved methods. The following methods were utilized for the corresponding parameters-of-concern: TAL Metals (200 and 300 series EPA Methods), TCL Volatiles (Method 8260), TCL Semivolatiles (Method 8270), TCL Pesticides and PCBs (Method 8081), Atrazine (Method 8141), and Dinoseb (Method 8270). A data quality report was prepared by the laboratory and included in the final report.

MANAGEMENT OF INVESTIGATIVE-DERIVED WASTE

All investigative-derived waste, IDW, (e.g., decontamination water, well purge water, personal protective equipment, etc.) was staged immediately following generation in a readily-accessible area to facilitate subsequent management by Vicksburg Chemical.. Best Management Practices (BMPs), as outlined in the Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EPA Region IV, May, 1996), were followed to minimize waste volumes and minimize client liability. No soil cuttings were generated during this event.

OTHER PROCEDURES

Procedures for sample containerization and packing, sample shipment, cross-contamination control, field documentation, chain-of-custody, and data review will be conducted in accordance with the Environmental Investigations Standard Operating Procedures and Quality Assurance Manual.

ESI

ATTACHMENT B

BORING LOGS

Project Name: SWMU #9 GROUNDWATER INVESTIGATION
Project Location: VICKSBURG, MS
Project Number: VCC-98183
Geologist: John Ryan

Classification Scheme: USCS
Driller: Walker-Hill
Drill Method: Geoprobe
Weather: Sunny and Mild

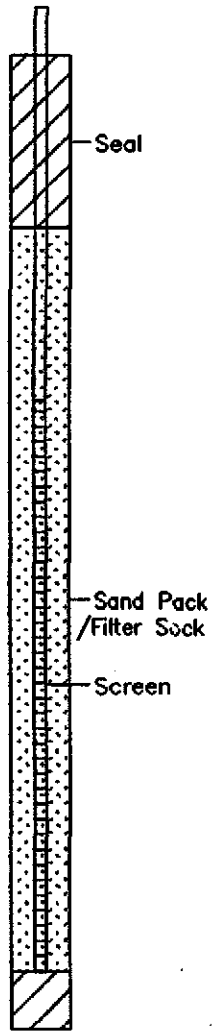
BORING GP-1

(Page 1 of 1)

Bore Hole Diameter: 2"
Boring Start Time, Date: 10:51, 11-10-98
Boring End Time, Date: 11:45, 11-10-98
Final Boring Depth: 20'

Depth in Feet	Recovery (inches)	Blow Count (Blows/6")	PID (HEADSPACE)	Sample Interval	LITHOLOGY	USCS	Moisture	DESCRIPTION
0-2	42					ML	Moist Damp	Soft-med. stiff Lt. gray w/ tan Clayey Silt -(loess)
2-4								
4-6	41					ML		
6-8		N/A	N/A				Moist Saturated	
8-10	32					ML		
10-12	33					ML		w. shelly fragments
12-14								
14-16	33					ML		
16-18								TD = 17'
18-20								

TP-1



Notes:

Boring was converted into temporary monitoring point TP-1.

Eco-Systems, Inc.
Environmental Engineers and Scientists

12-03-1998\mtech5\bif\wick-gp1.bor

Project Name: SWMU #9 GROUNDWATER ASSESSMENT
Project Location: VICKSBURG, MS
Project Number: VCC-98183
Geologist: John Ryan

Classification Scheme: USCS
Driller: Walker-Hill
Drill Method: Geoprobe
Weather: Sunny and Hot

BORING GP-3

(Page 1 of 2)

Bore Hole Diameter: 2"
Boring Start Time, Date: 14:15, 11-10-98
Boring End Time, Date: 9:07, 11-11-98
Final Boring Depth: 61'

Depth in Feet	Recovery (inches)	Blow Count (Blows/6")	PID (HEADSPACE)	Sample Interval	LITHOLOGY	USCS	Moisture	DESCRIPTION
0-2								No Sampling (0-4')
4	Full			X		ML	Moist	Loose, Gray with brown, Clayey Silt (loess)
6-8								No Sampling (6-9')
10	20			X		ML	V. Moist	Soft, Lt. brown with Gray, Clayey Silt
12								No Sampling (11-14')
14	21			X		ML	Wet	Soft, Lt. brown with Gray, Clayey Silt (trace lignite)
16-18								No Sampling (16-19')
20	21			X		ML	Saturated	Soft, Brown, Clayey Silt (trace lignite)
22								No Sampling (21-24')
24	21			X		CH	Saturated	Soft, Gray, V. Silty Clay
26-28								No Sampling (26-29')
30	30			X		CH	Saturated	Soft, Gray, Silty Clay

Notes:

No deeper water bearing zone was encountered.
Boring was grouted to surface.

Eco-Systems, Inc.
Environmental Engineers and Scientists

12-01-1998\ mtech6\ bf\ vick-gp3.bor

Project Name: SWMU #9 GROUNDWATER ASSESSMENT
Project Location: VICKSBURG, MS
Project Number: VCC-98183
Geologist: John Ryan

Classification Scheme: USCS
Driller: Walker-Hill
Drill Method: Geoprobe
Weather: Sunny and Hot

BORING GP-3

(Page 2 of 2)

Bore Hole Diameter: 2"
Boring Start Time, Date: 14:15, 11-10-98
Boring End Time, Date: 9:07, 11-11-98
Final Boring Depth: 61'

Depth in Feet	Recovery (inches)	Blow Count (Blows/6")	PID (HEADSPACE)	Sample Interval	LITHOLOGY	USCS	Moisture	DESCRIPTION
31								
33								No Sampling (31-34')
35	Full			X		CH	Saturated	Soft, Gray, Silty Clay
37								No Sampling (36-39')
39	Full			X		CH	Saturated	Soft, Gray, Silty Clay
41								
43								No Sampling (41-44')
45	Full			X		ML	Dry	Med-stiff, Gray, Silt tr. Clay
47								
49								No Sampling (46-54')
51								
53								
55	Full			X		ML	Damp	Med-stiff, Gray-green, Clayey Silt
57								No Sampling (56-59')
59	Full			X		CH	Damp	Stiff, Gray, Clay with Silt (marl)
61								TD = 61'

Notes:

No deeper water bearing zone was encountered.
Boring was grouted to surface.

Eco-Systems, Inc.
Environmental Engineers and Scientists

12-1998\mtech5\bfl\vick-gp3.bor

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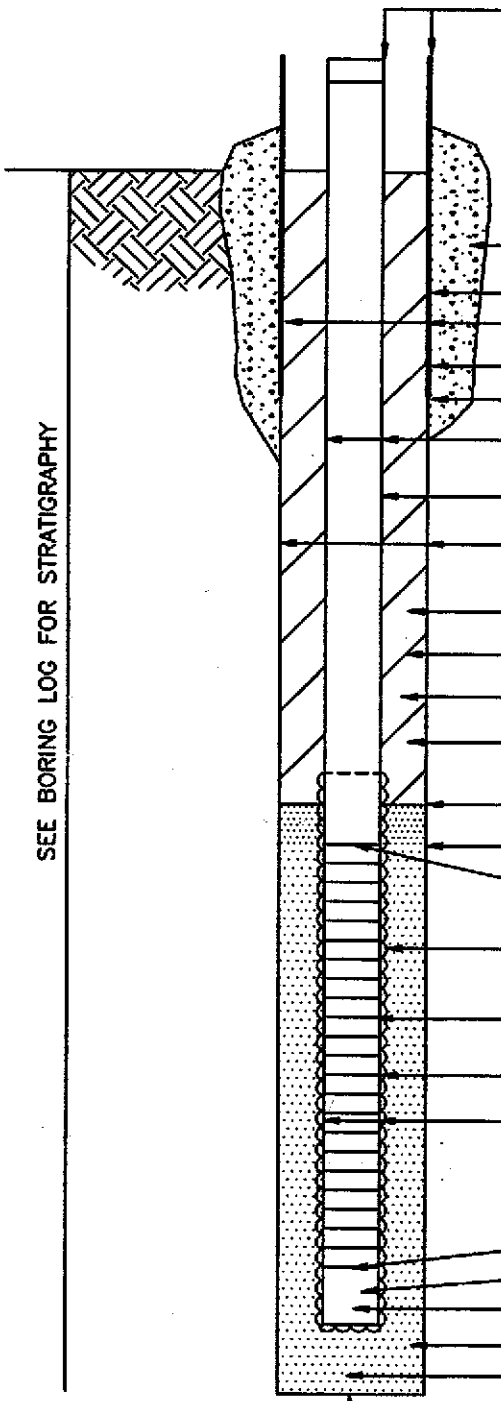
ATTACHMENT C

TEMPORARY MONITORING POINT COMPLETION FORM

TEMPORARY MONITORING POINT COMPLETION FORM

PROJECT NAME: SWMU #9 GROUNDWATER ASSESSMENT
PAGE: 1 OF 1
LOCATION: VICKSBURG CHEMICAL; VICKSBURG, MS
WELL NO.: TP-1
DATE COMPLETED: 11-10-98
BOREHOLE DEPTH: 17'
BOREHOLE WATER LEVEL: 8' BLS
DRILLER: WALKER-HILL
GEOLOGIST: RYAN
DRILL METHOD: GEOPROBE
STATIC WATER LEVEL: 4.2' BTOC
INSPECTED BY: RYAN
DATE: 11-11-98
SCREEN INTERVAL: 6-16' BLS



ELEVATION OF TOP OF SURFACE CASING/RISER PIPE: N/A
HEIGHT OF TOP OF SURFACE CASING/RISER PIPE ABOVE GROUND SURFACE: 4.1'
TYPE OF SURFACE SEAL: N/A
DEPTH OF SURFACE SEAL BELOW GROUND SURFACE: N/A
INSIDE DIAMETER OF SURFACE CASING: N/A
TYPE OF PROTECTIVE CASING: N/A
DEPTH OF PROTECTIVE CASING BELOW GROUND: N/A
INSIDE DIAMETER OF RISER PIPE: 7/8"
TYPE OF RISER PIPE: SCH. 40 PVC
DIAMETER OF BOREHOLE: 2"
TYPE OF BACKFILL: 1/8" BENTONITE PELLETS
ELEVATION / DEPTH TOP OF SEAL: SURFACE
TYPE OF SEAL: 1/8" BENTONITE PELLETS
ELEVATION / DEPTH BOTTOM OF SEAL: 3'
DEPTH OF TOP OF SAND PACK: 3'
TYPE OF SAND PACK: 20/40 SILICA SAND
ELEVATION / DEPTH TOP OF SCREENED SECTION: 6'
FILTER SOCK: YES
TYPE OF SCREENED SECTION: 0.01 SLOT SCH. 40 PVC
DESCRIBE OPENINGS: 0.01 SLOT
INSIDE DIAMETER OF SCREENED SECTION: 7/8"
ELEVATION / DEPTH BOTTOM OF SCREENED SECTION: 15.9'
LENGTH OF BLANK SECTION: 1"
ELEVATION/DEPTH BOTTOM OF PLUGGED BLANK SECTION: 16.0'
ELEVATION/DEPTH BOTTOM OF SAND COLUMN: 16.0'
TYPE OF BACKFILL BELOW OBSERVATION PIPE: NATURAL FORMATION
ELEVATION/DEPTH OF HOLE: 17.0'

Eco-Systems, Inc.
Environmental Engineers and Scientists

S.M. 1999 11:04 E:\DRWG\JR\SWMUTP1

ESI

ATTACHMENT D

GROUNDWATER COLLECTION REPORT

GROUNDWATER SAMPLE COLLECTION REPORT

FIELD LOG

PROJECT NAME: SWMU #9 GW Screening LOCATION: Vicksburg, MS

COLLECTOR (S): Ryan + Keen WELL IDENTIFICATION: TP-1

MONITORING WELL DATA

TOP OF CASING TO STATIC WATER LEVEL: 8.21' TOP OF CASING TO BOTTOM: 20'

ELEVATION TOP OF CASING: —

MONITORING WELL EVACUATION

EVACUATION: (DATE/TIME): 9:32 11-10-98

METHOD OF EVACUATION: Peristaltic Pump (Low flow - Low Stress)

PURGE/SAMPLING DEPTH (FEET B.T.O.C.): bottom

TOTAL GALLONS EVACUATED: 1.2 Gallons

WATER LEVEL FOLLOWING EVACUATION: —

MONITORING WELL SAMPLING

SAMPLING (DATE/TIME): 13:00 11-11-98

METHOD OF SAMPLING: as above

WATER LEVEL FOLLOWING SAMPLING: —

TYPE OF SAMPLE: GRAB: X COMPOSITE: OTHER:

SAMPLE REPRESENTATIVENESS DATA

No Metering "Well Purged Dry"

TIME: CUMULATIVE VOLUME: TEMP.: pH: CONDUCTIVITY: TURBIDITY:

TIME: CUMULATIVE VOLUME: TEMP.: pH: CONDUCTIVITY: TURBIDITY:

TIME: CUMULATIVE VOLUME: TEMP.: pH: CONDUCTIVITY: TURBIDITY:

TIME: CUMULATIVE VOLUME: TEMP.: pH: CONDUCTIVITY: TURBIDITY:

TIME: CUMULATIVE VOLUME: TEMP.: pH: CONDUCTIVITY: TURBIDITY:

TIME: CUMULATIVE VOLUME: TEMP.: pH: CONDUCTIVITY: TURBIDITY:

GENERAL INFORMATION

WEATHER CONDITIONS AT TIMES OF SAMPLING: Partly Sunny & WARM

SAMPLE IDENTIFICATION: VCC-SWMU9-GW-TP1-01

CONTAINERS AND PRESERVATIVES: 500ml Plastic w/ HNO_3; 3 VOA vials w/ HCl; 3 liter Amber bottles.

COMMENTS AND OBSERVATIONS: Very clear w/ no unnatural odor/color.

RECOMMENDATIONS:

CERTIFICATION

SIGNATURE: [signature] DATE: 11-15-98

Eco-Systems, Inc.

APPENDIX 3

ANALYTICAL

- Analytical Reports
- Holding Time Report
- Inorganic Q C
- Organic Q C

ANALYTICAL REPORTS

ARGUS ANALYTICAL, INC.
235 Highpoint Drive
Ridgeland, Mississippi 39157
Telephone: 601/957-2676 FAX: 601/957-1887

To: Vicksburg Chemical
PO Box 821003
Vicksburg, MS 39182

Attn: Steve Boswell

Date Reported: 11/11/98

Date Sampled: 11/04/98
Time Sampled: 13:15
Sampled by: DK

Project ID/Location: SWMU 9

Date Received: 11/05/98

Sample Description: A-A/B-1 Location A Soil Depth 1ft

Sample Number: AA66497

Sample Matrix: SOIL

Project Number: 92B007C

Page Number: 1

Parameter	Result	Det Limit	Units	Method	Analysts	Date
Atrazine	ND	0.333	mg/Kg	8141	MMP	11/10/98
Dinoseb	ND	0.333	mg/Kg	8270	KLP	11/06/98
TAL						
Aluminum	8790	2500	mg/Kg	7020	DPF	11/10/98
Antimony	ND	0.025	mg/Kg	7041	DPF	11/09/98
Arsenic	9.06	0.125	mg/Kg	7060	DPF	11/08/98
Barium	59.7	2.5	mg/Kg	7080	DPF	11/09/98
Beryllium	0.896	0.125	mg/Kg	7090	DPF	11/09/98
Cadmium	0.874	0.125	mg/Kg	7130	DPF	11/06/98
Calcium	30900	1250	mg/Kg	7140	DPF	11/10/98
Chromium	245.3	12.5	mg/Kg	7190	DPF	11/06/98
Cobalt	7.91	1.25	mg/Kg	7200	DPF	11/09/98
Copper	29.11	0.50	mg/Kg	7210	DPF	11/06/98
Iron	15500	750	mg/Kg	7380	DPF	11/10/98
Lead	46.09	1.25	mg/Kg	7420	DPF	11/06/98
Magnesium	1110	2.50	mg/Kg	7450	DPF	11/09/98
Manganese	627	25.0	mg/Kg	7460	DPF	11/10/98
Mercury	0.144	0.1000	mg/Kg	7471	PLP	11/09/98
Nickel	21.09	1.0	mg/Kg	7520	DPF	11/06/98
Potassium	981	10.0	mg/Kg	7610	DPF	11/10/98
Selenium	ND	0.125	mg/Kg	7740	DPF	11/08/98
Silver	ND	1.25	mg/Kg	7760	DPF	11/09/98
Sodium	273.5	0.50	mg/Kg	7770	DPF	11/09/98
Thallium	8.04	2.5	mg/Kg	7840	DPF	11/09/98
Vanadium	23.50	5.0	mg/Kg	7910	DPF	11/09/98
Zinc	82.04	5.0	mg/Kg	7950	DPF	11/06/98
Cyanide, Total	ND	1.0	mg/Kg	9010	ERM	11/09/98

TCL Volatile Organics

Sample Description: A-A/B-1 Location A Soil Depth 1ft

Sample Number: AA66497

Parameter	Result	Det Limit	Units	Method	Analysts	Date
Acetone	ND	0.100	mg/Kg	8260	KLP	11/10/98
Benzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
Bromochloromethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Bromodichloromethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Bromoform	ND	0.100	mg/Kg	8260	KLP	11/10/98
Bromomethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
2-Butanone (MEK)	ND	0.100	mg/Kg	8260	KLP	11/10/98
Carbon disulfide	ND	0.100	mg/Kg	8260	KLP	11/10/98
Carbon tetrachloride	ND	0.100	mg/Kg	8260	KLP	11/10/98
Chlorobenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
Chloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Chloroform	ND	0.100	mg/Kg	8260	KLP	11/10/98
Chloromethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Dibromochloromethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dibromo-3-chloropropane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dibromoethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dichlorobenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,3-Dichlorobenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,4-Dichlorobenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1-Dichloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dichloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1-Dichloroethene	ND	0.100	mg/Kg	8260	KLP	11/10/98
cis-1,2-Dichloroethene	ND	0.100	mg/Kg	8260	KLP	11/10/98
trans-1,2-Dichloroethene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dichloropropane	ND	0.100	mg/Kg	8260	KLP	11/10/98
cis-1,3-Dichloropropene	ND	0.100	mg/Kg	8260	KLP	11/10/98
trans-1,3-Dichloropropene	ND	0.100	mg/Kg	8260	KLP	11/10/98
Ethylbenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
2-Hexanone	ND	0.100	mg/Kg	8260	KLP	11/10/98
4-Methyl-2-pentanone (MIBK)	ND	0.100	mg/Kg	8260	KLP	11/10/98
Methylene chloride	ND	0.100	mg/Kg	8260	KLP	11/10/98
Styrene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1,2,2-Tetrachloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Tetrachloroethene (PCE)	ND	0.100	mg/Kg	8260	KLP	11/10/98
Toluene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1,1-Trichloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1,2-Trichloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Trichloroethene (TCE)	ND	0.100	mg/Kg	8260	KLP	11/10/98
Vinyl chloride	ND	0.100	mg/Kg	8260	KLP	11/10/98
Xylenes (total)	ND	0.100	mg/Kg	8260	KLP	11/10/98
TCL Semivolatile Organics						
Acenaphthene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Acenaphthylene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Anthracene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Benzo(a)anthracene	1.11	0.100	mg/Kg	8270	KLP	11/06/98
Benzo(a)pyrene	1.16	0.100	mg/Kg	8270	KLP	11/06/98
Benzo(b)fluoranthene	0.977	0.100	mg/Kg	8270	KLP	11/06/98

Sample Description: A-A/B-1 Location A Soil Depth 1ft

Sample Number: AA66497

Parameter	Result	Det Limit	Units	Method	Analysts	Date
Benzo(g,h,i)perylene	0.551	1.000	mg/Kg	8270	KLP	11/06/98
Benzo(k)fluoranthene	1.15	0.100	mg/Kg	8270	KLP	11/06/98
bis(2-Chloroethoxy)methane	ND	0.100	mg/Kg	8270	KLP	11/06/98
bis(2-Chloroethyl)ether	ND	0.100	mg/Kg	8270	KLP	11/06/98
bis(2-Chloroisopropyl)ether	ND	0.100	mg/Kg	8270	KLP	11/06/98
bis(2-Ethylhexyl) phthalate	ND	1.000	mg/Kg	8270	KLP	11/06/98
4-Bromophenyl phenyl ether	ND	0.100	mg/Kg	8270	KLP	11/06/98
Butyl benzyl phthalate	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Chloroaniline	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Chloro-3-methylphenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
2-Chloronaphthalene	ND	0.100	mg/Kg	8270	KLP	11/06/98
2-Chlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Chlorophenyl phenyl ether	ND	0.100	mg/Kg	8270	KLP	11/06/98
Chrysene	1.34	0.100	mg/Kg	8270	KLP	11/06/98
o-Cresol	ND	0.100	mg/Kg	8270	KLP	11/06/98
p-Cresol	ND	0.100	mg/Kg	8270	KLP	11/06/98
Dibenzo(a,h)anthracene	ND	1.000	mg/Kg	8270	KLP	11/06/98
Dibenzofuran	ND	0.100	mg/Kg	8270	KLP	11/06/98
Di-n-butyl phthalate	ND	0.100	mg/Kg	8270	KLP	11/06/98
1,2-Dichlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
1,3-Dichlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
1,4-Dichlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
3,3'-Dichlorobenzidine	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,4-Dichlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
Diethyl phthalate	ND	1.000	mg/Kg	8270	KLP	11/06/98
Dimethyl phthalate	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,4-Dimethylphenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
4,6-Dinitro-2-methylphenol	ND	1.000	mg/Kg	8270	KLP	11/06/98
2,4-Dinitrophenol	ND	1.000	mg/Kg	8270	KLP	11/06/98
2,4-Dinitrotoluene	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,6-Dinitrotoluene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Di-n-octyl phthalate	ND	0.100	mg/Kg	8270	KLP	11/06/98
Fluoranthene	1.35	0.100	mg/Kg	8270	KLP	11/06/98
Fluorene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Hexachlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Hexachlorobutadiene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Hexachlorocyclopentadiene	ND	1.000	mg/Kg	8270	KLP	11/06/98
Hexachloroethane	ND	0.100	mg/Kg	8270	KLP	11/06/98
Indeno(1,2,3-cd)pyrene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Isophorone	ND	0.100	mg/Kg	8270	KLP	11/06/98
2-Methylnaphthalene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Naphthalene	ND	0.100	mg/Kg	8270	KLP	11/06/98
2-Nitroaniline	ND	0.100	mg/Kg	8270	KLP	11/06/98
3-Nitroaniline	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Nitroaniline	ND	1.000	mg/Kg	8270	KLP	11/06/98
Nitrobenzene	ND	1.000	mg/Kg	8270	KLP	11/06/98
2-Nitrophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Nitrophenol	ND	1.000	mg/Kg	8270	KLP	11/06/98

Sample Description: A-A/B-1 Location A Soil Depth 1ft

Sample Number: AA66497

Parameter	Result	Det Limit	Units	Method	Analysts	Date
n-Nitrosodi-n-propylamine	ND	0.100	mg/Kg	8270	KLP	11/06/98
n-Nitrosodiphenylamine	ND	0.100	mg/Kg	8270	KLP	11/06/98
Pentachlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
Phenanthrene	0.338	0.100	mg/Kg	8270	KLP	11/06/98
Phenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
Pyrene	ND	0.100	mg/Kg	8270	KLP	11/06/98
1,2,4-Trichlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,4,5-Trichlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,4,6-Trichlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
TCL Pesticides & PCBs						
Aldrin	ND	0.0017	mg/Kg	8081	MMP	11/09/98
alpha-BHC	ND	0.0017	mg/Kg	8081	MMP	11/09/98
beta-BHC	ND	0.0017	mg/Kg	8081	MMP	11/09/98
gamma-BHC (Lindane)	ND	0.0017	mg/Kg	8081	MMP	11/09/98
delta-BHC	ND	0.0017	mg/Kg	8081	MMP	11/09/98
alpha-Chlordane	ND	0.0017	mg/Kg	8081	MMP	11/09/98
gamma-Chlordane	ND	0.0017	mg/Kg	8081	MMP	11/09/98
4,4'-DDT	ND	0.0033	mg/Kg	8081	MMP	11/09/98
4,4'-DDE	0.011	0.0033	mg/Kg	8081	MMP	11/09/98
4,4'-DDD	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Dieldrin	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endosulfan I	ND	0.0017	mg/Kg	8081	MMP	11/09/98
Endosulfan II	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endosulfan sulfate	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endrin	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endrin aldehyde	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endrin ketone	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Heptachlor	ND	0.0017	mg/Kg	8081	MMP	11/09/98
Heptachlor epoxide	ND	0.0017	mg/Kg	8081	MMP	11/09/98
Methoxychlor	ND	0.0165	mg/Kg	8081	MMP	11/09/98
PCB-1016	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1221	ND	0.0667	mg/Kg	8081	MMP	11/09/98
PCB-1232	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1242	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1248	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1254	0.527	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1260	ND	0.0333	mg/Kg	8081	MMP	11/09/98
Toxaphene	ND	0.0333	mg/Kg	8081	MMP	11/09/98

ND = Not Detected

Quality Assurance/Quality Control

B. G. Giessner, Ph.D.

argsmpr0

ARGUS ANALYTICAL, INC.

235 Highpoint Drive
Ridgeland, Mississippi 39157
Telephone: 601/957-2676 FAX: 601/957-1887

To: Vicksburg Chemical
PO Box 821003
Vicksburg, MS 39182

Attn: Steve Boswell

Date Reported: 11/10/98

Date Sampled: 11/04/98
Time Sampled: 13:30
Sampled by: DK

Project ID/Location: SWMU 9

Date Received: 11/05/98

Sample Description: B-A/B-2 Location B Soil Depth 2ft
Sample Matrix: SOIL
Project Number: 92B007C

Sample Number: AA66498

Page Number: 1

Parameter	Result	Det Limit	Units	Method	Analysts	Date
Atrazine	ND	0.333	mg/Kg	8141	KLP	11/10/98
Dinoseb	ND	0.333	mg/Kg	8270	KLP	11/06/98
TAL						
Aluminum	9800	2500	mg/Kg	7020	DPF	11/10/98
Antimony	ND	0.025	mg/Kg	7041	DPF	11/09/98
Arsenic	7.32	0.125	mg/Kg	7060	DPF	11/08/98
Barium	85.9	2.5	mg/Kg	7080	DPF	11/09/98
Beryllium	0.705	0.125	mg/Kg	7090	DPF	11/09/98
Cadmium	0.610	0.125	mg/Kg	7130	DPF	11/06/98
Calcium	14200	1250	mg/Kg	7140	DPF	11/10/98
Chromium	45.60	1.25	mg/Kg	7190	DPF	11/06/98
Cobalt	8.52	1.25	mg/Kg	7200	DPF	11/09/98
Copper	13.73	0.50	mg/Kg	7210	DPF	11/06/98
Iron	17800	750	mg/Kg	7380	DPF	11/10/98
Lead	14.38	1.25	mg/Kg	7420	DPF	11/06/98
Magnesium	799	2.50	mg/Kg	7450	DPF	11/09/98
Manganese	719	25.0	mg/Kg	7460	DPF	11/10/98
Mercury	ND	0.1000	mg/Kg	7471	PLP	11/09/98
Nickel	19.15	1.0	mg/Kg	7520	DPF	11/06/98
Potassium	1060	5.00	mg/Kg	7610	DPF	11/10/98
Selenium	ND	0.125	mg/Kg	7740	DPF	11/08/98
Silver	ND	1.25	mg/Kg	7760	DPF	11/09/98
Sodium	153.5	0.50	mg/Kg	7770	DPF	11/09/98
Thallium	6.85	2.5	mg/Kg	7840	DPF	11/09/98
Vanadium	22.00	5.0	mg/Kg	7910	DPF	11/09/98
Zinc	48.90	5.0	mg/Kg	7950	DPF	11/06/98
Cyanide, Total	ND	1.0	mg/Kg	9010	ERM	11/09/98
TCL Volatile Organics						

Sample Description: B-A/B-2 Location B Soil Depth 2ft

Sample Number: AA66498

Parameter	Result	Det Limit	Units	Method	Analysts	Date
Acetone	ND	0.100	mg/Kg	8260	KLP	11/10/98
Benzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
Bromochloromethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Bromodichloromethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Bromoform	ND	0.100	mg/Kg	8260	KLP	11/10/98
Bromomethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
2-Butanone (MEK)	ND	0.100	mg/Kg	8260	KLP	11/10/98
Carbon disulfide	ND	0.100	mg/Kg	8260	KLP	11/10/98
Carbon tetrachloride	ND	0.100	mg/Kg	8260	KLP	11/10/98
Chlorobenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
Chloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Chloroform	ND	0.100	mg/Kg	8260	KLP	11/10/98
Chloromethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Dibromochloromethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dibromo-3-chloropropane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dibromoethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dichlorobenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,3-Dichlorobenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,4-Dichlorobenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1-Dichloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dichloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1-Dichloroethene	ND	0.100	mg/Kg	8260	KLP	11/10/98
cis-1,2-Dichloroethene	ND	0.100	mg/Kg	8260	KLP	11/10/98
trans-1,2-Dichloroethene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dichloropropane	ND	0.100	mg/Kg	8260	KLP	11/10/98
cis-1,3-Dichloropropene	ND	0.100	mg/Kg	8260	KLP	11/10/98
trans-1,3-Dichloropropene	ND	0.100	mg/Kg	8260	KLP	11/10/98
Ethylbenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
2-Hexanone	ND	0.100	mg/Kg	8260	KLP	11/10/98
4-Methyl-2-pentanone (MIBK)	ND	0.100	mg/Kg	8260	KLP	11/10/98
Methylene chloride	ND	0.100	mg/Kg	8260	KLP	11/10/98
Styrene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1,2,2-Tetrachloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Tetrachloroethene (PCE)	ND	0.100	mg/Kg	8260	KLP	11/10/98
Toluene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1,1-Trichloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1,2-Trichloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Trichloroethene (TCE)	ND	0.100	mg/Kg	8260	KLP	11/10/98
Vinyl chloride	ND	0.100	mg/Kg	8260	KLP	11/10/98
Xylenes (total)	ND	0.100	mg/Kg	8260	KLP	11/10/98
TCL Semivolatile Organics						
Acenaphthene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Acenaphthylene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Anthracene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Benzo(a)anthracene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Benzo(a)pyrene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Benzo(b)fluoranthene	ND	0.100	mg/Kg	8270	KLP	11/06/98

Sample Description: B-A/B-2 Location B Soil Depth 2ft

Sample Number: AA66498

Parameter	Result	Det Limit	Units	Method	Analysts	Date
Benzo(g,h,i)perylene	ND	1.000	mg/Kg	8270	KLP	11/06/98
Benzo(k)fluoranthene	ND	0.100	mg/Kg	8270	KLP	11/06/98
bis(2-Chloroethoxy)methane	ND	0.100	mg/Kg	8270	KLP	11/06/98
bis(2-Chloroethyl)ether	ND	0.100	mg/Kg	8270	KLP	11/06/98
bis(2-Chloroisopropyl)ether	ND	0.100	mg/Kg	8270	KLP	11/06/98
bis(2-Ethylhexyl) phthalate	ND	1.000	mg/Kg	8270	KLP	11/06/98
4-Bromophenyl phenyl ether	ND	0.100	mg/Kg	8270	KLP	11/06/98
Butyl benzyl phthalate	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Chloroaniline	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Chloro-3-methylphenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
2-Chloronaphthalene	ND	0.100	mg/Kg	8270	KLP	11/06/98
2-Chlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Chlorophenyl phenyl ether	ND	0.100	mg/Kg	8270	KLP	11/06/98
Chrysene	ND	0.100	mg/Kg	8270	KLP	11/06/98
o-Cresol	ND	0.100	mg/Kg	8270	KLP	11/06/98
p-Cresol	ND	0.100	mg/Kg	8270	KLP	11/06/98
Dibenzo(a,h)anthracene	ND	1.000	mg/Kg	8270	KLP	11/06/98
Dibenzofuran	ND	0.100	mg/Kg	8270	KLP	11/06/98
Di-n-butyl phthalate	ND	0.100	mg/Kg	8270	KLP	11/06/98
1,2-Dichlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
1,3-Dichlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
1,4-Dichlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
3,3'-Dichlorobenzidine	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,4-Dichlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
Diethyl phthalate	ND	1.000	mg/Kg	8270	KLP	11/06/98
Dimethyl phthalate	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,4-Dimethylphenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
4,6-Dinitro-2-methylphenol	ND	1.000	mg/Kg	8270	KLP	11/06/98
2,4-Dinitrophenol	ND	1.000	mg/Kg	8270	KLP	11/06/98
2,4-Dinitrotoluene	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,6-Dinitrotoluene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Di-n-octyl phthalate	ND	0.100	mg/Kg	8270	KLP	11/06/98
Fluoranthene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Fluorene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Hexachlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Hexachlorobutadiene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Hexachlorocyclopentadiene	ND	1.000	mg/Kg	8270	KLP	11/06/98
Hexachloroethane	ND	0.100	mg/Kg	8270	KLP	11/06/98
Indeno(1,2,3-cd)pyrene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Isophorone	ND	0.100	mg/Kg	8270	KLP	11/06/98
2-Methylnaphthalene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Naphthalene	ND	0.100	mg/Kg	8270	KLP	11/06/98
2-Nitroaniline	ND	0.100	mg/Kg	8270	KLP	11/06/98
3-Nitroaniline	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Nitroaniline	ND	1.000	mg/Kg	8270	KLP	11/06/98
Nitrobenzene	ND	1.000	mg/Kg	8270	KLP	11/06/98
2-Nitrophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98

Sample Description: B-A/B-2 Location B Soil Depth 2ft

Sample Number: AA66498

Parameter	Result	Det Limit	Units	Method	Analysts	Date
4-Nitrophenol	ND	1.000	mg/Kg	8270	KLP	11/06/98
n-Nitrosodi-n-propylamine	ND	0.100	mg/Kg	8270	KLP	11/06/98
n-Nitrosodiphenylamine	ND	0.100	mg/Kg	8270	KLP	11/06/98
Pentachlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
Phenanthrene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Phenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
Pyrene	ND	0.100	mg/Kg	8270	KLP	11/06/98
1,2,4-Trichlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,4,5-Trichlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,4,6-Trichlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
TCL Pesticides & PCBs						
Aldrin	ND	0.0017	mg/Kg	8081	MMP	11/09/98
alpha-BHC	ND	0.0017	mg/Kg	8081	MMP	11/09/98
beta-BHC	ND	0.0017	mg/Kg	8081	MMP	11/09/98
gamma-BHC (Lindane)	ND	0.0017	mg/Kg	8081	MMP	11/09/98
delta-BHC	ND	0.0017	mg/Kg	8081	MMP	11/09/98
alpha-Chlordane	ND	0.0017	mg/Kg	8081	MMP	11/09/98
gamma-Chlordane	ND	0.0017	mg/Kg	8081	MMP	11/09/98
4,4'-DDT	ND	0.0033	mg/Kg	8081	MMP	11/09/98
4,4'-DDE	ND	0.0033	mg/Kg	8081	MMP	11/09/98
4,4'-DDD	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Dieldrin	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endosulfan I	ND	0.0017	mg/Kg	8081	MMP	11/09/98
Endosulfan II	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endosulfan sulfate	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endrin	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endrin aldehyde	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endrin ketone	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Heptachlor	ND	0.0017	mg/Kg	8081	MMP	11/09/98
Heptachlor epoxide	ND	0.0017	mg/Kg	8081	MMP	11/09/98
Methoxychlor	ND	0.0165	mg/Kg	8081	MMP	11/09/98
PCB-1016	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1221	ND	0.0667	mg/Kg	8081	MMP	11/09/98
PCB-1232	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1242	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1248	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1254	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1260	ND	0.0333	mg/Kg	8081	MMP	11/09/98
Toxaphene	ND	0.0333	mg/Kg	8081	MMP	11/09/98

ND = Not Detected

Louise E. Wells

Quality Assurance/Quality Control

B. G. Giessner, Ph.D.

argsmpr0

ARGUS ANALYTICAL, INC.

235 Highpoint Drive
Ridgeland, Mississippi 39157
Telephone: 601/957-2676 FAX: 601/957-1887

To: Vicksburg Chemical
PO Box 821003
Vicksburg, MS 39182

Attn: Steve Boswell

Date Reported: 11/10/98

Date Sampled: 11/04/98
Time Sampled: 13:45
Sampled by: DK

Project ID/Location: SWMU 9

Date Received: 11/05/98

Sample Description: B-A/B-4 Location B Soil Depth 4ft

Sample Matrix: SOIL

Sample Number: AA66499

Project Number: 92B007C

Page Number: 1

Parameter	Result	Det Limit	Units	Method	Analysts	Date
Atrazine	ND	0.333	mg/Kg	8141	KLP	11/10/98
Dinoseb	ND	0.333	mg/Kg	8270	KLP	11/06/98
TAL						
Aluminum	7250	2500	mg/Kg	7020	DPF	11/10/98
Antimony	ND	0.025	mg/Kg	7041	DPF	11/09/98
Arsenic	9.57	0.125	mg/Kg	7060	DPF	11/08/98
Barium	72.1	2.5	mg/Kg	7080	DPF	11/09/98
Beryllium	0.530	0.125	mg/Kg	7090	DPF	11/09/98
Cadmium	0.398	0.125	mg/Kg	7130	DPF	11/06/98
Calcium	7210	1250	mg/Kg	7140	DPF	11/10/98
Chromium	11.21	1.25	mg/Kg	7190	DPF	11/06/98
Cobalt	8.28	1.25	mg/Kg	7200	DPF	11/09/98
Copper	13.52	0.50	mg/Kg	7210	DPF	11/06/98
Iron	14900	750	mg/Kg	7380	DPF	11/10/98
Lead	12.18	1.25	mg/Kg	7420	DPF	11/06/98
Magnesium	521	2.50	mg/Kg	7450	DPF	11/09/98
Manganese	557	25.0	mg/Kg	7460	DPF	11/10/98
Mercury	ND	0.1000	mg/Kg	7471	PLP	11/09/98
Nickel	17.70	1.0	mg/Kg	7520	DPF	11/06/98
Potassium	726	5.00	mg/Kg	7610	DPF	11/10/98
Selenium	ND	0.125	mg/Kg	7740	DPF	11/08/98
Silver	ND	1.25	mg/Kg	7760	DPF	11/09/98
Sodium	118.6	0.50	mg/Kg	7770	DPF	11/09/98
Thallium	5.39	2.5	mg/Kg	7840	DPF	11/09/98
Vanadium	16.77	5.0	mg/Kg	7910	DPF	11/09/98
Zinc	49.79	5.0	mg/Kg	7950	DPF	11/06/98
Cyanide, Total	ND	1.00	mg/Kg	9010	ERM	11/09/98
TCL Volatile Organics						

Sample Description: B-A/B-4 Location B Soil Depth 4ft

Sample Number: AA66499

Parameter	Result	Det Limit	Units	Method	Analysts	Date
Acetone	ND	0.100	mg/Kg	8260	KLP	11/10/98
Benzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
Bromochloromethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Bromodichloromethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Bromoform	ND	0.100	mg/Kg	8260	KLP	11/10/98
Bromomethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
2-Butanone (MEK)	ND	0.100	mg/Kg	8260	KLP	11/10/98
Carbon disulfide	ND	0.100	mg/Kg	8260	KLP	11/10/98
Carbon tetrachloride	ND	0.100	mg/Kg	8260	KLP	11/10/98
Chlorobenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
Chloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Chloroform	ND	0.100	mg/Kg	8260	KLP	11/10/98
Chloromethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Dibromochloromethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dibromo-3-chloropropane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dibromoethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dichlorobenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,3-Dichlorobenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,4-Dichlorobenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1-Dichloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dichloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1-Dichloroethene	ND	0.100	mg/Kg	8260	KLP	11/10/98
cis-1,2-Dichloroethene	ND	0.100	mg/Kg	8260	KLP	11/10/98
trans-1,2-Dichloroethene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,2-Dichloropropane	ND	0.100	mg/Kg	8260	KLP	11/10/98
cis-1,3-Dichloropropene	ND	0.100	mg/Kg	8260	KLP	11/10/98
trans-1,3-Dichloropropene	ND	0.100	mg/Kg	8260	KLP	11/10/98
Ethylbenzene	ND	0.100	mg/Kg	8260	KLP	11/10/98
2-Hexanone	ND	0.100	mg/Kg	8260	KLP	11/10/98
4-Methyl-2-pentanone (MIBK)	ND	0.100	mg/Kg	8260	KLP	11/10/98
Methylene chloride	ND	0.100	mg/Kg	8260	KLP	11/10/98
Styrene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1,2,2-Tetrachloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Tetrachloroethene (PCE)	ND	0.100	mg/Kg	8260	KLP	11/10/98
Toluene	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1,1-Trichloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
1,1,2-Trichloroethane	ND	0.100	mg/Kg	8260	KLP	11/10/98
Trichloroethene (TCE)	ND	0.100	mg/Kg	8260	KLP	11/10/98
Vinyl chloride	ND	0.100	mg/Kg	8260	KLP	11/10/98
Xylenes (total)	ND	0.100	mg/Kg	8260	KLP	11/10/98
TCL Semivolatile Organics						
Acenaphthene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Acenaphthylene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Anthracene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Benzo(a)anthracene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Benzo(a)pyrene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Benzo(b)fluoranthene	ND	0.100	mg/Kg	8270	KLP	11/06/98

Sample Description: B-A/B-4 Location B Soil Depth 4ft

Sample Number: AA66499

Parameter	Result	Det Limit	Units	Method	Analysts	Date
Benzo(g,h,i)perylene	ND	1.000	mg/Kg	8270	KLP	11/06/98
Benzo(k)fluoranthene	ND	0.100	mg/Kg	8270	KLP	11/06/98
bis(2-Chloroethoxy)methane	ND	0.100	mg/Kg	8270	KLP	11/06/98
bis(2-Chloroethyl)ether	ND	0.100	mg/Kg	8270	KLP	11/06/98
bis(2-Chloroisopropyl)ether	ND	0.100	mg/Kg	8270	KLP	11/06/98
bis(2-Ethylhexyl) phthalate	ND	1.000	mg/Kg	8270	KLP	11/06/98
4-Bromophenyl phenyl ether	ND	0.100	mg/Kg	8270	KLP	11/06/98
Butyl benzyl phthalate	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Chloroaniline	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Chloro-3-methylphenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
2-Chloronaphthalene	ND	0.100	mg/Kg	8270	KLP	11/06/98
2-Chlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Chlorophenyl phenyl ether	ND	0.100	mg/Kg	8270	KLP	11/06/98
Chrysene	ND	0.100	mg/Kg	8270	KLP	11/06/98
o-Cresol	ND	0.100	mg/Kg	8270	KLP	11/06/98
p-Cresol	ND	0.100	mg/Kg	8270	KLP	11/06/98
Dibenzo(a,h)anthracene	ND	1.000	mg/Kg	8270	KLP	11/06/98
Dibenzofuran	ND	0.100	mg/Kg	8270	KLP	11/06/98
Di-n-butyl phthalate	ND	0.100	mg/Kg	8270	KLP	11/06/98
1,2-Dichlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
1,3-Dichlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
1,4-Dichlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
3,3'-Dichlorobenzidine	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,4-Dichlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
Diethyl phthalate	ND	1.000	mg/Kg	8270	KLP	11/06/98
Dimethyl phthalate	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,4-Dimethylphenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
4,6-Dinitro-2-methylphenol	ND	1.000	mg/Kg	8270	KLP	11/06/98
2,4-Dinitrophenol	ND	1.000	mg/Kg	8270	KLP	11/06/98
2,4-Dinitrotoluene	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,6-Dinitrotoluene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Di-n-octyl phthalate	ND	0.100	mg/Kg	8270	KLP	11/06/98
Fluoranthene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Fluorene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Hexachlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Hexachlorobutadiene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Hexachlorocyclopentadiene	ND	1.000	mg/Kg	8270	KLP	11/06/98
Hexachloroethane	ND	0.100	mg/Kg	8270	KLP	11/06/98
Indeno(1,2,3-cd)pyrene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Isophorone	ND	0.100	mg/Kg	8270	KLP	11/06/98
2-Methylnaphthalene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Naphthalene	ND	0.100	mg/Kg	8270	KLP	11/06/98
2-Nitroaniline	ND	0.100	mg/Kg	8270	KLP	11/06/98
3-Nitroaniline	ND	0.100	mg/Kg	8270	KLP	11/06/98
4-Nitroaniline	ND	1.000	mg/Kg	8270	KLP	11/06/98
Nitrobenzene	ND	1.000	mg/Kg	8270	KLP	11/06/98
2-Nitrophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98

Sample Description: B-A/B-4 Location B Soil Depth 4ft

Sample Number: AA66499

Parameter	Result	Det Limit	Units	Method	Analysts	Date
4-Nitrophenol	ND	1.000	mg/Kg	8270	KLP	11/06/98
n-Nitrosodi-n-propylamine	ND	0.100	mg/Kg	8270	KLP	11/06/98
n-Nitrosodiphenylamine	ND	0.100	mg/Kg	8270	KLP	11/06/98
Pentachlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
Phenanthrene	ND	0.100	mg/Kg	8270	KLP	11/06/98
Phenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
Pyrene	ND	0.100	mg/Kg	8270	KLP	11/06/98
1,2,4-Trichlorobenzene	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,4,5-Trichlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
2,4,6-Trichlorophenol	ND	0.100	mg/Kg	8270	KLP	11/06/98
TCL Pesticides & PCBs						
Aldrin	ND	0.0017	mg/Kg	8081	MMP	11/09/98
alpha-BHC	ND	0.0017	mg/Kg	8081	MMP	11/09/98
beta-BHC	ND	0.0017	mg/Kg	8081	MMP	11/09/98
gamma-BHC (Lindane)	ND	0.0017	mg/Kg	8081	MMP	11/09/98
delta-BHC	ND	0.0017	mg/Kg	8081	MMP	11/09/98
alpha-Chlordane	ND	0.0017	mg/Kg	8081	MMP	11/09/98
gamma-Chlordane	ND	0.0017	mg/Kg	8081	MMP	11/09/98
4,4'-DDT	ND	0.0033	mg/Kg	8081	MMP	11/09/98
4,4'-DDE	ND	0.0033	mg/Kg	8081	MMP	11/09/98
4,4'-DDD	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Dieldrin	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endosulfan I	ND	0.0017	mg/Kg	8081	MMP	11/09/98
Endosulfan II	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endosulfan sulfate	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endrin	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endrin aldehyde	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Endrin ketone	ND	0.0033	mg/Kg	8081	MMP	11/09/98
Heptachlor	ND	0.0017	mg/Kg	8081	MMP	11/09/98
Heptachlor epoxide	ND	0.0017	mg/Kg	8081	MMP	11/09/98
Methoxychlor	ND	0.0165	mg/Kg	8081	MMP	11/09/98
PCB-1016	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1221	ND	0.0667	mg/Kg	8081	MMP	11/09/98
PCB-1232	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1242	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1248	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1254	ND	0.0333	mg/Kg	8081	MMP	11/09/98
PCB-1260	ND	0.0333	mg/Kg	8081	MMP	11/09/98
Toxaphene	ND	0.0333	mg/Kg	8081	MMP	11/09/98

ND = Not Detected

Quality Assurance/Quality Control

B. G. Giessner, Ph.D.

argsmpr0

ARGUS ANALYTICAL, INC.

235 Highpoint Drive
Ridgeland, Mississippi 39157
Telephone: 601/957-2676 FAX: 601/957-1887

To: Vicksburg Chemical
PO Box 821003
Vicksburg, MS 39182

Attn: John Ryan

Date Reported: 11/17/98

Date Sampled: 11/11/98
Time Sampled: 13:00
Sampled by: John Ryan

Project ID/Location: SWMU #9 Grab Sampling

Date Received: 11/11/98

Sample Description: VCC-SWMU9-GW-TP1-01
Sample Matrix: WATER

Sample Number: AA66724

Project Number:

Page Number: 1

Parameter	Result	Det Limit	Units	Method	Analysts	Date
TAL						
Aluminum	0.38	0.1	mg/L	202.1	DPF	11/13/98
Antimony	0.012	0.001	mg/L	204.2	DPF	11/16/98
Arsenic	0.378	0.005	mg/L	206.2	DPF	11/16/98
Barium	0.22	0.1	mg/L	208.1	DPF	11/16/98
Beryllium	ND	0.005	mg/L	210.1	DPF	11/16/98
Cadmium	ND	0.005	mg/L	213.1	DPF	11/12/98
Calcium	87.6	5.0	mg/L	215.1	DPF	11/16/98
Chromium	ND	0.05	mg/L	218.1	DPF	11/12/98
Cobalt	0.06	0.05	mg/L	219.1	DPF	11/13/98
Copper	ND	0.02	mg/L	220.1	DPF	11/12/98
Iron	0.63	0.03	mg/L	236.1	DPF	11/13/98
Lead	ND	0.05	mg/L	239.1	DPF	11/12/98
Magnesium	50.7	0.001	mg/L	242.1	DPF	11/13/98
Manganese	3.66	0.10	mg/L	243.1	DPF	11/13/98
Mercury	ND	0.0002	mg/L	245.1	DPF	11/12/98
Nickel	0.09	0.04	mg/L	249.1	DPF	11/12/98
Potassium	3.02	0.10	mg/L	258.1	DPF	11/12/98
Selenium	ND	0.005	mg/L	270.2	DPF	11/16/98
Silver	ND	0.05	mg/L	272.1	DPF	11/13/98
Sodium	329	2.0	mg/L	273.1	DPF	11/13/98
Thallium	ND	0.1	mg/L	279.1	DPF	11/13/98
Vanadium	ND	0.2	mg/L	286.1	DPF	11/16/98
Zinc	0.07	0.02	mg/L	289.1	DPF	11/12/98
Cyanide, Total	ND	0.02	mg/L	335.4	ERM	11/13/98
TCL Volatile Organics						
Acetone	ND	0.010	mg/L	8260	KLP	11/16/98
Benzene	ND	0.005	mg/L	8260	KLP	11/16/98
Bromochloromethane	ND	0.005	mg/L	8260	KLP	11/16/98
Bromodichloromethane	ND	0.005	mg/L	8260	KLP	11/16/98

Sample Description: VCC-SWMU9-GW-TP1-01

Sample Number: AA66724

Parameter	Result	Det Limit	Units	Method	Analysts	Date
Bromoform	ND	0.005	mg/L	8260	KLP	11/16/98
Bromomethane	ND	0.010	mg/L	8260	KLP	11/16/98
2-Butanone (MEK)	ND	0.010	mg/L	8260	KLP	11/16/98
Carbon disulfide	ND	0.005	mg/L	8260	KLP	11/16/98
Carbon tetrachloride	ND	0.005	mg/L	8260	KLP	11/16/98
Chlorobenzene	ND	0.005	mg/L	8260	KLP	11/16/98
Chloroethane	ND	0.005	mg/L	8260	KLP	11/16/98
Chloroform	ND	0.005	mg/L	8260	KLP	11/16/98
Chloromethane	ND	0.010	mg/L	8260	KLP	11/16/98
Dibromochloromethane	ND	0.005	mg/L	8260	KLP	11/16/98
1,2-Dibromo-3-chloropropane	ND	0.005	mg/L	8260	KLP	11/16/98
1,2-Dibromoethane	ND	0.005	mg/L	8260	KLP	11/16/98
1,2-Dichlorobenzene	0.011	0.005	mg/L	8260	KLP	11/16/98
1,3-Dichlorobenzene	ND	0.010	mg/L	8260	KLP	11/16/98
1,4-Dichlorobenzene	ND	0.005	mg/L	8260	KLP	11/16/98
1,1-Dichloroethane	ND	0.005	mg/L	8260	KLP	11/16/98
1,2-Dichloroethane	ND	0.005	mg/L	8260	KLP	11/16/98
1,1-Dichloroethene	ND	0.005	mg/L	8260	KLP	11/16/98
cis-1,2-Dichloroethene	0.026	0.005	mg/L	8260	KLP	11/16/98
trans-1,2-Dichloroethene	0.006	0.005	mg/L	8260	KLP	11/16/98
1,2-Dichloropropane	ND	0.005	mg/L	8260	KLP	11/16/98
cis-1,3-Dichloropropene	ND	0.005	mg/L	8260	KLP	11/16/98
trans-1,3-Dichloropropene	ND	0.005	mg/L	8260	KLP	11/16/98
Ethylbenzene	ND	0.005	mg/L	8260	KLP	11/16/98
2-Hexanone	ND	0.010	mg/L	8260	KLP	11/16/98
4-Methyl-2-pentanone (MIBK)	ND	0.010	mg/L	8260	KLP	11/16/98
Methylene chloride	ND	0.005	mg/L	8260	KLP	11/16/98
Styrene	ND	0.005	mg/L	8260	KLP	11/16/98
1,1,2,2-Tetrachloroethane	ND	0.005	mg/L	8260	KLP	11/16/98
Tetrachloroethene (PCE)	ND	0.005	mg/L	8260	KLP	11/16/98
Toluene	ND	0.005	mg/L	8260	KLP	11/16/98
1,1,1-Trichloroethane	ND	0.005	mg/L	8260	KLP	11/16/98
1,1,2-Trichloroethane	ND	0.005	mg/L	8260	KLP	11/16/98
Trichloroethene (TCE)	0.068	0.005	mg/L	8260	KLP	11/16/98
Vinyl chloride	ND	0.001	mg/L	8260	KLP	11/16/98
Xylenes (total)	0.014	0.005	mg/L	8260	KLP	11/16/98
TCL Semivolatile Organics						
Acenaphthene	ND	0.002	mg/L	8270	RLT	11/12/98
Acenaphthylene	ND	0.002	mg/L	8270	RLT	11/12/98
Anthracene	ND	0.002	mg/L	8270	RLT	11/12/98
Benzo(a)anthracene	ND	0.002	mg/L	8270	RLT	11/12/98
Benzo(a)pyrene	ND	0.002	mg/L	8270	RLT	11/12/98
Benzo(b)fluoranthene	ND	0.005	mg/L	8270	RLT	11/12/98
Benzo(g,h,i)perylene	ND	0.005	mg/L	8270	RLT	11/12/98
Benzo(k)fluoranthene	ND	0.005	mg/L	8270	RLT	11/12/98
bis(2-Chloroethoxy)methane	ND	0.002	mg/L	8270	RLT	11/12/98
bis(2-Chloroethyl)ether	ND	0.005	mg/L	8270	RLT	11/12/98

Sample Description: VCC-SWMU9-GW-TP1-01

Sample Number: AA66724

Parameter	Result	Det Limit	Units	Method	Analysts	Date
bis(2-Chloroisopropyl)ether	ND	0.002	mg/L	8270	RLT	11/12/98
bis(2-Ethylhexyl) phthalate	ND	0.005	mg/L	8270	RLT	11/12/98
4-Bromophenyl phenyl ether	ND	0.002	mg/L	8270	RLT	11/12/98
Butyl benzyl phthalate	ND	0.005	mg/L	8270	RLT	11/12/98
4-Chloroaniline	ND	0.002	mg/L	8270	RLT	11/12/98
4-Chloro-3-methylphenol	ND	0.002	mg/L	8270	RLT	11/12/98
2-Chloronaphthalene	ND	0.002	mg/L	8270	RLT	11/12/98
2-Chlorophenol	ND	0.002	mg/L	8270	RLT	11/12/98
4-Chlorophenyl phenyl ether	ND	0.002	mg/L	8270	RLT	11/12/98
Chrysene	ND	0.002	mg/L	8270	RLT	11/12/98
o-Cresol	ND	0.002	mg/L	8270	RLT	11/12/98
p-Cresol	ND	0.002	mg/L	8270	RLT	11/12/98
Dibenzo(a,h)anthracene	ND	0.005	mg/L	8270	RLT	11/12/98
Dibenzofuran	ND	0.002	mg/L	8270	RLT	11/12/98
Di-n-butyl phthalate	ND	0.005	mg/L	8270	RLT	11/12/98
1,2-Dichlorobenzene	0.004	0.002	mg/L	8270	RLT	11/12/98
1,3-Dichlorobenzene	ND	0.002	mg/L	8270	RLT	11/12/98
1,4-Dichlorobenzene	ND	0.002	mg/L	8270	RLT	11/12/98
3,3'-Dichlorobenzidine	ND	0.002	mg/L	8270	RLT	11/12/98
2,4-Dichlorophenol	ND	0.002	mg/L	8270	RLT	11/12/98
Diethyl phthalate	ND	0.005	mg/L	8270	RLT	11/12/98
Dimethyl phthalate	ND	0.002	mg/L	8270	RLT	11/12/98
2,4-Dimethylphenol	ND	0.002	mg/L	8270	RLT	11/12/98
4,6-Dinitro-2-methylphenol	ND	0.005	mg/L	8270	RLT	11/12/98
2,4-Dinitrophenol	ND	0.005	mg/L	8270	RLT	11/12/98
2,4-Dinitrotoluene	ND	0.005	mg/L	8270	RLT	11/12/98
2,6-Dinitrotoluene	ND	0.002	mg/L	8270	RLT	11/12/98
Di-n-octyl phthalate	ND	0.002	mg/L	8270	RLT	11/12/98
Fluoranthene	ND	0.002	mg/L	8270	RLT	11/12/98
Fluorene	ND	0.002	mg/L	8270	RLT	11/12/98
Hexachlorobenzene	ND	0.002	mg/L	8270	RLT	11/12/98
Hexachlorobutadiene	ND	0.002	mg/L	8270	RLT	11/12/98
Hexachlorocyclopentadiene	ND	0.005	mg/L	8270	RLT	11/12/98
Hexachloroethane	ND	0.002	mg/L	8270	RLT	11/12/98
Indeno(1,2,3-cd)pyrene	ND	0.005	mg/L	8270	RLT	11/12/98
Isophorone	ND	0.002	mg/L	8270	RLT	11/12/98
2-Methylnaphthalene	ND	0.002	mg/L	8270	RLT	11/12/98
Naphthalene	ND	0.002	mg/L	8270	RLT	11/12/98
2-Nitroaniline	ND	0.002	mg/L	8270	RLT	11/12/98
3-Nitroaniline	ND	0.002	mg/L	8270	RLT	11/12/98
4-Nitroaniline	ND	0.005	mg/L	8270	RLT	11/12/98
Nitrobenzene	ND	0.005	mg/L	8270	RLT	11/12/98
2-Nitrophenol	ND	0.002	mg/L	8270	RLT	11/12/98
4-Nitrophenol	ND	0.005	mg/L	8270	RLT	11/12/98
n-Nitrosodi-n-propylamine	ND	0.002	mg/L	8270	RLT	11/12/98
n-Nitrosodiphenylamine	0.002	0.002	mg/L	8270	RLT	11/12/98
Pentachlorophenol	ND	0.005	mg/L	8270	RLT	11/12/98

Sample Description: VCC-SWMU9-GW-TP1-01

Sample Number: AA66724

Parameter	Result	Det Limit	Units	Method	Analysts	Date
Phenanthrene	ND	0.002	mg/L	8270	RLT	11/12/98
Phenol	ND	0.002	mg/L	8270	RLT	11/12/98
Pyrene	ND	0.002	mg/L	8270	RLT	11/12/98
1,2,4-Trichlorobenzene	ND	0.002	mg/L	8270	RLT	11/12/98
2,4,5-Trichlorophenol	ND	0.002	mg/L	8270	RLT	11/12/98
2,4,6-Trichlorophenol	ND	0.002	mg/L	8270	RLT	11/12/98
TCL Pesticides & PCBs						
Aldrin	ND	0.00005	mg/L	8081	MMP	11/12/98
alpha-BHC	ND	0.00005	mg/L	8081	MMP	11/12/98
beta-BHC	ND	0.00005	mg/L	8081	MMP	11/12/98
gamma-BHC (Lindane)	ND	0.00005	mg/L	8081	MMP	11/12/98
delta-BHC	ND	0.00005	mg/L	8081	MMP	11/12/98
alpha-Chlordane	ND	0.00005	mg/L	8081	MMP	11/12/98
gamma-Chlordane	ND	0.00005	mg/L	8081	MMP	11/12/98
4,4'-DDT	ND	0.00010	mg/L	8081	MMP	11/12/98
4,4'-DDE	ND	0.00010	mg/L	8081	MMP	11/12/98
4,4'-DDD	ND	0.00010	mg/L	8081	MMP	11/12/98
Dieldrin	ND	0.00010	mg/L	8081	MMP	11/12/98
Endosulfan I	ND	0.00005	mg/L	8081	MMP	11/12/98
Endosulfan II	ND	0.00010	mg/L	8081	MMP	11/12/98
Endosulfan sulfate	ND	0.00010	mg/L	8081	MMP	11/12/98
Endrin	ND	0.00010	mg/L	8081	MMP	11/12/98
Endrin aldehyde	ND	0.00010	mg/L	8081	MMP	11/12/98
Endrin ketone	ND	0.00010	mg/L	8081	MMP	11/12/98
Heptachlor	ND	0.00005	mg/L	8081	MMP	11/12/98
Heptachlor epoxide	ND	0.00005	mg/L	8081	MMP	11/12/98
Methoxychlor	ND	0.00050	mg/L	8081	MMP	11/12/98
PCB-1016	ND	0.00100	mg/L	8081	MMP	11/12/98
PCB-1221	ND	0.00200	mg/L	8081	MMP	11/12/98
PCB-1232	ND	0.00100	mg/L	8081	MMP	11/12/98
PCB-1242	ND	0.00100	mg/L	8081	MMP	11/12/98
PCB-1248	ND	0.00100	mg/L	8081	MMP	11/12/98
PCB-1254	ND	0.00100	mg/L	8081	MMP	11/12/98
PCB-1260	ND	0.00100	mg/L	8081	MMP	11/12/98
Toxaphene	ND	0.00100	mg/L	8081	MMP	11/12/98

ND = Not Detected

Quality Assurance/Quality Control

B. G. Giessner, Ph.D.

argsmpr0

ARGUS ANALYTICAL, INC.

235 Highpoint Drive
Ridgeland, Mississippi 39157
Telephone: 601/957-2676 FAX: 601/957-1887

To: Vicksburg Chemical
PO Box 821003
Vicksburg, MS 39182

Attn: Steve Boswell

Date Reported: 11/19/98

Date Sampled: 11/12/98
Time Sampled: 14:00
Sampled by: E. Blush

Project ID/Location: SWMU 9

Date Received: 11/16/98

Sample Description: TP-1
Sample Matrix: WATER
Project Number:

Sample Number: AA66928

Page Number: 1

Parameter	Result	Det Limit	Units	Method	Analysts	Date
Atrazine	ND	0.0100	mg/L	8141	MMP	11/18/98
Dinoseb	ND	0.01	mg/L	8270	RLT	11/18/98

ND = Not Detected

Quality Assurance/Quality Control

B. G. Giessner, Ph.D.

argsmpr0

HOLDING TIME REPORT

Holding Time Summary

Argus Analytical, Inc.

Sample Number	Analysis	Date Sample Collection	Date Analysis Started	Total # of Days (1)
AA66497	Pesticides, Organophosphorus	11/04/98	11/10/98	6
	TCL - SVOAs	11/04/98	11/06/98	2
	TCL - Pest/PCBs	11/04/98	11/09/98	5
	TCL - VOAs	11/04/98	11/10/98	6
AA66498	Pesticides, Organophosphorus	11/04/98	11/10/98	6
	TCL - SVOAs	11/04/98	11/06/98	2
	TCL - Pest/PCBs	11/04/98	11/09/98	5
	TCL - VOAs	11/04/98	11/10/98	6
AA66499	Pesticides, Organophosphorus	11/04/98	11/10/98	6
	TCL - SVOAs	11/04/98	11/06/98	2
	TCL - Pest/PCBs	11/04/98	11/09/98	5
	TCL - VOAs	11/04/98	11/10/98	6
AA66724	TCL - SVOAs	11/11/98	11/12/98	1
	TCL - Pest/PCBs	11/11/98	11/12/98	1
	TCL - VOAs	11/11/98	11/16/98	5
	Prep - ABNs in Water	11/11/98	11/12/98	1
AA66928	Pesticides, Organophosphorus	11/12/98	11/18/98	6
	Dinoseb	11/12/98	11/18/98	6

(1) From date of sampling

INORGANIC Q C

Argus

Inorganic QC

Vicksburg Chemical

SWMU 9

Sampled: November 4, 1998

Reported: November 11, 1998

The following table labeled "Inorganic QC Data Summary" contains the Inorganic QC data for the samples listed in the following "QC Sample Cross Reference".

Dilutions can result in the loss of Spike Recovery data (--).

Inorganic QC Data Summary

	Blank	Sample			Spike
		Results	Duplicate	% RPD	% Recovery
AA66497					
	ND	ND	ND	0	86
Aluminum	ND	8790.00000	7990.00000	9	--
Antimony	ND	ND	ND	0	--
Arsenic	ND	9.060000	8.120000	11	52
Barium	ND	59.700000	63.500000	6	95
Beryllium	ND	0.896000	0.997000	10	95
Cadmium	ND	0.874000	0.986000	12	96
Calcium	ND	30900.0000	33900.0000	9	--
Chromium	ND	245.300000	214.600000	13	--
Cobalt	ND	7.910000	8.240000	4	89
Copper	ND	29.110000	25.260000	14	78
Iron	ND	15500.0000	13600.0000	13	--
Lead	ND	46.090000	48.390000	4	151
Magnesium	ND	1110.00000	1080.00000	2	--
Manganese	ND	627.000000	636.000000	1	--
Mercury	ND	0.144000	ND	--	97
Nickel	ND	21.090000	18.510000	13	91
Potassium	ND	981.000000	1200.00000	20	--
Selenium	ND	ND	ND	0	76
Silver	ND	ND	ND	0	90
Sodium	ND	273.500000	281.000000	2	--
Thallium	ND	8.040000	9.130000	12	94
Vanadium	ND	23.500000	19.460000	18	--
Zinc	ND	82.040000	87.240000	6	--
AA66652					
Mercury	ND	ND	ND	0	80
AA66697					
Cyanide, Total	ND	ND	ND	0	104
AA66724					
Aluminum	ND	0.380000	0.410000	7	110
Antimony	ND	0.012000	0.012000	0	100
Arsenic	ND	0.378000	0.389000	2	113
Barium	ND	0.220000	0.260000	16	102
Beryllium	ND	ND	ND	0	92
Cadmium	ND	ND	ND	0	98
Calcium	ND	87.600000	89.800000	2	--
Chromium	ND	ND	ND	0	95
Cobalt	ND	0.060000	ND	--	96
Copper	ND	ND	ND	0	97
Iron	ND	0.630000	0.660000	4	95
Lead	ND	ND	ND	0	107
Magnesium	ND	50.700000	52.300000	3	--
Manganese	ND	3.660000	3.650000	0	--
Nickel	ND	0.090000	0.090000	0	100
Potassium	ND	3.020000	2.860000	5	--
Selenium	ND	ND	ND	0	86
Silver	ND	ND	ND	0	94

Inorganic QC Data Summary

	Blank	Sample			Spike
		Results	Duplicate	% RPD	% Recovery
Sodium	ND	329.000000	370.000000	11	--
Thallium	ND	ND	ND	0	102
Vanadium	ND	ND	ND	0	120
Zinc	ND	0.070000	0.050000	33	90

QC Sample Cross Reference - Inorganics

Sample number: **AA66497**

Parameter Codes	Sample reference for QC data (1)	Batch Name
AG_S	AA66497	AG_S-22965
AL_S	AA66497	AL_S-22991
AS_SG	AA66497	AS_SG-22953
BA_S	AA66497	BA_S-22973
BE_S	AA66497	BE_S-22974
CA_S	AA66497	CA_S-22984
CD_S	AA66497	CD_S-22936
CO_S	AA66497	CO_S-22969
CR_S	AA66497	CR_S-22960
CU_S	AA66497	CU_S-22930
FE_S	AA66497	FE_S-22988
HG_S	AA66497	HG_S-22977
K__S	AA66497	K__S-22993
MG_S	AA66497	MG_S-22978
MN_S	AA66497	MN_S-22986
NA_S	AA66497	NA_S-22970
NI_S	AA66497	NI_S-22933
PB_S	AA66497	PB_S-22940
SB_SG	AA66497	SB_SG-22981
SE_SG	AA66497	SE_SG-22955
TL_S	AA66497	TL_S-22966
V__S	AA66497	V__S-22975
ZN_S	AA66497	ZN_S-22945

Sample number: **AA66498**

Parameter Codes	Sample reference for QC data (1)	Batch Name
AG_S	AA66497	AG_S-22965
AL_S	AA66497	AL_S-22991
AS_SG	AA66497	AS_SG-22953
BA_S	AA66497	BA_S-22973
BE_S	AA66497	BE_S-22974
CA_S	AA66497	CA_S-22984
CD_S	AA66497	CD_S-22936
CO_S	AA66497	CO_S-22969
CR_S	AA66497	CR_S-22960
CU_S	AA66497	CU_S-22930
FE_S	AA66497	FE_S-22988
HG_S	AA66497	HG_S-22977
K__S	AA66497	K__S-22993
MG_S	AA66497	MG_S-22978

(1) Refer to the indicated sample number in the attached QC Data Summary for the actual QC data.

QC Cross Reference - Inorganics (continued)

MN_S	AA66497	MN_S-22986
NA_S	AA66497	NA_S-22970
NI_S	AA66497	NI_S-22933
PB_S	AA66497	PB_S-22940
SB_SG	AA66497	SB_SG-22981
SE_SG	AA66497	SE_SG-22955
TL_S	AA66497	TL_S-22966
V__S	AA66497	V__S-22975
ZN_S	AA66497	ZN_S-22945

Sample number: **AA66499**

Parameter Codes	Sample reference for QC data (1)	Batch Name
AG_S	AA66497	AG_S-22965
AL_S	AA66497	AL_S-22991
AS_SG	AA66497	AS_SG-22953
BA_S	AA66497	BA_S-22973
BE_S	AA66497	BE_S-22974
CA_S	AA66497	CA_S-22984
CD_S	AA66497	CD_S-22936
CO_S	AA66497	CO_S-22969
CR_S	AA66497	CR_S-22960
CU_S	AA66497	CU_S-22930
FE_S	AA66497	FE_S-22988
HG_S	AA66497	HG_S-22977
K__S	AA66497	K__S-22993
MG_S	AA66497	MG_S-22978
MN_S	AA66497	MN_S-22986
NA_S	AA66497	NA_S-22970
NI_S	AA66497	NI_S-22933
PB_S	AA66497	PB_S-22940
SB_SG	AA66497	SB_SG-22981
SE_SG	AA66497	SE_SG-22955
TL_S	AA66497	TL_S-22966
V__S	AA66497	V__S-22975
ZN_S	AA66497	ZN_S-22945

Sample number: **AA66724**

Parameter Codes	Sample reference for QC data (1)	Batch Name
AG	AA66724	AG-23061
AL	AA66724	AL-23070
AS__G	AA66724	AS__G-23093
BA	AA66724	BA-23085
BE	AA66724	BE-23082
CA	AA66724	CA-23087
CD	AA66724	CD-23037
CN_T	AA66697	CN_T-23076

(1) Refer to the indicated sample number in the attached QC Data Summary for the actual QC data.

QC Cross Reference - Inorganics (continued)

CO	AA66724	CO-23052
CR	AA66724	CR-23039
CU	AA66724	CU-23028
FE	AA66724	FE-23057
HG	AA66652	HG-23025
K	AA66724	K-23049
MG	AA66724	MG-23056
MN	AA66724	MN-23055
NA	AA66724	NA-23060
NI	AA66724	NI-23029
PB	AA66724	PB-23032
SB__G	AA66724	SB__G-23091
SE__G	AA66724	SE__G-23094
TL	AA66724	TL-23059
V	AA66724	V-23083
ZN	AA66724	ZN-23042

(1) Refer to the indicated sample number in the attached QC Data Summary for the actual QC data.

ORGANIC QC

Volatile Organics – QC Data Package Summary

Argus Analytical, Inc.

Client: Vicksburg Chemical

Date: November 20, 1998

Sample #	QC Data Package Starting Page # - Prefix	Surrogate Recoveries - %		
		Dibromo fluoromethane	Toluene-d8	4-Bromo fluorobenzene
AA 66497	981110	109	102	115
AA 66498	981110	112	102	111
AA 66499	981110	110	104	112
AA 66724	981116	98	101	110

Starting Page # – Suffix	Data Package Contents
.10	Blank results
.20	MS/MSD Results and Precision
.40	Tune Data
.50	Calibration Summary – Initial
.60	Calibration Summary – Continuing

Quantitation Report

Data File : C:\HPCHEM\1\DATA\981110\98111002.D
Acq On : 10 Nov 98 11:34 am
Sample : 5035/8260 Blank 5mL Soil
Misc : IS/Surs @ 50/50ppb; 5035/8260 Blank
Quant Time: Nov 10 11:56 1998

Vial: 2
Operator: klp
Inst : 5972 - In
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\8260SOIL.M
Title : SW-846 -8260
Last Update : Tue Sep 15 16:31:25 1998
Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc Units	Dev(Min)
1) pentafluorobenzene	11.01	168	24882	50.00 ug/L	0.02
25) 1,4-difluorobenzene	11.98	114	42322	50.00 ug/L	0.03
42) Chlorobenzene-d5	15.47	82	25178	50.00 ug/L	0.02
54) 1,4-dichlorobenzene-d4	18.29	152	17761	50.00 ug/L	0.02
System Monitoring Compounds					%Recovery
23) dibromofluoromethane	10.95	113	18588	55.99 ug/L	111.98%
37) toluene-d8	13.77	98	46366	51.12 ug/L	102.24%
56) 4-bromofluorobenzene	16.88	95	25525	53.48 ug/L	106.96%
Target Compounds					Qvalue
2) dichlorodifluoromethane	0.00	85		Not Detected	
3) chloromethane	0.00	50		Not Detected	
4) vinyl chloride*	0.00	62		Not Detected	
5) bromomethane	0.00	94		Not Detected	
6) chloroethane	0.00	64		Not Detected	
7) trichlorofluoromethane	0.00	101		Not Detected	
8) 1,1-dichloroethene*	0.00	61		Not Detected	
9) Iodomethane	0.00	142		Not Detected	
10) Carbon disulfide	0.00	76		Not Detected	
11) methylene chloride	9.04	84	1820	7.74 ug/L #	59
12) trans-1,2-dichloroethene	0.00	61		Not Detected	
13) Acetone	0.00	43		Not Detected	
14) Methyl ethyl ketone*	0.00	43		Not Detected	
15) Acrolein	0.00	56		Not Detected	
16) Acrylonitrile	0.00	53		Not Detected	
17) 1,1-dichloroethane	0.00	63		Not Detected	
18) Vinyl acetate	0.00	43		Not Detected	
19) 2,2-dichloropropane	0.00	77		Not Detected	
20) cis-1,2-dichloroethene	0.00	96		Not Detected	
21) bromochloromethane	0.00	128		Not Detected	
22) chloroform*	0.00	83		Not Detected	
24) 1,1,1-trichloroethane	0.00	97		Not Detected	
26) carbon tetrachloride*	0.00	117		Not Detected	
27) 1,1-dichloropropene	0.00	75		Not Detected	
28) benzene*	0.00	78		Not Detected	
29) 1,2-dichloroethane*	0.00	62		Not Detected	
30) trichloroethene*	0.00	95		Not Detected	
31) 1,2-dichloropropane	0.00	63		Not Detected	
32) dibromomethane	0.00	93		Not Detected	
33) bromodichloromethane	0.00	83		Not Detected	
34) 2-Chloroethylvinyl ether	0.00	63		Not Detected	

(#) = qualifier out of range (m) = manual integration

Quantitation Report

Data File : C:\HPCHEM\1\DATA\981110\98111002.D
Acq On : 10 Nov 98 11:34 am
Sample : 5035/8260 Blank 5mL Soil
Misc : IS/Surs @ 50/50ppb; 5035/8260 Blank
Quant Time: Nov 10 11:56 1998

Vial: 2
Operator: klp
Inst : 5972 - In
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\8260SOIL.M
Title : SW-846 -8260
Last Update : Tue Sep 15 16:31:25 1998
Response via : Multiple Level Calibration

	Compound	R.T.	QIon	Response	Conc Unit	Qvalue
35)	cis-1,3-dichloropropene	0.00	75		Not Detected	
36)	4-Methyl-2-pentanone	0.00	43		Not Detected	
38)	toluene	0.00	92		Not Detected	
39)	trans-1,3-dichloropropene	0.00	75		Not Detected	
40)	1,1,2-trichloroethane	0.00	83		Not Detected	
41)	2-Hexanone	0.00	43		Not Detected	
43)	tetrachloroethene*	0.00	166		Not Detected	
44)	1,3-dichloropropane	0.00	76		Not Detected	
45)	dibromochloromethane	0.00	127		Not Detected	
46)	1,2-dibromoethane	0.00	107		Not Detected	
47)	chlorobenzene*	0.00	112		Not Detected	
48)	1,1,1,2-tetrachloroethane	0.00	131		Not Detected	
49)	ethylbenzene	0.00	91		Not Detected	
50)	m,p-xylene	0.00	106		Not Detected	
51)	o-xylene	0.00	106		Not Detected	
52)	styrene	0.00	104		Not Detected	
53)	bromoform	0.00	173		Not Detected	
55)	isopropylbenzene	0.00	105		Not Detected	
57)	bromobenzene	0.00	156		Not Detected	
58)	1,1,2,2-tetrachloroethane	0.00	83		Not Detected	
59)	1,2,3-trichloropropane	0.00	110		Not Detected	
60)	n-propylbenzene	0.00	91		Not Detected	
61)	2-chlorotoluene	0.00	91		Not Detected	
62)	4-chlorotoluene	0.00	91		Not Detected	
63)	1,3,5-trimethylbenzene	0.00	105		Not Detected	
64)	tert-butylbenzene	0.00	91		Not Detected	
65)	1,2,4-trimethylbenzene	0.00	105		Not Detected	
66)	sec-butylbenzene	0.00	105		Not Detected	
67)	1,3-dichlorobenzene	0.00	146		Not Detected	
68)	4-isopropyltoluene	0.00	119		Not Detected	
69)	1,4-dichlorobenzene	0.00	146		Not Detected	
70)	1,2-dichlorobenzene	0.00	146		Not Detected	
71)	n-butylbenzene	0.00	91		Not Detected	
72)	1,2-dibromo-3-chloropropan	0.00	157		Not Detected	
73)	1,2,4-trichlorobenzene	0.00	180		Not Detected	
74)	hexachlorobutadiene	0.00	225		Not Detected	
75)	naphthalene	20.97	128	1638	2.41 ug/L	66
76)	1,2,3-trichlorobenzene	0.00	180		Not Detected	

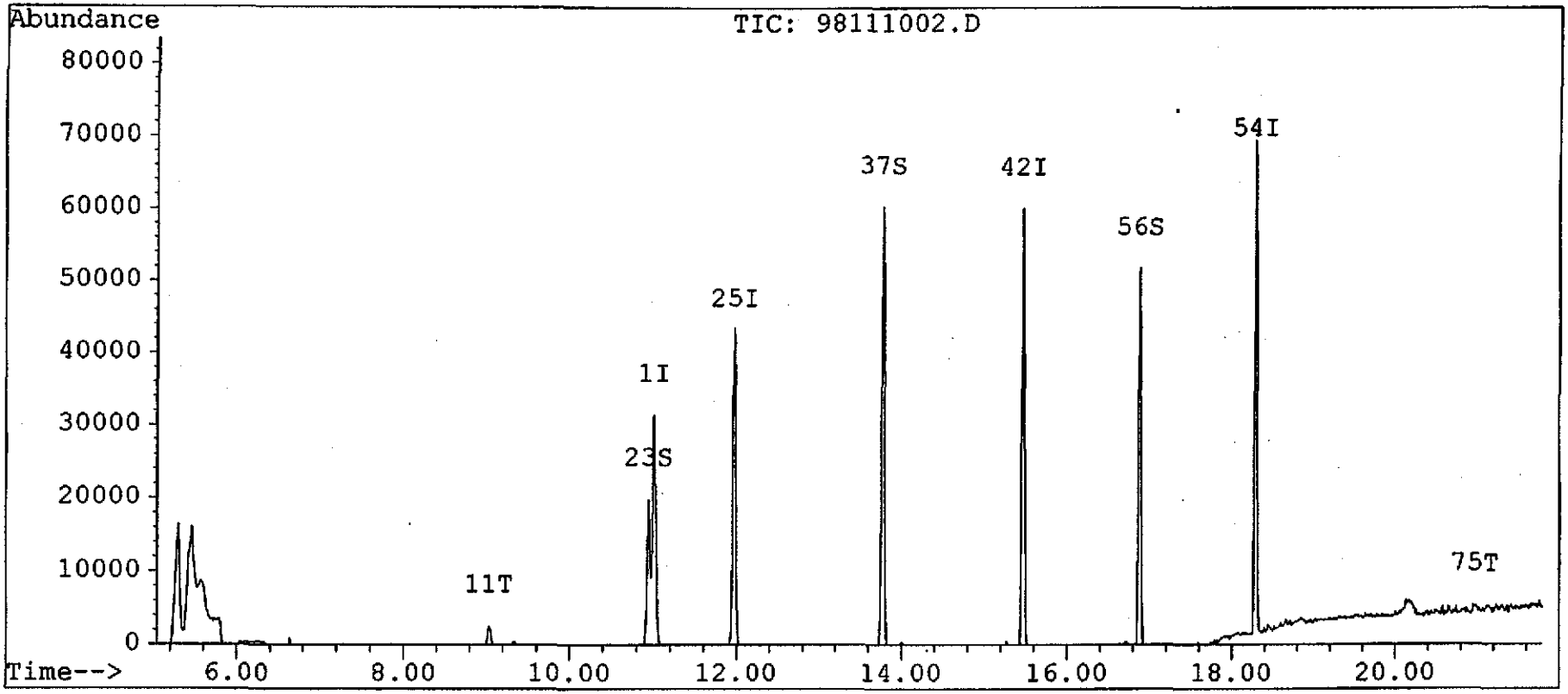
(#) = qualifier out of range (m) = manual integration

Quantitation Report

Data File : C:\HPCHEM\1\DATA\981110\98111002.D
Acq On : 10 Nov 98 11:34 am
Sample : 5035/8260 Blank 5mL Soil
Misc : IS/Surs @ 50/50ppb; 5035/8260 Blank
Quant Time: Nov 10 11:56 1998

Vial: 2
Operator: klp
Inst : 5972 - In
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\8260SOIL.M
Title : SW-846 -8260
Last Update : Tue Sep 15 16:31:25 1998
Response via : Multiple Level Calibration



Spike Recovery and RPD Summary Report - WATER

Method : C:\HPCHEM\1\METHODS\8260-H2O.M
Title : SW-846 -8260
Last Update : Mon Nov 16 17:22:09 1998
Response via : Initial Calibration

Non-Spiked Sample: 98111014.D

	Spike Sample	Spike Duplicate Sample
File ID :	98111015.D	98111016.D
Sample :	AA66463 5mL Water MS	AA66463 5mL Water MSD
Acq Time:	10 Nov 98 6:39 pm	10 Nov 98 7:10 pm

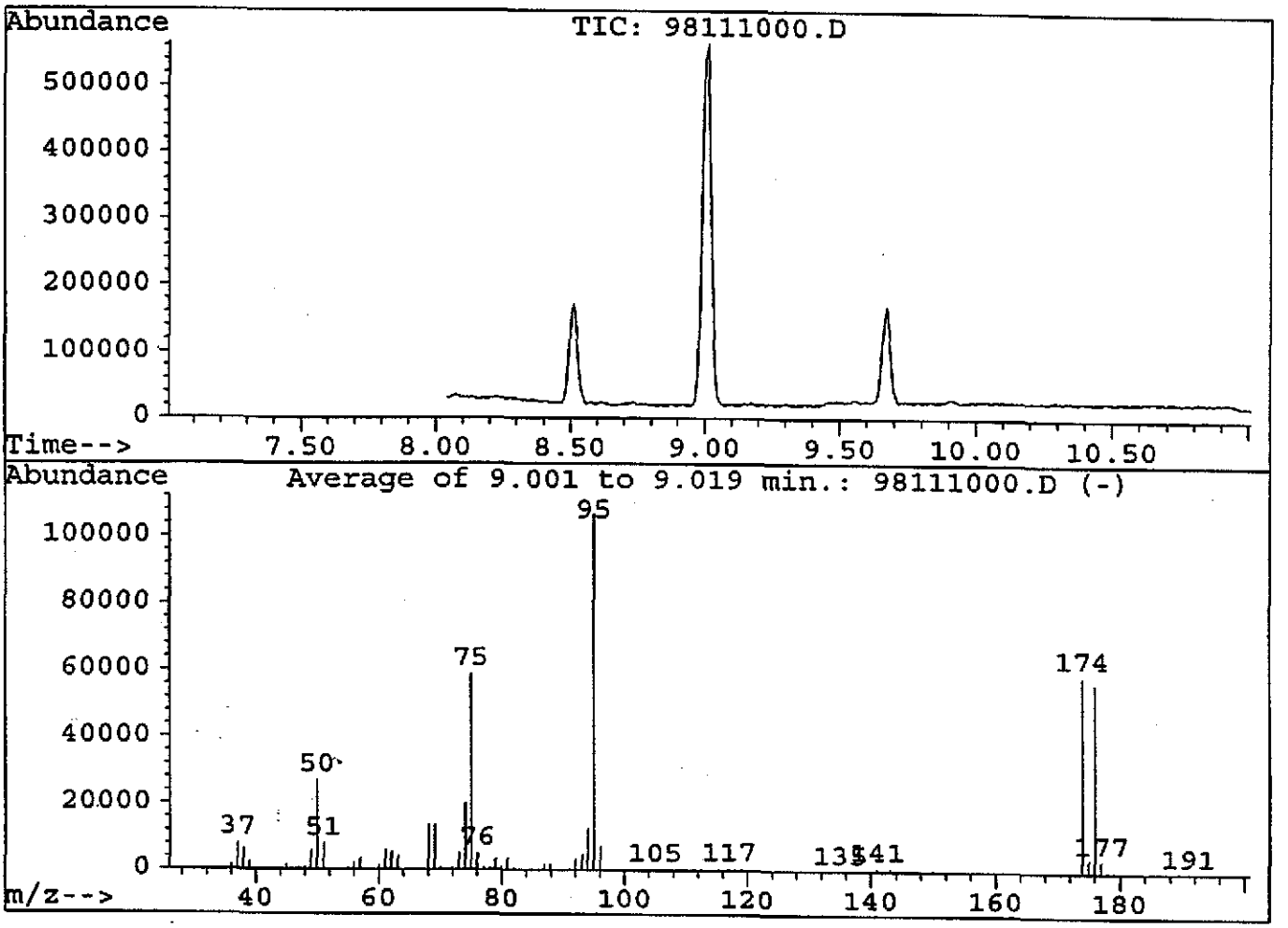
Compound	Sample Conc	Spike Added	Spike Res	Dup Res	Spike %Rec	Dup %Rec	RPD	QC Limits RPD	QC Limits % Rec
1,1-dichloroethene*	0.0	50	59	53	117	105	11	14	61-145
benzene*	0.0	50	49	46	98	92	7	11	76-127
trichloroethene*	0.0	50	51	46	101	91	10	14	71-120
toluene	0.0	50	52	49	105	98	6	13	76-125
chlorobenzene*	0.0	50	46	43	92	85	8	13	75-130

BFB

Data File : C:\HPCHEM\1\DATA\981110\98111000.D
Acq On : 10 Nov 98 10:35 am
Sample : BFB Tune Check
Misc : Tune Check

Vial: 1
Operator: klp
Inst : 5972 - In
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\BFB-VOC.M
Title : BFB Tune Check for Method EPA-8260 QC Criteria



Peak Apex is scan: 108

Target Mass	Rel. to Mass	Lower Limit%	Upper Limit%	Rel. Abn%	Raw Abn	Result Pass/Fail
50	95	15	40	25.2	26936	PASS
75	95	30	60	55.2	58981	PASS
95	95	100	100	100.0	106917	PASS
96	95	5	9	7.0	7476	PASS
173	174	0	2	0.0	0	PASS
174	95	50	100	55.1	58872	PASS
175	174	5	9	7.5	4406	PASS
176	174	95	101	96.2	56651	PASS
177	176	5	9	6.5	3657	PASS

Response Factor Report 5972 - In

Method : C:\HPCHEM\1\METHODS\8260SOIL.M
Title : SW-846 -8260
Last Update : Tue Sep 15 16:31:25 1998
Response via : Initial Calibration

Calibration Files
1 =980915L1.D 2 =980915L2.D 3 =980915L3.D
4 =980915L4.D 5 =980915L5.D 6 =980915L6.D

		Compound	1	2	3	4	5	6	Avg	%RSD
1)	I	pentafluorobenzene	----------ISTD----------							
2)	T	dichlorodifluoromet	0.906	0.869	0.849	0.820	0.840	0.811	0.849	4.06
3)	P	chloromethane	0.862	0.790	0.753	0.764	0.777	0.763	0.785	5.10
4)	C	vinyl chloride*	0.808	0.758	0.735	0.738	0.755	0.740	0.756	3.59
5)	T	bromomethane	0.471	0.451	0.453	0.456	0.466	0.442	0.457	2.32
6)	T	chloroethane	0.318	0.312	0.306	0.312	0.311	0.295	0.309	2.51
7)	T	trichlorofluorometh	1.845	1.688	1.672	1.657	1.681	1.590	1.689	4.98
8)	CM	1,1-dichloroethene*	1.279	1.181	1.145	1.126	1.149	1.106	1.165	5.28
9)	T	Iodomethane	0.096	0.141	0.159	0.172	0.187	0.200	0.159	23.36
10)	T	Carbon disulfide	0.357	0.340	0.326	0.323	0.326	0.316	0.331	4.45
11)	T	methylene chloride	0.882	0.636	0.520	0.507	0.499	0.454	0.583	27.15
12)	T	trans-1,2-dichloroe	1.064	0.997	0.983	0.977	1.002	0.945	0.995	3.95
13)	T	Acetone	0.044	0.070	0.073	0.084	1.002	0.945	0.068	24.67
14)	T	Methyl ethyl ketone	0.130	0.126	0.130	0.135	0.134	0.136	0.132	3.01
15)	T	Acrolein							0.000#	-1.00
16)	T	Acrylonitrile							0.000#	-1.00
17)	P	1,1-dichloroethane	1.280	1.198	1.155	1.150	1.171	1.126	1.180	4.59
18)	T	Vinyl acetate	0.507	0.510	0.479	0.460	0.430	0.368	0.459	11.68
19)	T	2,2-dichloropropane	1.189	1.227	1.205	1.229	1.247	1.158	1.209	2.68
20)	T	cis-1,2-dichloroeth	0.599	0.556	0.520	0.538	0.541	0.522	0.546	5.31
21)	T	bromochloromethane	0.224	0.245	0.230	0.241	0.243	0.233	0.236	3.48
22)	C	chloroform*	1.610	1.444	1.426	1.423	1.443	1.366	1.452	5.68
23)	S	dibromofluoromethan	0.675	0.661	0.662	0.664	0.673	0.669	0.667	0.89
24)	T	1,1,1-trichloroetha	1.617	1.551	1.542	1.567	1.591	1.489	1.559	2.82
25)	I	1,4-difluorobenzene	----------ISTD----------							
26)	T	carbon tetrachlorid	0.833	0.839	0.840	0.826	0.841	0.798	0.829	1.96
27)	T	1,1-dichloropropene	0.613	0.580	0.578	0.561	0.577	0.559	0.578	3.36
28)	M	benzene*	1.214	1.184	1.139	1.122	1.133	1.114	1.151	3.42
29)	T	1,2-dichloroethane*	0.743	0.709	0.710	0.714	0.732	0.701	0.718	2.23
30)	M	trichloroethene*	0.453	0.449	0.440	0.425	0.432	0.425	0.437	2.79
31)	C	1,2-dichloropropane	0.303	0.300	0.291	0.287	0.290	0.290	0.294	2.17
32)	T	dibromomethane	0.209	0.222	0.217	0.223	0.223	0.215	0.218	2.60
33)	T	bromodichloromethan	0.617	0.645	0.643	0.654	0.657	0.636	0.642	2.21
34)	T	2-Chloroethylvinyl	0.634	0.760	0.889	1.028	0.975		0.857	18.75
35)	T	cis-1,3-dichloropro	0.479	0.493	0.488	0.488	0.495	0.496	0.490	1.29
36)	T	4-Methyl-2-pentanon	0.245	0.261	0.261	0.284	0.271	0.266	0.265	4.96
37)	S	toluene-d8	1.059	1.072	1.067	1.081	1.061	1.089	1.072	1.11
38)	M	toluene	0.807	0.756	0.764	0.741	0.751	0.742	0.760	3.24
[illegible])	T	trans-1,3-dichlorop	0.442	0.487	0.478	0.492	0.503	0.505	0.485	4.81
[illegible])	T	1,1,2-trichloroetha	0.185	0.190	0.181	0.187	0.189	0.182	0.186	2.00

(#) = Out of Range

Response Factor Report 5972 - In

Method : C:\HPCHEM\1\METHODS\8260SOIL.M
Title : SW-846 -8260
Last Update : Tue Sep 15 16:31:25 1998
Response via : Initial Calibration

Calibration Files
1 =980915L1.D 2 =980915L2.D 3 =980915L3.D
4 =980915L4.D 5 =980915L5.D 6 =980915L6.D

		Compound	1	2	3	4	5	6	Avg	%RSD
41)	T	2-Hexanone	0.163	0.174	0.179	0.203	0.194	0.192	0.184	7.89
42)	I	Chlorobenzene-d5	----------	----------	----------	ISTD	----------	----------	----------	
43)	T	tetrachloroethene*	0.673	0.635	0.609	0.569	0.582	0.564	0.605	7.03
44)	T	1,3-dichloropropane	0.694	0.704	0.660	0.658	0.656	0.626	0.666	4.24
45)	T	dibromochloromethan	0.517	0.540	0.535	0.544	0.536	0.531	0.534	1.75
46)	T	1,2-dibromoethane	0.329	0.377	0.329	0.313	0.302	0.293	0.324	9.14
47)	M	chlorobenzene*	1.598	1.548	1.479	1.450	1.458	1.406	1.490	4.73
48)	T	1,1,1,2-tetrachloro	0.724	0.734	0.724	0.710	0.715	0.682	0.715	2.52
49)	C	ethylbenzene	3.361	3.178	3.100	2.975	3.003	2.883	3.083	5.52
50)	T	m,p-xylene	1.013	0.946	0.933	0.878	0.895	0.878	0.924	5.62
51)	T	o-xylene	0.934	0.930	0.906	0.869	0.873	0.845	0.893	4.05
52)	T	styrene	1.385	1.415	1.426	1.360	1.373	1.345	1.384	2.28
53)	P	bromoform	0.326	0.365	0.359	0.369	0.361	0.347	0.355	4.48
54)	I	1,4-dichlorobenzene-d	----------	----------	----------	ISTD	----------	----------	----------	
55)	T	isopropylbenzene	4.193	3.771	3.629	3.556	3.607	3.511	3.711	6.79
56)	S	4-bromofluorobenzen	1.414	1.329	1.298	1.343	1.334	1.344	1.344	2.84
57)	T	bromobenzene	0.944	0.878	0.838	0.839	0.845	0.829	0.862	5.06
58)	P	1,1,2,2-tetrachloro	0.694	0.657	0.612	0.657	0.645	0.619	0.647	4.59
59)	T	1,2,3-trichloroprop	0.202	0.206	0.200	0.209	0.208	0.195	0.203	2.69
60)	T	n-propylbenzene	5.796	5.233	4.993	4.897	4.951	4.782	5.109	7.21
61)	T	2-chlorotoluene	4.243	3.878	3.945	3.882	3.642	3.731	3.887	5.33
62)	T	4-chlorotoluene	3.883	3.442	3.067	2.995	3.296	2.974	3.276	10.66
63)	T	1,3,5-trimethylbenz	4.048	3.661	3.511	3.409	3.482	3.380	3.582	6.95
64)	T	tert-butylbenzene	3.777	3.437	3.266	3.199	3.232	3.071	3.331	7.47
65)	T	1,2,4-trimethylbenz	4.057	3.711	3.518	3.485	3.527	3.422	3.620	6.48
66)	T	sec-butylbenzene	4.870	4.426	4.236	4.118	4.191	4.103	4.324	6.74
67)	T	1,3-dichlorobenzene	1.794	1.681	1.577	1.588	1.587	1.534	1.627	5.85
68)	T	4-isopropyltoluene	4.053	3.740	3.540	3.475	3.548	3.407	3.627	6.52
69)	T	1,4-dichlorobenzene	1.778	1.639	1.577	1.582	1.553	1.513	1.607	5.79
70)	T	1,2-dichlorobenzene	1.640	1.557	1.465	1.484	1.464	1.427	1.506	5.21
71)	T	n-butylbenzene	4.523	4.128	3.942	3.830	3.865	3.722	4.002	7.22
72)	T	1,2-dibromo-3-chlor	0.123	0.126	0.129	0.135	0.127	0.132	0.128	3.38
73)	T	1,2,4-trichlorobenz	0.915	0.929	0.899	0.876	0.867	0.849	0.889	3.41
74)	T	hexachlorobutadiene	0.616	0.650	0.656	0.624	0.640	0.618	0.634	2.69
75)	T	naphthalene	1.712	1.964	1.883	2.002	1.985	1.937	1.914	5.61
76)	T	1,2,3-trichlorobenz	0.768	0.808	0.785	0.781	0.792	0.772	0.784	1.84

(#) = Out of Range

Evaluate Continuing Calibration Report

Data File : C:\HPCHEM\1\DATA\981110\98111001.D Vial: 1
Acq On : 10 Nov 98 11:05 am Operator: klp
Sample : 8260 Con Cal 50ppb Soil Inst : 5972 - In
Misc : 5035 (Soil) Con Cal; IS/Surs @ 50ppb Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\8260SOIL.M
Title : SW-846 -8260
Last Update : Tue Sep 15 16:31:25 1998
Response via : Multiple Level Calibration

Min. RRF : 0.010 Min. Rel. Area : 50% Max. R.T. Dev 0.50min
Max. RRF Dev : 20% Max. Rel. Area : 200%

		Compound	AvgRF	CCRF	%Dev	Area%	Dev(min)
1	I	pentafluorobenzene	1.000	1.000	0.0	90	0.02
2	T	dichlorodifluoromethane	0.849	0.716	15.7	75	0.00
3	P	chloromethane	0.785	0.786	-0.2	90	0.03
4	C	vinyl chloride*	0.756	0.691	8.6	82	0.00
5	T	bromomethane	0.457	0.491	-7.5	98	0.00
6	T	chloroethane	0.309	0.342	-10.8	99	-0.01
7	T	trichlorofluoromethane	1.689	1.893	-12.1	101	0.00
8	CM	1,1-dichloroethene*	1.165	1.196	-2.7	92	0.00
9	T	Iodomethane	0.159	0.559	-250.4#	357#	0.00
10	T	Carbon disulfide	0.331	1.716	-417.8#	456#	0.00
11	T	methylene chloride	0.583	1.154	-98.0#	164	0.00
12	T	trans-1,2-dichloroethene	0.995	1.060	-6.5	96	0.02
13	T	Acetone	0.068	0.000#	100.0#	0#	-8.30#
14	T	Methyl ethyl ketone*	0.132	0.088	33.0#	64	0.04
15	T	Acrolein	0.000	0.000#	0.0	0#	-8.40#
16	T	Acrylonitrile	0.000	0.000#	0.0	0#	-9.07#
17	P	1,1-dichloroethane	1.180	1.244	-5.4	94	0.00
18	T	Vinyl acetate	0.459	0.645	-40.4#	114	0.02
19	T	2,2-dichloropropane	1.209	1.293	-6.9	95	0.02
20	T	cis-1,2-dichloroethene	0.546	0.553	-1.3	90	0.00
21	T	bromochloromethane	0.236	0.215	8.7	80	0.00
22	C	chloroform*	1.452	1.558	-7.3	98	0.00
23	S	dibromofluoromethane	0.667	0.670	-0.4	92	0.00
24	T	1,1,1-trichloroethane	1.559	1.677	-7.5	98	0.00
25	I	1,4-difluorobenzene	1.000	1.000	0.0	88	0.03
26	T	carbon tetrachloride*	0.829	0.935	-12.8	99	0.00
27	T	1,1-dichloropropene	0.578	0.637	-10.2	97	0.02
28	M	benzene*	1.151	1.213	-5.3	90	0.02
29	T	1,2-dichloroethane*	0.718	0.670	6.6	84	0.00
30	M	trichloroethene*	0.437	0.491	-12.3	97	0.02
31	C	1,2-dichloropropane	0.294	0.296	-0.8	87	0.02
32	T	dibromomethane	0.218	0.186	14.8	74	0.00
33	T	bromodichloromethane	0.642	0.618	3.8	85	0.00
34	T	2-Chloroethylvinyl ether	0.857	0.000#	100.0#	0#	-12.67#
35	T	cis-1,3-dichloropropene	0.490	0.457	6.8	82	0.02
36	T	4-Methyl-2-pentanone	0.265	0.166	37.4#	56	0.02
[illegible]	S	toluene-d8	1.072	1.061	1.0	87	0.02
[illegible]	M	toluene	0.760	0.807	-6.2	94	0.02
39	T	trans-1,3-dichloropropene	0.485	0.398	17.9	72	0.02
40	T	1,1,2-trichloroethane	0.186	0.151	18.8	70	0.02
41	T	2-Hexanone	0.184	0.113	38.9#	57	0.02
42	I	Chlorobenzene-d5	1.000	1.000	0.0	90	0.02

43	T	tetrachloroethene*	0.605	0.733	-21.1#	104	0.02
44	T	1,3-dichloropropane	0.666	0.565	15.3	72	0.02
45	T	dibromochloromethane	0.534	0.445	16.6	74	0.02
[illegible]	T	1,2-dibromoethane	0.324	0.211	34.9#	50	0.02
[illegible]	M	chlorobenzene*	1.490	1.522	-2.2	88	0.02
48	T	1,1,1,2-tetrachloroethane	0.715	0.661	7.5	81	0.02
49	C	ethylbenzene	3.083	3.252	-5.5	92	0.02
50	T	m,p-xylene	0.924	1.000	-8.2	95	0.02
51	T	o-xylene	0.893	0.930	-4.2	90	0.02
52	T	styrene	1.384	1.382	0.2	88	0.00
53	P	bromoform	0.355	0.264	25.5#	65	0.02
54	I	1,4-dichlorobenzene-d4	1.000	1.000	0.0	85	0.02
55	T	isopropylbenzene	3.711	4.071	-9.7	92	0.02
56	S	4-bromofluorobenzene	1.344	1.417	-5.4	91	0.02
57	T	bromobenzene	0.862	0.840	2.6	82	0.02
58	P	1,1,2,2-tetrachloroethane	0.647	0.471	27.2#	61	0.02
59	T	1,2,3-trichloropropane	0.203	0.138	32.1#	57	0.02
60	T	n-propylbenzene	5.109	5.845	-14.4	95	0.00
61	T	2-chlorotoluene	3.887	4.300	-10.6	94	0.00
62	T	4-chlorotoluene	3.276	2.849	13.0	71	0.02
63	T	1,3,5-trimethylbenzene	3.582	4.154	-16.0	97	0.02
64	T	tert-butylbenzene	3.331	3.870	-16.2	96	0.00
65	T	1,2,4-trimethylbenzene	3.620	4.128	-14.0	95	0.02
66	T	sec-butylbenzene	4.324	4.922	-13.8	95	0.02
67	T	1,3-dichlorobenzene	1.627	1.739	-6.9	88	0.02
68	T	4-isopropyltoluene	3.627	4.258	-17.4	97	0.00
69	T	1,4-dichlorobenzene	1.607	1.700	-5.8	88	0.02
70	T	1,2-dichlorobenzene	1.506	1.469	2.5	80	0.02
71	T	n-butylbenzene	4.002	4.811	-20.2#	99	0.02
72	T	1,2-dibromo-3-chloropropane	0.128	0.067	48.2#	45#	0.02
73	T	1,2,4-trichlorobenzene	0.889	0.915	-2.9	84	0.02
74	T	hexachlorobutadiene	0.634	0.706	-11.3	93	0.00
75	T	naphthalene	1.914	1.293	32.4#	56	0.00
76	T	1,2,3-trichlorobenzene	0.784	0.598	23.8#	63	0.02

(#) = Out of Range SPCC's out = 0 CCC's out = 0

980915L2.D 8260SOIL.M Tue Nov 17 10:25:02 1998 VOLATILES

Quantitation Report

Data File : C:\HPCHEM\1\DATA\981016\98111606.D
Acq On : 16 Nov 98 1:26 pm
Sample : 5035/8260 Blank 5mL Water
Misc : IS/Surs @ 50/50ppb; 8260 Blank
Quant Time: Nov 16 17:27 1998

Vial: 1
Operator: klp
Inst : 5972 - In
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\8260-H2O.M
Title : SW-846 -8260
Last Update : Mon Nov 16 17:22:09 1998
Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc Units	Dev(Min)
1) pentafluorobenzene	11.02	168	72998	50.00 ug/L	0.01
25) 1,4-difluorobenzene	11.98	114	122920	50.00 ug/L	0.00
42) Chlorobenzene-d5	15.48	82	76244	50.00 ug/L	0.00
54) 1,4-dichlorobenzene-d4	18.40	152	57576	50.00 ug/L	0.00
System Monitoring Compounds					%Recovery
23) dibromofluoromethane	10.97	113	52184	49.91 ug/L	99.83%
37) toluene-d8	13.78	98	131225	48.55 ug/L	97.10%
56) 4-bromofluorobenzene	16.89	95	81781	54.00 ug/L	107.99%
Target Compounds					Qvalue
2) dichlorodifluoromethane	0.00	85		Not Detected	
3) chloromethane	0.00	50		Not Detected	
4) vinyl chloride*	0.00	62		Not Detected	
5) bromomethane	0.00	94		Not Detected	
6) chloroethane	0.00	64		Not Detected	
7) trichlorofluoromethane	0.00	101		Not Detected	
8) 1,1-dichloroethene*	0.00	61		Not Detected	
9) Iodomethane	0.00	142		Not Detected	
10) Carbon disulfide	0.00	76		Not Detected	
11) methylene chloride	9.04	84	1342	2.04 ug/L #	44
12) trans-1,2-dichloroethene	0.00	61		Not Detected	
13) Acetone	0.00	43		Not Detected	
14) Methyl ethyl ketone*	0.00	43		Not Detected	
15) Acrolein	0.00	56		Not Detected	
16) Acrylonitrile	0.00	53		Not Detected	
17) 1,1-dichloroethane	0.00	63		Not Detected	
18) Vinyl acetate	10.06	43	1273	1.51 ug/L #	88
19) 2,2-dichloropropane	0.00	77		Not Detected	
20) cis-1,2-dichloroethene	0.00	96		Not Detected	
21) bromochloromethane	0.00	128		Not Detected	
22) chloroform*	10.80	83	13948	6.56 ug/L	91
24) 1,1,1-trichloroethane	0.00	97		Not Detected	
26) carbon tetrachloride*	0.00	117		Not Detected	
27) 1,1-dichloropropene	0.00	75		Not Detected	
28) benzene*	0.00	78		Not Detected	
29) 1,2-dichloroethane*	0.00	62		Not Detected	
30) trichloroethene*	0.00	95		Not Detected	
31) 1,2-dichloropropane	0.00	63		Not Detected	
32) dibromomethane	0.00	93		Not Detected	
33) bromodichloromethane	0.00	83		Not Detected	
34) 2-Chloroethylvinyl ether	0.00	63		Not Detected	

(#) = qualifier out of range (m) = manual integration

Quantitation Report

Data File : C:\HPCHEM\1\DATA\981016\98111606.D
Acq On : 16 Nov 98 1:26 pm
Sample : 5035/8260 Blank 5mL Water
Misc : IS/Surs @ 50/50ppb; 8260 Blank
Quant Time: Nov 16 17:27 1998

Vial: 1
Operator: klp
Inst : 5972 - In
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\8260-H2O.M
Title : SW-846 -8260
Last Update : Mon Nov 16 17:22:09 1998
Response via : Multiple Level Calibration

	Compound	R.T.	QIon	Response	Conc Unit	Qvalue
35)	cis-1,3-dichloropropene	0.00	75		Not Detected	
36)	4-Methyl-2-pentanone	0.00	43		Not Detected	
38)	toluene	0.00	92		Not Detected	
39)	trans-1,3-dichloropropene	0.00	75		Not Detected	
40)	1,1,2-trichloroethane	0.00	83		Not Detected	
41)	2-Hexanone	0.00	43		Not Detected	
43)	tetrachloroethene*	0.00	166		Not Detected	
44)	1,3-dichloropropane	0.00	76		Not Detected	
45)	dibromochloromethane	0.00	127		Not Detected	
46)	1,2-dibromoethane	0.00	107		Not Detected	
47)	chlorobenzene*	0.00	112		Not Detected	
48)	1,1,1,2-tetrachloroethane	0.00	131		Not Detected	
49)	ethylbenzene	0.00	91		Not Detected	
50)	m,p-xylene	0.00	106		Not Detected	
51)	o-xylene	0.00	106		Not Detected	
52)	styrene	0.00	104		Not Detected	
53)	bromoform	0.00	173		Not Detected	
55)	isopropylbenzene	0.00	105		Not Detected	
57)	bromobenzene	0.00	156		Not Detected	
58)	1,1,2,2-tetrachloroethane	0.00	83		Not Detected	
59)	1,2,3-trichloropropane	0.00	110		Not Detected	
60)	n-propylbenzene	0.00	91		Not Detected	
61)	2-chlorotoluene	0.00	91		Not Detected	
62)	4-chlorotoluene	0.00	91		Not Detected	
63)	1,3,5-trimethylbenzene	0.00	105		Not Detected	
64)	tert-butylbenzene	0.00	91		Not Detected	
65)	1,2,4-trimethylbenzene	0.00	105		Not Detected	
66)	sec-butylbenzene	0.00	105		Not Detected	
67)	1,3-dichlorobenzene	0.00	146		Not Detected	
68)	4-isopropyltoluene	0.00	119		Not Detected	
69)	1,4-dichlorobenzene	0.00	146		Not Detected	
70)	1,2-dichlorobenzene	0.00	146		Not Detected	
71)	n-butylbenzene	0.00	91		Not Detected	
72)	1,2-dibromo-3-chloropropan	0.00	75		Not Detected	
73)	1,2,4-trichlorobenzene	0.00	180		Not Detected	
74)	hexachlorobutadiene	0.00	225		Not Detected	
75)	naphthalene	21.27	128	2214	2.09 ug/L	62
76)	1,2,3-trichlorobenzene	21.63	180	510	1.16 ug/L	94

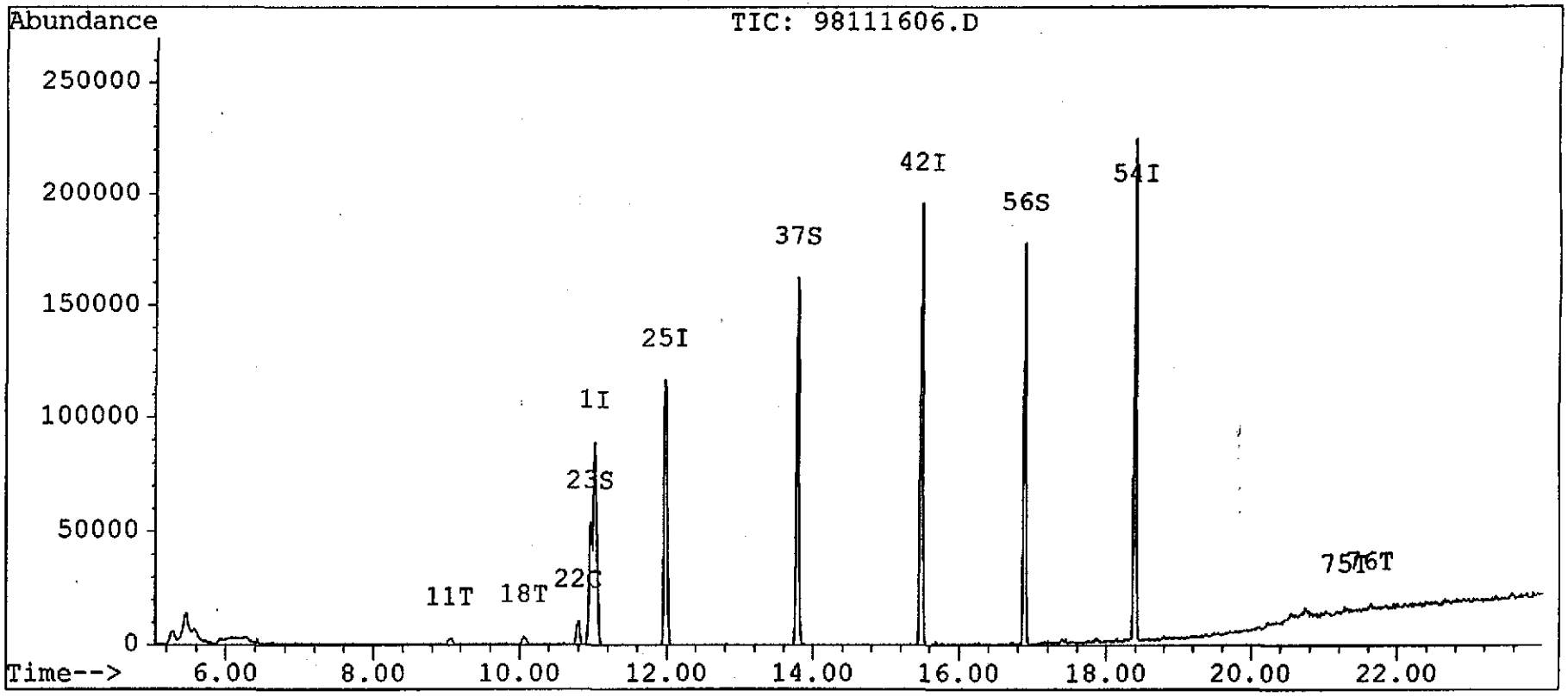
(#) = qualifier out of range (m) = manual integration

981116.12

Data File : C:\HPCHEM\1\DATA\981016\98111606.D
Acq On : 16 Nov 98 1:26 pm
Sample : 5035/8260 Blank 5mL Water
Misc : IS/Surs @ 50/50ppb; 8260 Blank
Quant Time: Nov 16 17:27 1998

Vial: 1
Operator: klp
Inst : 5972 - In
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\8260-H2O.M
Title : SW-846 -8260
Last Update : Mon Nov 16 17:22:09 1998
Response via : Multiple Level Calibration



Spike Recovery and RPD Summary Report - WATER

Method : C:\HPCHEM\1\METHODS\8260-H2O.M
Title : SW-846 -8260
Last Update : Mon Nov 16 17:22:09 1998
Response via : Initial Calibration

Non-Spiked Sample: 98111608.D

	Spike Sample	Spike Duplicate Sample
File ID :	98111609.D	98111610.D
Sample :	AA66674 5mL Water MS	AA66674 5mL Water MSD
Acq Time:	16 Nov 98 2:58 pm	16 Nov 98 3:28 pm

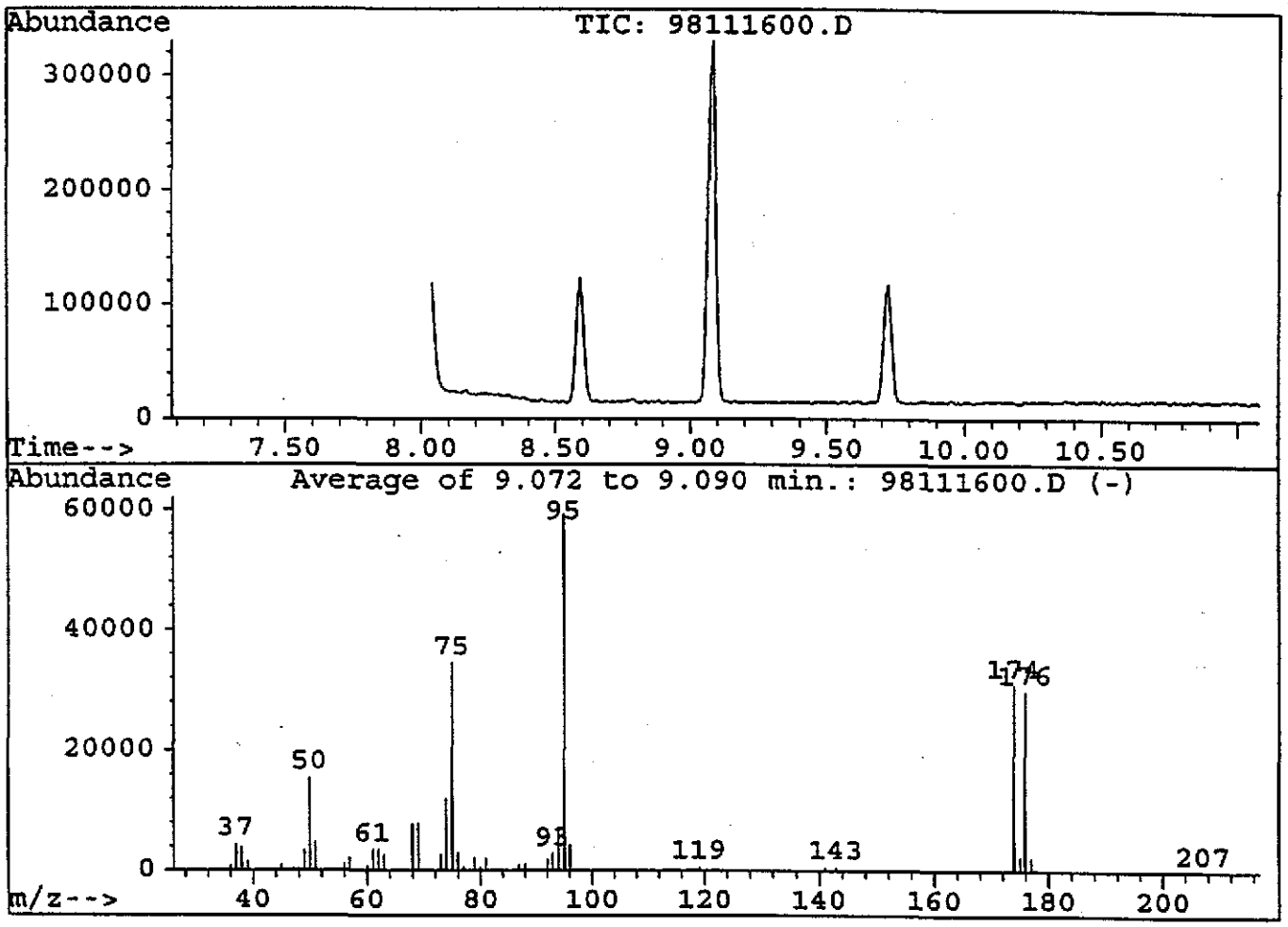
Compound	Sample Conc	Spike Added	Spike Res	Dup Res	Spike %Rec	Dup %Rec	RPD	QC Limits RPD	QC Limits % Rec
1,1-dichloroethene*	0.0	50	49	45	98	90	9	14	61-145
benzene*	0.0	50	53	49	106	97	9	11	76-127
trichloroethene*	0.0	50	52	47	104	94	10	14	71-120
toluene	0.0	50	53	51	105	101	4	13	76-125
chlorobenzene*	0.0	50	54	52	108	104	4	13	75-130

BFB

Data File : C:\HPCHEM\1\DATA\981016\98111600.D
Acq On : 16 Nov 98 10:06 am
Sample : BFB Tune Check
Misc : Tune Check

Vial: 1
Operator: klp
Inst : 5972 - In
Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\BFB-VOC.M
Title : BFB Tune Check for Method EPA-8260 QC Criteria



Peak Apex is scan: 116

Target Mass	Rel. to Mass	Lower Limit%	Upper Limit%	Rel. Abn%	Raw Abn	Result Pass/Fail
50	95	15	40	26.2	15474	PASS
75	95	30	60	58.6	34632	PASS
95	95	100	100	100.0	59125	PASS
96	95	5	9	7.3	4310	PASS
173	174	0	2	0.0	0	PASS
174	95	50	100	52.6	31112	PASS
175	174	5	9	7.7	2390	PASS
176	174	95	101	96.3	29957	PASS
177	176	5	9	7.5	2261	PASS

98111600.D BFB-VOC.M Mon Nov 16 10:21:45 1998 VOLATILES

Response Factor Report 5972 - In

Method : C:\HPCHEM\1\METHODS\8260-H2O.M
Title : SW-846 -8260
Last Update : Mon Nov 16 17:22:09 1998
Response via : Initial Calibration

Calibration Files
1 =981116L1.D 2 =981116L2.D 3 =981116L3.D
4 =981116L4.D 5 =981116L5.D

		Compound	1	2	3	4	5	Avg	%RSD
1)	I	pentafluorobenzene	----------ISTD----------						
2)	T	dichlorodifluorometha	1.352	1.300	1.133	1.194	1.214	1.239	7.03
3)	P	chloromethane	0.925	0.887	0.822	0.835	0.799	0.854	6.01
4)	C	vinyl chloride*	0.738	0.699	0.632	0.644	0.629	0.669	7.20
5)	T	bromomethane	0.426	0.433	0.426	0.438	0.434	0.431	1.29
6)	T	chloroethane	0.363	0.336	0.326	0.320	0.313	0.332	5.90
7)	T	trichlorofluoromethan	1.900	1.929	1.749	1.762	1.783	1.825	4.58
8)	CM	1,1-dichloroethene*	1.106	1.149	1.067	1.064	1.028	1.083	4.26
9)	T	Iodomethane	0.093	0.109	0.119	0.111	0.114	0.109	9.14
10)	T	Carbon disulfide	0.162	0.183	0.185	0.185	0.179	0.179	5.38
11)	T	methylene chloride	0.527	0.475	0.421	0.414	0.413	0.450	11.15
12)	T	trans-1,2-dichloroeth	0.972	0.992	0.933	0.946	0.912	0.951	3.32
13)	T	Acetone	0.053	0.071	0.075	0.082		0.070	17.38
14)	T	Methyl ethyl ketone*	0.077	0.085	0.104	0.101	0.102	0.094	12.65
15)	T	Acrolein						0.000#	-1.00
16)	T	Acrylonitrile						0.000#	-1.00
17)	P	1,1-dichloroethane	1.166	1.192	1.133	1.127	1.094	1.142	3.30
18)	T	Vinyl acetate	0.587	0.593	0.608	0.551	0.547	0.577	4.65
19)	T	2,2-dichloropropane	0.950	0.924	0.950	0.937	0.852	0.922	4.42
20)	T	cis-1,2-dichloroethen	0.510	0.537	0.505	0.513	0.511	0.515	2.48
21)	T	bromochloromethane	0.197	0.204	0.200	0.198	0.197	0.199	1.57
22)	C	chloroform*	1.575	1.545	1.398	1.400	1.360	1.456	6.69
23)	S	dibromofluoromethane	0.682	0.711	0.748	0.724	0.715	0.716	3.35
24)	T	1,1,1-trichloroethane	1.504	1.578	1.468	1.452	1.350	1.471	5.64
25)	I	1,4-difluorobenzene	----------ISTD----------						
26)	T	carbon tetrachloride*	0.802	0.821	0.766	0.723	0.673	0.757	7.92
27)	T	1,1-dichloropropene	0.553	0.573	0.508	0.499	0.464	0.519	8.43
28)	M	benzene*	1.135	1.084	1.033	1.027	0.991	1.054	5.32
29)	T	1,2-dichloroethane*	0.620	0.652	0.628	0.599	0.611	0.622	3.17
30)	M	trichloroethene*	0.442	0.439	0.419	0.405	0.385	0.418	5.73
31)	C	1,2-dichloropropane	0.273	0.275	0.267	0.256	0.251	0.265	3.96
32)	T	dibromomethane	0.182	0.183	0.178	0.171	0.171	0.177	3.35
33)	T	bromodichloromethane	0.577	0.574	0.568	0.562	0.559	0.568	1.38
34)	T	2-Chloroethylvinyl et	0.293	0.303	0.314	0.340	0.331	0.316	6.17
35)	T	cis-1,3-dichloroprope	0.391	0.383	0.396	0.388	0.382	0.388	1.48
36)	T	4-Methyl-2-pentanone	0.142	0.142	0.153	0.144	0.160	0.148	5.60
37)	S	toluene-d8	1.117	1.083	1.113	1.094	1.090	1.099	1.36
38)	M	toluene	0.729	0.698	0.677	0.653	0.594	0.670	7.65
39)	T	trans-1,3-dichloropro	0.331	0.333	0.358	0.337	0.352	0.342	3.51
	T	1,1,2-trichloroethane	0.137	0.140	0.136	0.133	0.136	0.136	1.80
	T	2-Hexanone	0.088	0.096	0.100	0.097	0.105	0.097	6.36
42)	I	Chlorobenzene-d5	----------ISTD----------						
43)	T	tetrachloroethene*	0.495	0.534	0.460	0.472	0.432	0.479	8.03
44)	T	1,3-dichloropropane	0.416	0.424	0.429	0.430	0.410	0.422	2.04
45)	T	dibromochloromethane	0.354	0.371	0.370	0.381	0.374	0.370	2.68

46)	T	1,2-dibromoethane	0.194	0.176	0.157	0.157	0.149	0.167	10.81
47)	M	chlorobenzene*	1.185	1.218	1.110	1.141	1.005	1.132	7.27
48)	T	1,1,1,2-tetrachloroet	0.523	0.558	0.525	0.535	0.475	0.523	5.81
	C	ethylbenzene	2.469	2.551	2.227	2.295	1.915	2.291	10.80
	T	m,p-xylene	0.747	0.783	0.703	0.725	0.611	0.714	9.03
51)	T	o-xylene	0.731	0.770	0.687	0.714	0.602	0.701	9.02
52)	T	styrene	1.044	1.117	1.040	1.054	0.917	1.034	7.03
53)	P	bromoform	0.204	0.201	0.209	0.208	0.205	0.205	1.47
54)	I	1,4-dichlorobenzene-d	----------ISTD----------						
55)	T	isopropylbenzene	2.779	2.668	2.340	2.316	2.029	2.426	12.36
56)	S	4-bromofluorobenzene	1.337	1.269	1.345	1.302	1.322	1.315	2.32
57)	T	bromobenzene	0.595	0.568	0.567	0.532	0.510	0.554	6.02
58)	P	1,1,2,2-tetrachloroet	0.347	0.303	0.316	0.306	0.325	0.319	5.50
59)	T	1,2,3-trichloropropan	0.099	0.108	0.101	0.096	0.102	0.101	4.23
60)	T	n-propylbenzene	3.912	3.829	3.356	3.257	2.835	3.438	12.84
61)	T	2-chlorotoluene	3.153	3.003	2.763	2.652	2.588	2.832	8.44
62)	T	4-chlorotoluene	2.758	2.752	2.599	2.300	2.082	2.498	11.91
63)	T	1,3,5-trimethylbenzen	2.804	2.956	2.541	2.516	2.256	2.615	10.41
64)	T	tert-butylbenzene	2.591	2.595	2.187	2.121	1.874	2.274	13.82
65)	T	1,2,4-trimethylbenzen	2.860	3.000	2.676	2.604	2.368	2.701	8.98
66)	T	sec-butylbenzene	2.830	2.786	2.432	2.405	2.363	2.563	8.80
67)	T	1,3-dichlorobenzene	1.249	1.205	1.160	1.119	1.035	1.154	7.13
68)	T	4-isopropyltoluene	2.521	2.774	2.212	2.215	2.166	2.378	11.05
69)	T	1,4-dichlorobenzene	1.196	1.209	1.149	1.095	1.027	1.135	6.65
70)	T	1,2-dichlorobenzene	1.025	0.997	0.979	0.931	0.909	0.968	4.93
71)	T	n-butylbenzene	2.541	2.690	2.252	2.248	2.291	2.404	8.33
72)	T	1,2-dibromo-3-chlorop	0.106	0.092	0.093	0.091	0.089	0.094	7.30
73)	T	1,2,4-trichlorobenzen	0.494	0.583	0.521	0.512	0.501	0.522	6.77
74)	T	hexachlorobutadiene	0.219	0.266	0.226	0.242	0.222	0.235	8.29
75)	T	naphthalene	0.930	0.940	0.909	0.874	0.947	0.920	3.18
76)	T	1,2,3-trichlorobenzen	0.385	0.420	0.375	0.363	0.361	0.381	6.27

(#) = Out of Range

Evaluate Continuing Calibration Report

Data File : C:\HPCHEM\1\DATA\981016\981116L2.D Vial: 2
Acq On : 16 Nov 98 11:24 am Operator: klp
Sample : 8260 Con Cal @ 50ppb Water Inst : 5972 - In
Misc : Con Cal; IS/Surs @ 50ppb Multiplr: 1.00

Method : C:\HPCHEM\1\METHODS\8260-H2O.M
Title : SW-846 -8260
Last Update : Mon Nov 16 17:22:09 1998
Response via : Multiple Level Calibration

Min. RRF : 0.010 Min. Rel. Area : 50% Max. R.T. Dev 0.50min
Max. RRF Dev : 20% Max. Rel. Area : 200%

		Compound	AvgRF	CCRF	%Dev	Area%	Dev(min)
1	I	pentafluorobenzene	1.000	1.000	0.0	100	0.00
2	T	dichlorodifluoromethane	1.239	1.300	-4.9	100	-0.01
3	P	chloromethane	0.854	0.887	-3.9	100	0.00
4	C	vinyl chloride*	0.669	0.699	-4.6	100	0.00
5	T	bromomethane	0.431	0.433	-0.4	100	0.00
6	T	chloroethane	0.332	0.336	-1.3	100	0.07
7	T	trichlorofluoromethane	1.825	1.929	-5.7	100	0.00
8	CM	1,1-dichloroethene*	1.083	1.149	-6.1	100	0.02
9	T	Iodomethane	0.109	0.109	0.1	100	0.02
10	T	Carbon disulfide	0.179	0.183	-2.3	100	0.00
11	T	methylene chloride	0.450	0.475	-5.5	100	0.04
12	T	trans-1,2-dichloroethene	0.951	0.992	-4.3	100	0.00
13	T	Acetone	0.070	0.053	24.1#	100	0.14
14	T	Methyl ethyl ketone*	0.094	0.085	9.5	100	0.00
15	T	Acrolein	0.000	0.000#	0.0	0#	-8.40#
16	T	Acrylonitrile	0.000	0.000#	0.0	0#	-9.07#
17	P	1,1-dichloroethane	1.142	1.192	-4.3	100	0.00
18	T	Vinyl acetate	0.577	0.593	-2.8	100	0.00
19	T	2,2-dichloropropane	0.922	0.924	-0.1	100	0.00
20	T	cis-1,2-dichloroethene	0.515	0.537	-4.3	100	0.00
21	T	bromochloromethane	0.199	0.204	-2.5	100	0.02
22	C	chloroform*	1.456	1.545	-6.1	100	0.00
23	S	dibromofluoromethane	0.716	0.711	0.7	100	0.00
24	T	1,1,1-trichloroethane	1.471	1.578	-7.3	100	0.02
25	I	1,4-difluorobenzene	1.000	1.000	0.0	100	0.00
26	T	carbon tetrachloride*	0.757	0.821	-8.5	100	0.02
27	T	1,1-dichloropropene	0.519	0.573	-10.4	100	0.00
28	M	benzene*	1.054	1.084	-2.8	100	0.00
29	T	1,2-dichloroethane*	0.622	0.652	-4.8	100	0.00
30	M	trichloroethene*	0.418	0.439	-5.0	100	0.00
31	C	1,2-dichloropropane	0.265	0.275	-4.0	100	0.00
32	T	dibromomethane	0.177	0.183	-3.4	100	0.00
33	T	bromodichloromethane	0.568	0.574	-1.1	100	0.00
34	T	2-Chloroethylvinyl ether	0.316	0.000#	100.0#	0#	-12.67#
35	T	cis-1,3-dichloropropene	0.388	0.383	1.2	100	0.00
36	T	4-Methyl-2-pentanone	0.148	0.142	4.4	100	0.00
[illegible]	S	toluene-d8	1.099	1.083	1.5	100	0.00
[illegible]	M	toluene	0.670	0.698	-4.2	100	0.00
39	T	trans-1,3-dichloropropene	0.342	0.333	2.7	100	0.00
40	T	1,1,2-trichloroethane	0.136	0.140	-2.4	100	0.00
41	T	2-Hexanone	0.097	0.096	1.4	100	0.00
42	I	Chlorobenzene-d5	1.000	1.000	0.0	100	0.00

43	T	tetrachloroethene*	0.479	0.534	-11.6	100	0.00
44	T	1,3-dichloropropane	0.422	0.424	-0.4	100	0.00
45	T	dibromochloromethane	0.370	0.371	-0.4	100	0.00
[illegible]	T	1,2-dibromoethane	0.167	0.176	-5.4	100	0.00
[illegible]	M	chlorobenzene*	1.132	1.218	-7.6	100	0.00
48	T	1,1,1,2-tetrachloroethane	0.523	0.558	-6.8	100	0.00
49	C	ethylbenzene	2.291	2.551	-11.3	100	0.00
50	T	m,p-xylene	0.714	0.783	-9.6	100	0.00
51	T	o-xylene	0.701	0.770	-9.9	100	0.00
52	T	styrene	1.034	1.117	-8.0	100	0.00
53	P	bromoform	0.205	0.201	1.9	100	0.00
54	I	1,4-dichlorobenzene-d4	1.000	1.000	0.0	92	0.00
55	T	isopropylbenzene	2.426	2.903	-19.7	100	0.00
56	S	4-bromofluorobenzene	1.315	1.381	-5.0	100	0.00
57	T	bromobenzene	0.554	0.618	-11.4	100	0.00
58	P	1,1,2,2-tetrachloroethane	0.319	0.330	-3.3	100	0.00
59	T	1,2,3-trichloropropane	0.101	0.117	-16.0	100	0.00
60	T	n-propylbenzene	3.438	4.167	-21.2#	100	0.00
61	T	2-chlorotoluene	2.832	3.268	-15.4	100	0.00
62	T	4-chlorotoluene	2.498	2.995	-19.9	100	0.00
63	T	1,3,5-trimethylbenzene	2.615	3.217	-23.1#	100	0.00
64	T	tert-butylbenzene	2.274	2.825	-24.2#	100	0.00
65	T	1,2,4-trimethylbenzene	2.701	3.265	-20.9#	100	0.00
66	T	sec-butylbenzene	2.563	3.386	-32.1#	112	0.00
67	T	1,3-dichlorobenzene	1.154	1.312	-13.7	100	0.00
68	T	4-isopropyltoluene	2.378	3.019	-27.0#	100	0.00
69	T	1,4-dichlorobenzene	1.135	1.316	-15.9	100	0.00
70	T	1,2-dichlorobenzene	0.968	1.085	-12.0	100	0.00
71	T	n-butylbenzene	2.404	3.281	-36.5#	112	0.00
72	T	1,2-dibromo-3-chloropropane	0.094	0.100	-5.7	100	0.00
73	T	1,2,4-trichlorobenzene	0.522	0.634	-21.5#	100	0.00
74	T	hexachlorobutadiene	0.235	0.378	-60.8#	130	0.00
75	T	naphthalene	0.920	1.023	-11.2	100	0.00
76	T	1,2,3-trichlorobenzene	0.381	0.457	-19.9	100	0.00

(#) = Out of Range SPCC's out = 0 CCC's out = 0

981116L2.D 8260-H2O.M Mon Nov 16 17:25:42 1998 VOLATILES

Semivolatile Organics (TCLP) – QC Data Package Summary Argus Analytical, Inc.

Client: Vicksburg Chemical Date: November 20, 1998

Sample #	QC Data Package Starting Page # - Prefix	Surrogate Recoveries - %					
		2-Fluorophenol	Phenol-d5	Nitrobenzene -d5	2-Fluorobiphenyl	2,4,6-Tribromophenol	p-Terphenyl -d14
AA 66497	981110	85	77	73	76	87	73
AA 66498	981110	81	70	64	66	73	67
AA 66499	981110	70	61	58	59	62	66
AA 66724	981117	65	51	53	61	101	65

Starting Page # - Suffix	Data Package Contents
.10	Blank results
.20	MS/MSD Results and Precision
.40	Tune Data
.50	Calibration Summary – Initial
.60	Calibration Summary – Continuing

Quantitation Report

Data File : D:\HPCHEM\1\DATA\981110\BLK-S.D
Acq On : 10 Nov 98 1:10 pm
Sample : pah_s blank
Misc : soil 30 g/1 ml
Quant Time: Nov 11 8:39 1998

Vial: 31
Operator: rlt
Inst : 5972 - In
Multiplr: 1.00

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Thu Oct 15 13:09:16 1998
Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) 1,4-Dichlorobenzene-d4	5.78	152	337849	40.00	ng	-0.02
19) Naphthalene-d8	7.23	136	1058350	40.00	ng	0.00
39) Acenaphthene-d10	9.92	164	559011	40.00	ng	0.03
66) Phenanthrene-d10	12.64	188	711562	40.00	ng	0.05
84) Chrysene-d12	18.86	240	112002	40.00	ng	0.03
92) Perylene-d12	23.33	264	63085	40.00	ng	0.11
System Monitoring Compounds						%Recovery
4) 2-Fluorophenol	4.63	112	1905115	182.86	ppb	91.43%
7) Phenol-d5	5.48	99	2012407	148.87	ppb	74.44%
21) Nitrobenzene-d5	6.39	82	977103	67.47	ppb	67.47%
44) 2-Fluorobiphenyl	8.80	172	1545828	72.23	ppb	72.23%
72) 2,4,6-Tribromophenol	11.39	330	494834	140.87	ppb	70.43%
85) p-Terphenyl-d14	15.99	244	710492	76.18	ppb	76.18%
Target Compounds						Qvalue
2) n-Nitrosodimethylamine	0.00	74		Not Detected		
3) Pyridine	0.00	79		Not Detected		
5) Aniline	0.00	93		Not Detected		
6) Phenol	0.00	94		Not Detected		
8) bis(2-Chloroethyl)ether	0.00	93		Not Detected		
9) 2-Chlorophenol	5.61	128	1314	0.14	ppb	# 43
10) 1,3-Dichlorobenzene	0.00	146		Not Detected		
11) 1,4-Dichlorobenzene	0.00	146		Not Detected		
12) 1,2-Dichlorobenzene	0.00	146		Not Detected		
13) Benzyl alcohol	0.00	108		Not Detected		
14) o-Cresol	0.00	107		Not Detected		
15) bis(2-Chloroisopropyl)ethe	0.00	45		Not Detected		
16) Hexachloroethane	0.00	117		Not Detected		
17) p-Cresol	0.00	107		Not Detected		
18) N-Nitrosodipropylamine	0.00	70		Not Detected		
20) N-Nitroso-morpholine	0.00	56		Not Detected		
22) Nitrobenzene	6.39	77	4929	0.33	ppb	# 31
23) N-Nitrosopiperidine	0.00	114		Not Detected		
24) Isophorone	0.00	82		Not Detected		
25) 2-Nitrophenol	0.00	139		Not Detected		
26) 2,4-Dimethylphenol	0.00	122		Not Detected		
27) bis(2-Chloroethoxy)methane	0.00	93		Not Detected		
28) 2,4-Dichlorophenol	0.00	162		Not Detected		
29) Benzoic acid	0.00	122		Not Detected		
30) 1,2,4-Trichlorobenzene	0.00	180		Not Detected		
31) Naphthalene	0.00	128		Not Detected		
32) 2,6-Dichlorophenol	0.00	162		Not Detected		
33) 4-Chloroaniline	0.00	127		Not Detected		

(#) = qualifier out of range (m) = manual integration

Quantitation Report

Data File : D:\HPCHEM\1\DATA\981110\BLK-S.D
Acq On : 10 Nov 98 1:10 pm
Sample : pah_s blank
Misc : soil 30 g/1 ml
Quant Time: Nov 11 8:39 1998

Vial: 31
Operator: rlt
Inst : 5972 - In
Multiplr: 1.00

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Thu Oct 15 13:09:16 1998
Response via : Multiple Level Calibration

	Compound	R.T.	QIon	Response	Conc	Unit		Qvalue
34)	Hexachlorobutadiene	0.00	225		Not Detected			
35)	N-Nitrosodi-n-butylamine	0.00	84		Not Detected			
36)	4-Chloro-3-methylphenol	0.00	107		Not Detected			
37)	1-Methylnaphthalene	0.00	142		Not Detected			
38)	2-Methylnaphthalene	0.00	142		Not Detected			
40)	1,2,4,5-Tetrachlorobenzene	0.00	216		Not Detected			
41)	Hexachlorocyclopentadiene	0.00	237		Not Detected			
42)	2,4,6-Trichlorophenol	0.00	196		Not Detected			
43)	2,4,5-Trichlorophenol	0.00	196		Not Detected			
45)	1-Chloronaphthalene	0.00	162		Not Detected			
46)	2-Chloronaphthalene	0.00	162		Not Detected			
47)	2-Nitroaniline	0.00	65		Not Detected			
48)	Acenaphthylene	0.00	152		Not Detected			
49)	Dimethyl phthalate	0.00	163		Not Detected			
50)	2,4-Dinitrotoluene	0.00	165		Not Detected			
51)	3-Nitroaniline	0.00	138		Not Detected			
52)	Acenaphthene	0.00	154		Not Detected			
53)	2,4-Dinitrophenol	0.00	184		Not Detected			
54)	Dibenzofuran	0.00	168		Not Detected			
55)	Pentachlorobenzene	0.00	250		Not Detected			
56)	4-Nitrophenol	0.00	139		Not Detected			
57)	1-Naphthylamine	0.00	143		Not Detected			
58)	2,6-Dinitrotoluene	0.00	165		Not Detected			
59)	2-Naphthylamine	0.00	143		Not Detected			
60)	2,3,4,6-Tetrachlorophenol	0.00	232		Not Detected			
61)	Fluorene	0.00	166		Not Detected			
62)	4-Chlorophenyl phenyl ethe	0.00	204		Not Detected			
63)	Diethyl phthalate	0.00	149		Not Detected			
64)	Azobenzene	0.00	77		Not Detected			
65)	4-Nitroaniline	11.37	138	1001	0.[illegible]7	ppb	#	2
67)	4,6-Dinitro-2-methylphenol	11.39	198	3463	0.[illegible]1	ppb	#	100
68)	Diphenylamine	11.39	169	16257	1.[illegible]0	ppb	#	38
69)	N-Nitrosodiphenylamine	11.39	169	16257	1.[illegible]2	ppb	#	38
70)	1,2-Diphenylhydrazine	0.00	77		Not Detected			
71)	p-Phenylenediamine	11.39	108	330	0.[illegible]1			100
73)	4-Bromophenyl phenyl ether	0.00	248		Not Detected			
74)	1,3,5-Trinitrobenzene	0.00	75		Not Detected			
75)	Hexachlorobenzene	0.00	284		Not Detected			
76)	4-Aminobiphenyl	0.00	169		Not Detected			
77)	Pentachlorophenol	0.00	266		Not Detected			
78)	Pentachloronitrobenzene	0.00	237		Not Detected			
79)	Phenanthrene	0.00	178		Not Detected			
80)	Anthracene	0.00	178		Not Detected			
81)	Di-n-butyl phthalate	0.00	149		Not Detected			

(#) = qualifier out of range (m) = manual integration

Quantitation Report

Data File : D:\HPCHEM\1\DATA\981110\BLK-S.D
Acq On : 10 Nov 98 1:10 pm
Sample : pah_s blank
Misc : soil 30 g/1 ml
Quant Time: Nov 11 8:39 1998

Vial: 31
Operator: rlt
Inst : 5972 - In
Multiplr: 1.00

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Thu Oct 15 13:09:16 1998
Response via : Multiple Level Calibration

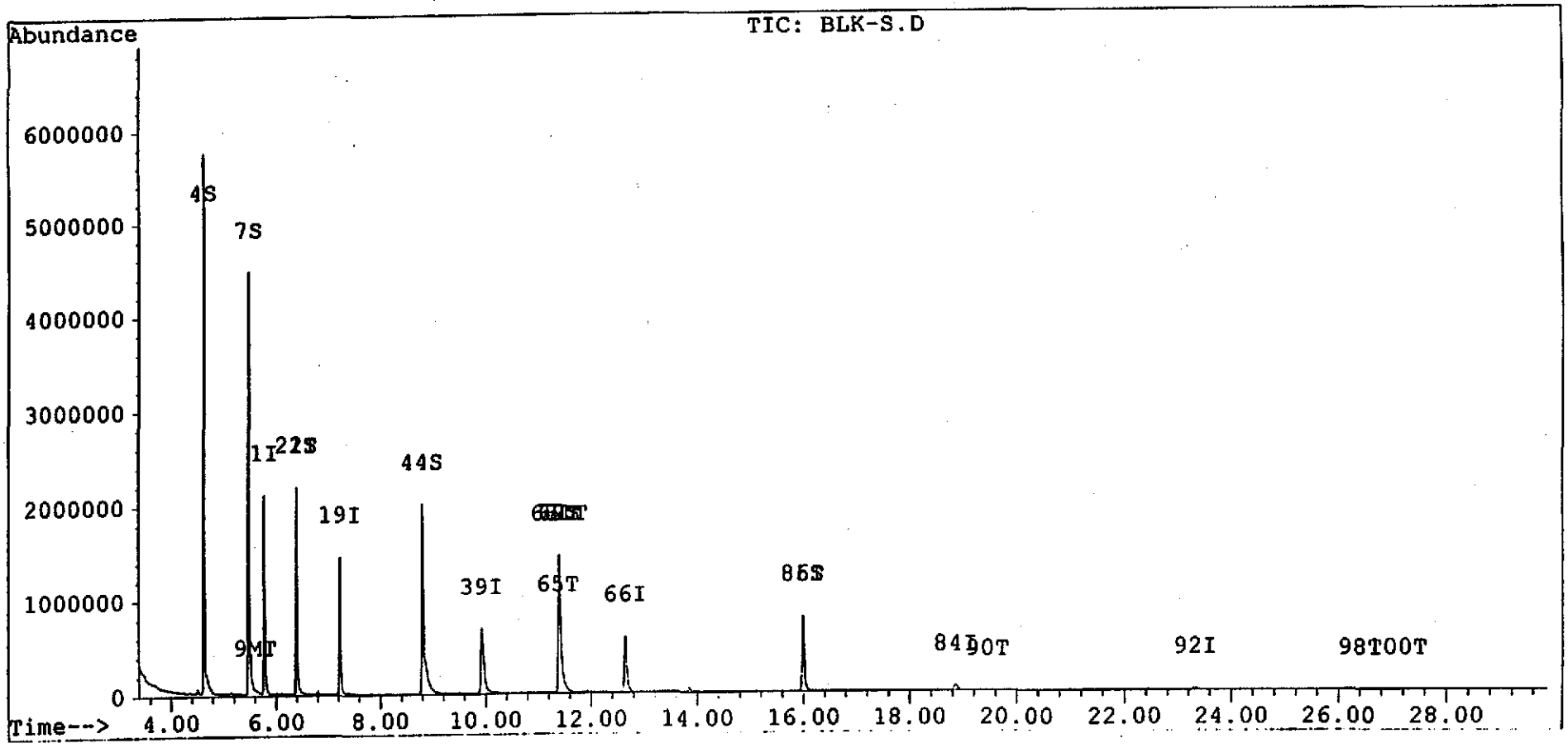
	Compound	R.T.	QIon	Response	Conc Unit	Qvalue
82)	Fluoranthene	0.00	202		Not Detected	
83)	Pyrene	0.00	202		Not Detected	
86)	p-Dimethylaminoazobenzene	15.99	225	401	240.12 ppb #	1
87)	Butyl benzyl phthalate	0.00	149		Not Detected	
88)	Benzo(a)anthracene	0.00	228		Not Detected	
89)	Chrysene	0.00	228		Not Detected	
90)	bis(2-Ethylhexyl) phthalat	19.45	149	1141	0.25 ppb #	48
91)	Di-n-octyl phthalate	0.00	149		Not Detected	
93)	Benzo(b)fluoranthene	0.00	252		Not Detected	
94)	Benzo(k)fluoranthene	0.00	252		Not Detected	
95)	7,12-dimethylbenz[a]anthra	0.00	126		Not Detected	
96)	Benzo(a)pyrene	0.00	252		Not Detected	
97)	3-Methylcholanthrene	0.00	268		Not Detected	
98)	Indeno(1,2,3-cd)pyrene	26.40	276	324	0.21 ppb #	57
99)	Dibenzo(a,h)anthracene	0.00	278		Not Detected	
100)	Benzo(g,h,i)perylene	27.10	276	352	0.27 ppb #	52

(#) = qualifier out of range (m) = manual integration

Data File : D:\HPCHEM\1\DATA\981110\BLK-S.D
Acq On : 10 Nov 98 1:10 pm
Sample : pah_s blank
Misc : soil 30 g/1 ml
Quant Time: Nov 11 8:39 1998

Vial: 31
Operator: rlt
Inst : 5972 - In
Multiplr: 1.00

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Thu Oct 15 13:09:16 1998
Response via : Multiple Level Calibration



981110.13

Spike Recovery and RPD Summary Report - SOIL

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Wed Nov 25 13:22:21 1998
Response via : Initial Calibration

Non-Spiked Sample: BLK-S.D

	Spike Sample	Spike Duplicate Sample
File ID :	MS-S.D	MSD-S.D
Sample :	tcabns ms	tcabns msd
Acq Time:	19 Nov 98 4:57 pm	19 Nov 98 5:33 pm

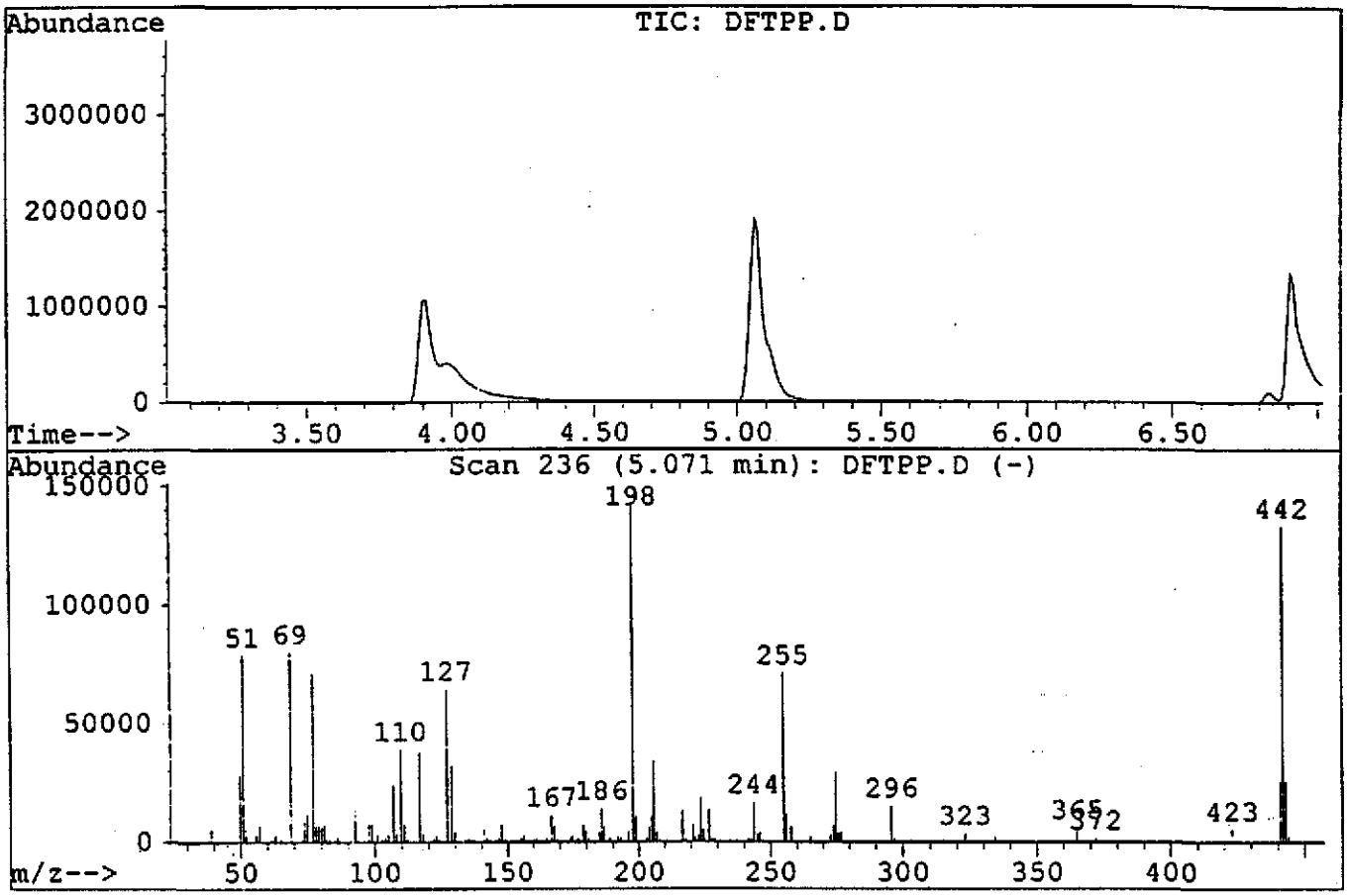
Compound	Sample Conc	Spike Added	Spike Res	Dup Res	Spike %Rec	Dup %Rec	RPD	QC Limits RPD	QC Limits % Rec
Phenol	0.0	200	119	108	60	54	10	35	26- 90
2-Chlorophenol	0.1	200	180	147	90	73	20	50	25-102
1,4-Dichlorobenzene	0.0	100	52	52	52	52	1	27	28-104
N-Nitrosodipropylami	0.0	100	83	60	83	60	33	38	41-126
1,2,4-Trichlorobenze	0.0	100	58	58	58	58	0	23	38-107
4-Chloro-3-methylphe	0.0	200	144	112	72	56	25	33	26-103
2,4-Dinitrotoluene	0.0	100	65	47	65	47	31	47	28- 89
Acenaphthene	0.0	100	44	45	44	45	3	19	31-137
4-Nitrophenol	0.0	200	64	44	32	22	38	50	11-114
Pentachlorophenol	0.0	200	61	40	31	20	42	47	17-109
Pyrene	0.1	100	58	41	58	41	35	36	35-142

DFTPP

Data File : D:\HPCHEM\1\DATA\981110\DFTPP.D
Acq On : 10 Nov 98 9:08 am
Sample : DFTPP Tune Check
Misc :

Vial: 2
Operator: rlt
Inst : 5972 - In
Multiplr: 1.00

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :



Peak Apex is scan: 231

Target Mass	Rel. to Mass	Lower Limit%	Upper Limit%	Rel. Abn%	Raw Abn	Result Pass/Fail
51	198	30	60	54.8	79000	PASS
68	69	0	2	0.0	0	PASS
69	198	0	100	55.7	80318	PASS
70	69	0	2	0.8	665	PASS
127	198	40	60	44.8	64640	PASS
197	198	0	1	0.0	0	PASS
198	198	100	100	100.0	144185	PASS
199	198	5	9	7.6	10905	PASS
275	198	10	30	20.7	29870	PASS
365	198	1	100	4.4	6364	PASS
441	443	0	100	99.8	26008	PASS
442	198	40	100	92.4	133252	PASS
443	442	17	23	19.5	26048	PASS

DFTPP.D 8270-019.M Tue Nov 10 09:21:11 1998

initial calibration

Response Factor Report 5972 - In

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Mon Nov 23 11:20:56 1998
Response via : Initial Calibration

Calibration Files
20 =STD20.D 50 =STD50.D 80 =STD80.D
120 =STD120.D 160 =STD160.D

		Compound	20	50	80	120	160	Avg	%RSD
1)	I	1,4-Dichlorobenzene-d	----------ISTD----------						
2)	T	n-Nitrosodimethylamin	0.635	0.699	0.755	0.708	0.737	0.707	6.52
3)	T	Pyridine	0.905	1.021	1.130	1.037	1.055	1.030	7.86
4)	S	2-Fluorophenol	1.225	1.157	1.299	1.229	1.257	1.233	4.20
5)	T	Aniline	1.190	1.383	1.412	1.441	1.546	1.394	9.31
6)	CMT	Phenol	1.481	1.689	1.904	1.916	2.146	1.827	13.80
7)	S	Phenol-d5	1.310	1.518	1.686	1.667	1.822	1.600	12.17
8)	T	bis(2-Chloroethyl)eth	1.267	1.219	1.348	1.441	1.539	1.363	9.51
9)	MT	2-Chlorophenol	1.023	1.043	1.125	1.097	1.126	1.083	4.40
10)	T	1,3-Dichlorobenzene	1.252	1.249	1.379	1.419	1.449	1.350	6.94
11)	CMT	1,4-Dichlorobenzene	1.557	1.762	1.751	1.656	1.726	1.690	5.04
12)	T	1,2-Dichlorobenzene	1.209	1.272	1.373	1.357	1.480	1.338	7.71
13)	T	Benzyl alcohol	0.574	0.656	0.717	0.686	0.761	0.679	10.37
14)	T	o-Cresol	0.900	0.976	1.026	1.012	1.077	0.998	6.60
15)	T	bis(2-Chloroisopropyl	1.740	1.775	1.839	1.756	1.764	1.775	2.15
16)	T	Hexachloroethane	0.806	0.735	0.739	0.721	0.809	0.762	5.49
17)	T	p-Cresol	1.045	1.232	1.295	1.229	1.218	1.204	7.78
18)	MPT	N-Nitrosodipropylamin	0.920	1.061	1.069	1.061	1.138	1.050	7.56
19)	I	Naphthalene-d8	----------ISTD----------						
20)		N-Nitroso-morpholine						0.000#	-1.00
21)	S	Nitrobenzene-d5	0.512	0.526	0.555	0.562	0.582	0.547	5.12
22)	T	Nitrobenzene	0.508	0.541	0.591	0.593	0.609	0.569	7.45
23)	T	N-Nitrosopiperidine						0.000#	-1.00
24)	T	Isophorone	0.771	0.878	0.922	0.915	0.923	0.882	7.30
25)	CT	2-Nitrophenol	0.196	0.207	0.210	0.224	0.263	0.220	11.81
26)	T	2,4-Dimethylphenol	0.330	0.317	0.376	0.397	0.418	0.368	11.75
27)	T	bis(2-Chloroethoxy)me	0.378	0.453	0.503	0.523	0.563	0.484	14.70
28)	CT	2,4-Dichlorophenol		0.282	0.309	0.335	0.382	0.327	13.05
29)	T	Benzoic acid	0.084	0.083	0.090	0.086	0.104	0.089	9.64
30)	MT	1,2,4-Trichlorobenzen	0.313	0.347	0.368	0.386	0.413	0.365	10.44
31)	T	Naphthalene	1.020	1.212	1.299	1.357	1.438	1.265	12.65
32)	T	2,6-Dichlorophenol	0.232	0.281	0.305	0.336	0.353	0.301	15.91
33)	T	4-Chloroaniline	0.253	0.311	0.355	0.312	0.378	0.322	14.90
34)	CT	Hexachlorobutadiene	0.238	0.250	0.265	0.292	0.324	0.274	12.60
35)	T	N-Nitrosodi-n-butylam						0.000#	-1.00
36)	CMT	4-Chloro-3-methylphen		0.365	0.394	0.418	0.447	0.406	8.65
37)		1-Methylnaphthalene	0.557	0.729	0.769	0.840	0.839	0.747	15.55
38)	T	2-Methylnaphthalene	0.557	0.729	0.771	0.841	0.839	0.747	15.58
39)	I	Acenaphthene-d10	----------ISTD----------						
40)	T	1,2,4,5-Tetrachlorobe						0.000#	-1.00
41)	PT	Hexachlorocyclopentad	0.226	0.271	0.296	0.298	0.337	0.285	14.39

(#) = Out of Range

Response Factor Report 5972 - In

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Mon Nov 23 11:20:56 1998
Response via : Initial Calibration

Calibration Files
20 =STD20.D 50 =STD50.D 80 =STD80.D
120 =STD120.D 160 =STD160.D

		Compound	20	50	80	120	160	Avg	%RSD
42)	CT	2,4,6-Trichlorophenol	0.292	0.373	0.402	0.430	0.453	0.390	15.95
43)	T	2,4,5-Trichlorophenol	0.415	0.403	0.392	0.455	0.513	0.436	11.31
44)	S	2-Fluorobiphenyl	1.138	1.610	1.579	1.570	1.760	1.531	15.20
45)	T	1-Chloronaphthalene	1.045	1.049	1.168	1.311	1.468	1.208	15.00
46)	T	2-Chloronaphthalene	1.045	1.049	1.168	1.311	1.468	1.208	15.00
47)	T	2-Nitroaniline	0.478	0.520	0.555	0.575	0.602	0.546	8.83
48)	T	Acenaphthylene	1.661	1.768	1.920	2.098	2.289	1.947	12.96
49)	T	Dimethyl phthalate	1.251	1.406	1.531	1.609	1.708	1.501	11.88
50)	MT	2,4-Dinitrotoluene	0.397	0.442	0.478	0.491	0.512	0.464	9.77
51)	T	3-Nitroaniline	0.330	0.353	0.319	0.350	0.442	0.359	13.56
52)	CMT	Acenaphthene	1.441	1.625	1.471	1.458	1.720	1.543	8.00
53)	PT	2,4-Dinitrophenol	0.188	0.182	0.214	0.230	0.248	0.212	13.03
54)	T	Dibenzofuran	1.651	1.912	2.013	2.251	2.395	2.044	14.24
55)	T	Pentachlorobenzene						0.000#	-1.00
56)	MPT	4-Nitrophenol	0.414	0.285	0.321	0.385	0.350	0.351	14.49
57)	T	1-Naphthylamine						0.000#	-1.00
58)	T	2,6-Dinitrotoluene	0.322	0.391	0.430	0.430	0.444	0.403	12.27
59)	T	2-Naphthylamine						0.000#	-1.00
60)	T	2,3,4,6-Tetrachloroph						0.000#	-1.00
61)	T	Fluorene	2.477	2.708	3.088	3.148	3.133	2.911	10.39
62)	T	4-Chlorophenyl phenyl	1.354	1.185	1.336	1.588	1.557	1.404	11.93
63)	T	Diethyl phthalate	2.408	2.680	2.989	2.979	3.509	2.913	14.09
64)		Azobenzene	2.428	2.692	2.831	3.032	3.350	2.866	12.15
65)	T	4-Nitroaniline	0.116	0.149	0.167	0.171	0.163	0.153	14.64
66)	I	Phenanthrene-d10	----------ISTD----------						
67)	T	4,6-Dinitro-2-methylp	0.322	0.272	0.294	0.328	0.373	0.318	11.98
68)	CT	Diphenylamine	0.560	0.787	0.772	0.772	0.911	0.760	16.62
69)	T	N-Nitrosodiphenylamin	0.560	0.735	0.772	0.772	0.911	0.750	16.77
70)	T	1,2-Diphenylhydrazine	1.405	1.831	1.508	1.662	1.822	1.646	11.49
71)		p-Phenylenediamine	0.131	0.181	0.155	0.174	0.183	0.165	13.42
72)	S	2,4,6-Tribromophenol	0.174	0.195	0.174	0.208	0.237	0.197	13.30
73)	T	4-Bromophenyl phenyl	0.196	0.241	0.235	0.259	0.291	0.244	14.25
74)		1,3,5-Trinitrobenzene						0.000#	-1.00
75)	T	Hexachlorobenzene	0.459	0.392	0.408	0.389	0.429	0.416	7.02
76)	T	4-Aminobiphenyl						0.000#	-1.00
77)	CMT	Pentachlorophenol	0.315	0.393	0.373	0.412	0.415	0.382	10.76
78)	T	Pentachloronitrobenze						0.000#	-1.00
79)	T	Phenanthrene	1.155	1.164	1.302	1.390	1.482	1.299	10.95
80)	T	Anthracene	1.095	1.114	1.269	1.402	1.488	1.274	13.60
81)	T	Di-n-butyl phthalate	1.637	1.786	1.941	2.011	1.925	1.860	8.01
82)	CT	Fluoranthene	1.046	1.035	1.038	1.028	0.991	1.028	2.09
83)	TM	Pyrene	1.033	0.980	0.945	0.925	0.866	0.950	6.56
84)	I	Chrysene-d12	----------ISTD----------						

(#) = Out of Range

Response Factor Report 5972 - In

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Mon Nov 23 11:20:56 1998
Response via : Initial Calibration

Calibration Files
20 =STD20.D 50 =STD50.D 80 =STD80.D
120 =STD120.D 160 =STD160.D

		Compound	20	50	80	120	160	Avg	%RSD
85)	S	p-Terphenyl-d14	2.544	3.387	3.557	3.494	3.672	3.331	13.56
86)	T	p-Dimethylaminoazoben						0.000#	-1.00
87)	T	Butyl benzyl phthalat	1.315	1.353	1.517	1.566	1.527	1.455	7.81
88)	T	Benzo(a)anthracene	1.123	1.213	1.262	1.330	1.337	1.253	7.07
89)	T	Chrysene	1.065	1.126	1.174	1.245	1.269	1.176	7.13
90)	T	bis(2-Ethylhexyl) pht	1.285	1.551	1.740	1.821	1.837	1.647	14.10
91)	CT	Di-n-octyl phthalate	1.367	1.294	1.395	1.492	1.577	1.425	7.77
92)	I	Perylene-d12	----------ISTD----------						
93)	T	Benzo(b)fluoranthene	1.570	1.568	1.580	1.524	1.604	1.569	1.85
94)	T	Benzo(k)fluoranthene	1.577	1.515	1.567	1.606	1.519	1.557	2.52
95)		7,12-dimethylbenz[a]a	0.139	0.164	0.172	0.172	0.164	0.162	8.47
96)	CT	Benzo(a)pyrene	1.054	1.180	1.231	1.231	1.259	1.191	6.85
97)	T	3-Methylcholanthrene						0.000#	-1.00
98)	T	Indeno(1,2,3-cd)pyren	0.759	0.946	1.053	1.091	1.046	0.979	13.69
99)	T	Dibenzo(a,h)anthracen	0.666	0.748	0.822	0.896	0.951	0.817	13.91
100)	T	Benzo(g,h,i)perylene	0.668	0.776	0.844	0.898	0.982	0.834	14.31

(#) = Out of Range

Continuing Calibration Report 5972 - In

11/19/98

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Wed Nov 18 14:42:28 1998
Response via : Initial Calibration

Continuing Calibration File: STD80.D

Min. RRF : 0.050 Min. Rel. Area : 50%
Max. RRF Dev : 25% Max. Rel. Area : 150%

		Compound	AvgRF	CCRF	%Dev	Area%
1	I	1,4-Dichlorobenzene-d4	1.000	1.000	0.0	102
2	T	n-Nitrosodimethylamine	0.707	0.648	8.3	88
3	T	Pyridine	1.030	0.941	8.6	85
4	S	2-Fluorophenol	1.233	1.303	-5.6	103
5	T	Aniline	1.394	1.395	-0.1	101
6	CMT	Phenol	1.827	1.875	-2.7	101
7	S	Phenol-d5	1.600	1.922	-20.1	117
8	T	bis(2-Chloroethyl)ether	1.363	1.395	-2.4	106
9	MT	2-Chlorophenol	1.083	1.213	-12.0	110
10	T	1,3-Dichlorobenzene	1.350	1.383	-2.5	103
11	CMT	1,4-Dichlorobenzene	1.690	1.887	-11.6	110
12	T	1,2-Dichlorobenzene	1.338	1.521	-13.7	113
13	T	Benzyl alcohol	0.679	0.720	-6.0	103
14	T	o-Cresol	0.998	1.190	-19.2	119
15	T	bis(2-Chloroisopropyl)ether	1.775	1.872	-5.5	104
16	T	Hexachloroethane	0.762	0.800	-5.0	111
17	T	p-Cresol	1.204	1.304	-8.3	103
18	MPT	N-Nitrosodipropylamine	1.050	1.302	-24.1	125
19	I	Naphthalene-d8	1.000	1.000	0.0	117
20		N-Nitroso-morpholine	0.000	0.000#	0.0	0#
21	S	Nitrobenzene-d5	0.547	0.531	3.0	112
22	T	Nitrobenzene	0.569	0.564	0.8	111
23	T	N-Nitrosopiperidine	0.000	0.000#	0.0	0#
24	T	Isophorone	0.882	0.831	5.8	105
25	CT	2-Nitrophenol	0.220	0.198	9.8	111
26	T	2,4-Dimethylphenol	0.368	0.345	6.2	107
27	T	bis(2-Chloroethoxy)methane	0.484	0.486	-0.3	113
28	CT	2,4-Dichlorophenol	0.327	0.280	14.5	106
29	T	Benzoic acid	0.089	0.093	-4.6	122
30	MT	1,2,4-Trichlorobenzene	0.365	0.374	-2.5	119
31	T	Naphthalene	1.265	1.343	-6.2	121
32	T	2,6-Dichlorophenol	0.301	0.302	-0.3	116
33	T	4-Chloroaniline	0.322	0.244	24.2	80
34	CT	Hexachlorobutadiene	0.274	0.285	-4.1	126
35	T	N-Nitrosodi-n-butylamine	0.000	0.000#	0.0	0#
36	CMT	4-Chloro-3-methylphenol	0.406	0.352	13.4	104
37		1-Methylnaphthalene	0.747	0.740	0.9	112
38	T	2-Methylnaphthalene	0.747	0.740	1.0	112
39	I	Acenaphthene-d10	1.000	1.000	0.0	86
40	T	1,2,4,5-Tetrachlorobenzene	0.000	0.000#	0.0	0#
41	PT	Hexachlorocyclopentadiene	0.285	0.248	13.1	72

(#) = Out of Range

Continuing Calibration Report 5972 - In

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Wed Nov 18 14:42:28 1998
Response via : Initial Calibration

Continuing Calibration File: STD80.D

Min. RRF : 0.050 Min. Rel. Area : 50%
Max. RRF Dev : 25% Max. Rel. Area : 150%

		Compound	AvgRF	CCRF	%Dev	Area%
42	CT	2,4,6-Trichlorophenol	0.390	0.381	2.3	81
43	T	2,4,5-Trichlorophenol	0.436	0.530	-21.6	116
44	S	2-Fluorobiphenyl	1.531	1.687	-10.2	92
45	T	1-Chloronaphthalene	1.208	1.399	-15.8	103
46	T	2-Chloronaphthalene	1.208	1.399	-15.8	103
47	T	2-Nitroaniline	0.546	0.486	11.1	75
48	T	Acenaphthylene	1.947	1.594	18.2	71
49	T	Dimethyl phthalate	1.501	1.527	-1.7	86
50	MT	2,4-Dinitrotoluene	0.464	0.387	16.6	70
51	T	3-Nitroaniline	0.359	0.314	12.4	85
52	CMT	Acenaphthene	1.543	1.418	8.1	83
53	PT	2,4-Dinitrophenol	0.212	0.195	8.1	79
54	T	Dibenzofuran	2.044	1.835	10.2	78
55	T	Pentachlorobenzene	0.000	0.000#	0.0	0#
56	MPT	4-Nitrophenol	0.351	0.366	-4.2	98
57	T	1-Naphthylamine	0.000	0.000#	0.0	0#
58	T	2,6-Dinitrotoluene	0.403	0.375	7.1	75
59	T	2-Naphthylamine	0.000	0.000#	0.0	0#
60	T	2,3,4,6-Tetrachlorophenol	0.001	0.000#	100.0#	0#
61	T	Fluorene	2.911	2.676	8.1	74
62	T	4-Chlorophenyl phenyl ether	1.404	1.057	24.7	68
63	T	Diethyl phthalate	2.913	2.856	1.9	82
64		Azobenzene	2.866	2.565	10.5	78
65	T	4-Nitroaniline	0.153	0.152	0.8	78
66	I	Phenanthrene-d10	1.000	1.000	0.0	69
67	T	4,6-Dinitro-2-methylphenol	0.318	0.282	11.4	66
68	CT	Diphenylamine	0.760	0.665	12.5	59
69	T	N-Nitrosodiphenylamine	0.750	0.665	11.3	59
70	T	1,2-Diphenylhydrazine	1.646	1.711	-4.0	78
71		p-Phenylenediamine	0.165	0.140	15.2	62
72	S	2,4,6-Tribromophenol	0.197	0.158	20.0	62
73	T	4-Bromophenyl phenyl ether	0.244	0.256	-4.8	75
74		1,3,5-Trinitrobenzene	0.000	0.000#	0.0	0#
75	T	Hexachlorobenzene	0.416	0.341	18.0	57
76	T	4-Aminobiphenyl	0.000	0.000#	0.0	0#
77	CMT	Pentachlorophenol	0.382	0.324	15.2	60
78	T	Pentachloronitrobenzene	0.000	0.000#	0.0	0#
79	T	Phenanthrene	1.299	1.223	5.8	65
80	T	Anthracene	1.274	1.136	10.8	61
81	T	Di-n-butyl phthalate	1.860	1.871	-0.6	66
82	CT	Fluoranthene	1.028	1.021	0.7	68
83	TM	Pyrene	0.950	1.007	-6.0	73

(#) = Out of Range

Continuing Calibration Report 5972 - In

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Wed Nov 18 14:42:28 1998
Response via : Initial Calibration

Continuing Calibration File: STD80.D

Min. RRF : 0.050 Min. Rel. Area : 50%
Max. RRF Dev : 25% Max. Rel. Area : 150%

		Compound	AvgRF	CCRF	%Dev	Area%
84	I	Chrysene-d12	1.000	1.000	0.0	55
85	S	p-Terphenyl-d14	3.331	2.659	20.2	41#
86	T	p-Dimethylaminoazobenzene	0.001	0.000#	100.0#	0#
87	T	Butyl benzyl phthalate	1.455	1.659	-14.0	60
88	T	Benzo(a)anthracene	1.253	1.194	4.7	52
89	T	Chrysene	1.176	1.137	3.3	53
90	T	bis(2-Ethylhexyl) phthalate	1.647	1.452	11.8	46#
91	CT	Di-n-octyl phthalate	1.425	1.541	-8.1	61
92	I	Perylene-d12	1.000	1.000	0.0	79
93	T	Benzo(b)fluoranthene	1.569	1.632	-4.0	82
94	T	Benzo(k)fluoranthene	1.557	1.632	-4.9	82
95		7,12-dimethylbenz[a]anthracen	0.162	0.151	6.5	70
96	CT	Benzo(a)pyrene	1.191	1.209	-1.5	78
97	T	3-Methylcholanthrene	0.000	0.000#	0.0	0#
98	T	Indeno(1,2,3-cd)pyrene	0.979	0.996	-1.7	75
99	T	Dibenzo(a,h)anthracene	0.817	0.866	-6.0	83
100	T	Benzo(g,h,i)perylene	0.834	0.803	3.7	75

(#) = Out of Range SPCC's out = 0 CCC's out = 0

Quantitation Report

Data File : D:\HPCHEM\1\DATA\981117\BLK-W.D Vial: 37
Acq On : 17 Nov 98 5:32 pm Operator: rlt
Sample : pah_w blank Inst : 5972 - In
Misc : water 1000 ml/1 ml Multiplr: 1.00
Quant Time: Nov 18 11:05 1998

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Wed Nov 18 11:12:36 1998
Response via : Multiple Level Calibration

Internal Standards	R.T.	QIon	Response	Conc	Units	Dev(Min)
1) 1,4-Dichlorobenzene-d4	5.78	152	242955	40.00	ng	-0.02
19) Naphthalene-d8	7.21	136	817760	40.00	ng	-0.01
39) Acenaphthene-d10	9.92	164	447637	40.00	ng	0.02
66) Phenanthrene-d10	12.65	188	703526	40.00	ng	0.05
84) Chrysene-d12	18.93	240	240938	40.00	ng	0.10
92) Perylene-d12	23.36	264	136769	40.00	ng	0.14
System Monitoring Compounds						%Recovery
4) 2-Fluorophenol	4.65	112	1681559	224.45	ppb	112.22%
7) Phenol-d5	5.50	99	1788706	184.01	ppb	92.00%
21) Nitrobenzene-d5	6.39	82	927424	82.88	ppb	82.88%
44) 2-Fluorobiphenyl	8.79	172	1527617	89.14	ppb	89.14%
72) 2,4,6-Tribromophenol	11.41	330	525725	151.37	ppb	75.69%
85) p-Terphenyl-d14	16.08	244	1106393	55.15	ppb	55.15%
Target Compounds						Qvalue
2) n-Nitrosodimethylamine	0.00	74		Not Detected		
3) Pyridine	0.00	79		Not Detected		
5) Aniline	0.00	93		Not Detected		
6) Phenol	0.00	94		Not Detected		
8) bis(2-Chloroethyl)ether	0.00	93		Not Detected		
9) 2-Chlorophenol	0.00	128		Not Detected		
10) 1,3-Dichlorobenzene	0.00	146		Not Detected		
11) 1,4-Dichlorobenzene	0.00	146		Not Detected		
12) 1,2-Dichlorobenzene	0.00	146		Not Detected		
13) Benzyl alcohol	0.00	108		Not Detected		
14) o-Cresol	0.00	107		Not Detected		
15) bis(2-Chloroisopropyl)ethe	0.00	45		Not Detected		
16) Hexachloroethane	0.00	117		Not Detected		
17) p-Cresol	0.00	107		Not Detected		
18) N-Nitrosodipropylamine	0.00	70		Not Detected		
20) N-Nitroso-morpholine	0.00	56		Not Detected		
22) Nitrobenzene	6.39	77	3762	0.82	ppb	# 36
23) N-Nitrosopiperidine	0.00	114		Not Detected		
24) Isophorone	0.00	82		Not Detected		
25) 2-Nitrophenol	0.00	139		Not Detected		
26) 2,4-Dimethylphenol	0.00	122		Not Detected		
27) bis(2-Chloroethoxy)methane	0.00	93		Not Detected		
28) 2,4-Dichlorophenol	0.00	162		Not Detected		
29) Benzoic acid	0.00	122		Not Detected		
30) 1,2,4-Trichlorobenzene	0.00	180		Not Detected		
31) Naphthalene	0.00	128		Not Detected		
32) 2,6-Dichlorophenol	0.00	162		Not Detected		
33) 4-Chloroaniline	0.00	127		Not Detected		

(#) = qualifier out of range (m) = manual integration

Quantitation Report

Data File : D:\HPCHEM\1\DATA\981117\BLK-W.D
Acq On : 17 Nov 98 5:32 pm
Sample : pah_w blank
Misc : water 1000 ml/1 ml
Quant Time: Nov 18 11:05 1998

Vial: 37
Operator: rlt
Inst : 5972 - In
Multiplr: 1.00

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Wed Nov 18 11:12:36 1998
Response via : Multiple Level Calibration

Compound	R.T.	QIon	Response	Conc Unit	Qvalue
34) Hexachlorobutadiene	0.00	225		Not Detected	
35) N-Nitrosodi-n-butylamine	0.00	84		Not Detected	
36) 4-Chloro-3-methylphenol	0.00	107		Not Detected	
37) 1-Methylnaphthalene	0.00	142		Not Detected	
38) 2-Methylnaphthalene	0.00	142		Not Detected	
40) 1,2,4,5-Tetrachlorobenzene	0.00	216		Not Detected	
41) Hexachlorocyclopentadiene	0.00	237		Not Detected	
42) 2,4,6-Trichlorophenol	0.00	196		Not Detected	
43) 2,4,5-Trichlorophenol	0.00	196		Not Detected	
45) 1-Chloronaphthalene	0.00	162		Not Detected	
46) 2-Chloronaphthalene	0.00	162		Not Detected	
47) 2-Nitroaniline	0.00	65		Not Detected	
48) Acenaphthylene	0.00	152		Not Detected	
49) Dimethyl phthalate	0.00	163		Not Detected	
50) 2,4-Dinitrotoluene	0.00	165		Not Detected	
51) 3-Nitroaniline	0.00	138		Not Detected	
52) Acenaphthene	0.00	154		Not Detected	
53) 2,4-Dinitrophenol	0.00	184		Not Detected	
54) Dibenzofuran	0.00	168		Not Detected	
55) Pentachlorobenzene	0.00	250		Not Detected	
56) 4-Nitrophenol	0.00	139		Not Detected	
57) 1-Naphthylamine	0.00	143		Not Detected	
58) 2,6-Dinitrotoluene	0.00	165		Not Detected	
59) 2-Naphthylamine	0.00	143		Not Detected	
60) 2,3,4,6-Tetrachlorophenol	0.00	232		Not Detected	
61) Fluorene	0.00	166		Not Detected	
62) 4-Chlorophenyl phenyl ethe	0.00	204		Not Detected	
63) Diethyl phthalate	0.00	149		Not Detected	
64) Azobenzene	11.42	77	5486	0.17	100
65) 4-Nitroaniline	0.00	138		Not Detected	
67) 4,6-Dinitro-2-methylphenol	11.42	198	2065	0.37 ppb #	100
68) Diphenylamine	11.41	169	14040	1.05 ppb #	37
69) N-Nitrosodiphenylamine	11.41	169	14040	1.76 ppb #	37
70) 1,2-Diphenylhydrazine	11.42	77	5486	0.09 ppb #	1
71) p-Phenylenediamine	0.00	108		Not Detected	
73) 4-Bromophenyl phenyl ether	0.00	248		Not Detected	
74) 1,3,5-Trinitrobenzene	0.00	75		Not Detected	
75) Hexachlorobenzene	0.00	284		Not Detected	
76) 4-Aminobiphenyl	0.00	169		Not Detected	
77) Pentachlorophenol	0.00	266		Not Detected	
78) Pentachloronitrobenzene	0.00	237		Not Detected	
79) Phenanthrene	0.00	178		Not Detected	
80) Anthracene	0.00	178		Not Detected	
81) Di-n-butyl phthalate	0.00	149		Not Detected	

(#) = qualifier out of range (m) = manual integration

Quantitation Report

Data File : D:\HPCHEM\1\DATA\981117\BLK-W.D
Acq On : 17 Nov 98 5:32 pm
Sample : pah_w blank
Misc : water 1000 ml/1 ml
Quant Time: Nov 18 11:05 1998

Vial: 37
Operator: rlt
Inst : 5972 - In
Multiplr: 1.00

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Wed Nov 18 11:12:36 1998
Response via : Multiple Level Calibration

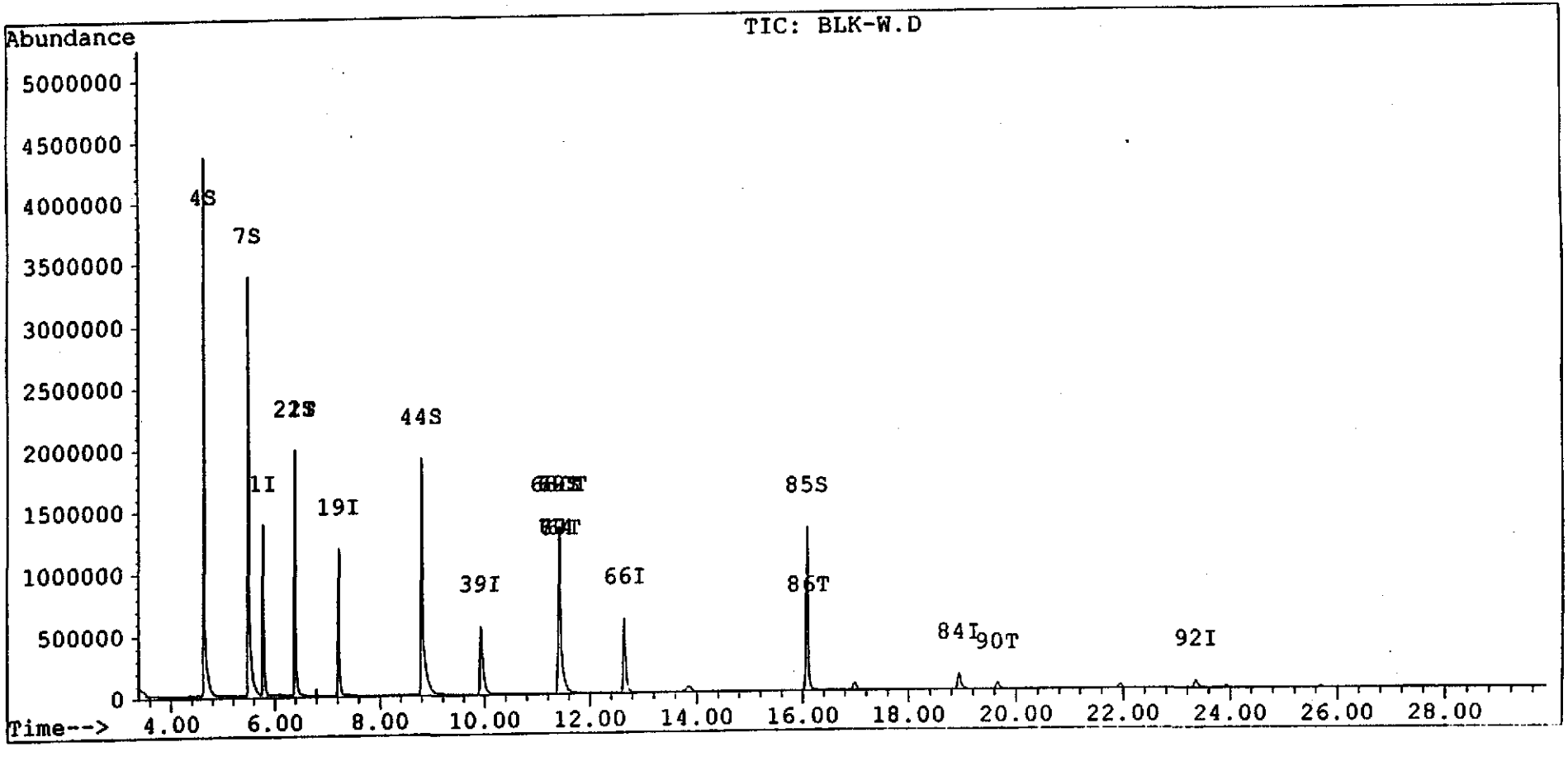
	Compound	R.T.	QIon	Response	Conc	Unit		Qvalue
82)	Fluoranthene	0.00	202		Not Detected			
83)	Pyrene	0.00	202		Not Detected			
86)	p-Dimethylaminoazobenzene	16.10	225	323	89.91	ppb	#	1
87)	Butyl benzyl phthalate	0.00	149		Not Detected			
88)	Benzo(a)anthracene	0.00	228		Not Detected			
89)	Chrysene	0.00	228		Not Detected			
90)	bis(2-Ethylhexyl) phthalat	19.64	149	2195	0.12	ppb	#	48
91)	Di-n-octyl phthalate	0.00	149		Not Detected			
93)	Benzo(b)fluoranthene	0.00	252		Not Detected			
94)	Benzo(k)fluoranthene	0.00	252		Not Detected			
95)	7,12-dimethylbenz[a]anthra	0.00	126		Not Detected			
96)	Benzo(a)pyrene	0.00	252		Not Detected			
97)	3-Methylcholanthrene	0.00	268		Not Detected			
98)	Indeno(1,2,3-cd)pyrene	0.00	276		Not Detected			
99)	Dibenzo(a,h)anthracene	0.00	278		Not Detected			
100)	Benzo(g,h,i)perylene	0.00	276		Not Detected			

(#) = qualifier out of range (m) = manual integration

Data File : D:\HPCHEM\1\DATA\981117\BLK-W.D
Acq On : 17 Nov 98 5:32 pm
Sample : pah_w blank
Misc : water 1000 ml/1 ml
Quant Time: Nov 18 11:05 1998

Vial: 37
Operator: rlt
Inst : 5972 - In
Multiplr: 1.00

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Wed Nov 18 11:12:36 1998
Response via : Multiple Level Calibration



981117.13

Spike Recovery and RPD Summary Report - WATER

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Wed Nov 25 13:22:21 1998
Response via : Initial Calibration

Non-Spiked Sample: BLK-W.D

	Spike Sample	Spike Duplicate Sample
File ID :	MS-W.D	MSD-W.D
Sample :	pah_w ms	pah_w msd
Acq Time:	17 Nov 98 6:09 pm	17 Nov 98 6:46 pm

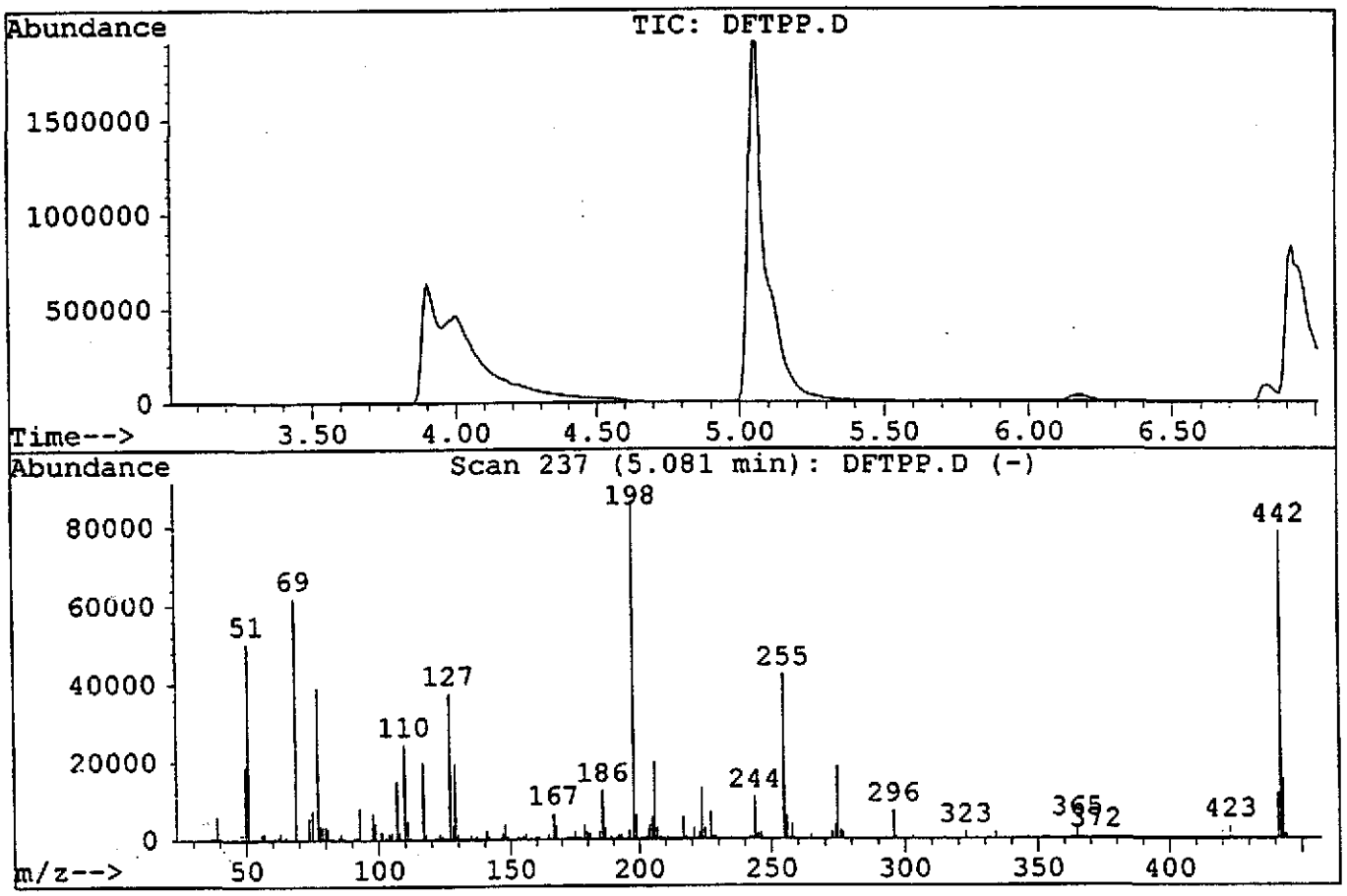
Compound	Sample Conc	Spike Added	Spike Res	Dup Res	Spike %Rec	Dup %Rec	RPD	QC Limits RPD	QC Limits % Rec
Phenol	0.1	200	168	146	84	73	14	42	12-110
2-Chlorophenol	0.0	200	228	204	114	102	11	40	27-123
1,4-Dichlorobenzene	0.0	100	77	71	77	71	8	28	36- 97
N-Nitrosodipropylami	0.0	100	93	82	93	82	12	38	41-116
1,2,4-Trichlorobenze	0.0	100	88	80	88	80	9	28	39- 98
4-Chloro-3-methylphe	0.0	200	149	130	75	65	14	42	23- 97
2,4-Dinitrotoluene	0.0	100	74	66	74	66	11	38	24- 96
Acenaphthene	0.0	100	67	59	67	59	14	31	46-118
4-Nitrophenol	0.0	200	62	58	31	29	8	50	10- 80
Pentachlorophenol	0.0	200	77	68	39	34	12	50	9-103
Pyrene	0.0	100	65	62	65	62	4	31	26-127

DFTPP

Data File : D:\HPCHEM\1\DATA\981117\DFTPP.D
Acq On : 17 Nov 98 9:14 am
Sample : DFTPP Tune Check
Misc :

Vial: 2
Operator: rlt
Inst : 5972 - In
Multiplr: 1.00

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :



Peak Apex is scan: 230

Target Mass	Rel. to Mass	Lower Limit%	Upper Limit%	Rel. Abn%	Raw Abn	Result Pass/Fail
51	198	30	60	58.1	50620	PASS
68	69	0	2	0.0	0	PASS
69	198	0	100	71.4	62168	PASS
70	69	0	2	0.0	0	PASS
127	198	40	60	43.4	37772	PASS
197	198	0	1	0.0	0	PASS
198	198	100	100	100.0	87072	PASS
199	198	5	9	7.4	6479	PASS
275	198	10	30	21.8	18964	PASS
365	198	1	100	4.3	3742	PASS
441	443	0	100	76.5	11898	PASS
442	198	40	100	90.5	78784	PASS
443	442	17	23	19.7	15558	PASS

DFTPP.D 8270-019.M Tue Nov 17 09:56:54 1998

initial calibration

Response Factor Report 5972 - In

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Mon Nov 23 11:20:56 1998
Response via : Initial Calibration

Calibration Files
20 =STD20.D 50 =STD50.D 80 =STD80.D
120 =STD120.D 160 =STD160.D

		Compound	20	50	80	120	160	Avg	%RSD
1)	I	1,4-Dichlorobenzene-d	ISTD						
2)	T	n-Nitrosodimethylamin	0.635	0.699	0.755	0.708	0.737	0.707	6.52
3)	T	Pyridine	0.905	1.021	1.130	1.037	1.055	1.030	7.86
4)	S	2-Fluorophenol	1.225	1.157	1.299	1.229	1.257	1.233	4.20
5)	T	Aniline	1.190	1.383	1.412	1.441	1.546	1.394	9.31
6)	CMT	Phenol	1.481	1.689	1.904	1.916	2.146	1.827	13.80
7)	S	Phenol-d5	1.310	1.518	1.686	1.667	1.822	1.600	12.17
8)	T	bis(2-Chloroethyl)eth	1.267	1.219	1.348	1.441	1.539	1.363	9.51
9)	MT	2-Chlorophenol	1.023	1.043	1.125	1.097	1.126	1.083	4.40
10)	T	1,3-Dichlorobenzene	1.252	1.249	1.379	1.419	1.449	1.350	6.94
11)	CMT	1,4-Dichlorobenzene	1.557	1.762	1.751	1.656	1.726	1.690	5.04
12)	T	1,2-Dichlorobenzene	1.209	1.272	1.373	1.357	1.480	1.338	7.71
13)	T	Benzyl alcohol	0.574	0.656	0.717	0.686	0.761	0.679	10.37
14)	T	o-Cresol	0.900	0.976	1.026	1.012	1.077	0.998	6.60
15)	T	bis(2-Chloroisopropyl	1.740	1.775	1.839	1.756	1.764	1.775	2.15
16)	T	Hexachloroethane	0.806	0.735	0.739	0.721	0.809	0.762	5.49
17)	T	p-Cresol	1.045	1.232	1.295	1.229	1.218	1.204	7.78
18)	MPT	N-Nitrosodipropylamin	0.920	1.061	1.069	1.061	1.138	1.050	7.56
19)	I	Naphthalene-d8	ISTD						
20)		N-Nitroso-morpholine						0.000#	-1.00
21)	S	Nitrobenzene-d5	0.512	0.526	0.555	0.562	0.582	0.547	5.12
22)	T	Nitrobenzene	0.508	0.541	0.591	0.593	0.609	0.569	7.45
23)	T	N-Nitrosopiperidine						0.000#	-1.00
24)	T	Isophorone	0.771	0.878	0.922	0.915	0.923	0.882	7.30
25)	CT	2-Nitrophenol	0.196	0.207	0.210	0.224	0.263	0.220	11.81
26)	T	2,4-Dimethylphenol	0.330	0.317	0.376	0.397	0.418	0.368	11.75
27)	T	bis(2-Chloroethoxy)me	0.378	0.453	0.503	0.523	0.563	0.484	14.70
28)	CT	2,4-Dichlorophenol		0.282	0.309	0.335	0.382	0.327	13.05
29)	T	Benzoic acid	0.084	0.083	0.090	0.086	0.104	0.089	9.64
30)	MT	1,2,4-Trichlorobenzen	0.313	0.347	0.368	0.386	0.413	0.365	10.44
31)	T	Naphthalene	1.020	1.212	1.299	1.357	1.438	1.265	12.65
32)	T	2,6-Dichlorophenol	0.232	0.281	0.305	0.336	0.353	0.301	15.91
33)	T	4-Chloroaniline	0.253	0.311	0.355	0.312	0.378	0.322	14.90
34)	CT	Hexachlorobutadiene	0.238	0.250	0.265	0.292	0.324	0.274	12.60
35)	T	N-Nitrosodi-n-butylam						0.000#	-1.00
36)	CMT	4-Chloro-3-methylphen		0.365	0.394	0.418	0.447	0.406	8.65
37)		1-Methylnaphthalene	0.557	0.729	0.769	0.840	0.839	0.747	15.55
38)	T	2-Methylnaphthalene	0.557	0.729	0.771	0.841	0.839	0.747	15.58
39)	I	Acenaphthene-d10	ISTD						
40)	T	1,2,4,5-Tetrachlorobe						0.000#	-1.00
41)	PT	Hexachlorocyclopentad	0.226	0.271	0.296	0.298	0.337	0.285	14.39

(#) = Out of Range

Response Factor Report 5972 - In

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Mon Nov 23 11:20:56 1998
Response via : Initial Calibration

Calibration Files
20 =STD20.D 50 =STD50.D 80 =STD80.D
120 =STD120.D 160 =STD160.D

		Compound	20	50	80	120	160	Avg	%RSD
42)	CT	2,4,6-Trichlorophenol	0.292	0.373	0.402	0.430	0.453	0.390	15.95
43)	T	2,4,5-Trichlorophenol	0.415	0.403	0.392	0.455	0.513	0.436	11.31
44)	S	2-Fluorobiphenyl	1.138	1.610	1.579	1.570	1.760	1.531	15.20
45)	T	1-Chloronaphthalene	1.045	1.049	1.168	1.311	1.468	1.208	15.00
46)	T	2-Chloronaphthalene	1.045	1.049	1.168	1.311	1.468	1.208	15.00
47)	T	2-Nitroaniline	0.478	0.520	0.555	0.575	0.602	0.546	8.83
48)	T	Acenaphthylene	1.661	1.768	1.920	2.098	2.289	1.947	12.96
49)	T	Dimethyl phthalate	1.251	1.406	1.531	1.609	1.708	1.501	11.88
50)	MT	2,4-Dinitrotoluene	0.397	0.442	0.478	0.491	0.512	0.464	9.77
51)	T	3-Nitroaniline	0.330	0.353	0.319	0.350	0.442	0.359	13.56
52)	CMT	Acenaphthene	1.441	1.625	1.471	1.458	1.720	1.543	8.00
53)	PT	2,4-Dinitrophenol	0.188	0.182	0.214	0.230	0.248	0.212	13.03
54)	T	Dibenzofuran	1.651	1.912	2.013	2.251	2.395	2.044	14.24
55)	T	Pentachlorobenzene						0.000#	-1.00
56)	MPT	4-Nitrophenol	0.414	0.285	0.321	0.385	0.350	0.351	14.49
57)	T	1-Naphthylamine						0.000#	-1.00
58)	T	2,6-Dinitrotoluene	0.322	0.391	0.430	0.430	0.444	0.403	12.27
59)	T	2-Naphthylamine						0.000#	-1.00
60)	T	2,3,4,6-Tetrachloroph						0.000#	-1.00
61)	T	Fluorene	2.477	2.708	3.088	3.148	3.133	2.911	10.39
62)	T	4-Chlorophenyl phenyl	1.354	1.185	1.336	1.588	1.557	1.404	11.93
63)	T	Diethyl phthalate	2.408	2.680	2.989	2.979	3.509	2.913	14.09
64)		Azobenzene	2.428	2.692	2.831	3.032	3.350	2.866	12.15
65)	T	4-Nitroaniline	0.116	0.149	0.167	0.171	0.163	0.153	14.64
66)	I	Phenanthrene-d10	----------ISTD----------						
67)	T	4,6-Dinitro-2-methylp	0.322	0.272	0.294	0.328	0.373	0.318	11.98
68)	CT	Diphenylamine	0.560	0.787	0.772	0.772	0.911	0.760	16.62
69)	T	N-Nitrosodiphenylamin	0.560	0.735	0.772	0.772	0.911	0.750	16.77
70)	T	1,2-Diphenylhydrazine	1.405	1.831	1.508	1.662	1.822	1.646	11.49
71)		p-Phenylenediamine	0.131	0.181	0.155	0.174	0.183	0.165	13.42
72)	S	2,4,6-Tribromophenol	0.174	0.195	0.174	0.208	0.237	0.197	13.30
73)	T	4-Bromophenyl phenyl	0.196	0.241	0.235	0.259	0.291	0.244	14.25
74)		1,3,5-Trinitrobenzene						0.000#	-1.00
75)	T	Hexachlorobenzene	0.459	0.392	0.408	0.389	0.429	0.416	7.02
76)	T	4-Aminobiphenyl						0.000#	-1.00
77)	CMT	Pentachlorophenol	0.315	0.393	0.373	0.412	0.415	0.382	10.76
78)	T	Pentachloronitrobenze						0.000#	-1.00
79)	T	Phenanthrene	1.155	1.164	1.302	1.390	1.482	1.299	10.95
80)	T	Anthracene	1.095	1.114	1.269	1.402	1.488	1.274	13.60
81)	T	Di-n-butyl phthalate	1.637	1.786	1.941	2.011	1.925	1.860	8.01
82)	CT	Fluoranthene	1.046	1.035	1.038	1.028	0.991	1.028	2.09
83)	TM	Pyrene	1.033	0.980	0.945	0.925	0.866	0.950	6.56
84)	I	Chrysene-d12	----------ISTD----------						

(#) = Out of Range

Response Factor Report 5972 - In

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Mon Nov 23 11:20:56 1998
Response via : Initial Calibration

Calibration Files
20 =STD20.D 50 =STD50.D 80 =STD80.D
120 =STD120.D 160 =STD160.D

		Compound	20	50	80	120	160	Avg	%RSD
85)	S	p-Terphenyl-d14	2.544	3.387	3.557	3.494	3.672	3.331	13.56
86)	T	p-Dimethylaminoazoben						0.000#	-1.00
87)	T	Butyl benzyl phthalat	1.315	1.353	1.517	1.566	1.527	1.455	7.81
88)	T	Benzo(a)anthracene	1.123	1.213	1.262	1.330	1.337	1.253	7.07
89)	T	Chrysene	1.065	1.126	1.174	1.245	1.269	1.176	7.13
90)	T	bis(2-Ethylhexyl) pht	1.285	1.551	1.740	1.821	1.837	1.647	14.10
91)	CT	Di-n-octyl phthalate	1.367	1.294	1.395	1.492	1.577	1.425	7.77
92)	I	Perylene-d12	----------ISTD----------						
93)	T	Benzo(b)fluoranthene	1.570	1.568	1.580	1.524	1.604	1.569	1.85
94)	T	Benzo(k)fluoranthene	1.577	1.515	1.567	1.606	1.519	1.557	2.52
95)		7,12-dimethylbenz[a]a	0.139	0.164	0.172	0.172	0.164	0.162	8.47
96)	CT	Benzo(a)pyrene	1.054	1.180	1.231	1.231	1.259	1.191	6.85
97)	T	3-Methylcholanthrene						0.000#	-1.00
98)	T	Indeno(1,2,3-cd)pyren	0.759	0.946	1.053	1.091	1.046	0.979	13.69
99)	T	Dibenzo(a,h)anthracen	0.666	0.748	0.822	0.896	0.951	0.817	13.91
100)	T	Benzo(g,h,i)perylene	0.668	0.776	0.844	0.898	0.982	0.834	14.31

(#) = Out of Range

Continuing Calibration Report 5972 - In

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Tue Nov 17 12:05:02 1998
Response via : Initial Calibration

11/17/98

Continuing Calibration File: STD80.D

Min. RRF : 0.050 Min. Rel. Area : 50%
Max. RRF Dev : 25% Max. Rel. Area : 150%

		Compound	AvgRF	CCRF	%Dev	Area%
1	I	1,4-Dichlorobenzene-d4	1.000	1.000	0.0	74
2	T	n-Nitrosodimethylamine	0.707	0.699	1.1	68
3	T	Pyridine	1.030	1.074	-4.3	70
4	S	2-Fluorophenol	1.233	1.267	-2.7	72
5	T	Aniline	1.394	1.441	-3.4	75
6	CMT	Phenol	1.827	1.879	-2.9	73
7	S	Phenol-d5	1.600	1.740	-8.8	76
8	T	bis(2-Chloroethyl)ether	1.363	1.441	-5.7	79
9	MT	2-Chlorophenol	1.083	1.284	-18.6	84
10	T	1,3-Dichlorobenzene	1.350	1.390	-3.0	74
11	CMT	1,4-Dichlorobenzene	1.690	1.823	-7.8	77
12	T	1,2-Dichlorobenzene	1.338	1.554	-16.2	83
13	T	Benzyl alcohol	0.679	0.688	-1.3	71
14	T	o-Cresol	0.998	1.080	-8.2	78
15	T	bis(2-Chloroisopropyl)ether	1.775	2.009	-13.2	80
16	T	Hexachloroethane	0.762	0.775	-1.7	77
17	T	p-Cresol	1.204	1.094	9.1	62
18	MPT	N-Nitrosodipropylamine	1.050	1.111	-5.8	77
19	I	Naphthalene-d8	1.000	1.000	0.0	90
20		N-Nitroso-morpholine	0.000	0.000#	0.0	0#
21	S	Nitrobenzene-d5	0.547	0.470	14.2	76
22	T	Nitrobenzene	0.569	0.486	14.5	74
23	T	N-Nitrosopiperidine	0.000	0.000#	0.0	0#
24	T	Isophorone	0.882	0.778	11.8	76
25	CT	2-Nitrophenol	0.220	0.199	9.7	85
26	T	2,4-Dimethylphenol	0.368	0.330	10.3	79
27	T	bis(2-Chloroethoxy)methane	0.484	0.455	6.1	81
28	CT	2,4-Dichlorophenol	0.327	0.285	12.8	83
29	T	Benzoic acid	0.089	0.082	8.4	82
30	MT	1,2,4-Trichlorobenzene	0.365	0.397	-8.8	97
31	T	Naphthalene	1.265	1.261	0.4	87
32	T	2,6-Dichlorophenol	0.301	0.285	5.5	84
33	T	4-Chloroaniline	0.322	0.253	21.5	64
34	CT	Hexachlorobutadiene	0.274	0.289	-5.4	98
35	T	N-Nitrosodi-n-butylamine	0.000	0.000#	0.0	0#
36	CMT	4-Chloro-3-methylphenol	0.406	0.392	3.5	89
37		1-Methylnaphthalene	0.747	0.799	-7.0	93
38	T	2-Methylnaphthalene	0.747	0.799	-6.9	93
39	I	Acenaphthene-d10	1.000	1.000	0.0	71
40	T	1,2,4,5-Tetrachlorobenzene	0.000	0.000#	0.0	0#
41	PT	Hexachlorocyclopentadiene	0.285	0.326	-14.1	78

(#) = Out of Range

Continuing Calibration Report 5972 - In

Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Tue Nov 17 12:05:02 1998
Response via : Initial Calibration

Continuing Calibration File: STD80.D

Min. RRF : 0.050 Min. Rel. Area : 50%
Max. RRF Dev : 25% Max. Rel. Area : 150%

		Compound	AvgRF	CCRF	%Dev	Area%
42	CT	2,4,6-Trichlorophenol	0.390	0.453	-16.3	80
43	T	2,4,5-Trichlorophenol	0.436	0.425	2.6	76
44	S	2-Fluorobiphenyl	1.531	1.610	-5.1	72
45	T	1-Chloronaphthalene	1.208	1.283	-6.2	77
46	T	2-Chloronaphthalene	1.208	1.283	-6.2	77
47	T	2-Nitroaniline	0.546	0.468	14.3	59
48	T	Acenaphthylene	1.947	1.612	17.2	59
49	T	Dimethyl phthalate	1.501	1.503	-0.1	69
50	MT	2,4-Dinitrotoluene	0.464	0.383	17.4	57
51	T	3-Nitroaniline	0.359	0.321	10.6	71
52	CMT	Acenaphthene	1.543	1.292	16.2	62
53	PT	2,4-Dinitrophenol	0.212	0.222	-4.4	73
54	T	Dibenzofuran	2.044	1.765	13.7	62
55	T	Pentachlorobenzene	0.000	0.000#	0.0	0#
56	MPT	4-Nitrophenol	0.351	0.347	1.1	76
57	T	1-Naphthylamine	0.000	0.000#	0.0	0#
58	T	2,6-Dinitrotoluene	0.403	0.364	9.7	60
59	T	2-Naphthylamine	0.000	0.000#	0.0	0#
60	T	2,3,4,6-Tetrachlorophenol	0.001	0.000#	100.0#	0#
61	T	Fluorene	2.911	3.530	-21.3	81
62	T	4-Chlorophenyl phenyl ether	1.404	1.446	-3.0	76
63	T	Diethyl phthalate	2.913	2.727	6.4	64
64		Azobenzene	2.866	3.101	-8.2	77
65	T	4-Nitroaniline	0.153	0.127	17.0	54
66	I	Phenanthrene-d10	1.000	1.000	0.0	56
67	T	4,6-Dinitro-2-methylphenol	0.318	0.311	2.0	60
68	CT	Diphenylamine	0.760	0.677	11.0	49#
69	T	N-Nitrosodiphenylamine	0.750	0.600	19.9	44#
70	T	1,2-Diphenylhydrazine	1.646	1.461	11.2	55
71		p-Phenylenediamine	0.165	0.135	17.9	49#
72	S	2,4,6-Tribromophenol	0.197	0.165	16.6	53
73	T	4-Bromophenyl phenyl ether	0.244	0.253	-3.8	61
74		1,3,5-Trinitrobenzene	0.000	0.000#	0.0	0#
75	T	Hexachlorobenzene	0.416	0.343	17.3	47#
76	T	4-Aminobiphenyl	0.000	0.000#	0.0	0#
77	CMT	Pentachlorophenol	0.382	0.323	15.3	49#
78	T	Pentachloronitrobenzene	0.000	0.000#	0.0	0#
79	T	Phenanthrene	1.299	1.097	15.5	47#
80	T	Anthracene	1.274	1.048	17.7	47#
81	T	Di-n-butyl phthalate	1.860	1.571	15.5	46#
82	CT	Fluoranthene	1.028	0.968	5.8	53
83	TM	Pyrene	0.950	0.757	20.3	45#

(#) = Out of Range

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Method : D:\HPCHEM\1\METHODS\8270-019.M
Title :
Last Update : Tue Nov 17 12:05:02 1998
Response via : Initial Calibration

Continuing Calibration File: STD80.D

Min. RRF : 0.050 Min. Rel. Area : 50%
Max. RRF Dev : 25% Max. Rel. Area : 150%

		Compound	AvgRF	CCRF	%Dev	Area%
84	I	Chrysene-d12	1.000	1.000	0.0	40#
85	S	p-Terphenyl-d14	3.331	2.581	22.5	29#
86	T	p-Dimethylaminoazobenzene	0.001	0.000#	100.0#	0#
87	T	Butyl benzyl phthalate	1.455	1.363	6.3	36#
88	T	Benzo(a)anthracene	1.253	1.209	3.5	38#
89	T	Chrysene	1.176	1.158	1.5	40#
90	T	bis(2-Ethylhexyl) phthalate	1.647	1.775	-7.8	41#
91	CT	Di-n-octyl phthalate	1.425	1.502	-5.4	43#
92	I	Perylene-d12	1.000	1.000	0.0	50
93	T	Benzo(b)fluoranthene	1.569	1.447	7.8	46#
94	T	Benzo(k)fluoranthene	1.557	1.719	-10.5	55
95		7,12-dimethylbenz[a]anthracen	0.162	0.123	24.1	36#
96	CT	Benzo(a)pyrene	1.191	1.253	-5.2	51
97	T	3-Methylcholanthrene	0.000	0.000#	0.0	0#
98	T	Indeno(1,2,3-cd)pyrene	0.979	0.883	9.8	42#
99	T	Dibenzo(a,h)anthracene	0.817	0.754	7.6	46#
100	T	Benzo(g,h,i)perylene	0.834	0.676	18.9	40#

(#) = Out of Range SPCC's out = 0 CCC's out = 0

Pesticides & PCBs
QC Data Package Summary

Argus Analytical, Inc.

Client: Vicksburg Chemical

Date: November 20, 1998

Sample #	Analyte	Spike Recoveries - %	
		MS	MSD
AA 66497	gamma-BHC (Lindane)	98	100
AA 66498	Heptachlor	75	72
AA 66499	Aldrin	64	62
	Dieldrin	93	97
	Endrin	103	102
	4,4'-DDT	93	90
	Aroclor 1242	73	

AA 66724	gamma-BHC (Lindane)	117	85
	Heptachlor	103	82
	Aldrin	80	56
	Dieldrin	100	69
	Endrin	95	74
	4,4'-DDT	83	64
	Aroclor 1242	57	

Pesticides
QC Data Package Summary

Argus Analytical, Inc.

Client: Vicksburg Chemical

Date: November 20, 1998

Sample #	Analyte	Spike Recoveries – %	
		MS	MSD
AA 66497	Atrazine	106	111
AA 66498	Atrazine	106	111
AA 66499	Atrazine	106	111
AA 66928	Atrazine	112	104

CORRECTIVE MEASURES IMPLEMENTATION PLAN

SWMU 12 - FORMER MSMA SALT UNLOADING AREA
SWMU 11 - FORMER MSMA PRODUCTION AREA
SWMU 15 - FORMER METHYL PARATHION PRODUCTION AREA

Prepared for
Vicksburg Chemical Company
Vicksburg, Mississippi

Cedar Chemical Corporation
Memphis, Tennessee

April 6, 1998

Woodward-Clyde

2822 O'Neal Lane
Baton Rouge, Louisiana 70816
(504) 751-1873
96B315-10

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Figure 6 North Pond Area Landfill

ATTACHMENTS

Attachment A Health and Safety Plan
Attachment B Community Relations Plan
Attachment C Stabilization of Arsenic Wastes

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ACRONYMS

Acronym	Meaning
AOC	Areas of Concern
bgs	below ground surface
CCC	Cedar Chemical Corporation
CMIP	Corrective Measures Implementation Plan
CMS	Corrective Measures Study
EPA	United States Environmental Protection Agency
MSDEQ	Mississippi Department of Environmental Quality
PECMT	Preinvestigation - Evaluation of Corrective Measures Technologies
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RFI Work Plan	Description of Overall Investigative Plan for Facility
RFI Expedited Work Plan	Description of Investigative Plan for SWMUs 12, 11 and 15
RFI Report	Summary of Investigative Analysis for Facility
RFI Expedited Report	Summary of Investigative Analysis for SWMUs 12, 11 and 15
SWMU	Solid Waste Management Unit
SWMU 1	Hazardous Waste Container Storage Area
SWMU 17	Off-specification Product Storage Area
SWMU 2	Inactive Landfill will include AOC 4
SWMU 7	Former Dinoseb Production Area
SWMU 14	Former Toxaphene Production Area
SWMU 4	Activated Carbon Treatment Unit
SWMU 5	South Plant Drainage System
SWMU 8	Dinoseb Loading/Unloading Area
SWMU 9	Dinoseb Drumming Area
SWMU 11	Former MSMA Production Area
SWMU 12	Former MSMA Unloading Area
SWMU 13	South Plant Drainage Ditches
SWMU 15	Former Methyl Parathion Production Area
SWMU 16	Former Atrazine Production Area
SWMU 17	Returned Product Storage Area
SWMU 18	Former Blue Tank
SWMU 20	Railroad Car Loading/Unloading Station
SWMU 22	North Plant Neutralization System Concrete Sump
SWMU 25	North Plant Subsurface Wastewater Pipes
SWMU 29	Floor under North Plan Oil Collection Unit
SWMU 30	North Plant Waste Accumulation Area
SWMU 31	North Plant No. 6 Fuel Oil Area
TCL	Target Compound List

ACRONYMS (Continued)

Acronym	Meaning
TAL	Target Analyte List
VCC	Vicksburg Chemical Company
Woodward-Clyde	Woodward-Clyde International-Americas (formerly Woodward-Clyde Consultants) a subsidiary of URS Corporation

1.1 PURPOSE AND ORGANIZATION OF REPORT

Vicksburg Chemical Company (VCC) retained Woodward-Clyde International-Americas (Woodward-Clyde) to perform activities associated with a RCRA corrective action program. The corrective action program is in response to a Consent Decree effective July 1, 1991. The Consent Decree requires that a RCRA Facility Investigation (RFI) be conducted at the Vicksburg, Mississippi manufacturing facility.

The purpose of the RFI is to determine the nature and extent of releases of hazardous wastes and/or constituents from regulated units, solid waste management units (SWMUs), and other areas of concern (AOCs) at the facility and to gather all necessary data to support any corrective action required.

The RFI constitutes the second phase of the RCRA corrective action program. The program's initial phase consists of the RCRA Facility Assessment (RFA) which is conducted by EPA and precedes the RFI. The RFI itself is divided into several separate tasks which includes the Preliminary Report (Report of Current Conditions, submitted previously by VCC then resubmitted as the Amended and Restated Preliminary Report and subsequently approved by the U.S. EPA), the RFI Work Plan (submitted in June 1996), the Facility Investigation, and the Investigative Analysis and Reports (RFI Report). In addition to these phases, a Groundwater Assessment Work Plan (submitted in June 1996), a Closure Plan for SWMU 1 and SWMU 17 (submitted and subsequently approved by the U.S. EPA) and Annual Groundwater Assessment Reports are required by the Consent Decree.

The RCRA corrective action program for SWMUs 12, 11 and 15 is very similar to that for SWMUs 16, 1 and 17. An RFI Report, Corrective Measures Study (CMS), RCRA Corrective Measures Implementation Plan and Application for Corrective Action Management Unit (CAMU) were published for SWMUs 16, 1 and 17 and initially submitted to the U.S. Environmental Protection Agency (EPA) and Mississippi Department of Environmental Quality (MSDEQ) in June 1997. The CAMU application, which is pertinent to the plant-wide corrective action program, has been approved. VCC adopts by reference the CMS for SWMUs 16, 1 and 17 (submitted to the EPA and MSDEQ in June 1997).

This document is the Corrective Measures Implementation Plan (CMIP). It is based on the RFI Expedited Report and the CMS adopted by reference. The RFI Expedited Report describes the activities and the results of analyses of samples obtained during the execution of the RFI

Expedited Work Plan (December 1997). The CMS identified, screened and developed alternatives for removal, containment, treatment, and/or other remediation of contamination based on the objectives established for the corrective action. The work plan, reports and plan are limited to the following areas:

- SWMU 12, Former MSMA Unloading Area;
- SWMU 11, Former MSMA Production Area; and
- SWMU 15, Former Methyl Parathion Production Area.

Pursuant to the RCRA Corrective Action Plan (OSWER Directive 9902-3-2A), a CMIP may be submitted rather than the Conceptual Design, Intermediate Plans and Specifications, and Construction Work Plan. This CMIP consists of describing the following tasks:

- CMI Program Plan;
- Corrective Measure Conceptual Design; and
- Corrective Measures Construction.

1.2 SITE DESCRIPTION

VCC is located in Warren County, Mississippi along the Mississippi River immediately on the south area of Vicksburg within the city limits. About 70 acres border on the Mississippi River, however, none of the plant production facilities are located along the river. The address is:

Vicksburg Chemical Company
Post Office Box 821003
Rifle Range Road
Vicksburg, Mississippi 39182-1003

The facility is a manufacturer of chemicals. The 650 acre plant site is divided into two separate and distinct operations known as the North Plant and the South Plant. Active operations are conducted or have been conducted on about 130 acres.

In operation since 1961, the North Plant produces potassium nitrate, liquid chlorine, and liquid nitrogen tetroxide. The raw materials for the North Plant include potassium chloride and nitric acid. The potassium nitrate is sold in varying grades as a chemical fertilizer and for industrial

uses. The chlorine is sold for various industrial uses. Most nitrogen tetroxide is sold to the government as an oxidizer for rocket fuels.

The South Plant, in operation since 1953, formerly manufactured chlorinated pesticides, nitrogen based herbicides, and other agricultural chemicals. The only active operations at the South Plant are a nitric acid unit constructed in 1986 and a potassium carbonate (Kcarb) plant constructed in 1995. The manufactured nitric acid is used primarily in the North Plant as a raw material. The potassium carbonate is a commercial product. During various periods prior to 1987, the South Plant produced dinitro butyl phenol (dinoseb or DNBP), monosodium methane arsonate (MSMA), diethyl hexyl phosphoric acid (DEHPA), 1-hydroxy-ethylidene-1,1-diphosphonic acid (UNIHIB), toxaphene, methyl parathion, cyanazine (bladex), and atrazine. Toxaphene and methyl parathion are insecticides, while atrazine, dinoseb, and MSMA are herbicides. Raw materials or solvent for these operating processes included chlorine, camphene, ortho secondary butyl phenol (OSBP), sodium arsenite, sodium hydroxide, methyl chloride, sulfuric acid, sodium paranitrophenolate, phosphorus trichloride, cyanuric chloride, tributylamine, carbon tetrachloride, epichlorohydrin, ortho-cresol, methanol, triethanolamine, xylene, isopropylamine, mono-ethylamine, toluene, poly glycol, diethanolamine and acetone.

Originally, the two plants were completely separate, owned and operated by two different companies. The South Plant was originally constructed by Spencer Chemical in 1953 to produce agricultural chemicals: ammonia, nitric acid, urea, and ammonium nitrate. After purchasing the facility in 1964, Gulf Chemical added a formaldehyde unit in 1966. American Metal Climax Corporation (Amax) constructed the North Plant in 1961 to produce chloride-free potassium nitrate for selected crops.

Vicksburg Chemical Company was formed in early 1972 and purchased both the Gulf Oil and Amax Chemical facilities except the formaldehyde plant on July 12, 1972. Production, under the new management, began in October of the same year. Vicksburg Chemical then operated the nitric acid, potassium nitrate, and nitrate solutions plants about 2 ½ years. By September, 1974 five more facilities were built for atrazine, methyl parathion, dinoseb, toxaphene, and UDMH (Unsymmetrical Dimethyl Hydrazine) production. The UDMH facility was shut down permanently a short time after construction.

In 1978, Vicksburg Chemical Company was merged into Vertac, Inc. Effective September 1, 1979 Vertac, Inc. was merged into Vertac Chemical Corporation (Vertac). In February, 1986 Cedar Chemical Corporation acquired the Vicksburg Chemical plant from Vertac pursuant to a

reorganization agreement among Vertac's shareholders and Fermenta A.B. of Sweden. Nine West Corporation, (a wholly owned subsidiary of Trans Resources, Inc.) acquired Cedar Chemical Corporation from Fermenta A.B. in January, 1988. Effective January 1, 1992 Cedar Chemical Corporation incorporated its Vicksburg, Mississippi facility as Vicksburg Chemical Company, a wholly owned subsidiary of Cedar Chemical Corporation.

A formaldehyde unit owned and operated by Borden Chemical is located inside the boundary of the South Plant. It was previously owned by Gulf and, later, Perkins Company and is referred to in this manner occasionally. The small portion of the South Plant site occupied by the Borden operation is not separated from the rest of the plant. There is no fence or other barrier.

The majority of the SWMUs and AOCs identified in the Consent Decree are located in the South Plant. Production operations at the South Plant have been discontinued except for a nitric acid plant, a newly constructed potassium carbonate plant, and a fertilizer blending facility under construction.

The subject of the CMIP are SWMU 12, SWMU 11 and SWMU 15; a brief summary of the production history is noted below:

SWMU Number	Unit Name	Physical Description	Former Function
12	Former MSMA Salt Unloading Area	Two concrete lined bays (15 to 10 feet) covered by a roof.	MSMA by-product salts were loaded into sludge dumpsters for offsite disposal.
11	Former MSMA Production Area	The unit consists of trenches, sumps and product storage tanks. The unit has been 90% dismantled.	Chemical processing area which produced MSMA.
15	Former Methyl Parathion Production Area	The unit is located on the same site as the Former MSMA Production Area (SWMU 11).	Chemical processing area which produced methyl parathion.

An extensive sampling and analysis program was carried out for SWMUs 12, 11 and 15. The results are reported in the RFI Expedited Report which is submitted simultaneously with the CMIP. The following conclusions can be drawn with regard to contamination of SWMUs 12, 11 and 15:

- The concrete floor comprising the main portion of the MSMA process is substantial (coring terminated at 55 inches, no cracks observed), appeared to have been well coated with concrete paint and is uncontaminated with arsenic. The same cannot be said about surrounding areas.

- The soil and concrete areas immediately adjacent and to the west and north of the process area are contaminated with arsenic. The area to the west is generally contaminated in excess of 20,000 ppb (the background concentration) to a depth of 8 feet; the volume is about 2,700 cubic yards of concrete and soil. The area to the north is generally contaminated in excess of 20,000 ppb to a depth of 1 to 4 feet; the volume is about 800 cubic yards of concrete, asphalt and soil. An estimated delineation of the contamination is presented in Figure 1.

- All of the drainage systems and sumps contain contaminated loose solid material (soil, gravel, etc.). The loose solid material is for the most part contaminated in excess of 20,000 ppb arsenic. The volume of material is estimated to be 5 cubic yards.

- Wipe samples show arsenic contamination of structural beams, corrugated fiberglass wells and steel floors.

- There is a plume of arsenic contamination in what may be the top 1-foot in a zone of the uppermost aquifer from the MSMA site extending generally to the southeast. An estimate of the concentration plume is presented in Figure 2. A potentiometric contour map is presented as Figure 3. The likely main source is the loading station where by-product salts (K031) generated in the production of MSMA were dumped into roll-off boxes. The ultimate disposition of the contents of the roll-off boxes was the Chemical Waste Management hazardous waste landfill in Emelle, Alabama.

  The plume extends well beyond the boundaries of the MSMA site and into areas that are free of surficial arsenic contamination. The nearest monitor wells (1A, 8, 9 and 12) exhibit detection of trace concentrations of arsenic that may be due to background concentrations of arsenic in soil.

2.1 CORRECTIVE ACTION OBJECTIVES

Corrective action objectives are goals for protecting human health and the environment that apply to a specific medium. Objectives for protecting human receptors generally specify both a contaminant criteria and an exposure route because protectiveness may be achieved by either reducing exposure or reducing the contaminant levels.

The clean closure standards are based upon closure of areas with no contamination remaining in place above the health based action levels. This plan is intended to result in a "clean" closure which will eliminate the need for post-closure maintenance and care of the storage areas. The levels of clean-up will be used for the soils underneath the concrete as well as the concrete. The following are the health based closure standards for soils and concrete, assuming that the exposure pathway is ingestion, and the receptors are workers at the site. This assumption will require a restriction on future land use at the site. (See OSWER Directive No. 9355.7-04, Land Use in the CERCLA Remedy Selection Process, May 25, 1995.)

Constituent	Concentration[1] (mg/kg)
Dinoseb	80
Arsenic	20,000[2]
Toxaphene	2.6
Atrazine	400
Toluene	16,000

NOTES:

(1) A discussion of the calculation is found in Closure Plan - SWMU 1 and SWMU 17 (February 1995).

(2) Modified because of high concentrations of arsenic in the background samples.

Offsite groundwater migration is also a medium through which human or environmental receptors could potentially be exposed to contaminants from the site. Contaminated vadose zone soils are of concern as a potential contributor of contaminants to the groundwater. Consequently, corrective action objectives are established for vadose zone soils.

Clean closure standards for soil leachate require that concentrations in TCLP extract of the soil shall not exceed MCLs. Where MCLs have not been established, concentrations in the TCLP

2.3.1 Project Task Definition

For the expedited corrective measures, VCC has retained the services of Woodward-Clyde as an independent engineering firm to develop the CMIP. Woodward-Clyde will provide construction management services and inspection to implement the CMIP. VCC will provide internal implementation supplemented by construction contractors (contractors will be contracted directly with VCC).

2.3.1.1 EPA and LDEQ Project Coordinator

The EPA and LDEQ project coordinators or designees will observe corrective measures activities to the extent deemed necessary to confirm that the requirements of the CMIP.

2.3.1.2 Project Director

The Project Director is Mr. Steve Boswell, Director of Environmental Affairs for VCC. He is in charge of administration of the work and the completion of the project. Personnel with VCC and equipment owned by VCC may be utilized for various aspects of the construction. Personnel have received the appropriate OSHA training and all work would be guided by the provisions of the CMIP. Outside construction contractors will report to Mr. Boswell. Woodward-Clyde will act as VCC's agent for that assistance provided for in the implementation of the CMIP.

2.3.1.3 Woodward-Clyde Corrective Measures Task Manager

The Woodward-Clyde Task Manager will develop the plans and oversee remediation work implementing the CMIP on behalf of VCC. The Woodward-Clyde CMIP Task Manager is Mr. Richard D. Karkkainen. He is also the Woodward-Clyde Project Manager to handle day to day coordination and administration.

2.3.1.4 Quality Assurance Observations and Measurements

Woodward-Clyde will provide construction quality assurance for this project. QA duties will be under the supervision of Mr. Bob SeGall, Professional Engineer, registered in the State of Mississippi.

2.3.1.5 VCC's Health and Safety Officer

A Health and Safety (H&S) Officer will be responsible for the administration and implementation of site health and safety. However, the H&S Officer will have the overall responsibility for safety and health and will:

- Ensure that an employee medical surveillance program which meets the requirements of 29 CFR 1910.120 is instituted and maintained.

- Be responsible for the initial pre-construction indoctrination of all on-site personnel with regard to the H&S Plan and other safety requirements to be observed during the construction, including but not limited to:

  - potential hazards
  - personal hygiene principles
  - personal protective equipment
  - respiratory protection equipment usage and fit testing
  - emergency response including site evacuation, dealing with fire and medical situations

Construction contractors are responsible for preparing and following their own Health and Safety Plan which meets the requirements of 29 CFR 1910.120. They may adopt by reference plans prepared by others but must assume responsibility for the health and safety of their own personnel.

2.4 WOODWARD-CLYDE'S HEALTH AND SAFETY PLAN

The Health and Safety Plan establishes guidelines and requirements for the safety of field personnel during the conduct of the field activities associated with the referenced project. The activities addressed by this plan are those described in Section 3.0, the Corrective Measures Conceptual Plan. All employees of Woodward-Clyde involved in this project are required to abide by the provisions of this plan. They are required to read this plan and sign the attached Compliance Agreement. The Health and Safety Plan is attached as Attachment A.

The health and safety guidelines and requirements are based on a review of available information and an evaluation of potential hazards. This plan outlines the health and safety procedures and equipment required for activities at this site to minimize the potential for exposures of field personnel. This plan may be modified by the project manager, the corporate health and safety officer, and the Baton Rouge health and safety officer in response to additional information obtained regarding the potential hazards to field personnel.

2.5 COMMUNITY RELATIONS PLAN

The Community Relations Plan (CRP) for VCC has been prepared. The CRP presented herein describes the mechanism for the dissemination of information to the public regarding RCRA corrective action activities and results. The CRP describes community relations objectives and techniques for implementing the community relations program. The community relations program will provide the public an opportunity to participate in the decision-making process regarding remedial actions at the site and inform the public of current and future site activities.

This CRP is a working document that serves as a guide for communicating with the affected community. Activities and schedules may be altered according to future circumstances. The CRP is attached as Attachment B.

3.1 REQUIRED ACTIVITY

The required activity is to permanently deal with corrective measures now by incorporating elements of the following for each remediation area, as necessary and appropriate:

- Excavate and dispose onsite 3,500 cubic yards of material. Backfill the excavation. The material would be stabilized onsite consistent with the CAMU prior to landfilling onsite;
- Clean all the drainage systems and sumps. During the excavation noted above some portions of the system may be removed;
- Install two sets of nested monitor wells downgradient of the arsenic plume. Conduct aquifer testing. Plan on groundwater recovery as part of an overall groundwater program after the site-wide groundwater assessment; and
- Monitor for airborne arsenic when the superstructure is sandblasted prior to painting.

The following are discussions of the excavation and disposal activities; specifically, the treatment process (Section 3.2), the onsite disposal (Section 3.3) and the disposal site after construction of the landfill (Section 3.4).

3.2 THE TREATMENT PROCESS

The waste that is excavated would all be solidified/stabilized. Solidification/stabilization of toxic waste uses chemical and physical processes to detoxify or immobilize a hazardous waste. The waste is immobilized in a normal earth environmental to form a less leachable product. This can be accomplished by addition of chemicals, surfactants, or complexing agents.

Stabilization refers to processes that reduce the risk posed by a waste by converting the contaminants into a less soluble, mobile, or toxic form. The physical nature of the waste is not necessarily changed.

Stabilization and solidification processes can be applied to a wide range of wastes. Since all the processes depend upon chemical and physical reactions of varying complexity between the wastes and the applied fixation agents, care is required in order to select the most appropriate process or system. The following table lists common kinds of wastes and the solidification/stabilization process that is most effective:

Kinds of Wastes	Stabilization/Solidification Process
Oily wastes, industrial sludges and contaminated soils (containing inorganics with low concentrations of organics), acid mine leachate and tailings, and radioactive liquid scintillation fluids	Sorbents and Surfactants
Contaminated foundry sands and sand-blasting grit; wastes from paint removal, metal finishing, and electroplating; petroleum-contaminated soils	Emulsified Asphalt
Refuse-to-energy plant and medical wastes ash, insulation wastes, metals-smelting dusts, contaminated soils, and metal-contaminated sludges	Soluble Phosphates
Low and medium level radioactive wastes, municipal solid waste ash, medical wastes, and contaminated soils and sludges	Bituminization
Predried particulate wastes, such as, incinerator ash, contaminated soils, sludges, metals, and mill tailings	Modified Sulfur Cement Process
Primary and secondary waste streams produced by waste management and restoration activities, nitrate salt wastes, sludges, ion-exchange resins, incinerator ash, and scrubber blow-down solution	Polyethylene Extrusion
(Specific process variation dependent) metal-containing wastes, auto shredder fluff, incinerator-bottomash, and contaminated debris	Soluble Silicates (Patented Processes)
Metal-refining wastes, metal-finishing wastes, and metal-bearing sludges	Soluble Silicates (Slags)
Steel pickle liquor, ferric chloride etching waste, oil waste, hydrocarbon waste, incinerator ash, petroleum sludge, phosphoric acid residue, oily wastes, and tars	Soluble Silicates (Lime)
(Specific process variation dependent) metal-containing wastes, auto shredder fluff, incinerator-bottomash, and contaminated debris	Soluble Silicates (Inorganic Polymers)

Stabilization/solidification techniques sometimes do not successfully bind all organic compounds. Volatile organics such as benzene will be substantially volatilized during the stabilization due to agitation during mixing and temperature increases due to heat of reaction of stabilization reactions.

The particular treatment process to be utilized for stabilization of the arsenic is based on the study "Stabilization of Arsenic Wastes" by Max Taylor and Robert Fuessle prepared for the Hazardous Waste Research and Information Center in October 1994. A copy of the entire study is provided as Attachment C.

The optimum mix (by weight) proposed from the study consists of the following:

- 100 parts waste;
- 9 parts cement;
- 6 parts fly ash cement;
- 24 parts water; and
- 14.4 parts $FeSO_4$ 7 H_2O.

Ferrous sulfate was selected for its capacity to immobilize arsenic. From the consideration of the chemistry of arsenic, iron and cement, various chemical models to explain the stabilization can be proposed. To quote from the study: "The most common of the single chemical models of the concrete matrix is that of an anionic silicate-aluminate lattice with cations bound to lattice sites by ionic attraction. The amorphous water rich regions of the matrix are at very high pH values. In order to hold an anionic material in the matrix, the stabilization process must provide either covalent bonding into the matrix during the curing of the matrix or formation of insoluble compounds inside the matrix. Previous work (Akhter, 1990) indicates that incorporation of the arsenic anions into the silicate-aluminate backbone is not likely. Therefore, the most obvious mechanism for stabilizing arsenic is to form insoluble compounds with iron (II), incorporated in the concrete."

The mix is being tested in the VCC laboratory and samples will be sent for Toxicity Characteristics Leaching Procedure and analysis of arsenic. The mix used in the field may vary somewhat from the mix noted, pending results of the analyses.

The sequence of mixing is an important part of the stabilization procedure The elements of that procedure are as follows:

- Mix the waste as thoroughly as possible.
- Add the binders, i.e., cement and fly ash cement to the waste and mix as thoroughly as possible. Preferably perform the mixing in a pug mill or other appropriate equipment.
- Mix the ferrous sulfate with water in a separate vessel.

- Add the ferrous sulfate solution to the waste plus binder mix. Mix thoroughly.

- Empty the stabilized waste into a final or intermediate repository. Allow to cure for at least 2 weeks.

- Place the waste in the final repository in 12-inch lifts. Compact the lift after it has cured at least 2 weeks.

- Cap the final repository with 2 feet of clay and 1 foot of topsoil. Vegetate the top soil.

3.3 ON-SITE DISPOSAL OF THE RESIDUALS

3.3.1 North Pond

The total volume of contaminated soil to be excavated is approximately 3,500 cubic yards. Once the material is stabilized the total volume will be approximately 5,000 cubic yards. The onsite repository planned as a landfill for that volume is the North Pond.

The North Pond was investigated as the potential site of new manufacturing operations in 1993. The manufacturing operations were not constructed. A work plan was issued in October 1993 which described the investigative plan for the area. The results of the investigation were published in "North Pond RCRA Facility Investigation Report", February 1994. Both reports were submitted to the U.S. EPA and MSDEQ. Results of the investigation were also incorporated into the "Amended and supplemental Preliminary Report RCRA Facility Investigation" submitted to and subsequently approved by the U.S. EPA and MSDEQ. The results of that investigation are herein utilized to assess the suitability of the North Pond as the repository of the stabilized wastes.

There is approximately 3,240 cubic yards of soil/sludge in the bottom of the North Pond that will also be excavated and solidified/stabilized. Once the soil/sludge is solidified/stabilized the total volume will be approximately 4,500 cubic yards.

3.3.3 North Pond Groundwater Hydrology

The Byram marl in the Vicksburg Formation constitutes the bottom of the uppermost water-bearing zone underlying the facility. The Byram marl is described as representing mixed clastic and carbonate sedimentation in an open shelf or platform environment. The argillaceous, massive and medium dense character of the marl would inhibit any significant movement of water through this unit, and there is no indication of secondary permeability. The uppermost water bearing zone is approximately 40 feet thick consisting almost exclusively of Pleistocene loess (silt). The clayey fill material placed atop the loess is acting as a "cap" inhibiting the vertical migration of the groundwater. The presence of the marl on the bottom of the aquifer creates a slightly artesian confined aquifer which is not hydraulically connected to any potential water-bearing zones at greater depths. The artesian property is characteristic of an aquifer which is under pressure from above and below. The background water quality of this aquifer is marginally acceptable for drinking water, however due to its low lateral flow and yield characteristics its usefulness as a domestic water supply is severely limited.

Figure 3 is a potentiometric contour of the uppermost aquifer with the potentiometric contour of the perched water table in the vicinity of the North Pond superimposed on it. The direction of groundwater flow is generally toward Stouts Bayou or Hennesseys Bayou. The evidence of the perched water table atop the clay lens in the North Pond area was established by the installation of shallow piezometers. The perched water table merges with or stops in the vicinity of the roadway that connects the North Plant with the South Plant.

The upper part of the saturated zone consists primarily of clay and silt-sized particles. This type of fine-grained material typically has a low hydraulic conductivity, resulting in relatively low groundwater and contaminant transport velocities. Such fine-grained material is also often relatively effective at either immobilizing of inhibiting migration of environmental contaminants. Vertical groundwater flow across layered deposits of varying hydraulic properties (such as are apparently present at this facility) may be a slow process for the vertical migration of groundwater contaminants. Because of the generally low hydraulic conductivity of the earth materials, and the possibility of contaminant immobilization or inhibition of vertical groundwater contaminant transport by contaminant-aquifer materials interactions, contaminants which may have leaked or leached from the source may be present mostly in the upper part of the saturated zone.

3.3.4 North Pond Waste Sludge Quality

There is sludge in the bottom of the North Pond. It is known from the history of the manufacturing facility that sludge in the bottom of the North Pond does not contain listed hazardous wastes. The sludge was additionally analyzed by the Toxicity Characteristic Leaching Procedure to determine if it was hazardous by characteristic. Analysis detected 29 parts per billion carbon tetrachloride and 440 parts per billion chloroform. The sludges would be hazardous by characteristic if the carbon tetrachloride concentration exceeded 500 parts per billion or the chloroform exceeded 6,000 parts per billion; therefore, the sludge is not hazardous by characteristic.

3.3.5 North Pond Soil Quality

Complete results of analyses of soil beneath and surrounding the North Pond are tabulated in Table 1 of the North Pond RFI Report, February 1995. Samples are clean with the exception of the following:

Location	Contaminant (Concentration in ppb)	Comment
B-20B Shallow Zone	Chloroform = 45	Action Level in Soil[1] = 100,000 Media Protection Standard[2], Maximum in Industrial Soil = 1,000,000 Preliminary Remediation Goal[3] in Industrial Soil = 1,600
B-20A Deep Zone	Chloroform = 13	See above
B-22B Shallow Zone	Chloroform = 830	See above
B-23A Deep Zone	Chloroform = 26	See above

NOTES:

1 EPA Proposed Corrective Action Rule for Solid Waste Management Units-Appendix A-Federal Register July 27, 1990.

2 EPA Proposed Corrective Action Rule for Solid Waste Management Units-Appendix C-Federal Register July 27, 1990.

3 U.S. EPA Region IX Preliminary Remediation Goals-August 6, 1993.

3.3.6 North Pond Groundwater Quality

Results of analyses of groundwater from piezometers surrounding the North Pond are also tabulated in Table 1 of the North Pond RFI Report, February 1995. Results are summarized below:

Inorganics

From the data it is evident that a plume of calcium, magnesium, potassium and sodium developed during the active use of the North Pond. The potassium is characteristically present in waste water from the North Plant. Potassium nitrate is manufactured in the North Plant. The source of sodium is the sodium hydroxide used to scrub streams containing chlorine and nitrogen oxides or for adjusting the pH of the wastewater stream. The source of the calcium and magnesium was the dolomite placed into the North Pond to adjust the pH of the pond.

Organics

The extent of migration of organics from the North Pond is not extensive. The concentration of organics in groundwater is limited to the shallow zone (perched water table) and the area directly east and adjacent to the North Pond. The following is a summary of results:

Location	Contaminant (Concentration in ppb)	Comment
B-20B Shallow Zone	Chloroform = 1,700	Media Protection Standard[2], Maximum in Water (Industrial Site) = 600 Action Level[1] in Water = 6 Preliminary Remediation Goal[3] in Tap Water = 0.28 MCL Trihalomethanes[4] = 100
	Bromodichloromethane = 36	Maximum Action Level[1] in water = 3.0 Preliminary Remediation Goal[3] in Tap Water = 0.14
	Dibromochloromethane = 14	Preliminary Remediation Goal[3] in Tap Water = 1.0
	Bromoform = 18	Preliminary Remediation Goal[3] in Tap Water = 11.0
	Carbon Tetrachloride = 4.0	Media Protection Standard[2], Maximum in Water (Industrial Site) = 30.0 Action Level[1] in Water = 0.3 Preliminary Remediation Goal[3] in Tap Water = 0.026 MCL = 5.0
	Trichloroethene = 1.0	MCL = 5.0

Location	Contaminant (Concentrationin ppb)	Comment
B-22B Shallow Zone	Chloroform= 6,200	See above
	Bromodichloromethane= 66	See above
	Dibromochloromethane= 78	See above
	Bromoform= 160	See above
		MCL Trihalomethanes[4] = 100
B-23B Shallow Zone	Chloroform= 79	See above
	Bromoform= 8	See above
	2 - Butanone	Laboratory Artifact

NOTES:

1 EPA Proposed Corrective Action Rule for Solid Waste Management Units-Appendix A-Federal Register July 27, 1990.

2 EPA Proposed Corrective Action Rule for Solid Waste Management Units-Appendix C-Federal Register July 27, 1990.

3 U.S. EPA Region IX Preliminary Remediation Goals-August 6, 1993.

4 Trihalomethanes (total) including chloroform, bromoform, bromodichloromethane and dibromochloromethane.

3.4 DESCRIPTION OF THE DISPOSAL SITE - POST CONSTRUCTION

A depiction of the appearance of the North Pond area during and after completion of the landfill construction is noted in Figures 4, 5 and 6.

3.4.1 Excavation

The North Pond area allows room for two excavations for the landfilling of the stabilized waste. The first is an area approximately 100 feet by 175 feet comprised of the present North Pond location. The first 5 feet of material excavated is soil/sludge to be solidified/stabilized prior to being placed in the excavation. The soil/sludge may be mixed directly with the arsenic wastes transported from the MSMA site. An additional 5 feet (to 120 feet msl) of soil would be excavated and set aside for construction of the landfill cap.

The second area to be excavated is an area approximately 100 feet by 150 feet located adjacent to and north of the North Pond. The location of both areas is noted on Figure 4. Approximately 8 feet (to 120 feet msl) of soil would be excavated from the second area and set aside for construction of the landfill cap.

A profile of the excavation is presented as Figure 5.

3.4.2 Placing the Solidified/Stabilized Waste and Construction of a Cap

The arsenic waste and the waste from the bottom of the North Pond would be solidified/stabilized in batches as generally described in Section 3.2 - The Treatment Process. After curing the solidified/stabilized waste would be placed in the excavations in 12-inch lifts and then compacted.

After placing all of the wastes in the excavation, the soil set aside from the excavation would be used to construct a cap on both areas. A compacted cap of 2 feet in depth would be constructed over the excavations and surrounding areas. Topsoil, at least 1 foot in depth, would be placed atop the cap. A profile of the capped area is presented as Figure 6.

3.4.3 Groundwater Monitoring of the Landfill

A groundwater monitoring system already surrounds the North Pond area with two nested wells at six locations. The locations are depicted on Figure 3 and Figure 6.

4.1 INTRODUCTION

Previous sections or paragraphs of the CMIP have included the following topics:

- **Site Description** - Section 1.2 - includes a discussion of areas and volumes encompassed by the CMIP;
- **Corrective Action Objectives and Approach** - Sections 2.1 and 2.2 - a discussion of what is to be accomplished by the CMIP;
- **Project Management Plan** - Section 2.3 - a discussion of the construction management approach; and
- **Corrective Measures Conceptual Design** - Sections 3.1, 3.2, 3.3 and 3.4 - a discussion of the required construction sequence of events, the treatment processes to be utilized for some of the material, location for the onsite disposal of the waste, and description of the disposal site - post construction.

Section 4.0 consists of the remaining elements of the CMIP:

- Construction Quality Assurance/Quality Control Programs
- Project Schedule

4.2 CONSTRUCTION QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

4.2.1 Scope of Plan

This Construction Quality Assurance (CQA) Plan parallels the guidelines outlined in the EPA Technical Guidance Document "Construction Quality Assurance for Hazardous Waste Land Disposal Facilities". The plan defines a system of construction quality management to verify, with a justifiable degree of certainty, that the construction activity encompassed by the CMIP will meet or exceed the corrective action objectives.

Construction Quality Management comprises both a planned system of inspection and testing activities that are necessary to monitor and control the quality of a construction project and a

planned system of construction management services that these activities are being properly performed and documented.

4.2.2 Plan Elements

The CQA Plan is comprised of the following elements:

- Responsibility and authority
- CQA personnel qualifications
- Inspection activities
- Sampling requirements
- Certification documentation

These elements are described in detail in the following sections.

4.2.3 Responsible Parties, Lines of Authority and CQA Personnel Qualifications

The management of construction quality is the responsibility of the facility Operator, VCC, and involves the use of scientific and engineering principles and practices to verify, with a justifiable degree of certainty, that the constructed facility meets or exceeds the Corrective Action Objectives. VCC will engage various contractors and material suppliers as required to provide services during construction of the work. The responsibility and lines of authority and communications are described below.

4.2.3.1 Operator

VCC is the Operator of the facility and is responsible for insuring compliance with the terms, conditions, rules and all other applicable regulatory and jurisdictional requirements. The Operator has the authority to select and dismiss parties charged with design, CQA and construction activities.

The Project Director is the official representative of VCC and is in charge of administration of the work and the completion of the project.

4.2.3.2 CQA Firm

Woodward-Clyde will be retained by VCC to provide quality assurance services, and certification. Personnel described below will be utilized:

- The Project Manager is the official representative of Woodward-Clyde and will report to the VCC Project Director. He will function as an agent of VCC to manage schedule and budget.

- The CQA Certifying Engineer will report to the Project Manager and the VCC Project Director. He will be responsible for the implementation of the CQA plan during construction. He will work closely with the Project Manager during construction activities. He will oversee all activities related to the Quality Assurance Program and act as a liaison between the Project Manager and CQA Officer. The CQA Certifying Engineer shall be experienced in construction, materials testing and quality assurance procedures and shall be a Professional Engineer registered in Mississippi.

- The CQA Officer will have day to day responsibility for quality assurance monitoring, inspection, and testing and will report to the CQA Certifying Engineer and the Project Manager. The CQA Officer shall have an engineering or other acceptable technical degree or other adequate formal training and sufficient practical, technical and administrative experience to execute and record inspection, testing and monitoring activities with experience in construction oversight and hazardous waste management projects. Specific responsibilities of the CQA Officer includes:

  - Being physically on-site to observe the critical work actually performed during construction work before accepting work
  - Reviewing and updating drawings and specifications for clarity and completeness
  - Scheduling inspection, monitoring and testing activities
  - Providing reports on monitoring and testing activities
  - Verifying that the CQA Plan is being implemented
  - Observing and documenting all work as it pertains to the CQA Plan

- Conducting and documenting all field testing required by the quality assurance program
- Performing independent on-site inspections of the work in progress

4.2.3.3 Contractors

The Contractors are responsible for the successful completion of their contractual duties and requirements as pertains to their portion of the work, and for the supervision and overall coordination and scheduling of their portion of the work. The contractors are also responsible for construction quality control during all phases of the contracted work.

4.2.3.4 Project Meetings

Periodic meetings are held during the course of the project to provide an interaction between the various lines of authority and a mechanism for quality assurance information transfer and resolution of uncertainties or deficient work. Types of meetings include:

- Preconstruction meeting
- Progress meetings
- Resolution and work deficiency meetings

A Preconstruction Meeting may be held at the site and shall be attended by all the responsible parties. The purpose of the Preconstruction Meeting is to:

- Review the responsibilities of each organization
- Review lines of authority and communication for each organization
- Discuss the established protocol for observations and tests
- Discuss the established protocol for handling construction deficiencies, repairs and retesting
- Review methods for documenting and reporting inspection data
- Review methods for distributing inspection data
- Review work area security and safety protocol
- Discuss any appropriate modifications of the CQA Plan to verify that site specific considerations are addressed

- Discuss procedures for the protection of materials and for the prevention of damage from inclement weather or other adverse effects
- Conduct a site walk-around to verify that the plans and specifications are understood and to review material and equipment storage locations

Progress Meetings are typically held at least weekly at the work area. As a minimum, the meeting should be attended by the CQA Officer and Contractor(s) representatives, as appropriate. The purpose of the meetings is to:

- Review previous activities and accomplishments
- Review future work locations and activities
- Identify the Contractor's personnel and equipment assignments
- Discuss any potential construction problems

Monitoring and inspection activities and test results will be reviewed in a way to allow the opportunity to provide an assessment of the quality assurance activities.

Resolution and Work Deficiency Meetings shall be held as needed to include the following:

- Define and discuss the uncertainty, problem or deficiency
- Review alternate solutions
- Implement a plan to resolve the uncertainty, problem or deficiency

Documentation of all meetings will be accomplished by minutes taken by the CQA attendee.

4.2.4 Quality Assurance Inspection Activities and Sampling/Testing Requirements

Quality Assurance inspection and sampling/testing activities will be the responsibility of the CQA Officer. The following activities are part of the program:

- Quality Control Verification testing during excavation of the arsenic waste
- Solidification/Stabilization Quality Assurance for arsenic waste and the North Pond sludge
- Earth Materials Quality Assurance for Cap Construction
- Protective Cover Quality Assurance

The work described in these sections will be conducted as part of the certification program. It does not preclude any additional quality control work that may be performed by the contractors at their expense and for their own information. Any results of such additional quality control work performed by the contractors shall be reported to the CQA Officer by submittal of copies of the test results.

The CQA Officer shall provide independent documentation that the work performed is in accordance with the project corrective measures objective. The quality controls shall be adequate to cover construction operations and will be keyed to the proposed construction sequence. The controls shall include at least three phases of inspection for all definitive features of work as follows:

- Preparatory inspection shall be performed prior to beginning any work or any definable feature of work. It shall include a review of contract requirements, verification that all materials and/or equipment have been tested, submitted, and approved, examination of the work area to verify preliminary work is complete and a physical examination of equipment and/or materials to be used.

- Initial inspection shall be performed as soon as a representative portion of the particular feature of work has been completed. It shall include an examination of the quality of workmanship, a review of control testing for compliance with contract documents, and any use of defective or damaged materials, omissions, and dimensional requirements as applicable.

- Final inspections shall be conducted and test deficiencies corrected.

At the completion of all work or any increment thereof established by a completion time stated in the specification, the CQA Officer shall conduct a completion inspection of the work and develop a "punch list" of items which do not conform to the approved plans and specifications. Such a list shall be included in the CQA documentation, as required below and shall include the estimated date by which the deficiencies will be corrected. The CQA Officer shall make a second completion inspection to ascertain that all deficiencies have been corrected.

4.2.4.1 Quality Control Verification Testing

The corrective action that is required is discussed in Section 3. During the corrective action, sampling and analysis will take place onsite. Verification sampling and analysis is to take place in order to provide assurance that the Corrective Action Objectives summarized in Section 2.1 are met. The verification sampling and analysis is summarized below:

Sample Point	Action Taken	Verification Sampling and Analysis
Every 2,500 ft^2	Obtain a composite sample consisting of four grab samples randomly selected.	Analyze for arsenic.
Four samples. One per color shaded area in Figure 1.	Obtain from composite samples selected for total arsenic analysis.	Analyze for TCLP arsenic.

The above noted verification sampling is for horizontal extent of contamination. Therefore, if the result of a verification sample does not meet the Corrective Action Objectives (Section 2.1) then additional excavation will be implemented in the direction of that sample. An additional verification sample will be obtained for analysis after the reexcavation is completed.

4.2.4.2 Solidification/Stabilization Quality Assurance

The corrective action objective for solidification/stabilization is to meet a compressive strength of at least 1 ton per square feet.

The solidified/stabilized arsenic waste will be tested for:

- unconfined compressive strength of cohesive soils - ASTM D-2166
- TCLP arsenic

The solidified/stabilized North Pond sludge will be tested for:

- unconfined compressive strength of cohesive soils - ASTM D-2166

The treatment will take place in transportable equipment equipped with a high intensity mixer. The treatment capacity is typically 50 to 100 tons per hour.

Samples will be taken for unconfined compressive strength on the basis of one sample per one-half days production or 500 tons, whichever is less. Samples (for incidental records) will be taken for TCLP extraction on the basis of one sample per 5,000 tons of production or five days production, whichever is less.

4.2.4.3 Earth Materials Quality Assurance for Cap Construction

Assurance that excavation and construction are in accordance with the plans shall be accomplished by the use of quality assurance testing. Specifically, quality assurance testing shall be conducted in two categories:

- Preconstruction testing
- Construction testing

Quality assurance testing within these categories shall consist of the following:

- Material evaluation and hydraulic conductivity evaluation
- Construction quality evaluation

Material Evaluation and Hydraulic Conductivity Evaluation

Material evaluation shall be performed on earth materials to ascertain their acceptability as construction materials. Evaluations shall also be performed during the course of the work. Criteria to be used for determination of acceptability of materials for use during construction is summarized below. All evaluation tests shall be performed by an approved geotechnical laboratory as part of the CQA program.

All materials not meeting the requirements of the specifications will be rejected, removed and replaced or reworked if possible so as to meet the requirements of the specifications.

The following tests shall be performed, as a minimum, to facilitate material evaluation to ensure compaction necessary to minimize infiltration through the cap.

Property Test	Method	Clay Cap Material
Laboratory Determination of Water (Moisture) Content of Rock & Soil Aggregate Mixtures D2216	--	--

Property Test	Method	Clay Cap Material
Particle-Size Analysis of Soils	ASTM D422	CL/CH
Soil Particle Size Smaller Than the U. S. No. 200 Sieve (Minimum)	ASTM D1140	>70%
Liquid Limit (Minimum)	ASTM D4318	30%
Plasticity Index of Soil	ASTM D4318	20%-55%
Moisture Density Relationships of Soils and Soil Aggregate Mixtures Using 5.5 lb. Rammer and 12 inch Drop (Standard Proctor)	ASTM D698	90%
Hydraulic Conductivity $1x10^{-7}$ Test	ASTM D5084 Method C	$1x10^{-7}$ cm/sec

Construction Quality Evaluation

Construction quality evaluation shall be performed on all components of the construction. These evaluations will become part of the certification program.

Construction evaluation testing shall include visual observations of the work, field density/moisture content determinations, surveys of as-built conditions, investigations into the adequacy of layer bonding and special testing. Visual evaluation of the construction work includes, as a minimum, observations of the water content and other physical properties of the soil during processing, placement and compaction.

Quality Control Testing Frequency

Testing frequencies for each of the quality assurance testing categories are summarized below. All quality assurance testing has been related to the construction sequence. To facilitate the CQA program, the following definitions are presented:

- A layer is defined as a compacted stratum composed of several lifts to a total thickness as specified in the plans and specifications.

- A lift is defined as a constructed segment of a layer composed of materials placed in approximately 8 to 10-inch loose thickness and compacted.

All quality assurance testing shall be conducted in accordance with this plan or as directed by the CQA Officer/Inspector. All applicable testing methods for soils as previously identified

shall be observed. Documentation and reporting of test results shall be in accordance with the requirements identified in Section 4.2.5

Construction testing for quality assurance shall be conducted on samples taken from the material during the course of the work. Construction quality testing shall consist of material evaluation tests and construction quality evaluation test and frequency as described below:

TESTING FREQUENCY FOR CONSTRUCTION QUALITY CONTROL AND CONSTRUCTION QUALITY CONTROL

Activity	Frequency of Test
Clay Cap*	1 per 2,000 cu yd or 1 minimum/day
Visual Observations	Full time
Clay Cap Density*	50 foot centers or minimum 2 per lift
Clay Cap Permeability**	1 per 25,000 sq. ft./lift or minimum 3 per lift
Surveys	
As built condition	All appurtenant components
Elevation Monitoring	50 feet center to center at a minimum 6 points per grade at a minimum of the following locations: Top of compacted waste layer Top of compacted clay cap Top of Topsoil Layer

* Tests include ASTM D2922, and D3017 or D1556

** Tests include ASTM D1140, D2216, D4318 and Permeability; three samples per test will be taken.

ASTM 2922	Density of Soil and Soil-Aggregate, In-Place, by Nuclear Methods (Shallow Depth).
ASTM 3017	Moisture Content of Soil and Soil-Aggregate, In-Place by Nuclear Methods (Shallow Depth).
ASTM D1556	Density of Soil In-Place by Sand Cone Method.
ASTM D1140	Amount of Material in Soils Finer than the No. 200 Sieve.
ASTM D2216	Laboratory Determination of Water (Moisture) Content of Soil Rock and Soil Aggregate Mixtures.
ASTM 4318	Liquid Limit, Plastic Limit and Plasticity Index of Soil.
ASTM D5084	Method C. Hydraulic conductivity test.
ASTM 4643-93	Moisture Content by Micro-Wave.
ASTM 1587-94	Thin Wall Tube Sampling of Soils.

Testing frequency may be changed at the discretion of the CQA Officer when visual observations of construction performance indicate a potential problem.

Protective Cover Quality Assurance

Construction Quality Assurance of the 12-inch top soil and a vegetative cover will be accomplished by evaluation of the materials used and the methods of construction.

Materials Evaluation

Material evaluation of the soils used for the 12-inch top soil layer will be by demonstration that the material is capable of supporting adequate vegetation.
Material evaluation of the vegetative cover materials (seed, fertilizer, mulch) shall be by quality control certificates supplied to the CQA Officer by the Contractor.

Construction Quality Evaluation

Construction quality evaluations shall be performed on all components of the construction. Criteria to be used for determination of the acceptability of the construction work will be by observation of the methods of construction.

Surveys and/or test pits will be performed to assess the as-built conditions and to verify layer thicknesses of the top soil.

Testing Frequency

Testing frequency for the top soil and vegetative cover for material evaluation shall be 1 sample for each material source for the project. These samples shall be retained by the CQA Officer.

4.2.5 Documentation/Certification

The CQA Officer will document all activities associated with the excavation, solidification/stabilization and capping and maintain current records of quality control operations, activities, and tests performed including the work of suppliers and subcontractors. These records shall be on an acceptable form and indicate factors affecting the project, acknowledgment of deficiencies noted along with the corrective actions taken on current and

previous deficiencies. In addition, these records shall include factual evidence that required activities or tests have been performed, including but not limited to the following:

- Type and number of control activities and tests involved
- Results of control activities or tests
- Nature of defects, causes for rejection
- Proposed remedial action
- Corrective actions taken

All the above noted will be included in a document which shall include, as a minimum, daily reports of construction activities, a final summary technical report on the construction project, and the closure certification.

4.2.5.1 Construction Records

All daily records shall include a record of observations, test data sheets, identification reports of problems encountered during construction and reports of corrective measures taken.

4.2.5.2 Certification

The CQA Officer will prepare a certification document addressing each item identified above for each phase of construction. Certification will include review of information on the area under construction, analysis of the Contractor's compliance with the plans and specifications and physical sampling and testing. The certification document will also include:

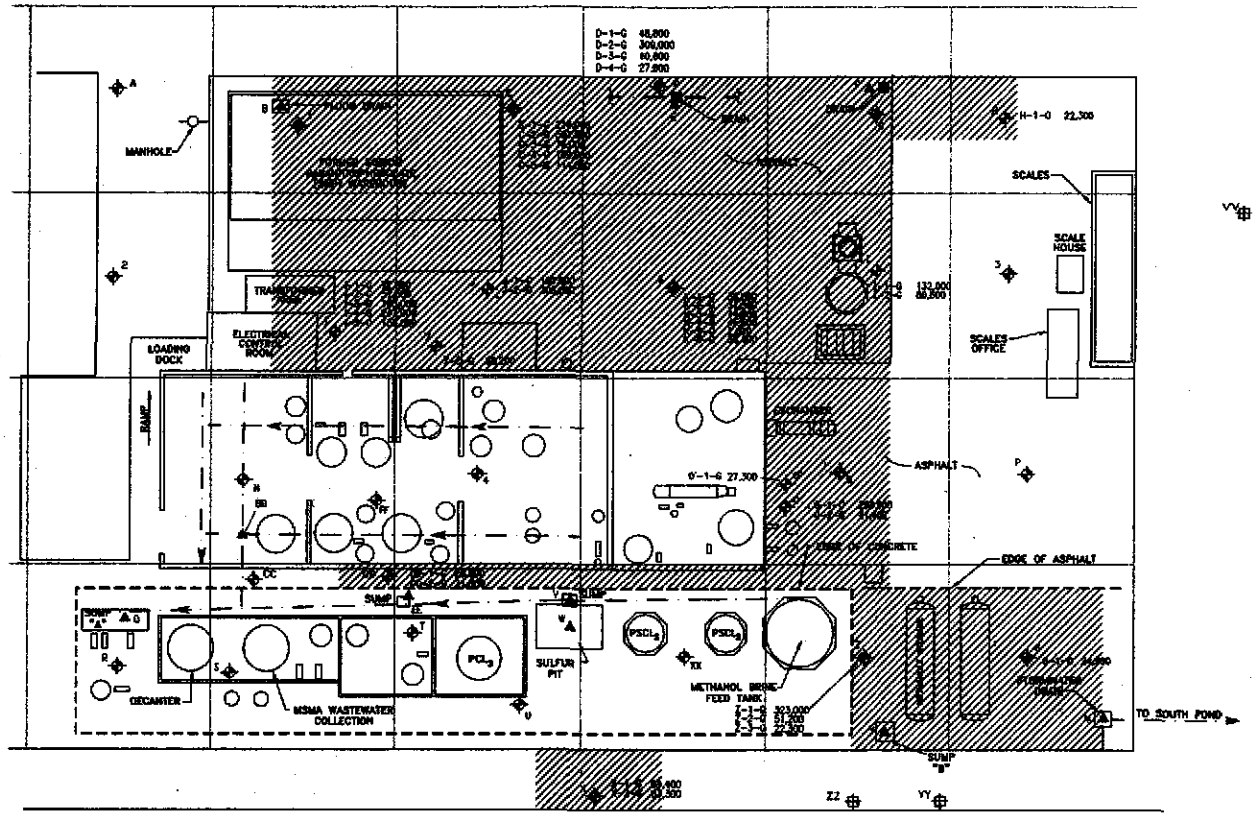
- Scale drawings depicting the location of the construction
- Statements pertaining to the extent of construction, i.e., depths, plan dimensions, evaluations and thickness, including cross sectional drawings

The summary technical report (CQA Report) will provide an evaluation of the construction project. The report will certify the results of the various field tests and laboratory permeability tests performed and assess whether or not the constructed project is in compliance with the plans and specifications. The report will be signed by the CQA Certifying Engineer. The CQA Certifying Engineer shall be a Professional Engineer who is registered in the State of Mississippi. Copies of the reports will be submitted to VCC.

4.3 PROJECT SCHEDULE

The proposed schedule for the project is as follows:

- May 15, 1998 - U.S. EPA and MSDEQ tentatively approve RFI Expedited Report and Corrective Measures Implementation Plan for SWMUs 12, 11 and 15.
- June 15, 1998 - Hold public meeting.
- July 6, 1998 - Mobilize contractor. Excavate North Pond sludge and then excavations for landfill.
- July 13, 1998 - Begin first one-half of 8-foot deep excavation of arsenic waste. Obtain verification samples. Haul arsenic waste to North Pond for mixing with North Pond sludge and solidification/stabilization.
- July 20, 1998 - Begin second one-half of 8-foot deep excavation of arsenic waste. Obtain verification samples. Haul arsenic waste to North Pond for mixing with North Pond sludge and solidification/stabilization.
- July 27, 1998 - Begin excavation of areas with 1- to 4-foot deep excavations of arsenic waste. Obtain verification samples. Haul arsenic waste to North Pond for mixing with North Pond sludge and solidification/stabilization. Begin placing solidified/stabilized waste that has cured into excavations in 12-inch lifts. Compact the lifts.
- August 3, 1998 - Backfill and compact MSMA areas. Continue placing waste in North Pond landfill that has cured into excavations in 12-inch lifts.
- August 10 , 1998 - Complete placing of wastes and compacting.
- August 17, 1998 - Begin construction of the landfill cap.
- August 24, 1998 - Complete construction of the cap and add topsoil and vegetation.
- August 31, 1998 - Demobilize.



LEGEND

SYMBOL OF SAMPLE LOCATION	ANALYTE LIST		DESCRIPTION	NUMBER OF SAMPLE LOCATIONS	NUMBER OF SAMPLES
▲		SEE FIGURE 2			
◈		SEE FIGURE 2			
◈	C	CONCRETE OR ASPHALT AND/OR SOIL (ARSENIC ONLY)		8	25 SOIL 9 WATER
⊕	C	NEW LOCATIONS – SPECIFIC TO PHASE II (ARSENIC ONLY)		4	25 SOIL 4 WATER

GRID 2500 FT²

NOTES

*SAMPLE ID = LOCATION – TYPE – ANALYTE LIST

LOCATION:
ALPHABETIC = SOIL, SLUDGE OR SEDIMENT
NUMERIC =CONCRETE, ASPHALT, OR SOIL

TYPE:
C = CONCRETE OR ASPHALT
1 = 0–12" SOIL
2 = 12"–24" SOIL
3 = 24"–48" SOIL
4 = 48"–72" SOIL
5 = 72"–96" SOIL
6 = 96"–120" SOIL
7 = 120"–144" SOIL
W = GROUNDWATER

ANALYTE LIST:
C = ARSENIC

* DID NOT PENETRATE CONCRETE AT FOLLOWING:

LOCATION	CONCRETE DEPTH EXCEEDS (FROM GROUND SURFACE)
4	55 INCHES
N	46 INCHES
FF	28 INCHES
XX	28 INCHES

* SECOND CONCRETE FOUNDATION AT 24" AT LOCATIONS 7, J, & L
* DID NOT PENETRATE RUBBLE BENEATH ASPHALT AT LOCATION 5 & O
* TWO CONCRETE CORES ANALYZED AT LOCATION 4 (0–18" & 18"–55")
* FIVE WIPE SAMPLES OF SUPERSTRUCTURE ANALYZED FOR ARSENIC (LOCATIONS NOT NOTED, SEE WRITTEN TEXT OF REPORT)
* //////// EXCAVATE TO 8 FT.
* //////// EXCAVATE TO 4 FT.
* //////// EXCAVATE TO 2 FT.
* //////// EXCAVATE TO 1 FT.

APPROXIMATE
SCALE: 1 INCH=30 FEET
30' 0 30'

REV	DESCRIPTION OF REVISION	BY	DATE
△			
△			
△			
△			
△			

VICKSBURG CHEMICAL
VICKSBURG, MISSISSIPPI

Woodward-Clyde Consultants
Engineering & sciences applied to the earth & its environment
2822 O'Neal Lane
Baton Rouge, Louisiana 70816

SCALE: AS SHOWN
DRAWN: GAT
CHECKED: RDK
PEER REVIEWED:
DATE: 5/13/98

SWMUS 11, 12, & 15 EXCAVATION AREAS

PHASE I & II SAMPLING RESULTS ABOVE 20,000 ug/kg FOR ARSENIC IN SOIL, CONCRETE OR ASPHALT; DRAINAGE SYSTEMS AND SUMPS NOT INCLUDED

REVISION: 0
PROJECT: 968315
DRAWING: 1

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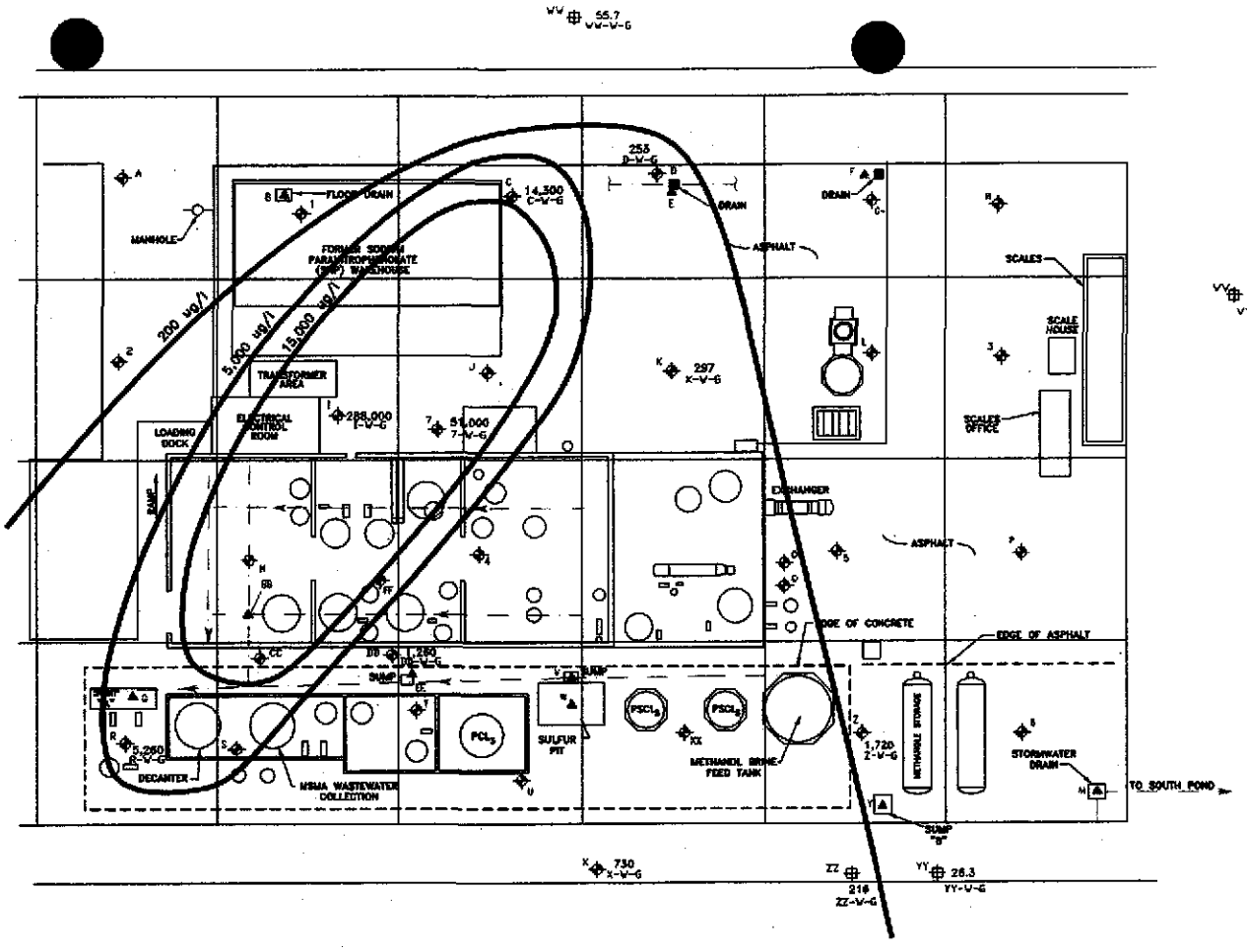

LEGEND

SYMBOL OF SAMPLE LOCATION	ANALYTE LIST	DESCRIPTION	NUMBER OF SAMPLE LOCATIONS	NUMBER OF SAMPLES
▲		SEE FIGURE 2		
◆		SEE FIGURE 2		
◆	G	CONCRETE OR ASPHALT AND/OR SOIL (ARSENIC ONLY)	9	26 SOIL 9 WATER
⊕	G	NEW LOCATIONS - SPECIFIC TO PHASE II (ARSENIC ONLY)	4	25 SOIL 4 WATER

GRID 2500 FT²

NOTES

•SAMPLE ID = LOCATION - TYPE - ANALYTE LIST

LOCATION:
ALPHABETIC = SOIL, SLUDGE OR SEDIMENT
NUMERIC =CONCRETE, ASPHALT, OR SOIL

TYPE:
C = CONCRETE OR ASPHALT
1 = 0-12" SOIL
2 = 12"-24" SOIL
3 = 24"-48" SOIL
4 = 48"-72" SOIL
5 = 72"-96" SOIL
6 = 96"-120" SOIL
7 = 120"-144" SOIL
W = GROUNDWATER

ANALYTE LIST:
G = ARSENIC

• DID NOT PENETRATE CONCRETE AT FOLLOWING:

LOCATION	CONCRETE DEPTH EXCEEDS (FROM GROUND SURFACE)
4	55 INCHES
N	46 INCHES
FF	28 INCHES
XX	28 INCHES

• SECOND CONCRETE FOUNDATION AT 24" AT LOCATIONS 7, J, & L

• DID NOT PENETRATE RUBBLE BENEATH ASPHALT AT LOCATION 5 & 0'

• TWO CONCRETE CORES ANALYZED AT LOCATION 4 (0-18" & 18"-55")

• FIVE WIPE SAMPLES OF SUPERSTRUCTURE ANALYZED FOR ARSENIC (LOCATIONS NOT NOTED. SEE WRITTEN TEXT OF REPORT)

• PERCHED WATER AT 2' BELOW GROUND SURFACE AT LOCATION 7; OTHERWISE, SAMPLES WERE OBTAINED AT 4' TO 6' BELOW GROUND SURFACE

• NUMBERS SHOWN ARE CONCENTRATIONS OF ARSENIC IN GROUNDWATER (ug/l)

APPROXIMATE
SCALE: 1 INCH=30 FEET
30' 0 30'

REV	DESCRIPTION OF REVISION	BY	DATE
0			
1			
2			
3			
4			
5			

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VICKSBURG, MISSISSIPPI

Woodward-Clyde Consultants
Engineering & sciences applied to the earth & its environment
2822 O'Neal Lane
Baton Rouge, Louisiana 70816

SCALE: AS SHOWN
DESIGNED
DRAWN: GAT
CHECKED: BOK
FOR REVIEW
DATE: 2/13/98

SWMUS 11, 12, 15 CMP - ESTIMATE OF GROUNDWATER PLUME

PHASE II GROUNDWATER SAMPLING
ARSENIC CONCENTRATIONS (ug/l)
NOTED ON SAMPLING BASE MAP

REVISION 0
PROJECT 968515
DRAWING 2

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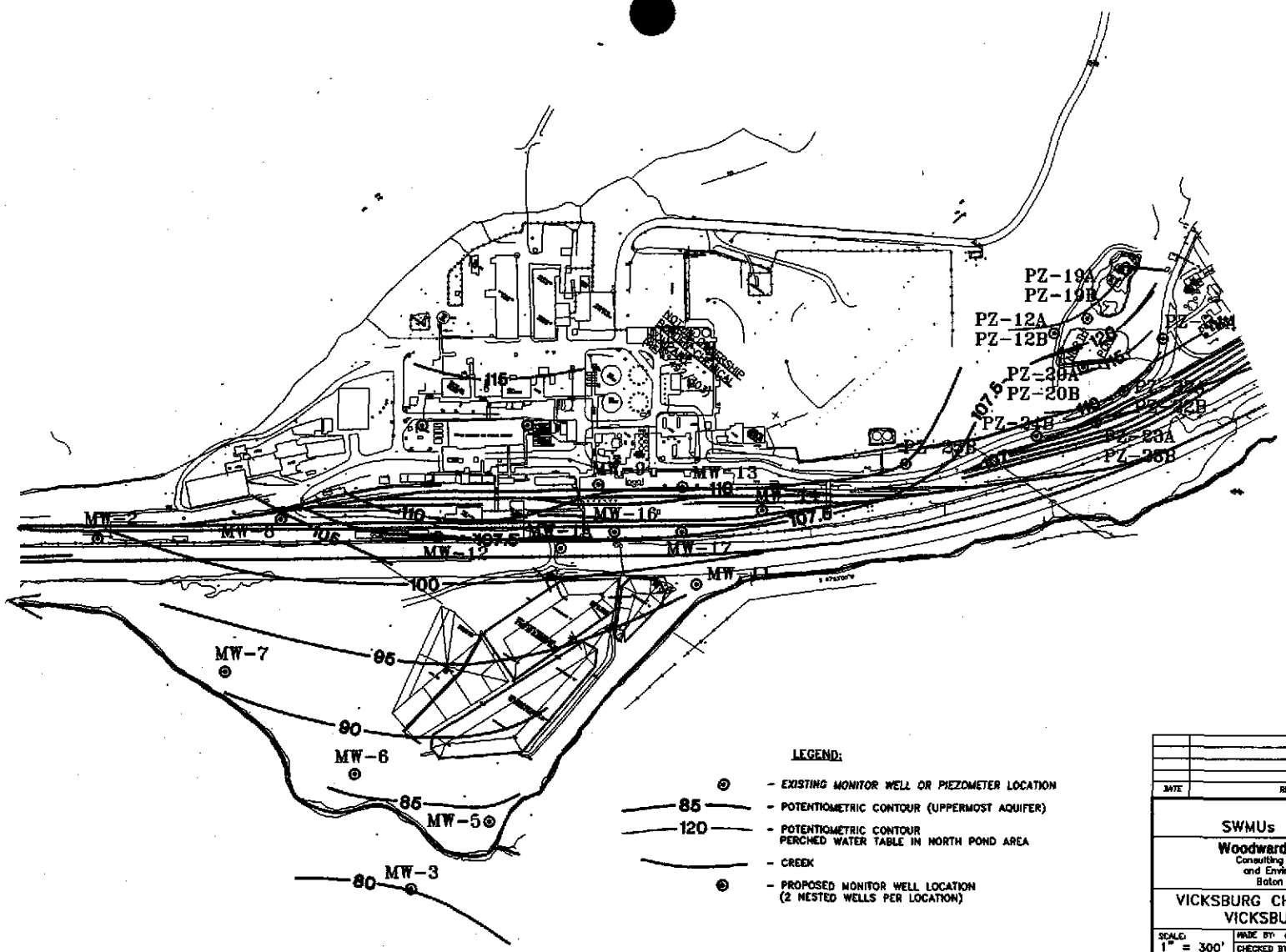

DATE	REVISION	DRWN/CHKD

CMIP
SWMUs 11, 12, & 15

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists
Baton Rouge, Louisiana

VICKSBURG CHEMICAL CORPORATION
VICKSBURG, MISSISSIPPI

SCALE:	MADE BY: GAT	DATE: 3/98	FILE NO.
1" = 300'	CHECKED BY:	DATE:	968315

POTENTIOMETRIC CONTOURS — FIGURE 3

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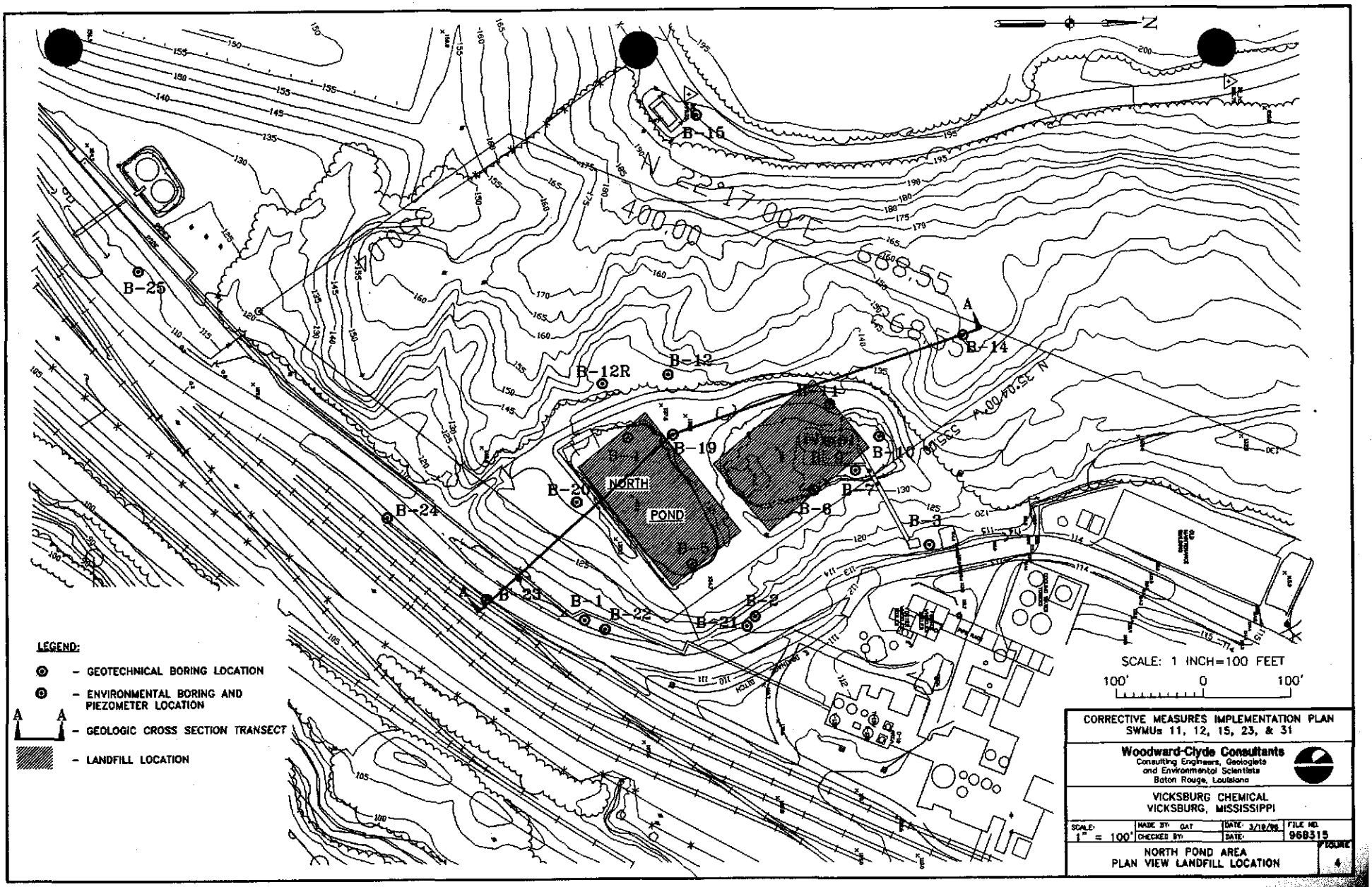

CORRECTIVE MEASURES IMPLEMENTATION PLAN
SWMUs 11, 12, 15, 23, & 31

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists
Baton Rouge, Louisiana

VICKSBURG CHEMICAL
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SCALE:	MADE BY: GAT	DATE: 3/18/98	FILE NO.
1" = 100'	CHECKED BY:	DATE:	968315

NORTH POND AREA
PLAN VIEW LANDFILL LOCATION

FIGURE 4

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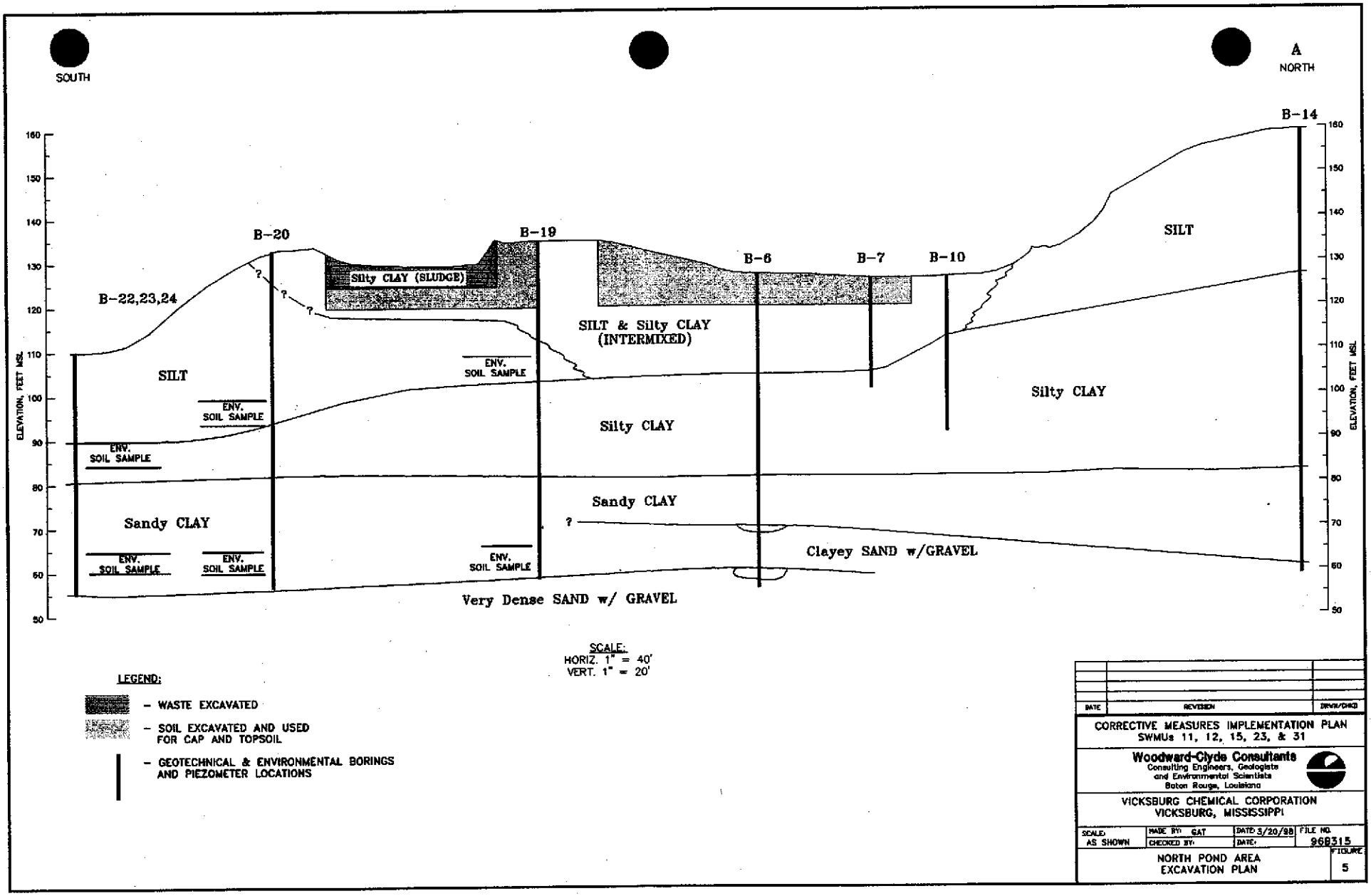

SCALE:
HORIZ. 1" = 40'
VERT. 1" = 20'

LEGEND:

- WASTE EXCAVATED
- SOIL EXCAVATED AND USED FOR CAP AND TOPSOIL
- GEOTECHNICAL & ENVIRONMENTAL BORINGS AND PIEZOMETER LOCATIONS

DATE	REVISION	DRWN/CHKD

CORRECTIVE MEASURES IMPLEMENTATION PLAN
SWMUs 11, 12, 15, 23, & 31

Woodward-Clyde Consultants
Consulting Engineers, Geologists and Environmental Scientists
Baton Rouge, Louisiana

VICKSBURG CHEMICAL CORPORATION
VICKSBURG, MISSISSIPPI

SCALE:	MADE BY: GAT	DATE: 3/20/98	FILE NO.
AS SHOWN	CHECKED BY:	DATE:	968315

NORTH POND AREA
EXCAVATION PLAN

FIGURE 5

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ATTACHMENT A

HEALTH AND SAFETY PLAN

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1.0
HEALTH AND SAFETY PLAN

Client:	Vickburg Chemical Corporation
Project:	RFI Field Investigation, Groundwater Assessment, and Interim Measures
Project Manager:	Richard D. Karkkainen
Project Number:	92B007C
Date of Plan:	Revised October 22, 1993
Estimated Dates of Work:	North Pond, October 25, 1993 through November 5, 1993, Additional Pending EPA and MSDEQ
Expiration Date:	Pending EPA and MSDEQ

1.1 HEALTH AND SAFETY PLAN APPROVALS

Richard D. Karkkainen
Project Manager
(504) 751-1873

10/22/93
Date

Tanya Pawley
Health and Safety Officer
Baton Rouge Business Unit
(318) 439-2683

10/22/93

Charles Self, C. I. H.
Corporate Health and Safety Officer
(318) 439-2683

10/22/93
Date

2.0 INTRODUCTION

This Health and Safety Plan establishes guidelines and requirements for the safety of field personnel during the conduct of the field activities associated with the referenced project. The specific activities addressed by this plan are defined in Section 3.0. All employees of Woodward-Clyde Consultants (WCC) involved in this project are required to abide by the provisions of this plan. They are required to read this plan and sign the attached Compliance Agreement.

The health and safety guidelines and requirements presented are based on a review of available information and an evaluation of potential hazards. This plan outlines the health and safety procedures and equipment required for activities at this site to minimize the potential for exposures of field personnel. This plan may be modified by the project manager, the corporate health and safety officer, and the Baton Rouge health and safety officer in response to additional information obtained regarding the potential hazards to field investigative personnel. This plan has been prepared for the exclusive use of WCC Personnel and WCC subcontractors. WCC liability is extended to WCC Personnel and WCC Subcontractors only.

2.1 KEY PERSONNEL

Project management will be handled out of the Baton Rouge Operating Unit of WCC. The following is a description of job responsibilities and authorities:

Project Manager: Richard D. Karkkainen

For this project, the Project Manager has the following responsibilities:

- To see that the project is performed in a manner consistent with the WCC Health and Safety Program.

- To have an approved Health and Safety Plan prepared and properly implemented for this project.

- To provide the Business Unit Health and Safety Officer with project information related to health and safety matters and development of the Health and Safety Plan.

- To implement the Health and Safety Plan.

- To insure compliance with the Health and Safety Plan by WCC and contractor personnel.

- To coordinate with the Business Unit Health and Safety Officer on health and safety matters.

The Project Manager has the authority to take the following actions:

- To determine matters relating to schedule, cost, and personnel assignments on hazardous waste management projects.

- To temporarily suspend field activities, if the health and safety of personnel are endangered, pending further consideration by the Business Unit Health and Safety Officer.

- To temporarily suspend an individual from field activities for infractions of Health and Safety Plan, pending further consideration by the Business Unit Health and Safety Officer.

Health and Safety Officer: Charles Self

The Health and Safety Officer has the following responsibilities:

- To interface with the Project Manager as may be required in matters of health and safety.

- To approve a Health and Safety Plan for the project.
- To appoint or approve a Site Safety Officer to assist in implementing the Health and Safety Plan.
- To monitor compliance with the approved Health and Safety Plan.
- To assist the Project Manager in seeing that proper health and safety equipment is available for the project.
- To approve personnel to work on this site with regard to medical examinations and health and safety training.

The Health and Safety Officer has the authority to take the following actions:

- To suspend work or otherwise limit exposures to personnel, if a Health and Safety Plan appears to be unsuitable or inadequate.
- To direct personnel to change work practices, if they are deemed to be hazardous to health and safety of personnel.
- To remove personnel from the project, if their actions or condition endangers their health and safety or the health and safety of co-workers.

<u>WCC Site Safety Officer:</u>

The Site Safety Officer (SSO) has the following responsibilities:

- To direct health and safety activities on-site.
- To report safety-related incidents or accidents to the Project Manager and Business Unit Health and Safety Officer.

- To assist the Project Manager in all aspects of implementing the Health and Safety Plan.

- To maintain health and safety equipment on-site, as specified in Health and Safety Plan.

- To perform health and safety activities on-site, as specified in the Health and Safety Plan, and report results to the Project Manager and the Business Unit Health and Safety Officer.

The SSO has the authority to take the following actions:

- To temporarily suspend field activities, if the health and safety of personnel are endangered, pending further consideration by the Business Unit Health and Safety Officer.

- To temporarily suspend an individual from field activities for infractions of the Health and Safety Plan, pending further consideration by the Business Unit Health and Safety Officer.

WCC Corporate Health and Safety Officer: Charles Self

The WCC CHSO has the following responsibilities:

- Direct the implementation of the Health and Safety Program of the operating group and provide recommendations for improvement of the program.

- Coordinate health and safety activities of the operating units in the operating group.

- Determine need for project Health and Safety Plans.

- Review and approve Health and Safety Plans.

- Monitor implementation of Health and Safety Plans.
- Investigation reports of incidents or accidents and report accidents or incidents to the CHSA and EVPP.
- Assist CHSA with employee health and safety training in the operating group.
- Determine whether an accidental exposure or injury merits a change in the affected individual's work assignments and whether changes in work practices are required.
- Coordinate business units with regard to health and safety equipment needs.

The WCC CHSO has the authority to take the following actions:

- Approve or disapprove Health and Safety Plans.
- Direct operating unit HSO to prepare project Health and Safety Plans.
- Access project files.
- Direct changes in personnel work practices to improve health and safety of employeees involved in hazardous waste management projects.
- Remove individuals from projects, if their conduct jeopardized their health and safety or that of co-workers.
- Suspend work on any project that jeopardizes the health and safety of personnel involved.

2.2 SITE LOCATION

Vicksburg Chemical Corporation (VCC) is located less than a mile south of Interstate 20 bordering the City of Vicksburg, Mississippi. To the north and west of the site is light residential properties. To the East of the site is light industrial properties including the Vicksburg water treatment facility and an asphalt mixing and gravel drying operation. To the South of the site is light residential to rural properties.

2.3 SITE DESCRIPTION

VCC is located off Highway 61 on Rifle Range Road. The facility is comprised of a North Plant and a South Plant and occupies approximately 640 acres. Currently, the only active areas of the plant include the nitric acid, potassium carbonate and potassium nitrate plants. All other portion of the plant are no longer in operation. Resources such as a potable water supply, electricity, and telephone service are available at the plant office located at the facility entrance on Rifle Range Road. Chemical on-site relative to the aforementioned active plants include anhydrous ammonia, nitric acid, potassium chloride, chlorine, nitrogen tetroxide, and nitrogen dioxide. Chemical on-site related to past production activities include atrazine, dinoseb, methyl parathion, monosodium methane arsenate (MSMA), and toxaphene. Other chemicals that have been detected on-site include carbon tetrachloride, chloroform, 1,1-dichloroethylene, ethylbenzene, methylene chloride, toluene, and xylene.

The work sites concerning this plan are associated with the South and North Plants (Figure 1) and include several Solid Waste Management Units (SWMUs) and Other Areas of Concern (OACs).

2.4 SITE HISTORY

In the past, VCC produced various types of pesticides and herbicides such as dinoseb, toxaphene, atrazine, and monosodium methane arsenate. All of these chemicals have been detected in the soil and water by VCC and the state of Mississippi. Concentrations range from non-detected on hazardous wastes to an average of about 5 part per million (ppm). Chlorinated solvents have been detected in sludge sediments in the ppm range for carbon tetrachloride, methylene chloride, chloroform, and 1,1,-dichloroethylene. The source of the

chlorinated solvents is unknown as well as the source of xylene toluene, and ethylbenzene, which have been detected in the range of 2-15 ppm. During the investigation of the site of the former MSMA plant (RFI Expedited Report SWMUs 12, 11 and 15, April 1998) the concentration of arsenic found in sludge/sediment samples in the drainage system was as high as 2,870 ppm and the concentration of arsenic found in concrete, asphalt or soil was as high as 322 ppm.

3.0
PURPOSE AND SCOPE OF PROPOSED WORK

WCC will perform work as required in a Consent Decree effective April 17, 1992. This Consent Decree requires Interim Measures activities, a Groundwater Assessment Program, and a RCRA Facility Investigation be conducted at the facility. These three workplans require geophysical borings, monitor well sampling and installation, subsurface soil sampling, and surface soil sampling. Construction in conjunction with closures may be included in the Interim Measures activities.

4.0 HAZARD ASSESSMENT

The following hazards have been identified and will be protected against:

- Heat stress.
- Biological hazardous.
- Physical hazards.
- Skin contact with contaminants.

4.1 BIOLOGICAL HAZARDS

If clearing has not been conducted or if biological hazards develop during work activities, practical guidelines for prevention of exposure to pests should be implemented.

4.2 HEAT STRESS HAZARDS

If heat stress becomes a concern, the heat stress casualty prevention plan, presented in Appendix A shall be implemented.

4.3 PHYSICAL HAZARDS

Personnel should be cognizant of the fact that when protective equipment such as respirators, gloves, and protective clothing are worn, visibility and manual dexterity are impaired. In addition, personnel should be alert to physical hazards such as slipping/tripping/falling potentially associated with dismantled process equipment and piping remnants/ladders/stairways in various stages of disrepair, and uneven ground surface due to foundation fragments distributed throughout the site. Drilling personnel should abide by standard safety guidelines applicable to drilling operation presented in Appendix B.

4.4 CHEMICAL HAZARDS

Due to past production activities at the facility, pesticides, herbicides, chlorinated solvents, and volatile organic solvents have been detected on-site during site characterization efforts conducted by VCC and the state of Mississippi. The constituents detected included arsenic, dinoseb, toxaphene, atrazine, carbon tetrachloride, methylene chloride, chloroform, 1,1-dichloroethylene, xylene, toluene, and ethylbenzene at concentration report in the parts per million range. Of the constituents detected on-site, arsenic, carbon tetrachloride, methylene chloride, and chloroform are classified by OSHA and/or ACGIH as known or suspected human carcinogens.

The constituents detected on-site are present in low concentrations. However, exposure to these chemicals may potentially occur through inhalation, ingestion, and/or direct contact. Chemical exposure via multiple exposure pathways is cumulative, therefore it is important to recognize potential exposure situations and to take precautions to minimize exposure to chemical hazards by all routes.

The following potential exposure routes and associated health hazards have been identified:

Inhalation: Chemical hazards associated with inhalation exposures may include irritation of the mucous membranes and respiratory tract or with more sever exposures, may include systemic effects. Table 1 presents recommended exposure limits for potential airborne constituents.

Ingestion. Ingestion of chemical will be controlled on-site by prohibiting eating, smoking, or drinking in the Exclusion Zone and by requiring all field personnel to conduct decontamination procedures prior to leaving the Exclusion Zone.

Direct Contact: Skin and eye contact with chemical hazards may potentially result in irritation, rashes, or burns. If a person should exhibit symptoms of eye or skin irritation, he/she should report to the SSO for immediate medical attention.

Potential hazards may be minimized by utilizing appropriate personal equipment designed to protect the body against contact with known or anticipated chemical hazards. Personal

protective equipment is classified by the EPA by the level of protection afforded and is divided into four categories designated as Level A, B, C, and D with Level A providing the most extensive level of protection.

The levels of protection required for the field activities specified by the work scope are presented in Section 5.1

Chemical information sheets for each constituent known to be present at the site are presented in Appendix C of this Health and Safety Plan. These sheets provide important information concerning physical/chemical properties, chemical/reactive hazards, exposure potentials, health hazards and symptoms of exposures, and appropriate treatment following exposure.

Table 1
Exposure Limits for Potential Airborne Contaminants

Constituent	ACGIH TWA	OSHA PEL-TWA	STEL	IDLH
+Toxaphene	0.5 mg/m^3	0.5 mg/m^3	1 mg/m^3	200 mg/m^3
Atrazine	5 mg/m^3	5 mg/m^3	--	--
+Carbon Tetrachloride	5 ppm	2 ppm	--	Ca
Methylene Chloride	50 ppm	500 ppm	--	Ca
Chloroform	10 ppm	2 ppm	--	Ca
Xylene	100 ppm	100 ppm	150 ppm	1000 ppm
Toluene	100 ppm	100 ppm	150 ppm	2000 ppm
Ethylbenzene	100 ppm	100 ppm	125 ppm	2000 ppm
Lime Kiln Dust	10 mg/m^3	10 mg/m^3	--	--
Ammonia	25 ppm	50 ppm	35 ppm	500 ppm
Arsenic	0.2 mg/m^3	0.01 mg/m^3	--	Ca

\+ Potential Skin Irritant
Ca Potential Human Carcinogen (Cancer Causing);
-- No IDLH level established.

5.0
GENERAL HEALTH AND SAFETY REQUIREMENTS

5.1 PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment (PPE) required to prevent contact with known or anticipated chemical hazards has been divided into four categories by the USEPA, Levels A, B, C and D, according to the degree of protection afforded. The following personnel protective equipment will be provided to personnel involved in site characterization work at the site.

Mobilization - Level D Protection

- Boots, steel toe and shank
- Hard hat
- safety glasses with side shields

Modified Level D Protection

- Coveralls, chemical resistant; tyvek (polycoated tyvek if splash hazard exists)
- Gloves (outer), chemical resistant, Polyvinyl Alcohol (PVAL)
- Gloves (inner), chemical-resistant, latex
- Boots, chemical-resistant (or bootie covers), steel toe and shank
- Safety glasses with side shields
- Hard hat (with faceshield if splash hazard exists)

Modified Level C Protection

- To include Modified Level D; PPE mentioned above
- Full-face air purifying respirators with organic vapor/pesticide/HEPA combination filter cartridges.

Tyvek coveralls will be discarded after each use or when they become worn or punctured. Suit materials are resistant to all known or anticipated chemicals at the site. If the disposable protective suits appear to be deteriorating under chemical action, the Site Safety Officer should be notified.

In addition to the personal protective equipment listed above, general safety equipment available for use will include a first aid kit, portable eye wash and fire extinguisher.

5.2 WORK ZONES

During activities conducted in Modified Level D PPE, management of this project shall be conducted in such a manner which will restrict access to the job site by unauthorized personnel. If Level D action levels established in Table 2 are exceeded resulting in an upgrade to Level C PPE, work zones as described in the following paragraphs shall be implemented.

To minimize the movement of contaminants from the site to uncontaminated areas, three work zones will be set up during activities conducted under Level C PPE. The three work zones will include the following:

Zone 1:	Exclusion Zone
Zone 2:	Contamination Reduction Zone
Zone 3:	Support Zone

The exclusion zone is the zone where contamination does or could occur. Observations by the site safety officer will determine the extent of the zones. All persons entering this zone must wear at a minimum the level of protection set forth in Section 5.1 (Level C PPE).

Between the exclusion zone and support zone is the personnel contamination reduction zone (CRZ) which provides a transition zone between the contaminated and clean areas of the site. This zone will be located directly outside of the exclusion zone and will be defined as 10-foot zone directly outside the exclusion zone.

The support zone will be an uncontaminated area from which operations will be directed. It is essential that contamination from the site be kept out of this area. Included in this area will be a storage area for decontaminated clothing, additional personal protective equipment, etc.

One additional work zone will be set up for decontaminating equipment.

5.3 DECONTAMINATION PROCEDURES

VCC will have a minimum of one personnel decontamination station, strategically located or in the contamination reduction zone (CRZ) if applicable. The decontamination station will have at least the following items:

- An adequate-sized plastic sheet for flooring
- Boot wash equipment
  - Water/alconox solution container
  - Rinse water container
  - Long-handled plastic brush
- Waste container (disposable PPE, tape, etc.)
- Hand wash equipment
  - Water/alconox solution container
  - Rinse water container
  - Paper towels

5.3.1 Equipment Decontamination

Decontamination of sample collection equipment will be accomplished by the following procedure:

- Washing in a detergent solution (Alconox)
- Triple rinsing with clean deionized water
- Rinsing with methanol
- Triple rinsing with clean deionized water

Decontamination of equipment shall be conducted in Modified Level D PPE as listed in Section 5.1. While utilizing methanol for deconning equipment, personnel shall position themselves upwind of decontamination operations to minimize inhalation exposures to methanol vapors. If this is not feasible, respiratory protection as listed under level C PPE is Section 5.1 shall be worn during methanol use.

5.3.2 Personnel Decontamination

Decontamination of personnel will be performed at a designated location at the perimeter of the work area. Decontamination will consists primarily of soap and water washings and water rinse of exterior protective gear to remove contaminants, followed by doffing of the gear.

Coveralls should be removed by turning the clothing inside out. A general sequence of doffing procedures is outlined below. The extent of washing required, or modifications to the sequence, may be specified as appropriate.

Personnel will be decontaminated by the following procedure:

- Wash and rinse outer protective coverall
- Wash work gloves and boots
- Remove outer protective clothing
- Rinse respirator if worn
- Wash hands and face

Contaminated disposable PPE and all decontamination fluids shall be containerized on-site for subsequent disposal by the direction of VCC.

5.4 MEDICAL EXAMINATION

Before commencing any of the field or laboratory activities defined in Section 3.0, all WCC personnel and all WCC subcontractors must take an annual WCC-approved medical examination as part of WCC's medical surveillance program.

5.5 SAFETY TRAINING DOCUMENTATION

Prior to commencing any of the field activities defined in Section 3.0, all WCC personnel working on-site will supply certificate or equivalent, attesting to completing 40 hours of training as required by OSHA, in 29 CFR 1910.120, to the SSO. Site supervisors will be required to supply documentation indicating that an additional 8 hours of training has been completed. Escorted visitors may be allowed in a defined area without 40 hours training at the discretion of the WCC SSO and the WCC site coordinator.

Documentation concerning respirator fit testing, in accordance with OSHA, 29 CFR 1910.134 shall be required of any WCC employee wearing a respirator.

5.6 COMPLIANCE AGREEMENT

The Project Manager and the Baton Rouge Health and Safety Officer shall hold meetings with all WCC field personnel before work commences. During the meeting, all personnel shall be provided with a copy of this safety plan; the plan shall be reviewed and discussed and questions answered. Signed Compliance Agreement Forms shall be collected by the Project Manager and filed by the Baton Rouge Health and Safety Officer. Individuals refusing to sign the form will not be allowed to work on the site.

5.7 PROJECT MANAGER NOTIFICATION

All field personnel must inform the Project Manager or his designated representative before entering the site. The "buddy system" will be employed during all project work. This means that at least two members of the field crew must be on-site whenever work is performed. Personnel must be in visual contact with each other or carry two-way radios at all times.

5.8 PROJECT SAFETY LOG

A project safety log will be used to record the names, entry and exit dates and times of all WCC and subcontractor personnel and of project site visitors; accidents, injuries, and illnesses; incidence of safety infractions by field personnel; air quality and personal exposure monitoring data; and other information related to safety matters. All accidents, illnesses or other incidence shall be reported immediately to the WCC Project Manager, and the WCC Baton Rouge Health and Safety Officer and subsequently documented for filing on the HS-502 Incident Report Form.

5.9 PROHIBITIONS

- Smoking, eating, drinking, chewing gum or tobacco, storing food or food containers shall not be permitted on the work site. Good personal hygiene should be practiced by field personnel to avoid ingestion of contaminants or spread of contaminated materials.

- Ignition of flammable liquids within, on, or through improvised heating devises or space heaters.

- Approach or entry into areas or spaces where toxic of explosive concentrations of gases or dust may exist without proper equipment available to enable safety entry.

- Conduct of on-site operations without off-site back up personnel.

5.10 SITE SAFETY MEETINGS

During all site characterization activities, daily safety meetings will be held by the site safety officer to review and plan the specific health and safety aspects of scheduled work for that day.

6.0
LABORATORY CONSIDERATIONS

The laboratory director must be informed of any contaminant level in the samples that would require special handling procedures to prevent risk to the health and safety of laboratory personnel.

7.0
PERSONAL PROTECTIVE EQUIPMENT

This section outlines the general usage guidelines for personal protective equipment.

7.1 HEAD PROTECTION

Hard hats must be worn by all personnel working on-site.

7.2 EYE PROTECTION

Safety glasses with side shields or goggles must be worn by all personnel performing activities where potential for eye or face exposure exists due to splash, dust, or vapor, etc. An eyewash station will be set up by the site safety officer prior to commencing field activities and should be placed so that it could be used quickly in an emergency.

7.3 SKIN PROTECTION

Due to the potential for skin absorption and carcinogenic properties chemical resistant gloves and coveralls shall be worn by all personnel during subsurface and sample handling activities. These will be disposed of in a designated sealable drum after each use of when they become worn or punctured.

7.4 FOOTWEAR

Chemical-resistant boots with steel toes and shanks will be worn by field personnel engaged in the field activities at the site. Chemical-resistant booties can be substituted for chemical resistant boots, although work boots to be covered must always maintain steel toes and shanks.

7.5 RESPIRATORY PROTECTION

For respiratory protection against possible volatile organics, full-face air purifying respirators (APR) will be required if Level D air monitoring action levels are exceeded. Specific cartridges to be utilized with the APRs will be combination organic vapor/ammonia filter cartridges. All personnel must be properly fit-tested for the specific brand and size respirator to be used. Documentation of fit testing is to be provided to WCC SSO prior to commencement of work. A respirator which has not been successfully fit-tested cannot be used by an individual on the project. To ensure a proper fit, no facial hair will be allowed that will interfere with mask operation. The site safety officer will determine if facial hair represents such an interference. Air purifying respirators will only be used if the following conditions are met:

- The oxygen content of the air is greater than 19.5 percent.
- Concentration of air contaminants are known and monitored.
- The contaminants of concern all have good warning properties (i.e., odor threshold below PEL value).
- The protection factor is adequate and PELs are not exceeded.
- If concentrations of air contaminants exceed IDLH value, personnel must immediately evacuate.
- Cartridges are changed daily or whenever breakthrough occurs, which ever occurs first.
- Each person has been fit-tested for the specific brand and size of respirator used.
- The respirator is MSHA- and/or NIOSH-approved.

8.0
AIR QUALITY MONITORING

The primary goal of on-site air quality monitoring will be compliance with the specified contaminant action levels. The secondary goal will be documentation of personal exposures as required by OSHA 1920.120.

8.1 AIR QUALITY SURVEY

During modified Level D field activities related to organic contamination at the site, an air quality survey will be performed utilizing an HNu-photoionization detector (PID) equipped with an 11.7 ev probe, or equivalent instrument to characterize volatile organics and ammonia concentrations on-site. Standard operating procedures for this instrument are attached as Appendix E. During Level C filed activities, additional sampling utilizing colorimetric tubes specific for detecting chloroform, methylene chloride, and carbon tetrachloride will be used along with the HNu for total organic vapors. At least two sampling events utilizing each of these tubes will be conducted in the breathing zone of personnel closest to the subsurface activities at the site. Table 2 lists air monitoring action levels for Level D and C work.

During modified Level D field activities related to construction at former MSMA areas, a determination shall be made of airborne exposure levels that are representative of each workers exposure to inorganic arsenic over an eight (8) hour period. Samples will be taken using a personal sampling pump at a flow rate of 2 liters per minute. Samples will be collected on 0.8 micrometer pore size filter (37 mm diameter). At least two consecutive measurements, taken at least seven (7) days apart, will be conducted. Table 2 lists air monitoring action levels for Level D and C work.

Table 2
Air Monitoring Action Levels for Level C and D Work

Contaminant	Instrument	Reading	Action Taken
Volatile Organic	HNu or equivalent*	<5 ppm	Continued Work in Modified D Level
Volatile Organic	HNu or equivalent*	5 - 25 ppm	Upgrade to Level C and Expand Work Zones; Commence additional colorimetric tube sampling
Volatile Organic	HNu or equivalent*	>25 ppm	Evacuate Area
Arsenic	Personal sampling pump**	<5 micrograms per cubic meter of air	Continue to work in Modified D Level
Arsenic	Personal sampling pump**	5 - 10 $\mu g/m^3$	Upgrade to Level C
Arsenic	Personal sampling pump**	>10 $\mu g/m^3$	Evacuate area until construction procedures are revised.

* Sustained reading above background (for 15 minutes continuous) which shall not be exceeded within worker breathing zones or exclusion zones.

9.0
EMERGENCIES/ACCIDENTS

A site map and direction to Vicksburg Hospital are included in Figure 1. Illnesses, injuries, and accidents occurring on-site must be attended to immediately in the following manner:

- Remove the injured or exposed person(s) from immediate danger.
- Render FIRST AID if necessary. Decontaminate affected personnel, if necessary.
- Call ambulance for transport to local. This procedure should be followed even if there is no apparent serious injury. Emergency numbers are listed on the following section.
- Evacuate other personnel on-site to a safe place until the engineer (assisted by the Site Safety Officer) determines that it is safe for work to resume.
- Report the accident to the Health and Safety Officer immediately.
- Develop procedures, in accordance with the Health and Safety Officer, Site Safety Officer, and Project Manager to prevent a recurrence.

In the event that an emergency site evacuation should be necessary for any reason, the Site Safety Officer will render an alarm using a horn and all personnel shall leave the site. The assembly point will be designated in the filed. Personnel will not return to the site until an all-clear has been received from the Site Safety Officer

9.1 EMERGENCY NUMBERS

For any on-site Emergency dial 911.

Emergency Service	Telephone
Fire Department	636-1121
Ambulance	911
Sheriff	636-1761
Vicksburg Police Department	636-2511
National Response Center (NRC)	1-800-424-8802
Poison Control Center	1-800-535-0525
Vicksburg Medical Center	636-2611
Mercy Regional Medical Center	631-2250

10.0
PERSONNEL ASSIGNMENTS

WCC personnel and subcontractors authorized to work on this project and enter the site are:

Project Manager:	Richard D. Karkkainen
Baton Rouge Health and Safety Officer:	Charles Self
Site Safety Officer:	As Needed
Field Personnel:	As Needed
Subcontractor:	As Needed

10.1 PROJECT SAFETY PERSONNEL

Personnel responsible for implementing this Safety Plan are the Project Manager and Site Safety Officer. Their specific responsibilities and authorities for all accountable WCC personnel are listed in this plan as well as Table 2-1 of the WCC Health and Safety manual dated November 1990.

11.0
SAFETY PLAN COMPLIANCE AGREEMENT

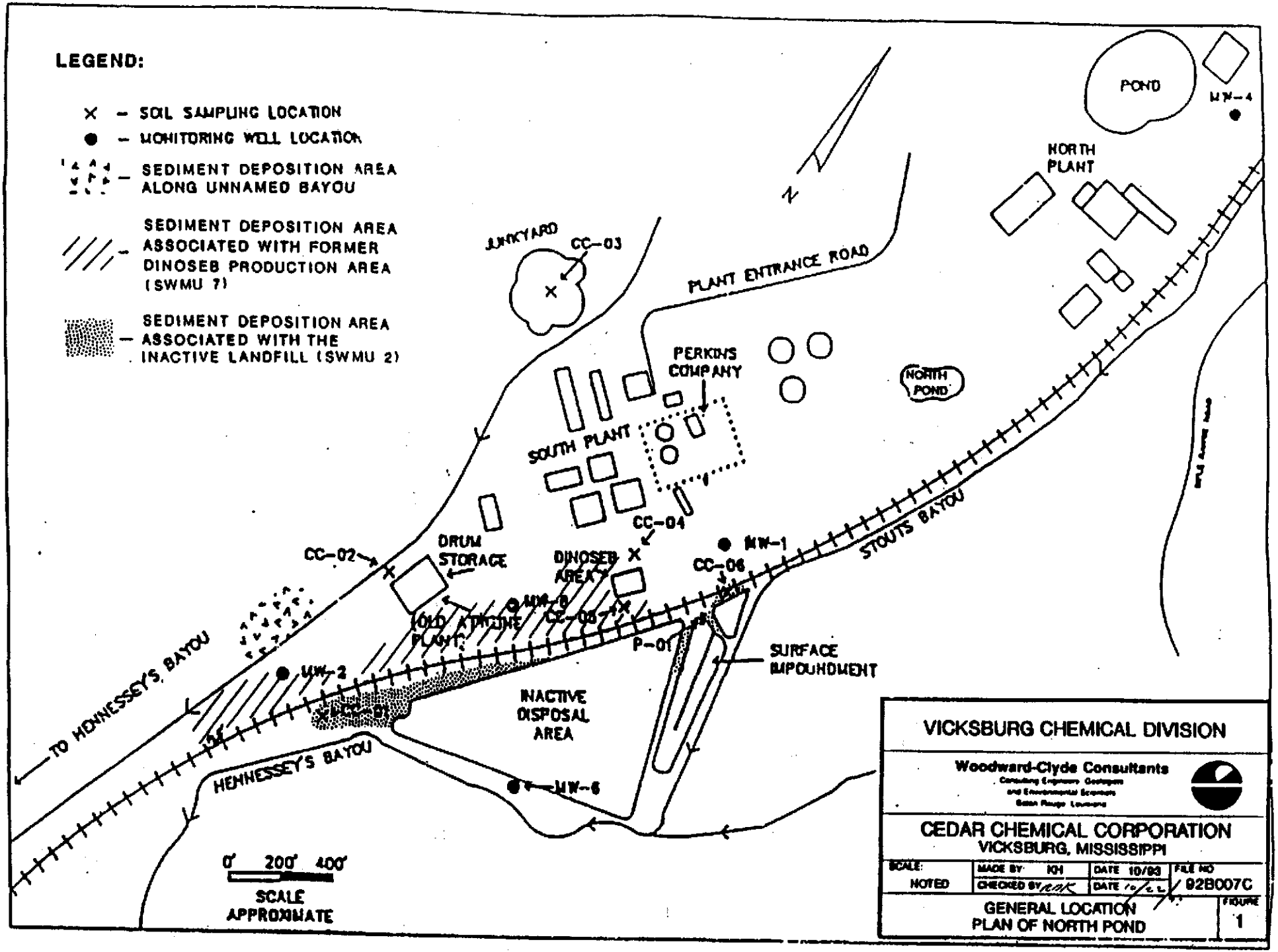
I, _____(print name), have received a copy of the Safety Plan for the Interim Measures, Groundwater Assessment, and RFI Field Investigation Workplans for VCC, Vicksburg, Mississippi and Corrective Measures Implementation Plans. I have read the plan, understand it, and agree to comply with all of its provisions. I understand that I could be prohibited from working on the project for violating any of the safety requirements specified in the plan.

Signed:

_____ _____

Signature Date

Firm:_____


LEGEND:
× – SOIL SAMPLING LOCATION
● – MONITORING WELL LOCATION
SEDIMENT DEPOSITION AREA ALONG UNNAMED BAYOU
SEDIMENT DEPOSITION AREA ASSOCIATED WITH FORMER DINOSEB PRODUCTION AREA (SWMU 7)
SEDIMENT DEPOSITION AREA ASSOCIATED WITH THE INACTIVE LANDFILL (SWMU 2)
POND
MW-4
NORTH PLANT
JUNKYARD
CC-03
PLANT ENTRANCE ROAD
PERKINS COMPANY
NORTH POND
SOUTH PLANT
CC-04
MW-1
CC-02
DRUM STORAGE
DINOSEB AREA
CC-06
STOUTS BAYOU
MW-3
OLD ADMIN. BLDG.
CC-05
P-01
SURFACE IMPOUNDMENT
MW-2
CC-01
INACTIVE DISPOSAL AREA
TO HENNESSEY'S BAYOU
HENNESSEY'S BAYOU
MW-6
0' 200' 400'
SCALE APPROXIMATE
VICKSBURG CHEMICAL DIVISION
Woodward-Clyde Consultants
CEDAR CHEMICAL CORPORATION
VICKSBURG, MISSISSIPPI
SCALE: NOTED
MADE BY KH
DATE 10/93
FILE NO 92B007C
CHECKED BY
DATE
GENERAL LOCATION PLAN OF NORTH POND
FIGURE 1

APPENDIX A

HEAT STRESS CASUALTY PREVENTION PLAN

APPENDIX A

HEAT STRESS CASUALTY PREVENTION PLAN

Due to the increase in ambient air temperatures and the affects of protective outer wear decreasing body ventilation, there exists an increase in the potential for injury, specifically, heat casualties. Site personnel will be instructed in identification of a heat stress victim, the first-aid treatment procedures for the victim and the preventing of heat stress casualties.

A. IDENTIFICATION AND TREATMENT

1) Heat Exhaustion

a) Symptoms: Usually begins with muscular weakness, dizziness, nausea, and staggering gait. Vomiting is frequent. The bowels may move involuntarily. The victim is very pale, his skin is clammy skin, and he may perspire profusely. The pulse is weak and fast, his breathing is shallow. He may faint unless he lies down. This may pass, but sometimes it remains and death could occur.

b) First Aid: Immediately remove the victim to the Personnel Decontamination Reduction Zone in a shady or cool area with good air circulation. Remove all protective outer wear. Call a physician. Treat the victim for shock. (Make him lie down, raise his feet 6 to 12 inches and loosen all clothing.) Transport victim to a medical facility as soon as possible.

2) Heat Stroke

a) Symptoms: This is the most serious of heat casualties due to the fact that the body excessively overheats. Body temperatures often are between 107 degrees to 110 degrees Fahrenheit. First there is often pain in the head, dizziness, nausea, oppression, and the skin is dry, red and hot. Unconsciousness follows quickly and death is imminent if exposure continues. The attack will usually occur suddenly.

b) First Aid: Immediately evacuate the victim to a cool and shady area in the Personnel Decontamination Reduction Zone. Remove all protective outer wear and all personal clothing. Lay him on his back with his head and shoulders slightly elevated. It is imperative that the body temperature be lowered immediately. This can be accomplished by applying cold wet towels, ice bags, etc., to the head. Sponge off bare skin with cool water or place him in a tub of cool water. The main objective is to cool him without chilling him. Give no stimulants. Transport the victim to a medical facility as soon as possible.

B. PREVENTION OF HEAT STRESS

1) One of the major causes of heat casualties is the depletion of body fluids. On the site there will plenty of fluids available. Personnel should replace water and salts loss from sweating. Salts can be replaced by either 0.1 percent solution, more heavily salted foods, or commercial mixes such as Gatorade. The commercial mixes are advised for personnel on low sodium diets.

2) A work schedule should be established so that the majority of the work day will be during the morning hours of the day before ambient air temperature levels reach their highs.

3) A work/rest guideline will be implemented for personnel required to wear Level B or Level C protection. This guideline is as follows:

Ambient Temperatures	Maximum Working Time
Above 90°F	1/2 hour
80°-90°F	1 hour
70°-80°F	2 hours
60°-70°F	3 hours
50°-60°F	4 hours
40°-50°F	5 hours
30°-40°F	6 hours
Below 30°F	8 hours

A sufficient period will be allowed for personnel to "cool down". This may require shifts of workers during operations.

C. HEAT STRESS MONITORING

For monitoring the body's recuperative ability to excess heat, one or more of the following techniques should be used as a screening mechanism. Monitoring of personnel wearing protective clothing should commence when the ambient temperature is 70 degrees Fahrenheit or above. Frequency of monitoring should increase as the ambient temperature increases or if slow recovery rates are indicated. When temperatures exceed 80 degrees Fahrenheit, workers must be monitored for heat stress after every work period.

- Heart rate should be measured at the radial pulse for 30 seconds as early as possible in the resting period. The heart rate at the beginning of the rest period should not exceed 110 beats per minute. If the heart rate is higher, the next work period should be shortened by 10 minutes (or 33 percent), while the length of the rest period stays the same. If the pulse rate is 100 beats per minute at the beginning of the next rest period, the following work cycle should be shortened by 33 percent.

- Body temperature should be measured orally with a clinical thermometer as early as possible in the resting period. Oral temperature at the beginning of the rest period should not exceed 99 degrees Fahrenheit. If it does, the next work period should be shortened by 10 minutes (or 33 percent), while the length of the rest period stays the same. However, if the oral temperature exceeds 99.7 degrees Fahrenheit at the beginning of the next period, the following work cycle should be further shortened by 33 percent. Oral temperature should be measured again at the end of the rest period to make sure that it has dropped below 99 degrees Fahrenheit.

- Body water loss due to sweating should be measured by weighing the worker in the morning and in the evening. The clothing worn should be similar at both weighings; preferably, the worker should be weighed nude. The scale should be accurate to plus or minus one-quarter pound. Body water loss should not exceed 1.5 percent of the total body weight. If it does, workers should be instructed to increase their daily intake of fluids by the weight lost.

Ideally, body fluids should be maintained at a constant level during the work day. This requires replacement of salt lost in sweat as well.

Good hygiene standards must be maintained by frequent changes of clothing and daily showering. Clothing should be permitted to dry during rest periods. Persons who notice skin problems should immediately consult medical personnel.

APPENDIX B

SAFETY GUIDELINES FOR DRILLING

APPENDIX B

SAFETY GUIDELINES FOR DRILLING

Drill rig maintenance and safety is the responsibility of the drill rig operator. However, safety requires the attention and cooperation of every worker and visitor to the job. The following is provided as a general guideline for safe drilling practices onsite.

OFF-ROAD MOVEMENT OF DRILL RIGS

The following safety guidelines relate to off-road movement:

- Before moving a drill rig, first walk the route of travel, inspecting for depressions, slumps, gullies, ruts and similar obstacles.
- Always check the brakes of a drill rig carrier before traveling, particularly on rough, uneven or hilly ground.
- Discharge all passengers before moving a drill rig on rough or hilly terrain.
- Engage the front axle (for 4x4, 6x6, etc., vehicles or carriers) when traveling off-highway on hilly terrain.
- Use caution when traveling side-hill. Conservatively evaluate side-hill capability of drill rigs because the arbitrary addition of drilling tools may raise the center of mass. When possible, travel directly uphill or downhill.
- Attempt to cross obstacles such as small logs and small erosion channels or ditches squarely, not at an angle.
- Use the assistance of someone on the ground as a guide when lateral or overhead clearance is narrow.

- After the drill rig has been moved to a new drilling site, set all brakes and/or locks. When grades are steep, block the wheels.

- Never travel off-road with the mast (derrick) of the drill rig in the raised or partially raised position.

- Tie-down loads on the drill rig and support trucks during transport.

OVERHEAD AND BURIED UTILITIES

The use of a drill rig near electrical power lines and other utilities requires that special precautions be taken by both supervisors and members of the exploration crew. Electricity can shock, it can burn and it can cause death.

Overhead and buried utilities should be located, noted and emphasized on all boring location plans and boring assignment sheets.

Before raising the drill rig mast (derrick) on a site in the vicinity of power lines, walk completely around the drill rig. Determine what the minimum distance from any point on the drill rig to the nearest power line will be when the mast is raised and/or being raised. Do not raise the mast or operate the drill rig if this distance is less than 20 feet.

Keep in mind that both hoist lines and overhead power lines can be moved toward each other by the wind.

CLEARING THE WORK AREA

Prior to drilling, adequate site cleaning and leveling should be performed to accommodate the drill rig and supplies and provide a safe working area. Drilling should not be commenced when tree limbs, unstable ground or site obstructions cause unsafe tool handling conditions.

NOTE: In coordination with the Drilling Crew, the Site Health and Safety Manager will review the precautions taken to insure that the drill rig is leveled and stabilized.

HOUSEKEEPING ON AND AROUND THE DRILL RIG

The first requirement for safe field operations is that the drilling crew safety supervisor understands and fulfills the responsibility for maintenance and "housekeeping" on and around the drill rig.

Suitable storage locations should be provided for all tools, materials and supplies so that they can be conveniently and safely handled without hitting or falling on a member of the drill crew or a visitor.

Avoid storing or transporting tools, materials or supplies within or on the mast (derrick) of the drill rig.

Pipe, drill rods, bits casing, augers and similar drilling tools should be orderly stacked on racks or sills to prevent spreading, rolling or sliding.

Penetration or other driving hammers should be placed at a safe location on the ground or be secured to prevent movement when not in use.

Work areas, platforms, walkways, scaffolding and other accessways should be kept free of materials, obstructions and substances such as ice, excess grease or oil that could cause a surface to become slick or otherwise hazardous.

Keep all controls, control linkages, warning and operation lights and lenses free of oil, grease and/or ice.

Do not store gasoline in any portable container other than a non-sparking, red container with a flame arrester in the fill spout and having the word "gasoline" easily visible.

SAFE USE OF HAND TOOLS

There are almost an infinite number of hand tools that can be used on or around a drill rig. "Use the tool for its intended purpose" is the most important rule. The following are a few specific and some general suggestions which apply to safe use of several hand tools that are often used on and around drill rigs.

- When a tool becomes damaged, either repair it before using it again or get rid of it.
- When using a hammer, any kind of hammer for any purpose, wear safety glasses and require all others near you to wear safety glasses.
- When using a chisel, any kind of chisel, for any purpose, wear safety glasses and require all others around you to wear safety glasses.
- Keep all tools cleaned and orderly stored when not in use.
- Replace hook and heel jaws when they become visibly worn.
- When breaking tool joints on the ground or on a drilling platform, position your hands so that your fingers will not be smashed between the wrench handle and the ground or the platform, should the wrench slip or the joint suddenly let go.

SAFE USE OF WIRE LINE HOISTS, WIRE ROPE AND HOISTING HARDWARE

The use of wire line hoists, wire rope, and hoisting hardware should be as stipulated by the American Iron and Steel Institute's Wire Rope Users Manual.

All wire ropes and fittings should be visually inspected during use and thoroughly inspected at least once a week for abrasion, broken wires, wear, reduction in rope diameter, reduction in wire diameter, fatigue, corrosion, damage from heat, improper weaving, jamming, crushing, bird caging, kinking, core protrusion, and damage to lifting

hardware and any other feature that would lead to failure. Wire ropes should be replaced when inspection indicates excessive damage according to the wire rope users manual.

If a ball-bearing-type hoisting swivel is used to hoist drill rods, swivel bearings should be inspected and lubricated daily to assure that the swivel freely rotates under load.

If a rod slipping device is used to hoist drill rods, do not drill through or rotate drill rods through the slipping device, do not hoist more than 1 foot (0.3m) of the drill rod column above the top of the mast (derrick), do not hoist a rod column with loose tool joints and do not make up, tighten or loosen tool joints while the rod column is being supported by a slipping device. If drill rods should slip back into the borehole, do not attempt to break the fall of the rods with your hands.

Most sheaves on drill rigs are stationary with a single-part line. The number of parts of line should never be increased without first consulting with the manufacturer of the drill rig. Wire ropes must be properly matched with each sheave.

The following procedures and precautions must be understood and implemented for safe use of wire ropes and rigging hardware.

Use tool-handling hoists only for vertical lifting of tools (except when angle-hole drilling). Do not use tool-handling hoists to pull on objects away from the drill rig; however, drills may be moved using the main hoist as the wire rope is spooled through proper sheaves according to the manufacturer's recommendations.

When stuck tools or similar loads cannot be raised with a hoist, disconnect the hoist line and connect the stuck tools directly to the feed mechanism of the drill. Do not use hydraulic leveling jacks for added pull to the hoist line or the feed mechanism of the drill.

When attempting to free a mired vehicle or drill rig carrier, only use a winch on the front or rear of the vehicle or drill rig carrier and stay as far away as possible from the wire rope. Do not attempt to use tool hoists to free a mired vehicle or drill rig carrier.

To minimize shock loading of a wire rope, always apply loads smoothly and steadily.

Some additional safety guidelines that should be followed are:

- Protect wire rope from sharp corners or edges.
- Replace faulty guides and rollers.
- Replace worn sheaves or worn sheave bearings.
- Replace damaged safety latches on safety hooks before use.
- Know the safe working load of the equipment and tackle being used. Never exceed this limit.
- Periodically inspect and test clutches and brakes of hoists.
- Know and do not exceed the rated capacity of hooks, rings, links, swivels, shackles and other lifting aids.
- Always wear gloves when handling wire ropes.
- Do not guide wire ropes on hoist drums with your hands.
- After installation of a new wire rope, lift a light load to allow the wire rope to adjust.
- Never carry out any hoisting operations when the weather conditions are such that hazards to personnel, the public or property are created.
- Never leave a load suspended when the hoist is unattended.

- Keep your hands away from hoists, wire rope, hoisting hooks, sheaves and pinch points as slack is being taken up and when the load is being hoisted.

- Never hoist a load over members of the crew.

SAFE USE OF AUGERS

The following general procedures should be used when advancing a boring with continuous-flight or hollow-stem augers:

- Prepare to start an auger boring with the drill rig level, the clutch or hydraulic rotation control disengaged, the transmission in low gear and the engine running at low RPM.

- The operator and tool handler should establish a system of responsibility for the various activities required for auger drilling, such as connecting and disconnecting auger sections and inserting and removing the auger fork. The operator must assure that the tool handler is well away from the auger column and that the auger fork is removed before starting rotation.

- Use only the manufacturer's recommended method of securing the auger to the power coupling. Do not touch the coupling or the auger with your hands, a wrench or any other tools during rotation.

- Whenever possible, use tool hoists to handle auger sections.

- Never place hands or fingers under the bottom of an auger section when hoisting the auger over the top of the auger section in the ground or other hard surfaces such as the drill rig platform.

- Never allow feet to get under the auger section that is being hoisted.

- When rotating augers, stay clear of the rotating auger and other rotating components of the drill rig. Never reach behind or around a rotating auger for any reason whatever.

- Never use your hands or feet to move cuttings away from the auger.

- When cleaning augers, be sure the drill rig is in neutral and the augers are stopped from rotating.

SAFETY DURING ROTARY AND CORE DRILLING

Rotary drilling tools should be safety-checked before use. In particular, check for the following:

- See that water swivels and hoisting plugs are lubricated and checked for frozen bearings before use.

- Check rod chuck jaws periodically and replace them when necessary.

- Check the capacities of hoists and sheaves against the anticipated weight on the drill rod string plus other expected hoisting loads. Inspect all cables daily.

These other special precautions should be taken for safe rotary or core drilling:

- Drill rods should not be braked during lowering into the hole with drill rod chuck jaws.

- Drill rods should not be held or lowered into the hole with pipe wrenches.

- If a string of drill rods are accidently or inadvertently released into the hole, do not attempt to grab the falling rods with your hands or a wrench.

- In the event of a plugged bit or other circulation blockage, the high pressure in the piping and hose between the pump and the obstruction should be relieved or bled down before breaking the first tool joint.

- When drill rods are hoisted from the hole, they should be cleaned for safe handling with a rubber or other suitable rod wiper. Do not use your hands to clean drilling fluids from drill rods.

- If work must progress over a portable drilling fluid (mud) pit, do not attempt to stand on narrow sides or cross members. The mud pit should be equipped with a rough surface and fitted cover panels of adequate strength to hold drill rig personnel.

- Drill rods should not be lifted and leaned unsecured against the mast. Either provide some method of securing the upper ends of the drill rod sections for safe vertical storage or lay the rods down.

- Inspect all hydraulic lines periodically and replace as needed.

START-UP

All drill rig personnel and visitors should be instructed to "stand-clear" of the drill rig immediately prior to and during starting of an engine.

Make sure all gear boxes are in neutral, all hoist levers are disengaged, all hydraulic levers are in the correct, non-actuating positions, and the cathead rope is not on the cathead before starting a drill rig engine.

SAFETY DURING DRILLING OPERATIONS

Safety requires the attention and cooperation of every worker and site visitor.

Do not drive the drill rig from hole to hole with the mast (derrick) in the raised position.

Before raising the mast (derrick) look up to check for overhead obstructions.

Before raising the mast (derrick), all drill rig personnel and visitors (with exception of the operator) should be cleared from the area immediately to the rear and the sides of the mast. All drill rig personnel and visitors should be informed that the mast is being raised prior to raising it.

Before the mast (derrick) of a drill rig is raised and drilling is commenced, the drill rig must be first leveled and stabilized with leveling jacks and/or solid cribbing. The drill rig should be releveled if it settles after initial set up. Lower the mast (derrick) only when leveling jacks are down and do not raise the leveling jack pads until the mast (derrick) is lowered completely.

Before starting drilling operations, secure and/or lock the mast (derrick) if required according to the drill manufacturer's recommendations.

The operator of a drill rig should only operate a drill rig from the position of the controls. The operator should shut down the drill engine before leaving the vicinity of the drill.

Do not consume alcoholic beverages or other depressants or chemical stimulants prior to starting work on a drill rig or while on the job.

Watch for slippery ground when mounting dismounting from the platform.

All unattended boreholes must be adequately covered or otherwise protected to prevent drill rig personnel, site visitors or animals from stepping or falling into the hole. All open boreholes should be covered, protected, or backfilled adequately and according to local or state regulations on completion of the drilling project.

"Horsing around" within the vicinity of the drill rig and tool and supply storage areas should never be allowed, even when the drill rig is shut down.

Be careful when lifting heavy objects.

Before lifting a relatively heavy object, approach the object by bending at the knees, keeping your back vertical and unarched while obtaining a firm footing. Grasp the object firmly with both hands and stand slowly and squarely while keeping your back vertical and unarched. In other words, perform the lifting with the muscles in your legs, not with the muscles in your lower back.

Drilling operations should be terminated during an electrical storm.

APPENDIX C

CHEMICAL INFORMATION SHEETS

AMMONIA

- Hazardous substance (EPA)

Description: NH_3, ammonia is a colorless, strongly alkaline, and extremely soluble gas with a characteristic pungent odor.

Code Numbers: CAS 7664-41-7 RTECS BO0875000 UN 1005

DOT Designation: Nonflammable gas.

Synonyms: Anhydrous ammonia.

Potential Exposures: Ammonia is used as a nitrogen source for many nitrogen-containing compounds. It is used in the production of ammonium sulfate and ammonium nitrate for fertilizers and in the manufacture of nitric acid, soda, synthetic urea, synthetic fibers, dyes, and plastics. It is also utilized as a refrigerant and in the petroleum refining and chemical industries. It is used in the production of many drugs (A-41) and pesticides (A-32).

Other sources of occupational exposure include the silvering of mirrors, glue-making, tanning of leather, and around nitriding furnaces. Ammonia is produced as a by-product in coal distillation and by the action of steam on calcium cyanamide, and from the decomposition of nitrogenous materials.

Incompatibilities: Strong oxidizers, calcium, hypochlorite bleaches, gold, mercury, silver, halogens.

Permissible Exposure Limits in Air: The Federal standard for ammonia is an 8-hour time-weighted average of 50 ppm (35 mg/m^3). NIOSH has recommended 50 ppm expressed as a ceiling and determined by a 5-minute sampling period. ACGIH as of 1983/84 has set TWA values of 25 ppm (18 mg/m^3). The tentative STEL value is 35 ppm (27 mg/m^3). The IDLH level is 500 ppm.

Determination in Air: Collection by midget impinger and colorimetric analysis using Nessler's reagent (A-10). Ammonia may also be determined using long-duration detector tubes (A-11).

Permissible Concentration in Water: EPA in 1976 (A-3) proposed a limit of 0.02 mg/ℓ (as unionized ammonia) for the protection of freshwater aquatic life. As of 1980, EPA (2) first proposed adding ammonia to the list of priority toxic pollutants and developing criteria for it, but then withdrew the proposal. NAS/NRC proposed (A-2) a limit of 0.5 mg/ℓ for drinking water.

Routes of Entry: Inhalation of gas, ingestion, skin and eye contact.

Harmful Effects and Symptoms: *Local* — Contact with anhydrous liquid ammonia or with aqueous solutions is intensely irritating to the mucous membranes, eyes, and skin. Eye symptoms range from lacrimation, blepharospasm, and palpebral edema to a rise of intraocular pressure, and other signs resembling acute-angle closure glaucoma, corneal ulceration, and blindness. There may be corrosive burns of skin or blister formation. Ammonia gas is also irritating to the eyes and to moist skin.

Systemic — Mild to moderate exposure to the gas can produce headache, salivation, burning of throat, anosmia, perspiration, nausea, vomiting, and substernal pain. Irritation of ammonia gas in eyes and nose may be sufficiently intense to compel workers to leave the area. If escape is not possible, there may be severe irritation of the respiratory tract with the production of cough, glottal edema, bronchospasm, pulmonary edema, or respiratory arrest. Bronchitis or pneumonia may follow a severe exposure if patient survives. Urticaria is a rare allergic manifestation from inhalation of the gas.

Points of Attack: Lungs, respiratory system, eyes.

Medical Surveillance: Preemployment physical examinations for workers in ammonia exposure areas should be directed toward significant changes in the skin, eyes, and respiratory system. Persons with corneal disease, and glaucoma, or chronic respiratory diseases may suffer increased risk. Periodic examinations should include evaluation of skin, eyes, and respiratory system, and pulmonary function tests to compare with baselines established at preemployment examination.

First Aid: If this chemical gets into the eyes, irrigate immediately. If this chemical contacts the skin, flush with water immediately. If a person breathes in large amounts of this chemical, move the exposed person to fresh air at once and perform artificial respiration. When this chemical has been swallowed, get medical attention. Do not induce vomiting.

Personal Protective Methods: Where ammonia hazards exist in concentrations above the standard, respiratory, eye, and skin protection should be provided. Fullface gas masks with ammonia canister or supplied air respirators, both with full facepieces, afford good protection. In areas where exposure to liquid ammonia occurs, goggles or face shields, as well as protective clothing impervious to ammonia and including gloves, aprons, and boots should be required. Where ammonia gas or concentrated ammonia solution is splashed in eyes, immediate flooding of the eyes with large quantities of water for 15 minutes or longer is advised, followed at once by medical examination.

In heavy concentrations of ammonia gas, workers should be outfitted with complete self-contained protective suits impervious to ammonia, with supplied air source, and full headpiece and facepiece. Appropriate clothing should be worn to prevent any possible skin contact with liquids of >10% content or reasonable probability of contact with liquids of <10% content. Wear eye protection to prevent any possibility of eye contact with liquids of >10% NH_3 content. Employees should wash immediately when skin is wet or contaminated with liquids of >10% content. Remove nonimpervious clothing immediately if wet or contaminated with liquids containing >10% and promptly remove if liquid contains <10% NH_3. Provide emergency showers and eyewash if liquids containing >10% NH_3 are involved.

Respirator Selection:

100 ppm: CCRS/SA/SCBA
300 ppm: CCRSF
500 ppm: GMS/SAF/SCBAF
Escape: GMS/SCBA

Disposal Method Suggested: Dilute with water, neutralize with HCl and discharge to sewer (A-38). Recovery is an option to disposal which should be considered for paper manufacture, textile treating, fertilizer manufacture and chemical process wastes (A-57).

References

(1) National Institute for Occupational Safety and Health, *Criteria for a Recommended Standard: Occupational Exposure to Ammonia*, NIOSH Doc. No. 74-136, Washington, DC (1974).
(2) U.S. Environmental Protection Agency, "Toxic Pollutant List: Proposal to Add Ammonia," *Federal Register*, 45, No. 2, 803-806 (January 3, 1980) Rescinded by *Federal Register*, 45, No. 232, 79692-79693 (December 1, 1980).
(3) National Research Council, Committee on Medical and Biologic Effects of Environmental Pollutants, *Ammonia*, Baltimore, MD, University Park Press (1979).
(4) Sax, N.I., Ed., *Dangerous Properties of Industrial Materials Report*, 2, No. 1, 65-68, New York, Van Nostrand Reinhold Co. (1982).
(5) See Reference (A-61).
(6) Sax, N.I., Ed., *Dangerous Properties of Industrial Materials Report*, 3, No. 3, 49-53, New York, Van Nostrand Reinhold Co. (1983).
(7) See Reference (A-60).
(8) Parmeggiani, L., Ed., *Encyclopedia of Occupational Health & Safety*, Third Edition, Vol. 1, pp 148-150, Geneva, International Labour Office (1983).

ATRAZINE

ATZ

Common Synonyms

Solid crystals White

Soluble in water.

AVOID CONTACT WITH SOLID AND DUST
PEOPLE AWAY
Wear goggles and self-contained breathing apparatus
Stay upwind. Use water spray to "knock down" dust
Isolate and remove discharged material
Notify local health and pollution control agencies

Fire

Not flammable
POISONOUS GASES MAY BE PRODUCED WHEN HEATED.

Exposure

CALL FOR MEDICAL AID

DUST
POISONOUS IF INHALED.
Wear goggles and self-contained breathing apparatus
Move victim to fresh air
If in eyes, flush eyelids with plenty of water
If breathing is difficult, give oxygen

SOLID
POISONOUS IF SWALLOWED
Wear goggles and self-contained breathing apparatus
Remove contaminated clothing and shoes
Flush affected areas with plenty of water
IF IN EYES, hold eyelids open and flush with plenty of water
IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk and have victim induce vomiting
IF SWALLOWED and victim is UNCONSCIOUS OR having CONVULSIONS, do nothing except keep victim warm

Water Pollution

HARMFUL TO AQUATIC LIFE IN VERY LOW CONCENTRATIONS
May be dangerous if it enters water intakes.
Notify local health and wildlife officials
Notify operators of nearby water intakes.

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook)
Issue warning-water contaminant
Should be removed
Chemical and physical treatment

2. LABEL

2.1 Category: None
2.2 Class: Not pertinent

3. CHEMICAL DESIGNATIONS

3.1 CG Compatibility Class: To be developed
3.2 Formula: $C_8H_{14}ClN_5$
3.3 BOD/UR Designation: 0.1/1000
3.4 DOT ID No.: 1935
3.5 CAS Registry No.: 1912-24-9

4. OBSERVABLE CHARACTERISTICS

4.1 Physical State (at shipping): Solid
4.2 Color: White
4.3 Odor: Data not available

5. HEALTH HAZARDS

5.1 Personal Protective Equipment: Dust mask, goggles, rubber gloves
5.2 Symptoms Following Exposure: Irritates eyes and skin. If ingested, irritates mouth and stomach
5.3 Treatment of Exposure: EYES: flush with copious amounts of water for 15 min. SKIN: wash with large amounts of water. INGESTION: no specific antidote. Induce vomiting and give a saline laxative and substantial drainage
5.4 Threshold Limit Value: 5 mg/m³
5.5 Short Term Inhalation Limits: Data not available
5.6 Toxicity by Ingestion: Grade 2; one rat LD_{50} = 3080 mg/kg
5.7 Late Toxicity: Data not available
5.8 Vapor (Gas) Irritant Characteristics: Vapors are noncorrosive to eyes and throat
5.9 Liquid or Solid Irritant Characteristics: Causes smarting of the skin and first-degree burns on short exposure and may cause second-degree burns on long exposure
5.10 Odor Threshold: Data not available
5.11 IDLH Value: Data not available

6. FIRE HAZARDS

6.1 Flash Point: Not flammable
6.2 Flammable Limits in Air: Not applicable
6.3 Fire Extinguishing Agents: Not pertinent
6.4 Fire Extinguishing Agents Not to Be Used: Data not available
6.5 Special Hazards of Combustion: Products: irritating hydrogen chloride and toxic oxides of nitrogen may be formed.
6.6 Behavior in Fire: Not pertinent
6.7 Ignition Temperature: Not pertinent
6.8 Electrical Hazard: Not pertinent
6.9 Burning Rate: Not pertinent
6.10 Adiabatic Flame Temperature: Data not available
6.11 Stoichiometric Air to Fuel Ratio: Data not available
6.12 Flame Temperature: Data not available

7. CHEMICAL REACTIVITY

7.1 Reactivity With Water: No reaction
7.2 Reactivity with Common Materials: No reaction
7.3 Stability During Transport: Stable
7.4 Neutralizing Agents for Acids and Caustics: Not pertinent
7.5 Polymerization: Not pertinent
7.6 Inhibitor of Polymerization: Not pertinent
7.7 Molar Ratio (Reactant to Product): Data not available
7.8 Reactivity Group: Data not available

8. WATER POLLUTION

8.1 Aquatic Toxicity: 10.6 ppm/48 hr/Rainbow trout/TL_m/Fresh water
8.2 Waterfowl Toxicity: >3000 mg/kg LD_{50}
8.3 Biological Oxygen Demand (BOD): Data not available
8.4 Food Chain Concentration Potential: None

9. SHIPPING INFORMATION

9.1 Grades of Purity: Various grades, 75-90%. Mixtures with sodium arsenite and sodium chlorate
9.2 Storage Temperature: Ambient
9.3 Inert Atmosphere: No requirement
9.4 Venting: Open

10. HAZARD ASSESSMENT RATING

(See Hazard Assessment Handbook)
II

11. HAZARD CLASSIFICATIONS

11.1 Code of Federal Regulations: Not listed
11.2 NAS Hazard Rating for Bulk Water Transportation:

Category	Rating
Fire	0
Health:	
Vapor Irritant	0
Liquid or Solid Irritant	3
Poisons	0
Water Pollution:	
Human Toxicity	3
Aquatic Toxicity	2
Aesthetic Effect	3
Reactivity:	
Other Chemicals	1
Water	-
Self Reaction	0

11.3 NFPA Hazard Classification: Not listed

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 Physical State at 15°C and 1 atm: Solid
12.2 Molecular Weight: 215.7
12.3 Boiling Point at 1 atm: Decomposes
12.4 Freezing Point: 347°F = 175°C = 448°K
12.5 Critical Temperature: Not pertinent
12.6 Critical Pressure: Not pertinent
12.7 Specific Gravity: (est.) 1.2 at 20°C (solid)
12.8 Liquid Surface Tension: Not pertinent
12.9 Liquid Water Interfacial Tension: Not pertinent
12.10 Vapor (Gas) Specific Gravity: Not pertinent
12.11 Ratio of Specific Heats of Vapor (Gas): Not pertinent
12.12 Latent Heat of Vaporization: Not pertinent
12.13 Heat of Combustion: (est.) −8,000 Btu/lb = −4,500 cal/g = −200 × 10³ J/kg
12.14 Heat of Decomposition: Not pertinent
12.15 Heat of Solution: Not pertinent
12.16 Heat of Polymerization: Not pertinent
12.20 Heat of Fusion: Data not available
12.21 Limiting Value: Data not available
12.27 Solid Vapor Pressure: Data not available

NOTES

Material Safety Data Sheet

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No. 193

ARSENIC PENTOXIDE

Issued: June 1986

SECTION 1. MATERIAL IDENTIFICATION

MATERIAL NAME: ARSENIC PENTOXIDE

OTHER DESIGNATIONS: Arsenic Acid Anhydride, Arsenic Anhydride, Arsenic (V) Oxide, As_2O_5, CAS #1303-28-2.

MANUFACTURER/SUPPLIER: Available from several suppliers, including:
Aldrich Chemical Co., Inc., PO Box 355, Milwaukee, WI 53201;
Telephone: (414) 273-3850
Cerac, Inc., PO Box 1178, Milwaukee, WI 53201; Telephone: (414) 289-9800

HMIS	Not Found
H 3	
F 0	R 1
R 0	I 4
PPE*	S 2
*See Sect. 8	K 0

SECTION 2. INGREDIENTS AND HAZARDS

	%	HAZARD DATA
Arsenic Pentoxide, CAS #1303-28-2	>99	ACGIH TLV* 8-hr TWA: 0.2 mg/m^3 OSHA PEL** 8-hr TWA: 0.01 mg/m^3 OSHA Action Level*** 8-hr TWA: 0.005 mg/m^3 Rat, Oral, LD_{50}: 8 mg/kg Mouse, Oral, LD_{50}: 55 mg/kg

* Current (1985-86) ACGIH TLV for arsenic and soluble compounds, as As.

** Current OSHA PEL for inorganic arsenic compounds, as As.

*** Concentration that triggers certain provisions of the OSHA Arsenic Standard (29 CFR 1910.1018).

SECTION 3. PHYSICAL DATA

Melting Point ... 599°F (315°C) (Decomposes)
Specific Gravity ... 4.32
Vapor Pressure @ 20°C ... Essentially Zero
Solubility in Water, @ 16°C ... 150 g/100cc
@ 100°C ... 76.7 g/100cc
Molecular Weight ... 229.84

Appearance and odor: White amorphous lumps or powder.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temp.	Flammability Limits in Air	LOWER	UPPER
Not Found	Not Found	Not Found	Not Found	Not Found

EXTINGUISHING MEDIA: Arsenic pentoxide is noncombustible. Use extinguishing agents (dry chemical, CO_2, water spray, or foam) that are suitable for extinguishing the surrounding fire.
UNUSUAL FIRE/EXPLOSION HAZARDS: Highly toxic fumes and gases may be evolved in a fire situation. Oxygen, which will intensify combustion, is evolved at temperatures greater than 572°F (300°C).
SPECIAL FIRE-FIGHTING PROCEDURES: Fire fighters need self-contained breathing apparatus (positive pressure) and full protective gear. Minimize runoff of fire-control water to prevent pollution.

SECTION 5. REACTIVITY DATA

Arsenic pentoxide is stable at room temperature. It does not polymerize.

INCOMPATIBILITIES: Arsenic pentoxide arsine can be generated when arsenic compounds come in contact with nascent (freshly formed) hydrogen. This can occur by contact of acid, alkalies, or water with arsenic compounds in the presence of an active metal (zinc, aluminum, magnesium, manganese, sodium, iron, etc.). Arsine is an extremely poisonous (lethal) gas with a garlic odor.

HAZARDOUS DECOMPOSITION PRODUCTS: Arsenic pentoxide decomposes at approximately 572°F (300°C), forming arsenic trioxide fumes. Poisonous arsine gas may also form on thermal decomposition.

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SECTION 6. HEALTH HAZARD INFORMATION

CARCINOGENIC ASSESSMENT: Exposure to arsenic compounds is associated with skin, lung, and possibly liver cancer. The NTP, IARC, and OSHA have identified arsenic compounds as human carcinogens. ROUTES OF ENTRY: Arsenic pentoxide can enter the body if it is inhaled or swallowed. EFFECTS OF OVEREXPOSURE: Skin contact can cause dermatitis characterized by erythema (abnormal redness of skin caused by capillary congestion), with burning, itching, swelling, and skin eruptions. Chronic skin effects include cracking, thickening, pigmentation, and drying of the skin. Eye contact can cause conjunctivitis with redness, swelling, and pain. Acute inhalation exposure can cause severe nose and respiratory tract irritation and pulmonary edema. Prolonged or repeated exposure can cause necrosis and perforation of the nasal septem. Other effects of chronic arsenic poisoning by inhalation or ingestion may include gastrointestinal disturbances (nausea, vomiting); nervous system effects involving the extremities (numbness, tingling, burning pain, weakness, incoordination); blood disorders (anemia);liver and kidney injury; and skin and lung cancer. Acute ingestion of arsenic causes burning of the mouth and throat, vomiting, watery or bloody diarrhea, convulsions, paralysis, coma, and death. FIRST AID: EYE CONTACT: Flush eyes, including under eyelids, with a gentle flow of running water for at least 15 minutes. Get medical help.* SKIN CONTACT: Thoroughly wash affected area with mild soap and water. Prevent further exposure. If irritation or other symptoms persist, get medical help.* INHALATION: Remove victim from exposure. Keep him warm and at rest. If breathing has stopped, begin artificial respiration immediately. Get medical help promptly.* INGESTION: Immediately give victim a large quantity (2-4) glasses of water to drink, then induce vomiting. Keep him warm and at rest. Get medical help immediately!* (Note: Never give anything by mouth or induce vomiting if victim is unconscious or convulsing.)

* GET MEDICAL ASSISTANCE = In plant, paramedic, community. Get medical help for further treatment, observation, and support after first aid.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

CLEANUP PROCEDURES: Notify safety/environmental personnel of large spills. Ventilate spill area. Cleanup personnel should wear protective clothing (gloves, coveralls, goggles, etc.) and respiratory equipment. Carefully vacuum up spilled material (*vacuum must have high-efficiency filters to prevent redispersion of dust*). Do not sweep or brush material, but place it into a suitable container for reclamation or disposal. Minimize dust generation and prevent skin/eye contact throughout the cleanup process. Wash spill area to remove all residues from environmental surfaces. Use swipe tests to verify cleanliness. DISPOSAL: This material requires disposal as a hazardous (toxic) waste. Contact supplier or a licensed chemical waste disposal contractor for treatment, packaging, and disposal instructions. Follow Federal, state, and local regulations.

Reportable Spill Quantity: 5000 lbs (2270 kg) (40 CFR 117.3)

EPA Hazardous Waste Number: P011 (40 CFR 261.33)

SECTION 8. SPECIAL PROTECTION INFORMATION

Use local exhaust ventilation when handling this material. Ventilation rates should be sufficient to maintain airborne levels below the PEL. NIOSH-approved respirators should be worn when airborne concentrations exceed the PEL and during nonroutine and emergency operations. Half-mask air-purifying respirators with high-efficiency filters are acceptable for concentrations not greater than 0.1 mg/m^3 (0.5 mg/m^3 with full facepiece). For concentrations above 0.5 mg/m^3, powered air-purifying respirators, positive-pressure-supplied air respirators, or self-contained breathing apparatus are required depending on the concentration of the material. Respirator usage must be in accordance with appropriate provisions of the OSHA Inorganic Arsenic Standard (29 CFR 1910.1018). Dust-/splash-proof safety goggles should be worn when handling this material. Protective clothing and equipment such as coveralls, gloves, hats, and shoes should be worn when airborne concentrations exceed the PEL or where the possibility of skin and eye contact exist. Provide clean body-covering work clothing weekly to workers exposed above the PEL (daily if exposed above 0.1 mg/m^3) and arrange for special handling and laundering of contaminated clothing. OTHER CONTROLS: Changing rooms with separate storage facilities for street and work clothing and showers are required for employees who are exposed to above the PEL. Prevent dust from being transported to lunchroom through the ventilation system or on contaminated clothing. Consult the OSHA Inorganic Arsenic Standard (29 CFR 1910.1018) for detailed requirements. Eyewash stations, washing facilities, and safety showers should be readily accessible. Contact lenses pose a special hazard; soft lenses may absorb irritants and all lenses concentrate them.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Store arsenic pentoxide in a cool, dry location in tightly closed containers away from incompatibles (see sect. 5). Protect containers from physical damage. Keep this material away from food products and feed. Maintain good housekeeping practices to prevent accumulation of dust. Use procedures that minimize dust generation such as vacuuming (with appropriate filter) or wet cleanup. Brushing or sweeping should be done only where vacuuming or other relevant methods are ineffective. All handling should be done in a careful manner and with appropriate controls (enclosure, ventilation) to prevent dust generation and dispersion. Practice good personal hygiene. Wash face and hands thoroughly before eating, drinking, and smoking. Showering after the workshift is required for employees exposed to above the PEL. Do not eat, drink, use tobacco, chew gum, or apply cosmetics in the work area. Remove contaminated clothing promptly. Launder it before wearing it again. Do not shake clothing to remove dust; use a vacuum cleaner. Avoid inhalation and skin/eye contact. DO NOT INGEST!

DOT Class: Poison B DOT ID No. UN1559 DOT Label: Poison

Data Source(s) Code: 2, 4, 9, 12, 14, 30, 44, 49, 55, 58, 61, 62, 84. CV

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Approvals D.O. Bennett, 11/87.

Indust. Hygiene/Safety 12/86

Medical Review

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GENIUM PUBLISHING CORP.

No. 194

ARSENIC TRIOXIDE

Issued: June 1986

SECTION 1. MATERIAL IDENTIFICATION

21

MATERIAL NAME: ARSENIC TRIOXIDE

OTHER DESIGNATIONS: Arsenic Oxide, Arsenic Sesquioxide, Arsenous Oxide, Arsenous Acid Anhydride, White Arsenic, As_2O_3, CAS #1327-53-3.

MANUFACTURER/SUPPLIER: Available from several suppliers, including:
Atomergic Chemetals Corp., 100 Fairchild Ave., Plainview, NY 11803;
Telephone: (516) 349-8800
Sharpe Chemicals Co., 1116 S. Varney St., Burbank, CA 91502;
Telephone: (818) 841-7605

HMIS	Not Found
H 3	
F 0	R 1
R 0	I 4
PPE*	S 2
*See Sect. 8	K 0

SECTION 2. INGREDIENTS AND HAZARDS

	%	HAZARD DATA
Arsenic Pentoxide, CAS #1327-53-3	>99	ACGIH TLV* 8-hr TWA: 0.2 mg/m^3 OSHA PEL** 8-hr TWA: 0.01 mg/m^3 OSHA Action Level*** 8-hr TWA: 0.005 mg/m^3 Man, Oral, LD_{50}: 1.43 mg/kg Rat, Oral, LD_{50}: 15.1 mg/kg Woman, Oral, TDLo: 600 mg/kg (Reproductive Effect)

* Current (1985-86) ACGIH TLV for arsenic and soluble compounds, as As.

** Current OSHA PEL for inorganic arsenic compounds, as As.

*** Concentration that triggers certain provisions of the OSHA Arsenic Standard (29 CFR 1910.1018).

SECTION 3. PHYSICAL DATA

Melting Point ... 275°F (135°C) (Sublimes)*
Specific Gravity ... 3.865*
Vapor Pressure @ 20°C ... Essentially Zero
Solubility in Water, @ 2°C ... 1.2 g/100cc
@ 100°C ... 11.46 g/100cc
Molecular Weight ... 197.84
Appearance and odor: White amorphous lumps or powder.

* Values are for arsenolite. Amorphous arsenic trioxide melts at 599°F (315°C).

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temp.	Flammability Limits in Air	LOWER	UPPER
			Not Found	Not Found
Not Found	Not Found	Not Found		

EXTINGUISHING MEDIA: Arsenic trioxide is noncombustible. Use extinguishing agents (dry chemical, CO_2, water spray, or foam) that are suitable for extinguishing the surrounding fire.
UNUSUAL FIRE/EXPLOSION HAZARDS: Highly toxic fumes and gases may be evolved from this material in a fire situation.

SPECIAL FIRE-FIGHTING PROCEDURES: Fire fighters need self-contained positive-pressure breathing apparatus and full protective gear. Minimize the runoff of fire-control water to prevent pollution.

SECTION 5. REACTIVITY DATA

Arsenic trioxide is stable at room temperature. It does not polymerize.

INCOMPATIBILITIES: Aresenic trioxide may react violently on contact with chlorine trifluoride, fluorine, hydrogen fluoride, oxygen difluoride, sodium chlorate, and other strong oxidizers. Arsine gas (arsenic hydride) can be generated when arsenic compounds come in contact with nascent (freshly formed) hydrogen. This can occur by contact of acid, alkalies, or water with arsenic compounds in the presence of an active metal (zinc, aluminum, magnesium, manganese, sodium, iron, etc.). Arsine is an extremely poisonous (lethal) gas with a garlic odor.
HAZARDOUS DECOMPOSITION PRODUCTS: Arsenic trioxide sublimes when heated. Poisonous arsine gas may also form on decomposition.

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SECTION 6. HEALTH HAZARD INFORMATION

CARCINOGENIC ASSESSMENT: Exposure to arsenic compounds is associated with skin, lung, and possibly liver cancer. The NTP, IARC, and OSHA have identified arsenic compounds as human carcinogens. ROUTES OF ENTRY: Arsenic trioxide can enter the body if it is inhaled or swallowed. EFFECTS OF OVEREXPOSURE: Skin contact can cause dermatitis characterized by erythema (abnormal redness of skin caused by capillary congestion) with burning, itching, swelling, and skin eruptions. Chronic skin effects include cracking, thickening, pigmentation, and drying of the skin. Eye contact can cause conjunctivitis and redness, swelling, and pain. Acute inhalation exposure can cause severe nose and respiratory tract irritation and pulmonary edema. Prolonged or repeated exposure can cause necrosis and perforation of the nasal septem. Other effects of chronic arsenic poisoning by inhalation or ingestion may include gastrointestinal disturbances (nausea, vomiting); nervous system effects involving the extremities (numbness, tingling, burning pain, weakness, incoordination); blood disorders (anemia); liver and kidney injury; and skin and lung cancer. Acute ingestion of arsenic trioxide causes burning of the mouth and throat, vomiting, watery or bloody diarrhea, convulsions, paralysis, coma, and death. A dose of 120 mg of arsenic trioxide can be fatal. FIRST AID: EYE CONTACT: Flush eyes, including under eyelids, with a gentle flow of running water for at least 15 minutes. Get medical help.* SKIN CONTACT: Thoroughly wash affected area with mild soap and water. Prevent further exposure. If irritation or other symptoms persist, get medical help.* INHALATION: Remove victim from exposure. Keep him warm and at rest. If breathing has stopped, administer oxygen under low pressure. Get medical help promptly.* INGESTION: Immediately give victim a large quantity (2-4 glasses) of water to drink; induce vomiting. Keep him warm and at rest. Get medical help immediately!* (Note: Never give anything by mouth or induce vomiting if victim is unconscious or convulsing.) * GET MEDICAL ASSISTANCE = In plant, paramedic, community. Get medical help for further treatment, observation, and support after firest aid.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

CLEANUP PROCEDURES: Notify safety/environmental personnel of large arsenic trioxide spills. Ventilate spill area. Cleanup personnel should wear protective clothing (gloves, coveralls, goggles, etc.) and use protective respiratory equipment. Carefully vacuum up spilled material (vacuum must have high-efficiency filters to prevent redispersion of dust). Do not sweep or brush it up. Place the waste into a suitable container for reclamation or disposal. Minimize dust generation and prevent skin/eye contact throughout the cleanup process. Wash spill area to remove all residues from environmental surfaces. Use swipe tests to verify cleanliness.

DISPOSAL: This material requires disposal as a hazardous (toxic) waste. Contact supplier or a licensed chemical waste disposal contractor for treatment, packaging, and disposal instructions. Follow Federal, state, and local regulations.

Reportable Spill Quantity: 5000 lbs (2270 kg) (40 CFR 117.3)

EPA Hazardous Waste Number: P012 (40 CFR 261.33)

SECTION 8. SPECIAL PROTECTION INFORMATION

Use local exhaust ventilation when handling this material. Ventilation rates should be sufficient to maintain airborne levels below the PEL. NIOSH-approved respirators should be worn when airborne concentrations exceed the PEL and during nonroutine and emergency operations. Half-mask air-purifying respirators with high-efficiency filters are acceptable for concentrations not greater than 0.1 mg/m^3 (0.5 mg/m^3 with full facepiece). For concentrations above 0.5 mg/m^3, powered air-purifying respirators, positive-pressure-supplied air respirators, or self-contained breathing apparatus are required, depending on the concentration of the material. Respirator usage must be in accordance with appropriate provisions of the OSHA Inorganic Arsenic Standard (29 CFR 1910.1018). Dust-/splash-proof safety goggles should be worn when handling this material. Protective clothing and equipment such as coveralls, gloves, hats, and shoes should be worn when airborne levels exceed the PEL or where the possibility of skin and eye contact exist. Provide clean body-covering work clothing weekly to workers who are exposed to above the PEL (daily if exposed to above 0.1 mg/m^3) and arrange for special handling and laundering of contaminated clothing. OTHER CONTROLS: Changing rooms with separate storage facilities for street and work clothing and showers are required for employees who are exposed to above the PEL. Prevent dust from being transported to the lunchroom through the ventilation system or on contaminated clothing. Consult the OSHA Inorganic Arsenic Standard (29 CFR 1910.1018) for detailed requirements. Eyewash stations, washing facilities, and safety showers should be readily accessible. Contact lenses pose a special hazard; soft lenses may absorb irritants and all lenses concentrate them.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Store arsenic trioxide in a cool, dry location in tightly closed containers away from incompatibles (see sect. 5). Protect containers from physical damage. Keep this material away from food products and feed. Maintain good housekeeping practices to prevent accumulation of arsenic trioxide dust. Use procedures that minimize dust generation such as vacuuming (with appropriate filter) or wet cleanup. Brushing or sweeping should be used only where vacuuming or other relevant methods are ineffective. All handling should be done in a careful manner and with appropriate controls (enclosure, ventilation) to prevent dust generation and dispersion. Practice good personal hygiene. Wash face and hands thoroughly before eating, drinking, and smoking. Showering after the workshift is required for employees exposed to above the PEL. Do not eat, drink, use tobacco, chew gum, or apply cosmetics in the work area. Remove contaminated clothing promptly. Launder it before it is worn again. Do not shake clothing to remove dust; use a vacuum cleaner. Avoid inhalation and skin/eye contact. DO NOT INGEST THIS MATERIAL!

DOT Class: Poison B DOT ID No. UN1561 DOT Label: Poison

Data Source(s) Code: 2, 4, 9, 12, 14, 30, 44, 49, 55, 58, 61, 62, 84. CV

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Approvals G.O. Clemmer, 11/87.

Indust. Hygiene/Safety 11-86

Medical Review

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GENIUM PUBLISHING CORP.

No. 22

CALCIUM OXIDE
(Revision C)
Issued: September 1978
Revised: April 1989

SECTION 1. MATERIAL IDENTIFICATION

28

Material: CALCIUM OXIDE

NFPA

Description (Origin/Uses): Used in the manufacture of steel, aluminum, glass, and paper; also found in plaster, mortar, bricks, stucco, and in other building and construction materials.

Other Designations: Lime; Quicklime; Burnt Unslaked Lime; High-Calcium Lime; CaO;
CAS No. 1305-78-8

Manufacturer: Contact your supplier or distributor. Consult the latest edition of *Chemicalweek Buyers' Guide* (Genium ref. 73) for a list of suppliers.

HMIS	
H 1	R 1
F 1	I 2
R 0	S 3
PPG*	K 0
*See sect. 8	

SECTION 2. INGREDIENTS AND OCCUPATIONAL EXPOSURE LIMITS

Calcium Oxide, ca 100%

OSHA PEL	ACGIH TLV, 1988-89	Toxicity Data
8-hr TWA: 5 mg/m³	TLV-TWA: 2 mg/m³	Not Listed*

*Monitor NIOSH, *RTECS* (EW3100000), for future data.

SECTION 3. PHYSICAL DATA

Boiling Point: 5162 °F (2850 °C)
Melting Point: 4658 °F (2570 °C)
pH: >10 (Strongly Basic)

Molecular Weight: 56 g/mol
Solubility in Water (%): Reacts
Specific Gravity (H_2O = 1): 3.2 to 3.4

Appearance and Odor: A white or grayish white solid (it can appear yellowish or brownish if iron impurities are present; commercial calcium oxide is available in a wide variety of forms such as lumps, pellets, pebbles, and powders); odorless.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point: *	Autoignition Temperature: *	LEL: *	UEL: *

Extinguishing Media: *Calcium oxide will not burn. Use an extinguishing agent that will put out the surrounding fire. Water reacts dangerously with calcium oxide and is not recommended as an extinguishing agent for fires that involve it. If water must be used, prevent it from coming into direct contact with the calcium oxide. If such contact is unavoidable, apply the water in flooding amounts to safely absorb the heat that will be generated. ***Unusual Fire or Explosion Hazards:*** Do not allow water to get inside containers of calcium oxide; reaction with the water will cause the calcium oxide to swell, generate heat, and burst its container. The heat generated by this reaction may ignite nearby combustible materials. **Special Fire-fighting Procedures:** Wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode.

SECTION 5. REACTIVITY DATA

Stability/Polymerization: Calcium oxide is stable in closed, airtight containers during routine work operations. Hazardous polymerization cannot occur. **Chemical Incompatibilities:** Calcium oxide can react dangerously with boric oxide and calcium chloride, boron trifluoride, chlorine trifluoride, fluorine, hydrofluoric acid, phosphorus pentoxide, and water. **Conditions to Avoid:** Control exposure to incompatible chemicals. Always establish the compatibility of calcium oxide with another material before using it in bulk operations by testing small quantities under appropriate conditions. Avoid exposing calcium oxide to air because it reacts with the ambient moisture and carbon dioxide. **Hazardous Products of Decomposition:** Oxides of calcium may be produced when calcium oxide reacts with other materials during fires.

SECTION 6. HEALTH HAZARD INFORMATION

Carcinogenicity: Calcium oxide is not listed as a carcinogen by the NTP, IARC, or OSHA.
Summary of Risks: Calcium oxide is a strongly alkaline material; its contact with the skin, eyes, or inhalation results in severe irritation. Dust containing 25 mg/m³ of this material causes strong nasal irritation; dust containing 9 to 10 mg/m³ does not. The presence of moisture on the skin or on the mucous membrane of the respiratory system increases the possibility of corrosive tissue damage (chemical burns). *Dehydration and thermal effects* (the heat generated from reaction with water) are contributing factors to the irritating properties of calcium oxide. **Medical Conditions Aggravated by Long-Term Exposure:** None reported. **Target Organs:** Skin, eyes, nose, and respiratory system. **Primary Entry:** Inhalation and contact with skin and eyes. **Acute Effects:** Irritation and burns to the skin, eyes, and nose; irritation and inflammation of the respiratory system; coughing; and sneezing. **Chronic Effects:** Ulceration and perforation of the nasal septum, pneumonia. May cause nails to become brittle and fissure (split). *(Cont'd.)*

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SECTION 6. HEALTH HAZARD INFORMATION, continued

FIRST AID

Eyes: Immediately flush eyes, including under the eyelids, gently but thoroughly with flooding amounts of running water for at least 15 minutes. An occupational ophthalmologist should monitor and treat the eye for calcium oxide burns. **Skin:** Do not rinse the affected area with water because severe skin damage is likely to occur if water is applied directly to the calcium oxide on the skin. *Before wetting the* calcium oxide, try to remove it from the skin with oil or grease; then apply water in a forcefully directed, powerful stream in flooding amounts that will mechanically and immediately remove the calcium oxide particles from the skin. **Inhalation:** Remove the exposed person to fresh air; restore and/or support his or her breathing as needed. Have qualified medical personnel administer oxygen as required. **Ingestion:** Unlikely. Get in plant, paramedic, or community medical help for all exposures. Seek prompt medical assistance for further treatment, observation, and support after first aid. **Note to Physician:** Severe exposure indicates hospitalization for 72 hours with careful monitoring for the delayed onset of pulmonary edema.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Spill/Leak: Notify safety personnel, prevent accidental contact between the spilled calcium oxide and water, and avoid generating dust. Cleanup personnel need protection against its contact with skin or eyes as well as against inhalation of its dust (see sect. 8). Carefully pick up the solid, creating a minimum of dust, and collect it in metal containers with covers for disposal. Flush the trace residue in the spill area to a drain, using plenty of water.

Waste Disposal: Consider reclamation, recycling, or destruction rather than disposal in a landfill. Follow all applicable Federal, state, and local regulations. Large amounts of calcium oxide may require neutralization by acid before disposal. Flush any residue to a sewer after diluting it properly. Alternatively, the waste calcium oxide can be used for neutralizing plant acid waste.

OSHA Designations

Listed as an Air Contaminant (29 CFR 1910.1000 Subpart Z)

EPA Designations

Assigned the RCRA Hazardous Waste No. D003 (40 CFR 261.23)

Assigned the CERCLA Reportable Quantity (RQ): 100 lb (45.4kg) (40 CFR 302.5 [b])

SECTION 8. SPECIAL PROTECTION INFORMATION

Goggles: Always wear protective eyeglasses or chemical safety goggles. Follow OSHA eye- and face-protection regulations (29 CFR 1910.133).

Respirator: Consult Genium reference 88 for recommendations on selecting the proper respirator for use around calcium oxide. Follow OSHA respirator regulations (29 CFR 1910.134). For emergency or nonroutine operations (spills or cleaning reactor vessels and storage tanks), wear an SCBA. **Warning:** Air-purifying respirators will *not* protect workers in oxygen-deficient atmospheres.

Other: Wear *dry* rubber gloves, boots, aprons, gauntlets, and coveralls.

Ventilation: Install and operate general and local ventilation systems powerful enough to maintain airborne concentrations of calcium oxide below the OSHA PEL standard cited in section 2.

Safety Stations: Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in work areas.

Contaminated Equipment: Contact lenses pose a special hazard; soft lenses may absorb irritants, and all lenses concentrate them. Do *not* wear contact lenses in any work area. Remove contaminated clothing and launder it before wearing it again; clean this material from your shoes and equipment.

Other: Design all work operations in a way that does not generate dust and prevents water from being accidentally introduced into any part of a production system that contains calcium oxide.

Comments: Practice good personal hygiene; always wash thoroughly after using this material and before eating, drinking, smoking, using the toilet, or applying cosmetics. Keep it off your clothing and equipment. Avoid transferring it from your hands to your mouth while eating, drinking, or smoking. Do *not* eat, drink, or smoke in any work area.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Storage/Segregation: Store calcium oxide in sealed, dry, airtight containers in a cool, dry, well-ventilated area separate from incompatible chemicals (see sect. 5). Store it away from strong oxidizing agents, acids, organic materials, water, and combustibles.

Special Handling/Storage: Protect containers of calcium oxide from physical damage. Prevent water from contacting stored calcium oxide. To maintain the full effectiveness of this material, avoid extended contact with air.

Comments: Calcium oxide generates substantial heat when mixed with water. Prevent accidental mixing by following planned work procedures in all shipping, receiving, transferring, and production operations. When calcium oxide is deliberately mixed with water, undertake proper precautions to ensure that the resulting heat can be safely generated. ***Always add calcium oxide to water; never add water to calcium oxide.***

Hazardous Materials Table (49 CFR 172.101)

DOT Shipping Name: Calcium Oxide
DOT Hazard Class: ORM-B
DOT ID No.: UN1910
DOT Label: None

References: 1, 26, 38, 84-94, 100, 116

Prepared by: PJ Igoe, BS; **Industrial Hygiene Review:** DJ Wilson, CIH; **Medical Review:** W Silverman, MD

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MATERIAL SAFETY DATA SHEET

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GENIUM PUBLISHING CORP.

NO. 410

CARBON TETRACHLORIDE

Revision A

Date December 1980

SECTION I. MATERIAL IDENTIFICATION

MATERIAL NAME: CARBON TETRACHLORIDE
OTHER DESIGNATIONS: Tetrachlormethane, Perchlormethane, Methane Tetrachloride, CCl_4, GE Material D5B50, CAS #000 056 235
MANUFACTURER: Available from several suppliers, including:
Linden Chemicals & Plastics
PO Drawer J,
Moundsville, WV 26041 Phone: (314) 843-1310

SECTION II. INGREDIENTS AND HAZARDS	%	HAZARD DATA
Carbon Tetrachloride *ACGIH (1980 Intended Changes List). OSHA 8-hr TWA is 10 ppm. NIOSH has proposed a 10-hr TWA of 2 ppm. ACGIH and NIOSH recommend labeling as a suspected human carcinogen. (skin) notation indicates absorption through the skin can contribute significantly to overall exposure.	ca 100	8-hr TWA 5 ppm (skin) or 30 mg/m^3* Human, oral LDlo 43 mg/kg Human, inhalation LCLo 1000 ppm TCLo 20 ppm (CNS) Hamsters and mice have developed cancer on long term feeding.

SECTION III. PHYSICAL DATA

Boiling point at 1 atm, deg C	76.7	Specific gravity, 25/4 C	1.585
Vapor pressure @ 20 C, mm Hg	ca 91	Melting point, deg C	-23
Vapor density (Air=1)	5.3	Volatiles, %	ca 100
Solubility in water @ 20 C, wt %	0.08	Molecular weight	153.8

Appearance & Odor: A clear, colorless liquid with a characteristic sweetish odor. Odor recognition threshold (100% of test panel): 21.4 ppm in air when prepared from CS_2; 100 ppm in air when prepared from CH_4. Odor may not be objectionable at acutely toxic levels.

SECTION IV. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temp.	Flammability Limits In Air	LOWER	UPPER

Extinguishing Media: It is nonflammable. Use that which is appropriate for the surrounding fire. Use water spray to cool fire-exposed containers.
When involved in a fire situation, this material will emit highly toxic and irritating fumes and gases. Metals, such as aluminum and magnesium, can react violently with carbon tetrachloride when hot or burning.
Firefighters must wear self-contained breathing apparatus and full protective gear to fight fires involving this material.

SECTION V. REACTIVITY DATA

This material is stable under normal conditions of handling and use. It does not polymerize.
Thermal-oxidative decomposition will produce toxic, corrosive fumes, including phosgene and hydrogen chloride.
Violent reactions or explosions can occur with incompatible materials, such as barium, lithium, sodium, and potassium metal, powdered aluminum, magnesium, dimethylformamide (above 65 C), fluorine, etc. (See NFPA, "Manual of Hazardous Chemical Reactions".)

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NO. 410

SECTION VI. HEALTH HAZARD INFORMATION

TLV 5 ppm (skin) (See Sect. II)

Carbon tetrachloride is highly toxic and irritating by inhalation and ingestion (mean lethal dose is 5-10 ml). It is toxic by skin absorption. Excessive exposure may result in CNS depression and/or gastrointestinal symptoms.* It is irritating to skin and eyes. Eye contact or systemic effects can produce visual disturbances (haze, blind spots, narrowing of visual field, etc.). Skin contacts can cause defatting & dermatitis.

Kidney & liver damage can occur from severe acute or chronic exposure. It is a suspected carcinogen in humans.

FIRST AID:

Eye Contact: Flush eyes with running water for 15 minutes, including under the eyelids. Get medical help if irritation persists or when visual disturbances occur.

Skin Contact: Remove contaminated clothing promptly. Wash exposed skin with soap and water. Get medical help for repeated or gross exposures.

Inhalation: Remove to fresh air. Restore and/or support breathing; have qualified person administer oxygen if needed. Get medical help.

Ingestion: Contact physician for gastric lavage. (If medical help and advice is not readily available, give water to drink and induce vomiting.)

*Also cardic arrhythmias.

SECTION VII. SPILL, LEAK, AND DISPOSAL PROCEDURES

Notify safety personnel when large spills occur. Evacuate area. Provided maximum exhaust ventilation. Clean-up personnel must use protection against contact and inhalation (see Sect.VIII). Contain spill; pick up liquid for disposal. Small spills and residues can be absorbed on paper, vermiculite, etc. and allowed to evaporate in a hood. Prevent release of CCl_4 to surface water or sewers. Spills or discharges in 24 hours of 5000 lb or more (proposed RQ* is 1000 lb) must be reported to U.S. Government.

DISPOSAL: Consider recovery and reuse, if feasible. Scrap may be burned in approved, high temperature incinerator with scrubber or it may be disposed of as hazardous waste (EPA number U211 or F001 as a spent degreasing solvent under RCRA). Follow Federal, State and Local regulations.

*Reportable Quantity.

SECTION VIII. SPECIAL PROTECTION INFORMATION

Provide general and local exhaust ventilation to meet TLV. Exhaust hoods need 100 lfm min. face velocity. Ventilate sumps and low lying areas. Use air-supplied or self-contained respirators above TLV, with full face piece above 100 ppm.

PVA or neoprene gloves and protective clothing needed to prevent skin contact. Wear safety goggles and/or face shield for eye protection.

An eyewash station and chemical safety shower should be readily accessible.

Provide preplacement and twice a year medical exams. Workers with obesity, diabetes, alcoholism or pulmonary problems should have a physician's approval before working with CCl_4. Retain medical records for 30 years after termination of employment.

Provide training to those exposed to CCl_4 in the workplace. Monitor vapor levels in the workplace.

SECTION IX. SPECIAL PRECAUTIONS AND COMMENTS

Store in closed containers in a cool, dry, well-ventilated, low fire-risk area. Protect containers against physical damage. Keep away from sources of heat, direct sunlight, and incompatible materials (see Sect. V). Prevent exposure of vapors to high temperature to prevent decomposition to toxic and corrosive gases and vapors. No smoking in areas where vapors may be present.

Prevent contact with the skin or eyes. Avoid exposure to vapors. Use good personal hygiene.

CCl_4 toxicity is markedly increased by the synergistic effects of alcohol. When possible, substitute a less hazardous solvent for CCl_4. DOT Classification - ORM-A

DATA SOURCE(S) CODE: 1-12,15,16,21-26,31,37,38,41

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APPROVALS: MIS J. M. Nielsen

CRD

Industrial Hygiene and Safety 12-9-80

MEDICAL REVIEW: 16 Dec. 1980

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No. 53

CHLORINE
(Revision B)
Issued: July 1979
Revised: April 1988

SECTION 1. MATERIAL IDENTIFICATION

25

Material Name: CHLORINE

Description (Origin/Uses): Used mainly to manufacture chlorinated lime for bleaching fabrics; as a versatile reagent in organic chemistry; in water purification; and as a military poison gas (bertholite).

Other Designations: Bertholite; Molecular Chlorine; Cl_2; NIOSH *RTECS* No. FO2100000; CAS No. 7782-50-5

Manufacturer: Contact your supplier or distributor. Consult the latest edition of the *Chemicalweek Buyers' Guide* (Genium ref. 73) for a list of suppliers.

HMIS			
H	3		
F	0	R	1
R	1	I	4
PPG*		S	4
*See sect. 8		K	0

SECTION 2. INGREDIENTS AND HAZARDS

	%	EXPOSURE LIMITS
Chlorine, CAS No. 7782-50-5	ca 100	IDLH* Level: 30 ppm **OSHA PEL** Ceiling: 1 ppm, 3 mg/m³ TLV-STEL: 3 ppm, 9 mg/m³ **NIOSH REL** 15-Min Ceiling: 0.5 ppm, 1.45 mg/m³ **Toxicity Data**** Rat, Inhalation, LC_{50}: 293 ppm (1 Hr) Mouse, Inhalation, LC_{50}: 137 ppm (1 Hr)

*Immediately dangerous to life and health
**See NIOSH, *RTECS*, for additional data with references to irritative and mutagenic effects.

SECTION 3. PHYSICAL DATA

Boiling Point: ca -29°F (-34°C)
Vapor Pressure: >760 Torr (Normal Atmospheric Pressure)
Vapor Density (Air = 1): 1.4085 at 68°F (20°C)
Melting Point: ca -150°F (-101°C)
Molecular Weight: 71 Grams/Mole
Water Solubility: Slight

Appearance and Odor: A greenish yellow, noncombustible gas; pungent, suffocating, nauseating odor. Its odor-recognition threshold is reported to be ca 0.3 ppm.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temperature	Flammability Limits in Air % by Volume	LOWER	UPPER
•	•		•	•

Extinguishing Media: *Chlorine will not burn, but it supports combustion of materials already involved in a fire. Use agents that will extinguish the surrounding fire. Use a water spray to cool fire-exposed tanks and to protect personnel attempting to stop a chlorine leak.
Unusual Fire or Explosion Hazards: Chlorine is a reactive/explosive gas. Fight fires involving it from the maximum possible distance; this gas greatly increases the flammability hazards of other combustibles that are present. **Warning:** Flammable gases, vapors, and mists form dangerously explosive mixtures with chlorine gas.
Special Fire-fighting Procedures: Wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode. Fire fighters must use the maximum personal protective equipment available. If possible, have specially trained personnel remove intact cylinders of chlorine from the fire area and protect them with any available resource such as directed water spray.

SECTION 5. REACTIVITY DATA

Chlorine is stable in closed, pressurized containers at room temperature under normal storage and handling conditions. It does not undergo hazardous polymerization.
Chemical Incompatibilities: Chlorine reacts dangerously with acetylene, ammonia, hydrogen, ether, fuel gas, hydrocarbons, turpentine, finely divided metals, diborane, benzene, and acetaldehyde (see Genium ref. 84, pp. 49-28 and 491M-53 to 491M-56).
Conditions to Avoid: Do not allow open flame, unprotected heaters, lighted tobacco products, electric sparks, or excessive heat in work areas because chlorine gas can form explosive mixtures with other gases. Do not heat pressurized storage tanks or cylinders containing chlorine because they may explode. Do not allow chlorine to be directly exposed to incompatible chemicals (see above).
Hazardous Products of Decomposition: Toxic gases such as carbon monoxide, phosgene, and hydrogen chloride (Genium Industrial MSDSs 35, 66, 30) can be produced in fires involving chlorine and other combustibles.

SECTION 6. HEALTH HAZARD INFORMATION

Chlorine is not listed as a carcinogen by the NTP, IARC, or OSHA.

Summary of Risks, Warning: This material is a powerful respiratory irritant. The most important acute health effect of exposure is lung damage from hydrochloric acid (HCl) caused by the reaction of chlorine with the moisture in the upper respiratory tract (URT). Fatal pulmonary edema (lungs filled with fluid) may be delayed from 24 to 48 hours after exposure. Erosion of teeth, decreased lung capacity, and increased susceptibility to tuberculosis are chronic effects in workers who handle this gas. **Medical Conditions Aggravated by Long-Term Exposure:** Cardiac, pulmonary, or respiratory problems. Administer preplacement and periodic medical exams emphasizing the respiratory system to workers who regularly handle chlorine. **Target Organs:** Respiratory system. **Primary Entry:** Inhalation, skin contact. **Acute Effects:** Burning and severe irritation of the eyes, skin, and URT; wheezing, shortness of breath; nausea; vomiting; headache; dizziness; and (delayed) pulmonary edema. **Chronic Effects:** Reduced respiratory capacity may result from chronic low-level exposure to chlorine.

FIRST AID: Eyes. Immediately flush eyes, including under the eyelids, gently but thoroughly with plenty of running water for at least 15 minutes. **Skin.** Skin contact with chlorine causes severe damage from frostbite (cryogenic injury) as well as chemical burns. Irrigate the area with water and treat the exposed person accordingly. **Inhalation.** Remove exposed person to fresh air; restore and/or support his or her breathing as needed. Recommended treatment includes administering pure oxygen gas (O_2) as soon as symptoms of exposure develop (Genium ref. 39, p. 1975). Observe exposed person for respiratory effects. **Ingestion.** This type of exposure to chlorine is highly unlikely because it is a gas.

GET MEDICAL HELP (IN PLANT, PARAMEDIC, COMMUNITY) FOR ALL EXPOSURES. Seek prompt medical assistance for further treatment, observation, and support after first aid.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Spill/Leak: Preplan and carefully explain proper emergency procedures to relevant personnel. Notify safety personnel, evacuate all nonessential personnel, provide maximum explosion-proof ventilation, and eliminate all sources of ignition immediately. Cleanup personnel must wear protection against contact with and inhalation of vapor (see sect. 8). Try to shut off the flow of chlorine gas. Use a water spray to protect personnel attempting to stop the leak.

Waste Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow Federal, state, and local regulations.

OSHA Designations
Air Contaminant (29 CFR 1910.1000 Subpart Z): Not Listed
EPA Designations (40 CFR 302.4)
RCRA Hazardous Waste: Listed without Number
CERCLA Hazardous Substance, Reportable Quantity: 10 lbs (4.54 kg)

SECTION 8. SPECIAL PROTECTION INFORMATION

Goggles: Always wear protective eyeglasses or chemical safety goggles. Follow the eye- and face-protection guidelines in 29 CFR 1910.133. **Respirator:** Use a NIOSH-approved respirator per the *NIOSH Pocket Guide to Chemical Hazards* for the maximum-use concentrations and/or the exposure limits cited in section 2. Follow the respirator guidelines in 29 CFR 1910.134. For emergency or nonroutine use (e.g., cleaning reactor vessels or storage tanks) wear an SCBA with a full facepiece operated in the pressure-demand or positive-pressure mode. **Warning:** Air-purifying respirators will *not* protect workers in oxygen-deficient atmospheres. **Other:** Wear impervious gloves; boots; aprons; and clean, impervious, body-covering clothing to prevent any possibility of skin contact. **Ventilation:** Install and operate general and local ventilation systems powerful enough to maintain airborne levels of chlorine gas strictly below the OSHA PEL standard cited in section 2. Make all ventilation systems of maximum explosion-proof design, e.g., nonsparking, electrically grounded and bonded, etc. **Safety Stations:** Make eyewash stations, washing facilities, and safety showers available in areas of use and handling. **Contaminated Equipment:** Contact lenses pose a special hazard; soft lenses may absorb irritants, and all lenses concentrate them. Do *not* wear contact lenses in any work area. **Other:** Use enclosed-containment processing operations; otherwise, the ventilation systems may not be able to keep airborne levels of chlorine below the legal ceiling limit of 1 ppm (3 mg/m³) set by OSHA. Automatic air-monitoring sensing equipment connected to an alarm system is recommended for continual-use operations. **Comments:** Practice good personal hygiene; always wash thoroughly after using this material. Avoid transferring it from your hands to your mouth while eating, drinking, or smoking. Do *not* eat, drink, or smoke in any work area. Avoid prolonged skin contact with this material.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Storage/Segregation: Store chlorine in a cool, dry, well-ventilated area away from organics, sources of ignition, any flammable or explosive materials, cylinders containing oxygen, and incompatible chemicals (see sect. 5). Use outside or detached storage. Store cylinders upright and secure them tightly. **Special Handling/Storage:** Chlorine is shipped/stored as a pressurized gas in cylinders or tank cars. Protect them against physical damage and regularly inspect them for cracks, leaks, or faulty valves. Follow standard safety procedures for handling compressed, corrosive gases. Electrically ground and bond all containers used in shipping and transferral operations to prevent static sparks. Do not drag or slide cylinders containing chlorine; move them in a carefully supervised manner with a suitable hand truck. Do not smoke in use or storage areas. **Engineering Controls:** All engineering systems (ventilation, production, etc.) must be of maximum explosion-proof design. Use chlorine in closed engineering systems to prevent dispersion of this gas into general work areas. Monitor all piping systems, reactor vessels, and holding tanks for unwanted moisture contamination or buildup. Liquid chlorine levels should be less than 85% of a tank's or cylinder's capacity. **Comments:** Perform all operations with chlorine carefully to prevent accidental ignition of explosive mixtures. Prevent any contact with incompatible chemicals (see sect. 5). Keep the valve-protection cap in place until immediately before using chlorine. Insert a check valve or trap into the transferral line to prevent a dangerous backflow into the original container. Use a pressure-reducing regulator when connecting a storage vessel to a lower-pressure piping system. A trained chemist or safety specialist familiar with the physical and chemical properties of this gas should be present during all work operations.

Transportation Data (49 CFR 172.101-2)
DOT Shipping Name: Chlorine
DOT Class: Nonflammable Gas
References: 1, 2, 12, 73, 84-94, 100, 103.
DOT Label: Nonflammable Gas *and* Poison
DOT ID No. UN1017
IMO Label: Poison Gas
IMO Class: 2.3

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Prepared by PJ Igoe, BS
Industrial Hygiene Review: DJ Wilson, CIH
Medical Review: MJ Hardies, MD

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Material Safety Data Sheet

From Genium's Reference Collection
Genium Publishing Corporation
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GENIUM PUBLISHING CORP.

No. 315

CHLOROFORM
(Revision D)
Issued: August 1979
Revised: April 1988

SECTION 1. MATERIAL IDENTIFICATION

25

Material Name: CHLOROFORM

Description (Origin/Uses): Used as a solvent for fats, oils, rubber, alkaloids, waxes, and resins; as a cleansing agent.

Other Designations: Trichloromethane; $CHCl_3$; NIOSH *RTECS* No. FS9100000; CAS No. 0067-66-3

Manufacturer: Contact your supplier or distributor. Consult the latest edition of the *Chemicalweek Buyers' Guide* (Genium ref. 73) for a list of suppliers.

HMIS	
H	2
F	0
R	0
PPG*	
*See sect. 8	
R	1
I	3
S	2
K	0

SECTION 2. INGREDIENTS AND HAZARDS

SECTION 2. INGREDIENTS AND HAZARDS	%	EXPOSURE LIMITS
Chloroform, CAS No. 0067-66-3	Ca 100	**OSHA PEL** Ceiling: 50 ppm, 240 mg/m³ **ACGIH TLV, 1987-88** TLV-TWA: 10 ppm, 50 mg/m³ **NIOSH REL** Ceiling: 2 ppm, 9.78 mg/m³ **Toxicity Data*** Human, Oral, LD_{Lo}: 140 mg/kg Rat, Oral, LD_{50}: 908 mg/kg
*See NIOSH, *RTECS*, for additional toxicity data with references to mutagenic, reproductive, tumorigenic, and irritative effects.		

SECTION 3. PHYSICAL DATA

Boiling Point: 142°F (61°C)
Melting Point: -82.3°F (-63.5°C)
Vapor Pressure: 158.4 Torrs at 68°F (20°C)
Vapor Density (Air = 1): 4.13

Water Solubility (%): 0.822 ml of $CHCl_3$ per 100 ml of H_2O at 68°F (20°C)
% Volatile by Volume: 100
Molecular Weight: 119 Grams/Mole
Specific Gravity (H_2O = 1): 1.484 at 68°F (20°C)

Appearance and Odor: A heavy, colorless, clear, volatile liquid; characteristic, pleasant, ethereal, sweet odor (recognition threshold: 0.3 mg/m³); sweet taste.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temperature	Flammability Limits in Air % by Volume	LOWER	UPPER
•	•		•	•

Extinguishing Media: *Chloroform does not burn. Use an agent that will put out the surrounding fire.

Unusual Fire or Explosion Hazards: None reported.

Special Fire-fighting Procedures: Wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode.

SECTION 5. REACTIVITY DATA

Chloroform is stable if kept in closed containers and protected from air and sunlight. It does not undergo hazardous polymerization; however, even when stabilized with ethanol, this material develops acidity from prolonged exposure to air and light.

Chemical Incompatibilities: This material is incompatible with strong alkalies.

Conditions to Avoid: Avoid prolonged exposure to air and light and to strong alkalies.

Hazardous Products of Decomposition: Toxic and corrosive gases like hydrochloric acid (HCl), chlorine (Cl_2), carbon monoxide (CO), and oxides of chlorine (ClO_2) can be produced during fires.

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SECTION 6. HEALTH HAZARD INFORMATION

Chloroform is listed as a suspected human carcinogen by ACGIH.

Summary of Risks: Exposure to this material affects the central nervous system (anesthesia); heart (arrhythmia, ventricular tachycardia, bradycardia); liver (necrosis, hepatoma); kidney (necrosis); and it is an embryonic toxin. Fatalities are associated with cardiovascular depression and ventricular fibrillation.
Medical Conditions Aggravated by Long-Term Exposure: Ailments of the heart, liver, and kidneys may be worsened by exposure to chloroform. **Target Organs:** Liver, kidneys, heart, skin, eyes. **Primary Entry:** Skin contact, inhalation.
Acute Effects: Dizziness, mental dullness, nausea, headache, fatigue, and anesthesia. **Chronic Effects:** Possible cancer.
FIRST AID
Eyes: Immediately flush eyes, including under the eyelids, gently but thoroughly with plenty of running water for at least 15 minutes. **Skin:** Immediately wash the affected area with soap and water. **Inhalation:** Remove the exposed person to fresh air; restore and/or support his or her breathing as needed.
Ingestion: Never give anything by mouth to someone who is unconscious or convulsing. If the exposed person is responsive, give him or her several glasses of milk or water to drink and induce vomiting. Repeat if large quantities were ingested.
Comments: Workers who are regularly exposed to chloroform require preplacement and periodic medical exams emphasizing kidney, liver, skin, and central nervous system functions. Carefully evaluate each exposure that produces a noticeable effect to determine the extent to which factors like alcohol or drugs have affected it.

GET MEDICAL HELP (IN PLANT, PARAMEDIC, COMMUNITY) FOR ALL EXPOSURES. Seek prompt medical assistance for further treatment, observation, and support after first aid.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Spill/Leak: Notify safety personnel of a chloroform spill or leak. Provide ventilation. Cleanup personnel need protection against contact with and inhalation of vapor (see sect. 8). Chloroform vapor is heavier than air and will collect in low-lying areas. Contain large spills and collect waste or absorb it with an inert material such as sand, earth, or vermiculite. Place waste liquid or absorbent into closable containers for disposal. Keep waste out of sewers, watersheds, and waterways.
Waste Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow Federal, state, and local regulations.
OSHA Designations
Air Contaminant (29 CFR 1910.1000 Subpart Z)
EPA Designations (40 CFR 302.4)
RCRA Hazardous Waste, No. U044
CERCLA Hazardous Substance, Reportable Quantity: 5000 lbs (2270 kg)

SECTION 8. SPECIAL PROTECTION INFORMATION

Goggles: Always wear protective eyeglasses or chemical safety goggles. Where splashing is possible, wear a full face shield as a supplementary protective measure. Follow the eye- and face-protection guidelines in 29 CFR 1910.133. **Respirator:** Wear a NIOSH-approved respirator per the *NIOSH Pocket Guide to Chemical Hazards* for the maximum-use concentrations and/or the exposure limits cited in section 2. Follow the respirator guidelines in 29 CFR 1910.134. For emergency or nonroutine use (e.g., cleaning reactor vessels or storage tanks), wear an SCBA with a full facepiece operated in the pressure-demand or positive-pressure mode. **Warning:** Air-purifying respirators will *not* protect workers in oxygen-deficient atmospheres. **Other:** To prevent contact with skin, wear impervious gloves, boots, aprons, gauntlets, etc., as required by the specific work environment. **Ventilation:** Install and operate general and local ventilation systems that are powerful enough to maintain airborne levels of chloroform below the OSHA PEL standard cited in section 2. **Safety Stations:** Make eyewash stations, washing facilities, and safety showers available in use and handling areas. **Contaminated Equipment:** Contact lenses pose a special hazard; soft lenses may absorb irritants and all lenses concentrate them. Do *not* wear contact lenses in any work area. Remove contaminated clothing and launder it before wearing it again; clean this material from shoes and equipment. **Comments:** Practice good personal hygiene; always wash thoroughly after using this material. Keep it off of your clothing and equipment. Avoid transferring it from your hands to your mouth while eating, drinking, or smoking. Do *not* eat, drink, or smoke in any work area. Avoid inhalation of vapor!

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Storage/Segregation: Store chloroform in closed containers away from light and alkalies.

Special Handling/Storage: Protect containers from physical damage. Do not transfer chloroform through plastic or rubber hoses or pipes.

Transportation Data (49 CFR 172.101-2)
DOT Shipping Name: Chloroform
DOT Class: ORM-A
DOT Label: None
DOT ID No. UN1888
IMO Label: Poison
IMO Class: 6.1

References: 1, 2, 12, 73, 84-94, 100, 103.

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Prepared by PJ Igoe, BS
Industrial Hygiene Review: DJ Wilson, CIH
Medical Review:

CEDAR CHEMICAL CORPORATION
MEMPHIS. TENNESSEE

MATERIAL SAFETY DATA SHEET
Equivalent to OSHA form 174

PRODUCT NAME: TECHNICAL DINOSEB DATE: 08/15/86 PAGE 1
EPA REG. NO.: 56077-3

SECTION I

Manufacturer's Name: Cedar Chemical Corporation
5100 Poplar Ave. 24th Floor
Memphis. TN 38137
Emergency Phone Number: 1-800-424-9300
Information Phone Number: 1-601-636-1231
Prepared by: M. S. Bernard

SECTION II HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

INGREDIENT	OSHA PEL	ACGIH TLV	PERCENT
Dinoseb	n/d	0.3mg/m³	95.00
Dinoseb (2-sec-butyl-4,6-dinitrophenol) CAS = 88-85-7			
Impurities	n/d	n/d	5.00

SECTION III PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point(°F)	above 212	Specific Gravity	1.258
Vapor Pressure(mm Hg.)	below 1	Melting Point(°F)	90
Vapor Density(Air=1)	n/a	Evaporation Rate	n/d

Solubility in Water: 0.0052g/100ml
Appearance and Odor: Brown solid. organic acid odor

SECTION IV FIRE AND EXPLOSION HAZARD DATA

Flash Point(Method Used): 350.6°F TCC
Flammable Limits: LEL- n/d UEL- n/d
Extinguishing Media:
Water Fog. Foam. Alcohol Foam. CO_2. and Dry Chemical

CONTINUED ON PAGE 2

Special Fire Fighting Procedures:
Self-contained air supply. Confine water used in fire fighting.

Unusual Fire and Explosion Hazards:
Noxious fumes may form. Material undergoes rapid exothermic decomposition at 190°C. Vapors may ignite.

SECTION V REACTIVITY DATA

Stability: Stable in normal use and storage.
Conditions to Avoid: Heating above 100°C. Product undergoes rapid exothermic decomposition at 190°C. Avoid ignition sources.
Incompatibility: Strong Bases and Strong Oxidizers
Hazardous Decomposition or Byproducts: Oxides of Nitrogen
Hazardous Polymerization: Will not occur. No known conditions to avoid.

SECTION VI HEALTH HAZARD DATA

Route(s) of Entry: Inhalation: Moderate Toxicity
Skin: Readily Absorbed
Ingestion: Highly Toxic

Health Hazards (Acute and Chronic):
Oral Ingestion: High Single Dose Oral Toxicity. LD_{50} for Rats 25 mg/kg. May be fatal if swallowed.
Eye Contact: May cause severe irritation and corneal injury. Corneal injury should heal in 1-2 weeks.
Skin Contact: May cause slight irritation or mild burn. Colors the skin yellow.
Skin Absorption: Readily absorbed through skin, high toxicity. LD_{50} rabbits 80mg/kg.
Inhalation: May be irritating. Cedar industrial guide for Dinoseb is 0.3 mg/m^3.

Carcinogenicity: NTP: Negative
IARC Monographs: Negative
OSHA Regulated: Negative

Signs and Symptoms of Exposure:
Fatigue, sweating, thirst, and fever. Increased metabolic rate.

Medical Conditions Generally Aggravated by Exposure:
Liver and kidney problems may be aggravated by extreme exposure.

Emergency and First Aid Procedures:

Oral Ingestion: Toxic by ingestion. Induce vomiting and seek medical help immediately.

Eye Contact: Flush immediately with continuous irrigation with flowing water for at least thirty minutes. Seek medical consultation immediately.

Skin Contact: Immediately flush skin with plenty of water for at least fifteen minutes while removing contaminated clothing. Consult physician. Wash clothing before reuse.

Inhalation: Remove to fresh air if effects occur. Consult physician.

Note to Physician:

Eyes: Stain for evidence of corneal injury. If cornea is burned, instill antibiotic steroid preparation frequently. Consult ophthalmologist. May cause temporary injury.

Overexposure: Treat for symptoms. No specific antidote. Human effects not established.

SECTION VII PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to Be Taken in Case Material Is Released or Spilled:

Use proper safety equipment. Absorb spill with absorbant inert material such as oil-dry. Dike area for large spills. Keep out of streams and water supplies.

Waste Disposal Method:

Dispose of in non-crop area away from water supplies or in an approved landfill in accordance with State, Federal, and local regulations.

Precautions to Be Taken in Handling and Storing:

Do not get on skin, on clothing, or in eyes. Keep out of reach of children.

Other Precautions:

Do not breathe spray mists. Keep away from heat or flame.

SECTION VIII CONTROL MEASURES

Respiratory Protection:

None normally needed. During spraying use organic vapor respirator.

Ventilation: Required to control level of dinoseb.

Protective Gloves: Impervious rubber gloves

Eye Protection: Chemical workers' goggles

Other Protective Clothing or Equipment: Rubber boots and apron and body-covering clothing.

Work/Hygenic Practices: Shower after handling.

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Material Safety Data Sheet

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GENIUM PUBLISHING CORP.

No. 385

ETHYL BENZENE
(Revision A)
Issued: August 1978
Revised: November 1988

SECTION 1. MATERIAL IDENTIFICATION

27

Material Name: ETHYL BENZENE

Description (Origin/Uses): Used as a solvent and as an intermediate in the production of styrene monomer.

Other Designations: Phenylethane; Ethylbenzol; $C_2H_5C_6H_5$; CAS No. 0100-41-4

Manufacturer: Contact your supplier or distributor. Consult the latest edition of the *Chemicalweek Buyers' Guide* (Genium ref. 73) for a list of suppliers.

NFPA

HMIS	
H 2	R 1
F 3	I 3
R 0	S 2
PPG*	K 4

*See sect. 8

SECTION 2. INGREDIENTS AND HAZARDS

	%	EXPOSURE LIMITS
Ethyl Benzene, CAS No. 0100-41-4	Ca 100	**OSHA PELs** 8-Hr TWA: 100 ppm, 435 mg/m³ 15- Min STEL: 125 ppm, 545 mg/m³ **ACGIH TLVs, 1988-89** TLV-TWA: 100 ppm, 435 mg/m³ TLV-STEL: 125 ppm, 545 mg/m³ **Toxicity Data*** Human, Inhalation, TC_{Lo}: 100 ppm (8 Hrs) Rat, Oral, LD_{50}: 3500 mg/kg

*See NIOSH, *RTECS* (DA0700000), for additional data with references to reproductive, irritative, and mutagenic effects.

SECTION 3. PHYSICAL DATA

Boiling Point: 277°F (136°C)
Melting Point: -139°F (-95°C)
Vapor Pressure: 7.1 Torrs at 68°F (20°C)
Vapor Density (Air = 1): 3.7
% Volatile by Volume: Ca 100

Molecular Weight: 106 Grams/Mole
Solubility in Water (%): Slight
Specific Gravity (H_2O = 1): 0.86258 at 77°F (25°C)

Appearance and Odor: A clear, colorless, flammable liquid; characteristic aromatic hydrocarbon odor.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method: 64°F (18°C) CC	Autoignition Temperature: 810°F (432.22°C)	LEL: 1% v/v	UEL: 6.7% v/v

Extinguishing Media: Use foam, dry chemical, or carbon dioxide to put out ethyl benzene fires. A water spray may be ineffective in extinguishing the fire, because it can scatter and spread the burning liquid. Use water spray to cool fire-exposed containers of ethyl benzene, to disperse ethyl benzene vapor, and to protect personnel attempting to stop an ethyl benzene leak. **Unusual Fire or Explosion Hazards:** This liquid can readily form explosive vapor-air mixtures, especially when heated. Ethyl benzene vapor is heavier than air and may travel a considerable distance to a low-lying source of ignition and flash back to its origin. **Special Fire-fighting Procedures:** Wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode.

SECTION 5. REACTIVITY DATA

Stability/Polymerization: Ethyl benzene is stable in closed containers during routine operations. Hazardous polymerization cannot occur. **Chemical Incompatibilities:** Hazardous chemical reactions can occur between ethyl benzene and strong oxidizing agents, acids, ammonia, and bases. *Conditions to Avoid:* Avoid any exposure to sources of ignition such as heat, sparks, open flame, and lighted tobacco products, etc., and to incompatible chemicals. Use caution when entering confined spaces, particularly low-lying areas where explosive concentrations of ethyl benzene vapor may be present. Provide good ventilation to such areas to prevent the concentration of this vapor. **Hazardous Products of Decomposition:** Thermal-oxidative degradation can include toxic gases such as carbon monoxide and/or aromatic hydrocarbon gases.

SECTION 6. HEALTH HAZARD INFORMATION

Carcinogenicity: Ethyl benzene is not listed as a carcinogen by the NTP, IARC, or OSHA.
Summary of Risks: Ethyl benzene vapor is severely irritating to the eyes and to the mucous membranes of the respiratory system. Sustained inhalation of excessive levels can cause depression of the central nervous system (CNS) characterized by dizziness, headache, narcosis, and coma. Skin contact with liquid ethyl benzene causes irritation; dermatitis and defatting can also develop. The acute oral toxicity of ethyl benzene is low; however, ingestion of it presents a serious aspiration hazard. Aspirating even a small amount into the lungs can result in extensive edema (lungs filled with fluid) and hemorrhaging of the lung tissue. No systemic effects are expected at the levels that produce pronounced, unignorable, disagreeable skin and eye irritation. The TLVs cited in section 2 are set to prevent this intolerable irritation. **Medical Conditions Aggravated by Long-Term Exposure:** None reported. **Target Organs:** Skin, eyes, respiratory system, and CNS. **Primary Entry:** Inhalation, skin contact **Acute Effects:** Irritation of the skin, eyes, and respiratory system. Also, cardiac-rhythm disturbance due to sensitization: acute bronchitis, bronchospasm, pulmonary and laryngeal edema; euphoria; headache; giddiness; dizziness; and incoordination, as well as possible depression; confusion; and coma. **Chronic Effects:** None reported. **First Aid:** Eyes. Immediately

SECTION 6. HEALTH HAZARD INFORMATION, cont.

flush eyes, including under the eyelids, gently but thoroughly with flooding amounts of running water for at least 15 minutes. Skin. Rinse the affected area with plenty of water, then wash it with soap and water. Inhalation. Remove the exposed person to fresh air; restore and/or support his or her breathing as needed. Have qualified medical personnel administer oxygen as required. Ingestion. Unlikely. Should this type of exposure occur, the aspiration hazard must be considered. Do not induce vomiting unless directed to do so by a physician. To prevent aspiration by spontaneous vomiting, keep the victim's head low (between his or her knees). Get medical help (in plant, paramedic, community) for all exposures. Seek prompt medical assistance for further treatment, observation, and support after first aid. Note to Physician: Professional judgment is required as to whether or not to induce vomiting because of the possibility of aspiration. A gastric lavage may be administered, followed by saline cathartic, if this procedure is appropriate to the specific incident. Monitor cardiac and pulmonary functions.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Spill/Leak: Notify safety personnel, evacuate unnecessary personnel, eliminate all sources of ignition immediately, and provide adequate explosion-proof ventilation. Cleanup personnel need protection against skin or eye contact with this liquid as well as inhalation of its vapor (see sect. 8). Contain large spills and collect waste or absorb it with an inert material such as sand, earth, or vermiculite. Use nonsparking tools to place waste liquid or absorbent *into* closable containers for disposal. Keep waste out of sewers, watersheds, and waterways. Waste Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow Federal, state, and local regulations.

OSHA Designations

Listed as an Air Contaminant (29 CFR 1910.1000 Subpart Z).

EPA Designations (40 CFR 302.4)

CERCLA Hazardous Substance, Reportable Quantity: 1000 lbs (454 kg), per the Clean Water Act (CWA), §§ 311 (b) (4) and 307 (a).

SECTION 8. SPECIAL PROTECTION INFORMATION

Goggles: Always wear protective eyeglasses or chemical safety goggles. Where splashing is possible, wear a full face shield. Follow OSHA eye- and face-protection regulations (29 CFR 1910.133). Respirator: Wear a NIOSH-approved respirator per Genium reference 88 for the maximum-use concentrations and/or the exposure limits cited in section 2. Follow OSHA respirator regulations (29 CFR 1910.134). For emergency or nonroutine operations (spills or cleaning reactor vessels and storage tanks), wear an SCBA. Warning: Air-purifying respirators will *not* protect workers in oxygen-deficient atmospheres. Other: Wear impervious gloves, boots, aprons, and gauntlets, etc., to prevent prolonged or repeated skin contact with this material. Ventilation: Install and operate general and local maximum, explosion-proof ventilation systems powerful enough to maintain airborne levels of this material below the OSHA PEL standard cited in section 2. Local exhaust ventilation is preferred because it prevents dispersion of the contaminant into the general work area by eliminating it at its source. Consult the latest edition of Genium reference 103 for detailed recommendations. Safety Stations: Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in work areas. Contaminated Equipment: Contact lenses pose a special hazard; soft lenses may absorb irritants, and all lenses concentrate them. Do *not* wear contact lenses in any work area. Remove contaminated clothing and launder it before wearing it again; clean this material from shoes and equipment. Comments: Practice good personal hygiene; always wash thoroughly after using this material and before eating, drinking, smoking, using the toilet, or applying cosmetics. Keep it off your clothing and equipment. Avoid transferring it from your hands to your mouth while eating, drinking, or smoking. Do *not* eat, drink, or smoke in any work area. Do not inhale ethyl benzene vapor.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Storage/Segregation: Store ethyl benzene in closed containers in a cool, dry, well-ventilated area away from sources of ignition and strong oxidizers. Protect containers from physical damage. Special Handling/Storage: Outside, isolated, detached, or remote storage is recommended for large quantities of ethyl benzene. Isolate bulk storage areas from acute fire hazards. Engineering Controls: Make sure all engineering systems (production, transportation) are of maximum explosion-proof design. To prevent static sparks, electrically ground and bond all containers, pipelines, etc., used in shipping, transferring, reacting, production, and sampling operations. Other: Use safety cans for transferring small amounts of ethyl benzene.

Transportation Data (49 CFR 172.101-2)

DOT Shipping Name: Ethyl Benzene
DOT Hazard Class: Flammable Liquid
ID No. UN1175
DOT Label: Flammable Liquid
DOT Packaging Exceptions: 49 CFR 173.118
DOT Packaging Requirements: 49 CFR 173.119

IMO Shipping Name: Ethylbenzene
IMO Hazard Class: 3.2
IMO Label: Flammable Liquid
IMDG Packaging Group: II

References: 1, 26, 38, 84-94, 100, 116, 117, 120, 122.

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Prepared by PJ Igoe, BS

Industrial Hygiene Review: DJ Wilson, CIH

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METHANEARSONIC ACID, SODIUM SALT

MSA

Common Synonyms
Disodium methane arsonate
Monosodium methane arsonate
MSMA
DSMA
Disodium methyl arsonate
Monosodium methyl arsonate

Solid — Colorless solid, solution may be red or green

Solid may dust or form in water; solid and solution mix with water.

Stop discharge if possible
Avoid contact with solid and solution
Isolate and remove discharged material
Notify local health and pollution control agencies

Fire

Not Combustible
POISONOUS GASES ARE PRODUCED WHEN HEATED
Wear goggles and self-contained breathing apparatus

Exposure

CALL FOR MEDICAL AID

SOLID OR SOLUTION
Irritating to eyes and skin
If unconscious, not alcohol intoxicated, vomiting, or case of convulsions
Remove contaminated clothing and shoes
Flush affected areas with plenty of water
IF IN EYES, hold eyelids open and flush with plenty of water
IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk and have victim induce vomiting
IF SWALLOWED and victim is UNCONSCIOUS OR HAVING CONVULSIONS, do nothing except keep victim warm

Water Pollution

Dangerous to aquatic life in high concentrations
May be dangerous if it enters water intakes

Notify local health and wildlife officials
Notify operators of nearby water intakes

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook)
Isolate at ***impoundment, water use or shore
Should be removed
Chemical and physical treatment

2. LABEL

2.1 Category: Poison
2.2 Class: 6

3. CHEMICAL DESIGNATIONS

3.1 CG Compatibility Class: Not listed
3.2 Formula: $CH_3AsO(OH)(ONa)$
$CH_3AsO(ONa)_2 \cdot 6H_2O$
3.3 IMO/IMR Designation: 6.1/1687
3.4 DOT ID No.: 1687
3.5 CAS Registry No.: 2163-80-6

4. OBSERVABLE CHARACTERISTICS

4.1 Physical State (as shipped): Solid or water solution
4.2 Color: Colorless, solutions may contain red or green dyes
4.3 Odor: None

5. HEALTH HAZARDS

5.1 Personal Protective Equipment: Protective clothing to prevent contact with skin; chemical goggles
5.2 Symptoms Following Exposure: Solutions poisoning by ingestion causes salty taste, burning in throat and stomach, and intestinal pain. Acute toxicity indicated by headaches, vomiting, shock, convulsions, coma/death. About 1 ounce to 1 pound must be taken to cause these symptoms
5.3 Treatment of Exposure: INGESTION: induce vomiting, give water and starch; give a saline cathartic such as sodium sulfate. SKIN: wash with soap and water. EYES: wash with water; consult physician if irritation remains
5.4 Threshold Limit Value: Does not establish
5.5 Short Term Inhalation Limits: Not pertinent
5.6 Toxicity by Ingestion: Grade 2; LD_{50} = 0.5-5 g/kg (rat)
5.7 Late Toxicity: Does not establish
5.8 Vapor (Gas) Irritant Characteristics: None
5.9 Liquid or Solid Irritant Characteristics: Powdered material may cause skin sensitivity
5.10 Odor Threshold: Not pertinent
5.11 IDLH Value: Does not establish

6. FIRE HAZARDS

6.1 Flash Point: Not flammable
6.2 Flammable Limits in Air: Not flammable
6.3 Fire Extinguishing Agents: Not pertinent
6.4 Fire Extinguishing Agents Not to be Used: Not pertinent
6.5 Special Hazards of Combustion Products: Toxic gases may be generated in fire.
6.6 Behavior in Fire: Not pertinent
6.7 Ignition Temperature: Not flammable
6.8 Electrical Hazard: Not pertinent
6.9 Burning Rate: Not flammable
6.10 Adiabatic Flame Temperature: Data not available
6.11 Stoichiometric Air to Fuel Ratio: Data not available
6.12 Flame Temperature: Data not available

7. CHEMICAL REACTIVITY

7.1 Reactivity With Water: None
7.2 Reactivity with Common Materials: None
7.3 Stability During Transport: Stable
7.4 Neutralizing Agents for Acids and Caustics: Not pertinent
7.5 Polymerization: Not pertinent
7.6 Inhibitor of Polymerization: Not pertinent
7.7 Molar Ratio (Reactant to Product): Data not available
7.8 Reactivity Group: Data not available

8. WATER POLLUTION

8.1 Aquatic Toxicity:
> 1000 ppm/48 hr/bluegill sunfish/LC_{50}/fresh water
8.2 Waterfowl Toxicity: Data not available
8.3 Biological Oxygen Demand (BOD): Data not available
8.4 Food Chain Concentration Potential: Data not available

9. SHIPPING INFORMATION

9.1 Grades of Purity: Technical grade (DSMA) contains water crystallization. Salts are often shipped as solutions in water with concentrations up to about 30% solids
9.2 Storage Temperature: Ambient
9.3 Inert Atmosphere: No requirement
9.4 Venting: Open

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)
SS

11. HAZARD CLASSIFICATIONS

11.1 Code of Federal Regulations: Poison, B
11.2 NAS Hazard Rating for Bulk Water Transportation: Not rated
11.3 NFPA Hazard Classification: Not rated

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 Physical State at 15°C and 1 atm: Solid or water solution
12.2 Molecular Weight: 162 (MSMA); 202 (MSMA hexahydrate)
12.3 Boiling Point at 1 atm: Decomposes
12.4 Freezing Point:
(MSMA) 243°F
= 117°C = 390°K
(DSMA) 197°F = 92°C = 352°K
12.5 Critical Temperature: Not pertinent
12.6 Critical Pressure: Not pertinent
12.7 Specific Gravity:
(DSMA) 1.9 at 20°C (sand)
(MSMA containing 3.4-1.5 at 20°C (sand)
12.8 Liquid Surface Tension: Not pertinent
12.9 Liquid Water Interfacial Tension: Not pertinent
12.10 Vapor (Gas) Specific Gravity: Not pertinent
12.11 Ratio of Specific Heats of Vapor (Gas): Not pertinent
12.12 Latent Heat of Vaporization: Not pertinent
12.13 Heat of Combustion: Not pertinent
12.14 Heat of Decomposition: Not pertinent
12.15 Heat of Solution: Not pertinent
12.16 Heat of Polymerization: Not pertinent
12.17 Heat of Fusion: Data not available
12.18 Limiting Value: Data not available
12.19 Reid Vapor Pressure: Data not available

NOTES

Material Safety Data Sheet

from Genium's Reference Collection

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GENIUM PUBLISHING CORP.

No. 310
METHYLENE CHLORIDE
(Revision F)

Issued: September 1985
Revised: November 1988

SECTION 1. MATERIAL IDENTIFICATION

27

Material Name: METHYLENE CHLORIDE

Description (Origin/Uses): Used widely in paint removers, as a solvent for plastics, as a degreasing agent, in propellant mixtures for aerosol sprays, and as a blowing agent in foams.

Other Designations: Dichloromethane; Freon 30®; Methane Dichloride; Methylene Bichloride; Methylene Dichloride; CH_2Cl_2; CAS No. 0075-09-2

Manufacturer: Contact your supplier or distributor. Consult the latest edition of the *Chemicalweek Buyers' Guide* (Genium ref. 73) for a list of suppliers.

HMIS			NFPA
H	2	R 1	
F	1	I 3	
R	0	S 3	
PPG*		K 1	

*See sect. 8

SECTION 2. INGREDIENTS AND HAZARDS/EXPOSURE LIMITS

Methylene Chloride, ca 100%

OSHA PEL
8-Hour TWA: 500 ppm
Ceiling: 1000 ppm Acceptable Maximum Peak above the Ceiling: 2000 ppm for 5 Minutes in Any 2-Hour Period

ACGIH TLV, 1988-89
TLV-TWA: 50 ppm, 175 mg/m³
(Adopted 1988-89)

Toxicity Data*
Rat, Oral, LD_{50}: 2136 mg/kg
Human, Inhalation, TC_{Lo}: 500 ppm (8 Hours)

*See NIOSH, *RTECS* (PA8050000), for additional data with references to irritative, reproductive, mutagenic, and tumorigenic effects.

SECTION 3. PHYSICAL DATA

Boiling Point: 103.55°F (39.75°C) at 76 Torrs
Melting Point: -142°F (-96.7°C)
Vapor Density (Air = 1): 2.9
Vapor Pressure: 440 Torrs at 77°F (25°C)

Molecular Weight: 84.94 Grams/Mole
Solubility in Water (%): 1% by Weight
Specific Gravity (H_2O = 1): 1.3255 at 68°F (20°C)
% Volatile by Volume: Ca 100

Appearance and Odor: A clear, colorless, volatile liquid; distinctive, penetrating, ethereal odor. The odor will not serve as a useful warning property because concentrations of 100 ppm are not easily perceptible. Most persons can detect this odor at above 300 ppm.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point*	Autoignition Temperature: 1033°F (556°C)	LEL: 12% v/v	UEL: 19% v/v

Extinguishing Media: *Methylene chloride is not flammable under ordinary conditions. However, flammable vapor-air mixtures can form at approximately 212°F (100°C). Use water spray to cool fire-exposed containers and to flush spills away from exposures. Use extinguishing agents that will put out the surrounding fire. **Unusual Fire or Explosion Hazards:** Methylene chloride vapor is heavier than air and may collect and concentrate in low-lying, confined spaces. The high vapor pressure of methylene chloride means that when it is spilled, its vapor concentration in air can increase rapidly. If this vapor is heated, an explosion hazard is associated with the vapor-air mixture. Containers of this material may rupture violently if they are involved in fires. **Special Fire-fighting Procedures:** Wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode.

SECTION 5. REACTIVITY DATA

Stability/Polymerization: Methylene chloride is stable in closed containers during routine operations. Hazardous polymerization cannot occur. **Chemical Incompatibilities:** Methylene chloride can react dangerously with nitrogen tetroxide, liquid oxygen, potassium, sodium, sodium-potassium alloys, lithium, potassium hydroxide with N-methyl-N-nitroso urea, potassium *t*-butoxide, and finely powdered aluminum and magnesium. **Conditions to Avoid:** Avoid all exposure to sources of ignition, heat, and incompatible chemicals. Prolonged exposure to water may cause hydrolysis to highly corrosive hydrochloric acid when the temperature is above 140°F (60°C). In oxygen-enriched atmospheres or when heated (>212°F [100°C]), methylene chloride vapor can be readily ignited. **Hazardous Products of Decomposition:** Exposure to high temperature (from open flame, hot surfaces, uninsulated steam lines, welding arcs, etc.) can produce toxic and corrosive thermal-oxidative products of decomposition such as hydrogen chloride, carbon monoxide, and even small quantities of phosgene gas, which is extremely poisonous.

SECTION 6. HEALTH HAZARD INFORMATION

Carcinogenicity: Methylene chloride is listed as a suspected human carcinogen by the ACGIH (which classifies it as a group A2 carcinogen). **Summary of Risks:** Accidental contact of liquid methylene chloride with skin or eyes causes painful irritation and possible burns if not promptly removed. Exposure by way of contaminated gloves, clothing, or paint remover formulations can produce these same irritant effects. Long-term exposure to mild or moderate doses of methylene chloride may cause a delayed (24 to 48 hours) onset of dizziness, headache, mental confusion, slurred speech, double vision, and sleeplessness. Medical recovery can be slow. Overexposure to methylene chloride can cause elevated levels of carboxy hemoglobin in the blood (this same effect results from overexposure to carbon monoxide). **Medical Conditions Aggravated by Long-Term Exposure:** None reported. **Target Organs:** Skin, eyes, respiratory system, CNS, liver, kidneys, and blood. **Primary Entry:** Inhalation, skin contact/absorption. **Acute Effects:** Headache, giddiness, stupor, irritability, fatigue, tingling in the limbs, and narcosis that is not usually fatal if the exposure is terminated before anesthetic death occurs. **Chronic Effects:** The ACGIH classification of this material as a suspected human carcinogen implies that cancer is a possible effect of chronic exposure to methylene chloride. **FIRST AID:** Eyes. Immediately flush eyes, including under the eyelids, gently but thoroughly with

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SECTION 6. HEALTH HAZARD INFORMATION, cont.

flooding amounts of running water for at least 15 minutes. Skin. Rinse the affected area with flooding amounts of water and then wash it with soap and water. Inhalation. Remove the exposed person to fresh air; restore and/or support his or her breathing as needed. Have qualified medical personnel administer oxygen as required. Note to Attending Physician: Do not administer adrenalin. Ingestion. Unlikely. Should this type of exposure occur, do not induce vomiting because of the danger of aspiration. If spontaneous vomiting should occur, position the exposed person's head below his or her trunk to resist aspiration. Get medical help (in plant, paramedic, community) for all exposures. Seek prompt medical assistance for further treatment, observation, and support after first aid. Note to Physician: Absorbed methylene chloride is stored in body fat and metabolizes to carbon monoxide. This produced carbon monoxide increases and sustains carboxyhemoglobin levels in the blood, which concommitantly reduces the oxygen-carrying capacity of the blood. NIOSH advises preplacement and annual medical exams that emphasize liver, kidney, eye, skin, CNS, and respiratory system functions and a complete blood count. Simultaneous exposure to tobacco smoke, alcohol, and carbon monoxide, along with heavy manual labor, increases the body burden of a worker as well as the toxic hazards of the methylene chloride. In significant exposures, serum methylene chloride levels are of no clinical importance. Neurologic and hepatic status as well as carboxy hemoglobin should be monitored.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Spill/Leak: Notify safety personnel, evacuate unnecessary personnel, eliminate all sources of ignition immediately, and provide adequate explosion-proof ventilation. Cleanup personnel need protection against this liquid's contact with the skin or eyes as well as inhalation of its vapor. Contain large spills and collect waste or absorb it with an inert material such as sand, earth, or vermiculite. Use nonsparking tools to place waste liquid or absorbent into closable containers for disposal. Keep waste out of sewers, watersheds, and waterways. Waste Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow Federal, state, and local regulations.

OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000 Subpart Z).
EPA Designations (40 CFR 302.4)
RCRA Hazardous Waste, NO. U080
CERCLA Hazardous Substance, Reportable Quantity: 1000 lbs (454 kg), per the Clean Water Act (CWA), § 307 (a), and the Resource Conservation and Recovery Act (RCRA), § 3001.

SECTION 8. SPECIAL PROTECTION INFORMATION

Goggles: Always wear protective eyeglasses or chemical safety goggles. Where splashing is possible, wear a full face shield. Follow OSHA eye- and face-protection regulations (29 CFR 1910.133). Respirator: Use a NIOSH-approved respirator per Genium reference 88 for the maximum-use concentrations and/or exposure limits cited in section 2. Follow OSHA respirator regulations (29 CFR 1910.134). For emergency or nonroutine operations (spills or cleaning reactor vessels and storage tanks), wear an SCBA. Warning: Air-purifying respirators will *not* protect workers in oxygen-deficient atmospheres. Other: Wear impervious neoprene, PVA, or Viton gloves, boots, aprons, and gauntlets, etc., to prevent any skin contact with liquid methylene chloride. Ventilation: Install and operate general and local maximum, explosion-proof ventilation systems powerful enough to maintain airborne levels of acetone below the exposure limits cited in section 2. Local exhaust ventilation is preferred because it prevents dispersion of the contaminant into the general work area by eliminating it at its source. Consult the latest edition of Genium reference 103 for detailed recommendations. Floor or sump ventilation may be necessary. Safety Stations: Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in work areas. Contaminated Equipment: Contact lenses pose a special hazard; soft lenses may absorb irritants, and all lenses concentrate them. Do *not* wear contact lenses in any work area. Remove contaminated clothing and launder it before wearing it again; clean this material from shoes and equipment. Other: Because the health effects of carbon monoxide and methylene chloride are additive (see sect. 6), workplaces should be equipped with automatic sensing equipment that identifies workroom atmospheric levels of both of these materials. Comments: Practice good personal hygiene; always wash thoroughly after using this material and before eating, drinking, smoking, using the toilet, or applying cosmetics. Keep it off your clothing and equipment. Avoid transferring it from your hands to your mouth while eating, drinking, or smoking. Do *not* eat, drink, or smoke in any work area. Do not inhale methylene chloride vapor.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Storage/Segregation: Store methylene chloride in closed, moisture-proof containers in a cool, dry, well-ventilated area away from sources of ignition, strong oxidizers, caustics, and incompatible chemicals (see sect. 5). Protect containers from physical damage. Special Handling/Storage: Prevent moist air from entering storage containers. Provide ventilation at the floor level in storage areas because methylene chloride vapor is denser than air. Installation of a dryer and a safety seal on each tank is recommended. Aluminum is not recommended for use as a storage material; appropriate storage materials include galvanized iron, black iron, or steel. Engineering Controls: Make sure all engineering systems (production, transportation) are of maximum explosion-proof design. Electrically ground and bond all containers and pipelines used in shipping, transferring, reacting, production, and sampling operations to prevent generating static sparks.

Transportation Data (49 CFR 172.101-2)
DOT Shipping Name: Dichloromethane *or* Methylene Chloride
DOT Hazard Class: ORM-A
ID No. UN1593
DOT Packaging Requirements: 49 CFR 173.605
DOT Packaging Exceptions: 49 CFR 173.505

IMO Shipping Name: Dichloromethane
IMO Hazard Class: 6.1
IMO Label: Saint Andrew's Cross (X)*
IMDG Packaging Group: III

*Harmful-Stow away from Foodstuffs.

References: 1, 26, 38, 84-94, 100, 116, 117, 120, 122.

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Industrial Hygiene Review: DJ Wilson, CIH
Medical Review: MJ Hardies, MD

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METHYL PARATHION

MPT

Solid and liquid with or without odor, solution floats on water. Boiling (freezing) point is 65°F.

AVOID CONTACT WITH LIQUID. Wash skin with soap and water. Remove contaminated clothing promptly. Wear goggles or face shield. Do not induce vomiting. Call for medical aid. Remove and isolate contaminated clothing promptly. Wash thoroughly with soap and water.

Fire

POISONOUS GASES ARE PRODUCED IN FIRE AND WHEN HEATED. Use water spray, dry chemical, or foam. Wear self-contained breathing apparatus and protective clothing. Contain runoff; prevent from entering drains, sewers, or waterways.

Exposure

CALL FOR MEDICAL AID.

LIQUID OR SOLID. POISONOUS IF SWALLOWED OR IF SKIN IS EXPOSED. Avoid breathing vapor. Avoid skin contact. Wash skin with soap and water. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. If SWALLOWED and victim is CONSCIOUS, have victim drink water or milk and induce vomiting. If SWALLOWED and victim is UNCONSCIOUS OR HAVING CONVULSIONS, do nothing except maintain victim's airway.

Water Pollution

HARMFUL TO AQUATIC LIFE IN VERY LOW CONCENTRATIONS. Solution is toxic to mammals. May be dangerous if it enters water intakes. Notify local health and wildlife officials. Notify operators of nearby water intakes.

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook.)

Wear protective clothing. Wear self-contained breathing apparatus. Restrict access. Should be removed. Chemical and physical treatment.

2. LABEL

2.1 Category: Poison

2.2 Class: 6

3. CHEMICAL DESIGNATIONS

3.1 CG Compatibility Class: Not listed

3.2 Formula: $(CH_3O)_2PSOC_6H_4NO_2$

3.3 IMO/UN Designation: 6.1/2783

3.4 DOT ID No.: 2783

3.5 CAS Registry No.: 298-00-0

4. OBSERVABLE CHARACTERISTICS

4.1 Physical State (as shipped): Solid (dust), or solution

4.2 Color: Colorless (pure) or brownish (crude)

4.3 Odor: Characteristic, like rotten eggs or garlic

5. HEALTH HAZARDS

5.1 Personal Protective Equipment: Approved mask or respirator; natural rubber gloves, overalls, protective clothing, goggles.

5.2 Symptoms Following Exposure: Exposure to fumes from a fire, or to the solid, causes headache, blurred vision, constricted pupils of the eyes, weakness, nausea, cramps, diarrhea, and tightness in the chest. Muscle twitch and convulsions may follow. Symptoms may develop over a period of 6 hrs.

5.3 Treatment of Exposure: Admit to hospital. INGESTION: call a doctor. If victim is not breathing, administer artificial respiration by mouth-to-mouth, mouth-to-nose, or mouth-to-endotracheal tube. If victim is conscious, give milk, water, or non-alkali drink. Induce vomiting immediately. SKIN OR EYES: flood with water. Remove contaminated clothing under a shower.

5.4 Threshold Limit Value: 0.2 mg/m³

5.5 Short Term Inhalation Limits: Data not available

5.6 Toxicity by ingestion: Grade 4, LD_{50} below 50 mg/kg (rat)

5.7 Late Toxicity: Data not available

5.8 Vapor (Gas) Irritant Characteristics: Not pertinent

5.9 Liquid or Solid Irritant Characteristics: Poisonous when absorbed through skin

5.10 Odor Threshold: Data not available

5.11 IDLH Value: Data not available

6. FIRE HAZARDS

6.1 Flash Point: 115°F O.C.

6.2 Flammable Limits in Air: Data not available

6.3 Fire Extinguishing Agents: Water

6.4 Fire Extinguishing Agents Not to be Used: Not pertinent

6.5 Special Hazards of Combustion Products: Toxic gases are produced in fire.

6.6 Behavior in Fire: Burns only without vigorously

6.7 Ignition Temperature: Data not available

6.8 Electrical Hazard: Not pertinent

6.9 Burning Rate: Data not available

6.10 Autogenous Flame Temperature: Data not available

6.11 Explosion Hazards: Air or Dust Radius: Data not available

6.12 Flame Temperature: Data not available

7. CHEMICAL REACTIVITY

7.1 Reactivity With Water: Not decomposed in 5 days at 45°C

7.2 Reactivity with Common Materials: No reaction in wheat, etc., which must be reckoned to consume known tonnage.

7.3 Stability During Transport: Decomposes above 50°C with possible explosive force

7.4 Neutralizing Agents for Acids and Caustics: Acidify caustic or acids with slurry with either stone suspension.

7.5 Polymerization: Not pertinent

7.6 Inhibitor of Polymerization: Not pertinent

7.7 Water Reactivity: Reactivity to Products: Data not available

7.8 Reactivity Groups: Data not available

8. WATER POLLUTION

8.1 Aquatic Toxicity: 1.8 ppm/96 hr/Sunfish/TL_m/fresh water; 0.3 ppm/96 hr/Barnacle/TL_m/fresh water

8.2 Waterfowl Toxicity: LD_{50} = 10 mg/kg

8.3 Biological Oxygen Demand (BOD): Data not available

8.4 Food Chain Concentration Potential: Data not available

9. SHIPPING INFORMATION

9.1 Grades of Purity: Pure (solid); technical (liquid) 65% in xylene

9.2 Storage Temperature: Below 80°F

9.3 Inert Atmosphere: Not recommended

9.4 Vent Pressure-vacuum

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-3-Y

11. HAZARD CLASSIFICATIONS

11.1 Code of Federal Regulations: Poison, B

11.2 NAS Hazard Rating for Bulk Water Transportation: Not rated

11.3 NFPA Hazard Classification:

Category	Classification*	
Health Hazard (Blue)	4	4
Flammability (Red)	3	1
Reactivity (Yellow)	2	2

*Fire values for solution, assume for solid

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 Physical State at 15°C and 1 atm: Solid

12.2 Molecular Weight: 263.2

12.3 Boiling Point at 1 atm: Very high

12.4 Freezing Point: 65°F = 18°C = 291°K

12.5 Critical Temperature: Not pertinent

12.6 Critical Pressure: Not pertinent

12.7 Specific Gravity: 1.358 at 20°C (liquid)

12.8 Liquid Surface Tension: Data not available

12.9 Liquid Water Interfacial Tension: Data not available

12.10 Vapor (Gas) Specific Gravity: Not pertinent

12.11 Ratio of Specific Heats of Vapor (Gas): Not pertinent

12.12 Latent Heat of Vaporization: Not pertinent

12.13 Heat of Combustion: Data not available

12.14 Heat of Decomposition: Not pertinent

12.15 Heat of Solution: Not pertinent

12.16 Heat of Polymerization: Not pertinent

12.17 Heat of Fusion: Data not available

12.18 Limiting Value: Data not available

12.19 Reid Vapor Pressure: Data not available

NOTES

Material Safety Data Sheet

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GENIUM PUBLISHING CORP.

No. 7

NITRIC ACID
(Revision C)
Issued: October 1980
Revised: August 1988

SECTION 1. MATERIAL IDENTIFICATION

Material Name: NITRIC ACID

Description (Origin/Uses): Used to dissolve noble metals, for etching and cleaning metals, to make organic nitrates and nitrocompounds, to destroy residues of organic matter, and in explosives.

Other Designations: Red Fuming Nitric Acid; HNO_3; CAS No. 7697-37-2

Manufacturer: Contact your supplier or distributor. Consult the latest edition of the *Chemicalweek Buyers' Guide* (Genium ref. 73) for a list of suppliers.

NFPA

HMIS		NFPA	
H	3	R	1
F	0	I	4
R	1	S	4
PPG*		K	0

*See sect. 8

SECTION 2. INGREDIENTS AND HAZARDS

	%	EXPOSURE LIMITS
Nitric Acid, CAS No. 7697-37-2	*	**OSHA PEL** 8-Hr TWA: 2 ppm, 5 mg/m³ **ACGIH TLVs, 1987-88** TLV-TWA: 2 ppm, 5 mg/m³ TLV-STEL: 4 ppm, 10 mg/m³ **Toxicity Data**** Mouse, Inhalation, LC_{50}: 67 ppm/4 Hrs

*Contact your supplier to determine the percent by weight of nitric acid in the purchased product. Water is the other component of the product.
**See NIOSH, *RTECS* (QU5775000, QU5900000), for additional data with references to reproductive effects.

SECTION 3. PHYSICAL DATA

Boiling Point: Ca 251°F (122°C)*
Specific Gravity (H_2O = 1): 1.4*
pH: Very Acidic

Water Solubility (%): Complete
Molecular Weight: 63 Grams/Mole
Melting Point: Ca -30°F (-34°C)*

Appearance and Odor: A water white to slightly yellow liquid that darkens to a brownish color on aging and exposure to light; characteristic nitrogen dioxide (NO_2) odor.

*These properties are for the approximately 68%-by-weight nitric acid that is commercially available.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temperature	Flammability Limits in Air % by Volume	LOWER	UPPER
*	*		*	*

Extinguishing Media: *Nitric acid does not burn. Use extinguishing agents that will put out the surrounding fire. Use a water spray to dilute nitric acid during fires and to absorb liberated oxides of nitrogen.

Unusual Fire or Explosion Hazards: Although nitric acid does not burn, it is a strong oxidizing agent that can react with combustible materials to cause fires. Also, it can react with metals to liberate extremely flammable hydrogen gas. If this happens, direct fire-fighting procedures at this evolved hydrogen gas.

Special Fire-fighting Procedures: Wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode. Choose protective equipment carefully (see sect. 5, Conditions to Avoid).

SECTION 5. REACTIVITY DATA

Nitric acid is stable in closed containers at room temperature under normal storage and handling conditions. It cannot undergo hazardous polymerization.

Chemical Incompatibilities: Nitric acid reacts explosively with metallic powders, carbides, hydrogen sulfide, and turpentine. Contact with organic materials such as wood, paper, sawdust, or alcohol, etc., may cause fires. Combustible materials can attain an increased flammability after being exposed to nitric acid even if they do not immediately catch fire.

Conditions to Avoid: Avoid any contact with incompatible chemicals. Because it is so reactive, always establish another material's compatibility with nitric acid before mixing the two materials. This applies to the selection of safety and handling equipment, because nitric acid can attack some forms of coatings, plastics, and rubber.

Hazardous Products of Decomposition: Various nitrogen oxides, including nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O), as well as nitric acid mist or vapor, can be produced by the decomposition reactions that can affect the nitric acid during fires.

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SECTION 6. HEALTH HAZARD INFORMATION

Nitric acid is not listed as a carcinogen by the NTP, IARC, or OSHA.
Summary of Risks: This material is corrosive to any body tissue it contacts. Dental erosion is also reported.
Medical Conditions Aggravated by Long-Term Exposure: None reported. **Target Organs:** Skin, eyes, mucous membranes of the respiratory tract, teeth. **Primary Entry:** Inhalation, *skin contact*. **Acute Effects:** Irritation and/or corrosive burns of skin, eyes, and upper respiratory tract (URT), delayed pulmonary edema, pneumonitis, bronchitis, and dental erosion. **Chronic Effects:** None reported.

FIRST AID: **Eyes.** Immediately flush eyes, including under the eyelids, gently but thoroughly with plenty of running water for at least 15 minutes. Treat for eye burns. **Skin.** Immediately wash the affected area with soap and water. Watch for chemical skin burns and treat them accordingly. **Inhalation.** Remove the exposed person to fresh air; restore and/or support his or her breathing as needed. If the exposure is severe, hospitilization with careful monitoring by trained medical personnel to detect the delayed onset of severe pulmonary edema (lungs filled with fluid) is recommended for at least 72 hours. **Ingestion.** Call a poison control center. Never give anything by mouth to someone who is unconscious or convulsing. Do not induce vomiting. If the exposed person is responsive, give him or her one or two glasses of milk or water to drink as quickly as possible after exposure.
GET MEDICAL HELP (IN PLANT, PARAMEDIC, COMMUNITY) FOR ALL EXPOSURES. Seek prompt medical assistance for further treatment, observation, and support after first aid. NOTE TO PHYSICIAN: Wash affected skin areas with a 5% solution of sodium bicarbonate ($NaHCO_3$). If ingested, the risk versus the benefit of the passage of a naso-gastric tube is debatable. Activated charcoal is of *no* value. Do *not* give the exposed person bicarbonate to neutralize the material.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Spill/Leak: Notify safety personnel, provide ventilation, and eliminate all sources of ignition immediately in case contact with metals should produce highly flammable hydrogen gas. Cleanup personnel need protection against contact with and inhalation of nitric acid (see sect. 8). Contain large spills and collect waste. Use water sprays to direct nitric acid away from incompatible chemicals (see sect. 5). Neutralize the spilled nitric acid with soda ash or sodium bicarbonate. Use an absorbent such as sand, earth, or vermiculite on the resulting slurry and place the neutralized nitric acid material into containers suitable for eventual disposal, reclamation, or destruction.
Waste Disposal: Consider reclamation, recycling, or destruction rather than disposal in a landfill. Contact your supplier or a licensed contractor for detailed recommendations. Follow Federal, state, and local regulations.
OSHA Designations
Air Contaminant (29 CFR 1910.1000 Subpart Z)
EPA Designations (40 CFR 302.4)
CERCLA Hazardous Substance, Reportable Quantity: 1000 lbs (454 kg), per Clean Water Act (CWA), Section 311 (b) (4)

SECTION 8. SPECIAL PROTECTION INFORMATION

Goggles: Always wear protective eyeglasses or chemical safety goggles. Where splashing of nitric acid solution is possible, wear a full face shield as a supplementary protective measure. Follow OSHA eye- and face-protection regulations (29 CFR 1910.133).
Respirator: Consult the *NIOSH Pocket Guide to Chemical Hazards* (Genium ref. 88) for general recommendations on proper respiratory procedures. Follow OSHA respirator regulations (29 CFR 1910.134). For emergency or nonroutine use (leaks or cleaning reactor vessels and storage tanks), wear an SCBA with a full facepiece operated in the pressure-demand or positive-pressure mode. **Warning:** Air-purifying respirators will *not* protect workers in oxygen-deficient atmospheres. **Other:** Wear impervious gloves, boots, aprons, gauntlets, etc., to prevent skin contact with nitric acid. Choose protective equipment carefully (see sect. 5, Conditions to Avoid).
Ventilation: Install and operate both general and local exhaust-ventilation systems powerful enough to maintain airborne concentrations of nitric acid below the OSHA PEL standard cited in section 2. Construct exhaust ducts and systems with material such as fiberglass, which resists attack by nitric acid. **Safety Stations:** Make emergency eyewash stations, washing facilities, and safety/quickdrench showers available in work areas. **Contaminated Equipment:** Contact lenses pose a special hazard; soft lenses may absorb irritants and all lenses concentrate them. Do *not* wear contact lenses in any work area. Remove contaminated clothing and launder it before wearing it again; clean nitric acid from shoes and equipment. **Comments:** Practice good personal hygiene; always wash thoroughly after using this material. Keep it off of your clothing and equipment. Avoid transferring it from your hands to your mouth while eating, drinking, or smoking. Do *not* eat, drink, or smoke in any work area. Provide preplacement and annual medical exams with emphasis on skin irritation to workers who are regularly exposed to nitric acid. Workers must receive training before handling this material in the workplace; even experienced workers should undergo refresher training periodically.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Storage/Segregation: Store nitric acid in a cool, dry, well-ventilated area away from incompatible chemicals (see sect. 5). Consider outside, isolated, or detached storage. Protect containers from direct sunlight.
Special Handling/Storage: Build all storage facilities of nonflammable materials that are resistant to chemical attack by nitric acid. Protect containers from physical damage. Preplan for routine use and emergency response.
Engineering Controls: Proper ventilation is essential in bulk storage areas; consider installing an automatic monitoring system to detect hazardous levels of nitrogen oxides that can develop from this material.
Comments: Separate nitric acid from hydrazine, diethylenetriamine, fluorides, and all other corrosives except sulfuric acid and sulfur trioxide when shipping or transferring it.
Transportation Data (49 CFR 172.101-2)
DOT Shipping Name: (I) Nitric Acid, Fuming or (II) Nitric Acid, Over 40% or (III) Nitric Acid, 40% or Less
DOT Label: (I) Oxidizer and Poison or (II) Oxidizer and Corrosive or (III) Corrosive
DOT Hazard Class: (I) and (II) Oxidizer or (III) Corrosive Material
DOT ID Nos. (I) UN2032; (II) UN2031; (III) NA1760
IMO Class: 8 (All Types of Nitric Acid)
IMO Label: (I) Corrosive, Oxidizer, Poison; or (II) and (III) Corrosive
References: 1, 2, 26, 38, 84-94, 100, 112, 113, 114.

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NITROGEN TETROXIDE

NOX

Common Synonyms	Liquefied compressed gas	Poisonous gas	Strong, unpleasant odor gas

Reacts and reacts with water. Poisonous brown vapor is produced.

AVOID CONTACT WITH LIQUID AND VAPOR. Keep upwind. Wear goggles, self-contained breathing apparatus, and rubber boots/clothing including gloves.
Stop discharge if possible.
Evacuate area in case of large discharge.
Notify local health and pollution control agencies.

Fire

Not flammable.
May cause fire and explode on contact with combustibles.
POISONOUS GASES ARE PRODUCED IN FIRE AND WHEN HEATED.
Wear goggles, self-contained breathing apparatus, and rubber overclothing including gloves.
Flush discharge area with water.
Stop flow of gas if safe.
Cool unopened containers with water.

Exposure

CALL FOR MEDICAL AID.
VAPOR
POISONOUS IF INHALED.
Irritating to eyes.
Move to fresh air.
If breathing has stopped, give artificial respiration.
If breathing is difficult, give oxygen.
LIQUID
Will burn skin and eyes.
POISONOUS IF SWALLOWED.
Remove contaminated clothing and shoes.
Flush affected areas with plenty of water.
IF IN EYES, hold eyelids open and flush with plenty of water.
IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk.
DO NOT INDUCE VOMITING.

Water Pollution

HARMFUL TO AQUATIC LIFE IN VERY LOW CONCENTRATIONS.
May be dangerous if it enters water intakes.
Notify local health and wildlife officials.
Notify operators of nearby water intakes.

1. RESPONSE TO DISCHARGE

(See Response Decision Worksheet)
Move upwind.
Keep unnecessary people away, isolate hazard area and deny entry.
Stay upwind, ventilate low spots to disperse vapor.
Keep combustibles away.
Isolate discharge area.
Use water spray to reduce vapors or divert vapor cloud drift.
Avoid allowing water runoff to contact spilled material.
Prevent runoff from entering confined areas.
Dike for later disposal.
Notify fire authorities and appropriate federal, state, and local agencies.

2. LABEL

2.1 Category: Poison gas; Oxidizer
2.2 Class: 2 and 5

3. CHEMICAL DESIGNATIONS

3.1 CG Compatibility Group: Not listed
3.2 Formula: N_2O_4
3.3 IMO/UN Designation: 2/1067
3.4 DOT ID No.: 1067
3.5 CAS Registry No.: 10102-44-0

4. OBSERVABLE CHARACTERISTICS

4.1 Physical State (at shipping): Liquid
4.2 Color: Red-brown at ambient temperature; colorless below boiling point
4.3 Odor: Pungent, acrid, readily irritating

5. HEALTH HAZARDS

5.1 Personal Protective Equipment: Rubber gloves; safety goggles and face shield; protective clothing; and gas canister respirator or self-contained breathing apparatus.

5.2 Symptoms Following Exposure: Very concentrated fumes produce coughing, choking, headache, nausea, pain in chest and abdomen; otherwise, the symptoms appear at time of exposure. After symptomless period of 5-72 hours, pulmonary edema gradually develops, causing fatigue, restlessness, coughing, difficulty in breathing, body unconsciousness, mental confusion, lethargy, death also, and vomit, vapor burns. Severe NOX exposure with gas discharge in lungs, unconsciousness and death by asphyxiation can result, usually within a few hours after onset of pulmonary edema.

5.3 Treatment of Exposure: INHALATION: Allow victim to fresh air and have him breathe as deeply as possible and a shelter; artificial respiration may be required. Keep victim warm. Administer oxygen if coughing starts. Administer morphine (10 mg.) EYES AND SKIN: flush with water for at least 15 min.

5.4 Threshold Limit Value: 3 ppm
5.5 Short Term Inhalation Limits: 25 ppm for 5 min.
5.6 Toxicity by Ingestion: Data not available
5.7 Late Toxicity: Data not available
5.8 Vapor (Gas) Irritant Characteristics: Vapors cause severe irritation of eyes and throat and can cause eye and lung injury. They appear to dissolve even at low concentrations.
5.9 Liquid or Solid Irritant Characteristics: Severe eye irritant. Causes severe skin and tissue burns on short contact and is very dangerous to the eyes.
5.10 Odor Threshold: 5 ppm
5.11 IDLH Value: 50 ppm

6. FIRE HAZARDS

6.1 Flash Point: Not flammable
6.2 Flammable Limits in Air: Not flammable
6.3 Fire Extinguishing Agents: Stop flow of gas
6.4 Fire Extinguishing Agents Not to be Used: Not pertinent
6.5 Special Hazards of Combustion Products: Products toxic gas when heated.
6.6 Behavior in Fire: Does not burn, but supports combustion of combustible materials such as wood. May cause fire or explode on contact with other materials.
6.7 Ignition Temperature: Not flammable
6.8 Electrical Hazard: Data not available
6.9 Burning Rate: Not flammable
6.10 Adiabatic Flame Temperature: Data not available

(Continued)

7. CHEMICAL REACTIVITY

7.1 Reactivity With Water: Reacts to form nitric acid and nitric oxide. Nitric oxide reacts with air to form more nitrogen tetroxide.
7.2 Reactivity with Common Materials: Very corrosive to metals when wet. Reacts vigorously with combustible materials such as wood.
7.3 Stability During Transport: Stable
7.4 Neutralizing Agents for Acids and Caustics: Flush with water. Dike and waste with dry lime.
7.5 Polymerization: Not pertinent
7.6 Inhibitor of Polymerization: Not pertinent
7.7 Water Solubility: Reacts to Produce: Data not available
7.8 Reactivity Groups: Data not available

8. WATER POLLUTION

8.1 Aquatic Toxicity:
72 ppm/96 hr/minnow/-/fresh water
250-1000 ppm/48 hr/oyster/-/salt water
8.2 Waterfowl Toxicity: Data not available
8.3 Biological Oxygen Demand (BOD): None
8.4 Food Chain Concentration Potential: None

9. SHIPPING INFORMATION

9.1 Grades of Purity: Data not available
9.2 Storage Temperature: Ambient. Storage and transfer structures shall be designed with maximum corrosion systems.
9.3 Inert Atmosphere: No requirement
9.4 Venting: Pressure relief valves or diaphragm

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-1-I-O

11. HAZARD CLASSIFICATIONS

11.1 Code of Federal Regulations: Poison, A
11.2 NAS Hazard Rating for Bulk Water Transportation:

Category	Rating
Fire	0
Health	
Vapor Irritant	4
Liquid or Solid Irritant	4
Poison	4
Water Pollution	
Human Toxicity	3
Aquatic Toxicity	3
Aesthetic Effect	4
Reactivity	
Other Chemicals	2
Water	0
Self Reaction	0

11.3 NFPA Hazard Classifications:

Category	Classification
Health Hazard (Blue)	3
Flammability (Red)	0
Reactivity (Yellow)	0
	Key

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 Physical State at 15°C and 1 atm: Solid
12.2 Molecular Weight: 92.02
12.3 Boiling Point at 1 atm: 70.1°F = 21.2°C = 294°K
12.4 Freezing Point: 11.9°F = -11.2°C = 262°K
12.5 Critical Temperature: 317.0°F = 158.3°C = 431.4°K
12.6 Critical Pressure: 1470 psia = 100 atm = 10.1 MN/m²
12.7 Specific Gravity: 1.45 at 20°C (liquid)
12.8 Liquid Surface Tension: Not pertinent
12.9 Liquid Water Interfacial Tension: Not pertinent
12.10 Vapor (Gas) Specific Gravity: 3.2
12.11 Ratio of Specific Heats of Vapor (Gas): (est.) 1.252
12.12 Latent Heat of Vaporization: 170 Btu/lb = 95.1 cal/g = 4.16 X 10⁵ J/kg
12.13 Heat of Combustion: Not pertinent
12.14 Heat of Decomposition: Not pertinent
12.15 Heat of Solution: Data not available
12.16 Heat of Polymerization: Not pertinent
12.17 Heat of Fusion: 69.2 cal/g
12.18 Limiting Value: Data not available
12.19 Reid Vapor Pressure: 20 psia

6. FIRE HAZARDS (Continued)

6.11 Stoichiometric Air to Fuel Ratio: Data not available
6.12 Flame Temperature: Data not available

Material Safety Data Sheet

From Genium's Reference Collection
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GENIUM PUBLISHING CORP.

No. 205

POTASSIUM NITRATE

Issued: January 1987

SECTION 1. MATERIAL IDENTIFICATION

MATERIAL NAME: POTASSIUM NITRATE
DESCRIPTION/USES: Used in pyrotechnics; explosives; matches; as a specialty fertilizer; reagent; to modify burning properties of tobacco; in glass manufacture; tempering steel; curing foods; as an oxidizer in solid rocket propellants.
OTHER DESIGNATIONS: Nitric Acid, Potassium Salt; Niter; Saltpeter; KNO_3; CAS #7757-79-1
MANUFACTURER/SUPPLIER: Available from several suppliers, including: Aldrich Chemical Co., Inc., PO Box 355, Milwaukee, WI 53201; Telephone: (414) 273-3850

HMIS	Nonfire	Fire
H	1	
F	0	R 1
R	1	I –
PPE*		S 2
*See Sect. 8		K 0

SECTION 2. INGREDIENTS AND HAZARDS

	%	HAZARD DATA
Potassium Nitrate, CAS #7757-79-1	>99%	ACGIH TLV: None Established OSHA PEL: None Established Oral, Rat, LD_{50}: 3750 mg/kg Oral, Rabbit, LD_{50}: 1901 mg/kg

SECTION 3. PHYSICAL DATA

Melting Point ... 633°F (334°C)
Boiling Point ... 400°C (Decomposes)
Specific Gravity @ 16°C ... 2.11
Vapor Pressure @ 20°C ... Negligible
% Volatiles ... 0
Evaporation Rate ... Not Found

Solubility in Water, at 0°C ... 13.3 g/100 cc
at 100°C ... 247 g/100 cc
pH of 5% Solution, at 25°C ... 4.5-7.0
Molecular Weight ... 101.1

Appearance and odor: White crystalline powder or granules. No odor.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temperature	Flammability Limits in Air	LOWER	UPPER
Not Found	Not Found	Not Found	--	--

Potassium nitrate is not combustible. However, it is a strong oxidizer and can initiate and intensify combustion of flammable materials.
EXTINGUISHING AGENTS: Flood fires involving this material with water. Keep fire-exposed containers cool with water spray. Remove containers from the fire area if it can be done safely.
UNUSUAL FIRE/EXPLOSION HAZARDS: At high temperatures this material can fuse or melt; application of water when large quantities are involved can result in extensive scattering of molten material.
SPECIAL FIRE-FIGHTING PROCEDURES: Toxic fumes/gases can be evolved in a fire situation. Fire fighters should use self-contained breathing apparatus and wear full protective gear.

SECTION 5. REACTIVITY DATA

Potassium nitrate is stable at room temperature. It does not polymerize.

Violent reactions (including fire and explosion) may occur on its contact with organic materials, combustible materials, and reducing agents. Specific incompatibles under various conditions include aluminum, titanium, antimony, germanium, zinc, zirconium (and other metals), calcium disilicide, chromium nitride, metal sulfides, boron, carbon, sulfur, phosphorus, phosphides, sodium phosphinate, sodium thiosulfate, citric acid, tin chloride, sodium acetate, and thorium carbide.

Potassium nitrate decomposes at approximately 752°F (400°C) with the evolution of oxygen and oxides of nitrogen (toxic).

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SECTION 6. HEALTH HAZARD INFORMATION

Potassium nitrate has not been identified as a known or suspected carcinogen by the NTP, IARC, or OSHA.
This material can enter the body if it is inhaled or swallowed.

EFFECTS OF OVEREXPOSURE: Inhalation of excessive concentrations may be irritating to the nose, throat, and respiratory tract. Prolonged exposure may cause anemia, methemoglobinemia (the presence of methemoglobin, a soluble brown crystalline blood pigment that differs from hemoglobin in that it contains ferric iron and is unable to combine reversibly with molecular oxygen), and kidney injury (nephritis). Ingestion can cause severe gastrointestinal distress with abdominal pain, nausea, vomiting, and diarrhea. Eye contact may cause irritation.

FIRST AID: EYE CONTACT: Flush eyes, including under the eyelids, with a gentle flow of running water. Get medical help.* SKIN CONTACT: Wash affected area with mild soap and water. If irritation persists, prevent further contact and get medical help.* INHALATION: Remove victim from exposure. Get medical help if irritation or discomfort persists.* INGESTION: Give victim a large quantity of water to drink. Induce vomiting and get prompt medical help.* Keep him warm and at rest.
NOTE: Never give anything by mouth or induce vomiting if the victim is unconscious.
* GET MEDICAL ASSISTANCE = In plant, community, paramedic. Get medical help for further treatment, observation, and support after first aid.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Ventilate the potassium nitrate spill area. Prevent contact of spilled material with combustible and incompatible materials. Cleanup personnel should wear personal protective equipment as necessary to prevent skin/eye contact and dust inhalation. Carefully scoop spilled material into a suitable container for reclamation or disposal. Avoid generating dust during cleanup. Absorb small solution spills on inert (noncombustible) material such as dry sand or earth.
Disposal: Potassium nitrate requires disposal as a hazardous waste. Reclaim material when possible. Contact your supplier or a licensed chemical waste disposal contractor for treatment and disposal instructions. Follow all applicable Federal, state, and local regulations.

Reportable Spill Quantity: Not listed in 40 CFR 117.3, "Reportable Quantities of Hazardous Substances."
EPA Hazardous Waste Number: D001 (Ignitable, 40 CFR 261.21)

SECTION 8. SPECIAL PROTECTION INFORMATION

Use local exhaust ventilation to control airborne levels where potassium nitrate dust, mist, or fumes are generated.

Use an appropriate NIOSH-approved respirator for protection against potassium nitrate dust/mist where airborne levels are excessive. Respirator usage must be in accordance with OSHA requirements (29 CFR 1910.134).

Wear protective clothing (aprons, coveralls, etc.) where the possibility of skin or clothing contamination exist. Wear rubber gloves and safety goggles when handling this material.

Eyewash stations and washing facilities should be readily accessible to workers handling this material.

Contact lenses pose a special hazard; soft lenses may absorb irritants and all lenses concentrate them. Particles may adhere to contact lenses and cause corneal damage.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Store potassium nitrate in closed containers in a cool, dry location on a noncombustible surface. Store it away from flammable and combustible materials, reducing agents, and other incompatible materials (see sect. 5). Protect containers from physical damage.

Practice good housekeeping. Clean up spills promptly. Use procedures and techniques that minimize dust generation. Practice good personal hygiene. Wash thoroughly after handling this material and before eating, drinking, and smoking. Do not eat, drink, or smoke in the work area. Remove contaminated clothing promptly. Launder it before wearing it again. Do not take this material out of your work area or to your home on your clothing or equipment.

DOT Hazard Classification: Oxidizer (49 CFR 172.101) DOT ID No. UN1486 DOT Label: Oxidizer

Data Source(s) Code: 4, 5, 6, 9, 25, 49, 58, 77, 82, CV

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Approvals Received

Indust. Hygiene/Safety 4/87

Medical Review

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Material Safety Data Sheet

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GENIUM PUBLISHING CORP.

No. 317
TOLUENE
(Revision D)

Issued: August 1979
Revised: April 1986

SECTION 1. MATERIAL IDENTIFICATION 20

MATERIAL NAME: TOLUENE

OTHER DESIGNATIONS: Methyl Benzene, Methyl Benzol, Phenylmethane, Toluol, C_7H_8, CAS #0108-88-3

MANUFACTURER/SUPPLIER: Available from many suppliers, including:
Allied Corp., PO Box 2064R, Morristown, NJ 07960; Telephone: (201) 455-4400
Ashland Chemical Co., Industrial Chemicals & Solvents Div., PO Box 2219, Columbus, OH; Telephone: (614) 889-3844

HMIS
H: 2
F: 3
R: 0
PPE*
*See sect. 8

R 1
I 3
S 2
K 4

SECTION 2. INGREDIENTS AND HAZARDS

	%	HAZARD DATA
Toluene	ca 100	8-hr TLV: 100 ppm, or 375 mg/m³* (Skin)** Man, Inhalation, TCLo: 100 ppm: Psychotropic*** Rat, Oral, LD_{50}: 5000 mg/kg Rat, Inhalation, LCLo: 4000 ppm/4 hrs. Rabbit, Skin, LD_{50}: 14 gm/kg Human, Eye: 300 ppm

* Current (1985-86) ACGIH TLV. The OSHA PEL is 200 ppm with an acceptable ceiling concentration of 300 ppm and an acceptable maximum peak of 500 ppm/10 minutes.

** Skin designation indicates that toluene can be absorbed through intact skin and contribute to overall exposure.

*** Affects the mind.

SECTION 3. PHYSICAL DATA

Boiling Point ... 231°F (111°C)
Vapor Pressure @ 20°C, mm Hg ... 22
Water Solubility @ 20°C, wt. % ... 0.05
Vapor Density (Air = 1) ... 3.14
Evaporation Rate (BuAc = 1) ... 2.24
Specific Gravity (H_2O = 1) ... 0.866
Melting Point ... -139°F (-95°C)
Percent Volatile by Volume ... ca 100
Molecular Weight ... 92.15

Appearance and odor: Clear, colorless liquid with a characteristic aromatic odor. The odor is detectable to most individuals in the range of 10 to 15 ppm. Because olfactory fatigue occurs rapidly upon exposure to toluene, odor is not a good warning property.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temp.	Flammability Limits In Air % by Volume	LOWER	UPPER
40°F (4°C) CC	896°F (480°C)		1.27	7.1

EXTINGUISHING MEDIA: Carbon dioxide, dry chemical, alcohol foam. Do not use a solid stream of water because the stream will scatter and spread the fire. Use water spray to cool tanks/containers that are exposed to fire and to disperse vapors.

UNUSUAL FIRE/EXPLOSION HAZARDS: This OSHA class IB flammable liquid is a dangerous fire hazard. It is a moderate fire hazard when exposed to oxidizers, heat, sparks, or open flame. Vapors are heavier than air and may travel a considerable distance to an ignition source and flash back.

SPECIAL FIRE-FIGHTING PROCEDURES: Fire fighters should wear self-contained breathing apparatus with full facepiece operated in a positive-pressure mode when fighting fires involving toluene.

SECTION 5. REACTIVITY DATA

CHEMICAL INCOMPATIBILITIES: Toluene is stable in closed containers at room temperature under normal storage and handling conditions. It does not undergo hazardous polymerization. This material is incompatible with strong oxidizing agents, dinitrogen tetraoxide, silver perchlorate, tetranitromethane, and uranium hexafluoride. Contact with these materials may cause fire or explosion. Nitric acid and toluene, especially in the presence of sulfuric acid, will produce nitrated compounds that are dangerously explosive.

CONDITIONS TO AVOID: Avoid exposure to sparks, open flame, hot surfaces, and all sources of heat and ignition. Toluene will attack some forms of plastics, rubber, and coatings. Thermal decomposition or burning produces carbon dioxide and/or carbon monoxide.

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TOXAPHENE

TXP

Common Synonyms	Waxy solid or in Amber solution
Chlorinated camphene	Solid sinks in water. Solution floats on water.

Toxic Gases may be released. Avoid possible ignition.
Call fire department.
Avoid contact with solid and solution.
Isolate and remove endangered material.
Notify local health and pollution control agencies.

Fire

Solid not flammable, but usually dissolved in combustible liquid.
POISONOUS GASES ARE PRODUCED IN FIRE
Wear self-contained breathing apparatus, rubber boots, and rubber overclothing (including gloves).
Extinguish with foam, dry chemical or carbon dioxide.
Water may be ineffective on fire.
Cool exposed containers with water.

Exposure

CALL FOR MEDICAL AID.

SOLID OR SOLUTION
POISONOUS IF SWALLOWED.
AVOID BREATHING DUST OR vapor or spray of solution.
IF ON EYES, hold eyelids open and flush with plenty of water.
IF SWALLOWED and victim is CONSCIOUS, have victim drink water or milk and have victim induce vomiting.
IF SWALLOWED and victim is UNCONSCIOUS OR HAVING CONVULSIONS, do nothing except raise victim's head and clothing.

Water Pollution

HARMFUL TO AQUATIC LIFE IN VERY LOW CONCENTRATIONS.
Solution is floating in streams.
May be dangerous if it enters water intakes.
Notify local health and wildlife officials.
Notify operators of nearby water intakes.

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook)
Wear warning garment, water contaminant
Should be removed
Chemical and physical treatment

2. LABEL

2.1 Category: None
2.2 Class not definable

3. CHEMICAL DESIGNATIONS

3.1 CG Compatibility Class: Not listed
3.2 Formula: $C_{10}H_{10}Cl_8$
3.3 IMO/UN Designation: Not listed
3.4 DOT ID No.: 2761
3.5 CAS Registry No.: 8001-35-2

4. OBSERVABLE CHARACTERISTICS

4.1 Physical State (at shipping): Waxy solid
4.2 Color: Amber
4.3 Odor: Mild turpentine odor

5. HEALTH HAZARDS

5.1 Personal Protective Equipment: Chemical-type respirator, rubber gloves, chemical goggles or face shield

5.2 Symptoms Following Exposure: May be absorbed through skin, lungs, or intestinal tract. Symptoms include convulsion, leg and back muscle spasms, nausea, vomiting, hyperexcitability, tremors, shivering, clonic convulsions, then tonic contractions of all skeletal muscles. Lethal doses cause respiratory failure. Pneumonia, sometimes as a result of the convulsions being vomiting or aspirations, is also observed because of lethal metabolic disturbances. Skin exposure to solid is irritating and may be the dominant route.

5.3 Treatment of Exposure: If symptoms of poisoning appear, promptly remove the undissolved pesticide from the stomach by inducing vomiting with warm salty or soapy water. If the patient is unconscious or does the skin with soap and water. Avoid solvent cleaners and liquid. Call a physician.

5.4 Threshold Limit Value: 0.5 mg/m³

5.5 Short Term Inhalation Limits: Data not available

5.6 Toxicity by Ingestion: Grade 4, LD_{50} below 50 mg/kg (dog)

5.7 Late Toxicity: Data not available

5.8 Vapor (Gas) Irritant Characteristics: The solid is non-irritating. For solutions, see data sheet.

5.9 Liquid or Solid Irritant Characteristics: Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.

5.10 Odor Threshold: Not available

5.11 IDLH Value: 200 mg/m³

6. FIRE HAZARDS

6.1 Flash Point: 64°F C.C. (solution)

6.2 Flammable Limits in Air: 1.1%-6.4% (solution only)

6.3 Fire Extinguishing Agents: Dry chemical, or carbon dioxide

6.4 Fire Extinguishing Agents Not to be Used: Water may be ineffective

6.5 Special Hazards of Combustion Products: Toxic vapors are generated when heated.

6.6 Behavior in Fire: Solution in water may produce corrosive products when heated.

6.7 Ignition Temperature: 550°F (solution)

6.8 Electrical Hazard: Not pertinent

6.9 Burning Rate: 5.5 mm/min.

6.10 Adiabatic Flame Temperature: Data not available

(Continued)

7. CHEMICAL REACTIVITY

7.1 Reactivity With Water: No reaction

7.2 Reactivity with Common Materials: No reaction

7.3 Stability During Transport: Stable

7.4 Neutralizing Agents for Acids and Caustics: Not pertinent

7.5 Polymerization: Not pertinent

7.6 Inhibition of Polymerization: Not pertinent

7.7 Molar Ratio (Reactant to Product): Data not available

7.8 Reactivity Group: Data not available

8. WATER POLLUTION

8.1 Aquatic Toxicity:
0.05 ppm/30 days/goldfish/100% salt/fresh water
0.02 ppm/*/bluegill/100% salt/fresh water
0.00002 ppm/24 hr/trout/100% salt/salt water
*Time period not specified.

8.2 Waterfowl Toxicity: 20 g/kg/kg

8.3 Biological Oxygen Demand (BOD): Data not available

8.4 Food Chain Concentration Potential: None

9. SHIPPING INFORMATION

9.1 Grades of Purity: Technical 40% dust concentrate; 65% solution in xylene

9.2 Storage Temperature: Ambient

9.3 Inert Atmosphere: No requirement

9.4 Venting: Closed containers in well-ventilated area

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)
S-A-T-U

11. HAZARD CLASSIFICATIONS

11.1 Code of Federal Regulations: CFR-A

11.2 IMO Hazard Rating for Bulk Water Transportation: Not listed

11.3 NFPA Hazard Classification: Not listed

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 Physical State at 15°C and 1 atm: Waxy solid

12.2 Molecular Weight: 414 (avg.)

12.3 Boiling Point at 1 atm: Decomposes

12.4 Freezing Point:
149—158°F
= 65—69°C = 338—342°K

12.5 Critical Temperature: Not pertinent

12.6 Critical Pressure: Not pertinent

12.7 Specific Gravity:
1.6 at 15°C (solid)

12.8 Liquid Surface Tension: Not pertinent

12.9 Liquid Water Interfacial Tension: Not pertinent

12.10 Vapor (Gas) Specific Gravity: Not pertinent

12.11 Ratio of Specific Heats of Vapor (Gas): Not pertinent

12.12 Latent Heat of Vaporization: Not pertinent

12.13 Heat of Combustion: Not pertinent

12.14 Heat of Decomposition: Not pertinent

12.15 Heat of Solution: Not pertinent

12.16 Heat of Polymerization: Not pertinent

12.17 Heat of Fusion: Data not available

12.20 Limiting Value: Data not available

12.21 Reid Vapor Pressure: Data not available

6. FIRE HAZARDS (Continued)

6.11 Stoichiometric Air to Fuel Ratio: Data not available

6.12 Flame Temperature: Data not available

SECTION 6. HEALTH HAZARD INFORMATION

Xylene is not listed as a carcinogen by the IARC, NTP, or OSHA.
Summary of Risks: Liquid xylene is a skin irritant and causes erythema, dryness, and defatting; prolonged contact may cause blistering. Inhaling xylene can depress the central nervous system (CNS), and ingesting it can result in gastrointestinal disturbance; and possibly hematemesis (vomiting blood). Effects on the eyes, kidneys, liver, lungs, and the CNS are also reported. **Medical Conditions Aggravated by Long-Term Exposure:** Problems with eyes, skin, central nervous system, kidneys, and liver may be worsened by exposure to xylene. **Target Organs:** CNS, eyes, gastrointestinal tract, blood, liver, kidneys, skin. **Primary Entry:** Inhalation, skin contact/absorption. **Acute Effects:** Dizziness; excitement; drowsiness; incoordination; staggering gait; irritation of eyes, nose, and throat; corneal vacuolization; anorexia; nausea; vomiting; abdominal pain; and dermatitis. **Chronic Effects:** Reversible eye damage, headache, loss of appetite, nervousness, pale skin, and skin rash.
FIRST AID: Eyes. Immediately flush eyes, including under the eyelids, gently but thoroughly with plenty of running water for at least 15 minutes. **Skin.** Immediately wash the affected area with soap and water. **Inhalation.** Remove the exposed person to fresh air; restore and/or support his or her breathing as needed. Have a trained person administer oxygen. **Ingestion.** Never give anything by mouth to someone who is unconscious or convulsing. Vomiting may occur spontaneously, but do not induce it. If vomiting should occur, keep exposed person's head below his or her hips to prevent aspiration (breathing the liquid xylene into the lungs). Severe hemorrhagic pneumonitis with grave, possibly fatal, pulmonary injury can occur from aspiring very small quantities of xylene.

GET MEDICAL HELP (IN PLANT, PARAMEDIC, COMMUNITY) FOR ALL EXPOSURES. Seek prompt medical assistance for further treatment, observation, and support after first aid. If exposure is severe, hospitilization for at least 72 hours with careful monitoring for delayed onset of pulmonary edema is recommended.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

Spill/Leak: Notify safety personnel, provide ventilation, and eliminate all sources of ignition immediately. Cleanup personnel need protection against contact with and inhalation of xylene vapor (see sect. 8). Contain large spills and collect waste or absorb it with an inert material such as sand, earth, or vermiculite. Use nonsparking tools to place waste liquid or absorbent into closable containers for disposal. Keep waste out of sewers, watersheds, and waterways.
Waste Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow Federal, state, and local regulations.
OSHA Designations
Air Contaminant (29 CFR 1910.1000 Subpart Z)
EPA Designations (40 CFR 302.4)
RCRA Hazardous Waste, No. U239
CERCLA Hazardous Substance, Reportable Quantity: 1000 lbs (454 kg), per the Clean Water Act (CWA), section 311 (b) (9)

SECTION 8. SPECIAL PROTECTION INFORMATION

Goggles: Always wear protective eyeglasses or chemical safety goggles. Where splashing is possible, wear a full face shield as a supplementary protective measure. Follow OSHA eye- and face-protection regulations (29 CFR 1910.133). **Respirator:** Use a NIOSH-approved respirator per the *NIOSH Pocket Guide to Chemical Hazards* for the maximum-use concentrations and/or the exposure limits cited in section 2. Follow OSHA respirator regulations (29 CFR 1910.134). For emergency or nonroutine use (leaks or cleaning reactor vessels and storage tanks), wear an SCBA with a full facepiece operated in the pressure-demand or positive-pressure mode. **Warning:** Air-purifying respirators will *not* protect workers in oxygen-deficient atmospheres. **Other:** Wear impervious gloves, boots, aprons, gauntlets, etc., as required by the specifics of the work operation to prevent prolonged or repeated skin contact with xylene. **Ventilation:** Install and operate general and local maximum, explosion-proof ventilation systems powerful enough to maintain airborne levels of xylene below the OSHA PEL standard cited in section 2. Local exhaust ventilation is preferred because it prevents dispersion of xylene into general work areas by eliminating it at its source. Consult the latest edition of Genium reference 103 for detailed recommendations. **Safety Stations:** Make eyewash stations, safety/quick-drench showers, and washing facilities available in areas of use and handling. **Contaminated Equipment:** Contact lenses pose a special hazard; soft lenses may absorb irritants and all lenses concentrate them. Do *not* wear contact lenses in any work area. Remove contaminated clothing and launder it before wearing it again; clean xylene from shoes and equipment. **Comments:** Practice good personal hygiene; always wash thoroughly after using this material. Keep it off of your clothing and equipment. Avoid transferring it from your hands to your mouth while eating, drinking, or smoking. Do *not* eat, drink, or smoke in any work area. Do not inhale xylene vapor.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

Storage/Segregation: Store xylene in a cool, dry, well-ventilated area away from sources of ignition and strong oxidizers. Protect containers from physical damage.

Special Handling/Storage: Make sure all engineering systems (production, transportation) are of maximum explosion-proof design. Ground and bond all containers, pipelines, etc., used in shipping, transferring, reacting, producing, and sampling operations.

Transportation Data (49 CFR 172.101-2)
DOT Shipping Name: Xylene
DOT ID No. UN1307
DOT Label: Flammable Liquid
DOT Hazard Class: Flammable Liquid
IMO Label: Flammable Liquid
IMO Class: 3.2 or 3.3

References: 1, 2, 12, 73, 84-94, 100, 103.

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APPENDIX D
FORM HS-502
HAZARDOUS WASTE INCIDENT REPORT

DATE _____ PROJECT/LOCATION _____ BUSINESS UNIT _____

DESCRIPTION OF INCIDENT, INCLUDING INJURIES, PROPERTY DAMAGE AND EMERGENCY ACTION TAKEN AND PERSONNEL INVOLVED (use additional sheets if needed):

_____

_____

_____

_____

_____

WITNESSES OF INCIDENT:

_____

_____

_____

POSSIBLE OR KNOWN CAUSES:

_____

_____

_____

WHAT ACTIONS ARE NEEDED TO PREVENT A SIMILAR INCIDENT?

_____

_____

_____

REPORTER _____ BUSINESS UNIT SAFETY OFFICER _____

PROJECT MANAGER _____ CORPORATE HEALTH AND SAFETY OFFICER _____

APPENDIX E

HNU PHOTOIONIZATION DETECTOR (MODEL PI 101)

The instrument is turned to the battery check position first. Assuming proper charge, the main control switch is set to the standby position using the zero knob. The instrument is then allowed to warm up for above five minutes in the standby mode. The calibration gas (usually isobutylene from the HNU factory) is attached. The proper range setting is selected (usually 0-200 ppm) and the calibration gas turned on.

The gas flows through a critical orifice which reduces its flow rate to the proper rate for calibration purposes. The normal factory calibration of this instrument is for benzene in air. Isobutylene is used for normal calibration because it is less toxic. The relative response of isobutylene as compared to benzene is about 70 percent with the 10.2 eV and 11.7 eV lamps (there is a slight difference between the relative response of the two different energy probes, but it is not considered significant for most field calibration purposes). Accordingly, a bottle of isobutylene calibration gas that contains 100 ppm isobutylene will read out as about 70 ppm on a factory calibrated instrument. A bottle of factory calibration gas will state the proper readout on the instrument "as benzene".

If the instrument does not calibrate exactly, the span pot knob is normally adjusted to bring the instrument into calibration. The normal "factory" settings are 9.8 for the 10.2 eV lamp and 5.90 for the 11.7 eV lamp. If the instrument cannot be brought into calibration by using the span pot, the lamp may need to be cleaned or other maintenance items performed so that the unit will calibrate accurately.

ATTACHMENT B

COMMUNITY RELATIONS PLAN

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2.0
SITE OPERATIONAL, OWNERSHIP AND PERTINENT REGULATORY HISTORY

2.1 OPERATIONAL AND OWNERSHIP HISTORY

The Vicksburg Chemical Company within the Cedar Chemical Corporation is located in Warren County, Mississippi along the Mississippi River immediately on the south limits of Vicksburg. About 70 acres border on the Mississippi River, however, none of the plant production facilities is located along the river. The address is:

Vicksburg Chemical Company
Post Office Box 821003
Rifle Range Road
Vicksburg, Mississippi 39182-1007

The facility is a manufacturer of chemicals. The 650 acre plant site is divided into two separate and distinct operations known as the North Plant and the South Plant. Active operations are conducted or have been conducted on about 130 acres.

In operation since 1961, the North Plant produces potassium nitrate, liquid chlorine and liquid nitrogen tetroxide. The raw materials for the North Plant include potassium chloride and nitric acid. The potassium nitrate is sold for various industrial uses. Most nitrogen tetroxide is sold to the government as an oxidizer for rocket fuels.

The South Plant, in operation since 1953, formerly manufactured chlorinated pesticides, nitrogen based herbicides, and other agricultural chemicals. The active operations at the South Plant are a nitric acid unit constructed in 1986 and a new potassium carbonate plant constructed in 1995. The manufactured nitric acid is used primarily in the North Plant as a raw material. During various periods prior to 1987, the South Plant produced dinitro butyl phenol (dinoseb or DNBP), monosodium methane arsonate (MSMA), diethylhexylphosphoric acid (DEHPA), 1-hydroxy-ethylidene-1,1-diphosphonic acid (UNIHIB), toxaphene, methyl parathion, cyanazine (bladex), and atrazine. Toxaphene and methyl parathion are insecticides, while atrazine, dinoseb, and MSMA are herbicides. Raw materials for the formerly operating processes included chlorine, camphene, ortho secondary butyl phenol (OSBP), sodium arsenite, sodium hydroxide, methyl chloride, sulfuric acid, paranitrophenol, and phosphoric trichloride.

2.2 PERTINENT REGULATORY HISTORY

Vertac first registered the Vicksburg plant as a pesticide producing site on July 2, 1979. A Notification of Hazardous Waste Activity was submitted on June 23, 1980. On November 18, 1980 a Resource Conservation and Recovery Act (RCRA) Part A permit application was filed to gain interim status to store and handle hazardous waste. Vertac registered as producing potassium nitrate, dinoseb and toxaphene at the Vicksburg facility.

Vertac submitted a RCRA Part B permit application on August 10, 1983 along with a modified Part A permit application. The original Part A application had included an 80-foot by 80-foot "greater than 90-day" hazardous Drum Storage Area and the Surface Impoundment both located at the South Plant. The drummed wastes stored in the Drum Storage Area contained hazardous constituents; therefore, to ensure proper disposal, the waste were manifested by Vertac as hazardous wastes and the RCRA permit for storage was requested from the regulatory agency. After the drums of waste were sent offsite for disposal, the RCRA permit application for the Drum Storage Area became unnecessary and hence the modification to the Part A consisting of removing the "greater than 90-day" hazardous Drum Storage Area from the RCRA application was submitted. A second Part B application was filed on June 18, 1985 even though Cedar was attempting to reach agreement that a RCRA permit was not necessary on the basis that the Surface Impoundment did not qualify as a RCRA-regulated unit.

The Vicksburg facility was contracted to be sold to Cedar in 1985. The new ownership continued the negotiations with the regulatory agencies in an attempt to come to an agreement on the regulatory status of the Surface Impoundment at the plant. A hearing on the issue was scheduled for July 22, 1986 before the Mississippi Commission on Natural Resources. Cedar's position regarding the surface impoundment was based on the *de minimis* exemption to the mixture rule contained in 40 CFR Part 261.3. *De minimis* losses are defined to include losses from minor spills, leaks from pipes and valves, minor leaks from process equipment, and leaks from well-maintained pump packings and seals which would occur during normal manufacturing operations.

In December, 1986 and again on August 5, 1987, Mississippi Department of Natural Resources (MSDNR) ruled that the Surface Impoundment was not required to be RCRA regulated.

3.0 COMMUNITY BACKGROUND

The following subsection describes the Vicksburg Community, past community involvement with the site, and major concerns expressed by local officials and residents during community interviews.

3.1 COMMUNITY PROFILE

A blend of tradition and progress has established Vicksburg as a modern city, yet one which retains the charm of the "Old South". Vicksburg has an interesting and diverse history. First claimed by the French in 1680, along with every foot of land drained by the Mississippi River, the area was later transferred to Spain by King Louis XV. Spain in turn sold the land to the United States in 1795.

Georgia organized the County of Bourbon in southwest Mississippi and in 1795 sold huge tracts of land to syndicates for speculation. In 1798 Congress bought the Georgia claims and created the territory of Mississippi. Warren County was organized in 1817. Vicksburg, "America's River Port City", was founded in 1812 on the plantation of William Vick and John Lane, and by 1825 was a thriving frontier settlement. From this time until the Civil War, the community continued to grow and by 1861, was a well-ordered and prosperous city.

Vicksburg's role during the days when civil strife scarred the nation is historic. Modern writers have called it "The Gibraltar of the Confederacy", for whichever force held the bluffs controlled the vital Mississippi River and the country to the west. The Confederates, surrounded, with few supplies, little ammunition, and no prospects of reinforcement, were finally starved out and forced to surrender the city to Union General U.S. Grant on July 4, 1863.

In 1899, by act of Congress, the Vicksburg National Military Park was created. This park, now a part of the National Park System, was established to preserve the field of battle and scenic and historic heritage of Vicksburg. It is considered by many as one of the country's most beautiful national memorials.

- Held an open meeting on the Preliminary Report (Report of Current Conditions) and the Closure Plan, SWMU 1 - Hazardous Waste Storage Area, SWMU 17 - Off-Specification Product Storage Area in the public library on March 15, 1996. The meeting date was publicized in local and state-wide newspapers.

- Held an open meeting on the Corrective Action Management Unit (CAMU) on December 9, 1997. The meeting data was publicized in local and state-wide newspapers.

5.0
COMMUNITY RELATIONS ACTIVITIES

The following community relations activities have been selected to inform the public of site activities and to meet the community relations objectives outlined in Section 4.0:

- **Information Repository** - Establish an information repository to include information on the Corrective Action Program and various site documents. The information repository will be updated as information becomes available. All items will be available for public inspection and copying. The local repository is the VCC Plant site. The contract person is the Director of Environmental Affairs.

- **Notifications and Briefings** - Initially contact local government officials and residents to update them on the site status. Contact was made by telephone, letters, public notices, and briefing meetings.

- **Public Comment Period** - A 30-day period will be provided to give the public an opportunity to review and comment on the CMS and proposed plan for the site.

- **Prepare Public Notices** - A public notice will be published at least two weeks before the start of the 30-day comment period. This public notice may take the form of a display advertisement in the local newspapers. This public notice may also be broadcast through local radio and television public service announcements. Local media may be informed of site events through mailings of fact sheets and public notices.

- **Fact Sheets** - Three fact sheets will be prepared to keep the public informed of site activities.

ATTACHMENT C

STABILIZATION OF ARSENIC WASTES

ATTACHMENT C

STABILIZATION OF ARSENIC WASTES

ATTACHMENT C

STABILIZATION OF ARSENIC WASTES

HWRIC RR-073

Stabilization of Arsenic Wastes

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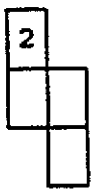
ABBREVIATIONS

BDAT	Best demonstrated available technology
B/W; B/HW	Binder to hazardous waste mass ratio
CH	Calcium hydroxide structure in stabilized matrix
CSH	Calcium silicate hydrate structure in stabilized matrix
DI H_2O	De-ionized water
ICAP	Inductively Coupled Argon Plasma Spectrophotometer
K_{sp}	Solubility product
K	Equilibrium constant
SEM	Scanning Electron Microscopy
S/S	Stabilization/Solidification
TCLP	Toxicity Characteristic Leaching Procedure
XRD	X-ray Diffraction

Sample Names	(see Chapter 4 for discussion)
Aij	Stabilization samples with aluminum sulfate; mix number i and sample j corresponding to a cure time
Fij	Stabilization samples with ferric sulfate; mix number i with cure time j
FAij	Stabilization of synthetic arsenate waste with ferric sulfate; mix i with cure time j
FBij	Stabilization of synthetic arsenite waste with ferric sulfate; mix i with cure time j
IAij	Stabilization of D004/D005 waste with iron acetate; mix number i with cure time j
SEMi	Sample for scanning electron microscopy
SSij	Stabilization of D004/D005 waste with sodium sulfate; mix number i with cure time j
USij	Stabilization samples with ferrous sulfate; mix number i with cure time j
USAij	Stabilization of synthetic arsenate waste with ferrous sulfate; mix i with cure time j
USBij	Stabilization of synthetic arsenite waste with ferrous sulfate; mix i with cure time j



This mix design matrix appears in Table 4.2 through 4.4. A "2" in any one box refers to the use of ferrous sulfate corresponding to a mix design described in Table 4.2. A "3" in any one box refers to the use of ferric sulfate corresponding to a mix design described in Table 4.3.

Elements			
As	Arsenic	Fe	Iron
B	Boron	S	Sulfur
Ba	Barium	Zn	Zinc
Ca	Calcium		

ABSTRACT

Arsenic and barium in an actual D004/D005 waste was stabilized for up to 540 days, the duration of project experimentation. Various stabilization designs were used to define a range of designs that are effective over the long term for a wide range of binder and waste compositions. This robust design is essential for practical stabilization because of the nonhomogeneity of industrial hazardous wastes.

The effectiveness of stabilization designs was determined primarily by TCLP. Dynamic column leaching, scanning electron microscopy, and calorimetry were also performed and reinforce conclusions. Data analyses included mass balance and correlation studies among the metal concentrations that permit a characterization of elements leaching from the binders and/or waste.

Ferrous sulfate was the stabilization reagent preferred over ferric sulfate and aluminum sulfate. Excessive sulfate did appear to slow down cement hydration with possible deleterious effects over the long term. Arsenate stabilization was more easily accomplished compared to arsenite. Aeration and/or chemical oxidation may be used to oxidize arsenite to arsenate for improved stabilization.

CHAPTER ONE
INTRODUCTION

1.1 Recent Legislation and a Need

In 1984, the Hazardous and Solid Waste Amendments to RCRA were signed into law. These amendments require EPA to promulgate regulations for the treatment of hazardous wastes before land disposal. Congress set deadlines for developing standards for wastes containing solvents and dioxins, for wastes containing constituents from the "California List", and all remaining hazardous wastes. The remaining hazardous wastes were ranked and partitioned into thirds according to volume and toxicity. In 1990, EPA promulgated the final rule for treatment requirements of the third one-third (Third Third) of scheduled wastes (Federal Register, 1990).

Treatment standards are based on performance of best demonstrated available technology (BDAT) which is a commercially available or leasable technology that yields statistically better treatment results than other treatment technologies. Treatment standards may be specified either by a required technology or by concentration standards for the leachant. EPA has elected to specify concentration standards for the leachant based on BDAT. Other treatment technologies may be used if these concentration standards are satisfied.

Arsenic wastes are included in the Third Third of scheduled wastes and are classified by several codes: D004, K031, K101, K102, P010, P011, P012, P036, P038, and U136, according to their origin and/or chemical form. In 1988, most of the arsenic waste generated in Illinois was coded D004 and amounted to 109,872 gallons. The total RCRA D004 waste treated, stored, or disposed in Illinois during 1988 was 20,949,963 gallons. This amount is 1.3 times the amount of all types of waste handled by the largest treatment/ storage/disposal facility in Illinois (Illinois EPA, 1990).

The focus of this research report is the development and understanding of a promising treatment technology for arsenic wastes that are nonwastewaters. Nonwastewaters are defined by having either greater than 1% total suspended solids or 1% total organic carbon. In this report, arsenic wastes will mean arsenic nonwastewaters.

1.2 Basis for Legislation

In 1990, EPA solicited comments for the treatment of arsenic wastes. The responses and the rationale for the final EPA ruling (Federal Register, 1990) included a discussion of the treatment technologies of stabilization and vitrification. Stabilization (S/S) involves chemical bonding of the waste with binders and proprietary compounds. A variety of binders were used including asphalt, cement, fly ash, and cement kiln dust. Vitrification involves the application of heat generated by electrodes or direct

flame to a mixture of waste and glass-forming compounds. The cooled solid matrix is a glass/slag matrix. The intense heat of 1200-1500 degrees Celsius will destroy any organics present.

For stabilization of arsenic nonwastewaters, data reported to the EPA (Federal Register, 1990) are summarized in Table 1-1. The first observation is that stabilization appears to have potential for D004 arsenic wastes but not for K031 wastes. According to the EPA, the data are inconclusive for the following reasons: 1) the possible presence of organic interferences with the stabilization processes were not investigated; 2) the data did not include QA/QC data; and 3) the binder/waste ratio was not always stated or was too high. A high binder/waste ratio indicates more dilution and less treatment. Furthermore, the effect of cure time on treatment effectiveness has not been investigated.

There is some debate among commentors whether vitrifica-tion is "available" and "demonstrated". Nevertheless, based on 14 data points for a variety of wastes having 0.3%-23.5% arsenic, EP Toxicity Leaching of vitrified wastes yielded 0.007 to 1.8 mg/L arsenic. Neither QA/QC data nor volume increases were furnished. Furthermore, commentors expressed concerns about air emissions. EPA's response is that emissions from the vitrification process will be governed by current air quality regulations, and "a special furnace configuration with a recycling vapor scrubbing system is being investigated" and is "currently under development" (Federal Register, 1990).

Although the data are "equivocal", EPA decided that vitrification is BDAT because it appears to treat a variety of arsenic wastes based on current information. Since the data were for EP toxicity leaching, EPA expressed a concentration standard of 5.0 mg/L arsenic for EP leachate. If the arsenic in the extract from the toxicity characteristic leaching procedure (TCLP) is 5 mg/L or less, the treatment of arsenic satisfies treatment standards (Federal Register, 1990). EPA states that stabilization may be considered for certain arsenic wastes on a case-by-case basis. EPA issued a variance for the treatment of arsenic nonwastewaters until May, 8, 1992. Apparently, vitrification capacity and/or capability (e.g. air quality concerns) need to be addressed.

Although EPA declared vitrification as BDAT for arsenic wastes in general, research for effective arsenic stabilization is worthwhile for several reasons: 1) certain arsenic wastes, especially D004 which Illinois has the most of, may be stabilized effectively on a case-by-case basis, according to the EPA (Federal Register, 1990); 2) vitrification is costly; assuming a contaminated soil amenable to both vitrification and stabilization, and a specific gravity of 2.6 for soil, vitrification costs are $150-$220/cubic meter whereas stabilization is $92/cubic meter (Cullinane, 1985 and Pacific Northwest Laboratories, 1986); 3) vitrification may have air quality impacts; and 4) the proposed stabilization methodology allows an improved binder/hazardous waste ratio, i.e. more treatment and less dilution.

STABILIZATION OF ARSENIC WASTES

Table 1-1. Summary of Stabilization Data Submitted to EPA[1]

Waste Type	--------WASTE---------- Untreated Leachant Conc. or [As Concentration]	Treated Leachant Conc.	Treatment Technology	EPA Comments
D004	41 mg/L (EP Tox.)	1.7 mg/L	asphalt	
D004	[73,000 ppm]	2.7 mg/L	Chemfix	no binder/ waste ratio no QA/QC organic interfer-ences?
D004	409 mg/L (TCLP)	2.27 mg/L	proprietary stabilization	binder/ waste=1
D004	[35,000 ppm]	0.08 mg/L	proprietary stabilization	no QA/QC no binder/ waste ratio organic interference
D004	[750,000 ppm]	0.75 mg/L	American Nukem	high binder/ waste ratio high sludge production
K031	533 mg/L (EP Tox.)	25.3 mg/L	asphalt	
K031	5930 mg/L (TCLP)	10% inc.	cement	
K031	5930 mg/L (TCLP)	4687 mg/L	fly-ash	

1. Federal Register, 1990.

1.3 Objectives

1.3.1 Volume Efficiency, Treatment Effectiveness and Endurance

The goals of the research were to determine if S/S is a treatment for arsenic nonwastewaters that is cost-effective and volume-efficient. Satisfactory stabilization entails compliance with treatment standards for all time. Stabilization that is cost-effective will make it preferable to the costly and energy-intensive vitrification process with attending potential air emission problems. Volume efficiency, indicated by the volumetric ratio of untreated arsenic waste to treated arsenic waste, is important in that a waste is not really stabilized if it has been diluted greatly to decrease leachant concentrations. Furthermore, volume efficiency is important for the limited capacity of hazardous waste landfills. Finally, stabilization treatment must endure through time to avoid the potential migration of arsenic into the groundwater.

1.3.2 Development of Stabilization Technology

The investigators have stabilized a D004/D005 waste containing arsenic and barium. The stabilization included two steps: 1) a chemical pretreatment of arsenic using ferrous sulfate, ferric sulfate or aluminum sulfate; 2) stabilization with fly ash cement. This stabilization with pretreatment is promising because of the precipitation of barium sulfate and iron-arsenic compounds. This chemistry has been used for arsenic removal in the treatment of wastewaters. The precipitates may be encapsulated within or adsorbed onto the cement matrix.

This research was conducted to understand and develop this promising stabilization process. The mechanism of stabilization and its treatment effectiveness was investigated.

Research with a variety of pretreatment reagents, binders, and pozzolans was conducted on actual D004/D005 arsenic wastes from a glass manufacturer. This development includes a determination of the type and amount of pretreatment, binder, and pozzolan required for a lasting, satisfactory stabilization of arsenic. Ferrous sulfate and other pretreatment reagents were selected for their capacity to immobilize arsenic. Excessive amounts of these reagents and other waste components may be detrimental to the development of the cement matrix. For example, excess sulfate is deleterious to cement matrix development by reacting with hydrous or anhydrous calcium aluminate to form a crystalline ettringite structure. Cracking of the cement paste will occur if too much ettringite is formed (Mindess, 1981). There are types of cements and fly ash that minimize the impact of excess sulfate on the development of the cement matrix (Mehta, 1986; Mindess, 1981; Odler, 1988).

1.3.3 More Fundamental Understanding of Arsenic Stabilization

EPA has suggested that stabilization of certain arsenic wastes may be considered on a case-by-case basis. This project addresses a research need by developing a deeper microchemical/microstructural understanding of why stabilization works in some cases and not in others and by comparing methods of pretreatment to eliminate or minimize interferences. A more fundamental understanding of arsenic stabilization will aid in the characterization of those arsenic wastes amenable to stabilization. Furthermore, a deeper understanding of the microstructure and chemistry of arsenic stabilization is necessary to predict whether the treatment is lasting or not.

1.3.4 Development of Guidelines

Guidelines and recommendations for the stabilization of arsenic nonwastewaters have been developed. The guidelines aid in the decision as to which arsenic wastes are amenable to stabilization. The recommendations include pretreatment dosages and mix design parameters. These guidelines are intended to improve the design and operation of commercial arsenic stabilization processes.

1.4 Report Organization

A review of stabilization, arsenic chemistry, and treatment is provided in Chapter 2. Experimental methods and procedures are described in Chapter 3. Chapter 4 contains a description of the experimental design, and results are discussed in Chapter 5. Sections in Chapters 4 and 5 are written in parallel so the reader may follow the design and results of any part of the project without any loss of continuity. Stabilization mix design critical to understanding the results is found in Tables 4-2 to 4-4 on pages 52 to 54. These tables are repeated in Appendix A for convenience. Notations for mix designs are defined in the list of abbreviations and in Section 5.1 of Chapter 5. Chapter 6 provides a final summary and recommendations. Appendix B contains the analytical data for TCLP extractions of samples discussed in the report.

CHAPTER TWO
STABILIZATION AND TREATMENT OF ARSENIC AND BARIUM

2.1 Introduction

After a brief introduction to occurrences and sources of arsenic and barium, the relevant chemistries of these elements are discussed in sections 2.2 through 2.5. The hydration and chemical microstructure of cement is reviewed in section 2.6. A literature review of arsenic stabilization is presented followed by a discussion of arsenic adsorption and precipitation from wastewaters and natural waters. Adsorption and precipitation are reviewed since they may be important in stabilization.

2.2 Sources and Occurrences of Arsenic

Arsenic is an ubiquitous element occurring in land, air, and natural waters. The average arsenic content in the soil is 5-6 ppm (NAS, 1977) and may range from 1 ppm to 6000 ppm depending on the type of soil or rock (Gulledge and O'Connor, 1973). Arsenic occurs in about 100 different minerals such as arsenopyrite (FeAsS) and realgar (AsS). Nearby industrial sources such as smelters or the use of arsenical agricultural products may increase natural soil concentrations.

Arsenic residues enter natural waters by the weathering of rocks and soils and by runoff from decaying vegetation containing arsenic. Concentrations in the water are generally low. Seawater concentrations range from 1-8 ppb with sediments at 2-20 ppm (Penrose, 1974). Inorganic arsenic exists in several oxidation states and forms in water depending on pH and Eh. Arsenic may be metabolized by anaerobes to methylated forms that may bioaccumulate in certain seafoods.

Primary industrial contributions of arsenic to the environment are by-products of the smelting of non-ferrous metal ores, primarily copper with minor contributions by lead, zinc, and gold (NAS, 1977). Arsenic has also been used in agricultural herbicides, insecticides, and feed additives. In the 1940's and 50's, inorganic arsenic such as lead arsenate and calcium arsenate were used for herbicides. The development of organic arsenicals in the 60's replaced the inorganic forms for herbicidal use. Arsenic also enters the environment by accompanying phosphates in fertilizers and detergents.

Other industrial uses for arsenic include: wood preservation by zinc and chromium arsenates, additives in metallurgical applications and glass production, and catalysis in manufacturing processes. Arsenic trioxide is added to molten glass to coalesce air bubbles which can then rise out of the glass. The arsenic trioxide is captured in the flue as a tan colored dust. This hazardous waste, coded as D004/D005, must be treated before land disposal.

2.3 Arsenic Chemistry

The chemistry of stabilization is a very complex process. Arsenic stabilization, in particular, is currently not well characterized in the literature. In order to begin a study of arsenic stabilization, it is helpful to review the chemistry of arsenic in simple systems.

2.3.1 Oxidation States, Equilibrium, and Adsorption on Iron

The chemistry of arsenic in the condensed phase is primarily that of the +3 and +5 oxidation states. Unless insoluble sulfide compounds are formed, the normal forms found are the arsenite, AsO_2^-, the arsenate, AsO_4^{3-}, and their protonated species. $AsCl_3$ and $AsCl_5$ hydrolyze rapidly in water to form HCl(aq) and the corresponding arsenic acid.

Metallic arsenic (oxidation state 0) is a facile reducing agent, reducing solutions of $CuSO_4$, $Hg_2(NO_3)_2$, $FeCl_3$, $KMnO_4$, and $PtCl_4$. The other common oxidation state of arsenic (-3) is normally found only in the highly toxic compound $AsH_3(g)$, formed by reduction with nascent hydrogen.

Equilibrium constants for arsenic compounds are difficult to find in the literature, and various sources disagree significantly due to the difficulties of measurement and correction for solution nonidealities. In general, it is quite common to find reported values of ionization and solubility equilibrium constants varying over a one or two order-of-magnitude range. Several values for equilibrium constants from primary and secondary literature sources are listed in Table 2-1. Because iron(III) hydroxide is extremely insoluble ($K_{sp} = 4x10^{-38}$), iron arsenate and arsenite are reported to be soluble in basic solutions. It is reported that $FeAsO_4$ dissolves completely and quickly in concentrated ammonia to form a blood-red solution (H. Metzke, 1899). An examination of the solubility product of $Al(OH)_3$ ($K_{sp} = 1.3x10^{-33}$) indicates that aluminum arsenate should also be soluble in strong bases.

As(III) in aqueous solution behaves as a monobasic acid, while As(V) is a tribasic acid in aqueous solution. All known soluble As(III) compounds reduce nitric acid and decolorize $Br_2(aq)$, with the subsequent oxidation of As(III) to As(V). Strong solutions of H_2O_2 will oxidize As(III) to As(V) in acidic solution.

G. Lockemann (1911) found that arsenic is strongly adsorbed onto the surface of freshly precipitated $Fe(OH)_3$. This was used as an antidote for arsenic poisoning during the early part of the twentieth century. The process was shown to be a reversible adsorption reaction, not the formation of a basic arsenate precipitate. Because As(III) is oxidized to As(V) by the presence of Fe(III), the adsorption process takes place with arsenate or arsenite in solution. The amount of $Fe(OH)_3$ necessary for the

Table 2-1. Arsenic Equilibrium Constants

Dissociation of arsenous acid:

$HAsO_2(aq) \longrightarrow H^+(aq) + AsO_2^-(aq)$ $\quad K = 2.1\times10^{-9}$

Dissociation of arsenic acid:

$H_3AsO_4(aq) \longrightarrow H+(aq) + H_2AsO_4^-(aq)$ $\quad K_1 = 5.0\times10^{-3}$

$H_2AsO_4^-(aq) \longrightarrow H^+(aq) + HAsO_4^{2-}(aq)$ $\quad K_2 = 8.3\times10^{-6}$

$HAsO_4^{2-}(aq) \longrightarrow H^+(aq) + AsO_4^{3-}(aq)$ $\quad K_3 = 6.0\times10^{-10}$

Solubility products:

Ag_3AsO_3	1.2×10^{-17}	
Ag_3AsO_4	3.1×10^{-18}	(brownish-red)
$AlAsO_4$	1.6×10^{-16}	
$Al_2(HAsO_4)_3$	1.7×10^{-17}	
As_2S_3	4.4×10^{-27}	(yellow)
$Ba_3(AsO_4)_2$	8.0×10^{-51}	
$BiAsO_4$	4.4×10^{-10}	
$Ca_3(AsO_4)_2$	6.8×10^{-19}	
$FeAsO_4(s)$	5.7×10^{-21}	(red or yellow)
$Mg_3(AsO_4)_2$	2.1×10^{-20}	

complete adsorption of arsenic is given by the formula

$$E = k\ A^{0.57}$$

where E is the milligrams of $Fe(OH)_3$ in 100 mL of solution containing A milligrams of As. The constant k varies with temperature:

t, °C:	0	25	80
k :	70	90	130

W. Blitz (1904) found that the amount of As_2O_3 adsorbed from aqueous solution by $Al(OH)_3$ is very small and is practically independent of the As_2O_3 concentration.

In the sulfide qualitative analysis scheme used by Sorum (1960) and Hogness & Johnson (1954) arsenic appears in the acid

sulfide group, being precipitated as the sulfide from a solution ranging from 0.2 M to 2 M HCl saturated with $H_2S(g)$. As(III) is precipitated as $As_2S_3(s)$ while As(V) is both reduced by the H_2S to As(III) and precipitated as $As_2S_5(s)$.

From the chemical background above we can conclude that the predominant forms of arsenic in any waste to be stabilized are the AsO_2^- or AsO_4^{3-} anions in various stages of protonation. The most common of the simple chemical models of the concrete matrix is that of an anionic silicate-aluminate lattice with cations bound to lattice sites by ionic attraction. The amorphous, water-rich regions of the matrix are at very high pH values. In order to hold an anionic material in the matrix, the stabilization process must provide either covalent bonding into the matrix during the curing of the matrix or formation of insoluble compounds inside the matrix. Previous work (Akhter, 1990) indicates that incorporation of the arsenic anions into the silicate-aluminate backbone is not likely. Therefore, the most obvious mechanism for stabilizing arsenic is to form insoluble compounds with iron(II), iron(III), or aluminum(III) incorporated in the concrete.

Both iron(III) and aluminum(III) stabilizations appear to be difficult because the solubility of the arsenates should increase with increasing pH. The reactions supporting this argument are:

$$FeAsO_4(s) + 3\ OH^-(aq) \text{ -----> } Fe(OH)_3(s) + AsO_4^{3-}(aq) \qquad (1)$$

$$K = K_{sp}[FeAsO_4] \ / \ K_{sp}[Fe(OH)_3] = 5x10^{+15}$$

and

$$AlAsO_4(s) + 3\ OH^-(aq) \text{ -----> } Al(OH)_3(s) + AsO_4^{3-}(aq) \qquad (2)$$

$$K = K_{sp}[AlAsO_4] \ / \ K_{sp}[Al(OH)_3] = 1x10^{+17}$$

Accordingly, in order to keep the concentration of the arsenate ion low enough to meet TCLP standards, the solution must have a very low concentration of hydroxide ion (pH < 7). This observation may explain why arsenic stabilization fails in a cement only matrix.

This argument is too simplistic in this form, because we have not considered the fraction of the total arsenate in the solution which is actually present as the AsO_4^{3-} ion. The TCLP protocol is based on the total arsenic in the leachate from the sample. At pH = 7, only 0.6% of the total arsenic in solution is present as the AsO_4^{3-} ion, due to the weak acid character of H_3AsO_4. After we take the hydrolysis of arsenate anions into account we find the requirement that the pH must be below 5.5 to meet the TCLP standard from $AlAsO_4$ or $FeAsO_4$ for stabilization by simple precipitation. In the dynamics of a TCLP leaching procedure, it is unlikely that the equilibrium concentrations calculated would be reached because the surface of particles of $FeAsO_4(s)$ would be coated with a gelatinous precipitate of $Fe(OH)_3(s)$, slowing the rate of dissolution.

The weak acid character of the arsenate and arsenite anions indicates that the solubility of most arsenite and arsenate precipitates should increase markedly in acidic solution. If the pH becomes too low, the hydrolysis of the anion in the precipitate could lead to solubilization of the arsenic precipitate. The reaction to be considered is:

$$FeAsO_4(s) + H^+(aq) \text{ -----> } Fe^{3+}(aq) + HAsO_4^{2-}(aq) \qquad (3)$$

$$K = K_{sp}[FeAsO_4] \; / \; K_3[H_3AsO_4] = 1.1x10^{-18}$$

The total concentration of arsenic expected from this process is below 6 mg/L at pH = 1.0, indicating that it is unlikely to find much dissolution of the precipitate in acidic solutions.

The weak acid nature of H_3AsO_4 complicates any equilibrium discussions due to ionization and hydrolysis of the ions involved. Using the ionization constants reported in Table 2-1, the distribution of total arsenate in solution among the various species can be calculated, assuming ideal solution behavior. The results are presented in Figure 2-1. Examining these results, one notices that in solutions near pH 2, if the total concentration of As(V) is below the TCLP 5.0 mg/L standard (equal to $6.67x10^{-5}$M), then the concentration of AsO_4^{3-} anion, which is controlled by the solubility of $FeAsO_4$, must be below $1.1x10^{-15}$M.

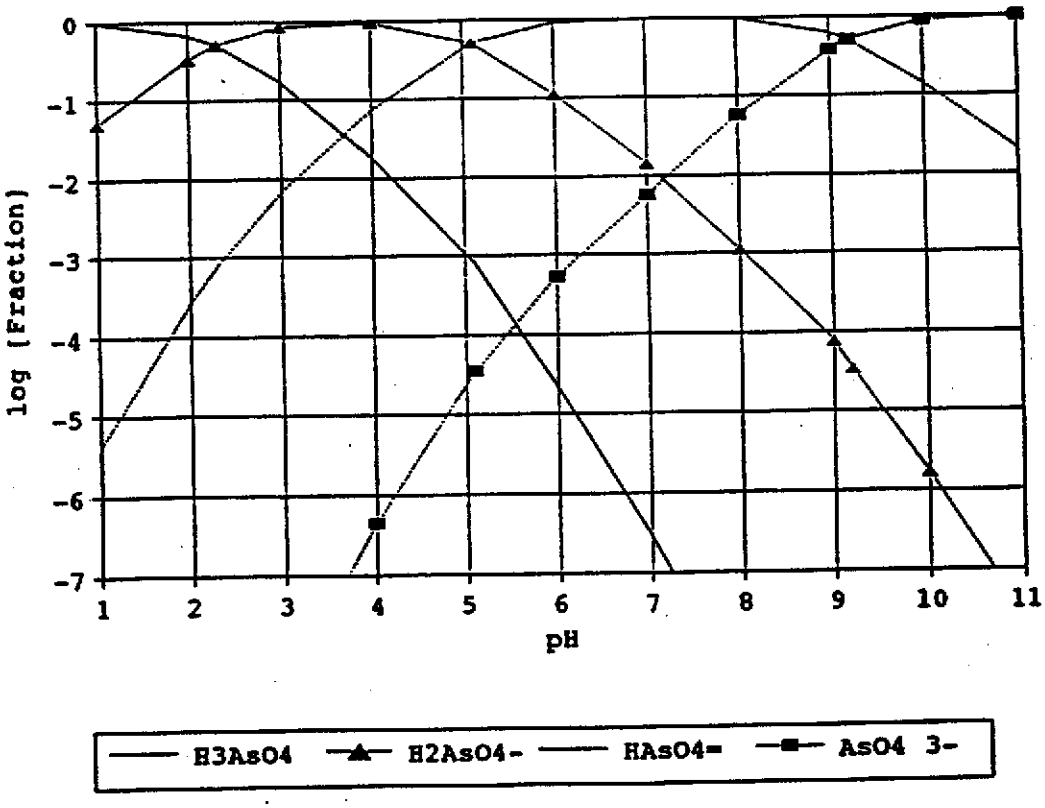


Figure 2-1. Principal Species Analysis for Arsenic Acid

$FeAsO_4(s)$ is a very insoluble material, with $K_{sp} = 5.7 \times 10^{-21}$. The solubility of $FeAsO_4$ is complicated by the fact that AsO_4^{3-} is the anion of a very weak acid. When we look at the solution properties, we should keep in mind the strong similarities between H_3AsO_4 and H_3PO_4. Another complicating factor is the extreme insolubility of $Fe(OH)_3(s)$, with $K_{sp} = 4 \times 10^{-38}$.

When appropriate solubility products and physical properties are collected, we note that comprehensive handbooks do not list nor contain properties for intermediate iron hydrogen arsenates or iron hydrogen phosphates.

In the simplest case, $FeAsO_4$ solubility is not affected by the pH of the solution. In this case the equilibrium is

$$FeAsO_4(s) \xrightleftharpoons{} Fe^{3+}(aq) + AsO_4^{3-}(aq) \qquad (4)$$

If we consider only the dissolving of $FeAsO_4(s)$, then $[Fe^{3+}] = [AsO_4^{3-}]$ and

$$[AsO_4^{3-}] = (5.7 \times 10^{-21})^{1/2} = 7.5 \times 10^{-11} \text{ M} = 5.6 \times 10^{-6} \text{ mg As/L}$$

This very small value, when compared to experimental results, appears to be unrealistic. Therefore we must consider the effect of pH on the solubility.

As seen in Figure 2-1, in mildly acidic solutions the arsenate anion is often at least monoprotonated, and in some cases multiply protonated at equilibrium. In this case, the major equilibrium to be considered is:

$$FeAsO_4(s) + H^+(aq) \xrightleftharpoons{} Fe^{3+}(aq) + HAsO_4^{2-}(aq) \qquad (5)$$

The equilibrium constant for this process is the solubility product for $FeAsO_4(s)$ divided by K_3 for arsenic acid. If we consider the process to be dissolving $FeAsO_4(s)$, then the concentration of $Fe^{3+}(aq)$ is equal to the concentration of $HAsO_4^{2-}(aq)$ and

$$[HAsO_4^{2-}] = \{[H^+] \times 1.80 \times 10^{-9}\}^{1/2}$$

Using this equation produces the expected concentrations of arsenic shown in Table 2-2. It has been assumed that no protonation of the arsenic anion occurs beyond the monohydrogenarsenate form. This oversimplification predict solubilities that are too small when the pH is below 4. In any case, note that the concentration of arsenic from the dissolution of $FeAsO_4(s)$ becomes significant only in the pH range below 3.

When the system has appreciable hydroxide ion concentrations, then another complication can arise from the competition of hydroxide ion for the iron(III) species. The extreme insolubility of $Fe(OH)_3(s)$ provides a large driving force for this competition.

Table 2-2. Solubility of Ferric Arsenate in Acidic Solutions

pH	3.0	4.0	5.0	6.0	7.0
$[HAsO_4^{2-}]$, M	1.3E-6	4.2E-7	1.3E-7	4.3E-8	1.3E-8
conc As, mg/L	0.10	0.03	0.01	0.003	.001

The relevant main equilibrium reaction now becomes

$$FeAsO_4(s) + 3\ OH^-(aq) \xleftrightarrow{\quad} Fe(OH)_3(s) + AsO_4^{3-}(aq) \qquad (6)$$

The equilibrium constant for this reaction is

$$K_{sp}(FeAsO_4)/K_{sp}(Fe(OH)_3) = 1.4x10^{+17}$$

which indicates that the reaction should lie far to the right. Our only hope of maintaining low arsenic concentrations is to keep the solution acidic enough so that the concentration of hydroxide ion is very low. We can calculate the concentration of dissolved arsenic using the equilibrium expression:

$$[AsO_4^{3-}] = [OH^-]^3 \times 1.4 \times 10^{+17}$$

This equation leads to the results in Table 2-3. It should be noted that iron(III) is not useful for precipitation of arsenate at pH levels above 7.0

Table 2-3. Estimated Solubilities of Ferric Arsenate in Weakly Basic Solutions

pH	6.0	6.5	7.0	7.25	7.5	8.0
$[AsO_4^{3-}]$, M	1.4E-7	4.5E-6	1.4E-4	8.0E-4	4.5E-3	0.14
conc As, mg/L	0.01	0.34	1.1	6.0	34.	1100.

When dealing with simple precipitates of $FeAsO_4(s)$, one can conclude that the pH must be kept in the range of 3.0 to 7.0 in order for arsenic to be effectively immobilized. The system is much more sensitive on the basic side than on the acidic side. This result is verified by column leaching results discussed in Section 5.3.

2.3.2 Implications for Stabilization in a Concrete Matrix.

This brings up the question, "How does the presence of ferric

sulfate improve the stabilization of arsenate wastes in a basic cement matrix?" There are several possible explanations to be considered: First, the Fe^{3+} ions may be serving as bridges between the arsenate anions and the silicate matrix. The geometry of the silicate oxygen atoms around the ferric ion could be quite similar to that of the oxygen atoms around the ferric ion in ferric hydroxide gel. If this were true, then hydroxide ions could not compete as effectively for ferric ion sites. Second, the concentration of free hydroxide ions in the cement matrix decreases as the matrix hardens. Most of the hydroxide has been immobilized by reaction with calcium and other species. This immobility reduces the ability of hydroxide ions to compete with arsenic for iron sites. Third, the ferric arsenate is physically protected from the leachant by the low diffusion rates in the cement matrix. If this is the case, then the amount of arsenic release should be related to the amount of cement matrix broken down by the leaching process.

Several methods for helping to distinguish between the possibilities were tried. Correlation of arsenic release with calcium and zinc release from the cement matrix during TCLP and column leaching tests allows the estimation of the contribution of the third case. Using atomic spectroscopy in the scanning electron microscope enabled us to look at the spatial arrangement of iron and arsenic. If the arsenic is bound to the lattice through iron, then the arsenic should be fairly evenly distributed. If the arsenic is immobilized through the physical encapsulation of ferric arsenate precipitate particles, then the arsenic should be found as separated clumps and correlate highly with the iron distribution.

As the problem of arsenic stabilization equilibria was investigated further, it was decided to consider the possibility of using a stabilizing agent such as Fe(II) to immobilize arsenic. Because the value of the K_{sp} for $Fe(OH)_2$ is larger than that for the tri-hydroxides, the solubility of iron-arsenate precipitates should be less in basic solutions. Quantitative calculations could not be attempted because not enough applicable equilibrium constants could be found in the literature.

2.4 Sources and Occurrences of Barium

Barium, a very reactive member of the alkaline earth family, is widely distributed over the earth's crust, mostly in conjunction with calcium. Barium ores include baryites ($BaSO_4$) and witherite ($BaCO_3$). In addition to the barium mined as the major product of an operation, barium is found in the tailings of lead, zinc, silver, fluorite and rare-earth mines. The metal is used as a sealed-tube vacuum system getter for residual gases and to deoxidize steel and other metals. Over 90% of the over one-million tons of barium used annually is as $BaSO_4$. The major use of this insoluble compound is in the petroleum industry as high-density well-drilling muds. $BaSO_4$ is also used as an extender in automotive paints and a rubber and plastics filler, particularly

for sound-deadening applications.

Barium sulfate is used in the glass industry as a flux to promote melting of the glass at a lower temperature and thus to increase the production rate, reduce seed imperfections, and reduce annealing time. As a glass additive, barium sulfate increases the refractive index of the glass and thus its brilliance.

About ten thousand tons of barium carbonate are used annually by the U.S. glass industry as a flux to decrease melting temperatures, and as an additive to increase durability, add weight and density, increase refractive index and increase x-ray absorption. The more expensive barium carbonate is often preferred over barium sulfate in glass melting because the dense carbonate doesn't become airborne when furnaces are charged. Other uses of barium carbonate include brick and tile glazes, ferrite molded and flexible magnets, and photographic papers.

2.5 Chemistry of Barium

Barium is being stabilized in a cement lattice using an additive such as iron(II) sulfate, iron(III) sulfate or aluminum sulfate in this project. The most probable mechanism for this stabilization process involves the precipitation of barium as barium sulfate and the mechanical incorporation of this solid into the cement lattice. In considering the concentration of barium to be expected in TCLP or column extracts, chemical principles can provide some guidelines.

Because barium sulfate is the insoluble precipitate formed from the interaction of a strong base and a strong acid, its solubility in aqueous systems is independent of the pH of the solution. The only effect which is expected to change the solubility of $BaSO_4$ is the activity coefficient correction due to the total ionic strength of the solution. Taking the solubility reaction to be

$$BaSO_4(s) \xleftrightarrow{\quad} Ba^{2+}(aq) + SO_4^{2-}(aq) \qquad (7)$$

the solubility product constant expression is

$$K_{sp} = [Ba^{2+}][SO_4^{2-}] = 1.1 \times 10^{-10}$$

If solid $BaSO_4$ is dissolved in pure water, the equilibrium concentration of Ba^{2+} is equal to the concentration of SO_4^{2-}. The equilibrium concentration of barium in pure water will be

$$[Ba^{2+}] = (1.1 \times 10^{-10})^{1/2} = 1.05 \times 10^{-5} M = 1.4 \text{ mg/L} \qquad (8)$$

if the solution is ideal.

In a real solution, activity coefficients must be taken into account. The Debye-Huckel theory can provide correction factors

which are accurate enough for our purposes. Debye-Huckel activity coefficients are determined by the total ionic strength of the solution. In the case above, the ionic strength, I, is given by

$$I = 0.5\ \{[Ba^{2+}](+2)^2 + [SO_4^{2-}](-2)^2\} = 2.1x10^{-5}M$$

In these rather dilute ionic environments, we can substitute concentrations in molarity for concentrations in molality with enough accuracy for our purposes. The Debye-Huckel limiting law defines the mean ionic activity coefficient, y, by:

$$\log(y) = 0.509(+2)(-2)(I)^{1/2} = -0.00933 \qquad (9)$$

which implies that y = 0.979. The corrected solubility is the ideal solubility (8) divided by the activity coefficient y (9), or 1.47 mg/L. Table 2-4 relates ionic strengths, activity coefficients, and expected solubilities.

Table 2-4. Barium Sulfate Solubility

Ionic Strength M	Activity Coefficient	Ba^{2+} Solubility mg/L	
0	1	1.4	
$2x10^{-5}$	0.98	1.4	
$1x10^{-3}$	0.86	1.7	(pH 3 extract)
$1x10^{-2}$	0.63	2.3	
$2x10^{-2}$	0.52	2.8	
$5x10^{-2}$	0.35	4.1	(pH 8.5 extract)
$1x10^{-1}$	0.23	6.3	

The pH 3 extract solution is $5x10^{-2}$M acetic acid.
The pH 8.5 extract solution is $5x10^{-2}$M sodium acetate.

If the concentration of free sulfate ion is different from the concentration of barium in an extract fluid, the solubility of barium can be affected. When the barium concentration is 1.4 mg/L ($1x10^{-5}$M), the equivalent sulfate concentration is 0.3 mg/L. Because the barium concentration is inversely proportional to the sulfate concentration, when the sulfur concentration is larger than 0.3 mg/L in an extract fluid (working with the reasonable assumption that the predominant sulfur species is sulfate) then the barium concentration should be smaller than that calculated above.

2.6 Chemistry of Cement

2.6.1 Manufacture of Cement

Raw materials for the manufacture of portland cement consist of calcium carbonates such as limestone, chalk, and shell deposits and iron-bearing aluminosilicates such as clays, silts, and shales. These materials are ground and conveyed through a kiln with zones of increasing temperatures. The initial zone drives off moisture and makes the materials reactive. In the calcination zone at about 1200 deg. C, calcium aluminates and ferrites are formed. Calcium silicates are formed in the liquid form of the charge in the clinkering zone at 1400 - 1600 deg. C. The material from the kiln is known as clinker which is mixed with a small amount of gypsum to make portland cement. The gypsum is necessary to prevent a flash set of the cement as explained in Section 2.6.3.

2.6.2 Chemical Composition of Cement

Based on the mix and type of raw materials as well as the operation of the kiln, the exact chemical composition of portland cement may vary. Approximate compositional formulae and abbreviations are shown in Table 2-5.

The proportions of the various components may be controlled to yield five different types of portland cement as shown in Table 2-5. Type I is used for most construction purposes where no special properties are required. If a more rapid set is required, then C_3S may be increased to yield Type III cement. A more rapid set may also be accomplished by grinding the cement to finer particles. The heat liberated during cement hydration may cause tensile cracking due to thermal stresses developing during cool-down periods. Thermal cracking is especially problematic with larger concrete placements. A decrease in C_3S and C_3A provides Type IV cement with a lower heat of liberation and longer set times. The exposure of concrete to sulfates (e.g. seawater) can cause cement deterioration. The replacement of C_3A with C_4AF yields a sulfate-resistant Type V cement.

2.6.3 Cement Hydration

All chemical reactions are written in a shorthand notation that is commonly used in the study of concrete chemistry. These notations are defined in Table 2-6.

The hydration of portland cement can be described by a series of consecutive and interacting reactions between clinker materials and water. As shown in Table 2-5, the general rates of hydration proceed in the approximate order: $C_3A > C_3S > C_4AF > C_2S$ although there may be considerable overlapping of reactions. The reactivities of the various compounds are affected by differences

Table 2-5. Principal Compounds of Portland Cement and Their Characteristics

Approximate Composition	$3CaO \cdot SiO_2$	$B2CaO \cdot SiO_2$	$3CaO \cdot Al_2O_3$	$4CaO \cdot Al_2O_3 \cdot Fe_2O_3$
Abbreviated formula	C_3S	BC_2S	C_3A	C_4AF
Common name	Alite	Belite		Ferrite Phase, Fss
Principal impurities	MgO, Al_2O_3, Fe_2O_3	MgO, Al_2O_3, Fe_2O_3	SiO_2, MgO, alkalies	SiO_2, MgO
Common crystalline form	Monoclinic	Monoclinic	Cubic, orthorhombic	Orthorhombic
Proportion present (%)	35 - 65	10 - 40	0 - 15	5 - 15
Average in Type:				
I	50	25	12	8
II	45	30	7	12
III	60	15	10	8
IV	40	40	4	10
Rate of reaction with H_2O	Medium	Slow	Fast	Medium
Contribution to strength:				
Early age	Good	Low	Good	Good
Ultimate	Good	High	Medium	Medium
Typical heat of hydration (cal/g)	Medium 120	Low 60	High 320	Medium 100

Refs: Jones, 1990; Mindess and Young, 1981.

Table 2-6. Cement Chemistry Notations

Abbreviation	Chemical Formula
C	CaO
S	SiO_2
H	H_2O
C_2S	$2CaO \cdot SiO_2$
C_3S	$3CaO \cdot SiO_2$
$C\bar{S}H_2$	$CaSO_4 \cdot 2H_2O$
C_3A	$3CaO \cdot Al_2O_3$
C_4AF	$4CaO \cdot Al_2O_3 \cdot Fe_2O_3$

in particle size and the presence of impurities. Cement hydration initially yields dramatic chemical and structural changes with smaller changes continuing for a period of years. The chemical reactions describing the hydration of cement compounds have been studied by investigating the hydration of each compound separately; this assumes that the hydration of each compound is independent of the hydration of other compounds. This pragmatic assumption is considered reasonable although there is some interaction among hydration reactions.

The exothermic reactions yield a rate of heat evolution curve as shown in Figure 2-2 for portland cement. The general shape of two heat peaks is determined by individual contributions of a similar shape from C_3A and C_3S as shown in Figures 2-3 and 2-4, respectively.

Within a few minutes of cement hydration, C_3A reacts with gypsum according to reaction (10) to form ettringite in the form of long slender prismatic needles growing into capillary pores between cement grains.

$$\underset{\substack{\text{tricalcium}\\\text{aluminate}}}{C_3A} + \underset{\text{gypsum}}{3C\bar{S}H_2} + \underset{\text{water}}{26H} \text{ ------> } \underset{\text{ettringite}}{C_6A\bar{S}_3H_{32}} \qquad (10)$$

C_3A is highly reactive; if gypsum is not available, C_3A reacts with the sulfate in ettringite according to reaction (11) to form monosulfoaluminates which are thin hexagonal plates set in an irregular cluster. The formation of ettringite slows down the hydration of C_3A by creating a diffusive barrier. This barrier may be removed as the ettringite is converted to monosulfoaluminate. The first heat peak occurs within 10-15 minutes and the second occurs within 12-36 hours depending on the

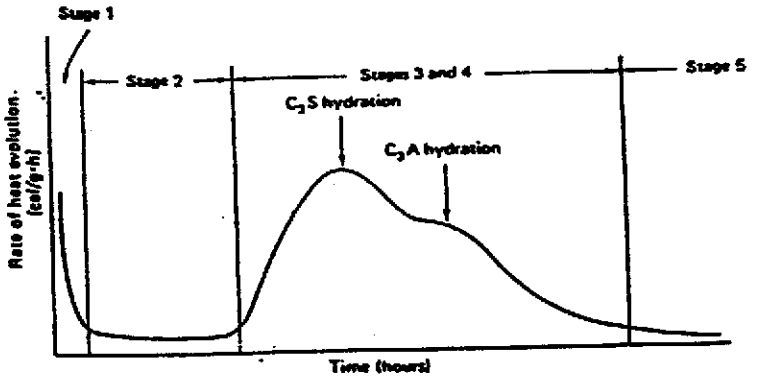


Figure 2-2. Rate of Heat Evolution During the Hydration of Portland Cement. (Mindness and Young, 1981)

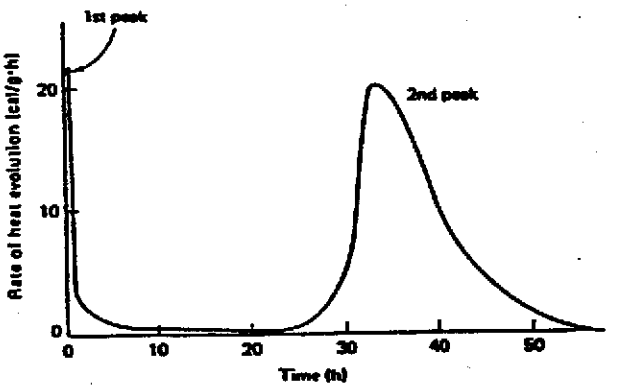


Figure 2-3. Rate of Heat Evolution During the Hydration of Tricalcium Aluminate with Gypsum. (Mindness and Young, 1981)

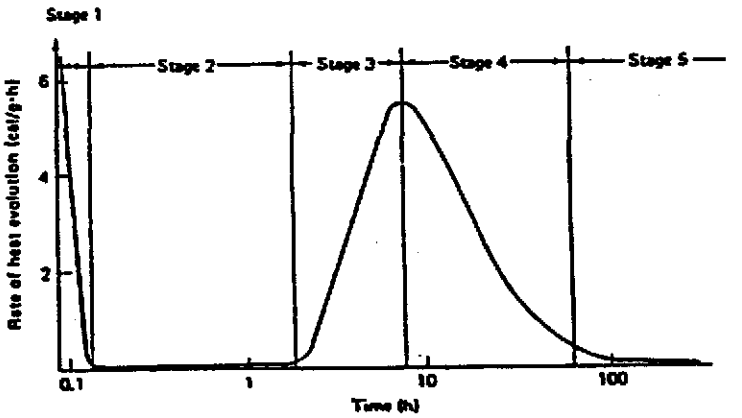


Figure 2-4. Rate of Heat Evolution during the Hydration of Tricalcium Silicate with Gypsum. (Mindness and Young, 1981)

amount of gypsum available. More gypsum prolongs the occurrence of a second heat peak and allows ettringite to remain stable.

$$2C_3A + C_6A\bar{S}_3H_{32} + 4H \text{ ------>} 3C_4A\bar{S}H_{12} \quad (11)$$

$2C_3A$: tricalcium aluminate; $C_6A\bar{S}_3H_{32}$: ettringite; 4H: water; $3C_4A\bar{S}H_{12}$: tetracalcium aluminate mono-sulfate-12-hydrate "monosulfoaluminate"

The formation of monosulfoaluminate in reaction (11) occurs because of an apparent deficiency of sulfate ions. If a new source of sulfate appears, ettringite can be formed again according to reaction (12).

$$C_4A\bar{S}H_{12} + 2C\bar{S}H_2 + 16H \text{ ----> } C_6A\bar{S}_3H_{32} \quad (12)$$

$C_4A\bar{S}H_{12}$: monosulfoaluminate; $2C\bar{S}H_2$: new sulfur source; 16H: water; $C_6A\bar{S}_3H_{32}$: ettringite

The reaction of sulfate with calcium hydroxide and the formation of ettringite after initial stages of cement hydration are the cause of cement deterioration due to excessive exposure to sulfates. The volume expansion of the paste accompanying these reactions creates internal stresses that ultimately lead to cracking.

To a lesser extent, the absence of sulfate may also lead to the formation of hydrogarnet according to reactions (13) and (14).

$$C_3A + 21\,H \text{ -----> } C_4AH_{13} + C_2AH_8 \quad (13)$$

C_3A: tricalcium aluminate; 21 H: water; C_4AH_{13}: calcium aluminate hydrates

$$C_4AH_{13} + C_2AH_8 \text{ -----> } 2C_3AH_6 + 9H \quad (14)$$

C_4AH_{13}: calcium aluminate hydrates; $2C_3AH_6$: hydrogarnet

The heat curve consisting of two peaks also describes the exothermic reactions of the calcium silicates as shown in Figure 2-4. As indicated in reactions (15) and (16), the reactions of the two calcium silicates are very similar, differing only in the amount of calcium hydroxide formed. The principal product, calcium silicate hydrate (C-S-H), has an approximate formula because its composition may vary. C_2S hydrates in a similar manner to C_3S but is much slower with less heat of evolution. A discussion of C_3S follows.

$$2C_3S + 6H \text{ ------> } C_3S_2H_3 + 3CH \quad (15)$$

$2C_3S$: tricalcium silicate; 6H: water; $C_3S_2H_3$: C-S-H; 3CH: calcium hydroxide

$$2C_2S + 4H \text{ ------> } C_3S_2H_3 + CH \quad (16)$$

$2C_2S$: dicalcium silicate; 4H: water; $C_3S_2H_3$: C-S-H; CH: calcium hydroxide

During stage I, the initial hydrolysis of C_3S yields a rapid heat of evolution with the dissolution of various ions such as

calcium and hydroxyl ion into the surrounding pore water. At the end of stage I, an insulating rind of C-S-H about 10 nm thick surrounds the C_3S particle. In stage II, a dormant period of relative inactivity occurs because of the diffusive control of calcium hydroxide through the C-S-H rind. Relative inactivity also occurs because concentrations of calcium hydroxide in the pore water have not reached limits necessary for the initial formation of crystal nuclei.

During stage III, C-S-H continues to develop from the particle surface growing outward to form a coating around the grain. The spinal morphology on the surface is various: pointed, blunt, flat, long, and thin. The presence of admixtures and impurities influences the morphology. The principal growth of C-S-H occurs in the underlying layer that surrounds the cement grain. When C-S-H surfaces expand and contact other C-S-H surfaces, the spines intermesh and a solid bond continues to develop as hydration proceeds.

At the same time, calcium hydroxide crystallizes from solution. Calcium hydroxide is a highly crystalline material with dimensions on the order of 0.01 to 0.1 mm. It occupies approximately 20-25% of the volume of a fully developed paste. Calcium hydroxide crystals grow toward free spaces within the capillary pore space. They stop growing at points of contact with other crystals or cement grains. They may grow around and occlude cement grains. Calcium hydroxide morphology depends on admixtures, impurities, and temperature of hydration. Increasing the thickness of the C-S-H layer presents an increasing barrier for ionic diffusion necessary for calcium hydroxide growth, so hydration approaches completion asymptotically as indicated by the heat of evolution for stages 4 and 5 in Figure 2-2.

The development of C-S-H and calcium hydroxide is shown schematically in Figure 2-5. The initial unreacted cement grains and water are shown in Figure 2-5a. The growth of C-S-H around cement particles is indicated in Figure 2-5b. The pore space is occupied by calcium hydroxide and water. In Figure 2-5c, the C-S-H occupies more and more volume as about 50-60% of a well-developed paste is C-S-H by volume. The remaining pore space is occupied mostly by calcium hydroxide with a small amount of pore water indicated.

C_4AF reacts slower with less heat of evolution. Gypsum retards these reactions more than C_3A. An increase of iron content slows the rate of hydration. As seen in reactions (17) and (18), the presence of gypsum affects the end products.

$$C_4AF + 3C\bar{S}H_2 + 21H \longrightarrow C_6(A,F)\bar{S}_3H_{32} + (A,F)H_3 \qquad (17)$$

$$C_4AF + C_6(A,F)\bar{S}_3H_{32} + 7H \longrightarrow 3C_4(A,F)\bar{S}H_{12} + (A,F)H_3 \qquad (18)$$

The term (A,F) indicates that iron oxide and alumina occur interchangeably in the compound.

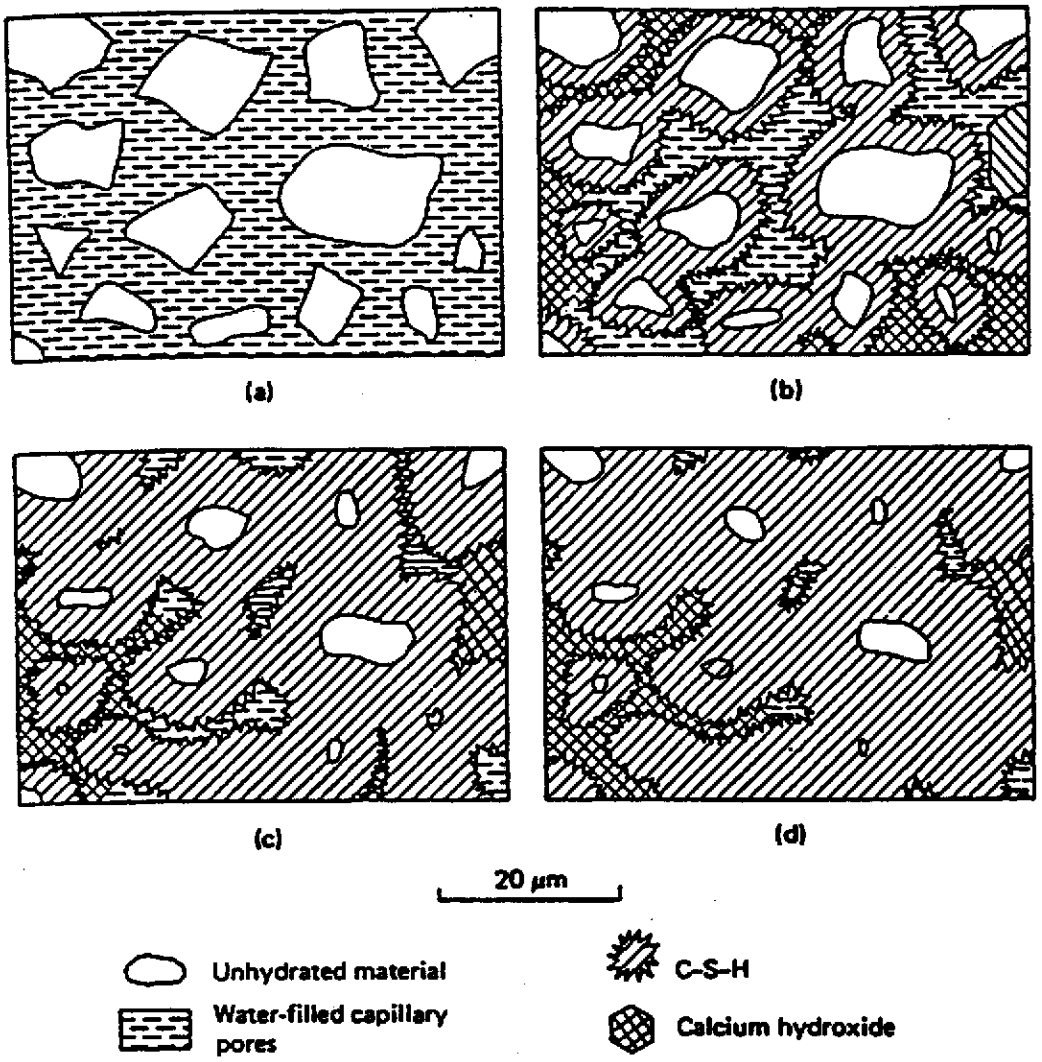


Figure 2-5. Schematic Outline of Microstructural Development of Portland Cement Paste. (Calcium Sulfoaluminates are included as part of C-S-H although they crystalize as separate phases.) (a) Initial (b) 7 days (c) 28 days (d) 90 days (Mindness and Young, 1981)

As cement paste hydration continues, the composition and pore structure continually changes. In a fully hydrated paste, 50-60% of the volume is occupied by C-S-H. The voids within the C-S-H structure are about 0.5 to 2.5 nm in diameter and account for about 25-30% of the C-S-H porosity. These voids have little effect on strength and permeability but appear to be important for drying shrinkage and creep.

Capillary voids are larger spaces not filled by solid components. In well-hydrated, low water/cement ratio mixes, voids range from 10 - 50 nm. In higher water/cement mixes, these voids may be 3000 - 5000 nm. Figures 2-6 and 2-7 illustrate how hydration time and water/cement ratio affect the amount of capillary space. Capillary voids larger than 50 nm are thought to be detrimental to strength and porosity.

2.7 Stabilization of Arsenic

In U.S. Patent 4,118,243 Sandesara (1978) stated that mixing a source of iron(II) with $Ca(OH)_2$ and sulfuric acid with an aqueous arsenic product led to a set-up matrix containing the arsenic. Arsenate ion is reduced to arsenite by the ferrous ion, and the precipitated arsenic is in the form of insoluble ferric arsenite after iron air oxidation.

In U.S. Patent 4,142,912 Young (1979) stated that combining arsenic wastes with water, portland cement, sand and "one or more water-soluble manganese and alkaline earth metal compounds" produced a solid that was "completely impervious" to arsenic leaching after a curing time of about 2 days. Leaching studies were done with a simulated oil well brine, providing a less stringent test than the TCLP procedure. Effective mole ratios of transition metals to arsenic were in the 2 to 12 range.

In a 2-year dynamic leaching study of cement-based solidified wastes using distilled water, Cote (1987) observed that arsenite anion was much more leachable than cadmium, chromium, or lead cations. Leachate pH varied from 11.5 to 9.0 during the study on several different matrices. With about 3000 mg/L As in the stabilized waste form, from 4.0% to 15% of the As was leached from the stabilized form over a 2-year period. Leaching percents for cadmium, chromium and lead ranged from 0.03% to 0.9% in the study. Arsenic was found to be present as $Ca(AsO_2)_2 \cdot Ca(OH)_2$ which had a leaching rate linear with time. The mechanism of leaching was inferred to be limited by the amount of CO_2 available. $CO_2(aq)$ reacts with basic calcium arsenite to form the more soluble calcium arsenite, $Ca(AsO_2)_2$. The water used in the leaching experiments was saturated with air. A mass balance of the dissolved $CO_2(aq)$ with the total As liberated was successful.

Sakata (1987) noted a high correlation between the adsorption of arsenic(III) on soil and the dithionite-extractable iron content. This correlation implies that arsenic(III) adsorption is

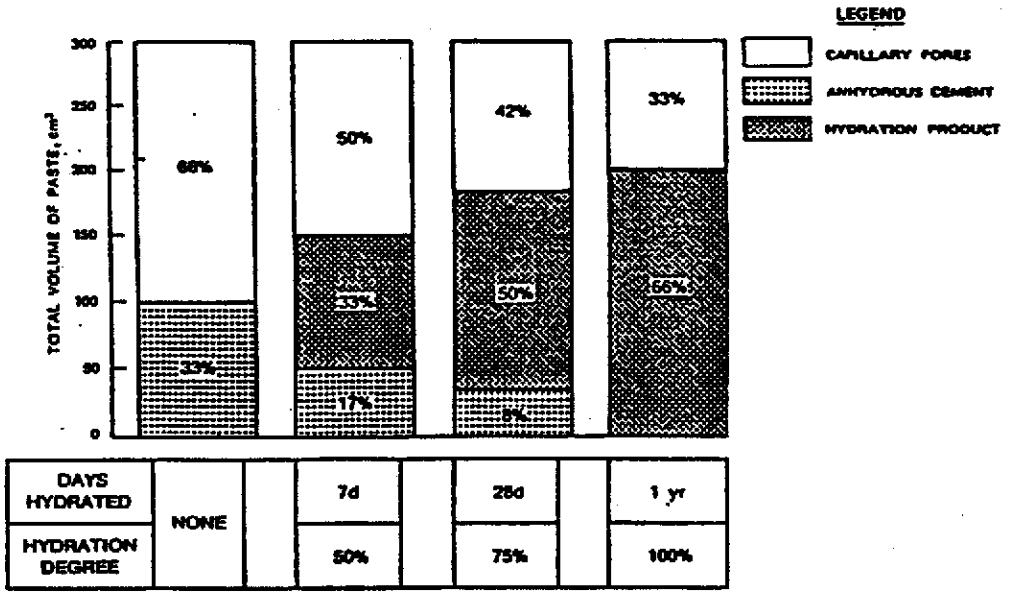


Figure 2-6. Changes in Capillary Pore Sapce with the Degree of Hydration for a Cement Paste with Water/Cement = 0.66 (Mehta, 1987)

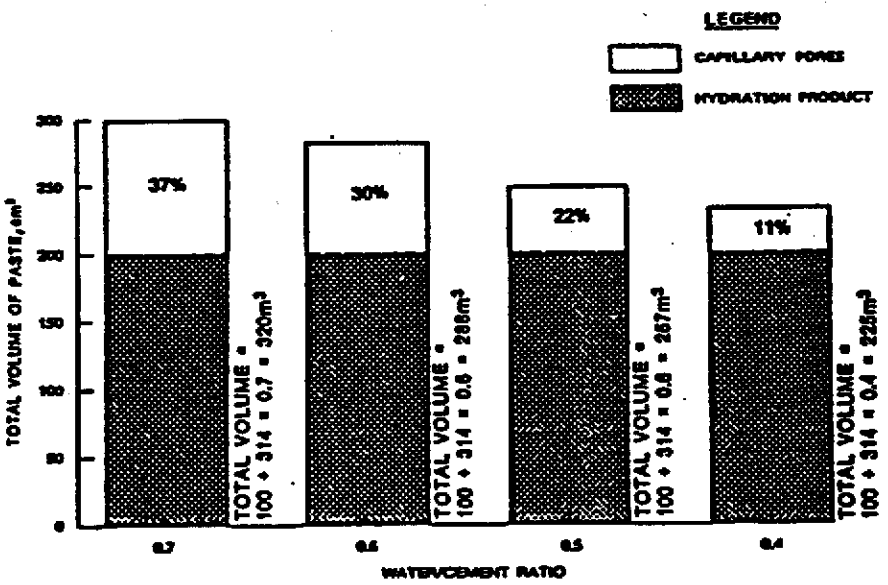


Figure 2-7. Changes in Capillary Pore Space for a Fully Hydrated Cement Paste with Variable Water/Cement Ratios, Based on Equal Amounts of Portland Cement. (Mehta, 1987)

controlled mainly by levels of amorphous iron oxides and hydroxides.

In a model study of soils contaminated with 12,200 mg/L of sodium arsenite, Akhter, et. al., (1990) found that cement or pozzolanic fixing agents were largely ineffective in immobilizing the arsenite. The study concluded that arsenic was probably immobilized in a cement-based binding system primarily through encapsulation. The soil matrix was a Mississippi Loess with a 2% organic content. Additions of type-F fly ash, blast furnace slag, and lime worsened or did not improve stabilization of arsenite. Silica fume provided only a marginal improvement in stabilization. The only formulation which was able to meet the 5 mg/L As TCLP standard was 44 parts cement in 100 parts contaminated soil.

Artiola et. al., (1990) treated arsenic-contaminated soils with iron oxides, ferrous sulfate, ferric sulfate, gypsum, and ferrous carbonate. Ferric and ferrous sulfate provided over 95% stabilization of the arsenic according to the EP toxicity test. All other treatments provided little or no treatment.

In a study of leaching models, Batchelor (1990) developed values for a leachability index for various contaminants. Increases in this parameter measure the degree of chemical or physical immobilization of a contaminant in a stabilization matrix. The leachability index for arsenic was determined to be 11.9. Nitrate anion has a value of 10.7 and nonreactive sodium ion has a value of 8.3.

A series of studies by Ortego (1990) has provided a better understanding of the chemical environment of cationic metals in a portland-cement matrix. The presence of barium or other sulfate-insoluble ions reduces the effectiveness of gypsum ($CaSO_4$) added as a "flash-set" inhibitor. Many metal ions enhance the formation of carbonate in the hardened cement. This series of studies used the TCLP procedure and a modification in which the pH of the leachant was kept near 5.0 Dramatic differences in metal ion extractabilities were found (Table 2-7). Additional work is being done in an attempt to understand these results. In the TCLP procedure the sample was treated with 0.040 M acetic acid in a 50:1 solvent-to-solid ratio. The pH 5.0 buffer was constructed from acetic acid and sodium acetate. Metal ions could be

Table 2-7. Weight Percent Metal Extracted (Ortego, 1990)

Metal	TCLP	Final pH	pH 5.0 buffer
Cd	6.20 %	7.7	16.84 %
Cr	0.12 %	9.5	62.99 %
Cu	4.36 %	9.9	92.43 %
Pb	0.004%	11.0	69.35 %
Ni	0.21 %	9.9	48.16 %
Zn	3.16 %	10.5	48.44 %

effectively prevented from leaching by coupling the portland cement treatment with the addition of an anion which forms a precipitate insoluble in dilute acetic acid (e.g. cadmium sulfide, lead phosphate).

Chu et al, 1991, conducted a study comparing fixation techniques for soil containing inorganic arsenic at concentrations ranging from 1200-2100 mg/kg. The TCLP of untreated soil yielded 22 mg/L arsenic. At least one of three tests: Extraction Procedure Toxicity, TCLP, or California Waste Extraction Test were performed on three types of treated samples. The first treatment used ferric chloride and aluminum sulfate with calcium carbonate for neutralization. The pH was important for the effectiveness of this treatment. The second treatment involved S/S with fly ash and Portland cement. The third treatment used calcium aluminate silicates with a proprietary cementitious mixture. The latter treatment appeared to be most effective, but conclusions are difficult when binder/waste ratios are not reported and some mix designs are proprietary.

U.S. EPA, 1992, contains several articles on the supply and demand, chemistry, industrial use, stabilization, and recovery of arsenic compounds. Cartledge (1992) and Connor (1990) present a summary of arsenic stabilization. Both arsenate and arsenite were stabilized using a binder/arsenic weight ratio of ten percent. Cartledge has observed that the percent hydration of the cement silicate phase is significantly retarded by arsenate and more so by arsenite. After one year of curing, both salts greatly retarded silicate polymerization. Also, a new crystalline material, $NaCaAsO_4 \cdot 7.5H_2O$ was found depending on the amounts of sodium and calcium available. In normal fly ash-Portland cement development, Cartledge also observed that the aluminate phase converts from tetrahedral to octahedral forms for up to 28 days. After 28 days, the conversion slowly reverts itself. Arsenic compounds appeared to catalyze the reversion process and current research is investigating the long-term effects on arsenic S/S. Table 2-8 presents a summary of data reported by Cartledge showing the degradation of some stabilization maxtures over curing times up to one year.

In a study of the bioavailability of arsenic and lead from soils, Davis (1992) found that the kinetics of dissolution or extraction of metals from soils in simulated pH 1.3 gastric acids could be quite slow. While enough pure sodium arsenite dissolved under the experimental conditions in about one hour to reach a concentration of 100 mg/L As, with soil present the concentration of As took 4 hours to reach 12 mg/L, and did not achieve higher concentrations after 30 hours. The arsenic species in the soil were identified to be enargite (85%) (Cu_3AsS_4) with impure arsenopyrite (FeAsS) and tennentite ($Cu_{10}(Cu\text{-}Fe)_2As_4S_{13}$). The total arsenic content of the soil was 1400 mg/L. These mineral species are quite insoluble in aqueous media, with only limited solubility in dilute acids. Further studies with rabbits indicated that As(III) in soils is less labile than As(V) compounds, as determined from fecal concentrations. The study

Table 2-8. TCLP Leachate Concentration from S/S Waste with 1 Year or (28 days) of Curing[1]

Binder[2]	Leachate Concentration (mg/L)				
	As(III)[3]	As(V)	Pb(II)	Cr(III)	Cr(VI)
OPC	1.7(2.1)	1.4(1.7)	35(48)	0.4(0.4)	2500(1400)
OPC,no gyp.	3.1(2.7)		43(2.2)		3200(2400)
1/1OPC,FFA	430(540)	94(7.9)	0.9(0.3)	0.7(0.2)	2900(1600)
20/1OPC,SiO2	2.3(2.4)		25(24)		2500(1600)
20/1OPC with Na_2SiO_3	2.0(3.5)	0.4(0.1)	28(1.8)	0.5(0.2)	2500(1800)
10/1OPC with Betonite	2.4(30)		46(1.4)		2400(1700)
10/1OPC with Organoclay	1.1(3.0)		40(16)		2800(2400)
20/1 TypeIA SiO_2	2.5(3.1)	0.4(0.1)	41(5.2)	0.2(0.2)	2800(1900)
White	0.9(1.7)	10(3.6)	54(1.0)	0.4(0.2)	2900(2000)
20/1 White Na_2SiO_3	1.0(2.5)	15(8.0)	38(6.0)	0.8(0.2)	2800(2000)
Luminite	240(140)		4(400)		3700(2300)
Refcon	190(150)		190(680)		3600(1900)
Pyrament	47	4.4	1.7	1.4	2800

1. After Cartledge (1992).
2. OPC = Type I portland cement; FA = fly ash; SiO_2 silica fume; Na_2SiO_3 = Type N soluble sodium silicate; White = portland cement with low iron content; Luminite and Refcon are specialty cements that are for refractory applications and high in alumina content. The water to binder weight ratio is 0.5 and the metal to binder ratio is 0.1.
3. The salts are $Pb(NO_3)_2$, $NaAsO_2$, $Na_2HAsO_4 \cdot 7H_2O$, $Cr(NO_3)_3 \cdot 9H_2O$, and $Na_2CrO_4 \cdot 4H_2O$.

concluded that the use of soluble arsenic compounds to model the bioavailability of soil arsenic seriously overestimates the amount of arsenic liberated.

Cheng and Bishop (1992a) used synthetic metal sludge generated from 0.01 molar solutions of cadmium nitrate, lead nitrate, and sodium arsenite with the pH adjusted to 8.5 using 6.0 molar sodium hydroxide. These metal sludges served as the only water source for the hydration of type I portland cement with water/cement mixtures of 0.4, 0.6, and 0.75. Curing was performed in spherical molds for at least 78 days at 100% humidity. Static leaching tests with periodic leachant renewal was performed with various acetic acid solutions. After leaching, the surface layer of the leached samples was removed from the unleached sphere, "kernel", with a knife. SEM/X-ray and wet digestion/AA analyses

of the leached surface layer and kernel were performed. The AA analyses indicated that heavy metals were released only in the surface layer and not the kernel. SEM/X-ray indicated a sharp change in heavy metal content and calcium at the leaching boundary. Calcium appeared to leach most easily while silicon, iron, and aluminum appeared to remain in the leached layer. The authors suggest that the leached layer may create a resistant barrier to slow down the acid attack on the waste form.

Cheng and Bishop (1992b) used a modified Generalized Acid Neutralizing Capacity Test (Isenburg and Moore, 1992) which is similar to the Acid Neutralization Capacity test (Environmental Canada and Alberta Environmental Center, 1986) with acetic acid leachant instead of nitric acid. The test is a single-batch leaching procedure that utilizes a series of dried crushed samples extracted in parallel with increasing acidic leachant. Metal concentrations in leachates permit development of a relationship between leached metal concentrations and pH. Approximately 100% of Ca, 90% of Cd, 70% of Pb, and 60% of As were desorbed in acetic acid solutions of pH = 5. Dissolved metal concentrations decreased with increasing pH. If the pH of the pore water in the cement-based form remained above 9, the desorption process of most heavy metals did not occur to any large extent. The amphoteric nature of certain metals was not evident. The authors suggest that these metals were adsorbed on solid surfaces since these surfaces are negatively charged under alkaline conditions. They assert that the silicon-rich leached layer has lost most of its calcium hydroxide and adsorbs like an amorphous silica gel. This leached layer provides some adsorption capacity and provides a barrier to diffusing metals leaching out and acid leaching in. As evidence of this fact, they provide a comparison of adsorption profiles as a function of pH for the leached layer and silicon material.

2.8 Treatment of Arsenic in Waters

A limited literature review is presented that includes arsenic treatment in waters and solids. An exhaustive review is beyond the scope of this report. The chemistry and treatment processes may be pertinent to the stabilization of arsenic nonwastewaters.

Gulledge and O'Connor (1973) simulated coagulation, flocculation, sedimentation, and filtration for arsenic removal by alum and ferric sulfate. Ferric sulfate was more effective with 90-100% removal at doses of 10 mg/L to 50 mg/L over the tested pH range of 5-8. Alum was less effective and could only compare to that of ferric sulfate at a lower pH of 5 or 6 with a higher concentration of 30-50 mg/L.

Gupta, et. al., (1978) studied arsenic adsorption on activated alumina, activated carbon, and activated bauxite. Adsorption was carried out in fresh water, diluted seawater,

seawater, and sodium chloride. Activated alumina adsorbed more and was faster than other adsorbents. The rate of arsenic(V) adsorption was greater than that for arsenic(III). A ranking of adsorption capacity was: alumina first, bauxite a close second, and activated carbon a distant third. Arsenic(V) adsorption by activated alumina or bauxite decreases above pH = 7. Activated carbon adsorbs arsenic(V) better in the 3-5 pH range. Increasing the ionic strength by using seawater decreased the adsorption of arsenic significantly.

Bhattacharyya, et. al., (1980) observed that metal sulfide precipitation is attractive over a broad pH range because of the high reactivity of sulfides (S^{2-}, HS^-, H_2S) with heavy metal ions and the low solubilities of heavy metal sulfides. Using Na_2S and NaHS with heavy metal and arsenic wastes, the extent of metal sulfide precipitation is a function of pH, type of metal, sulfide dosage, and interfering ions. At a pH of 8, heavy metals were 98-99.6% removed with a dosage of 0.6 mole sulfide to mole metal. Arsenic removal was not effective unless ferric iron was added at a Fe/As mole ratio of 2.

Schlicher and Ghosh (1985) investigated ion exchange, activated carbon, activated alumina, and air flotation with the goal of less expensive arsenic removal with less sludge production. For ion exchange, they used a strong base anionic resin but the resin reached exhaustion quickly with 100% arsenates removal and only 50% arsenite removal. They estimated a selectivity sequence of common ions by strong base anionic resin by the similarity between arsenic and phosphate chemistry. Therefore:

known sequence: $SO_4^{2-} > HPO_4^{2-} > NO_3^- > Cl^- > HCO_3^- > H_2PO_4^-$

estimated: $SO_4^{2-} > HAsO_4^{2-} > NO_3^- > Cl^- > HCO_3^- > H_2AsO_4^-$

Adsorbing colloid flotation for metal removal has been widely studied. The process consists of adding a flocc-forming substance such as ferric chloride or alum to collect metals by adsorption or coprecipitation on metal hydroxides formed by addition of a base. The floccs are removed by flotation using a surfactant, e.g. sodium lauryl sulfate (NLS). Arsenates are highly removed but arsenites are not. The optimum pH for arsenate removal was 5-6 with alum as the coagulant. The rate of adsorption on activated alumina was faster than that for activated carbon. Also, the adsorption capacity of activated alumina was greater than that for activated carbon.

Egawa, et. al., (1985) manufactured a macroreticular chelating resin containing mercapto groups. Three resins were used in batch and column experiments to determine the adsorption rate and capacity of three different resins. One of the resins appeared to be successful in removing As(III) in columns and batches. They also showed that the resin was selective for As in the presence of other ions such as Ca and Na.

Ghosh and Teoh (1985) studied adsorption kinetics and capacity for arsenites and arsenates on activated alumina. The rate of arsenate adsorption varied significantly with pH. The rate of arsenite adsorption increased slightly with increasing pH. Arsenate adsorption was described by the Langmuir isotherm. Fixed bed column studies showed the effect of mass loading and empty bed contact time on the breakthrough curve. Competitive adsorption by bicarbonate, sulfate, and silicate yielded an earlier breakthrough of arsenic species.

Sen and De (1987) used coal fly ash and powdered activated carbon in batch adsorption studies of As(III) and As(V). Adsorption rates and capacities were studied. Fly ash was adsorbed at a slower rate than activated carbon but in the end it was comparable in capacity. The optimal adsorption pH for both activated carbon and fly ash was about 3-4. The solutions were 0.9 mg/L in As(III) and As(V). The fly ash dose was varied from 0.35 g to 1.4 g, the adsorption of arsenic increased up to about 1.0 g/50 mL and became constant after that. Various diverse ions showed no effect on the adsorption of arsenic on fly ash. Data was fit to the Freundlich isotherm.

Wagemann (1978) investigated four metals: Ba, Cr, Fe, and Ca as controlling factors on solubility of metal arsenates in freshwater systems. Barium at typical concentrations in freshwaters was found to be most likely to limit the solubility of arsenate. He developed an Eh-pH diagram which summarizes a theoretical As speciation in freshwater environments.

Harper and Kingham (1992) were concerned with the treatment of contaminated water generated from cleanup activities at a former pesticide facility. Initial laboratory treatment studies included chemical precipitation using either alum, Na_2S, or $FeCl_3$ as a coagulant with pH adjustment by hydrated lime. The initial arsenic concentration was 9.8 mg/L and coagulant doses were 500 to 1000 mg/L. $FeCl_3$ with hydrated lime was the most successful coagulant with 98-99% removal. In another sample having 31 mg/L As, dosages of $FeCl_3$ ranging from 200 mg/L - 1000 mg/L resulted in As removals of 86-93%. Multiple doses of coagulants in series did not improve results significantly. Filtration of the treated wastewater did not yield significant improvements.

Brewster (1992) describes a process for arsenic removal from wastewaters. The wastewater passes through an electrochemical cell where ferrous ions and hydroxyl ions are generated at the anode and cathode, respectively. Hydrogen peroxide is added to the wastewater in an ensuing reactor tank where the ferrous hydroxide is oxidized to its ferric form. Hydrogen peroxide also oxidizes any arsenite to arsenate. The pH is maintained at 6.5 for optimum ferric arsenate precipitation and maximum adsorption. Small amounts of polymers are added between the reactor tank and clarifier to improve settling characteristics.

If arsenic is the only contaminant of concern and proper pH

levels are maintained, a 5:1 iron to arsenic ratio can reduce residual arsenic to near or below analytical detection limits. If other metals are to be removed and different pH levels are necessary, then higher amounts of iron are required.

Process advantages are: low dissolved solids since the added ferrous and hydroxyl ions are removed by precipitation; the sludge is stable since arsenic concentrations in TCLP extracts are less than standards; low residual As concentrations; low sludge production rate; and low operating cost.

Brewster (1992) explains the process chemistry with reference to common arsenic removal mechanisms: the addition of the counter ion to form an insoluble precipitate; surface complexation; and electrostatic attractions. Ferric ion is effective to remove arsenate by forming ferric arsenate precipitate with a residual of 7.5 mg/L of dissolved arsenic. Ferric ion is not effective for arsenite precipitation, hence the need for hydrogen peroxide.

Surface complexation is also important for arsenic removal. The addition of ferric iron results in the formation of hydrous ferric oxide [FeO(OH)] with ferric arsenate. If undissociated arsenic acid donates a proton to the hydroxyl group of the hydrous ferric oxide to form water, surface complexation may occur with the arsenate ion taking the place of the hydroxyl group. Surface complexation is more favorable at low pH because of the greater potential for proton donation by arsenic acid. As the pH is increased, the potential for proton donation decreases and surface complexation is less important. Therefore, at higher pH values, the iron to arsenic ratio must be increased for effective arsenic removal. After surface complexation, electrostatic attractions may occur between complexes.

Arsenate removal is approximately 50% greater than arsenite for two reasons: ferric arsenate is less soluble than ferric arsenite and arsenous acid does not readily lose its protons. Other anions such as sulfates, chlorides, and nitrates can hinder treatment by directly occupying adsorption sites or orienting around positively charged sites.

CHAPTER THREE
METHODS AND MATERIALS

3.1 Sample Collection and Composition of Wastes, Binders, and Reagents

Approximately 70 pounds of D004/D005 waste were collected at one time from Peoria Disposal Company. This amount was sufficient for the project duration. A chemical analysis is provided in Table 3-1.

Table 3-1. Chemical Composition of D004/D005[1] Waste

Metal	Average Concentration[2] (grams /kilogram of waste)	TCLP Concentration (mg/L)
Aluminum	8.0	.03
Antimony	0.3	7.7
Arsenic	6.0	280
Barium	133.	3350
Boron	29.4	5560
Cadmium	0.003	0.015
Calcium	2.3	16.
Chromium	0.009	0.015
Copper	0.03	0.093
Iron	2.7	0.6
Lead	0.10	0.13
Magnesium	0.65	1.2
Manganese	0.17	0.021
Nickel	0.012	0.057
Phosphorus	<0.05	0.21
Potassium	2.0	94.
Sodium	2.1	81.
Sulfur	0.37	0.29
Zinc	0.95	0.57

1. Density = 0.116 g/cc; moisture content = 9.0%
2. Average concentration based on three samples; nitric acid digestion followed by chemical analysis with an inductively coupled plasma emission spectrometer (USEPA, 1986, Method 6010).

Arsenic valence speciation was carried out using the Dionex Ion Chromatograph at the Hazardous Materials Laboratory of HWRIC. An anion column was used with 120 mM NaOH eluant. Arsenic(III) was detected using a pulsed amperometric detector and was quantitated as AsO_2^-. Arsenic(V) was detected with a conductivity detector and was quantitated as AsO_4^{3-}. TCLP extracts were diluted 1:15 to match the dynamic range of the ion chromatograph detector system as well as to prevent column flooding.

The arsenic in distilled-water extracts of D004/D005 waste extracted under a N_2 blanket was up to 15% arsenic(III). If a TCLP extraction with acetic acid was performed, with or without a N_2 blanket, less than 5% of the arsenic was present as As(III).

Arsenic(III) is easily oxidized in diute aqueous solution to form arsenic(V). Fifty mg/L aqueous laboratory standards were approximately half oxidized in two to three days.

X-ray diffraction is nearly the only tool suitable for determining the compound composition of an inorganic material. Other inorganic analysis techniques identify elemental or ionic compositions, but do not enable the identification of compounds as such. In order for x-ray diffraction to be useful, the sample must be crystalline in nature, with particle sizes over the micrometer range. Highly mechanically-distorted components, glasses, and amorphous materials do not produce analytically useful diffraction patterns.

An x-ray diffraction powder pattern was obtained on a sample of the D004/D005 waste using a Phillips Automated Diffractometer. The diffraction pattern obtained is shown in Figure 3-1. Manual analysis of the major peaks of the diffraction pattern indicated high confidence matches for $Ba(OH)_2$ and BPO_4 (ASTM patterns 1-0630 and 11-237) (ASTM, 1965), in addition to several polymorphs of silica, SiO2. By no means have all the major line intensities been accounted for, but no other matches which agree with Table 3-1 have been identified. A second, insoluble compound of barium was not identified in the x-ray diffraction pattern to account for the half of the Ba that is not extractable from the raw waste by TCLP. X-ray diffraction only characterizes crystalline components, while glasses and other phases of low crystallinity do not produce strong diffraction lines.

Sufficient amounts of binders were stocked and homogenized before beginning this project. Two bags of Type I Portland Cement, manufactured by Continental Cement Company were used. Class C fly ash from Davenport Cement Company was used. Table 3-2 provides information on the binder chemical compositions provided by the suppliers. Table 3-3 presents an ICAP analysis of nitric acid digestates.

3.2 Stabilization Procedures

Mixing was performed in a kitchen mixer with an acid-rinsed stainless steel bowl and stainless steel wire impeller. All the dry materials including pozzolan, cement, and hazardous waste were mixed thoroughly before water was added. Various additives such as ferrous sulfate, ferric sulfate, sodium sulfate, or iron acetate were dissolved in the water prior to mixing with the binders (see Chapter 4). The purpose of this mixing procedure is to ensure a consistent application of water and additive to dry materials from one mix to another. Four hundred to nine hundred grams were mixed at one time for at least one minute. Consistent results were obtained with mix durations of at least one minute (Bayasi, 1992). The sample was partitioned into approximately 110-gram samples and cured. Since at least 100 grams are required for the TCLP, the additional 10 grams allows for moisture loss during curing. If more weight was lost, then like samples were

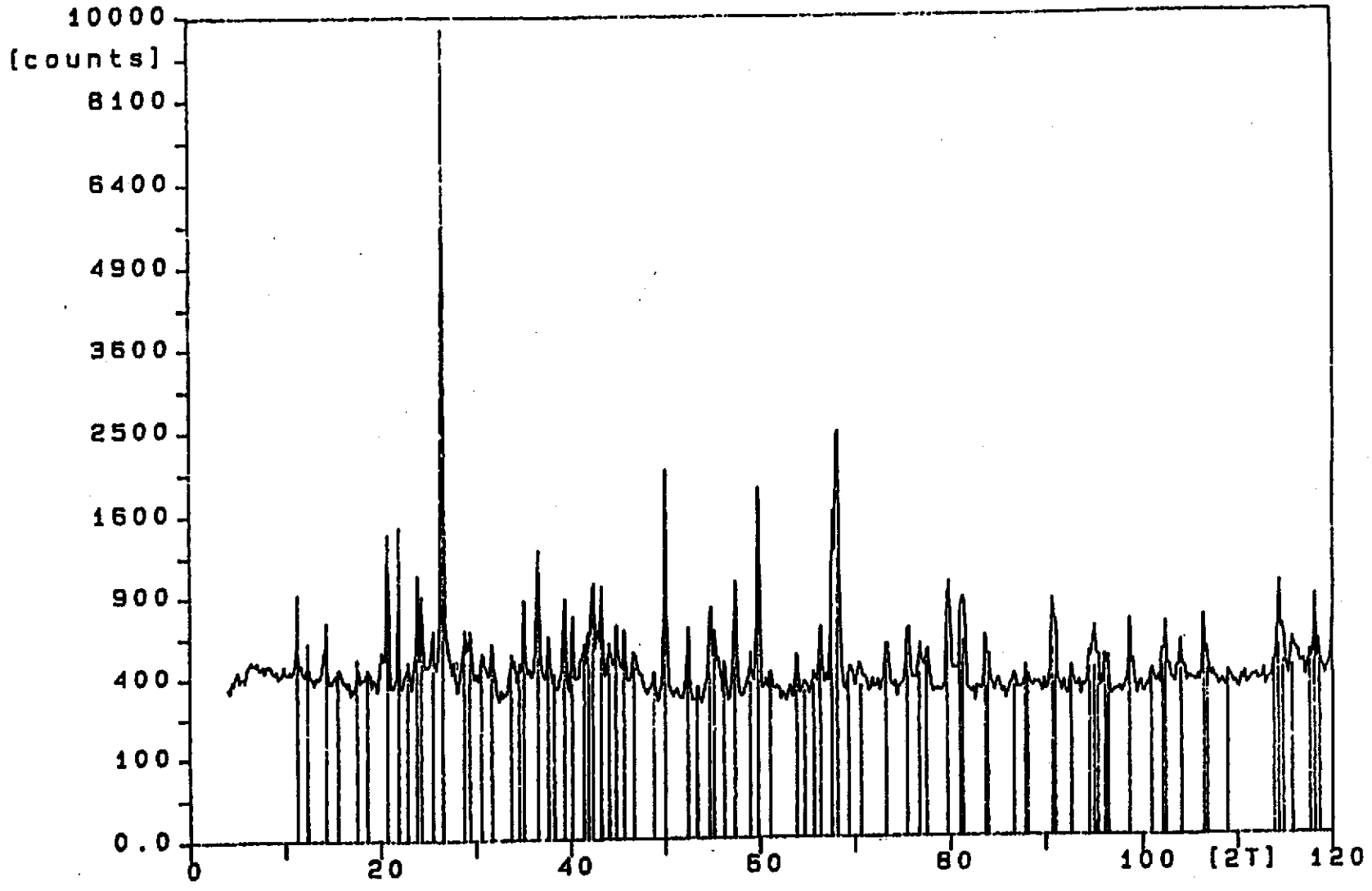


Figure 3-1. X-Ray Diffraction Pattern of D004/D005 Waste

Table 3-2. Manufacturers' Composition of Binders
Fraction of Total Mass (%)

Compound	Portland Cement[1]	Class C Fly Ash[2]
SiO_2	20.80	33.55
Al_2O_3	4.10	18.95
Fe_2O_3	2.78	6.35
SO_3	2.60	1.87
CaO	63.90	27.25
MgO	4.50	3.88
Na_2O		1.73
K_2O		0.35
C		0.20

1. Loss in ignition 1.80%. Insoluble residue 0.15%.
2. Particles greater than No. 325 sieve (45 microns = 0.018 in.) = 18%. Specific gravity = 2.72.

Table 3-3. Chemical Composition of Binders

Metal	Cement[1] Total (mg/kg binder)	Cement TCLP (mg/L)	Fly Ash[1] Total (mg/kg binder)	Fly Ash TCLP (mg/L)
Arsenic	1.	0.13	24.	0.14
Barium	170	0.30	5742	0.32
Cadmium	3.4	0.02	8.3	0.02
Chromium	170	1.2	57.	0.26
Lead	8.5	0.13	19.	0.14
Nickel	40.	0.05	53.	0.05
Calcium	381,000	3120	180,000	1490
Iron	14,600	0.10	34,100	0.10
Copper	24.	0.021	140	0.14
Potassium	2820	53	1560	1.7
Magnesium	22,700	0.16	30,300	52.
Manganese	910	0.015	202	0.02
Sodium	815	8.4	9560	36.
Sulfur	10,200	204	11,300	160
Zinc	207	0.33	237	0.21

1. Nitric acid digestion followed by chemical analysis with an inductively coupled plasma emission spectrometer. (USEPA, 1986, Method 6010).

combined to satisfy the 100-grams requirement.

Stabilization (S/S) forms were cured with air. Air curing of small samples in acid-rinsed plastic cups took place within the protection of a lab cabinet which reduced any air-borne dust deposition on the sample. Air curing provides samples that are similar to surface samples taken from a stockpile of treated waste awaiting treatment verification before landfilling. Cure times of 2 days were selected to model common industrial practice. Longer

cure times were studied to assess S/S durability.

3.3 Leaching Procedures

3.3.1 TCLP

The TCLP (USEPA, 1986, Method 1311) is recognized by the U.S. EPA as the standard method for measuring treatment effectiveness of S/S. The TCLP is a batch procedure with a leaching duration of 18 hours $\pm$ 2 hours. Information pertaining to the time and sequence of metals leached cannnot be obtained by the TCLP so a dynamic leaching procedure was also used. Equipment and procedures for both leaching tests are described below.

Standard equipment for TCLP testing were used (Code of Federal Regulations, 1987). These include: a) Model DC-18 rotary agitator from Analytical Testing and Consulting Services, Inc.; b) type 316, stainless steel, 142 mm (5.6 in) filter holder from Fisher Scientific; c) borosilicate glass fiber filters (GF/F Whatman Grade) with a 0.7 micrometer effective pore size; d) high-density polyethylene bottles for agitation and for sample storage which were obtained from Crown Glass Corporation; and e) pH meter with a relative accuracy and repeatability of 0.01 pH.

Standard TCLP procedures were used. Pertinent to the inorganic hazardous waste used in this research, a brief, nontechnical summary of the TCLP procedure follows (Code of Federal Regulations, 1987): One hundred grams of stabilized waste were ground with mortar and pestle to pass a 9.5 mm standard sieve. The waste was put into a 2000-cc bottle containing 2.000 kg of an extraction fluid consisting of diluted glacial acetic acid. Although the bottle size is designated as 2000-cc, sufficient headspace was available for fluid agitation. Extraction fluid type 2 (pH = 2.88 $\pm$ 0.05) was selected on the basis of EPA-specified test procedures. The mixture of S/S form and extraction fluid was agitated end-over-end for 18 $\pm$ 2 hours. The fluid was extracted from the solids by means of positive pressure filtration through a 0.7 micron borosilicate fiber filter. The pH and alkalinity of the extract were measured. Alkalinity was measured by the amount of 1.00N sulfuric acid necessary to decrease the pH to 4.5. Fluid samples were preserved by acidification to pH < 2 with nitric acid and stored at 4 degrees C prior to chemical analysis.

In addition to standard procedures, the following precautions were taken in order to achieve consistent high-quality data. First, nitrogen was the pressuring gas. Second, approximately 2000-cc of extract were obtained during the extraction which takes 5-20 minutes. In initial TCLP tests, the pH and possibly the chemical composition of the extraction fluid varied depending on whether the fluid passed the filter earlier or later during the extraction process. Therefore, the 2000-cc of extract were well-mixed to obtain a representative sample for preservation and

chemical analysis. Third, new acid-rinsed bottles were used for agitation and for storage of the TCLP extract.

3.3.2 Column Leaching

For dynamic leaching, a vertical glass column 47 cm long and 1.6 cm in diameter, was used. Perpendicular tapered glass connections at the bottom and top allow the introduction and exit of extraction fluid. A 3.0 mL/min flow from bottom to top of the column was driven by a peristaltic pump using 0.8 mm (inner diameter) Norprene tubing. Openings at the top and bottom of the glass column allowed easy filling and removal of waste samples from the column. During the leaching process, the open ends were plugged with stoppers covered with Parafilm.

During the column leaching experiment, effluent samples were collected at time intervals given by the empty bed detention time which equals the column volume divided by the leachant flowrate. The effluents were first tested for pH and acid neutralization capacity followed by preservation with nitric acid to pH < 2. The analyses of samples collected over time allows the observation of relative leaching rates for various metals.

Three different leachants: DI water, 0.10 M glacial acetic acid (pH = 3.0), and 0.10 M sodium acetate (pH = 8.7) solutions were used to observe the effects of leachant pH on metal leaching rates. Fresh leachant was continuously fed to the column in each case.

3.4 Chemical Analyses

All extracts and solid digestates were analyzed with an inductively coupled argon plasma (ICAP) emission spectrophotometer, Model ICAP 61 made by Thermo Jarrel Ash Corporation. This is a simultaneous vacuum spectrophotometer with a 23-element configuration. A standard cross-flow nebulizer is used to atomize the extract or digestate into a plasma emission source. The intensity and wavelength of the photon emissions resulting from orbital transitions of excited electrons are determined. A number of orbital transitions are possible for a given element leading to a number of possible emission lines for the element. The excitation energy is provided by the high temperature of the inductively coupled plasma, a largely ionized gas in an oscillating magnetic field.

After the temperature of the plasma has equilibrated after startup, a mercury vapor lamp is used to precisely align the optics of the instrument. Instrument calibration follows by using three points plus a blank for each element. This calibration is confirmed by verification measurements that must be within $\pm$ 10% of their known concentration value for the initial calibration to be considered valid. These calibration and verification procedures are repeated after the analysis of every ten samples.

If an element could not be calibrated properly, that data were flagged and samples were rerun at a later date. Samples with questionably extreme values were typically rerun.

For each element, the calibration and verification standards, detection limits for TCLP and solid measurements, and analytical ranges are provided in Tables 3-4 and 3-5. The acid-preserved TCLP extracts were routinely diluted ten-fold to avoid emission interference by the high levels of calcium present in the extracts.

Table 3-4. Standards and Detection Limits for ICAP

Element	Calibration Standard (mg/L)	Calibration Verification (mg/L)	Instrumental Detection Limits[2] (mg/L)	Project Detection Limits[1] TCLP (mg/L)	Project Detection Limits[1] Solids (mg/kg)
Aluminum	10	1	0.02	0.20	1.0
Antimony	10	1	0.05	0.50	2.5
Arsenic	10	1	0.025	0.25	1.25
Barium	10	1	0.002	0.02	0.1
Beryllium	10	1	0.001	0.01	0.05
Boron	10	1	0.04	0.4	2.0
Cadmium	10	1	0.003	0.03	0.15
Calcium	100	10	0.01	0.10	0.5
Chromium	10	1	0.003	0.03	0.15
Cobalt	10	1	0.003	0.03	0.15
Copper	10	1	0.003	0.03	0.15
Iron	10	1	0.02	0.20	1.0
Lead	10	1	0.025	0.25	1.25
Magnesium	100	10	0.02	0.20	1.0
Manganese	10	1	0.003	0.03	0.15
Nickel	10	1	0.007	0.07	0.35
Phosphorus	10	1	0.06	0.60	3.0
Potassium	100	10	0.15	1.5	7.5
Selenium	10	1	0.04	0.40	2.0
Silver	10	1	0.005	0.05	0.25
Sodium	100	10	0.02	0.20	1.0
Sulfur	10	1	0.05	0.50	2.5
Vanadium	10	1	0.002	0.02	0.1
Zinc	10	1	0.005	0.05	0.25

1. Project detection limits for TCLP extracts and solids are respectively 10 and 50 times the instrumental detection limits.
2. Instrumental detection limits according to USEPA, 1990b.

3.5 Digestion Studies

TCLP extracts were not routinely digested because there is no significant difference observed in the chemical analyses of digested and undigested TCLP extracts. This conclusion has been verified by independent testing performed by PDC Laboratories,

Table 3-5. ICAP Analytical Range[1] for Elements

Element	Analytical Range (mg/L)
Aluminum	0.025-500
Antimony	0.05-1000
Arsenic	0.050-500
Barium	0.001-100
Beryllium	0.001-100
Boron	0.006-500
Cadmium	0.004-200
Calcium	0.01-1000
Chromium	0.005-500
Cobalt	0.003-300
Copper	0.002-200
Iron	0.005-500
Lead	0.025-1000
Magnesium	0.015-1000
Manganese	0.001-100
Nickel	0.01-500
Phosphorus	0.06-1000
Potassium	0.3-1500
Selenium	0.05-1000
Silver	0.003-300
Sodium	0.01-500
Sulfur	0.08-1000
Vanadium	0.002-200
Zinc	0.004-200

1. Supplied by manufacturer.

Inc. and by studies conducted during earlier research in this laboratory (Bayasi, 1992). Twelve TCLP extracts were selected from S/S with K061 waste; six from fly ash S/S and six from silica fume S/S. Within each set of six samples, three were from S/S with one-day curing and three were from samples that had cured 11 months before TCLP. These samples provide a wide range of concentration values ranging from detection level to 3100 mg/L.

Table 3-6 presents the results for six metals. Cadmium, chromium, lead, and nickel were selected for presentation because they are regulated metals for K061 waste used in the earlier project (Bayasi, 1992). Calcium was selected because it occurs in high concentrations since it is a significant component of cement and fly ash. Zinc was selected because its concentration values were most variable and are not highly correlated with the regulated metals.

An inspection of Table 3-6 shows that the correlation between chemical analyses of TCLP extracts with and without digestion is significantly high. This high degree of correlation is reasonable because the extracts have been filtered through a 0.7 micron filter and stored at a pH < 2. Furthermore, extracts were shaken just before injection to the ICAP to suspend any small particles

that might have passed a 0.7 micron filter. With the high energy levels of ICAP, metals in these particles would be measured.

Table 3-6. Correlations Between Digestates and Extracts

Metal	Silica Fume Samples	Fly Ash Samples
Cadmium	1.00	1.00
Chromium	0.959	0.995
Lead	1.00	0.999
Nickel	0.841	0.903
Calcium	0.998	0.989
Zinc	1.00	0.999

3.6 Spike Recovery

Two sample digestates with relatively high concentrations of calcium, lead, nickel, chromium and cadmium were matrix spiked to show that instrumental interference effects are minimal for these samples. Five milliliters of these standard solutions: 2500 mg/L barium, 500 mg/L arsenic, 500 mg/L chromium, 500 mg/L lead, 100 mg/L cadmium, and 500 mg/L nickel were added to 50 milliliter samples. TCLP results of the digestates and the spiked samples are presented in Table 3-7 along with spike recoveries. All spike recoveries are within a reasonable range of 75% to 125%.

Table 3-7. TCLP of Spiked Digestates

	SAMPLE MEASUREMENTS[1]						Metal
	1	2	3	4	5	6	
Arsenic	<0.13	<0.13	5.5 (120%)	0.04	0.10	5.0 (108%)	
Barium	0.29	0.31	27.5 (120%)	0.84	0.84	25.5 (108%)	
Cadmium	<0.02	<0.02	1.04(115%)	6.47	6.46	7.29 (91%)	
Calcium	1030	1070		4020	4010		
Chromium	1.58	1.66	6.77(113%)	0.14	0.14	4.68(100%)	
Lead	<0.14	<0.14	5.09(110%)	10.7	10.6	14.7 (90%)	
Nickel	<0.04	<0.04	5.04(112%)	0.52	0.52	4.97 (98%)	

1. Measurements 1 and 2 are duplicate digestates of the same sample; matrix spike results are shown under measurement 3. Measurements 4 and 5 are duplicate digestates of the same sample; matrix spike results are shown under measurement 6. Spike recoveries are indicated as percentages in parenthesis.

3.7 Error Analysis

In considering the potential sources of variability in the concentrations found for a TCLP extract of a stabilized waste mix, the following factors can be identified: (1) composition of stabilized waste mix, (2) mixing parameters, (3) TCLP leaching procedure, (4) storage of extracts, (5) analysis of TCLP extracts by ICAP, and (6) data reduction. Each factor will be discussed below and its contribution to the overall uncertainty estimated.

3.7.1 Composition of Stabilized Waste Mix.

A stabilized waste mix is assembled from five components, each weighed to the nearest 0.1 gram. The range of masses used for a single 110-gram TCLP mix is from 5 grams to 100 grams, with the smallest component being the stabilization additive. The stabilization additive (ferrous sulfate, ferric sulfate or aluminum sulfate) is an ACS reagent-grade material and should make no contribution to the hazardous trace metal content of the TCLP extract. These chemicals are used in the form of soluble crystalline powders and are expected to be uniformly distributed in the final mixed sample. The water used is deionized, and does not contribute to the concentrations of metals in the extracts. The composition of cement and fly ash are given in Table 3-3. A quantity of these raw materials sufficient for the project duration was thoroughly mixed before being stocked in the laboratory.

The D004/D005 hazardous waste used is the most inhomogeneous of the raw materials. Although the bulk of the industrial waste is a fine powder, a visual examination shows pieces of broken glass up to several millimeters across and variations in apparent color in different regions. The waste used was mixed in a bulk mixer and then stored for laboratory use. Table 3-8 presents results of triplicate nitric acid digestion analyses and TCLP extraction procedures on 100.0-gram samples of this mixed D004/D005 waste. An examination of the data for zinc in Table 3-8 shows the variability of industrial wastes. This variability is why practical S/S research must be done with actual waste materials. Variations in regulated as well as non-regulated components of the wastes being treated require the development and use of very robust treatment procedures.

Examination of the compositions of the raw materials given in Table 3-3 indicates that following concentrations of the trace metal zinc can give us information on the cement and fly ash binder variability in the samples. The elements arsenic, barium and boron can be used as indicators of waste content in samples.

The variability of the analytical results in Table 3-8 indicates that the composition of industrial hazardous wastes is not uniform. The relative error in the composition of the stabilized mixtures is about 10% for arsenic and barium as a result of waste nonuniformity. One result of this is that any

treatment procedures must be very well-designed so that variations in the waste will not cause treatment procedures to fail.

Table 3-8. Untreated D004/D005 Waste Variability

Concentration (mg/kg) in Nitric Acid Digest

Metal	Sample 1	Sample 2	Sample 3	Average	Std. Dev.
Arsenic	6220	5520	6200	5980	6.7%
Barium	131500	128600	140000	13340	4.4%
Calcium	3740	1260	1970	2323	55.0%
Iron	4540	2420	1000	2653	67.1%
Magnesium	1160	267	520	649	70.9%
Potassium	1930	1860	2110	1967	6.6%
Sodium	2360	1740	2180	2093	15.2%
Sulfur	620	110	380	370	69.0%
Zinc	2630	98	120	949	153. %

Concentration (mg/L) in TCLP Extract

Metal	Sample 1	Sample 2	Sample 3	Average	Std. Dev.
Arsenic	296	295	247	279	10.0%
Barium	2790	2890	4370	3350	26.4%
Calcium	15.4	18.2	15.0	16.2	10.8%
Iron	0.10	0.19	1.5	0.60	131. %
Magnesium	0.83	0.93	1.9	1.22	48.4%
Potassium	126	120	35	93.7	54.3%
Sodium	105	101	38	81.3	46.2%
Sulfur	0.42	0.71	0.58	0.57	25.4%

3.7.2 Mixing Parameters

These include the type of mixer used in the laboratory, the speed of mixing, the time of mixing, and the order of addition of components to the mix. Mix homogeneity has been a concern in the past (USEPA, 1990a). The same mixer was used as in previous projects (Bayasi, 1992) and the speed of mixing was kept constant throughout the study. As shown in previous studies (Bayasi, 1992) , mixing intensities longer than one minute at 140 rpm do not contribute to an improved consistency of results. The order of mixing, whenever experimentally possible, included thorough mixing of dry components before adding water, so that uniform wetting of the solid is possible. When cured stabilized waste mix forms are broken up for TCLP analysis, non-wetted zones or large inhomogenieties (with the exception of glass cullet) are not observed visually.

3.7.3 TCLP Leaching

The TCLP leaching procedure involves several steps: crushing the stabilized-waste form, extraction of the crushed material with the extraction fluid for 18 ± 2 hours, and filtration to separate the leachant from unreacted material. In the sample preparation stage, 100.0 grams of sample were used to minimize effects of inhomogeniety. Care was taken during the crushing operation to not lose fine material which might have a different composition than coarser particles. The 2.000 kilograms of extraction fluid was measured to a precision of 0.05% and care was taken to avoid leakage during the 24-hour extraction period. The small particle size of the sample coupled with the long time of extraction serves to minimize effects due to diffusion within particles as well as surface sealing in the curing of S/S waste forms.

The filtration step is potentially the greatest source of error in the TCLP extraction process. Some materials, e.g. $BaSO_4$, produce very fine, chemically inert precipitates. The particle size of precipitated $BaSO_4$ is easily small enough to pass through the filter specified for the TCLP process (Koltoff, 1969). If a fine solid were suspended in the extract, it would produce a false reading in the ICAP experiment. This potential problem was not judged to be severe because a visual spot check of several extracts showed very little turbidity. Also, normal operating procedures for ICAP used the average and standard deviation of three repeated aspirations for each sample and our relative standard deviation for barium was judged to be sufficiently small after taking waste inhomogeniety into account. Even though ICAP determinations of samples with small particles may be reproducible, particulate penetration of the filter may not be reproducible or controllable. One consequence of this is that the variance in barium determinations can be larger than other elements.

3.7.4. Extract Storage

TCLP extracts were acidified with nitric acid to below pH 2 before storage at $4^{o}C$, following recommended EPA procedures. EPA recommendations are that samples stored in this manner should yield satisfactory results for storage periods up to six months. In a few instances in this study, samples were reanalyzed after interim storage for periods of several weeks with comparable results, indicating that no severe changes were taking place during the storage process.

3.7.5 Analysis of Extracts

The analysis of TCLP extracts by ICAP was carried out following the standard quality control procedures of the US EPA. Samples were diluted 1:10 before analysis to extend the linear range while still maintaining sufficient sensitivity to meet TCLP standards. The instrument was standardized with three sets of

standard solutions with concentration ratios in 1:10:100 ratios before and after samples were analyzed. Standards agreement before and after samples are required to meet instrument manufacturer's specifications for the data to be considered valid.

Samples were analyzed three times with blanks aspirated between to prevent sample cross-talk in the ICAP torch. A percent relative standard deviation was calculated for the three sample determinations and reported along with the mean of the values. Because the sources of instrumental noise are varied, the precision of determinations often is best understood as a function of the concentration being determined. In this project the detection limit for such a determination is defined as the concentration where the noise is 100% of the analytical signal. Figure 3-2 presents plots showing the instrumental relative standard deviation for elements important in this project versus concentration for 24 representative samples.

The instrumental precision at the TCLP standard limit of 5 mg/L for As is better than 5%, at the 100 mg/L limit for Ba the precision is about 1%, at the average concentration in the project for iron of about 40 mg/L the precision is better than 1%, and at the average sulfur concentration of 150 mg/L the instrumental precision is better than 2%. For calcium the concentration in the TCLP extracts is between 1000 and 3000 mg/L and the relative precision observed is 0.6% on the average. In summary, we can assume that instrumental precision is always better than 5% in this project, justifying the use of at least 2 significant figures.

3.7.6 Data Entry and Reduction

Data entry and reduction is also a possible source of error. Notebook protocols for laboratory personnel were constructed to ensure complete records. When large amounts of data were to be entered into a computer, the data entered was proofed by more than one person.

3.7.7 Error Analysis Summary

The overall error associated with the TCLP process can be considered using a propagation of errors approach. This method of error estimation will provide a very pessimistic view of the overall error associated with an experimental result. The TCLP concentration is written as a function of the independent variables:

TCLP(mix composition, mix parameters, extract analysis)

and the derivative is taken. Assuming linear behavior for the independent variables and stochastic independence, the maximal estimated relative error in the final TCLP extracts can be written

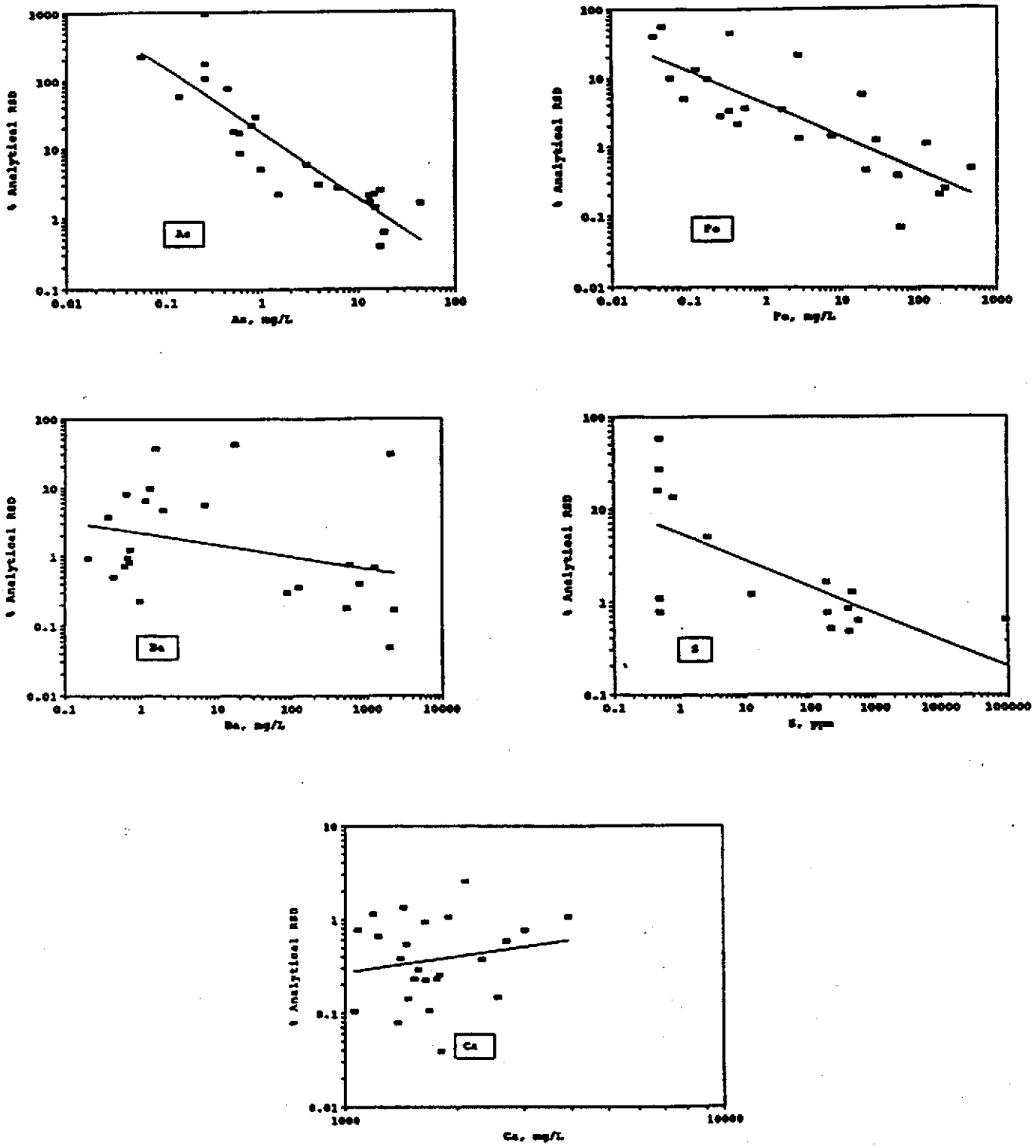


Figure 3-2. ICAP Replicate Relative Standard Deviation as a Function of Concentration with Regression Lines.

as

$$\frac{\text{TCLP error}}{\text{TCLP}} = \frac{\text{comp error}}{\text{comp}} + \frac{\text{mix error}}{\text{mix}} + \frac{\text{anal error}}{\text{anal result}}$$

In this case, following the discussion above, the relative error in the composition of the stabilized mixtures is about 10% for arsenic and barium. The uncertainties found in the mixing study in previous projects were 10% or less for elements of interest (Bayasi, 1992) and probably are insignificant compared to the variability in composition of the raw waste because waste variabilities are folded into the mixing experiment design. As discussed above, a conservative estimate for analytical precision is 5%, so that the overall uncertainty in the TCLP results expected is about 15%.

As a check on this, two mixes with large masses were prepared of the same nominal composition. The composition of these mixes was designed to produce a poor stabilization of the waste so that measurable concentrations may be compared. After suitable curing, these large masses were crushed and partitioned into 4 aliquots for separate TCLP extractions. Each TCLP extract was analyzed independently. The results are shown in Table 3-9 and Figure 3-3.

Table 3-9. TCLP Precision Results

Metal	Sample A		Sample B		All Data	
	Avg mg/L	% Std Dev	Avg mg/L	% Std Dev	Avg mg/L	% Std Dev
Arsenic	48.3	0.7	28.8	15.8	38.5	26.8
Barium	3623	5.7	3638	7.9	3630	6.9
Boron	1242	4.7	1053	7.0	1147	10.0
Calcium	992	3.8	930	7.3	961	6.6
Magnesium	58.9	3.0	59.4	9.4	59.2	14.2
Manganese	1.11	9.0	1.21	10.7	1.16	11.2
Average % RSD		4.5%		9.7		12.6

The average standard deviations among the TCLP extracts of each S/S mix are within the expected uncertainties for the TCLP extraction and instrumental analysis components being tested. The larger uncertainty found when both S/S mixes are compared ("All Data") indicates the variation from inhomogeniety of the raw waste. Examination of the data in Table 3-10 for iron and sulfur sheds light on the problems of mixing of samples of this type.

Even though the samples appeared homogeneous to the eye and uniform in color, some sections had higher concentrations of iron and sulfur from the addition of ferrous sulfate as a stabilizing additive. With all the data included, the iron results have a 105% relative standard deviation. If sample B3 is discarded, the

Table 3-10. TCLP Repeatability Data for Iron and Sulfur

Sample	Fe, ppm	% RSD	S, ppm	% RSD
A1	0.3	6.1	24.9	9.4
A2	0.1	20.	30.7	14.
A3	0.06	21.	0.5	29.
A4	0.05	9.4	0.8	13.
B1	0.06	53.	0.3	34.
B2	0.12	11.	8.5	3.4
B3	0.63	8.2	59.2	8.0
B4	0.07	7.8	4.8	7.5

relative standard deviation is 8.8%. In a conventional analytical chemistry laboratory, one would consider discarding sample B3 via a traditional mechanism such as a Q test. However, when the large value for sulfur is also noted, it seems that an explanation more likely than an analytical error is a volume of incomplete mixing which contains excess levels of ferrous sulfate additive.

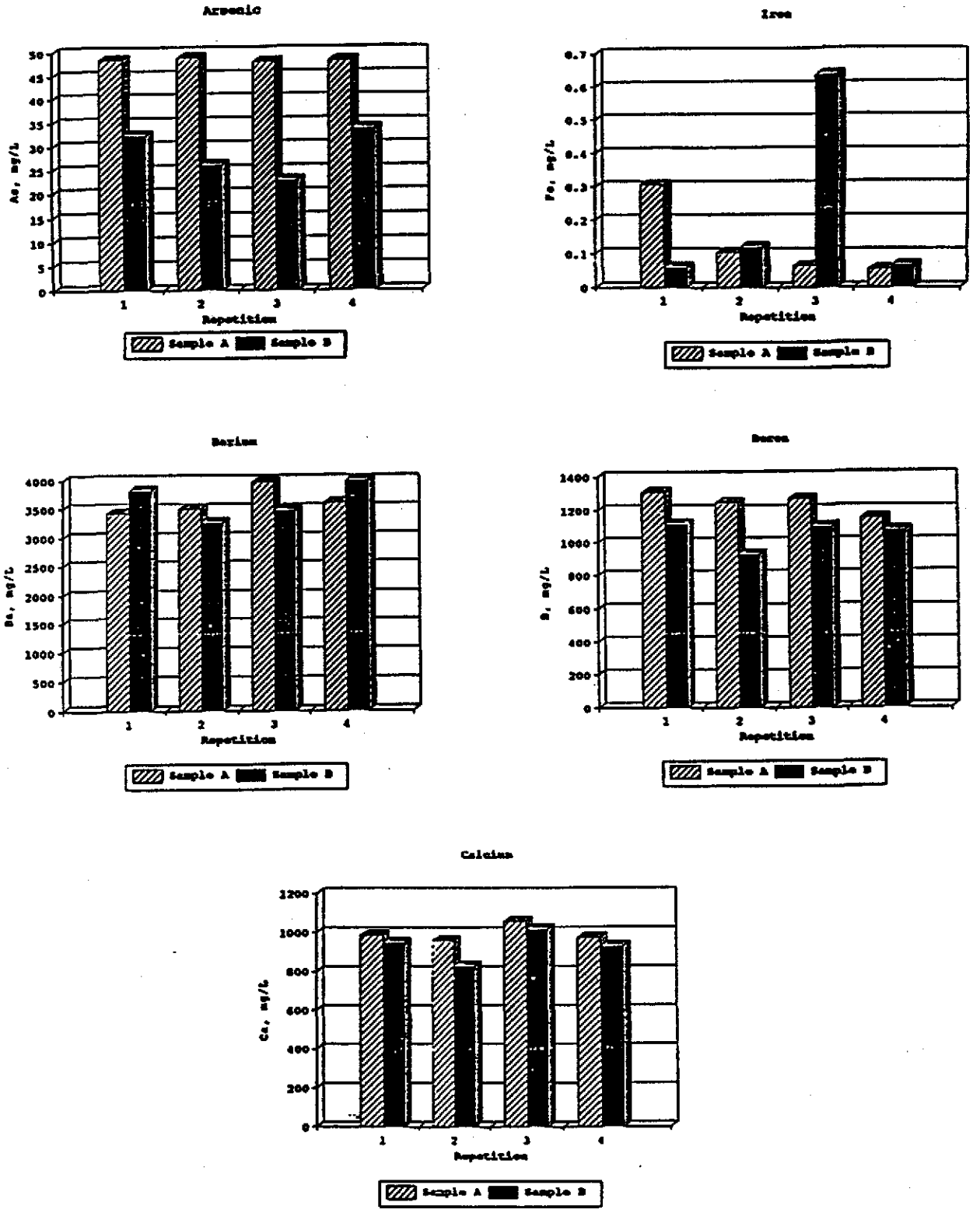


Figure 3-3. TCLP Repeatability Replication Study

CHAPTER FOUR
EXPERIMENTAL DESIGN

4.1 TCLP Experimentation for Arsenic and Barium Stabilization

Arsenic and barium are the primary contaminants of concern in the D004/D005 waste generated by a glass manufacturer. Stabilization mixes were prepared using portland cement and either silica fume or fly ash. Numerous experiments were conducted, but no treatment designs were effective, and no significant differences between silica fume and fly ash were discovered. Table 4-1 shows two typical results from these stabilization efforts. The mix designs use comparable amounts of the pozzolan, and both arsenic and barium TCLP standards are exceeded with no significant difference between treatments. The mix design parameters were: water/binder = 0.87; binder/D-waste = 0.40, silica fume/binder = 0.30, and fly ash/binder = 0.40. These results were for samples cured for seven days. Other data showed that curing time did not appear to improve treatment effectiveness.

Table 4-1. TCLP Results with D004/D005 Waste

Stabilization Method	Arsenic (mg/L) Sample 1	Arsenic (mg/L) Sample 2	Barium (mg/L) Sample 1	Barium (mg/L) Sample 2
Silica Fume	48.6	50.1	528	548
Fly Ash	66.3	66.2	565	565
Untreated Waste	296	295	2790	2890
TCLP Standard	5.0		100.	

An hypothesis for effective S/S was to precipitate the barium with sulfate and to precipitate or change the oxidation state of arsenic. Therefore, ferrous sulfate was added to both silica fume and fly ash S/S designs at dosages measured as grams of ferrous sulfate per gram of water. Other mix design parameters were: water + ferrous sulfate solution/binder = 2.3, binder/D-waste = 0.40, silica fume/binder = 0.30, and fly ash/binder = 0.40.

The TCLP concentrations for arsenic and barium are presented in Figures 4-1 and 4-2, respectively. Increasing amounts of ferrous sulfate up to 60 grams ferrous sulfate/100 grams of water decrease both arsenic and barium TCLP concentrations. Arsenic appears to decrease more rapidly with fly ash S/S. More effective arsenic stabilization with fly ash may be because of the adsorptive capability of fly ash (Sen and De, 1987). On the other hand, barium stabilization is more effective with silica fume S/S.

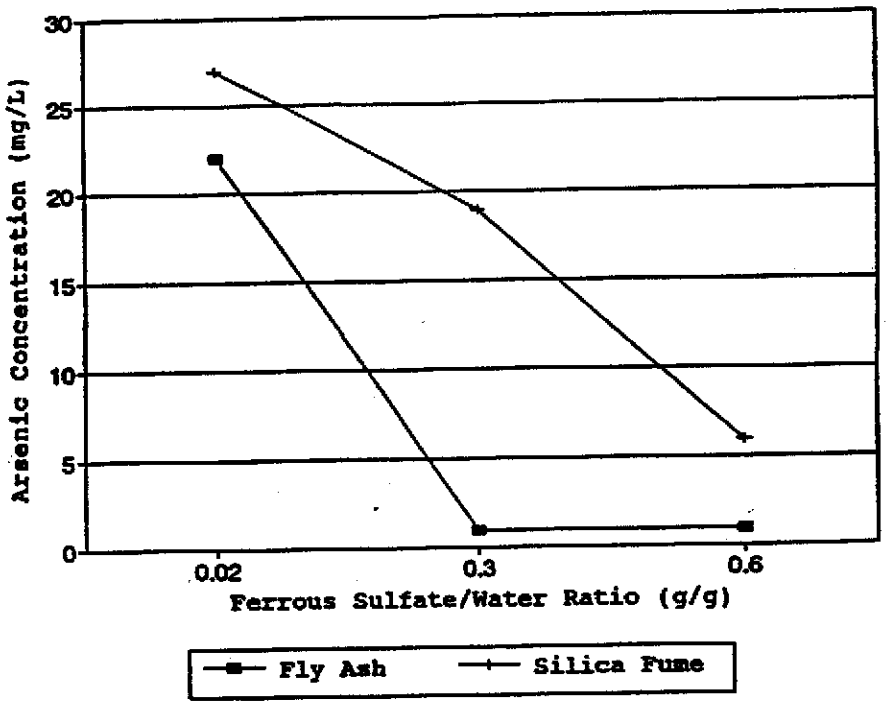


Figure 4-1. TCLP Results for Arsenic

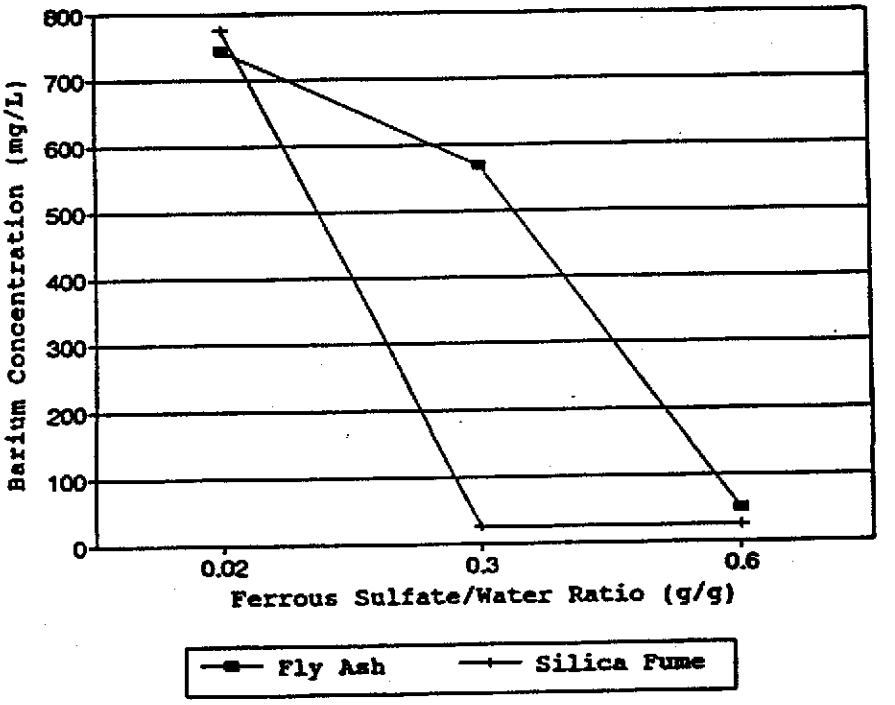


Figure 4-2. TCLP Results for Barium

Barium sulfate is a very fine precipitate, and its more effective encapsulation by silica fume may indicate the improved impermeability of silica fume cement paste.

4.2 Stabilization Mix Designs

Based on this preliminary work, a matrix of mix designs for stabilization treatments using ferric sulfate, ferrous sulfate, and aluminum sulfate are presented in Tables 4-2 through 4-4 respectively. In the top line of each box, each mix design is named with a prefix US, F, or A for ferrous sulfate, ferric sulfate, and aluminum sulfate, respectively. The first number in the mix name refers to a series of stabilizations with an additive, and the second number is a sample number that is associated with a particular length of curing before undergoing TCLP. Samples one through four of each mix have undergone TCLP after 2, 60, 360, and 540 days of cure, respectively.

Each matrix in Tables 4-2 through 4-4 consists of four mix designs set out in two columns and three rows. For each mix design, the mass of each component and important ratios are provided. Mix designs in a column have the same binder/waste mass ratio; those in the left column have binder/waste mass ratios of 0.15, and those in the right column have ratios of 0.40. Binders are defined to be cement and fly ash. The lower ratio is more volume efficient.

Mix designs in each row are characterized by comparable mole ratios of additive to waste in terms of iron/arsenic and sulfur/barium. The amounts of arsenic and barium in these ratios are the moles of arsenic and barium leached during the TCLP of the raw waste. The water/binder mass ratio was constant at 1.6 for all these designs. Thirty percent of the total binder was fly ash.

Mix design parameters were chosen to produce a workable wet mix that would set up into a monolithic solid. These solids generally had sufficient mechanical integrity to require crushing before TCLP extraction.

These mix designs were selected for preparation in a random order to confound any systematic error. Replicate studies were performed on comparable mix designs and results are discussed in Section 3.5.

4.3 Column Leaching

The use of column leaching procedures provides different information from the TCLP. The TCLP is designed as an exhaustive leaching procedure. With a column leaching procedure, data can be obtained on the relative rates of leaching of various components of the stabilized matrix. It is to be expected that the

Table 4-2. MATRIX OF MIX DESIGNS FOR FERRIC SULFATE STABILIZATION OF D004/D005 WASTE

F1x Series

Component per 100.0 g waste	Mass g
Water	24.0
Cement	9.0
Fly Ash	6.0
$Fe_2(SO_4)_3 \cdot 9H_2O$	4.8

Important ratios:		
Binder/Waste	0.15	g/g
Binder/H_2O	0.59	g/g
Fe^{3+}/binder	0.063	g/g
Fe^{3+}/As	2.1	mol/mol
SO_4^{2-}/binder	0.16	g/g
SO_4^{2-}/Ba^{2+}	0.53	mol/mol

F2x Series

Component per 100.0 g waste	Mass g
Water	24.0
Cement	9.0
Fly Ash	6.0
$Fe_2(SO_4)_3 \cdot 9H_2O$	14.4

Important ratios:		
Binder/Waste	0.15	g/g
Binder/H_2O	0.53	g/g
Fe^{3+}/binder	0.19	g/g
Fe^{3+}/As	6.4	mol/mol
SO_4^{2-}/binder	0.49	g/g
SO_4^{2-}/Ba^{2+}	1.6	mol/mol

F3x Series

Component per 100.0 g waste	Mass g
Water	64.0
Cement	24.0
Fly Ash	16.0
$Fe_2(SO_4)_3 \cdot 9H_2O$	12.8

Important ratios:		
Binder/Waste	0.40	g/g
Binder/H_2O	0.59	g/g
Fe^{3+}/binder	0.064	g/g
Fe^{3+}/As	5.7	mol/mol
SO_4^{2-}/binder	0.16	g/g
SO_4^{2-}/Ba^{2+}	1.4	mol/mol

F4x Series

Component per 100.0 g waste	Mass g
Water	64.0
Cement	24.0
Fly Ash	16.0
$Fe_2(SO_4)_3 \cdot 9H_2O$	38.4

Important ratios:		
Binder/Waste	0.40	g/g
Binder/H_2O	0.53	g/g
Fe^{3+}/binder	0.19	g/g
Fe^{3+}/As	17.	mol/mol
SO_4^{2-}/binder	0.49	g/g
SO_4^{2-}/Ba^{2+}	4.2	mol/mol

Notes:
1. Water of hydration is taken into account in Binder/H_2O ratio.
2. 100 g waste contains 0.060 g Arsenic.
3. 100 g waste contains 13.3 g Barium of which 43% is found to be extractable in TCLP.
4. Assume 50% of Ba in waste is available for reaction in ratios calculated.

Table 4-3. MATRIX OF MIX DESIGNS FOR FERROUS SULFATE STABILIZATION OF D004/D005 WASTE

US1x Series

Component per 100.0 g waste	Mass g
Water	24.0
Cement	9.0
Fly Ash	6.0
$FeSO_4 \cdot 7H_2O$	4.8

Important ratios:

Binder/Waste	0.15	g/g
Binder/H_2O	0.57	g/g
Fe^{2+}/binder	0.064	g/g
Fe^{2+}/As	2.2	mol/mol
SO_4^{2-}/binder	0.11	g/g
SO_4^{2-}/Ba^{2+}	0.36	mol/mol

US2x Series

Component per 100.0 g waste	Mass g
Water	24.0
Cement	9.0
Fly Ash	6.0
$FeSO_4 \cdot 7H_2O$	14.4

Important ratios:

Binder/Waste	0.15	g/g
Binder/H_2O	0.49	g/g
Fe^{2+}/binder	0.19	g/g
Fe^{2+}/As	6.5	mol/mol
SO_4^{2-}/binder	0.33	g/g
SO_4^{2-}/Ba^{2+}	1.1	mol/mol

US3x Series

Component per 100.0 g waste	Mass g
Water	64.0
Cement	24.0
Fly Ash	16.0
$FeSO_4 \cdot 7H_2O$	12.8

Important ratios:

Binder/Waste	0.40	g/g
Binder/H_2O	0.57	g/g
Fe^{2+}/binder	0.064	g/g
Fe^{2+}/As	5.7	mol/mol
SO_4^{2-}/binder	0.11	g/g
SO_4^{2-}/Ba^{2+}	0.95	mol/mol

US4x Series

Component per 100.0 g waste	Mass g
Water	64.0
Cement	24.0
Fly Ash	16.0
$FeSO_4 \cdot 7H_2O$	38.4

Important ratios:

Binder/Waste	0.40	g/g
Binder/H_2O	0.49	g/g
Fe^{2+}/binder	0.19	g/g
Fe^{2+}/As	17.	mol/mol
SO_4^{2-}/binder	0.33	g/g
SO_4^{2-}/Ba^{2+}	2.9	mol/mol

Notes:

1. Water of hydration is taken into account in Binder/H_2O ratio.
2. 100 g waste contains 0.060 g Arsenic.
3. 100 g waste contains 13.3 g Barium of which 43% is found to be extractable in TCLP.
4. Assume 50% of Ba in waste is available for reaction in ratios calculated.

Table 4-4. MATRIX OF MIX DESIGNS FOR ALUMINUM SULFATE STABILIZATION OF D004/D005 WASTE

A1x Series

Component per 100.0 g waste	Mass g
Water	24.0
Cement	9.0
Fly Ash	6.0
$Al_2(SO_4)\cdot 18H_2O$	4.8

Important ratios:

Binder/Waste	0.15	g/g
Binder/H_2O	0.57	g/g
Al^{3+}/binder	0.026	g/g
Al^{3+}/As	1.8	mol/mol
SO_4^{2-}/binder	0.14	g/g
SO_4^{2-}/Ba^{2+}	0.45	mol/mol

A2x Series

Component per 100.0 g waste	Mass g
Water	24.0
Cement	9.0
Fly Ash	6.0
$Al_2(SO_4)\cdot 18H_2O$	14.4

Important ratios:

Binder/Waste	0.15	g/g
Binder/H_2O	0.48	g/g
Al^{3+}/binder	0.078	g/g
Al^{3+}/As	5.4	mol/mol
SO_4^{2-}/binder	0.42	g/g
SO_4^{2-}/Ba^{2+}	1.3	mol/mol

A3x Series

Component per 100.0 g waste	Mass g
Water	64.0
Cement	24.0
Fly Ash	16.0
$Al_2(SO_4)\cdot 18H_2O$	12.8

Important ratios:

Binder/Waste	0.40	g/g
Binder/H_2O	0.57	g/g
Al^{3+}/binder	0.026	g/g
Al^{3+}/As	4.8	mol/mol
SO_4^{2-}/binder	0.14	g/g
SO_4^{2-}/Ba^{2+}	1.2	mol/mol

A4x Series

Component per 100.0 g waste	Mass g
Water	64.0
Cement	24.0
Fly Ash	16.0
$Al_2(SO_4)\cdot 18H_2O$	38.4

Important ratios:

Binder/Waste	0.40	g/g
Binder/H_2O	2.1	g/g
Al^{3+}/binder	0.79	g/g
Al^{3+}/As	14.	mol/mol
SO_4^{2-}/binder	0.42	g/g
SO_4^{2-}/Ba^{2+}	3.6	mol/mol

Notes:

1. Water of hydration is taken into account in Binder/H_2O ratio.
2. 100 g waste contains 0.060 g Arsenic.
3. 100 g waste contains 13.3 g Barium of which 43% is found to be extractable in TCLP.
4. Assume 50% of Ba in waste is available for reaction in ratios calculated.

leachabiity rate of different metals depends on the matrix surrounding each metal.

Mix design numbers US1 and US4 shown in Table 4-2 have undergone column leaching so that TCLP results can be compared with dynamic leaching results.

4.4 Calorimetric Analyses of Hydration Reactions

The objective of this series of experiments was to determine the adiabatic temperature of the cement hydration reactions in a waste stabilization process. This information should be useful in determining the rates of the hydration reactions and the relative completion of the hydration reaction processes.

Thermal isolation was achieved by placing the reacting sample in a styrene foam cup inside a glass dewar insulating flask with a foam lid. The sample cup was supported inside the dewar flask on thin insulating legs to reduce conductive heat transfer to the glass (Figure 4-3). Two matching samples and dewars were run simultaneously inside a foamed styrene isolation container.

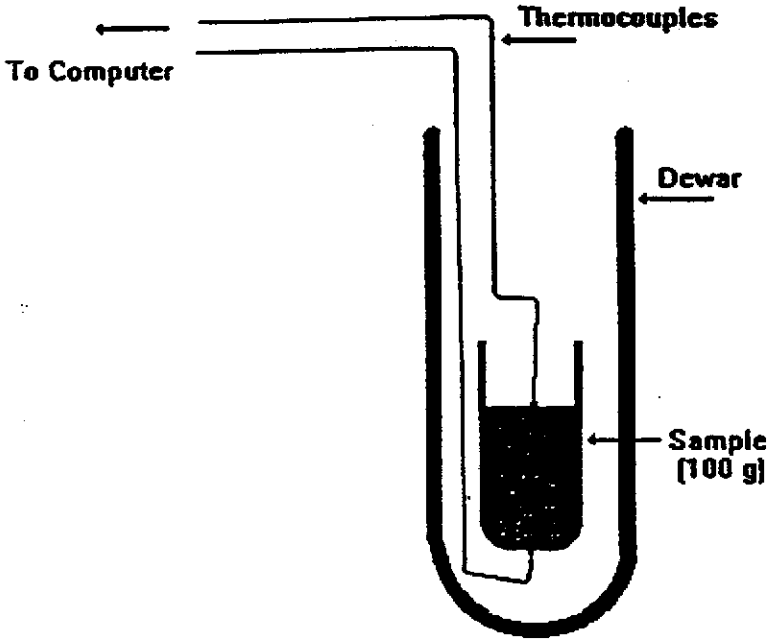


Figure 4-3. Calorimetric Heat of Hydration Apparatus

Temperatures were determined with ASTM Type E chromel-constantan thermocouples, inserted in the top and the bottom of each reaction mass. Another thermocouple was used to determine the background temperature in the outer isolation container. The output voltages of the thermocouples were determined using a MINI-16 analog-to-digital interface board manufactured by Industrial Computer Source (4837 Mercury Street, San Diego, CA 92111). A ± 50-millivolt range was used with 16-bit analog-to-digital resolution. After conversion to temperature, a relative precision of ± 0.01°C was obtained. The offset voltages of the individual thermocouples were made internally consistent by forcing the temperatures determined from all thermocouples to be the same when the measuring junctions of the thermocouples were in the same stirred thermal bath. The agreement between the temperatures indicated by the thermocouples and a laboratory thermometer was better than ± 0.1°C in the 20 to 35°C temperature range used in the experiment.

Temperature data were acquired from all measuring junctions at 1800-second intervals to provide sufficient data to allow smoothing while keeping the data file size manageable during the 3000-minute reaction time. Data presented in Section 5.3 are the averages of the top and bottom temperatures which was then smoothed with a 3- or 5-point moving average low-pass data filter.

A three-point moving average low-pass data filter is calculated using the formula

$$\bar{x}_i = (x_{i-1} + x_i + x_{i+1}) / 3$$

where $\bar{x}_i$ = filtered i-th data point
x_{i-1}, x_i and x_{i+1} = i-th and surrounding data points.

A five-point moving average filter is calculated similarly. In principle, any odd number of terms can be used in a moving average filter. For these experiments, the response time of the apparatus becomes too slow and the data features hard to distinguish when more than 7-point smoothing is used. The data presented has been subjected to three-point smoothing for graphical purposes.

Samples for calorimetric analysis were prepared following the procedures outlined above. Samples were dry-mixed and then water was added. The data acquisition time clock was started when the water was added. As soon as the mixture appeared to be consistent, the 100.0 g sample was placed in the calorimeter cup, the thermocouples inserted, and the thermal isolation put in place. Data logging of sample temperatures was continuous for periods of about two days after mixing. Reactions with the waste replaced by an equal mass of sand were used for baseline comparisons.

4.5 Arsenite Stabilization

4.5.1 Ferrous and Ferric Sulfate Stabilization

As shown in Table 4-5, a study was designed to compare arsenate and arsenite stabilization with either ferrous sulfate or ferric sulfate. A synthetic but realistic waste was made by adding sodium arsenite to a F006 waste (which has very little arsenic) so that the total arsenic was comparable to that of the project waste. Other synthetic waste samples were made using sodium arsenate for comparison. The arsenic compounds were added to the F006 waste according to the mole ratios in the left column. The binder/waste ratios were either 0.15 or 0.40 as shown in the top row. Two samples for each possible mix design in Table 4-5 underwent TCLP after 2 and 60 days of cure.

Table 4-5. Matrix of Mix Designs for the Stabilization of Arsenite and Arsenate

Mole Ratio	Binder/F Waste (doped with arsenic) 0.15		Binder/F Waste (doped with arsenic) 0.40	
$\underline{Fe}^{2+}$ As 2.0	USA2x (USB2x series)		USA4x (USB4x series)	
	Component per 100.0 g waste	Mass (g)	Component per 100.0 g waste	Mass (g)
	Na_2HAsO_4 or	2.50	Na_2HAsO_4 or	2.50
	$NaAsO_2$	1.04	$NaAsO_2$	1.04
	Water	24.	Water	64.
	Binder	21.	Binder	56.
	$FeSO_4 \cdot 7H_2O$	4.5	$FeSO_4 \cdot 7H_2O$	4.5
$\underline{Fe}^{3+}$ As 1.1	FA1x (FB1x series)		FA3x (FB3x series)	
	Component per 100.0 g waste	Mass (g)	Component per 100.0 g waste	Mass (g)
	Na_2HAsO_4 or	2.50	Na_2HAsO_4 or	2.50
	$NaAsO_2$	1.04	$NaAsO_2$	1.04
	Water	24.	Water	64.
	Binder	21.	Binder	56.
	$Fe_2(SO_4)_3 \cdot 9H_2O$	2.4	$Fe_2(SO_4)_3 \cdot 9H_2O$	2.4

4.5.2 Pretreatment with Oxidation

Results of the study shown in Table 4-5 indicated that stabilization of arsenite was less effective than arsenate. Another study using arsenite waste was designed to evaluate pre-treatments that oxidize arsenite to arsenate making the waste more amenable to effective stabilization. A synthetic waste was made with a similar arsenic/waste mass fraction as the actual D004/D005

waste used in the project. For 100 grams of F006 waste, either 1.04 grams of sodium arsenite or 2.50 grams of sodium arsenate were added to the F006 waste by first dissolving the arsenic compound in 1.0 M NaOH prior to mixing it with the F006 waste.

Two pretreatments of the arsenite waste were investigated as shown in the experimental design in Table 4-6. Oxidation of arsenite was attempted with either air entrainment by intense mixing or with compressed air diffusion. Chemical oxidation with hydrogen peroxide was also used at H_2O_2/AsO_3^{3-} mole ratios of 0.5 and 1.0.

Table 4-6. Pretreatment and Stabilization of Synthetic Arsenite Waste

Pre-treatment	Binder/F Waste (doped with arsenic) 0.15		0.40	
Aeration 11 min. 200 rpm	**USB1x**		**USB2x**	
	Component per 100.0 g waste	Mass (g)	Component per 100.0 g waste	Mass (g)
	$NaAsO_2$	0.72	$NaAsO_2$	0.496
	Water	16.28	Water	30.45
	Binder	10.35	Binder	19.1
	$FeSO_4 \cdot 7H_2O$ or	3.1	$FeSO_4 \cdot 7H_2O$ or	2.15
	$Fe_2(SO_4)_3 \cdot 9H_2O$	1.68	$Fe_2(SO_4)_3 \cdot 9H_2O$	1.15
Hydrogen Peroxide Oxida-tion	**USBP1x**		**USBP2x**	
	Component per 100.0 g waste	Mass (g)	Component per 100.0 g waste	Mass (g)
	$NaAsO_2$	0.72	$NaAsO_2$	0.496
	Water	12.83	Water	27.95
	Binder	10.35	Binder	19.08
	$FeSO_4 \cdot 7H_2O$ or	3.12	$FeSO_4 \cdot 7H_2O$ or	2.15
	$Fe_2(SO_4)_3 \cdot 9H_2O$	1.75	$Fe_2(SO_4)_3 \cdot 9H_2O$	1.15
	H_2O_2 (5% or 2%)	3.75	H_2O_2 (5% or 2%)	2.58

4.6 Individual Ion Study

This study was designed to investigate the effect of sulfate and the binder/waste ratio on the early curing of the cement matrix. The effect of iron and sulfate on stabilization can be isolated by the selection and individual application of iron acetate and sodium sulfate as additives. The use of iron acetate will treat the arsenic in the same way as ferrous sulfate without the sulfate. On the other hand, sodium sulfate will precipitate the barium in the same way as ferrous sulfate without arsenic stabilization. The experimental design is presented in Tables 4-7 and 4-8.

Table 4-7. Stabilization Design Using Ferrous Acetate

Mole Ratio Fe^{2+}/As	Binder/Waste Mass Ratio: 0.15		Binder/Waste Mass Ratio: 0.40	
1.5	**IA1x Series**		**IA3x Series**	
	Component per 100.0 g waste	Mass g	Component per 100.0 g waste	Mass g
	Water	22.5	Water	60.
	Cement	9.	Cement	24.
	Fly Ash	6.	Fly Ash	16.
	$Fe(CH_3CH_2)_2$	2.09	$Fe(CH_3CH_2)_2$	2.09
	Fe/binder	0.045	Fe/binder	0.017
3.0	**IA2x Series**		**IA4x Series**	
	Component per 100.0 g waste	Mass g	Component per 100.0 g waste	Mass g
	Water	22.5	Water	60.
	Cement	9.	Cement	24.
	Fly Ash	6.	Fly Ash	16.
	$Fe(CH_3CH_2)_2$	4.	$Fe(CH_3CH_2)_2$	4.
	Fe/binder	0.086	Fe/binder	0.032

Table 4-8. Stabilization Design Using Sodium Sulfate

Mole Ratio SO_4^{2-}/Ba^{2+}	Binder/Waste Mass Ratio: 0.15		Binder/Waste Mass Ratio: 0.40	
1.0	**SS1x Series**		**SS3x Series**	
	Component per 100.0 g waste	Mass g	Component per 100.0 g waste	Mass g
	Water	22.5	Water	60.
	Cement	9.	Cement	24.
	Fly Ash	6.	Fly Ash	16.
	Na_2SO_4	10.	Na_2SO_4	10.
	SO_4/binder	0.451	SO_4/binder	0.17
2.0	**SS2x series**		**SS4x series**	
	Component per 100.0 g waste	Mass g	Component per 100.0 g waste	Mass g
	Water	22.5	Water	60.
	Cement	9.	Cement	24.
	Fly Ash	6.	Fly Ash	16.
	Na_2SO_4	20.	Na_2SO_4	20.
	SO_4/binder	0.90	SO_4/binder	0.338

4.7 Scanning Electron Microscopy

Scanning electron microscopy with x-ray emission analysis was carried out on a series of samples to enable an understanding of the relationship between the cement lattice structure, waste components and treatment additives. Eight samples were prepared for analysis using the ISI 40 Scanning Electron Microscope (SEM) at the Center for Electron Microscopy of the University of Illinois, Champaign. The composition of the samples is given in Table 4-9.

Table 4-9. Composition Table for SEM Samples

SEM Sample Number	CURE TIME (Days)	RATIO B/HW	MASSES (g): HW	Cement	Fly Ash	Water	Fe	Total
Ferrous Sulfate Additive								
SEM1	2	0.080	100	5.6	2.4	16.0	1.6	125.6
SEM2	60	0.080	100	5.6	2.4	16.0	1.6	125.6
SEM3	365	0.080	100	5.6	2.4	16.0	1.6	125.6
SEM6	60	0.12	100	8.4	3.6	24.0	2.4	138.4
SEM7	60	0.12	100	8.4	3.6	24.0	9.6	145.6
SEM8	2	0.12	100	8.4	3.6	24.0	9.6	145.6
Ferric Sulfate Additive								
SEM4	2	0.40	100	24.0	16.0	64.0	12.8	216.8
SEM5	2	0.40	100	24.0	16.0	64.0	38.4	242.8

Polished flat surfaces were prepared on each sample using techniques normal for cement samples. Samples were chipped with a chisel to form a nearly flat surface with less than one square inch cross-sectional area. Samples were then soaked in 100% ethanol overnight to remove any water and dust particles and to help prevent cracking of samples in the subsequent steps of sample preparation. The alcohol was removed and the sample baked overnight in a 70°C oven.

Samples were then encapsulated in LR White resin from Fullem, Inc. The resin was cured at 70°C overnight. Using a Buehler Minimet polishing apparatus, samples were polished using increasingly finer grades of abrasives with Buehler polishing oil, starting with 200 grit and ending with 600 grit. Finish polishing was done using 3 micron Leco Microid Diamond Paste on a Buehler Polisher Ecomet III grinder.

After cleaning with ethanol, samples were coated with carbon from a carbon string source in a Denton vacuum evaporator. SEM

microscopy was carried out using magnifications from 130x to 1000x. Atomic composition analyses of areas under examination were done with electron-induced X-ray emission analysis using a Tracor Northern 2010 energy-dispersive detector. Average concentrations over the area scanned by the electron beam were determined as well as spatial distributions of important elements such as arsenic, barium, iron and sulfur. The SEM results are discussed in Section 5.6.

CHAPTER FIVE
Results and Discussion

5.1 Mix Design Review

In chapter four, a matrix of mix designs for stabilization treatments using ferric sulfate, ferrous sulfate, and aluminum sulfate are presented in Tables 4-2 through 4-4 respectively. These tables are repeated in Appendix A. In the top line of each box, each mix design is named with a prefix US, F, or A for ferrous sulfate, ferric sulfate, and aluminum sulfate, respectively. The first number in the mix name refers to a series of stabilizations with an additive, and the second number is a sample number that is associated with a particular length of curing before undergoing TCLP. Samples one through four of each mix have undergone TCLP after 2, 60, 360, and 540 days of cure, respectively.

Each matrix containing four mix designs consists of two columns and three rows as shown in Figure 5-1a. Mix designs in a column have the same binder/waste mass ratio where binders are defined to be cement and fly ash. Thirty percent of the total binder was fly ash. Those in the left column have binder/waste mass ratios of 0.15, and those in the right column have ratios of 0.40. Mix designs with the lower ratio in the left column are more volume efficient. Mix designs in each row are characterized by comparable mole ratios of additive to waste in terms of iron/arsenic and sulfur/barium. The ratio of additive to waste increases moving downward through the matrix. The water/binder mass ratio was constant at 1.6 for all these designs.

A convenient reference for mix designs in the figures in this chapter is shown in Figures 5-1b and 5-1c. If stabilizations are being compared where only one additive was used, then results of different mix designs are distinguished by a symbol in the corresponding box. For example, the symbol, ■ , refers to a volume efficient (low binder/waste) mix with a lower amount of additive. If stabilizations are being compared using ferrous and ferric sulfate, then a symbol 2 or 3 in the corresponding box indicates ferrous sulfate and ferric sulfate, respectively. An example is shown in Figure 5-1c.

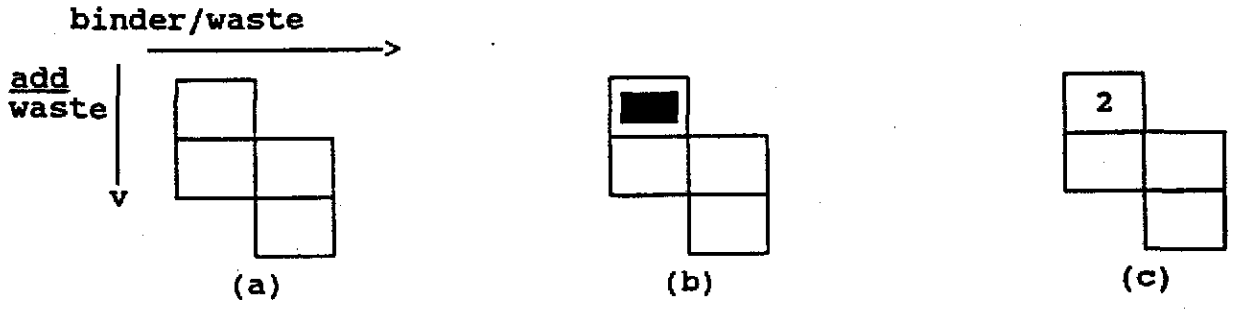


Figure 5-1. Legend of Mix Designs

5.2 TCLP Results

Analytical results for TCLP extracts of S/S using ferrous sulfate, ferric sulfate or aluminum sulfate additives are presented in Appendix B. Sample numbers used in Appendix B are those used consistently throughout this report.

5.2.1 Stabilization with Ferrous Sulfate

Figure 5-2 presents results of analyses for selected metals in TCLP extracts of waste stabilized with ferrous sulfate. With only two days of curing, arsenic concentrations are predictable according to the iron/arsenic molar ratio of the mix. Design US1 (closed rectangle) has a significantly higher arsenic concentration because its iron/arsenic molar ratio is only 2.16 which is insufficient given the pH conditions and presence of other ions. From the literature survey in Chapter 2, this ratio value was considered too low for arsenic removal from water. For mix design US1, the improvement of arsenic stabilization with curing time is attributed to the more favorable pH conditions for more mature stabilized forms during the TCLP test. As the cement matrix matures, calcium hydroxide becomes less prevalent and calcium silicates more dominant, so the acid neutralization capacity of the stabilized form decreases as indicated by a drop in the extract pH. The pH for extracts of mix US1 at 2, 60, 360, and 540 days was 7.97, 6.86, 5.01, and 4.96, respectively. This pH decrease provided more favorable conditions for the maintenance of the ferrous-arsenate complex.

The significant improvement in arsenic stabilization by mix designs US2, US3, and US4 can be explained by the higher iron/arsenic molar ratio of 6.47, 5.74, and 17.2, respectively. The excess amounts of iron are necessary to maintain the iron/arsenate complex under higher pH conditions during the early cure. However, at longer cure times with more favorable pH conditions, mixes with excess iron leach more arsenic and iron as shown in Figure 5-2.

The barium release in TCLP extracts reflects the amount of sulfate available for precipitation with barium. Mix US1 with a sulfate/binder molar ratio of 0.36 has insufficient sulfate and higher barium concentrations are the result. Mixes US2 and US3 have marginal ratios of 1.07 and 0.95, respectively, and barium concentrations increase moderately with curing age. This increase may be caused by the adsorption of sulfate by the binder to form ettringite. The more porous nature of the cement matrix associated with more ettringite formation is indicated by the higher releases of zinc associated with mixes of higher sulfate/binder mass ratios (mixes US2 and US4).

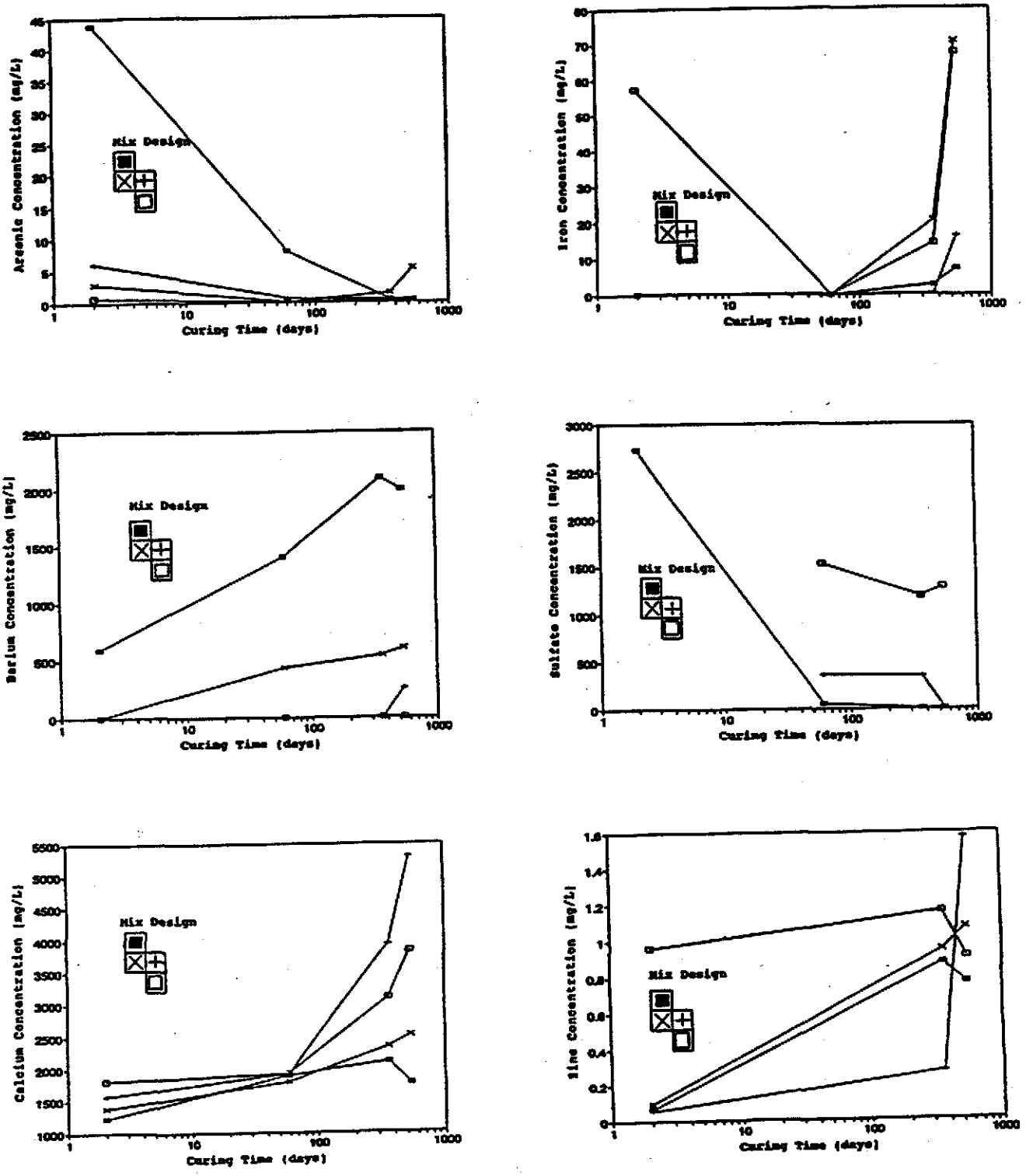


Figure 5-2. Stabilization with Ferrous Sulfate. Mix designs given in Table 4-2.

5.2.2 Stabilization with Ferric Sulfate

Samples of stabilized wastes were cured for 2, 60, 360, and 540 days before TCLP. For each curing time, Figure 5-3 presents results of analyses for selected metals in TCLP extracts. The effectiveness of arsenic stabilization changes significantly with curing time. The comparable performance of stabilization designs F1 (closed rectangle) and F3 (plus) in contrast with the comparable performance of design F2 (X) and F4 (open rectangle) can be explained by observing mix design parameters that are equal for comparable designs but different for contrasting designs. One such design parameter is the iron/binder mass ratio which is 0.064 for designs F1 and F3 and is 0.19 for designs F2 and F4. This observation suggests that arsenate and binder compete for iron during the initial curing time when calcium hydroxide is prevalent. A small amount of iron relative to the amount of binder (as in designs F1 and F3) could preclude the complexation of some arsenate with iron. The insufficient amount of iron in mixes F1 and F3 is also indicated by Figure 5-3 by the very low levels of iron in TCLP extracts of mixes F1 and F3 (2 and 60 day curing). Therefore, stabilization designs F1 and F3 perform poorly during initial curing times because the hydroxide phase of the binder reacts with most of the iron leaving an insufficient amount of iron to react with arsenic.

There are other reasons that help explain the success of designs F2 and F4 for short curing times. The larger amounts of iron in these mix designs allow for more fresh ferric hydroxide precipitate which strongly adsorbs arsenic. The high insolubility of ferric hydroxide and the relative abundance of it in mixes F2 and F4 yield lower TCLP pH's of 5.3 and 5.4 in those mixes. In contrast, the TCLP pH of mixes F1 and F3 was 6.8 and 7.6, respectively. The lower pH of mixes F2 and F4 provides more favorable iron-arsenate precipitation and adsorption onto fly ash surfaces (Sen and De, 1987).

Although cement curing is retarded by the presence of the waste, eventually the calcium hydroxide phase becomes less dominant. At extended curing times, another mix parameter provides evidence to explain these results. The sulfate/binder mass ratio is 0.16 for mix designs F1 and F3 and is 0.49 for mix designs F2 and F4. The relative abundance of sulfate in mixes F2 and F4 may lead to more ettringite formation which deteriorates cement by increasing porosity and causing cracking. Roy, et. al., (1992) report that the amount of excess sulfate controls the extent of ettringite formation. Therefore, stabilization designs F2 and F4 perform well early on, but deteriorate later because of a more porous matrix induced by excess sulfate. Additional evidence for the more extensive ettringite (containing aluminum) formation in mixes F2 and F4 is provided by the higher releases of aluminum to the TCLP extract.

The iron/arsenic ratio does not appear to be a critical factor in Figure 5-3. Mix F1 with an iron/arsenic molar ratio of 2.13 performs well with extensive curing. Furthermore, mix F3

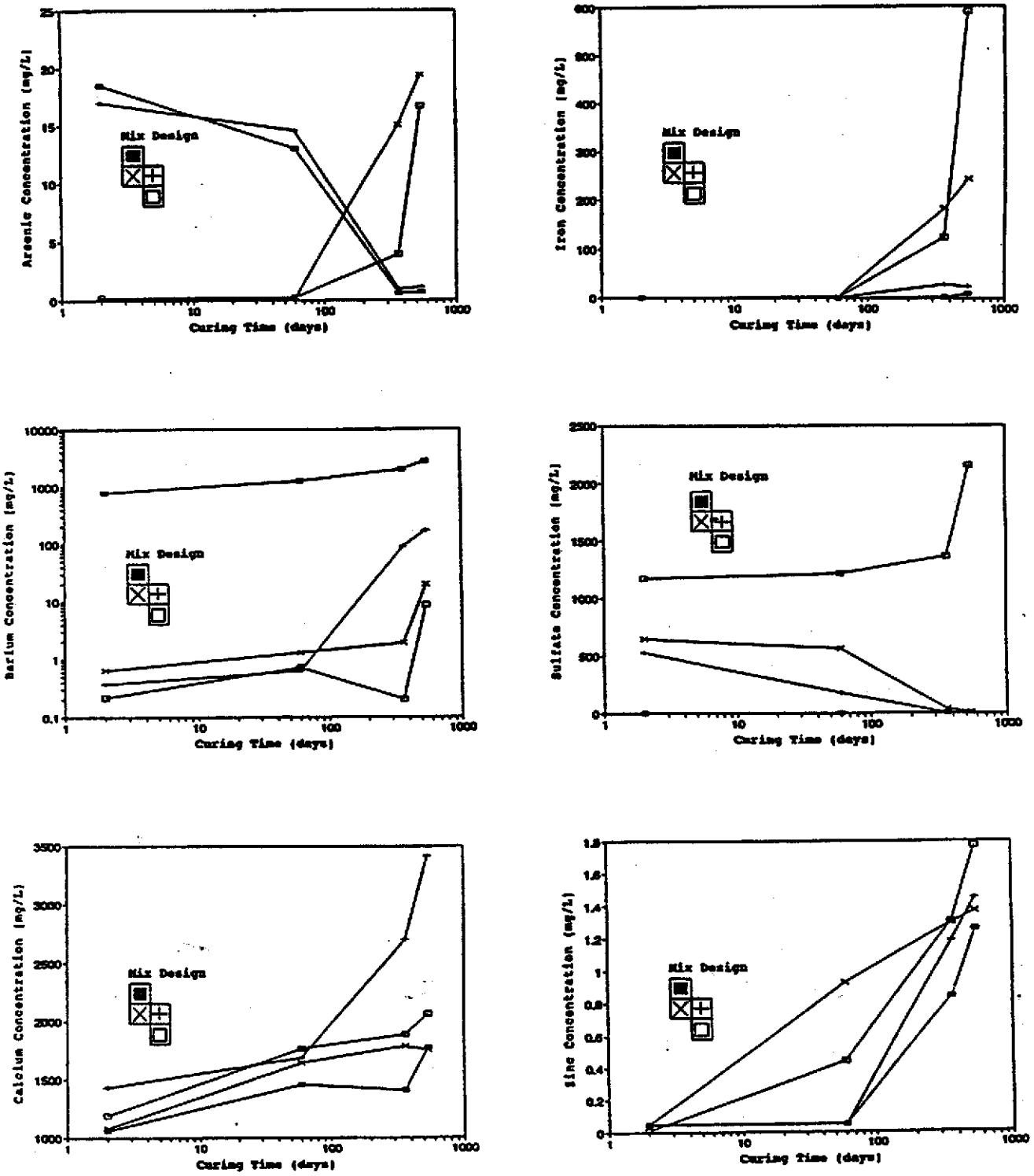


Figure 5-3. TCLP Results for Ferric Sulfate Stabilization. Mix designs defined in Table 4-3.

with an iron/arsenic molar ratio of 5.69 yields results similar to that of mix F1. Stabilization designs F2 and F4 also yield similar results but with iron/arsenic molar ratios of 6.39 and 17.1, respectively.

The barium results can be explained by sulfate/barium molar ratios. Mix F1 with a ratio of 0.45 does not have adequate sulfate to react with the barium as indicated in Figure 5-3 by the high concentrations. At the other extreme, mix F4 with a ratio of 3.6 does have an adequate amount of sulfate. The other two mixes are marginal with a ratio of 1.3. The overall trend of increasing barium concentrations with longer curing times may indicate some consumption of sulfate by the binder to form ettringite. The consumption of sulfate during ettringite formation over the long term is also indicated by Figure 5-3. The sulfate concentrations decrease over longer curing times for 3 of the 4 mixes. Only mix F4 with the highest amount of sulfate shows sulfate release from stabilized forms with longer curing times.

5.2.3 Stabilization with Aluminum Sulfate

Figures 5-4 and 5-5 present a comparison of TCLP results for arsenic and barium respectively, using as additives ferrous sulfate, ferric sulfate, or aluminum sulfate. These three-dimensional bar graphs reflect the experimental designs shown in Tables 4-2 through 4-4 in the horizontal plane with the metal concentration plotted on the vertical axis. The results associated with 60 through 540 days of curing indicate a consistent pattern for the effectiveness of additives. All mix designs at 540 days curing and three of four designs for 60 days curing indicate that the order of effectiveness is $Fe^{2+} > Fe^{3+} > Al^{3+}$. After only two days of curing, either ferrous or ferric sulfate may provide best treatment. The strong affinity of arsenic for freshly precipitated ferric hydroxide may explain why ferric sulfate can be most effective with early curing.

The possibility of long-term sulfate damage to the stabilized form is also evident from Figure 5-4. After two days of curing, more metal addition always means more arsenic removal. In the early curing, the binder succesfully competes for the metal additive. On the other hand after 540 days of curing, more metal addition always results in less arsenic removal in every mix design. This may be the result of excess sulfate.

The consistent pattern of competition of waste and binder for metal during early curing can also be seen by a comparison of mixes two and three with approximately equal metal/arsenic ratios but with a binder/waste ratio of 0.15 and 0.40 respectively. Mix two with the lower amount of binder allows more metal for precipitation of arsenic so arsenic concentrations are predictably lower. After 540 days of curing, mix two has higher arsenic concentrations because of more sulfate damage indicated by the higher sulfate/binder ratio of mix two compared to mix three.

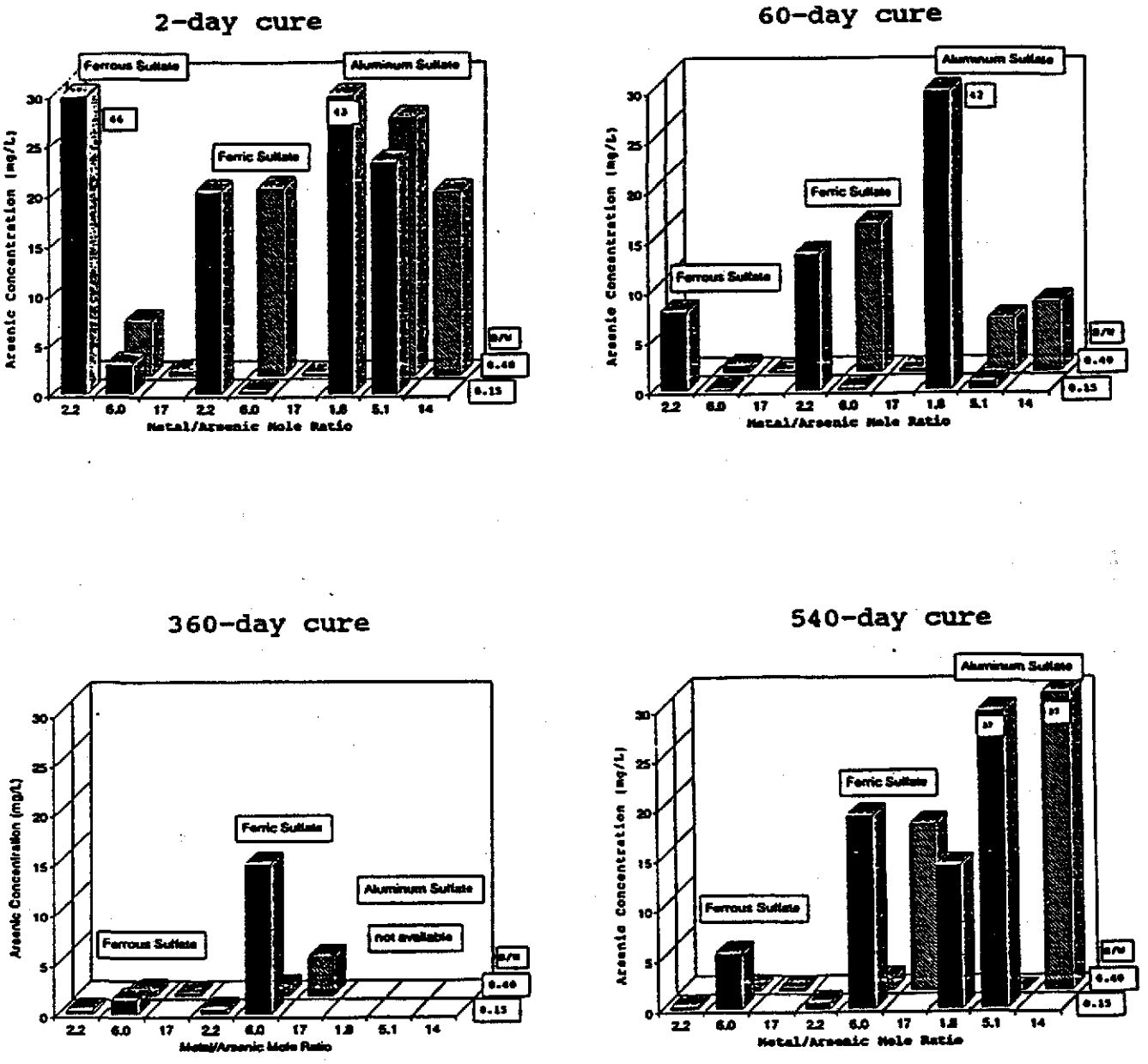


Figure 5-4. Comparison of TCLP Data for Arsenic.

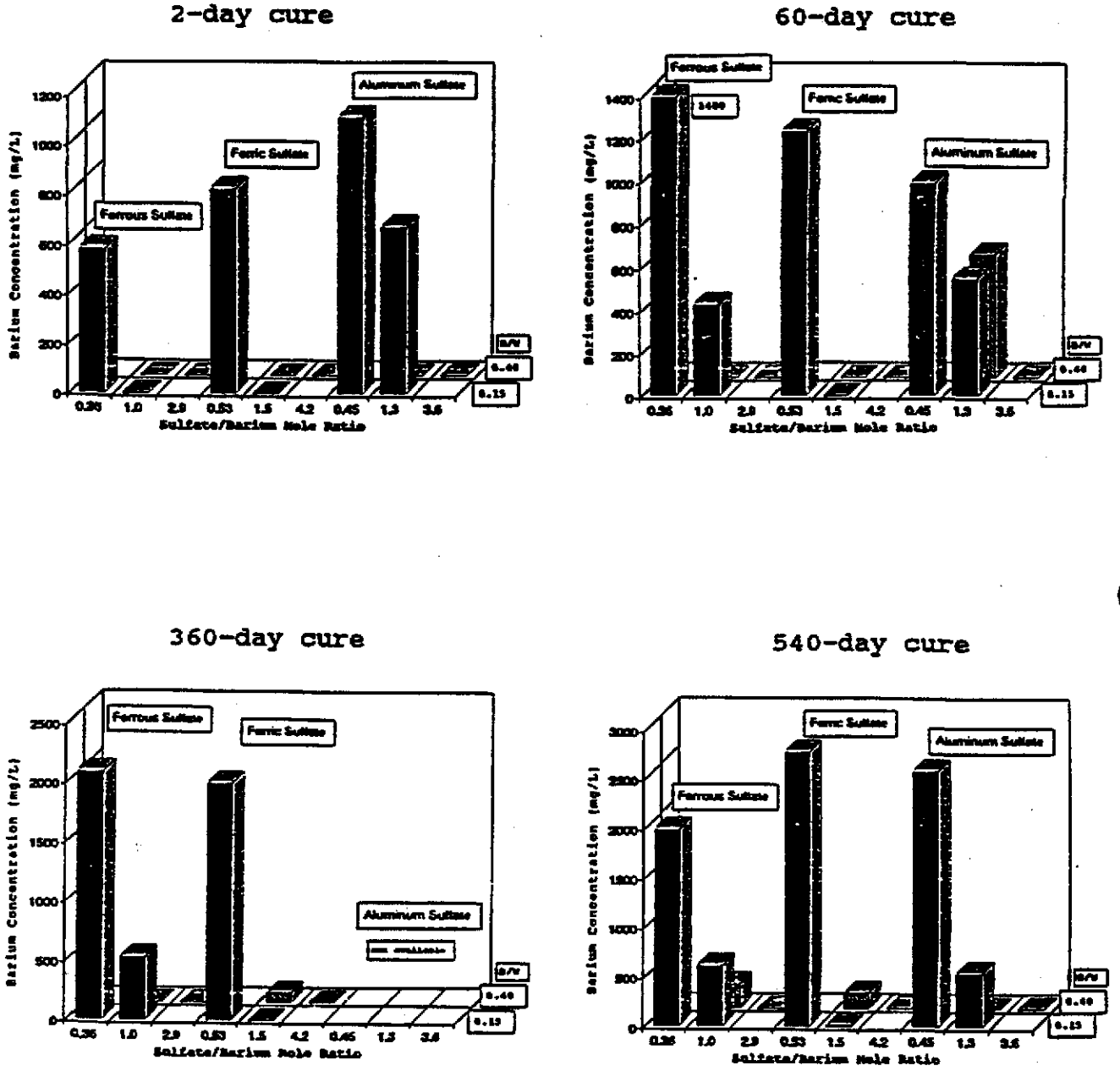


Figure 5-5. Comparison of TCLP Data for Barium.

For barium stabilization, the treatment effectiveness depends only on the amount of sulfate and is independent of the metal counterion used in the additive. This indicates that the removal mechanism is by barium sulfate precipitation.

5.2.4 Percent Retention in TCLP

To investigate the effect of curing of the cement lattice on S/S, a comparison of extractability was made between individual unreacted components and cured S/S mixtures by using a mass balance approach. Retention is defined as the fraction of total metal in the S/S mixture not extracted by TCLP. Percent retention figures were calculated for individual components, ferric sulfate S/S mixes (Table 4-2), and ferrous sulfate S/S mixes (Table 4-3). Using data on the nitric acid digestion of cement, fly ash (Table 3-3) and the D004/D005 waste (Table 3-1), the total amount of each metal was calculated component by component for each S/S mixture. The percent retention of individual S/S components was calculated from the TCLP data of those individual components as reported in Tables 3-1 and 3-3.

The retention percentages for important elements are shown graphically in Figure 5-6 for mixes one and four using ferrous sulfate or ferric sulfate stabilizations. The elements arsenic and barium are primarily found in the waste. Potassium and manganese are found mainly in the cement. Calcium occurs in all components of the S/S mix. The decreasing percent retention for calcium as the S/S mix stabilizes is possible evidence that the cement lattice is degrading as the curing reactions take place. Even when about half the calcium in the S/S mix has been extracted out in the TCLP process, indicating severe destruction of the cement lattice, the elements listed as "Tightly Bound" in Table 5-1 are retained more than 90%. Therefore, we can conclude that "Tightly Bound" elements are bound through different mechanisms than calcium ions.

Using TCLP results on the cured S/S mixture, the effect of the curing reactions of the cement lattice on individual elements could be examined. Table 5-1 lists elements which are tightly bound (>90%) by the cured cement lattice and those which are only loosely bound (<50%). Some elements appear to be more tightly bound at a short 2-day curing time but quite loosely bound at longer 540-day curing times. Arsenic and barium are tightly bound when enough additive is in the S/S mix to ensure reaction. The retention percentage of manganese is very interesting, with low retention in good mixes for arsenic and barium stabilization but high retention in poorer S/S mixtures.

Boron is very extractabile from the raw waste and as well as from S/S mixtures. This can be interpreted by remembering that sodium borates are generally soluble in aqueous matrices. The borate anions are unlikely to be bound to the anionic silicate matrix of the cement lattice.

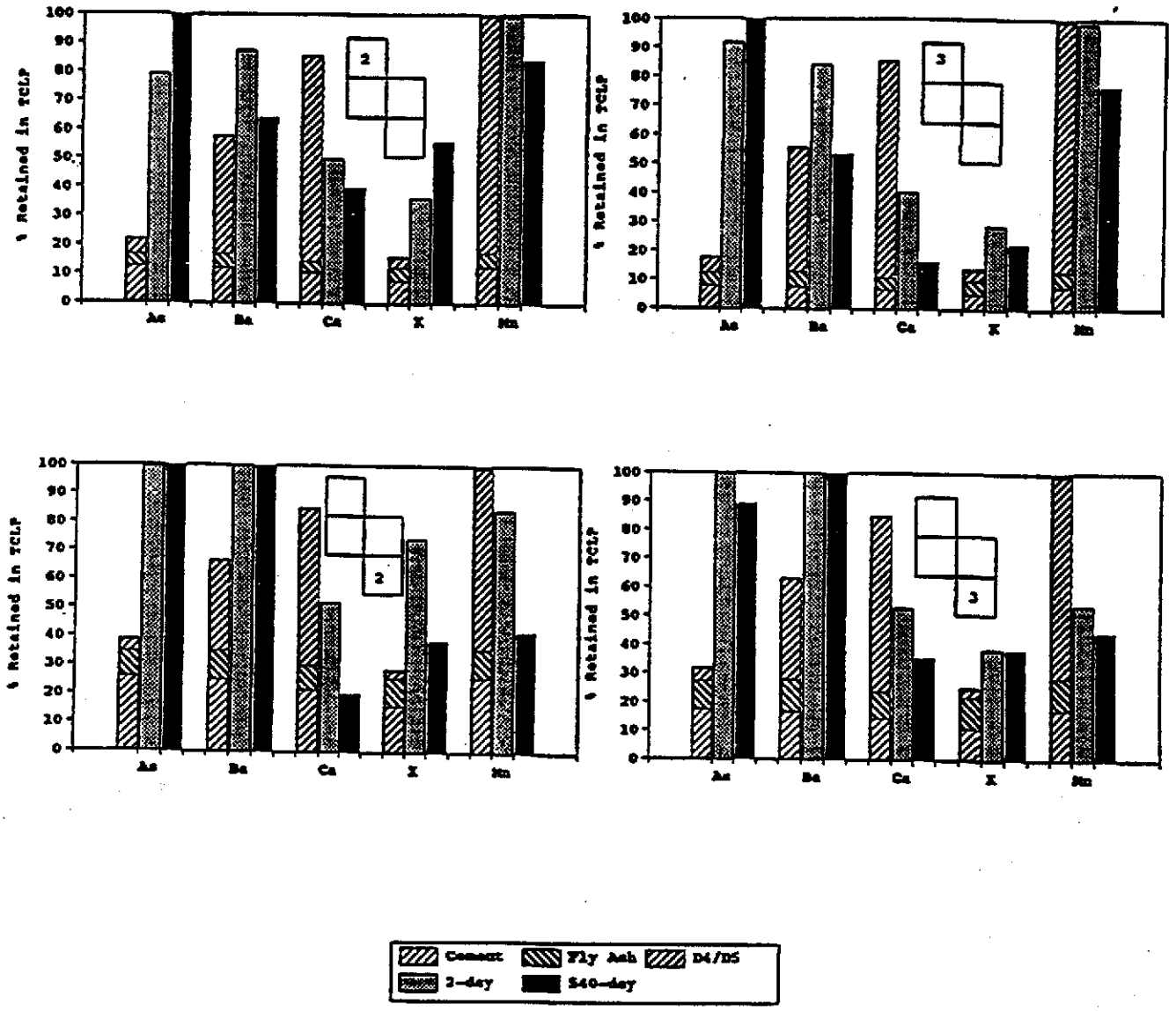


Figure 5-6. Percent Extraction by TCLP

Table 5-1. Classification of Elements by Retention in Cured S/S

Loosely Bound(<50%) in Cured S/S	Tightly Bound(>90%) in Cured S/S	Binding Degrades as S/S Cures
B	As	Al
Ca	Ba	Mn
K	Fe	
Mg	P	
Na	Sb	
	Zn	

5.2.5 Correlation

Another way of viewing the same data presented in Section 5.2 is to correlate "tracer" metals of specific stabilization components with arsenic, barium and each other. Tracer metals are TCLP-leachable metals found principally in one stabilization component but not in others. Accounting for differing amounts of materials in the mix design and using information in Tables 3-1 and 3-2, some tracer metals yield at least three times more leachable metals from a component (e.g. cement, fly ash, waste) compared to others.

Table 5-2 presents correlation matrices for all the data and for ferrous sulfate and ferric sulfate S/S separately. Sodium, potassium, and boron are principally from the waste. Correlations of these elements with arsenic is insignificant which may indicate that arsenic is not uniformly distributed throughout the waste or that arsenic is bound through a different mechanism. It may also be a result of comparing larger amounts of sodium, potassium, and boron with small amounts of arsenic. Barium is present in larger amounts and is moderately correlated with these waste elements. Calcium, a binder and waste component, is not significantly correlated with arsenic or barium.

Table 5-3 presents selected significant correlations of TCLP data from all S/S designs for 2 through 540 days. Iron and arsenic have a low correlation up to 60 days of curing, but significant correlations were found after 365 days. This observation reflects how some short term stabilizations exceed arsenic TCLP standards because of the competition of fresh concrete in binding with iron. With additional curing, arsenic and iron either remain encapsulated or leach out together. If significant iron and arsenic are leaching out, then sulfur also tends to be high as evidenced by the increasing iron-sulfur correlation with more cure time.

Table 5-2. Correlation Matrices for Stabilizations Across All Curing Times

a) Correlation Marix for Ferric Stabilization

	As	Ba	Ca	Fe	Mg	Mn	Na	B	K	S	Zn
As	100										
Ba	-15	100									
Ca	-26	-26	100								
Fe	37	-27	8	100							
Mg	-46	-39	64	41	100						
Mn	-25	-36	27	58	77	100					
Na	7	52	4	3	-27	6	100				
B	12	48	-20	-17	-55	-17	92	100			
K	23	69	-2	-19	-46	-35	83	80	100		
S	-16	-47	-14	41	53	49	-72	-76	-86	100	
Zn	-15	-1	58	61	62	72	44	13	12	1	100

b) Correlation Matrix for Ferrous Stabilization

	As	Ba	Ca	Fe	Mg	Mn	Na	B	K	Zn
As	100									
Ba	8	100								
Ca	-38	-28	100							
Fe	-17	-20	17	100						
Mg	-45	-29	92	25	100					
Mn	-46	-18	77	43	83	100				
Na	18	43	-2	-12	5	6	100			
B	11	52	-9	-10	-2	-3	98	100		
K	42	15	36	-11	25	2	56	50	100	
Zn	-13	-1	-22	-33	-29	0	0	0	-29	100

c) Ferrous Sulfate and Ferric Sulfate S/S

	As	Ba	Ca	Fe	Mg	Mn	Na	B	K	S
As	100									
Ba	6	100								
Ca	-47	-22	100							
Fe	6	-22	1	100						
Mg	-52	-35	76	29	100					
Mn	-50	-26	61	45	80	100				
Na	17	49	-12	8	-16	1	100			
B	22	47	-31	-1	-31	-16	92	100		
K	33	52	5	-10	-21	-21	73	68	100	
S	-5	-36	-26	37	23	22	-39	-32	-67	100

Table 5-3. Correlation of All S/S Data: Selected Curing Times

(a) Two Day Curing Time

	As	Ba	Ca	Fe	Mg	Mn	Na	B	K	S
As	100									
Ba	70	100								
Ca	-38	-66	100							
Fe	-30	-25	67	100						
Mg	-49	-49	5	22	100					
Mn	-53	-37	0	30	92	100				
Na	56	81	-84	-46	-40	-35	100			
B	41	76	-89	-45	-28	-24	92	100		
K	64	85	-45	-26	-73	-59	67	60	100	
S	-26	-38	-20	-10	89	75	-23	-6	-66	100

(b) Sixty Day Curing Time

	As	Ba	Ca	Fe	Mg	Mn	Na	B	K	S
As	100									
Ba	45	100								
Ca	-59	-25	100							
Fe	-7	-26	-6	100						
Mg	-51	-73	48	30	100					
Mn	-71	-39	62	0	51	100				
Na	37	50	-57	6	-60	-35	100			
B	22	38	-48	10	-50	-28	94	100		
K	67	66	-39	-15	-60	-68	73	65	100	
S	-38	-60	12	22	52	46	-65	-54	-83	100

(c) 365 Day Curing Time

	As	Ba	Ca	Fe	Mg	Mn	Na	B	K	S
As	100									
Ba	-33	100								
Ca	-38	-51	100							
Fe	92	-45	-42	100						
Mg	-24	-75	76	-3	100					
Mn	41	-70	9	62	57	100				
Na	60	33	-59	36	-84	-28	100			
B	57	40	-63	33	-88	-39	98	100		
K	25	44	-13	-12	-69	-72	73	77	100	
S	11	-27	-27	48	36	61	-36	-33	-75	100

(d) 540 Day Curing Time

	As	Ba	Ca	Fe	Mg	Mn	Na	B	K	S
As	100									
Ba	-42	100								
Ca	-46	-48	100							
Fe	82	-44	-37	100						
Mg	-19	-66	88	7	100					
Mn	23	-74	58	30	66	100				
Na	21	42	-42	-16	-52	-47	100			
B	23	46	-50	-18	-63	-53	99	100		
K	-10	37	4	-41	-13	-26	84	78	100	
S	52	-27	-27	91	19	17	-32	-36	-48	100

Another significant observation is the increasing calcium-magnesium correlation with cure time. Both calcium and magnesium are principally from the binders as shown in Table 3-3. One explanation for some of the failures in stabilization was matrix deterioration due to sulfate damage. An increasing calcium-magnesium correlation over cure time reinforces that conclusion.

As shown in Table 5.4, column leaching data present many more significant correlations as shown by correlation results using the US1 mix design. Correlation results from the US4 mix design are shown in Table 5-5. These mix designs are defined in Table 4-3. Each mix design underwent leaching with three different leachants after two days of curing. These significant correlations illustrate that the rate of metal release follows a similar pattern in many cases. This result does not necessarily imply that the total amount of metals leached will correlate.

5.3 Column Leaching

5.3.1 Model Development

During column extraction, stabilized waste components located in chemically reactive regions (such as calcium hydroxide, CH) of the S/S matrix are easily mobilized. Initially, the dissolution of the CH phase occurs at the head end of the column and a "front" of CH dissolution proceeds toward the column exit as time progresses. Waste and binder components will transport through this column in two different ways depending on their solubility and molecular size.

If the components are insoluble in the extraction fluid, then components mobilized at the head of the column because of CH dissolution are trapped farther down the column in the undissolved stabilization matrix. As the deterioration of the CH phase proceeds toward the column exit, the exit portion of the column becomes filled to capacity, and breakthrough is observed. Under these conditions the concentration of the component in the column eluant steadily increases similar to an ion exchange breakthrough curve. After breakthrough, concentrations decrease exponentially.

As explained in Chapter Two, the more reactive CH volume will decrease with cure time as the less reactive CSH phase develops. Samples with higher fractions of reactive regions have had less time to cure. Higher fractions of reactive regions also imply that components will diffuse through the column more quickly and smaller breakthrough volumes are observed.

If the component leached from the reactive region is not reprecipitated or captured by sample solids nearer to the column exit, then exponentially decreasing concentrations are observed in the column eluant. If the logarithm of the concentration in the column eluant is plotted against the volume of eluant issuing from the column, a straight line with a negative

Table 5-4. Correlation Matrices for Column Leaching, US1 Mix Design, 2-day Cure Time

(a) DI Leachant

	As	B	Ba	Ca	Fe	K	Mg	Na	S	Zn	pH
As	100										
B	81	100									
Ba	-48	-74	100								
Ca	87	96	-84	100							
Fe	87	94	-77	98	100						
K	89	94	-81	100	98	100					
Mg	90	94	-80	100	98	100	100				
Na	90	94	-80	100	98	100	100	100			
S	90	93	-80	100	98	100	100	100	100		
Zn	5	-13	-20	53	6	9	9	9	10	100	
pH	-54	-90	58	-74	-73	-72	-71	-71	-69	37	100

(b) pH = 3 Leachant

	As	B	Ba	Ca	Fe	K	Mg	Na	S	Zn	pH
As	100										
B	92	100									
Ba	-55	-77	100								
Ca	92	98	-73	100							
Fe	72	68	-61	81	100						
K	88	91	-83	94	88	100					
Mg	88	80	-57	89	95	92	100				
Na	89	91	-82	94	88	100	92	100			
S	86	85	-78	89	91	98	93	99	100		
Zn	63	59	-18	71	66	55	75	55	55	100	
pH	-47	-58	52	-39	11	-38	-7	-37	-28	18	100

(c) pH = 8.7 Leachant

	As	B	Ba	Ca	Fe	K	Mg	Na	S	Zn	pH
As	100										
B	96	100									
Ba	-39	-37	100								
Ca	88	91	-68	100							
Fe	85	84	-61	93	100						
K	87	90	-70	100	93	100					
Mg	87	91	-69	100	93	100	100				
Na	90	94	-56	95	90	94	95	100			
S	85	87	-65	98	96	98	98	91	100		
Zn	67	68	-57	66	58	66	66	69	56	100	
pH	-93	-98	27	-85	-77	-83	-84	-86	-80	-68	100

Table 5-5. Correlation Matrices for Column Leaching, US4 Mix Design, 2-day Cure Time

(a) DI Leachant

	As	Ni	SO4	Zn	Ca	Pb	Mg	pH
As	100							
Ni	97	100						
S	97	99	100					
Zn	91	97	98	100				
Ca	94	95	98	96	100			
Pb	-20	-16	-13	5	-2	100		
Mg	97	99	99	97	98	-12	100	
pH	62	66	70	63	68	-23	69	100

(b) pH = 3 Leachant

	As	Ba	Ni	S	Ca	Zn	Pb	Mg	Cr	pH
As	100									
Ba	69	100								
Ni	-68	-41	100							
S	-76	-43	99	100						
Ca	19	-1	24	13	100					
Zn	41	44	01	-3	-9	100				
Pb	60	36	-74	-74	-22	54	100			
Mg	-24	-08	81	77	26	32	-53	100		
Cr	18	38	-67	-58	-75	3	53	-54	100	
pH	-63	-46	83	81	81	-38	-82	54	-77	100

(c) pH = 8.7 Leachant

	As	Ni	S	Zn	Ca	Cr	Pb	Mg	pH
As	100								
Ni	-48	100							
S	16	77	100						
Zn	01	52	68	100					
Ca	09	65	85	49	100				
Cr	19	24	45	60	0	100			
Pb	-15	-20	-33	7	-47	31	100		
Mg	15	32	52	19	85	-43	-58	100	
pH	45	48	87	56	85	16	-49	73	100

slope results. The slope of the line is steeper if the reactive region makes up a larger fraction of the sample or the concentration of the waste component in the reactive region is larger.

Once the reactive CH region has been largely leached from the sample by the eluant, then the less reactive regions of the sample become the major sources of leached components. These silicate networked regions, labeled here as CSH or calcium silicate hydrate, dissolve very slowly. The leaching process from this region follows first-order kinetics so that a plot of the logarithm of the component concentration in the eluant versus the eluant volume issuing from the column is linear. A more negative slope indicates the component is more loosely bound, and a less negative slope indicates tightly bound component.

For components which are not reprecipitated in the column, a simple kinetic model may be illustrative. Extraction of components from a solid phase follows first-order kinetics with the rate law

$$-dc/dt = k\ c \qquad (1)$$

where c = concentration in the column effluent [mg/L];
k = first-order rate constant [1/sec].

Equation (1) can be integrated to yield

$$c = c_o\ e^{-kt} \qquad (2)$$

where c_o = concentration at time = 0.

Waste encapsulated in the reactive CH phase is easily extracted with rate constant k_1. The extraction of waste encapsulated in the less reactive CSH phase proceeds at a slower rate modeled with constant k_2. If both processes are assumed to be taking place simultaneously and independently, then the total rate of leaching is the sum of the two rates. The final result of the model is that the concentration in the extract is

$$[\text{extract}] = \{\text{const}\}\{CHS_o\exp(-k_1t) + CH_o\exp(-k_2t)\} \qquad (3)$$

where $k_1 > k_2$ and CHS_o and CH_o are the initial amounts of contaminants residing in the CSH and CH phases.

A prediction of this theory is that a systematic study of column leaching will reveal the relative amount of labile CH phase in samples and the behavior of individual waste components with respect to the development of the concrete lattice.

5.3.2 Column Extraction Results

Column extraction experiments were all carried out with a flow rate of 3.0 mL/min and a 50.0-gram sample. Figure 5-7 shows

data for calcium extraction from US1 and US4 ferrous sulfate-stabilized waste mixes. Data for three eluants are presented: pH 3.00 acetic acid, deionized water, and pH 8.77 sodium acetate. Two S/S mix designs are shown, both with two day cure times. Calcium is not reprecipitated in the column and therefore the shape of the data is that represented by Equation (3) above. Unfortunately, the density of data was not sufficient in the beginning of the experiment to accurately define k_1 in many cases. It is important to note that the logarithmic vertical axis does not always show the same range because the concentrations being presented vary widely. The general shape of the data obtained illustrates the validity of the model developed above. Table 5-6 presents the model parameters for the latter part of the curve, CSH extraction, for the calcium data shown in Figure 5-7.

Table 5-6. Column Data Model Parameters for Calcium

Mix	Cure Time	Eluant	Intercept[a]	Slope
US1	2 days	pH 3.00	2.98	$-6x10^{-5}$
		DI H_2O	2.44	$1x10^{-5}$
		pH 8.77	2.71	$-7x10^{-5}$
US4	2 days	pH 3.00	2.84	$-9x10^{-5}$
		DI H_2O	2.30	$-2x10^{-4}$
		pH 8.50	2.42	$-3x10^{-4}$

(a) Intercept: log of the calcium concentration in mg/L

Examination of the graphs in Figure 5-7 shows that the early positive deviations from the CSH fitted line, which correspond to CH extraction, last until approximately 200 mL of eluant has passed the column for all eluants and mixes. Figure 5-8c shows the results for small volumes of DI H_2O eluant for a US1 mix cured for 390 days. Not enough data was gathered to accurately define the large volume slope but the marked difference in shape of the curve illustrates the changes apparent as S/S mixes cure.

The data for barium concentrations in column extractions of US1 S/S mix cured for two days is shown in Figure 5-9. Data is not shown for good S/S mix designs such as US4 because all barium concentrations in the eluant were at the analytical detection limit; barium is not extractable from this S/S mix. The barium data for poor S/S mixes at two day cure times have shapes expected for a system undergoing breakthrough. The large-volume exponential line meets the breakthrough rising curve at about

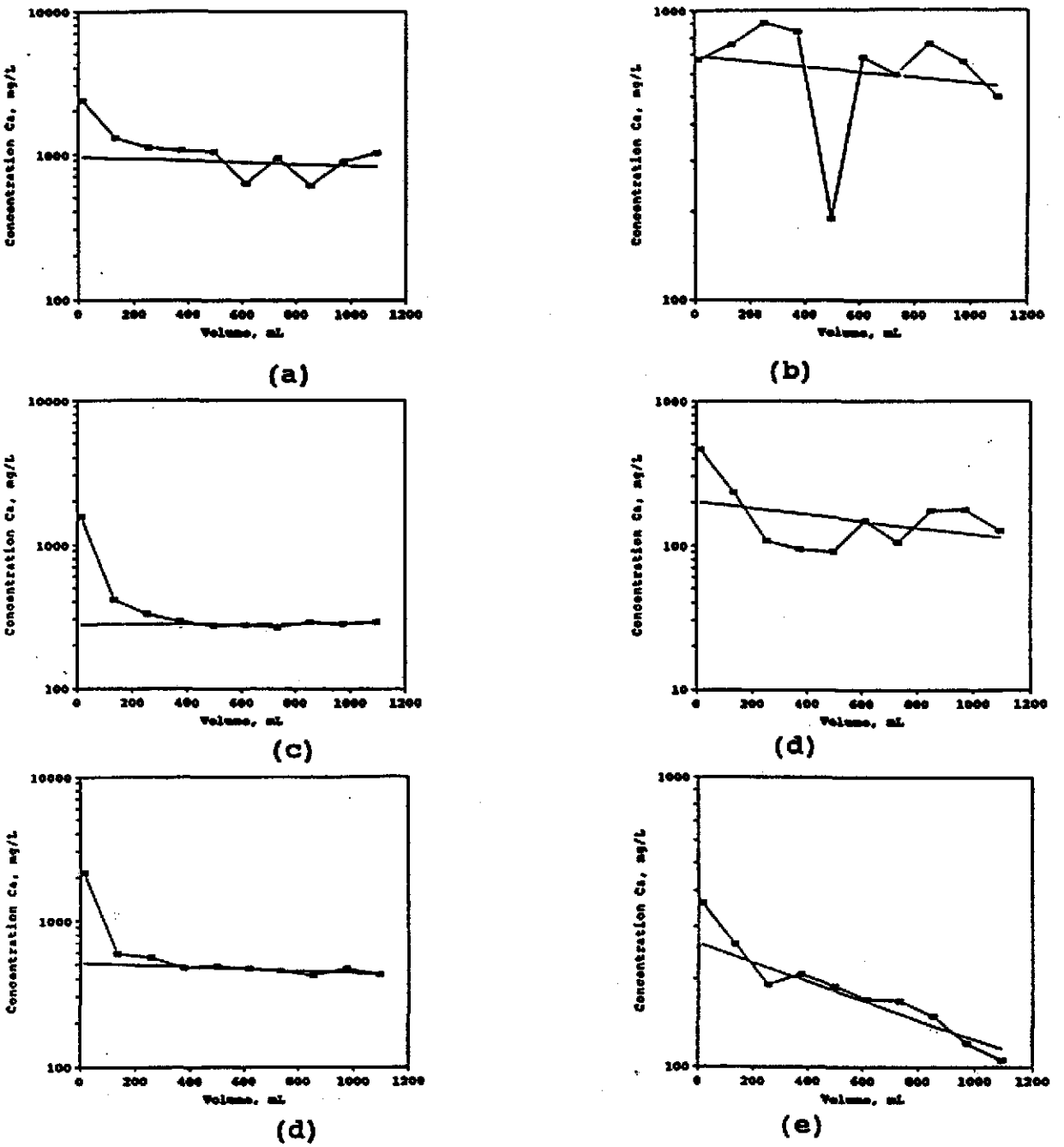


Figure 5-7. Column Extraction Data for Calcium.
(a) Mix US1 (Table 4-2), pH 3.00 Eluant.
(b) Mix US4, pH 3.00 Eluant.
(c) Mix US1, DI H_2O Eluant.
(d) Mix US4, DI H_2O Eluant.
(e) Mix US1, pH 8.77 Eluant.
(f) Mix US4, pH 8.50 Eluant.
All samples cured for two days.

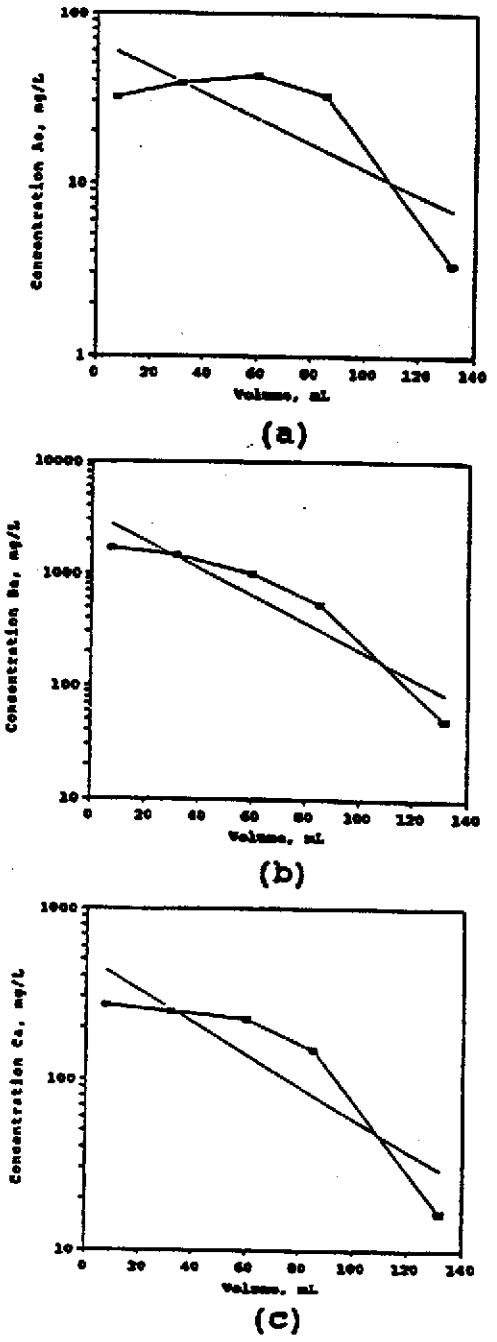


Figure 5-8. Column Extraction Data, 390-day Cure, Mix US1, DI H_2O Eluant.

(a) Arsenic (b) Barium (c) Calcium

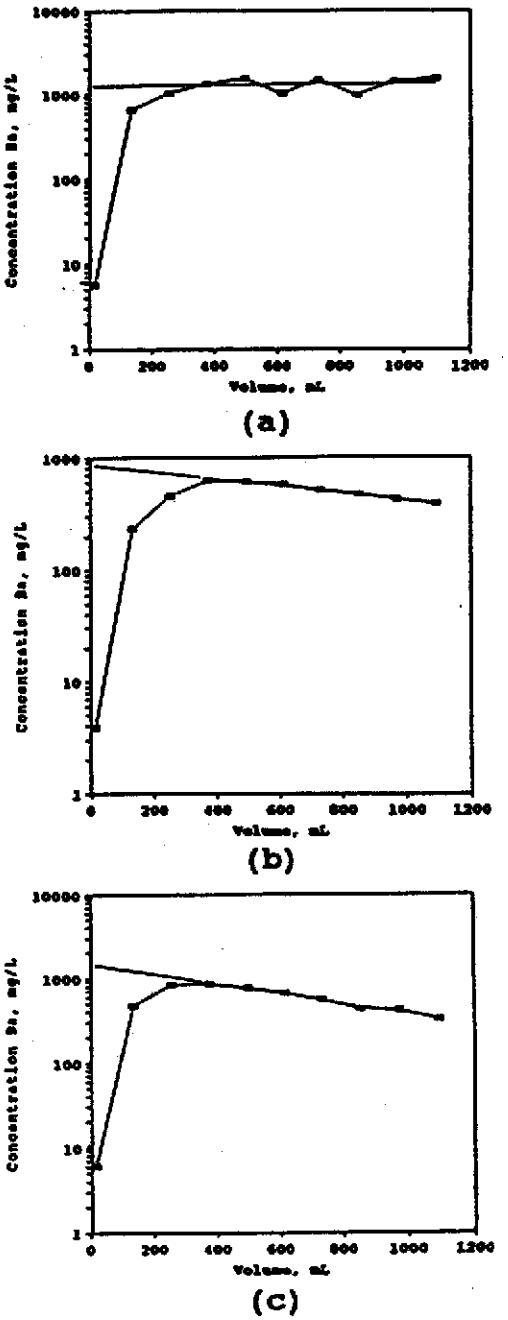


Figure 5-9. Column Extraction Data for Barium, Mix US1, 2-day Cure.

(a) pH 3.00 Eluant. (b) DI H_2O Eluant. (c) pH 8.77 Eluant

400 mL of eluant in all cases, indicating little pH dependence in the extractability of barium. However, examination of the model parameters for the CSH extraction region data shown in Table 5-7 indicates that barium extractability from a CSH matrix into a neutral solution is less than into acidic or basic solutions.

Table 5-7. Column Data Model Parameters for Barium.

Mix	Cure Time	Eluant	Intercept	Slope
US1	2-days	pH 3.00	3.10	$2x10^{-5}$
		DI H_2O	2.93	$-3x10^{-4}$
		pH 8.77	3.17	$-6x10^{-4}$

Comparison of the shapes of the barium extraction concentration curves for samples cured for two days with the shape for the same S/S mix composition cured for 390 days (Figure 5-8b) shows the drastic changes in column extraction concentrations as S/S mixes cure.

Figure 5-10 shows column extraction data for arsenic. The quality of the fit of the data to the exponential decay curve seems to be somewhat poorer than for the other elements. Reasons for this might include penetration of arsenic-containing solid particles through the eluant filtration system at the exit of the column or variability due to low concentrations. After taking this into account it is still apparent that arsenic leaching does not fit either of our simple models very well. Evidence of breakthrough-type behavior is seen in Figure 5-10, parts b, c, and f. The data points were not taken at short enough intervals to define the early behavior accurately. If the first data point is significant, then the general shape of independent first-order processes with different rate constants can be ascertained. Figure 5-8a shows the arsenic data for S/S mixes cured for 390 days. The drastic change in shape again illustrates the effects of reducing the fraction of CH phase present in the S/S mix as the sample cures.

Model parameters for the arsenic data are in Table 5-8. The relative independence from the eluant pH of the slope for poor S/S formulations indicates that the extraction of arsenic from CSH lattices fortified with ferrous sulfate additive is relatively independent of pH. The changes in slope and intercept from a poor (US1) to a good (US4) S/S formulation indicate the improvement in arsenic stabilization taking place.

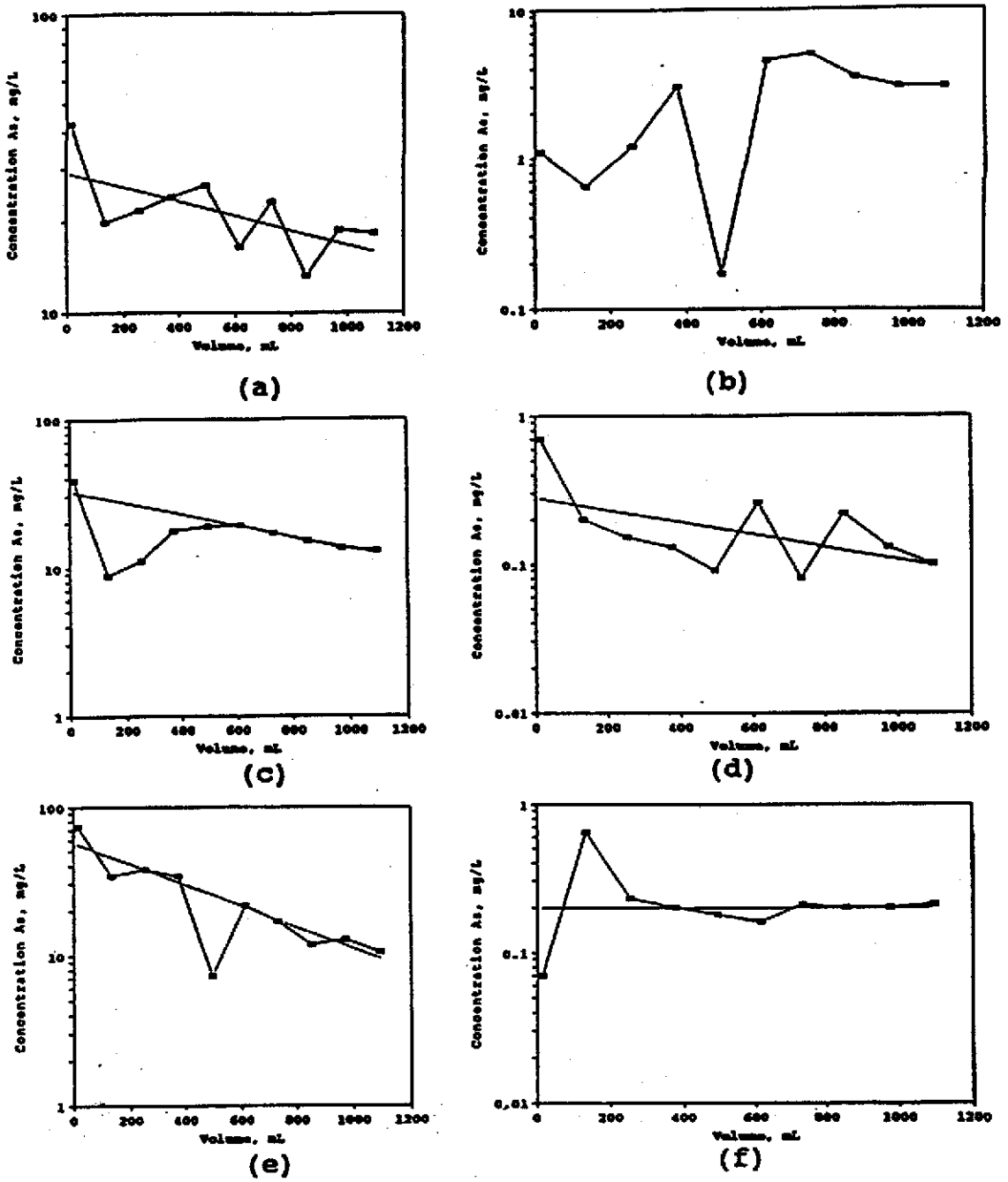


Figure 5-10. Column Extraction Data for Arsenic.

(a) Mix US1 (Table 4-2), pH 3.00 Eluant.
(b) Mix US4, pH 3.00 Eluant.
(c) Mix US1, DI H_2O Eluant.
(d) Mix US4, DI H_2O Eluant.
(e) Mix US1, pH 8.77 Eluant.
(f) Mix US4, pH 8.50 Eluant.
All samples cured for two days.

Table 5-8. Column Data Model Parameters for Arsenic

Mix	Cure Time	Eluant	Intercept	Slope
US1	2-days	pH 3.00	1.47	$-2x10^{-4}$
		DI H_2O	1.51	$-4x10^{-4}$
		pH 8.77	1.69	$-7x10^{-4}$
US4	2-days	DI H_2O	-0.55	$-4x10^{-4}$
		pH 8.50	-0.70	$-2x10^{-6}$
US1	390-days	DI H_2O	1.82	$-7x10^{-3}$

5.4 Calorimetric Analyses of Hydration Reactions

Figures 5-11 and 5-12 present data for reactions of cement with sand and cement with fly ash and sand. The ordinate is the average temperature of the tops and bottoms of two identical reaction mixtures (four points). The initial rise seen for the first three to five data points represents the time required to complete mixing of the sample, place the sample in the calorimeter, install the thermocouples and thermal isolation and achieve thermal uniformity. As can be seen in Figure 2-4, the initial hydration exotherm is complete in a cement paste sample in less than 30 minutes. The stage 3/stage 4 exotherm takes place about 500 to 700 minutes after mixing. The last exotherm experimentally observed normally takes place around 2000 minutes after mixing.

In the cement/sand mixture (Figure 5-11) the stage 3/ stage 4 is observed about 800 minutes after mixing. The first hydration isotherm was complete before data collection began. Small isotherms, about equal to the diurnal noise in the experiment, can be seen at 1700 and 2100 minutes and may be the second peak noted in Figure 2-2.

In the cement/fly ash/sand mixture (Figure 5-12) the tail of the initial hydration exotherm can be seen before 200 minutes. The stage 3/stage 4 exotherm (C_3S hydration) has been delayed to about 1000 minutes due to dilution of the matrix by the sand. The composition of the mixture was a "good mix" (mix 4, Tables 4-2 and 4-3) with fine sand substituting for the hazardous waste. The shoulder at 1700 minutes probably corresponds to C_3A hydration (Figure 2-4) although it might be due to diurnal laboratory temperature changes.

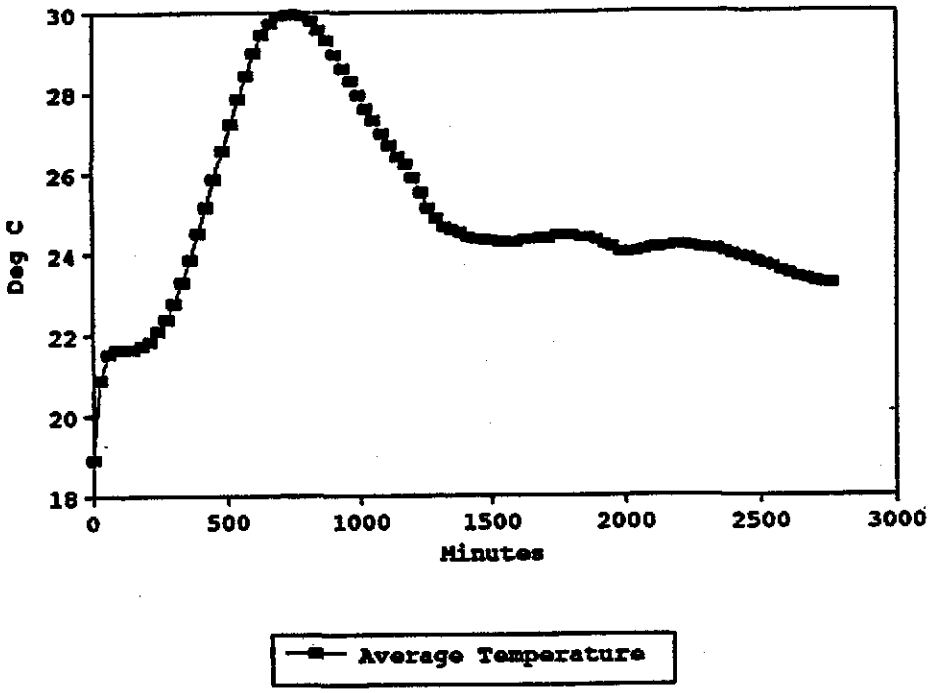


Figure 5-11. Calorimetric Curve for Cement-Sand Mix

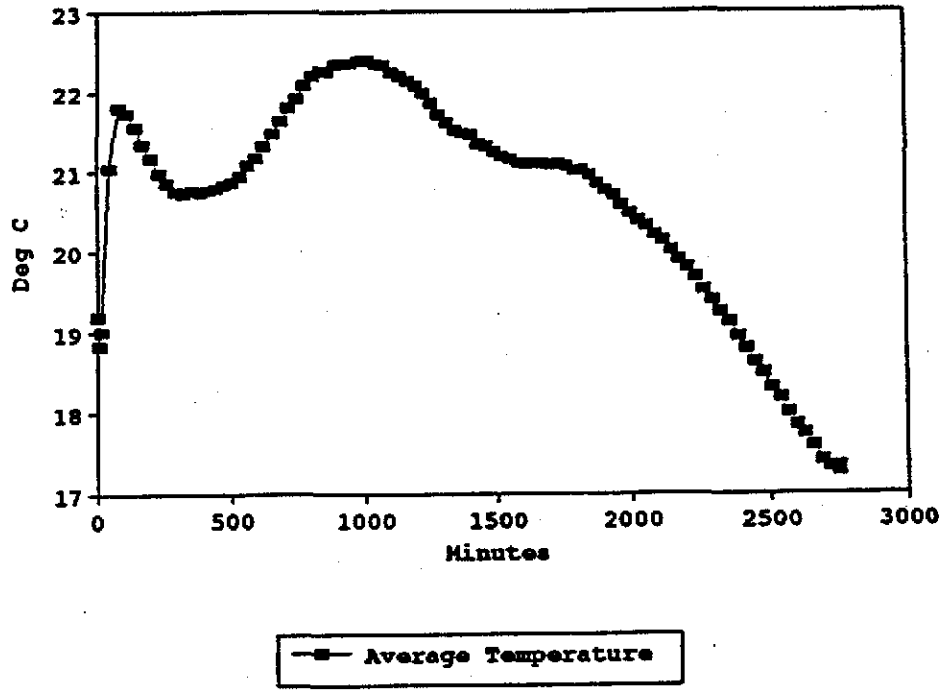


Figure 5-12. Calorimetric Curve for Cement, Fly Ash & Sand Mix

Figures 5-13 and 5-14 show the data for ferrous sulfate and ferric sulfate stabilization additives in a lean stabilized mix with a binder/waste ratio of 0.15 (mixes US1 and F1 in Table 4-2 and 4-3). Because only 10% of the total mass of the reacting system is cement/fly ash binder, the reactive ingredients are quite dilute and the rate of chemical reaction is slower. As a result, the initial hydration exotherm is observed about 80 minutes after mixing and the cement-hardening hydration reaction exotherms are much smaller and delayed more than 10%. The exotherms from the slower reactions are difficult to distinguish from experimental and ambient noise. The data show that hazardous waste stabilization mixtures will cure much slower than conventional construction concretes.

In Figures 5-15 and 5-16 are the calorimetric data using ferrous sulfate and ferric sulfate stabilization additives in richer cement/fly ash stabilizing mixes, US4 and F4. These mixes are 16% cement/fly ash binder by mass so that the chemical reactions of the binder are somewhat faster. The initial hydration isotherm has peaked by 80 minutes after mixing. The 800-minute isotherm seen in sand mixes is discernable in the ferrous sulfate experiment, although the peak is broader and less well-defined. This is probably a result of inhibition of the hydration reactions by the iron and sulfate present in excess in the mixture. The ferric sulfate experiment in Figure 5-16 was terminated early due to failure of laboratory temperature controls, leading to a widely drifting baseline.

The conclusions of the calorimetric study are that the hardening hydration reactions of stabilized waste mixtures are inhibited as a result of dilution of the reactive ingredients by the waste and through chemical interference by waste components and stabilizing additives.

5.5 Arsenite Stabilization

5.5.1 Ferrous and Ferric Sulfate Stabilization

To investigate the effect of arsenic oxidation number on stabilization, a series of experiments were carried out with a synthetically-prepared waste with a known amount of arsenic in a known oxidation state.

In Table 5-9, stabilization with ferrous sulfate and ferric sulfate is compared using a F006 waste containing sodium arsenate. The different values for the additive/waste mass ratio for ferric and ferrous sulphate were assigned so that an equal number of moles of iron were added in either case. For a binder/waste of 0.15, ferrous sulfate is significantly more effective for two reasons: the ferrous arsenate solubility product is less than the ferric arsenate solubility product; and the arsenate anions must compete with the hydroxyl ion for precipitation with the ferric ion. For a binder/waste of 0.40 with more abundance of calcium

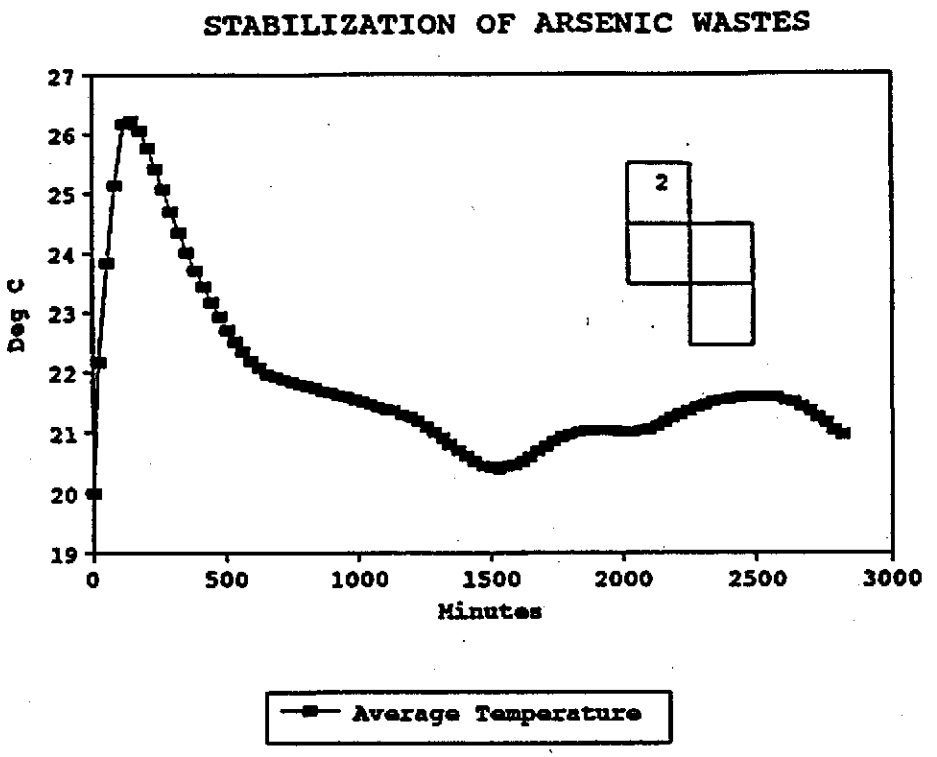


Figure 5-13. Calorimetric Curve for Mix Design US1. (Appendix A)

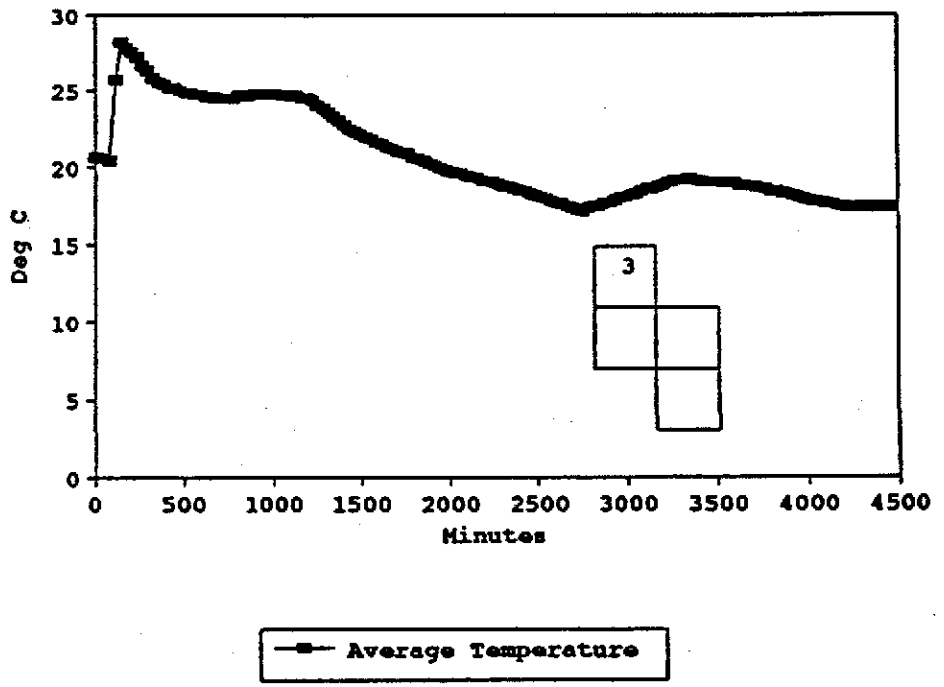


Figure 5-14. Calorimetric Curve for Mix Design F1. (Appendix A)

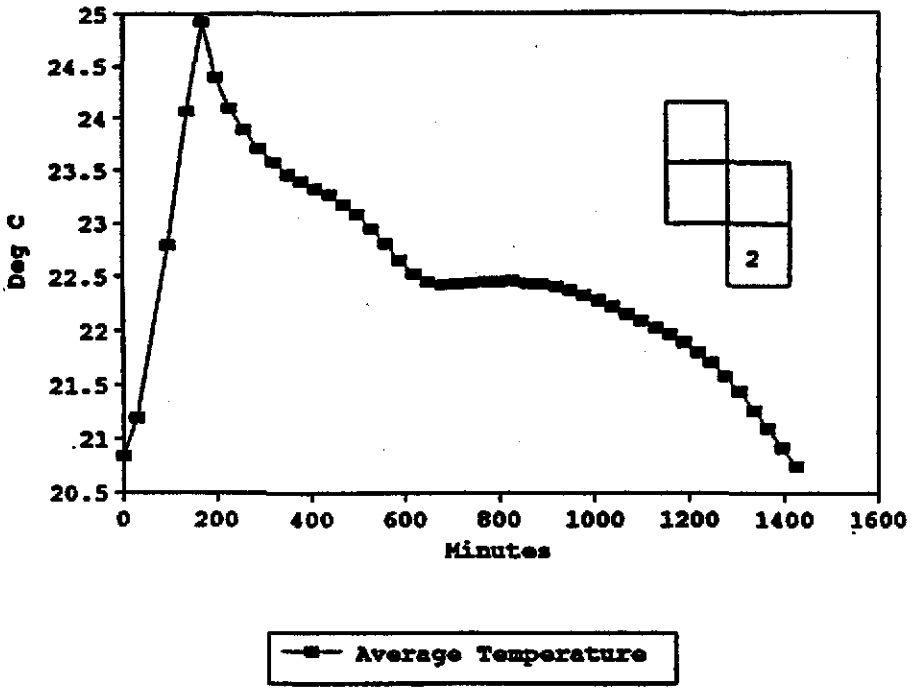


Figure 5-15. Calorimetric Curve for Mix Design US4. (Appendix A)

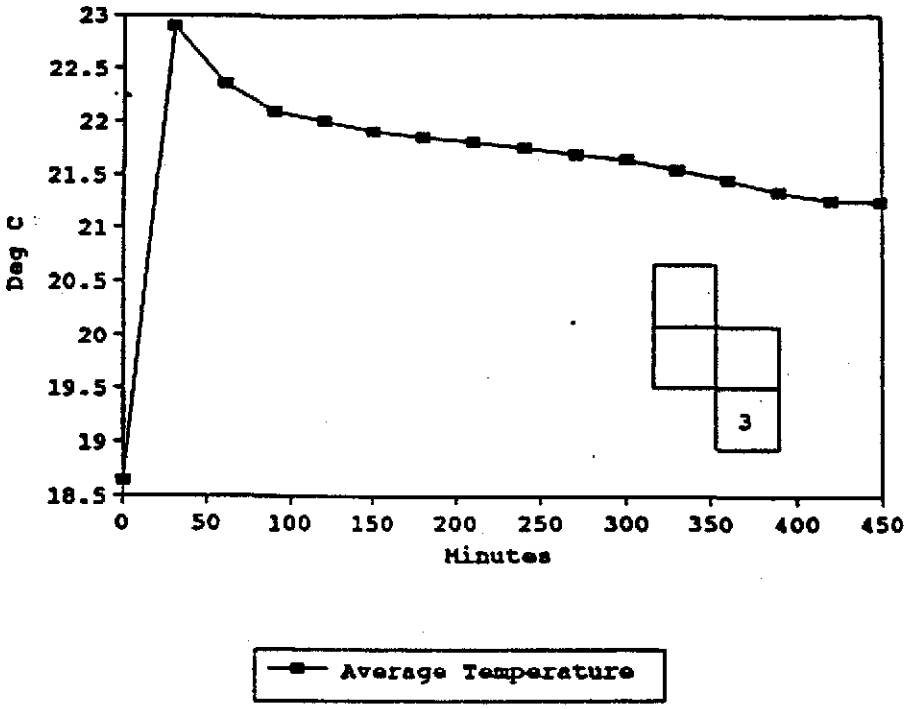


Figure 5-16. Calorimetric Curve for Mix Design F4. (Appendix A)

Table 5-9. Ferrous and Ferric Sulfate Stabilization of Arsenate Added to F006 Waste

TCLP Concentrations (mg/L)

FA1x Series		
Metal	Cure Time 2-days	60-days
As	20.9	6.05
Ca	1480	1750
Fe	0.08	0.07
S	356	16300

FA3x Series		
Metal	Cure Time 2-days	60-days
As	1.59	1.18
Ca	1490	1650
Fe	0.052	0.525
S	242	10300

Binder
F006/Arsenate Waste
0.15 0.40

$\frac{Fe^{+3}}{As}$ mole ratio = 1.1

$\frac{Fe^{+2}}{As}$ mole ratio = 2.0

USA2x Series		
Metal	Cure Time 2-days	60-days
As	2.84	1.67
Ca	1500	1800
Fe	0.25	0.31
S	382	16500

USA4x Series		
Metal	Cure Time 2-days	60-days
As	2.60	0.83
Ca	2070	1820
Fe	0.208	0.77
S	684	14200

hydroxide, both ferric and ferrous sulfates yield comparable TCLP results. The large amount of sulfate in the extracts indicates the lack of barium in this modified F006 waste.

In a similar format, Table 5-10 presents results for arsenite stabilization using ferrous and ferric sulfates. Ferrous sulfate yields more effective stabilization for arsenites at either binder/waste ratio. As shown in Figures 5-17 and 5-18, the most striking result is the relative ease of stabilizing arsenate as compared to arsenite. This observation has lead to a consideration of oxidation as a pretreatment for the stabilization of arsenite wastes.

Table 5-10. Ferrous and Ferric Sulfate Stabilization of Arsenite in F006 Waste

TCLP Concentrations (mg/L)

FB1x Series		
Metal	Cure Time 2-days	60-days
As	52.6	61.4
Ca	1580	1890
Fe	0.08	0.36
S	311	3890

FB3x Series		
Metal	Cure Time 2-days	60-days
As	28.65	10.1
Ca	1580	1680
Fe	0.102	0.56
S	34.4	7530

$\frac{Fe^{+3}}{As}$ mole ratio = 1.1

$\frac{Fe^{+2}}{As}$ mole ratio = 2.0

	Binder F006/Arsenate Waste 0.15	0.40

USB2x Series		
Metal	Cure Time 2-days	60-days
As	23.0	24.8
Ca	1760	1780
Fe	0.49	0.57
S	34.8	68.1

USB4x Series		
Metal	Cure Time 2-days	60-days
As	7.97	4.73
Ca	1500	1740
Fe	0.53	0.172
S	236	79.5

5.5.2 Pretreatment with Oxidation

Air oxidation and chemical oxidation with hydrogen peroxide were used to convert arsenites to arsenates for more effective stabilization. Air oxidation was accomplished by intense mixing over 45 minutes with several interruptions for redox potential measurements. Chemical oxidation of arsenite was accomplished by adding hydrogen peroxide at a mole ratio of either 1:1 or 0.5:1. Either 50 or 100 percent of the water required by the stabilization design was added to permit more effective oxidation. The experiment design is described in Table 4-6.

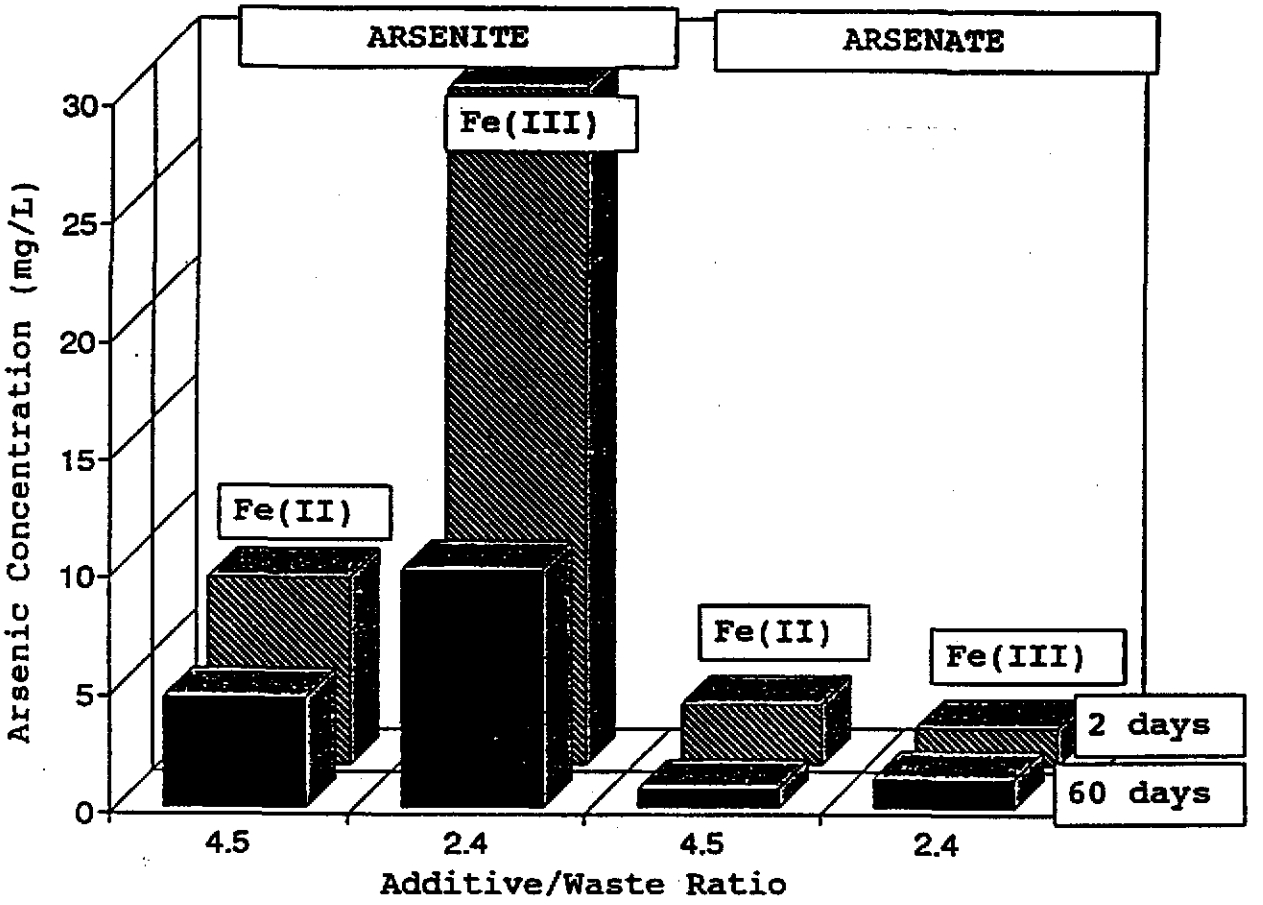


Figure 5-17. Two-Day and Sixty-Day Stabilization of Modified Arsenate and Arsenite Waste Using Ferrous Sulfate and Ferric Sulfate Additives. Binder/Waste = 0.15

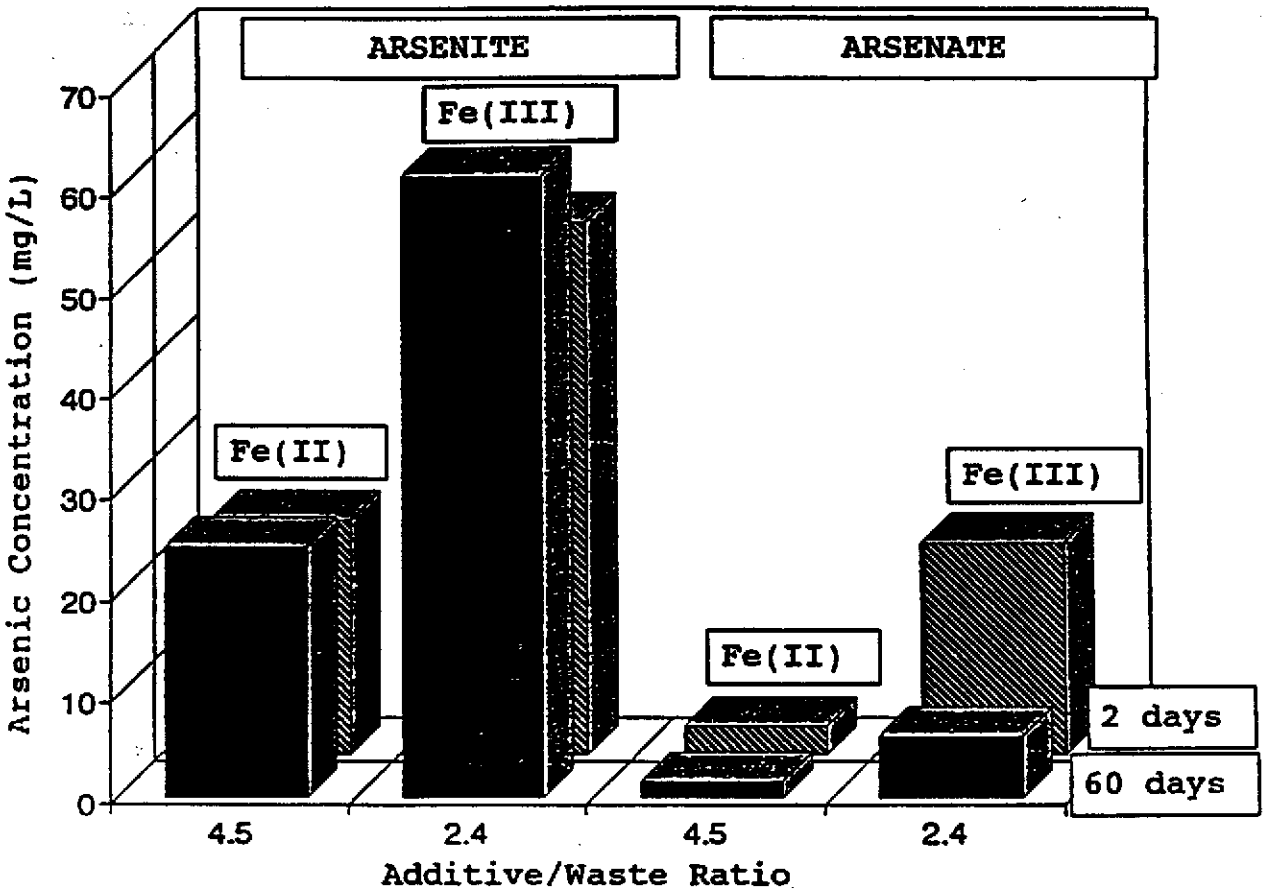


Figure 5-18. Two-Day and Sixty-Day Stabilization of Modified Arsenate and Arsenite Waste Using Ferrous Sulfate and Ferric Sulfate Additives. Binder/Waste = 0.40

After oxidative pretreatment of the waste, the cement and fly ash were added. After mixing, either ferric sulfate or ferrous sulfate was added to stabilize the arsenic. Samples were then air cured for two days before undergoing TCLP. Water is involved in the oxidation reactions as a reaction medium to allow contact between reacting species and as a reactant or product in the ideal balanced oxidation-reduction reactions. To enhance the oxidative reaction chemistry, varying fractions of the total water used in the final S/S mixture were added during the oxidative pretreatment step. The remainder of the water, if any, was added with the cement and fly ash.

Figure 5-19 presents a comparison of ferrous sulfate and ferric sulfate S/S of arsenite with air oxidation. The water to waste mass ratio indicated on the horizontal axis reflects the amount of water added during the air oxidation step. For either binder/waste ratio, lesser amounts of water will improve the performance of air oxidation, probably due to enhanced difussion through thinner aqueous films on the waste particles.

In Figure 5-20, a similar comparison is made with chemical oxidation as the pretreatment. The mole ratio of hydrogen peroxide to arsenic is indicated on the horizontal axis. Hydrogen peroxide is very effective for oxidizing arsenite to arsenate. The dramatic improvement in arsenic S/S emphasizes the relative ease of treating arsenate compared to arsenite.

Data for other elements is shown in Table 5-11. Examination of the data for calcium leads to the conclusion that oxidative pretreatment does not effect the stability of the cementitious lattice, at least in the short term. Sulfate concentrations in the TCLP extracts similarly appear to be relatively independent of the manner in which oxidative pretreatment is performed. The waste used in this set of experiments did not contain much barium, so that the extractable sulfate concentrations are quite high.

5.6 Individual Ion Effect

The TCLP results of the experimental design shown in Table 4-7 are presented in Table 5-12. A comparison of these results using a binder/waste of 0.15 with that from ferrous sulfate stabilizations is shown in Figure 5-21. This plot of arsenic versus iron/arsenic molar mix ratio also shows iron/binder ratios for each mix and the pH of the TCLP extract. The US series represents stabilization with ferrous sulfate as defined in Table 4-2. The lighter-shaded bars represent iron acetate stabilization which yields more effective stabilization of arsenic with lower iron/arsenic molar ratios.

Similar results occur for mix designs with binder/waste equal to 0.40. Iron acetate stabilizations yield arsenic concentrations of 3.84 and 0.09 mg/L for 1.5 and 3.0 iron/arsenic molar concentrations. Ferrous sulfate stabilization requires an

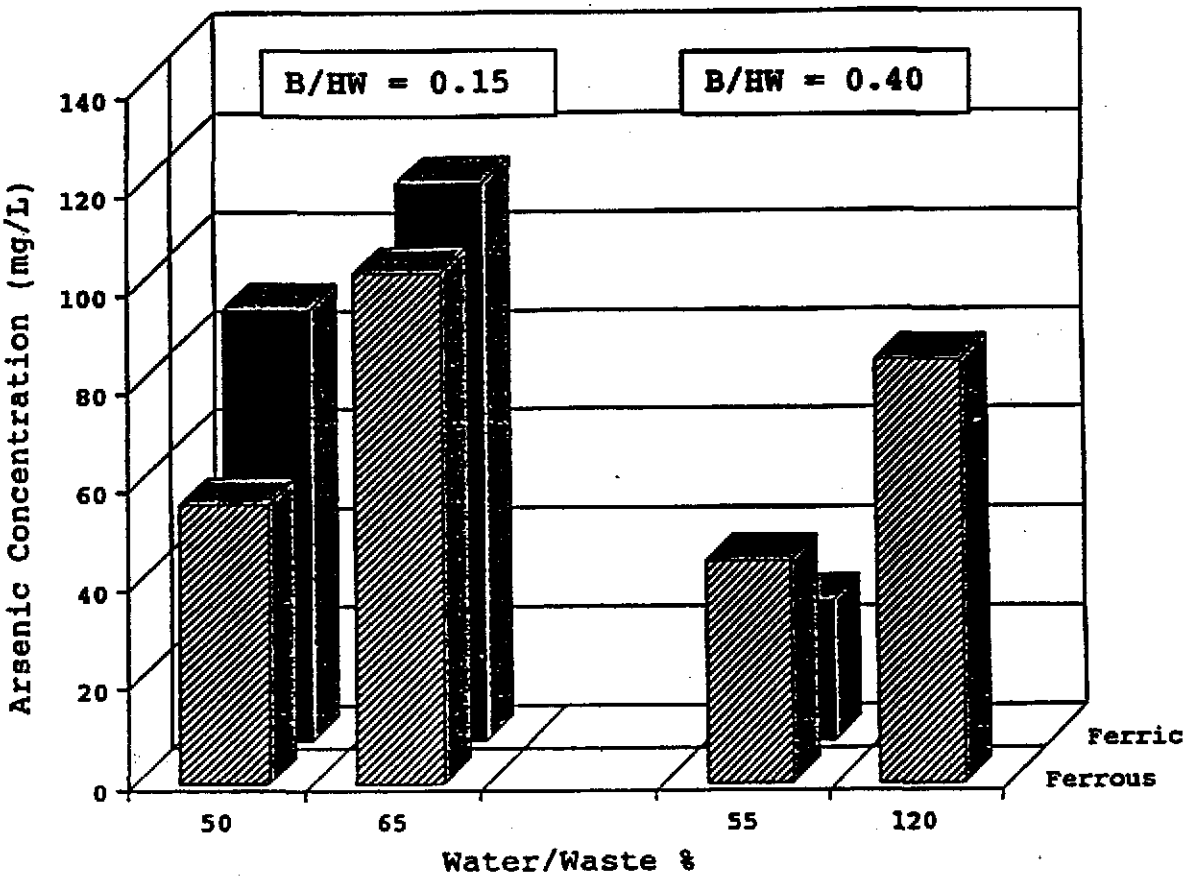


Figure 5-19. Arsenite Pretreatment by Air Oxidation, TCLP Results

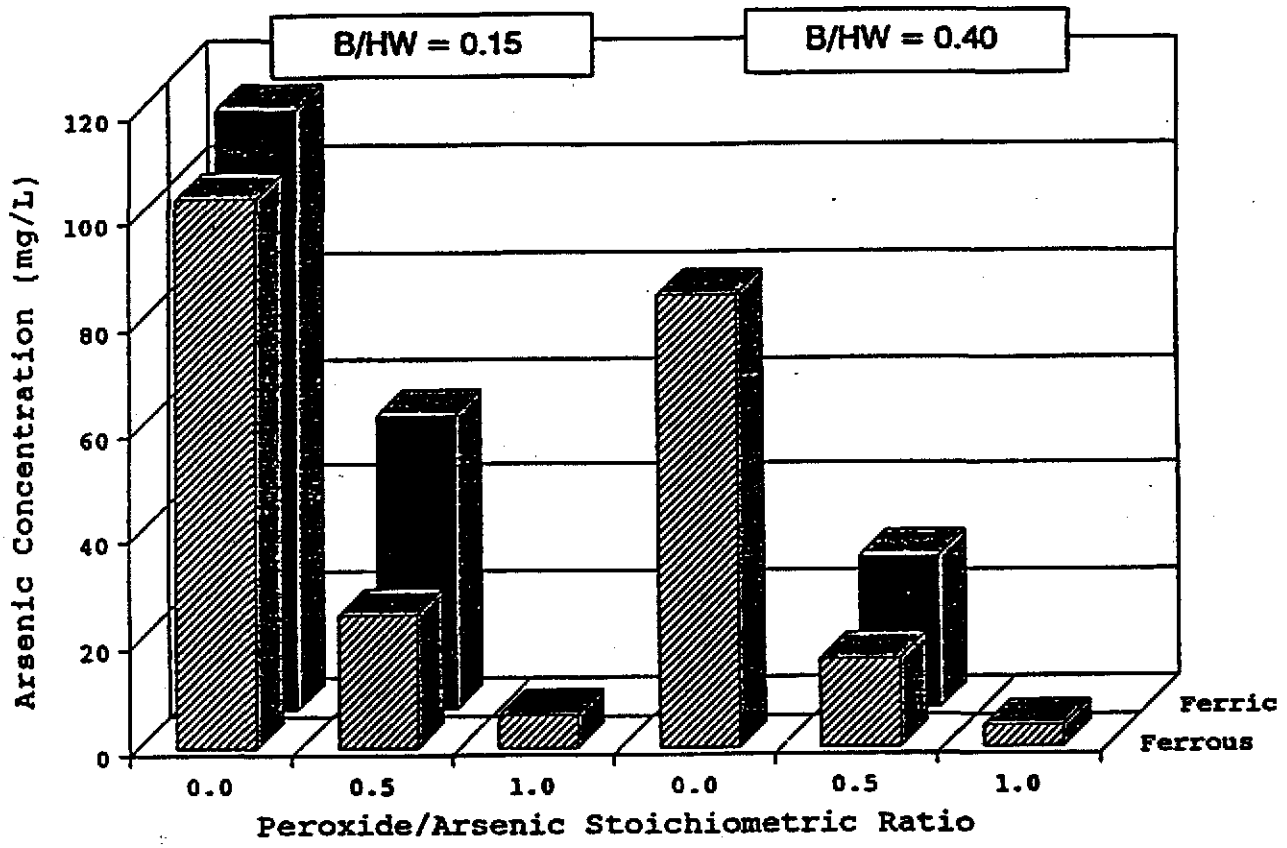


Figure 5-20. Arsenite Pretreatment by Peroxide Oxidation, TCLP Results

Table 5-11. Experimental Design for Arsenite Stabilization.

Binder / waste mass ratio

0.15 0.40

Air Oxidation

TCLP Results for USB1x
Note: The % denotes the amount of the water added in the beginning. Also if Fe(II) or Fe(III) was used is indicated.

Element	sample with 50%,Fe (II)	sample with 100%,Fe (II)	sample with 50%,Fe (III)	sample with 100%,Fe (III)
Arsenic		56.3	87.4	113.
Barium		0.25	0.26	0.32
Calcium		1700	1350	1760
Iron		1.2	0.33	28.6
Sulfate		957.	654.	735.
pH	5.8	6.6	5.9	4.7

TCLP Results for USB2x
Note: The % denotes the amount of the water added in the beginning. Also if Fe(II) or Fe(III) was used is indicated.

Element	sample with 50%,Fe (II)	sample with 100%,Fe (II)	sample with 50%,Fe (III)	sample with 100%,Fe (III)
Arsenic	44.9		28.2	
Barium	0.38		0.34	
Calcium	1070		1440	
Iron	45.8		0.18	
Sulfate	435.		627.	
pH	5.2	6.1	6.2	5.1

H_2O_2 Oxidation

TCLP Results for USBP1x
Note: The % denotes the amount of the water added in the beginning. Also if Fe(II) or Fe(III) was used is indicated.

Element	sample with 50%,Fe (II)	sample with 100%,Fe (II)	sample with 50%,Fe (III)	sample with 100%,Fe (III)
Arsenic	33.0	17.2	57.5	53.7
Barium	1.7	1.1	1.2	1.2
Calcium	1440	1340	1300	1390
Iron	211.	76.6	0.09	4.4
Sulfate	987.	978.	660.	540.
pH	5.2	5.3	6.7	4.7

TCLP Results for USBP2x
Note: The % denotes the amount of the water added in the beginning. Also if Fe(II) or Fe(III) was used is indicated.

Element	sample with 50%,Fe (II)	sample with 100%,Fe (II)	sample with 50%,Fe (III)	sample with 100%,Fe (III)
Arsenic	16.2	17.1	59.6	27.9
Barium	2.7	0.35	0.55	0.33
Calcium	1280	2210	2060	1600
Iron	0.08	115.	0.12	0.07
Sulfate	1280	759.	660.	639.
pH	7.2	5.25	5.8	8.3

Table 5-12. TCLP Results Using Iron Acetate

Mole Ratio Fe/As	Binder/Waste Mass Ratio 0.15		Binder/Waste Mass Ratio 0.40	
	IA1x Series		IA3x Series	
1.5	Arsenic	15.67	Arsenic	3.84
	Barium	3600.	Barium	1930.
	Iron	2.04	Iron	70.
	Sulfate	1.40	Sulfate	7.5
	Calcium	1430.	Calcium	2500.
	Extract pH	5.26	Extract pH	4.5
	IA2x Series		IA4x Series	
3.0	Arsenic	3.45	Arsenic	0.09
	Barium	3430.	Barium	1850.
	Iron	58.	Iron	21.4
	Sulfate	0.83	Sulfate	2.5
	Calcium	1650.	Calcium	2380.
	Extract pH	4.3	Extract pH	5.67

iron/arsenic ratio of 5.7 to achieve 6.2 mg/L arsenic.

The superior results of iron acetate stabilization can be explained by sulfate interference with the early cement matrix or by more favorable pH conditions. The TCLP extract pH of the iron acetate stabilizations was about 4 to 5 which is more favorable for arsenic adsorption and iron-arsenic precipitation. In contrast, the pH of extracts from ferrous sulfate stabilizations was 7 to 8.

More evidence for deleterious effects of sulfate on the early development of the cement matrix is presented in Table 5-13. Sodium sulfate is being added to precipitate barium with no iron addition for arsenic. For either binder/waste ratio, TCLP concentrations of arsenic increase significantly with increased additions of sodium sulfate.

Sulfate corrosion of stabilized forms is an explanation for the performance of certain high-sulfate mixes as discussed in Section 5.2. Moderate amounts of sulfate do not appear to be detrimental to long-term stabilizations especially those with ferrous iron.

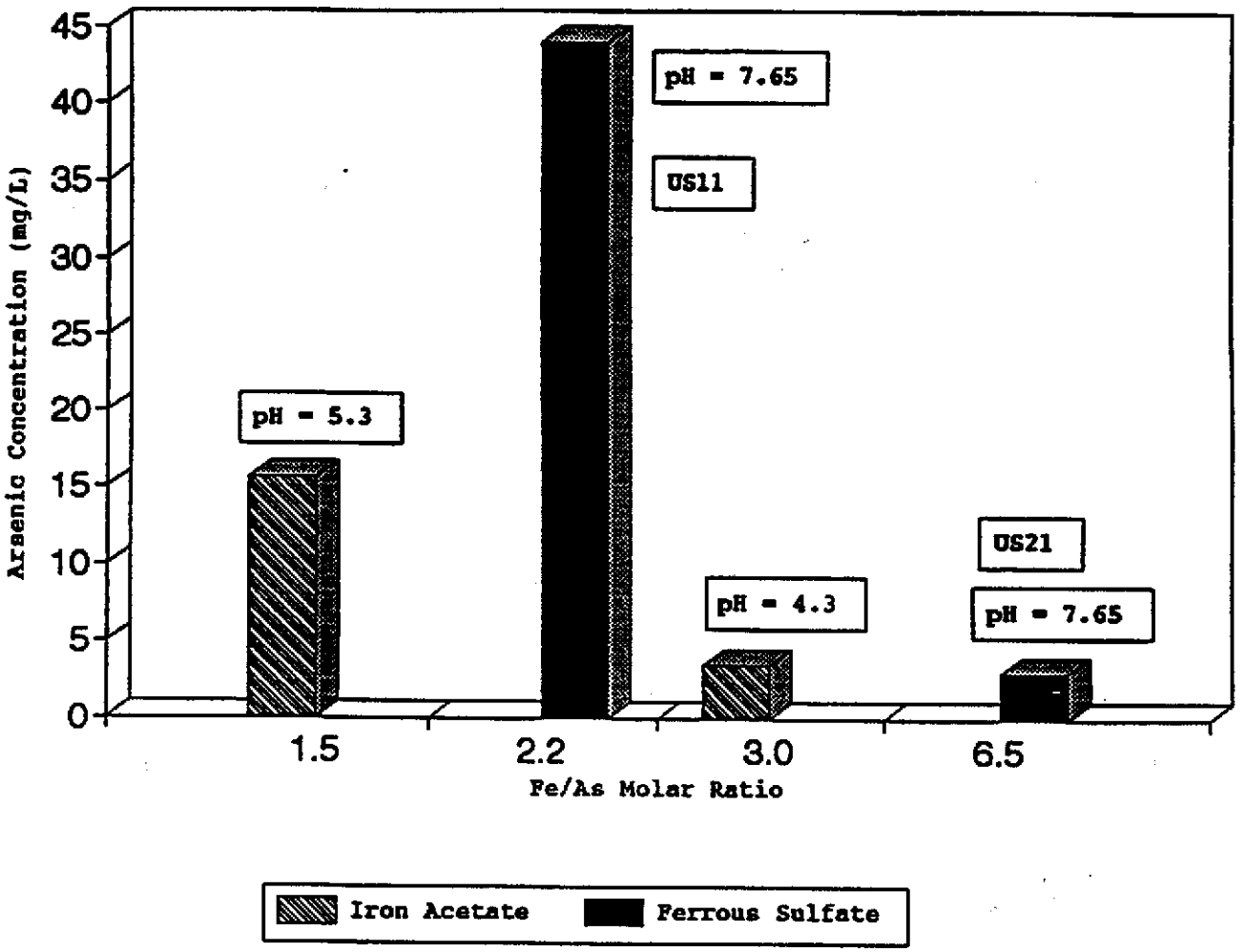


Figure 5-21. TCLP Arsenic Results for Ferrous Sulfate and Ferrous Acetate Stabilizations

Table 5-13. TCLP Results Using Sodium Sulfate

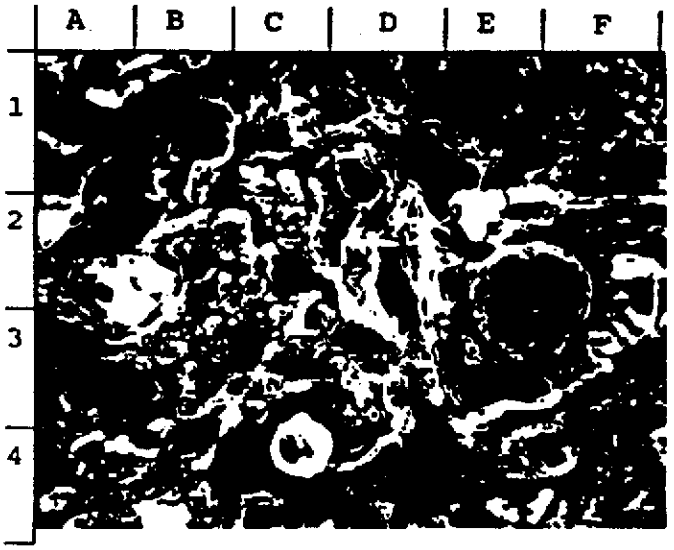
Mole Ratio SO_4^{2-}/Ba^{2+}	Binder/Waste Mass Ratio: 0.15		Binder/Waste Mass Ratio: 0.40	
1.0	SS1x Series		SS3x Series	
	Arsenic	27.7	Arsenic	33.1
	Barium	0.582	Barium	80.6
	Iron	<0.02	Iron	0.125
	Sulfate	35.5	Sulfate	2.28
	Calcium	384.	Calcium	2370
	Extract pH	5.26	Extract pH	4.5
2.0	SS2x Series		SS4x Series	
	Arsenic	67.2	Arsenic	41.2
	Barium	0.58	Barium	0.85
	Iron	0.14	Iron	0.284
	Sulfate	715.3	Sulfate	530
	Calcium	1030	Calcium	1850
	Extract pH	4.3	Extract pH	5.67

5.7 Scanning Electron Microscope Study

Scanning electron microscope photographs and elemental dot maps are presented in Figures 5-22 to 5-26. All of these samples were cast using ferrous sulfate additive in S/S. The magnification used in these photographs is 130x so that the area of the sample shown is 0.50 mm by 0.64 mm or 0.31 mm^2.

During this discussion, a grid system modeled after commonly-used spreadsheet conventions will be used. Six cells, lettered "A" through "F", are defined across the top, each about 0.1 mm wide on the sample and 13 mm wide on the figures. Four cells, numbered "1" through "4", are defined down the left side, each about 0.1 mm on the sample and 13 mm in the figures. A feature in the lower right corner of a photo will be indicated as being located in cell "F4". The elemental dot maps are positive images, with light-colored spots representing the occurrence of an x-ray photon characteristic of the target element. The density of light spots is proportional to the surface concentration of the element at that location.

Particles of fly ash are easily recognized as spherical balls 0.05 to 0.1 mm in diameter. These particles typically have high iron concentrations and are visible as light areas on the iron elemental dot map. A fly ash particle can be seen at C4 in Figure 5-22.



Magnification 130x

Photo	
As	Fe
Ba	S

Key

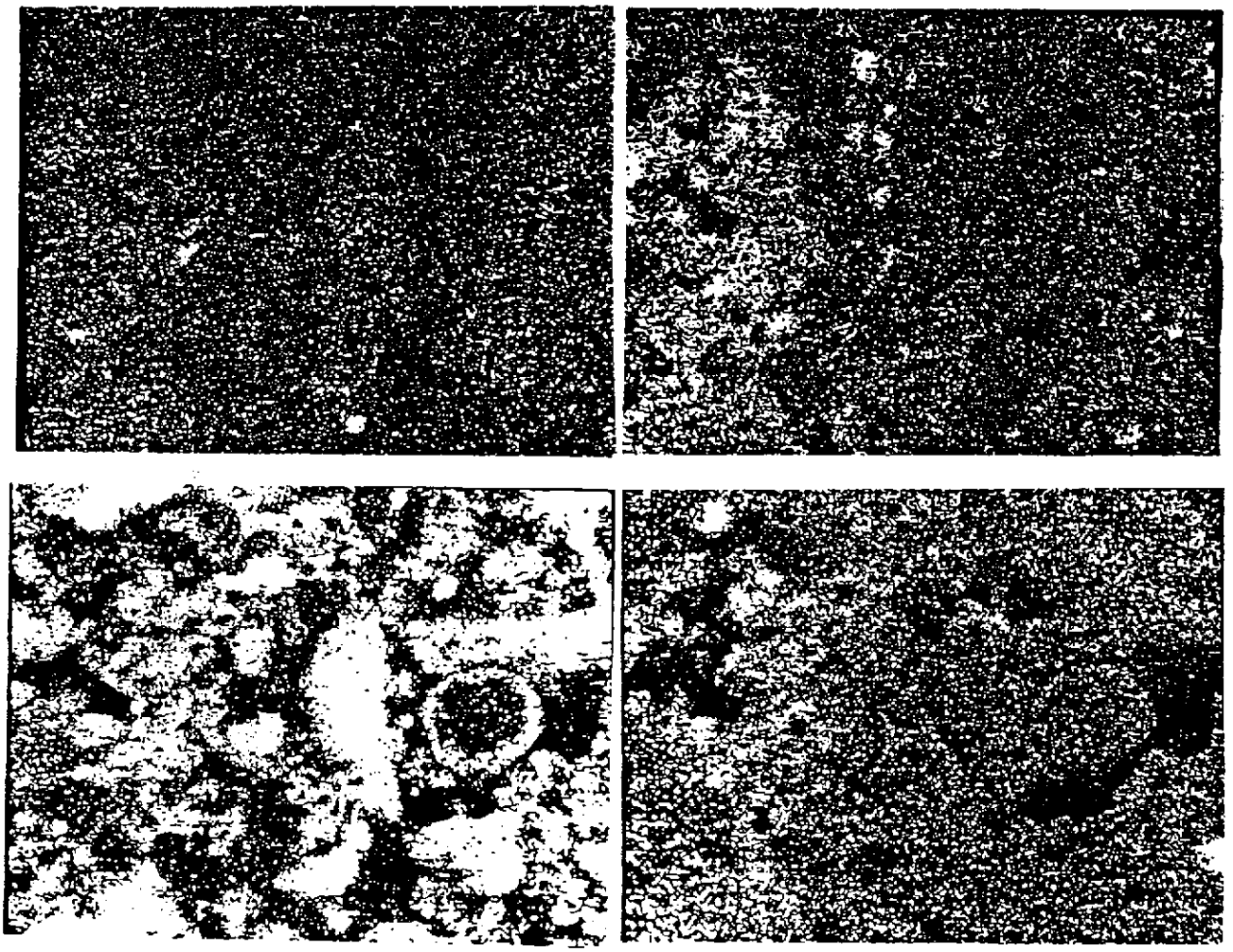
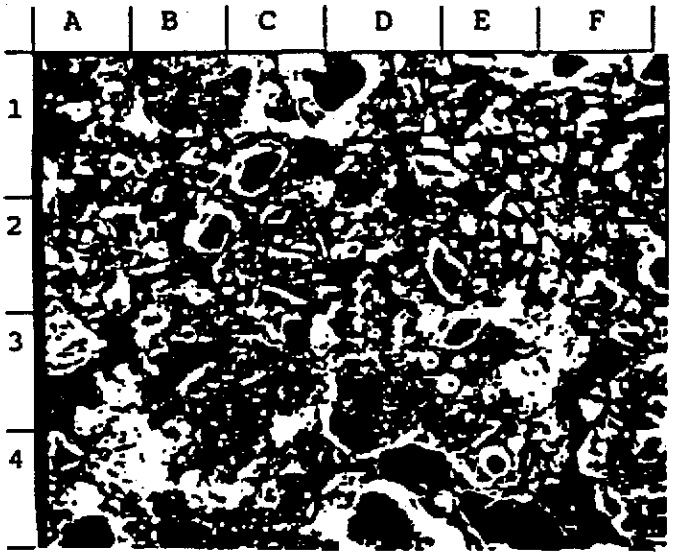


Figure 5-22. SEM Data for Sample SEM1, 2-day Cure Time

STABILIZATION OF ARSENIC WASTES



Magnification 130x

Photo	
As	Fe
Ba	S

Key

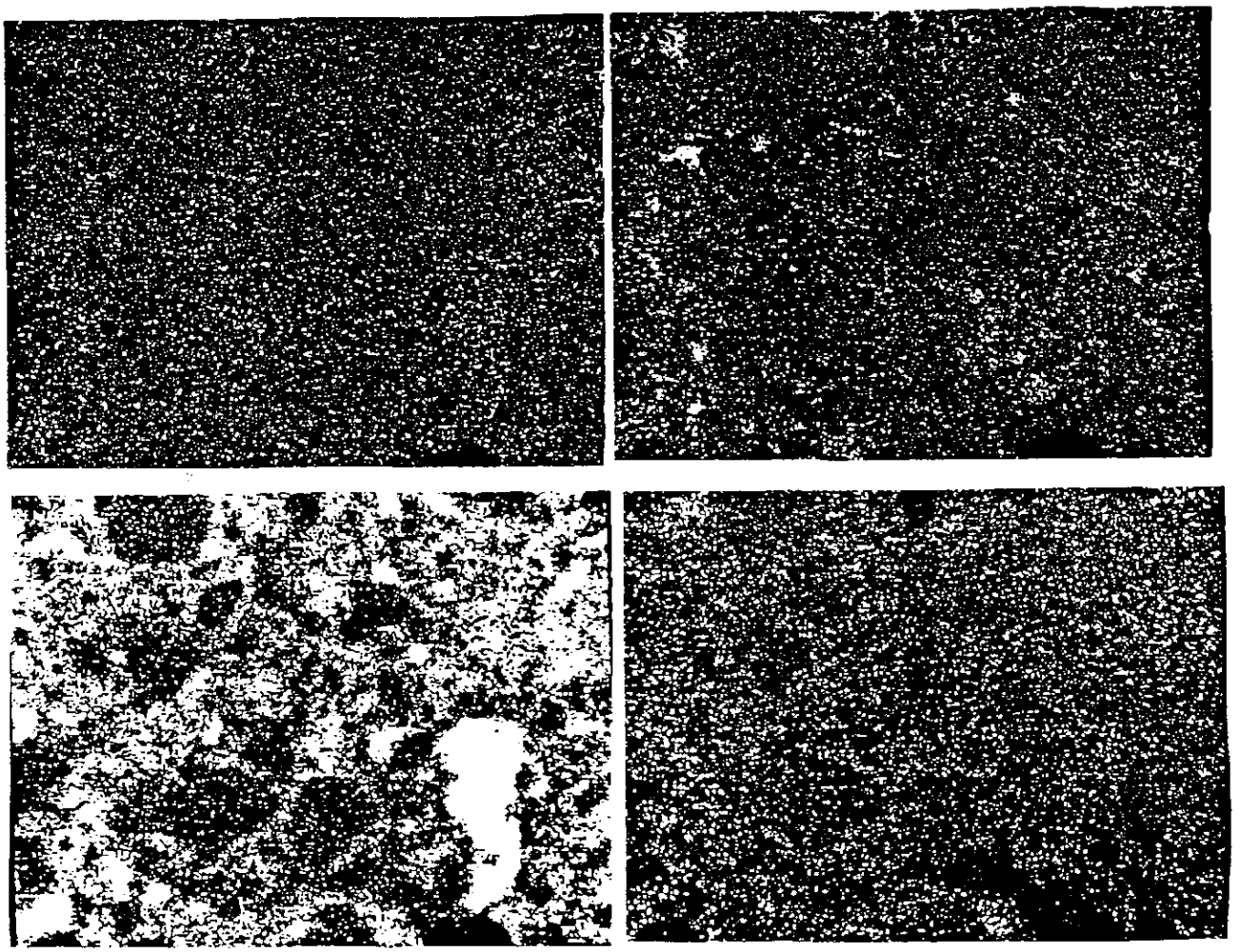
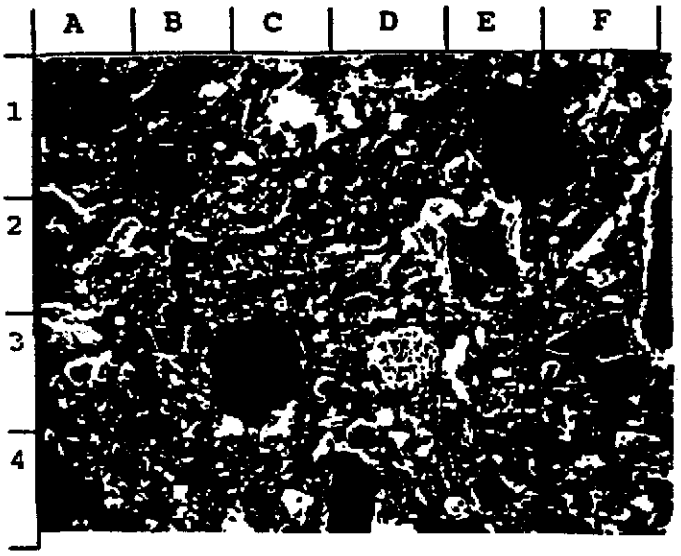


Figure 5-23. SEM Data for Sample SEM2, 60-day Cure Time

STABILIZATION OF ARSENIC WASTES



Magnification 130x

Photo	
As	Fe
Ba	S

Key

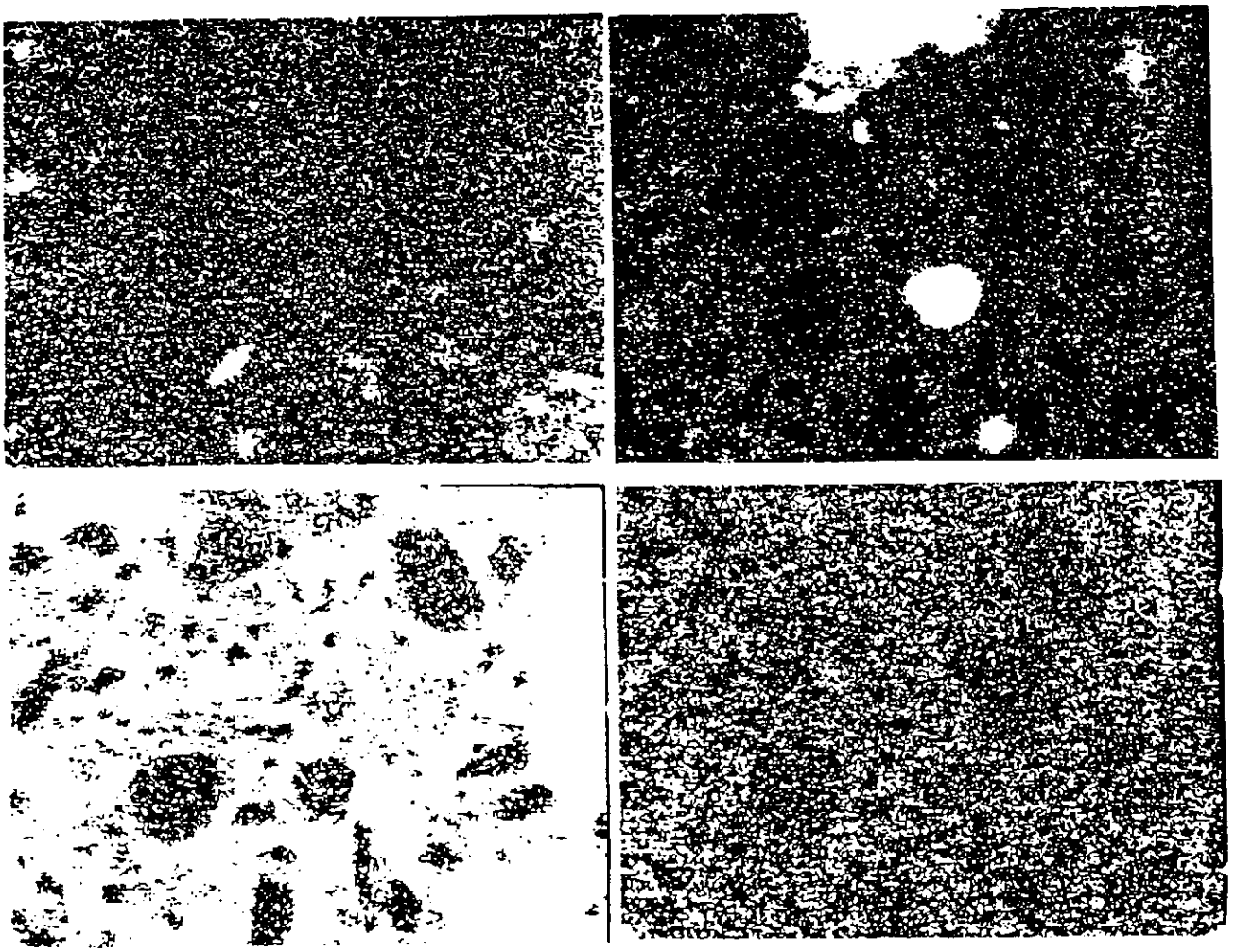


Figure 5-24. SEM Data for Sample SEM3, 365-day Cure Time

Glass particles from the industrial grinding operations which generated the D004/D005 waste are common. Glass particles can be identified by relatively straight-edged geometric-appearing shapes. Glass particles are also often characterized by voids in the iron, barium and sulfur elemental dot maps.

Calcium hydroxide (CH) gel areas, formed early in the hydration process, appear as irregularly-shaped dark areas in photographs, and as dark areas in elemental dot maps. Calcium hydroxide gel is softer than the solid components of the cement S/S mix and is often dug away in the surface preparation polishing process. The resulting hole in the surface will appear as a dark shadow in the SEM photographs.

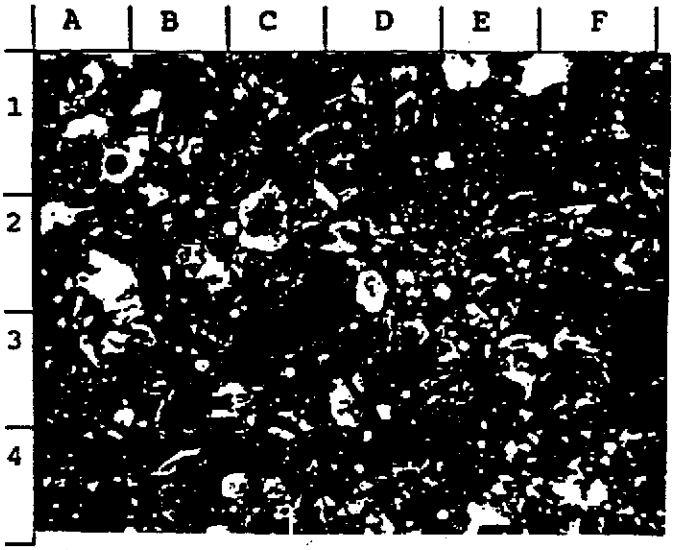
In Figure 5-22, sample SEM1 is shown. The arsenic dot map is essentially featureless, typical of the arsenic distributions observed in this study. This sample has a cure time of two days, so that the CH gel phase is still present in significant amounts. Large zones of gel phase can be identified at locations F2, E4, C3, and A1. Integration of the areas of the recognizable gel zones and dividing by the area of the whole photograph indicates approximately 40% CH phase at two days cure time. Barium and sulfur (and to a lesser extent iron) are at reduced concentrations in the CH gel. It is difficult to recognize correlations between iron and arsenic in the dot maps. High concentrations of sulfur seem to correlate with locations of high barium, although not all high barium concentrations are correlated with sulfur concentrations. This is not surprising because about half of the barium in the waste is not extractable by TCLP. The barium concentration at E2 is perhaps an example of the inert barium component of the waste.

Figure 5-23 is for a sample of the same composition as that in Figure 5-22, but at 60 days of curing. The CH gel phase is smaller, visible only at E4 and D1. These two large areas still account for about 30% of the sample volume. The large barium hot spot at E3 has no corresponding hot spot in the sulfur dot map, so therefore it is probably part of the inert barium part of the waste. Again, very little correlation can be found between the arsenic and iron concentrations. This is not necessarily indicative of no arsenic reaction with iron because the gross amount of iron is several times the gross amount of arsenic in the S/S sample.

Figure 5-24 presents data for a sample of the same composition as shown in Figures 5-22 and 5-23. The sample in Figure 5-24 has been cured for 365 days. A fly ash particle is visible at location D3. A glass chunk is visible at location A2, and is accompanied by a high barium concentration. After 365 days of curing, very little CH gel phase is visible. Only 1.7% of the sample surface (and volume) is recognizably CH gel. The arsenic concentration at location F4 is accompanied by a visibly low concentration of iron. The number of such concentrations observed in the SEM study amount to less than 1% of the total area observed. These arsenic hot spots could account for the

observation that there appears to be a minimum concentration for the TCLP concentration of arsenic, no matter what treatment is used.

Figures 5-25 and 5-26 are the data from samples using ferric sulfate additive at two different levels. Both S/S mixes had the same binder/waste ratio and were cured two days. In Figure 5-25 a prominent feature is the glass chip at location C3. This object is visible on the Ba, Fe, and S elemental dot maps as a region of low density. No apparent deviation in the arsenic dot density can be found at the location of the glass chip. The glass chip is approximately 0.12 mm long and 0.06 mm wide. In Figure 5-26 a very prominent bright feature appears at location E2. This feature appears as a region of high intensity on both the barium and arsenic dot maps, and as a region of low intensity on the iron and sulfur dot maps. This is indicative of a piece of waste material which was not broken up in the preparation of the S/S mixture. This feature is 0.2 mm long and 0.1 mm wide and is the largest single object found in the SEM observation process. A fly ash sphere is also visible at location C4 in Figure 5-26. This sphere is somewhat unique in that it is low in iron.



Magnification 130x

Photo	
As	Fe
Ba	S

Key

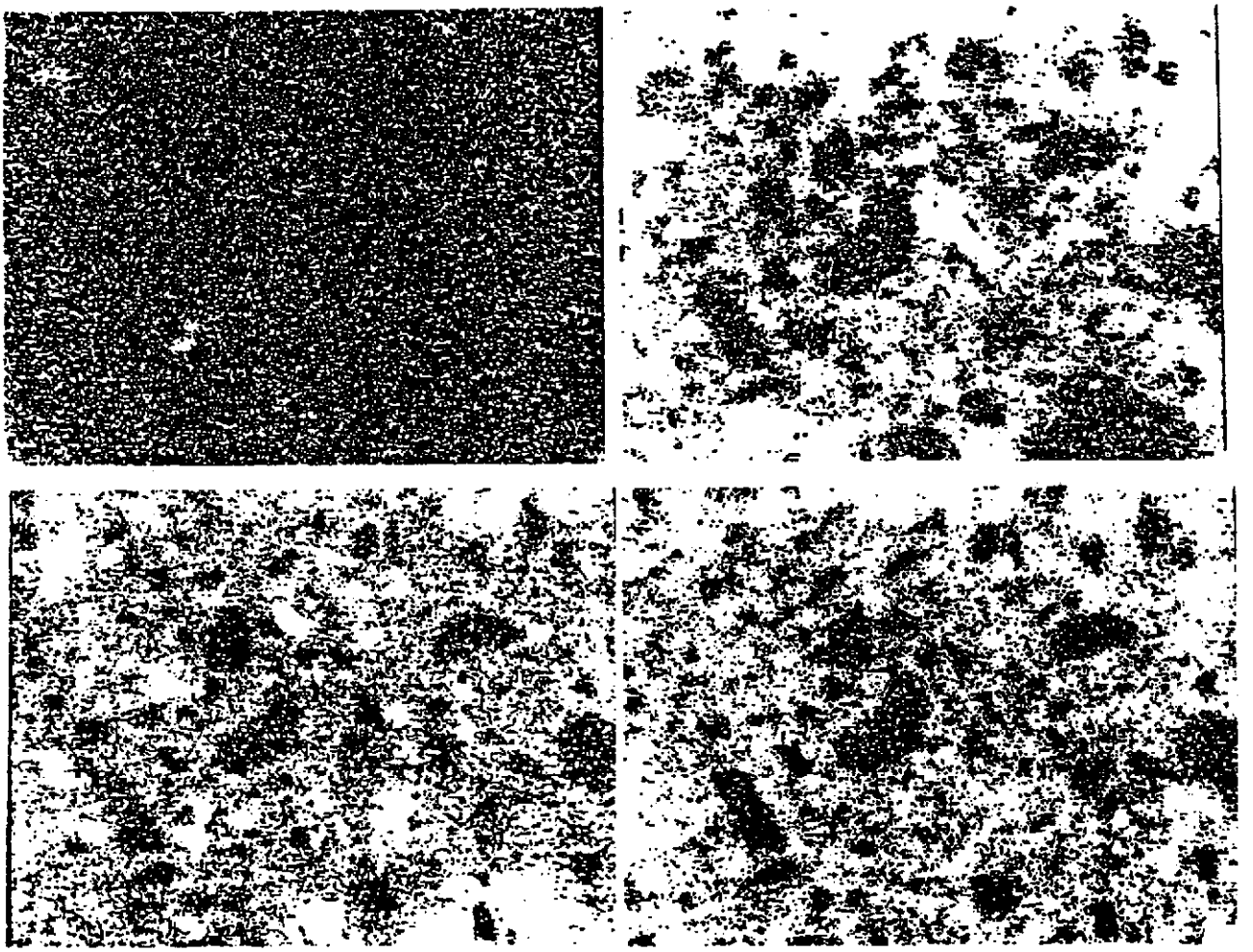


Figure 5-25. SEM Data for Sample SEM4, 2-day Cure Time

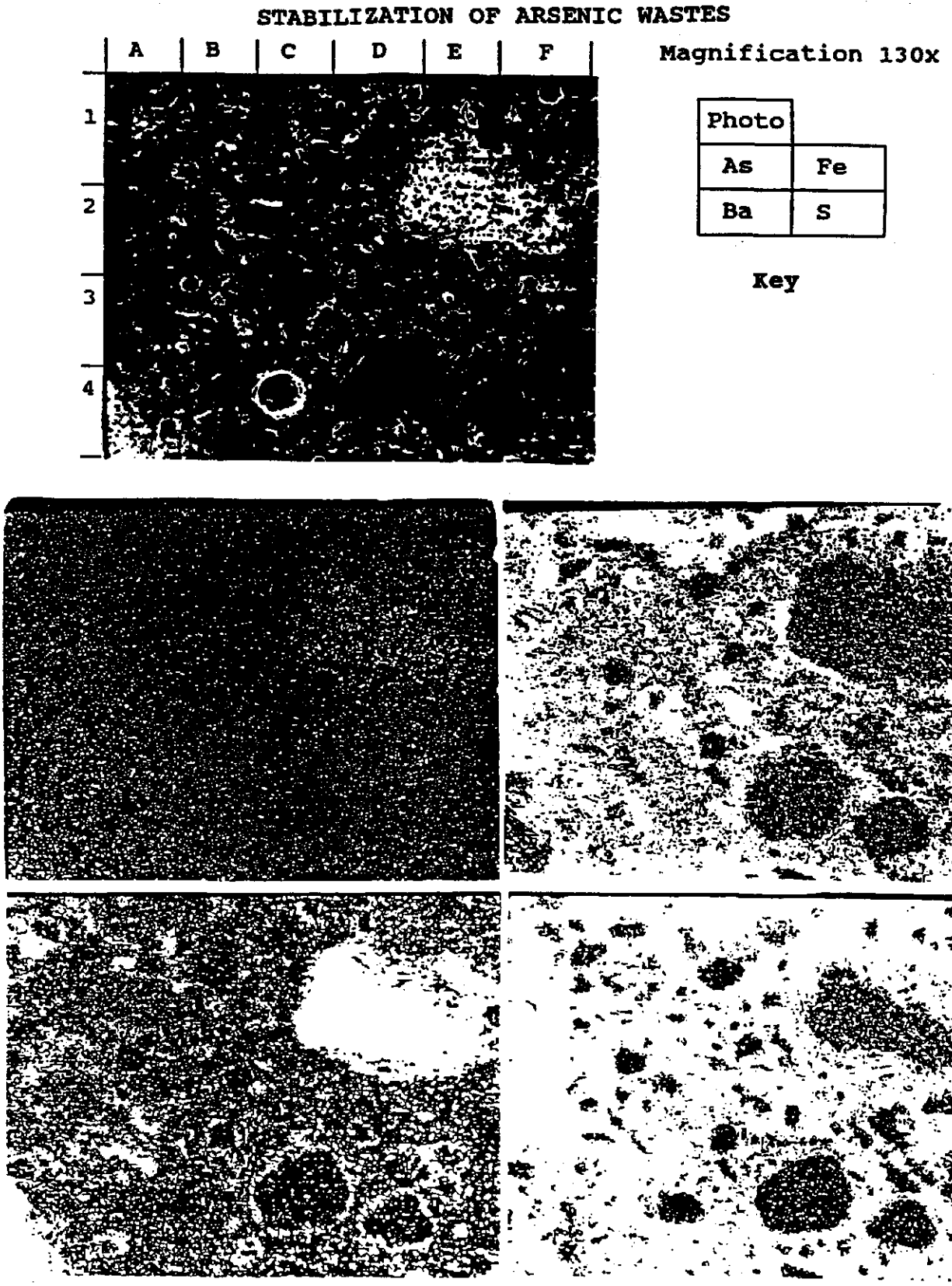


Figure 5-26. SEM Data for Sample SEM5, 2-day Cure Time

CHAPTER SIX
SUMMARY AND RECOMMENDATIONS

Table 1-1 summarizes EPA comments regarding solicited results of arsenic stabilization. These comments include no reported binder/waste ratios, no QA/QC data, and the possible interference of organics. Furthermore, the effect of cure time on treatment effectiveness had not been investigated. This summary of project findings provides recommendations and guidelines with respect to these concerns.

Inorganic arsenic was effectively stabilized for up to 540 days. There are several concerns for stabilization design: 1) the use of ferric sulfate, ferrous sulfate, or aluminum sulfate as stabilization additive; 2) arsenite versus arsenate stabilization; 3) the use of sulfate to immobilize barium; 4) binder/waste ratios and volume efficiency. Each concern is addressed and guidelines are presented below.

Precipitation of arsenic with iron in the stabilized matrix is more effective than using aluminum. Two iron salts, ferrous sulfate and ferric sulfate, were selected for experimentation because of cost and commercial availability. Ferrous sulfate is available as a K001 waste. In general, ferrous sulfate is preferred for arsenic stabilization because it is effective over a wider range of mix designs and over the long term. It is recommended that the iron(II)/ arsenic mole ratio be at least six. Slightly lower dosages of iron(II) may be effective if cure times of at least 60 days are permitted. The use of iron(III) is not recommended for arsenate stabilization since the fresh cement mix adsorbs ferric ion and does not permit adequate S/S until long cure times have elapsed. Furthermore, the ferric hydroxy-arsenic complex is a larger molecule than the ferrous arsenic compound. Ferrous stabilization is preferred to ferric stabilization because encapsulation of larger molecules in cement is more difficult.

Arsenate, As(V), is more effectively stabilized than arsenite, As(III). There are several ways to pretreat the waste so arsenite is oxidized to arsenate before stabilization. The selection of a pretreatment should be based on a knowledge of the arsenite levels in the waste. The most effective method is chemical oxidation with an appropriate reagent. Hydrogen peroxide at stoichiometric dosages and adequate mixing will provide sufficient oxidation of the arsenite. Moderate arsenite oxidation can be achieved by air oxidation using just enough water to eliminate dust escaping the mixing operation.

Barium may be encapsulated within the S/S matrix as barium sulfate. Recommended range of sulfate/barium mole ratios is 1.1 to 2.2. This ratio may be affected by the portion of barium that is extractable in the waste being stabilized. Higher dosages of sulfate are not recommended because of potential sulfate corrosion of the cement matrix over the long term. Sulfate may be introduced in any form. If additional sulfate is required beyond

the amount of iron sulfate determined by the recommended mole ratio of iron/arsenic, then sodium or aluminum sulfate may also be used.

Comments in Table 1-1 also focused on the lack of information regarding binder/waste ratios and effective arsenic S/S. Mix designs in this project used a range of binder/waste ratios from 0.15 to 0.40. A binder/waste ratio of 0.15 is more volume efficient and effective mix designs were found, but there are precautions here. The mix design must be carefully controlled to the prescribed mole ratios for iron/arsenic and sulfate/barium. In practice, the heterogeneity of wastes and large scale mixing operations may preclude this close control of reagent dosages. The resulting S/S in practice may be ineffective or may pass only with extended cure times. A binder/waste ratio of 0.4 permits successful S/S over a wider range of mix designs with shorter cure times.

Project experimentation has included TCLP and dynamic column leaching. These experimental data were analyzed for 25 metals using ICP. Data analysis included mass balance and correlation studies among the metal concentrations that permit a characterization of elements: 1) those elements that are strongly bound to the matrix; 2) the fraction of metal present that is leachable; 3) a comparison of leaching rates among metals; 4) the contribution of binders and wastes to metals appearing in the extracts. Calorimetric and SEM studies conducted on selected samples also were presented to reinforce the conclusions of this project. These techniques were useful in elucidating the relative amounts and rates of leaching from different compositional areas of the curing S/S matrix.

The results of this study can be used to design S/S treatment protocols for wastes containing inorganic arsenic. However, treatment procedures for organic arsenicals have not been addressed in this study.

Industrial wastes contain a wide variety of regulated and unregulated components. The concentrations of these components vary widely in practice. Due to these wide variations, it is crucial that research developing S/S treatment procedures be carried out using representative industrial wastes.

REFERENCES

Akhter, H., L.G. Butler, S. Branz, F.K. Cartledge, and M.E. Tittlebaum. 1990. "Immobilization of As, Cd, Cr and Pb-Containing Soils by Using Cement or Pozzolanic Fixing Agents." *Journal of Hazardous Materials*, 24:145-155.

Artiola, Janick F., David Zabcik, and Sidney H. Johnson. 1990. "In Situ Treatment of Arsenic Contaminated Soil From A Hazardous Industrial Site: Laboratory Studies," *Waste Management*, 10(1):73-78.

ASTM, 1965. *Index (Inorganic) for the Powder Diffraction File and Powder Diffraction File, Sets 1-18*, American Society for Testing and Materials, Philadelphia, Pa.

Batchelor, B. 1990. "Leach Models: Theory and Application." *Journal of Hazardous Materials*, 24:255-266.

Bayasi, Z., R. Fuessle, M. Taylor. 1992. *Improvements in the Solidification of Hazardous Inorganic Wastes by Silica Fume (Microsilica) Concrete*, Final Report submitted to the State of Illinois Hazardous Waste Research and Information Center, March.

Bhattacharyya, D., A.B. Jumawan, G. Sun, C. Sund-Hagelberg, and K. Schwitzgebel. 1980. "Precipitation of heavy Metals with Sodium Sulfide: Bench-Scale and Full-Scale Experimental Results," *American Institute of Chemical Engineers*, 77(209):31-38.

Blitz, W. 1904. *Berichte* 37:1766, 3108.

Brewster, Michael D. 1992. "Removing Arsenic from Contaminated Wastewater." *Water Environment & Technology*, 4(11):54.

Cartledge, F.K, H.C. Eaton, and M. Tittlebaum, 1989. *Morphology and Microchemistry of Solidified/Stabilized Hazardous Waste Systems*, EPA Report No. EPA/600/2-89/056, November 1989.

Cartledge, Frank K. 1992. "Solidification/Stabilization of Arsenic Compounds," in U.S. EPA, *Mercury and Arsenic Wastes, Removal, Recovery, Treatment, and Disposal* Proceedings of a workshop held in Alexandria, VA, Aug. 17-20, 1992, Noyes Data Corp.

Cheng, K.Y. and P. Bishop. 1992. "Metals Distribution in Solidified/Stabilized Waste Forms after Leaching." *Hazardous Waste & Hazardous Materials*, 9(2):163-171.

Cheng, Kuang Ye and Paul L. Bishop. 1992. "Sorption, Important in Stabilized/Solidified Waste Forms." *Hazardous Waste & Hazardous Materials*, 9(3):289-296.

Chu, Peylina, Michael T. Rafferty, Thomas A. Delfino, and Richard F. Gitschlag, 1991. "Comparison of Fixation Techniques for Soil Containing Arsenic," in Tedder, D. William and Frederick G. Pohland, eds., *Emerging Technologies in Hazardous Waste Management II* Industrial and Engineering Chemistry Special Symposium sponsored by the Division of Industrial and Engineering Chemistry, Inc, American Chemical Society Atlantic City, NJ, June 4-7, 1990.
Code of Federal Regulations. 1987. "Toxicity Characteristic Leaching Procedure (TCLP)," Vol. 40, Part 268, App. I, July, pp. 692-707.

Conner, Jesse R. 1990. *Chemical Fixation and Solidification of Hazardous Wastes* Van Nostrand Reinhold NY, NY.

Cote, P.L., T.W. Constable and A. Moreira. 1987. "An Evaluation of Cement-Based Waste Forms Using the Results of Approximately Two Years of Dynamic Leaching." *Nuclear and Chemical Waste Management*, 7:129-139.
Davis, A., M.V. Ruby, and P.D. Bargstrom. 1992. "Bioavailability of Arsenic and Lead in Soils from the Butte, Montana, Mining District." *Environmental Science and Technology*, 26:461-8.

Egawa, Hiroaki, Takamasa Nonaka, and Hironori Maeda. 1985. "Studies of Selective Adsorption Resins. XXII. Removal and Recovery of Arsenic Ion in Geothermal Power Waste Solution with Chelating Resin Containing Mercapto Groups," *Separation Science and Technology*, 20(9,10):653-664.

Environmental Laboratory of the U.S. Army Engineer Waterways Experiment Station. 1980. *Guide to the Disposal of Chemically Stabilized and Solidified Waste*, Report SW-872, Interagency Agreement No. EPA-IAG-D4-0569 with Municipal Environmental Research Laboratory, Office of Research and Development, U.S. EPA, Cincinnati, OH.

Environmental Canada and Alberta Environmental Center. "Acid Neutralization Capacity Test." 1986. In *Test Methods for Solidified Waste Characterization*, Canada.

EPA. 1989. *Stabilization/Solidification of CERCLA and RCRA Wastes*, EPA/625/6-89/022. Center for Environmental Research Information and Risk Reduction Engineering Laboratory, Office of Research and Development, US EPA, Cinn. OH.

Federal Register. 1990. "Hazardous Waste Management System," Vol. 55, Part No. 61, pp. 11796ff and Part No. 126, pp. 26986ff.

Ghosh, M.M. and R.S. Teoh. 1985. "Adsorption of Arsenic on Hydrous Aluminum Oxide," *Toxic and Hazardous Wastes Proceedings of the Seventeenth Mid-Atlantic Industrial Waste Conference*, Irwin Irwin J. Kugelmann (ed.) pp. 139-155.

Gulledge, John H. and John T. O'Connor. 1973. "Removal of Arsenic (V) From Water by Adsorption on Aluminum and Ferric Hydroxides," *Journal of the American Water Works Assocation,* 65(8):548-552.

Gupta, Shailendra K. and Kenneth Y. Chen. 1978. "Arsenic Removal by Adsorption," *Journal of the Water Pollution Control Federation,* 50(3): 493-506.

Harper, Thomas R. and Neville W. Kingham. 1992. "Removal of Arsenic from Wastewater Using Chemical Precipitation Methods," *Water Environment Research,* 64(3):200-203.

Hogness, T.R. and W.C. Johnson. 1954. *Qualitative Analysis and Chemical Equilibrium,* Fourth Ed., Holt, Reinhart and Winston.

Isenburg, J. and M. Moore. 1992. "Generalized Acid Neutralizing Capacity Test." *Stabilization and Solidification of Hazardous, Radioactive, and Mixed Wastes,* 2nd Volume, ASTM STP 1123, T.M Gilliam and C.C. Wiles, Eds., American Society for Testing and Materials, Philadelphia, pp. 361-377.

Jones, Larry W. 1990. *Interferences Mechanisms in Waste Stabilization/Solidification Processes,* EPA/600/2-89/067. Risk Reduction Engineering Laboratory, Office of Research and Development, U.S. Environmental Protection Agency. Cinn. OH.

Lockemann, G. 1911. *Zeit. Koll,* 8:273.

Mindess, Sidney and J. Francis Young. 1981. *Concrete,* Prentice-Hall, Inc. Englewood Cliffs, NJ.

NAS. 1977. "Arsenic," National Academy of Sciences, Washington DC.

Neville, A.M., 1972. *Properties of Concrete,* Pitman Publishing, London.

Ortego,J.D. 1990. "Spectroscopic and Leaching Studies of Solidified Toxic Metals," *Journal of Hazardous Materials,* 24:137-44.

Ortego, J.D. 1989. *Environmental Science and Engineering,* 24:589-602.

Penrose, W.R. 1974. "Arsenic in the Marone and Aquatic Environments: Analysis, Occurence and Significance." *CRC Crit. Rev. Environ. Control,* 4:465.

"Prudent Practices for Handling Hazardous Chemicals in Laboratories", 1981. National Academy Press.

Sakata, Masahiro. 1987. "Relationship between Adsorption of Arsenic(III) and Boron by Soil and Soil Properties." *Environmental Science and Technology,* 21(11):1126-1130.

Sandesara, M. D. 1978. *Process for Disposal of Arsenic Wastes,* U.S. Patent 4,118,243.

Schlicher, R.J. and M.M. Ghosh. 1985. "Removal of Arsenic from Water by Physical-Chemical Processes." *American Institute of Chemical Engineers,* 81(243):152-164.

Sen, Asit K. and Arnab K. De. 1987. "Adsorption of Arsenic on Coal Fly Ash." *Indian Journal of Technology,* 25:259-261.

Sorum, C.H. 1960. *Introduction to Semimicro Qualitative Analysis,* Third Ed., Prentice-Hall.

Tan, L. K. and J.E. Dutrizac, 1985a. "Determination of Arsenic(III) and Arsenic(V) in Ferric Chloride-Hydrochloric Acid Leaching Media by Ion Chromatography", *Anal. Chem.,* 57, 1027-1032.

Tan, L. K. and J.E. Dutrizac, 1985b. "Determination of Arsenic(V) and Arsenic(III) in Ferric Sulfate-Sulfuric Acid Leaching Media by Ion Chromatography", *Analytical Chemistry,* 57, 2615-2620.

Urasa, I.T. and F. Ferede, 1987. "Use of Direct Current Plasma as an Element Selective Detector for Simultaneous Ion Chromatographic Determination of Arsenic(III) and Arsenic(V) in the Presence of Other Common Anions" , *Analytical Chemistry,* 59, 1563-1568.

US EPA. 1990b. *Scope of Work: Inorganics,* Document ILM01.0. CERCLA Contract Lab Program.

US EPA. 1987. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods,* _SW 846, 3 volumes, Sept. 1986 and 1 revision, Dec. 1987.

USEPA. 1990. "Land Disposal Restrictions for Thind Third Scheduled Wastes," Federal Register 55(106): 22556-22560.

Wagemann, R. 1978. "Some Theoretical Aspects of Stability and Solubility of Inorganic Arsenic in the Freshwater Environment," *Water Research,* 12:139-145.

Young, D.A. 1979. *Landfill Material,* U.S. Patent 4,142,912

MATRIX OF MIX DESIGNS FOR FERRIC SULFATE STABILIZATION OF D004/D005 WASTE (Table 4-2 repeated for ease of reference)

F1x Series

Component per 100.0 g waste	Mass g
Water	24.0
Cement	9.0
Fly Ash	6.0
$Fe_2(SO_4)_3 \cdot 9H_2O$	4.8
Important ratios:	
Binder/Waste	0.15 g/g
Binder/H_2O	0.59 g/g
Fe^{3+}/binder	0.063 g/g
Fe^{3+}/As	2.1 mol/mol
SO_4^{2-}/binder	0.16 g/g
SO_4^{2-}/Ba^{2+}	0.53 mol/mol

F2x Series

Component per 100.0 g waste	Mass g
Water	24.0
Cement	9.0
Fly Ash	6.0
$Fe_2(SO_4)_3 \cdot 9H_2O$	14.4
Important ratios:	
Binder/Waste	0.15 g/g
Binder/H_2O	0.53 g/g
Fe^{3+}/binder	0.19 g/g
Fe^{3+}/As	6.4 mol/mol
SO_4^{2-}/binder	0.49 g/g
SO_4^{2-}/Ba^{2+}	1.6 mol/mol

F3x Series

Component per 100.0 g waste	Mass g
Water	64.0
Cement	24.0
Fly Ash	16.0
$Fe_2(SO_4)_3 \cdot 9H_2O$	12.8
Important ratios:	
Binder/Waste	0.40 g/g
Binder/H_2O	0.59 g/g
Fe^{3+}/binder	0.064 g/g
Fe^{3+}/As	5.7 mol/mol
SO_4^{2-}/binder	0.16 g/g
SO_4^{2-}/Ba^{2+}	1.4 mol/mol

F4x Series

Component per 100.0 g waste	Mass g
Water	64.0
Cement	24.0
Fly Ash	16.0
$Fe_2(SO_4)_3 \cdot 9H_2O$	38.4
Important ratios:	
Binder/Waste	0.40 g/g
Binder/H_2O	0.53 g/g
Fe^{3+}/binder	0.19 g/g
Fe^{3+}/As	17. mol/mol
SO_4^{2-}/binder	0.49 g/g
SO_4^{2-}/Ba^{2+}	4.2 mol/mol

Notes:
1. Water of hydration is taken into account in Binder/H_2O ratio.
2. 100 g waste contains 0.060 g Arsenic.
3. 100 g waste contains 13.3 g Barium of which 43% is found to be extractable in TCLP.
4. Assume 50% of Ba in waste is available for reaction in ratios calculated.

MATRIX OF MIX DESIGNS FOR FERROUS SULFATE STABILIZATION OF D004/D005 WASTE (Table 4-3 repeated for ease of reference)

US1x Series

Component per 100.0 g waste	Mass g
Water	24.0
Cement	9.0
Fly Ash	6.0
$FeSO_4 \cdot 7H_2O$	4.8

Important ratios:

Binder/Waste	0.15	g/g
Binder/H_2O	0.57	g/g
Fe^{2+}/binder	0.064	g/g
Fe^{2+}/As	2.2	mol/mol
SO_4^{2-}/binder	0.11	g/g
SO_4^{2-}/Ba^{2+}	0.36	mol/mol

US2x Series

Component per 100.0 g waste	Mass g
Water	24.0
Cement	9.0
Fly Ash	6.0
$FeSO_4 \cdot 7H_2O$	14.4

Important ratios:

Binder/Waste	0.15	g/g
Binder/H_2O	0.49	g/g
Fe^{2+}/binder	0.19	g/g
Fe^{2+}/As	6.5	mol/mol
SO_4^{2-}/binder	0.33	g/g
SO_4^{2-}/Ba^{2+}	1.1	mol/mol

US3x Series

Component per 100.0 g waste	Mass g
Water	64.0
Cement	24.0
Fly Ash	16.0
$FeSO_4 \cdot 7H_2O$	12.8

Important ratios:

Binder/Waste	0.40	g/g
Binder/H_2O	0.57	g/g
Fe^{2+}/binder	0.064	g/g
Fe^{2+}/As	5.7	mol/mol
SO_4^{2-}/binder	0.11	g/g
SO_4^{2-}/Ba^{2+}	0.95	mol/mol

US4x Series

Component per 100.0 g waste	Mass g
Water	64.0
Cement	24.0
Fly Ash	16.0
$FeSO_4 \cdot 7H_2O$	38.4

Important ratios:

Binder/Waste	0.40	g/g
Binder/H_2O	0.49	g/g
Fe^{2+}/binder	0.19	g/g
Fe^{2+}/As	17.	mol/mol
SO_4^{2-}/binder	0.33	g/g
SO_4^{2-}/Ba^{2+}	2.9	mol/mol

Notes:

1. Water of hydration is taken into account in Binder/H_2O ratio.
2. 100 g waste contains 0.060 g Arsenic.
3. 100 g waste contains 13.3 g Barium of which 43% is found to be extractable in TCLP.
4. Assume 50% of Ba in waste is available for reaction in ratios calculated.

MATRIX OF MIX DESIGNS FOR ALUMINUM SULFATE STABILIZATION OF D004/D005 WASTE (Table 4-4 repeated for ease of reference)

A1x Series

Component per 100.0 g waste	Mass g
Water	24.0
Cement	9.0
Fly Ash	6.0
$Al_2(SO_4)\cdot 18H_2O$	4.8
Important ratios:	
Binder/Waste	0.15 g/g
Binder/H_2O	0.57 g/g
Al^{3+}/binder	0.026g/g
Al^{3+}/As	1.8 mol/mol
SO_4^{2-}/binder	0.14 g/g
SO_4^{2-}/Ba^{2+}	0.45 mol/mol

A2x Series

Component per 100.0 g waste	Mass g
Water	24.0
Cement	9.0
Fly Ash	6.0
$Al_2(SO_4)\cdot 18H_2O$	14.4
Important ratios:	
Binder/Waste	0.15 g/g
Binder/H_2O	0.48 g/g
Al^{3+}/binder	0.078g/g
Al^{3+}/As	5.4 mol/mol
SO_4^{2-}/binder	0.42 g/g
SO_4^{2-}/Ba^{2+}	1.3 mol/mol

A3x Series

Component per 100.0 g waste	Mass g
Water	64.0
Cement	24.0
Fly Ash	16.0
$Al_2(SO_4)\cdot 18H_2O$	12.8
Important ratios:	
Binder/Waste	0.40 g/g
Binder/H_2O	0.57 g/g
Al^{3+}/binder	0.026g/g
Al^{3+}/As	4.8 mol/mol
SO_4^{2-}/binder	0.14 g/g
SO_4^{2-}/Ba^{2+}	1.2 mol/mol

A4x Series

Component per 100.0 g waste	Mass g
Water	64.0
Cement	24.0
Fly Ash	16.0
$Al_2(SO_4)\cdot 18H_2O$	38.4
Important ratios:	
Binder/Waste	0.40 g/g
Binder/H_2O	2.1 g/g
Al^{3+}/binder	0. 79g/g
Al^{3+}/As	14. mol/mol
SO_4^{2-}/binder	0.42 g/g
SO_4^{2-}/Ba^{2+}	3.6 mol/mol

Notes:
1. Water of hydration is taken into account in Binder/H_2O ratio.
2. 100 g waste contains 0.060 g Arsenic.
3. 100 g waste contains 13.3 g Barium of which 43% is found to be extractable in TCLP.
4. Assume 50% of Ba in waste is available for reaction in ratios calculated.

Appendix B-1. TCLP Results for Two-Day and Sixty-Day Ferric Sulfate Stabilization of D004/D005 Waste

BINDER / D004-D005 Waste

Fe/As (S/Ba)	0.15	0.40

2.2 (0.36)

Metal (mg/L)	MIX F1x Cure Time(days) 2	60	365	540
As	22.1	14.4	0.59	0.57
Ba	850.	1200	2000	2320
Ca	1360	1380	1410	1480
S	10.5	6.66	<0.5	<0.5
Fe	0.62	0.90	1.6	7.2
Zn	0.10	0.12	0.84	1.1
pH	6.8	6.45		

6.0 (1.0)

Metal (mg/L)	MIX F2x Cure Time(days) 2	60	365	540
As	0.25	0.25	15.	17.
Ba	0.55	1.36	1.9	17.3
Ca	1400	1520	1790	1540
S	230.	173.	12.7	2.67
Fe	1.01	3.24	183.	214.
Zn	0.16	1.14	1.30	1.2
pH	5.31	4.8		

Metal (mg/L)	MIX F3x Cure Time (days) 2	60	365	540
As	20.6	15.3	0.96	0.85
Ba	0.31	0.68	88.1	125.
Ca	1840	2050	2700	2570
S	189.	152.	0.48	<0.5
Fe	0.70	0.46	27.6	18.1
Zn	0.035	0.04	1.18	1.1
pH	7.6	7.8		

17 (2.9)

Metal (mg/L)	MIX F4x Cure Time(days) 2	60	365	540
As	0.25	0.25	3.91	13.1
Ba	0.15	0.88	0.20	6.74
Ca	1520	1670	1890	1630
S	423.	385.	454.	564.
Fe	0.61	0.50	125.	464.
Zn	0.27	0.58	1.3	1.4
pH	5.4	5.4		

Appendix B-2. TCLP Results for Two-Day and Sixty-Day Ferrous Sulfate Stabilization of D004/D005 Waste

Fe/As (S/Ba) — BINDER / D004-D005 Waste

0.15 — 0.40

2.2 (0.36)

MIX US1x

Metal (mg/L)	Cure Time(days) 2	60	365	540
As	47.3	8.0	0.44	<0.25
Ba	574.	1400	2100	1660
Ca	1460	1900	2100	1470
S	9.0		3.14	<0.5
Fe	0.60		2.68	6.14
Zn	0.076	103.	0.87	1.0
pH	7.97	6.86		

6.0 (1.0)

MIX US2x

Metal (mg/L)	Cure Time(days) 2	60	365	540
As	3.16	0.11	1.48	4.64
Ba	1.11	430.	540.	520.
Ca	1650	1790	2330	2200
S	125.		0.71	1.3
Fe	0.83		20.8	61.8
Zn	0.089	222.	0.95	
pH	7.65	5.83		

MIX US3x

Metal (mg/L)	Cure Time(days) 2	60	365	540
As	4.96	0.7	0.50	0.30
Ba	0.99	2.3	0.68	188.
Ca	1490	1920	3940	3970
S	134.		115.	1.65
Fe	0.62		0.34	12.3
Zn	0.049	53.4	0.27	
pH	8.51	7.39		

17. (2.9)

MIX US4x

Metal (mg/L)	Cure Time(days) 2	60	365	540
As	0.25	0.15	<0.25	<0.25
Ba	0.44	1.1	0.21	1.52
Ca	2240	1930	3100	3010
S	566.		395.	336.
Fe	59.5		14.4	53.1
Zn	0.67	151.	1.16	
pH	7.54	6.72		

Appendix B-3. TCLP Results for Two and Sixty-Day Aluminum Sulfate Stabilization of D004/D005 Waste

Fe/As (S/Ba)	BINDER / D004-D005 Waste	
	0.15	0.40

1.8 (0.45)

Metal (mg/L)	MIX A1x Cure Time(days) 2	60	540	540
As	42.6	41.9	16.2	12.5
Ba	1110	995.	2650	2540
Ca	1270	1200	1370	1340
S	28.4	61.3	8.5	10.
Fe	0.323	0.73	1.1	1.5
Zn	<0.05	<0.05	0.94	0.81
pH	7.59	7.45		

5.1 (1.3)

Metal (mg/L)	MIX A2x Cure Time(days) 2	60	540	540
As	23.2	0.89	31.4	42.1
Ba	671.	554.	520.	584.
Ca	1350	1280	906.	1030
S	15.3	46.	16.	9.4
Fe	2.97	0.90	13.5	6.2
Zn	1.39	0.65	4.3	2.2
pH	4.62	5.22		

Metal (mg/L)	MIX A3x Cure Time(days) 2	60	540	540
As	25.9	5.32		
Ba	1.63	578.		
Ca	1740	2290		
S	139.	27.2		
Fe	0.077	2.02		
Zn	<0.05	0.81		
pH	8.02	7.75		

14. (3.6)

Metal (mg/L)	MIX A4x Cure Time(days) 2	60	540	540
As	18.4	7.07		73.8
Ba	2.47	1.32		0.8
Ca	1760	1690		1950
S	456.	393.		351.
Fe	18.9	3.14		43.7
Zn	0.969	0.70		1.18
pH	4.89	5.19		

PREINVESTIGATION - EVALUATION OF CORRECTIVE MEASURES TECHNOLOGIES

VICKSBURG CHEMICAL COMPANY
VICKSBURG, MISSISSIPPI

Prepared for
Vicksburg Chemical Company
Vicksburg, Mississippi

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LIST OF ACRONYMS

Acronym	Meaning
AOC	Area of Concern
APEG	akaline polyethylene glycol
BOD	biological oxygen demand
BTEX	benzene, toluene, ethylbenzene, xylene
BTU	British Thermal Unit
CB	cement bentonite
CMS	Corrective Measure Study
COD	chemical oxygen demand
EDTA	ethylene diamine tetra-acetic acid
EPA	United States Environmental Protection Agency
EPDM	ethylene propylene diene monomer
F/M	food to microorganism
GAC	granular activated carbon
GWA	Groundwater Assessment
HDPE	high density polyethylene
kg	kilograms
LDR	land disposal restrictions
MSDEQ	Mississippi Department of Environmenta Quality
PCB	polychlorinated biphenyl
PCP	pentachlorophenol
PECMT	Preinvestigative Evaluation of Corrective Measures Technology
PVC	polyvinyl chloride
RBC	rotating biological contactor
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SB	soil bentonite

LIST OF ACRONYMS

Acronym	Meaning
SVE	Soil Vapor Extraction
SVOC	semivolatile organic carbon
SWMU	Solid Waste Management Units
TCE	trichloethylene
TEA	triethyl amine
VCC	Vicksburg Chemical Company
VOC	volatile organic carbon

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1.0
INTRODUCTION

This Preinvestigation Evaluation of Corrective Measures Technologies (PECMT) report is a listing of technologies that may be utilized as corrective measures for the remediation of Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs) at Vicksburg Chemical Company's (VCC) Facility in Vicksburg, Mississippi.

VCC is conducting a RCRA Facility Investigation/Corrective Measures Study (RFI/CMS) in response to a Consent Decree. For purposes of the schedule that follows the effective date of the Consent Decree will be called Day 0. A work plan for the RFI activities has been submitted as a separate document. Concurrently with the RFI/CMS, VCC will conduct a Groundwater Assessment (GWA). A separate work plan has been submitted for the GWA. A summary of the initial submittals to the EPA and MSDEQ and other significant events are as follows:

Document or Event:	Submittal or Event Date:
Consent Decree Effective Date	Day 0
RFI Preliminary Report	Day 30
Closure Plan for Container Management Area	Day 60
EPA Approval of RFI Preliminary Report	Day X (November 1995)
RFI Work Plan	X + 60 or less
GWA Work Plan	X + 60 or less
PECMT Report	X + 60 or less

2.0
OBJECTIVES

Solid Waste Management Units (SWMUs) and Areas of Concern (AOC) have been identified in the RCRA Facility Assessment, Consent Decree and RFI Preliminary Report. Implementation of the RFI and Groundwater Assessment will yield additional definitive data on the contaminants and extent of contamination on soils and within the groundwater. Nevertheless there is sufficient existing data on the contaminants and range of concentrations expected to be found in soil and groundwater to be able to list technologies that are applicable to the site. Detailed discussions of existing data are found in the RFI Preliminary Report.

It is the objective of this report to identify potential corrective measures technologies that may be used on-site or off-site for the containment, treatment, remediation, and/or disposal of contamination. The emphasis will be on source control and destruction technologies. There may be ancillary pump and treat technology associated with source control, therefore, pump and treat technology will also be discussed. This report will also identify any field, laboratory, bench, or pilot scale data that needs to be collected during the RFI to facilitate the evaluation and selection of the final corrective measures (e.g., compatibility of waste and construction materials, information to evaluate effectiveness, treatability of wastes, etc.).

3.0
TECHNICAL CONSIDERATIONS FOR CLEANUP

This preinvestigation-evaluation concentrates on technologies available to VCC to meet requirements of the EPA at its Vicksburg Facility. Consideration is given to evaluating various remediation solutions that will satisfy federal and state cleanup standards. An analysis will be performed on those technologies during the conduct of a feasibility study to determine which technique will effectively remedy the problems and do so in a cost-effective manner. In this report, particular emphasis is placed on those remediation technologies that offer cost-effective, on-site treatment.

A clear definition of the goals of a remedial action program along with an understanding of the site-specific parameters and the technical and economic limitations of the technologies under consideration will allow selection of the most effective treatment option. The site-specific chemical, geologic, and hydrogeologic parameters are subjects of the RFI. By consideration of those parameters along with the available technologies, specific recommendations for further work will be made during the feasibility study.

3.1 PROBLEM DEFINITION

No single treatment technology will be universally applicable for all corrective action. A thorough evaluation of all the site-specific parameters is necessary in order to select the most technically suitable and cost-effective treatment technology for the job. Because major corrective action programs, especially those involving source control and aquifer restorations, are likely to take several years to completely accomplish, the investment of time and effort to properly evaluate the site initially will more than pay for cost/benefit evaluation in the long run. The following generalized parameters are among those that should be defined.

3.2 CONTAMINANT COMPOSITION AND CONCENTRATION

Previous analysis of the site contamination has been made by VCC, EPA, and MSDEQ. The level of contamination ranges from several thousands of parts per million pesticides in the soil to parts per billion pesticides in the groundwater. With an understanding of the type of

contaminant, concentration of contaminant, and desired removal rates, technologies can be correctly applied. Technologies such as carbon adsorption and oxidation are dependent on concentrations and type of compound while technologies such as air stripping are more closely related to the treatment rate and desired removal efficiency.

3.3 DESIRED CLEANUP CRITERIA AND EFFLUENT DISPOSITION

Stringent cleanup criteria will eliminate some technologies from consideration because they will not meet the criteria within reasonable time frames. The ultimate disposition of the effluent or residues after treatment will have significant bearing on the treatment method.

3.4 VOLUME TO BE TREATED

Treatment volumes, defined by the horizontal and vertical extent of contamination, are not well defined at this point. A small volume may be best treated by a technology with low capital costs with possible high operating costs, while remediation of a larger magnitude is more likely to be accomplished utilizing an equally effective technology with lower operating costs. An evaluation of treatment options should include consideration of leasing equipment to treat small volume sources or purchasing equipment for treatment of large volume sources.

3.5 FATE OF TREATMENT BY-PRODUCTS

The disposition of treatment by-products must be considered in the choice of the treatment solution. Local requirements for disposition of treatment by-products will have a major impact on the viability and economics of various treatment technologies. Air stripping of groundwater can be an extremely effective technology if the organic-laden air can be emitted directly to the environment; but compliance with RCRA, the Clean Air Act, and in certain areas strict local air emission standards may require that air stripping be followed by air pollution control equipment such as a vapor-phase adsorption system. Similar considerations exist with the generation of potentially toxic by-products from chemical oxidation processes, or the possible need for nutrient removal (phosphorus and nitrogen) from the effluent of biological oxidation processes. The economics of using activated carbon adsorption is affected by the accessibility of an approved regeneration site for the contaminated carbon.

3.6 UTILITIES AVAILABILITY AND COST

The selection of certain technologies will be influenced by the availability of utilities, such as steam at the treatment site. Likewise, some processes such as oxidation in the presence of ultra-violet light can require a substantial resource of electrical power. The energy-intensive processes are also likely to be more attractive in certain parts of the country where electrical costs are less than in other regions.

3.7 LAND USE

At VCC where normal production is ongoing, the operation of treatment systems or maintenance of closed facilities can be accomplished with the existing operations staff. The intention is that the processing areas and waste areas in the Vicksburg site remain an industrial site in perpetuity as a covenant maintained by deed restrictions.

3.8 IMPLEMENTATION TIME

The system to be used for remediation must be capable of being installed quickly enough to satisfy agency requirements.

3.9 EFFECTIVENESS

The proposed method and system for cleanup must accomplish containment of the source of contamination and effective removal or destruction of the contaminants that may be in the aquifer in a reasonable time.

3.10 LIMIT FUTURE LIABILITY

Cleanup must be accomplished in a way that will have minimal future liability for additional environmental remediation.

3.11 COST EFFECTIVENESS

A cleanup system should be selected that will accomplish the required remediation in the most cost-effective manner for both initial and long-term operations.

3.12 MINIMAL INTERFERENCE WITH NEIGHBORS

Installation and operation of the remediation system should cause minimum interference with the property and operations of adjacent property owners.

4.0
REMEDIAL ALTERNATIVES

The remedial alternatives that are being considered in the preevaluation are as follows:

- Groundwater Remediation - Containment
  - Surface Cap
  - Grading, Diversion and Collection Systems
  - Containment Barriers
- Groundwater Remediation - Hydraulic Control
  - Groundwater Pumping, Well Systems
  - Subsurface Collection Drains and Trenches
- Groundwater Remediation - Treatment
  - Air Stripping
  - Carbon Adsorption
  - Synthetic Polymer Adsorption Process
  - Biological Treatment
  - Chemical Oxidation
  - Volatilization
- In Situ Vapor Technologies
  - Soil Vapor Extraction
  - Bioventing
  - Multi-Phase Extraction
- Soil Remediation - Thermal Treatment
  - Incineration
  - Thermal Desorption
- Soil Remediation - Solvent Extraction
- Soil Remediation - Biological Degradation
- Soil Remediation - Soil Flushing
- Soil Remediation - Soil Washing
- Soil Remediation - Dehalogenation
- Soil Remediation - Vitrification - Aboveground

The actual remediation for each SWMU or AOC may be a combination of the above. Specific technologies within the categories are discussed below.

4.1 GROUNDWATER REMEDIATION - CONTAINMENT SYSTEMS

Zones of contaminated groundwater may be contained by various barrier systems or hydraulic control systems. Barriers control the vertical inflow of surface water or groundwater through the contaminated soil zone. Surface caps, grading, vegetation, diversions, and collection systems can be used for control, containment, or collection of surface water. These technologies prevent run-on, control vertical infiltration, prevent erosion, collect and transfer water for treatment, store and discharge treated water, and protect against flooding.

Containment barriers such as bentonite slurry walls, grout curtains, vibratory beams/asphalt walls, or steel sheet piles are vertical walls that prevent migration of contaminated water out of an area or prevent flow into an area. These types of containment barriers are utilized in soil layers that transmit water horizontally.

4.1.1 Surface Cap

A cap system provides a mechanism for surface water runoff control. This eliminates contact of the wastes with air and minimizes infiltration/leaching of the rainfall which consequently controls the risk of contamination or further contamination of the near-source subsurface soils, rock and/or groundwater.

A cap prevents direct contact with any waste which may be left on site. Should all the waste be removed or treated to render it nonhazardous and immobile, then a cap system would not be necessary. Core component materials used in the construction of a cap are relatively impermeable to minimize infiltration and reduce the potential for contaminant migration to the groundwater; such materials may include synthetic membranes, compacted natural soils, cement or bituminous asphalt pavements, or chemical sealants/stabilizers.

Synthetic membranes are generally plastic/resin based materials which have low permeability compared to other materials. Membranes are typically made of butyl rubber, hypalon, polyvinyl chloride (PVC), ethylene, propylene diene monomer (EPDM), or high density

polyethylene (HDPE). The membranes are manufactured in sheets which require field installation to form a single cover for an area. The membranes may be subject to physical degradation and damage resulting from improper handling and installation.

A clay soil cap provides a natural low permeability barrier and is constructed using earth moving equipment to spread and compact the clay. Clay is not subject to appreciable physical deterioration and consequently is a durable long-term material. The clay is susceptible to cracking if exposed at the ground surface.

An asphalt cap is a more permeable barrier than the synthetic membrane. Asphalt is relatively flexible and, due to weathering and cracking, would require periodic long-term repair. The asphalt could be applied as paving with a sealant, to provide a relatively thick, semi-permanent material.

Concrete is also more permeable than synthetic membranes and is susceptible to cracking. A concrete cap would require maintenance on a periodic basis.

Chemical sealants/stabilizers can provide permeability characteristics similar to that of the clay cap and in many cases are merely added to improve the sealant characteristics of on-site or imported clays. Adding lime to clay, for example, would reduce the shrink/swell properties if the clay were used without a cover.

A drainage zone of highly permeable material typically overlies the low permeability zone of the cap in order to enhance lateral drainage of infiltrating rainwater. A soil/vegetation zone is usually provided at ground surface to provide erosion stabilization by promoting vegetative cover without penetration of the cap by plant roots.

Synthetic membranes provide the least permeable barrier and consequently restrict the infiltration of rainfall but, left unprotected the membranes are subject to deterioration. A clay cap would be most durable if not exposed at the surface. The synthetic membrane augmented by the durability of natural clay cap may provide the optimum cap with the compacted clay overlain by the synthetic membrane. Protection of the synthetic membrane is also required. A free draining sand, with a vegetated soil cover, would serve a dual

purpose of allowing storm water to run off more rapidly to site surface drainage channels, and prevent direct exposure of the membrane to the environment.

4.1.2 Grading, Diversion and Collection Systems

Grading of a site is performed to reduce the potential for erosion. Grading is reshaping of the contours of the existing ground surface to allow storm water runoff to drain without scouring away the topsoil, thereby protecting the cap and minimizing the potential for infiltration.

A number of technologies can be used for the control, containment or collection of surface water. Water exclusion measures include barriers and landscaping techniques. These technologies are designed to perform six basic functions; prevent run-on, control infiltration, prevent erosion, collect and transfer water for treatment, store and discharge treated water to a drainage ditch or sewer, and protect against flooding. A surface water management system may require a combination of technologies to minimize the production of leachate and prevent off-site contamination.

Dikes and berms are compacted earthen ridges designed to divert or retain surface water flow. They can be used to control flood water eliminating the potential for cap scour/erosion and also the potential for standing flood waters to infiltrate the cap. Also, control of runoff will reduce erosion potential.

Seepage basins and seepage ditches are used to discharge water collected from surface water diversions or groundwater pumping. Both types discharge collected water to the groundwater by allowing it to seep through the ground.

Channels are excavated ditches that are generally wide and shallow. Diversion channels are used primarily to intercept runoff or reduce drainage runs across slopes.

Terraces are embankments or combinations of embankments and channels constructed across a slope. Terraces can be used to intercept and divert surface flow away from a site to control erosion by reducing slope drainage runs.

Sedimentation basins are used to control suspended soiled particles in surface water flow. They can be part of the water treatment process, and their design will depend on that process and the amount of solids in the surface water.

Grading, diversion systems and collection system are an effective means of control, containment or collection of surface water and therefore and protective of cap barriers by means of minimizing the potential for erosion and infiltration.

4.1.3 Revegetation

Revegetation can perform several basic functions: it can stabilize soil and earthen structures against wind and water erosion by intercepting rainfall, slowing runoff, and holding soil together with a tight root system. Vegetation can reduce the quantities of water available for runoff through interception, infiltration, uptake and transpiration and can sometimes treat contaminated soil and leachate through the uptake and removal of waste constituents, nutrients, and water from soil. During the process of uptake of contaminants, vegetation can biologically modify some contaminants.

Vegetation also can improve the aesthetic appearance of a site. Plants used for revegetation include various types of grasses, legumes, shrubs and trees. A vegetation program involves a careful plant selection, land preparation (such as increasing soil depth, grading, fertilizing and tilling), seeding and maintenance. As part of the selection process, consideration should be given to the remedial action implemented in conjunction with revegetation. For example, a cap would require a mix of grass such that it is covered throughout the year, whereas, a backfill could be revegetated with a lower maintenance cover.

Selection of vegetation will depend on site-specific requirements and plant characteristics. In general, grasses provide quick and lasting dense growth. They effectively anchor the soil, have high evapotranspiration characteristics, and may be suitable in wet areas such as waterways. They do, however, require periodic mowing and maintenance. Legumes, on the other hand, are a low maintenance cover providing long-term protection. They are most useful for stabilization and erosion control. They also have the added benefit of increasing the soil fertility through nitrogen fixation. Shrubs are useful in providing a dense surface

cover and are tolerant to acidic soils. Trees are most suited for preparing a site for post-closure use.

4.1.4 Containment Barriers

Containment barriers are vertical walls installed to provide a more impermeable zone through a soil layer which transmits fluid horizontally. The two basic applications are to prevent migration of contaminated fluids out of the area defined by the barrier or prevent flow into the area enclosed by the barrier, primarily for dewatering purposes.

For the first application, the barrier is able to contain contaminated water in shallow aquifers to limit the extent of horizontal migration. Once containment by the barrier is established, contamination is either left in the groundwater and further isolated by placing a cap over the entire contained area, or a removal and treatment/disposal program is initiated to remove contaminated groundwater while minimizing the volume of groundwater requiring pumping. With the second application, the barrier may also function to reduce the dewatering requirements of excavations which extend beneath the water table to remove contaminated soil or wastes.

Containment barriers include the following:

- Soil bentonite slurry wall
- Cement bentonite slurry wall
- Grout curtains
- Vibratory beam/asphaltic wall.

A soil bentonite (SB) slurry wall is a method frequently utilized to contain hazardous waste migration. It involves excavating a 2 to 3 foot wide trench, extending beneath the contaminated zone to be cut off. The excavated soil (or clean import soil) is mixed with a bentonite slurry (also used in the trench to keep it open) and then pushed back into the trench. The SB slurry sets up us a flexible gel, which retards fluid flow. As a thick flexible wall, it will be adversely affected by ground movements associated with settlements or creep of subsurface formations. A permeability of 10^{-7} cm/second or less is usually achievable with a properly designed and constructed SB wall. Further, slurry walls may be constructed to

function as "skimmer walls" to cut off movement of lighter than water constituents, or as full penetrating walls, keyed into a "bottom" formation which is itself a barrier to vertical movement of contaminated groundwater; this also affects the movement of heavier than water constituents.

A cement bentonite (CB) slurry wall is constructed by excavating a 2 to 3 foot trench and maintaining slurry in the trench. The slurry, a mixture of cement and bentonite, sets up as a more rigid wall than the SB was and consequently is frequently used around a deep excavation because it can be placed closer to the edge of the excavation without a resulting slope failure. A CB wall is more permeable than a SB wall and is also more expensive. It is usually not possible to achieve a permeability significantly lower than 10^{-6} cm/second.

Grout Curtains can be constructed by pumping grout down into a permeable zone to seal off the contained area. The grout can be either a particulate or a chemical grout which fills the voids between the soil particles. Considerable control is required to ensure a water tight seal; placement of the curtain generally involve injections at a 4 to 8 foot spacing and possibly more than a single row of holes.

A vibratory beam wall is a thin (about 3 to 4 inches wide) asphaltic or cement bentonite mix wall which is installed by driving wide-flange H-section beams through the permeable zone. As the beam is withdrawn a void is created into which a relatively impermeable asphaltic or cement bentonite mix is injected. A wall is created by overlapping the sections. The cement bentonite mix will generally achieve a lower permeability of about 10^{-6} cm/second; the asphaltic mix can generally achieve a lower permeability. The vibrating beam wall is more subject to gaps than a soil bentonite wall. Because of its narrow width, it will also directly transmit more water than a soil bentonite wall. Its main advantage is in locations which do not have adequate space or stability for trenching, such as in areas where numerous subsurface pipelines or other subsurface obstacles are present.

4.2 GROUNDWATER REMEDIATION-HYDRAULIC CONTROL SYSTEMS

With hydraulic-control approaches, an aquifer is pumped in order to remove contaminated water, which is then disposed of off-site (with or without treatment) or reinjected on-site (after treatment). When one or more wells are used for hydraulic control, the wells must be located and constructed such that they (1) prevent the chemical plumes from escaping, i.e., reverse the flow of contaminated groundwater, and (2) recover the majority of the total mass of contaminants, which are usually concentrated near the center of the plume. With extensive plumes, many wells are required both to control the plume and to recover the water that is contaminated.

Hydraulic control with wells is a viable alternative for control and elimination of the chemical plumes in aquifers that have significant saturated thickness and are permeable. In aquifers where saturated thickness of groundwater is only a few feet or where the sediments have low permeability, pumping wells have very small radii of influence.

Recovery trenches are excavated though the saturated zone to intercept the flow of groundwater or free phase contaminant and eliminate migration of chemicals past them. Recovery trenches are well suited to situations where the depth to groundwater and the saturated thickness are small. They become cost-prohibitive when depths are too great for excavation with standard equipment. Recovery trenches are also restricted when surface features, such as buildings, trees, or heavy paving, or subsurface features, such as large boulders, hard to excavate soils, or buried utilities, interfere with excavation.

4.2.1 Groundwater Pumping, Well Systems

Groundwater pumping can achieve the following:

- Gradient control or migration control in which the groundwater withdrawal establishes a hydraulic flow regime which eliminates or minimizes migration of contaminated groundwater to sensitive areas; and/or

- Contaminant removal, in which contaminated groundwater is pumped from the aquifer until the aquifer contamination reaches acceptable levels.

Groundwater pumping could be necessary depending on the assessment of risk of further horizontal and vertical migration of the contamination. Groundwater pumping for gradient control can be adequate for controlling horizontal migration but is generally not adequate where vertical migration is a major risk. Pumping for contaminant removal can be adequate control for both horizontal and vertical migration. Groundwater pumping may not be necessary if neither horizontal nor vertical migration presents a risk to public health or the environment.

Typical groundwater pumping scenarios are as follows:

- Pumping of the contaminated zone to control horizontal migration, remove contamination and reduce the risk of vertical migration; or

- Limited pumping of pressure relief wells within a barrier wall containment area to prevent possible rise in water levels within the contained area.

Groundwater pumping involves the following basis elements;

- Collection system (well)
  - Well points
  - Recovery wells

- Pumping system
- Recovered fluid handling system (storage, treatment, disposal).

Well Point collection systems consist of relatively closely spaced shallow wells connected to a central manifold suction lift system. Well points are usually small diameter (1.5 to 2 inch inside diameter) and are commonly installed by jetting techniques, or less commonly, by borehole drilling techniques.

Well point systems are subject to certain limitations including:

- Lift is limited to one atmosphere of pressure minus friction losses and system inefficiencies, usually the equivalent of about 25 feet or less.

- Drawdown within the well should not exceed the depth to the top of the well screen.

Use of the well point method often requires very close spacing of a large number of low pump rate wells. This technique is potentially applicable for remedial actions requiring gradient control along a limited perimeter of contamination. Contaminant removal over a large area would probably require a prohibitively large number of well points.

Recovery wells are generally drilled boreholes into which well screen, sand/gravel pack, well casing and borehole annulus seals have been placed. Well diameters of 4 inches or greater are generally used. Wells can be designed for recovery of dissolved phase contaminants, lighter than water free phase liquids, heavier than water free phase liquids, or a combination of different contaminant phases. With appropriate pumps recovery can be utilized in deep well systems.

Recovery rate, well spacing, and total number of wells required is primarily determined by hydrogeologic conditions. The main requirement is that sufficient flow rates are maintained to create a gradient toward the recovery wells.

Pumping systems for the recovery wells could include submersible pumps, jet pumps, positive displacement pumps or ejector pumps. Submersible pumps are generally better suited for deep, high yielding wells. Selection of the pumping system is also dependent or desirability of preferential recovery of free phase liquids and required discharge pressure. Wells and pumps may be designed to preferentially scavenge (recover) lighter than water phases from the groundwater. Specific pumping equipment selection requires evaluation of detailed recovery schemes.

Materials of Construction

When recovery systems are designed, consideration must be given to the effective life of the components, with respect to the chemical environment into which they will be installed. After detailed review of the operating environment, it may be determined that expenditures on exotic materials such as stainless steel, etc. may not extend the life of the recovery system. Contaminated groundwater may not be constant in quality with space and time and

what is compatible at the initiation of the operation of the recovery system may not be compatible in the future.

The area where the greatest amount of improvement can be made is the compatibility of pumping equipment with the contaminated groundwater. Most recovery wells using standard off-the-shelf water well equipment result in frequent pump failure because of attack on the pumps by chemicals. Pump failures include chemical attack of the pump and motor casings, deterioration of the plastic and elastomer seals, fittings, and cable sheaths. Low flow aquifers create situations where pump motors are run at temperatures in excess of manufacturer's design and experience subsequently shorter lives. Frequent cycling and pumping of abrasive materials also contribute to shortening of pump life. Pumps are being introduced into the market that will operate effectively in contaminated low flow environments. These pumps, many of which are operated with air, are expensive and still subject to failure during the life of the remediation project.

Well screens are also subject to failure as a result of chemical attack, corrosion, or mechanical plugging. When plugging occurs because of geo-chemical or biological reactions of the waste, the materials of construction have little effect. The plugging can be migration of sediment fines, chemical scales or biologic fouling.

Maintenance of Recovery System

In planning for a recovery system, consideration must be given to system maintenance. Recovery wells or trenches will not operate for the length of time required to clean up contaminated aquifers without maintenance during the life of the project. The wells and trenches must be designed and installed in such a manner so that "workovers" can be performed.

Many recovery systems are designed today based upon the results of transmissivity values derived from pumping test/recovery test. Using these values, well spacing programs have been developed to insure overlapping cones of depression. However, in many contaminated aquifers the zone of saturation is thin. If the well is inefficient, water levels in the pumping wells may drop to a point where very reduced pumping rates are required. Although the

water level in the well may be low, the water level in the aquifer will be higher and overlapping cones of depression may not be maintained.

Corrosion and scaling of water wells and oil wells have long been problems. These historical problems in uncontaminated areas are magnified many times when dealing with contaminated aquifers that are often unstable from both a geochemical and geologic standpoint. The effects of the contaminants on the gravel pack, and slots of the well screen are very unpredictable. Many recovery wells require extensive maintenance to keep screens open. Replacement of recovery wells at 4-year intervals is not uncommon and clean-out operations at 6-month intervals. In terms of cost of operations, recovery well maintenance may be a large cost factor.

4.2.2 Subsurface Collection Drains and Trenches

Subsurface collection drains and trenches include several variations but all involve placing linear permeable collection devices in the subsurface which collect fluid which is then pumped out from sumps.

Subsurface collection drains include:

- Tile drains
- Pipe drains
- French drains

Utilization of drains involve placement of the drains to depths sufficient to intercept contaminated groundwater. The system must be capable of intercepting the entire thickness of the aquifer. Tile drains and pipe drains only intercept a thin section of a saturated zone.

Difficulty of construction of french drains is a function of the following:

- Thickness of the aquifer
- Head within the aquifer
- Depth of the aquifer
- Trench stability problems resulting from the above

French drains or trenches may be potentially applicable for intercepting lighter than water phases present on the groundwater at some locations. For this purpose, the drain or trench would not need to penetrate the entire aquifer. The drain or trench would involve the following:

- Excavation of a trench on the downgradient perimeter of the floating phase layer to a depth of at least a few feet below the floating phase layer, and
- Placement of a synthetic liner on the downgradient side

If the trench were to be completed as a french drain, the following steps would be necessary:

- Placement of a perforated collection pipe in the trench
- Backfilling with sand/gravel to above the top of water
- Clay cap over the surface
- Installation of a sump or sumps containing a pumping system
- Means of handling and disposing pumped groundwater and excavated soil

4.3 GROUNDWATER REMEDIATION-TREATMENT

Treatment systems for recovered contaminants are typically the same systems that are in use for treating various waste streams from industrial facilities. For example, air stripping has been used conventionally for many years in the treatment of industrial effluent. This technology is now being used to treat groundwater contaminated with fuels. The use of activated carbon for aquifer restoration programs is widespread, especially for treating water to meet drinking water standards. Most treatment applications are specific to the type of contaminant in the recovered water. Treatment technology includes biological treatment for organic wastes, chemical oxidation for organics that do not respond to biological treatment, gas stripping for removal of volatile materials.

4.3.1 Air Stripping

Air stripping has conventionally been used in the treatment of industrial effluents. Within the last 10 years the technology has been used to treat contaminated groundwater, especially those groundwaters contaminated with fuels. The limiting factor is the organic carbon

emissions which may be regulated. The technology is relatively simple and generally has low maintenance requirements. Air stripping is a contaminant removal technique based on concentration differentials between a liquid phase and a contacting gas phase. As air is contacted with a contaminated water streams in a stripping tower, the concentration differential drives the organic contaminant from the liquid to the gas phase.

Air stripping is most applicable to compounds of a volatile nature with relatively low solubility in water. Chlorinated organics such as trichloroethylene, 1,1,1 trichloroethane and aromatic compounds such as benzene and toluene are good examples. The overall applicability of the technology can be expanded to compounds with lower Henry's law constants by preheating the water prior to its entering the stripping column.

Air stripping is effective in removing the aromatic gasoline components from groundwater at normal groundwater temperature of 50°F. However, as would be expected, air stripping is ineffective in removing more soluble components of gasoline such as tert-butyl alcohol.

The major advantage of air stripping is its low overall treatment costs. Both capital and operating costs requirements are low compared to most other technologies. In many cases, however, air emission standards will require that air stripping be used in conjunction with a vapor-phase adsorption unit, significantly affecting the cost-effectiveness of the technology.

4.3.2 Carbon Adsorption

The use of activated carbon adsorption for aquifer restoration programs is widespread. Several literature sources indicate the ability to achieve exceptionally good effluent quality, and the EPA has endorsed it as the preferred treatment method for meeting drinking water standards. Three basic ways in which carbon can be used are:

- Throwaway carbon basis
- Thermal regeneration basis
- Nondestructive regeneration basis

Throwaway Carbon

One way to consistently ensure good effluent quality is to use activated carbon adsorption on a once-through carbon basis. Virgin carbon is capable of removing a broad range of organic contaminants to low parts per billion levels. A once-through carbon adsorption system is easy to operate, requiring a minimum of operation attention, and the capital cost requirements are relatively low.

Unfortunately, carbon treatment costs associated with once-through carbon adsorption systems are very high. The large treatment volumes and/or high concentrations usually associated with remedial programs results in a high carbon consumption rate. In addition, hazardous substances loaded onto activated carbon make the carbon a hazardous substance, requiring disposal in an approved hazardous waste facility.

Thermal Regeneration

The most common regeneration technique for activated carbon is thermal oxidation, usually accomplished in a multiple hearth, fluidized-bed or rotary-kiln furnace. A thermal regeneration unit can be built at the treatment site, but the level of carbon consumption associated with most remedial programs usually makes it more economical to utilize a thermal regeneration service.

Nondestructive Regeneration

There are two ways that granular activated carbon would be nondestructively regenerated at the VCC Site.

- Using steam for volatile organics
- Using a solvent for a wider variety of organics

Steam has long been used to desorb volatile organics from vapor-phase adsorbers. Application of steam regeneration of activated carbon to wastewater treatment is an extension of this technology. After the lead carbon bed has been loaded in the usual manner, regeneration is accomplished by passing steam through the bed to a condenser. The waste-

organic condensate in then either decanted (for water immiscible solvents) or forwarded to a distillation step for recovery (for water miscible solvents).

Solvent regeneration of adsorbent involves the use of a solvent phase to desorb the organic chemicals from the adsorbent. The solvent is then removed (as in conventional solvent vapor recovery systems) by steam. The only requirement is that the organics to be removed be soluble in a common solvent. Solvents such as methanol, acetone, benzene, and methylene chloride have been used.

Regeneration is accomplished by contacting the spent carbon bed with the solvent found to be most effective. The solvent regenerate is distilled to recover solvent, leaving an organic concentrate suitable for recovery or incineration. (When a solvent already employed in the process is used to regenerate, added equipment for distilling the solvent may not be needed). The carbon, now saturated with solvent, is restored to adsorptive capacity by steaming off the solvent. The steam plus solvent vapors are condensed and separated. With solvent regeneration, the cycle of adsorption - desorption can be repeated many times before the carbon has to be replaced. Typical designs call for carbon replacement after 100 cycles.

4.3.3 Synthetic Polymer Adsorption Process

Adsorption systems consist of columns loaded with synthetic polymer adsorbents. Flow can either be down (fixed bed operation) or up (expanded bed operation). Loading rates are typically within the range of 2 to 8 US gal/min per ft^2s of bed cross section. The columns can be arranged in series or parallel, depending on the requirements.

The design of adsorption systems requires a knowledge of the equilibrium capacity (isotherm) of the adsorbent for the solutes to be removed and the overall rate of adsorption, factors normally determined by laboratory techniques. Column performance data at the temperature and pH of the system are generally required in order to obtain breakthrough curves to enable design for a specific effluent quality.

4.3.4 Biological Treatment

Biological waste treatment is a generic term applied to a variety of processes that utilize active microorganisms to convert wastewater or contaminant constituents to more stable and less harmful forms. As the name implies, biological treatment is applicable only to those materials that are biodegradable. While certain inorganic chemicals (e.g., ammonia, reduced sulfur compounds, etc.) are recognized to be amenable to biodegradation, the technique is most commonly utilized to achieve the stabilization of organic matter. Biological treatment processes essentially simulate the biological reactions that would occur in the environment. However, since biological processes generally employ high concentrations of active microorganisms, under controlled conditions, the decomposition rates of degradable materials are vastly accelerated.

Biological oxidation uses active microorganisms to biodegrade organics to acceptable forms. The two major forms of biological treatment are aerobic, which produces CO_2 and H_2O and anaerobic, which produces CO_2 and CH_4. Biological treatment is getting increased attention as a remedial alternative because of its potential for in situ treatment. Bioreclamation is basically just the use of indigenous soil bacteria to degrade organic contaminants. Nutrients, such as oxygen, and specific biological cultures can be added to enhance the degradation.

Bioreclamation (In situ Biological Treatment)

In situ bioreclamation is a method for remediating groundwater aquifers contaminated with hydrocarbons through the addition of nutrients and oxygen into the subsurface. The results in enhanced growth and activity of naturally occurring bacterial that use the organics as source of carbon and energy. Since most contaminated soils do not contain the optimum concentrations of all the necessary elements for bacterial growth, natural biodegradation, though present is not rapid enough to cleanse aquifers of gross amounts of contaminants. The enhanced bioreclamation process provide the oxygen, nitrogen, phosphorus and trace minerals needed to increase the natural biodegradation process.

There are a number of site specific factors which can impact enhanced bioremediation by altering the capacity of the indigenous microorganisms to grow and degrade the contaminant. In general, microbial degradation of contaminants in the subsurface is controlled by the same

factors that control these processes in surface waters and biological treatment facilities which include but are not limited to: microbial viability, nutrient availability and specific contaminant chemistry. These variables must be assessed and understood for each in situ bioreclamation project before an effective remediation strategy can be developed and implemented.

The basic principles involved in the assessment and design of an in situ bioreclamation project differentiate in-situ bioreclamation from surface biological treatment.

Above Surface Bioreactors

The major process equipment in biological treatment is basically a reactor to provide contact between the contaminated groundwater and the microorganisms, a solids-liquid separation device (such as a settling tank), sludge recycle pumps, and monitoring and control devices. Equipment for pH control and/or nutrient addition may also be required. Highly concentrated or variable waste loads may necessitate the use of an equalization tank before treatment. Finally, solids handling devices for final sludge treatment and disposal may be necessary. Descriptions of other variant schemes are given in the following paragraphs.

Aerobic Biological Treatment Systems may be subdivided into suspended growth and attached growth processes. Suspended growth processes utilize mixing mechanisms to suspend biological solids in a mixed liquor. Attached growth processed involve the contact of contaminants with biological films which are attached to a support medium.

The conventional activated sludge process is the most common example of an aerobic suspended growth process and consists of the following steps:

- Primary sedimentation to remove settleable organic and inorganic solids
- Aeration of a mixture of contaminated groundwater and a biologically active sludge
- Separation of the biological sludge from its associated treated liquor by sedimentation
- Return of settled biological sludge to be admixed with the raw wastes

Activated sludge processes can be classified according to the design process loading factor, or food-to-microorganism (F/M) ratio, which is commonly expressed as the rate of organic loading (kg BOD/day) per unit weight of biomass (kg mixed liquor volatile suspended solids). High rate processes are commonly operated at an F/M of 0.5 or greater, while "conventional" activated sludge systems are normally designed for an F/M in the range of 0.2 to 0.5. Extended aeration processes, with organic loading rates less than 0.2, provide longer detention times than conventional systems and achieve higher removals of organic matter and greater destruction of bio-solids through endogenous respiration. Such systems thus minimize the amount of sludge requiring disposal. System selection often involves an economic balance between the relative costs of increased aeration tankage and solids handling facilities.

In fixed-film biological treatment process, the biomass that affects degradation of contaminant components grown in the surface of a supporting medium. Historically, the most commonly applied aerobic fixed-film process has been the trickling filter. In its simplest form, the trickling filter is comprised of a cylindrical tank, filled with graded rock media. Recovered contaminated groundwater is applied to the surface via a series of rotating distributor arms, allowed to pass through the bed, and collected at the bottom. Oxygen transfer and biodecomposition are achieved by diffusion through the slime layer that grows on the media. Several process modifications have been applied to trickling filters, including multistage designs, recycle, and forced-draft aeration. Most modern trickling filters utilize plastic media designed to promote water flow over a large surface area while maintaining a high void ratio for adequate oxygen transfer and alleviation of plugging problems. The principal advantages of trickling filters, in comparison to suspended growth processes, have been operational simplicity and low cost. However, since trickling filters can seldom achieve the increasingly more restrictive discharge limitations, few systems have been designed in recent years.

The rotating biological contactor (RBC) is an attached growth system consisting of a series of large diameter discs that are mounted on a horizontal shaft and slowly rotated in a tank. Approximately 35 to 40 percent of each disc is immersed in the contaminated water to be treated. The organisms present in the groundwater adhere to the discs, eventually forming aerobic biological layers. During operation, the discs rotate and pick up a thin film of contaminated water from which the organisms remove organic materials and oxygen. In

comparison to suspended growth systems (such as activated sludge), the RBC System generally entails a higher capital cost, but requires lower operating costs

The historical application of anaerobic processes has been primarily for digestion of primary and water activated sludges in industrial waste treatment. More recently, anaerobic processes have been seriously reconsidered as an economically attractive alternative to aerobic processes, particularly for pretreatment of higher strength industrial wastewaters, severely contaminated groundwater and contaminated solid media. Anaerobic processes require no oxygen, thereby eliminating the capital and operating costs of oxygen transfer equipment. Moreover, methane, as a by-product of the biological reaction, may be recovered for use as a fuel. Both suspended growth and fixed film anaerobic processes have been considered for treating contaminants.

The anaerobic contact process is a suspended growth anaerobic process. The process may be operated as a two-stage system, involving two anaerobic digesters in series. The contaminated water is fed to a high rate digester, and the sludge from this digester is pumped to a second-stage digester. The second-stage digester operates as a settling basin to permit the removal of microorganisms for the water. The biological organisms, as in the activated sludge process, are returned to the first-stage digester along with the raw waste. A more recent variant of the anaerobic contact process employs a single-stage digester, followed by a proprietary solids-liquid separation device, from which solids are returned to the reactor.

Applicability

Biological treatment has been widely used in the treatment of aqueous organic wastes and contaminants but has fundamental limitations. The biodegradability of organic compounds has been shown to vary widely among different chemical structures. Many factors make it difficult to determine the biodegradability of a compound based solely on its molecular structure. These factors include the size and solubility of the molecule, the presence of more than one functional group in the molecule, and isomerism. Chemical or biochemical changes may occur in the compound so that its capacity for biological oxidation is different than for the original compound. Also, the type of biological organisms, the environmental conditions, and the effects of acclimatization may determine whether a specific compound is biodegradable.

In general, biological processes are applicable to the treatment of soluble, degradable organics in the concentration range of 0.01 to 1 percent. Removal efficiencies can vary from 50 to 99+ percent (BOD or COD), depending on the process configuration, loading factor, and the nature and distribution of organic material present in contaminated groundwater.

An example of using both chemical and biological oxidation involved treatment of a chemical spill with alkaline hydrogen peroxide. This chemical oxidation process was successful in reducing the spill concentrations to a level where biological oxidation could be used. This biological process made use of a portable aeration tank, a spray system and railroad ballast. Liquid was pumped from a sump dug next to the ballast, passed through the aeration tank, and sprayed back onto the ballast. The system was inoculated with a specially cultured microorganism that would degrade the spill. The ballast, being composed of coarse rock, supported the growth of the biological medium in a manner similar to a trickling filter. Nutrients were added to the systems as needed. After one month, the system successfully reduced the contaminant concentration from several hundred parts per million to less than 1 ppm.

4.3.5 Chemical Oxidation

Chemical oxidation is used to chemically modify waste streams either by completely oxidizing the organics to CO_2 and H_2O or by partial oxidation of the organics in order to detoxify them. These waste streams are often aqueous wastes that cannot be handled directly by biological oxidation (either because of organic strength or bioinhibitory characteristics) or incineration (because the organic concentration is too low or there is excessive corrosion caused by the presence of inorganic salts or halogens). Oxidation is also used to purify aqueous streams (such as waste sodium chloride brines) to permit recycle.

Most of the chemical oxidation processes are based on one of two oxidizing -- agents chlorine or oxygen. Chlorine is generally not used for remediation because of the potential to create toxic byproducts. Many oxidation processes have been developed to modify the ability of these oxidizing agents to accomplish specific goals. These modifications usually seek to adjust the stoichiometry and/or kinetics of the chemical reactions.

Because of the varying optimum conditions for the effluent reactions, no one chemical oxidation process can be considered. The ones that come closest to being universally applicable (catalyzed and uncatalyzed wet oxidation) are the most expensive in terms of capital and operating costs. These processes are usually reserved for the tougher oxidation problems because the easier problems can be handled by the cheaper processes.

Selection of a process is usually based on process economics, which in turn depend on the contaminated groundwater volume, reaction stoichiometry, and kinetics. Considerations of the completeness of the oxidation and the formation of by-products are becoming more and more important as more data on trace levels of materials are developed.

4.3.6 Volatilization

Volatilization is defined as a process where the components of a liquid mixture are separated by virtue of the differences in volatility of the components into a liquid-phase product and a gas or vapor-phase product. There are as many different types or categories of volatilization as there are mixtures to be separated. In general, volatilization can be divided into four major categories: fractional distillation, steam stripping, evaporation, and inert gas stripping.

Fractional Distillation

Distillation is applicable to the separation of components from virtually any liquid mixture, including aqueous-organic and organic-organic liquids. It is also an integral part of many contaminant treatment and/or recovery processes such as carbon adsorption and solvent extraction. Depending on the nature of the separations required, distillation is a practical and very widely used separation technique.

To produce a degree of separation by distillation, a number of successive vaporization and condensation operations are usually required. This is accomplished by causing the boiling liquid and a saturated vapor to contact each other counter-currently in a distillation column. Countercurrent contacting of the gas and liquid streams in a distillation tower is achieved by causing either the gas to be dispersed in the liquid or the liquid to be dispersed in a continuous gas phase.

Steam Stripping

Steam stripping is a special case of distillation which is directly applicable to removing volatile organic and/or dissolved gases from contaminated groundwater.

Ordinarily, heat is applied at the base of a distillation tower by means of a heat exchanger (boiler). When an aqueous solution is to be fractionated to give the nonaqueous solute as the distillate (overhead vapor product), and the water is removed as residue (bottom product), the heat can be provided by using open steam at the bottom of the tower. The distillate is a mixture of volatile solute and steam. For water-immiscible organics, phase separation yields an organic distillate.

The design and operation of a steam stripper for removing dissolved impurities from water is primarily dependent on relative volatility, just like other distillations. The relative volatility is the basis for the heat requirements to boil groundwater and cause a greater fraction of the volatile organic to separate into the vapor phase as compared to the fraction remaining dissolved in groundwater. The relative volatility ($a_{1,2}$) of the ratio of vapor to liquid composition for the two components under consideration is:

$$a_{1,2} = \frac{Y1/X1}{Y2/X2}$$

where:

Y	=	fraction in a vapor
X	=	fraction in a liquid

In the case of steam stripping, the first component is the impurity and the second is water. For a heterogeneous azeotrope involving water, the aqueous phase is saturated with the organic solute at the azeotrope temperatures. The azeotrope composition reported is the vapor phase composition. The relative volatility of the solute to water in a steam stripper is the ratio of the composition in the azeotrope vapor to the compositions in the saturated aqueous phase at the azeotrope temperature.

The preferred application of steam stripping is the removal of organic compounds or solvents which are contained in contaminated groundwater at dilute concentrations. If the relative volatility of an impurity to water in a steam stripper is greater than 4.0, the steam stripping may be an economically viable alternative for aquifer cleanup. If it is less than 4.0, extraction or carbon adsorption may be more economically attractive.

Gas Stripping

Volatile materials can be removed from a solution by passing a gas such as air or nitrogen through the mixture. The volatile component or components transfer from the liquid phase to the vapor phase. This can be accomplished stagewise in a column similar to steam stripping. A gas stripping system normally requires that the gas from the top of the column be treated in some manner to remove the stripped material before it is discharged to the atmosphere or sent to an existing flare or incinerator for destruction. In the common case of air or nitrogen stripping of organics from water, the organics are removed from the gas by carbon adsorption.

The principal applications of air or inert gas stripping would be the same as that for steam stripping -- removal of volatile components from contaminated water. Gas stripping might be preferred over steam stripping when the contaminants to be removed are very volatile and a column is not required. Capital and carbon regeneration costs for gas stripping are normally higher than the capital and steam costs required for steam stripping, depending on the flow and volatility of the contaminants. In many cases, the off gas (air) can be flared or sent to an incinerator, thereby eliminating the cost of gas treatment.

4.4 IN SITU VAPOR TECHNOLOGIES

Three technologies using air are often used for in situ remediation of soil and groundwater. The terms describing the technologies are sometimes used interchangeably, but should not be. The three technologies are:

- *Soil Vapor Extraction (SVE)*

  The removal of volatile organics from soil above the water table by applying a vacuum to extract contaminated vapors.

- *Bioventing*

  Biodegradation of organic compounds in soil above the water table accomplished by introducing air (oxygen) under low pressure or low vacuum into the ground. This technology is usually used along with a soil vapor extraction system.

- *Multi Phase Extraction*

  The removal of volatile organics from the soil above the water table and from the underlying groundwater by simultaneously extracting groundwater to lower the water table and using soil vapor extraction to remove contaminated vapors, usually under high vacuum.

4.4.1 Soil Vapor Extraction

Soil vapor extraction was developed in the early 1980's as an alternative to soil excavation. SVE has been used to remove chlorinated solvents from soils at sites. SVE is particularly applicable to the removal of VOCs, such as fuel hydrocarbons and chlorinated solvents, from relatively permeable soils above the water table.

Compounds with vapor pressure greater than 0.5 mm Hg, are relatively easy to strip from soil by moving air, and are collected at the vapor extraction well for removal. Prior to discharge into the atmosphere, the extracted vapors are often routed to an air emissions control system.

SVE is a physical means of removing VOCs from contaminated soil. The typical SVE system and Bioventing system consists of a network of vacuum extraction wells screened in the contaminated vadose zone. The extraction wells are joined together by a common header

pipe, which is connected to a vapor water separator where water is removed. The water is discharged to the plant waste water treatment system.

The separator is then connected to a positive displacement blower, which provides a negative pressure gradient in the subsurface. Discharge from the blower is vented to the atmosphere or connected to an offgas treatment system.

The key feature of the SVE process is the stripping and volatilization of VOCs from the soil matrix into the vacuum induced air flow. With SVE, large volumes of air are removed from the contaminated soils through vapor extraction wells and vacuum blowers.

Selection of the most appropriate vapor technology system can be made once the following key parameters are identified:

- Permeability of the soil
- Uniformity of the soil
- Presence of VOCs/SVOCs
- Concentrations of constituents present
- Location of constituents relative to the water table
- Depth to water table
- Volume and depth of contaminated soil

Selection of an in situ vapor technology generally starts with conducting a short-term, pilot-scale test at the site. Typically, the test consists of connecting a mobile blower assembly to an extraction well and observing the performance over a period of a few hours of operation. The purpose of a pilot test for an SVE, multi-phase extraction, or bioventing system includes:

- Development of a vapor flow versus applied vacuum relationship - to assess individual well extraction performance.

- Evaluation of constituent vapor concentrations in the extracted vapor -to assess mass removal rate and assess air treatment needs

- Identification of the effective zone of influence of the extraction wells - to optimize extraction well location

- Selection of proper mechanical equipment

Modeling of the underground air flow may be required for some site conditions. Several software packages are used to model underground air flow. These software packages are similar to modeling groundwater flow. The modeling is part of the output provided by the pilot plant study.

The use of soil vapor extraction stems from the advantages, including ones related to regulatory factors, associated with the in situ nature of the technology. These advantages include the following:

- SVE is minimally intrusive to contaminated soils. The potential release of VOCs to onsite and offsite receptors is insignificant when compared to excavation and removal of contaminated soils.

- Optimal sizing and specification of this equipment on a medium-sized or larger site does require assistance from experienced personnel; however, it is not a complicated technology to operate.

- SVE can hasten reduction in VOCs.

- SVE can reduce the vadose zone source input, thereby decreasing the time required for saturated zone pump-and-treat alternatives.

- SVE can be more cost-effective than other in situ technologies. When compared to excavation costs (with subsequent disposal or treatment), its costs can easily be an order of magnitude lower.

Soil vapor extraction requires construction and operation of equipment and devices, some of which are subsurface and some of which are aboveground. Relatively high capital costs are required. Relatively high operation and maintenance costs are required.

4.4.2 Bioventing

Bioventing is an enhancement of soil venting or Soil Vapor Extraction. SVE is a physical means of removing VOC's from contaminated soil. The typical SVE system and Bioventing system consists of a network of vacuum extraction wells screened in the contaminated vadose zone. The extraction wells are joined together by a common header pipe, which is connected to a vapor water separator where water is removed. The separator is then connected to a positive displacement blower, which provides a negative pressure gradient in the subsurface. Discharge from the blower is vented to the atmosphere or connected to an offgas treatment system.

The key feature of the SVE process is the stripping and volatilization of VOCs from the soil matrix into the vacuum induced air flow. With the introduction of air into the subsurface, aerobic microbial activity is also stimulated, resulting in increased rates of in situ contaminant biodegradation. Modifying the SVE process to Bioventing can enable the biological destruction of hydrocarbon contaminants in situ.

With SVE, large volumes of air are removed from the contaminated soils through vapor extraction wells and vacuum blowers. Clean atmospheric air is introduced from the soil surface or is supplied with either passive vents or active air injection wells causing soil gas oxygen concentrations to increase up to 20 percent within several days. The SVE process can be modified to Bioventing by limiting the air removal and the corresponding clean air influx rate to the minimum flow needed to promote biodegradation. With Bioventing hydrocarbon volatilization is minimized and air emissions are greatly reduced.

Biodegradability and Bioavailability:
Hydrocarbon-degrading microbes are present in virtually all natural soils. In theory, any soil in the vadose zone containing biodegradable contamination can be treated through Bioventing. To increase rates of hydrocarbon biodegradation, six key factors that affect hydrocarbon biodegradation must be enhanced:

- Oxygen availability
- Availability of hydrocarbons to microbes
- Soil moisture

- Presence of inorganic nutrients (e.g., nitrogen and phosphorus)
- pH
- Temperature

Aboveground treatments (e.g., land farming) have been used to optimize these environmental factors and promote biodegradation. The environmental requirements of the hydrocarbon-degrading bacteria are the same in all aerobic bio-treatment processes; the only difference is the methodology used to enhance the microbial environment.

Groundwater:
If the depth to groundwater is less than 5 to 10 feet, excavating rather than Bioventing could be more cost-effective, depending on the quantity of contaminated soil and regulations governing excavation and disposal.

Bioventing usually is a good alternative for sites where the majority of contamination is in the vadose zone. Sites where the majority of contaminants are in the saturated zone must be evaluated for groundwater pumping and treatment possibly in conjunction with Bioventing. This evaluation should consider the saturated zone characteristics, the overall cleanup schedule, and the regulations governing discharge.

Soil:
Bioventing is typically more applicable to cases where the contaminated unsaturated zone is relatively permeable; however, the technology has been used in less permeable clayey or silty soils. Although bioventing is considered an emerging technology, several field-scale applications have been successfully completed (Dupont et. al., 1991; Miller et. al., 1991; Downer et. al., 1992; van Eyk, 1994; Downey et. al., 1994; Ong et. al., 1994). Downey et. al. (1992) investigated the feasibility of bioventing at a site contaminated with diesel fuel. Site lithology consisted of a low permeability zone located 35 to 50 feet below ground surface where lateral migration of contamination resulted in total recoverable petroleum hydrocarbon concentrations of 18,800 mg/kg to 40,200 mg/kg. To evaluate the ability of a bioventing system to supply oxygen to this low permeability zone one vapor extraction well and six monitoring vapor monitoring points were installed. Prior to vapor extraction, oxygen and carbon dioxide concentrations were measured at each vapor monitoring point to establish background levels. Low oxygen concentrations appeared to be associated with high

contaminant concentrations. After 48 hours of vapor extraction at a rate of 135 scfm (approximately 1.4 pore volumes/day), oxygen concentrations increased by 1.6 to 7% in the low permeability zone.

It is important to note that many other physical characteristics that will influence vapor transport should be investigated at the site before a system design and construction. These characteristics include stratigraphy, particle size distribution, moisture content, bulk density, and particle density.

SVE and Bioventing contractors rely heavily upon a field gas permeability test to select well spacing and blower requirements. In this test, one or more extraction wells are installed in contaminated soil strata. Vacuum piezometers are installed at different depths, and in each representative strata, and at various radial distances from the extraction well(s). Air pressure data is obtained from the piezometers at different air flow rates. The data is used to calibrate a steady state air flow model, which can be used to estimate well spacings, screened intervals of wells, and the size and type of blowers required. This information would be provided as part of a pilot plant effort.

For SVE systems the goal is to move large volumes of clean air through the contaminated soils as efficiently as possible. The primary objective of Bioventing is to supply a sufficient concentration of oxygen to promote high rates of biodegradation. Bioventing systems are designed and configured to optimize oxygen transfer and oxygen utilization efficiency, and are usually operated at much lower flow rates than those utilized in conventional SVE applications. Since Bioventing efficiency is enhanced by a long flow path, large volume of soil contact, and long retention time for the contaminated soil vapors, Bioventing wells are not placed in the center of contamination as in conventional SVE systems, but are located on the periphery of the site. Under these conditions, low flow rates (0.1 to 0.5 pore volumes/day) maximize the residence time of vent gas in the soil to enhance biodegradation and minimize volatilization. To further enhance bioremediation conditions, nutrients and moisture may also be introduced into the vadose zone.

Offgas treatment may be required to comply with stringent ambient air quality criteria and permitting requirements, rather than allowing direct discharge to the atmosphere. Offgas treatment methods include:

- Vapor phase granular activated carbon (GAC) or vapor phase resins with offsite or onsite regeneration or offsite disposal
- Condensation
- Incineration or flaring

The need for offgas treatment can be determined by investigating state and federal air emissions requirements. If offgas treatment is required, the most cost-effective technology needs to be determined by evaluating the type, concentration, and quantity of contaminants; permit requirements; and availability of required utilities. It is critical that design and estimates of total costs for the Bioventing system include offgas emission requirements to allow a valid comparison with other in situ alternatives and with the excavation alternative.

The use of Bioventing stems from the advantages, including ones related to regulatory factors, associated with the in situ nature of the technology. These advantages include the following:

- Bioventing is minimally intrusive to contaminated soils. The potential release of VOCs to onsite and offsite receptors is insignificant when compared to excavation and removal of contaminated soils.

- Optimal sizing and specification of this equipment on a medium-sized or larger site does require assistance from experienced personnel; however, it is not a complicated technology to operate.

- Bioventing can hasten reduction in VOCs.

- Bioventing can reduce the vadose zone source input, thereby decreasing the time required for saturated zone pump-and-treat alternatives.

- Bioventing can be more cost-effective than other in situ technologies. When compared to excavation costs (with subsequent disposal or treatment), its costs can easily be an order of magnitude lower.

- Bioventing can biodegrade less volatile hydrocarbons.

- Since reduced airflow is required, when compared with SVE, Bioventing can be more effective for impermeable soils.

4.4.3 Multi-Phase Extraction

Multi-phase extraction, a form of vacuum-enhanced groundwater extraction, was developed in the late 1980s as a means of increasing the effectiveness of SVE systems in low to moderate permeability soils. This process can save time and money by providing simultaneous cleanup of constituents in groundwater and vadose zone soil. A high vacuum is used to increase the hydraulic and pneumatic gradient toward each extraction well. Typically fewer wells and less time are needed to clean up an area when compared to a conventional pump and treat system.

Installing extraction wells at the capillary fringe of groundwater and vadose zone and applying vacuum, high-velocity entrainment of water droplets in the air stream can remove simultaneously contaminated groundwater and treat vadose zone soil in an area of high pollutant concentration. Similarly, several processes use wells for groundwater circulation and air stripping within the well.

Selection of the most appropriate vapor technology system can be made once the following key parameters are identified:

- Permeability of the soil
- Uniformity of the soil
- Presence of VOCs/SVOCs
- Concentrations of constituents present
- Location of constituents relative to the water table
- Depth to water table
- Volume and depth of contaminated soil

Selection of an in situ vapor technology generally starts with conducting a short-term. pilot-scale test at the site. Typically, the test consists of connecting a mobile blower assembly to an extraction well and observing the performance over a period of a few hours of operation. The purpose of a pilot test for a multi-phase extraction system includes:

- Development of a vapor flow versus applied vacuum relationship - to assess individual well extraction performance

- Evaluation of constituent vapor concentrations in the extracted vapor -to assess mass removal rate and assess air treatment needs

- Identification of the effective zone of influence of the extraction wells - to optimize extraction well location

- Selection of proper mechanical equipment

Modeling of the underground air flow may be required for some site conditions. Several software packages are used to model underground air flow. These software packages are similar to modeling groundwater flow.

4.5 SOIL REMEDIATION-SOLIDIFICATION/STABILIZATION

Solidification/stabilization of toxic waste use chemical and physical processes to detoxify a hazardous waste. The waste is immobilized in a normal earth environment to form a less leachable product. This can be accomplished by addition of chemicals, surfactants, or complexing agents. If Land Disposal Restrictions (LDR) are applicable to the waste being treated and the waste has a high concentration of organics, then stabilization may not be applicable since Land Disposal Restrictions for organics are based on total concentrations rather than leachable concentrations. There are instances where LDR are not applicable and organic as well as inorganic contaminants can be effectively stabilized.

Stabilization refers to processes that reduce the risk posed by a waste by converting the contaminants into a less soluble, mobile, or toxic form. The physical nature of the waste is not necessarily changed.

Solidification refers to processes that encapsulate the waste in a monolithic solid of high-structural integrity. The encapsulation may be that of fine waste particles (microencapsulation) or of a large block or container of wastes (macroencapsulation). Solidification does not necessarily involve a chemical interacting between the waste and the

solidifying reagents, but may mechanically bind the waste in the monolith. Contaminant migration is restricted by decreasing the surface area exposed to leaching and/or by isolating the waste within an impervious capsule.

Stabilization and solidification processes can be applied to a wide range of wastes. Since all the processes depend upon chemical and physical reactions of varying complexity between the wastes and the applied fixation agents, care is required in order to select the most appropriate process or system. The following table lists common kinds of wastes and the solidification/stabilization process that is most effective:

Kinds of Wastes	Stabilization/Solidification Process
Oily wastes, industrial sludges and contaminated soils (containing inorganics with low concentrations of organics), acid mine leachate and tailings, and radioactive liquid scintillation fluids	Sorbents and Surfactants
Contaminated foundry sands and sand-blasting grit; wastes from paint removal, metal finishing, and electroplating; petroleum-contaminated soils	Emulsified Asphalt
Refuse-to-energy plant and medical wastes ash, insulation wastes, metals-smelting dusts, contaminated soils, and metal-contaminated sludges	Soluble Phosphates
Low and medium level radioactive wastes, municipal solid waste ash, medical wastes, and contaminated soils and sludges	Bituminization
Predried particulate wastes, such as, incinerator ash, contaminated soils, sludges, metals, and mill tailings	Modified Sulfur Cement Process
Primary and secondary waste streams produced by waste management and restoration activities, nitrate salt wastes, sludges, ion-exchange resins, incinerator ash, and scrubber blow-down solution	Polyethylene Extrusion
(Specific process variation dependent) metal-containing wastes, auto shredder fluff, incinerator-bottom ash, and contaminated debris	Soluble Silicates (Patented Processes)
Metal-refining wastes, metal-finishing wastes, and metal-bearing sludges	Soluble Silicates (Slags)
Steel pickle liquor, ferric chloride etching waste, oil waste, hydrocarbon waste, incinerator ash, petroleum sludge, phosphoric acid residue, oily wastes, and tars	Soluble Silicates (Lime)

Kinds of Wastes	Stabilization/Solidification Process
(Specific process variation dependent) metal-containing wastes, auto shredder fluff, incinerator-bottom ash, and contaminated debris	Soluble Silicates (Inorganic Polymers)

Stabilization/solidification techniques often do not successfully bind organic compounds. Volatile organics may be substantially volatilized during the stabilization due to agitation during mixing and temperature increases due to heat of reaction of stabilization reactions. Consequently, release of volatile organics to the air is a potential problem.

Solidification/stabilization is, in general, not difficult to implement. What is required is the mixture of the stabilizing ingredient with the soil. The most appropriate in situ technique involves shallow and/or deep soil mixing equipment, which mix ingredients with the soil.

In the event that soils are stabilized and chemically fixed, a containment system is constructed around the soil. In addition hydraulic control systems may be utilized in conjunction with the containment structure. Section 4.1 and 4.2 discuss the appropriate technologies.

4.5.1 Fly Ash and/or Kiln Dust and/or Cement

Samples of sludge can be mixed in various proportions with fly ash and kiln dust. Results must be acceptable for both structural strength and leaching characteristics. Organic compounds should be targeted as the difficult compound to immobilize.

Addition of large amounts of cement (perhaps 15 to 40 percent) will form a sample of adequate structural strength. Laboratory tests must be determined for leaching characteristics.

4.5.2 Proprietary Polymers

There have been various formulations of propriety polymers created which attempt to bind organics within the solidified mass. Such polymers have been so expensive that acceptance

and commercial application has not had wide spread succes. Nevertheless three examples are noted herein.

The Hazcon process uses cement and a proprietary additive called "Chloranan" to immobilize and encapsulate hazardous waste into a concrete-like mass. Cement based solidification involves the mixing of wastes directly with Portland Cement, a readily available construction material. However, Portland Cement alone is not effective in immobilizing organics. The Hazcon additive Chloranan acts to neutralize the inhibiting effect that organics normally have on the hydration of cement. The relatively high concentrations of organics will require more Chloranan to be added to the waste to allow the concrete to properly cure. The Hazcon process does not claim to fix organics, only to result in a solidified product with physical properties that inhibit mobility of the organics and additionally will support construction equipment.

Since the Hazcon process depends upon the cement to treat the waste, immobilization of the metal constituents can be expected because most multivalent cations are converted into insoluble hydroxides or carbonates at the pH of typical cement mixtures. However, mildly acidic leaching solutions as rain, will allow metal hydroxides and carbonates to leach out of solution. For this reason disposal should be in a facility with multiple liners and a leachate collection system.

There are silicate based processes which use proprietary formulas of siliceous materials, lime, cement and special setting agents to solidify, stabilize and chemically fix hazardous waste. Most silicate based processes employ a typical silicate material as fly-ash or other pozzolanic material as additives. Soluble silicates such as sodium silicate or potassium silicate can also be used. Additives can include selected emulsifiers, surfactants, and absorbent.

The IWT hazardous waste treatment technology is based on solidification, stabilization and chemical fixation. IWT employs three sets of functional chemical groups including cement matrix chemistry, free radical and ion attack chemistry, and organophilic linking mechanisms.

4.6 SOIL REMEDIATION - THERMAL TREATMENT

Onsite thermal treatment by fully pre-packaged ready to operate transportable modules are readily available and accepted by the technical and regulatory community. The acceptance has not spread to the neighborhood and environmental groups.

4.6.1 Incineration

Three types of modular incinerators have been considered:

- Rotary kiln
- Circulating bed combustion
- Infrared

Rotary Kiln

The rotary kiln incinerator is the most versatile. The feed systems and the kiln can handle a wide spectrum of waste materials. Solid feed is introduced by gravity into the rotary kiln combustion system which operates below atmospheric pressure is a closely controlled air supply mode.

The kiln ashes (soil) are cooled in a moisture controlled environment and conveyed to storage when they are sampled for verification of full treatment.

The kiln gases are incinerated in a secondary combustion chamber designed to handle large variations in gas composition and volumes and to avoid any operating problems which may be caused by entrainment of fine solids in the kiln gas.

The secondary combustion chamber gases are water quenched and then processed through a high efficiency air pollution control module capable of removing submicron particulate matter and acid gases. Treated gases are exhausted by a induced draft through a stack which includes an automated, computer controlled monitoring system.

There are many sizes of rotary kiln modular units available. Thermal capacity ranges from 10 million BTUs per hour to 60 million BTUs per hour. Mobilization costs can range upwards of 1 million dollars for the large incinerators that are designed to handle large quantities of wastes. The smaller incinerators cost less to mobilize but are more expensive to operate per unit of throughput.

Circulating Bed Combustion

Circulating bed combustion is an outgrowth of conventional fluidized bed incineration. However, the circulating bed operates with higher velocities than conventional fluid beds and it recirculates the fluidized material within the system returning solid, liquid, sludge, or gaseous waste streams. The advantages of this incinerator are similar to those of a conventional fluidized bed system with lower susceptibility to corrosion of the boiler, a less complicated scrubbing, close temperature control and dry solid waste recovery.

The circulating bed combustor incinerates hazardous wastes in the presence of an entrained bed of solids. Rather than maintaining a fixed fluidized bed, this process utilizes much higher gas velocities to entrain the solids in a combustion chamber. The high turbulence and resulting high heat-transfer efficiency allow the system to operate at much lower temperatures than are typically encountered in a hazardous waste incinerator. Solid wastes are added along with limestone in the solids return line. Liquid wastes are injected into the bottom of the unit. Combustion occurs at 1450°F to 1600°F and is attained at these relatively low temperatures because of the high degree of turbulence in the combustion chamber, and because of efficient heat transfer from the recirculating solids of the waste stream.

Entrained solids are removed from the combustion gases in an integral cyclone. The solids are returned to the combustion chamber through a nonmechanical seal and reentered the combustion chamber within about 50°F of their exit temperature. Particulates (including ash) that are not removed by the cyclone remain entrained in the combustion gas. This gas passes through a heat recovery/filtration system prior to discharge to the atmosphere. In the steam generation mode, water is preheated by the combustion gas, and then flows through "water wall" tubes in the combustion chamber.

NO_x formation is minimized by the relatively low combustion temperatures, and by the addition of secondary combustion air at higher locations in the combustor. Because the circulating limestone absorbs halogens, phosphates, and sulfur, a scrubbing system may not be needed to remove acid gases.

The existing circulating combustion bed incinerators are large, mobilization cost will exceed 1 million dollars.

Infrared Incinerator

Infrared conveyor furnace combustion uses silicon carbide resistance heating elements to volatilize organics from conveyed solids, soils and sludges. The organic gases are then destroyed in a secondary chamber or afterburner.

The system consists of a waste preparation system, feed metering system, infrared primary chamber, supplemental propane-fired secondary chamber, exhaust gas scrubber, data acquisition and control systems, and heating element power centers, all mounted on transportable trailers. The compact, size of a typical unit allows for relatively quick and low cost mobilization.

Waste material is first processed in waste preparation equipment designed to reduce particle sizes to dimensions that can be handled by the incinerator. After leaving the waste preparation equipment, the feed is weighed. Waste material is then fed to a hopper mounted over the furnace conveyor belt. A feed chute on the hopper distributes the material across the width of the conveyor belt. The feed hopper screw speed is used in conjunction with the conveyor belt speed to control the feed rate and bed depth.

The incinerator conveyor, a tightly woven wire belt, moves the waste material through the insulated heating modules (primary unit) where it is brought to combustion temperature by infrared heating elements. Rotating rakes gently stir the material to ensure adequate mixing and complete burnout. When the material (ash) reaches the discharge end of the furnace, it is cooled with a water spray. The material is then discharged by means of screw conveyors to an ash hopper.

Combustion air is supplied to the primary unit through a series of overfire air ports located at various points along the length of the chamber, and flows countercurrent to the conveyed waste.

Exhaust gases exit the primary chamber near the feed module to a secondary chamber (afterburner), where propane-fired burners are used to ignite any organics present in the exhaust stream, and burn them at a predetermined set-point temperature. Secondary air is supplied to the afterburner to insure adequate excess oxygen levels for complete combustion. Exhaust gases from the secondary chamber then pass through a scrubber type pollution control system to the exhaust stack. The infrared unit is indeed portable and can be mobilized in less than one month.

4.6.2 Thermal Desorption

Incineration is often not considered favorably in a study of alternatives because of perceived high capital cost, high operating cost an high exposure to publicity in the permitting process. The thermal treatment proposed here involves indirect heating in a nitrogen atmosphere in a multipass screw flight dryer. This thermal treatment or thermal desorption may be more acceptable because:

- The capital requirement is moderate
- Operating cost is moderate
- It would not require a RCRA incinerator permit although it would require an air permit and a RCRA permit as a miscellaneous unit pursuant to 40 CFR 264 Part X
- There would be less tendency to volatilize heavy metals

A screw flight dryer is an indirect hollow-screw jacketed-trough thermal dryer for dewatered filter cake. The screw rotates, pushing the material down stream while a heat transfer fluid flows through the screw and jacket, drying the material. The vapors are removed by operating under pressure with an inert gas passed through to carry the vapors away from the discharge end. The vapors are passed through a cyclone to remove entrained soil then to a cooler to condense organics. Non-condensed gas could be recycled to the inert gas stream with a purge stream to a flare or vent. The process is well defined but untried. In order to

proceed along this route without risk, a pilot program should be run to determine rate of throughput, maintenance downtime due to fouling, and optimum operating temperatures. It would take an additional eight months to construct a commercially sized treatment unit if one is not now available.

4.7 SOIL REMEDIATION - SOLVENT EXTRACTION

Resources Conservation Company has a process they refer to as the B.E.S.T. process. They have constructed a modular unit and have successfully operated on oily sludges at a Superfund Site. The process takes advantage of the fact that triethyl amine (TEA) solvent and water are miscible at 50°F and undergo a phase separation at 120°F.

The basic steps in the process are:

- Extraction of oil and water from the solids with TEA at approximately 50°F
- Drying of the solids to remove residual TEA and water
- Heat exchange of the single phase effluent from the contractor to bring about TEA/water phase separation
- Distillation of the decanted water to reduce its TEA concentration
- Distillation of the decanted TEA/oil mixture to recover purified TEA for recycle and produce oil

4.8 SOIL REMEDIATION - BIOLOGICAL DEGRADATION

Heterotrophic bacteria and fungi are the primary agents of decomposition of natural organic matter. Some of these microorganisms have the capability to utilize natural organic compounds - such as petroleum hydrocarbon, phenols, cresols, acetone, and cellulosic wastes - as sources of carbon and energy. These and other naturally-occurring compounds can be converted to carbon dioxide, methane, water, microbial biomass, and by-products that are usually less complex than the parent material. This naturally occurring process is a major component of municipal and industrial water treatment systems.

Microbial communities in soil typically have tremendous potential to degrade a wide range of compounds. The highly successful application of bioremediation to the treatment of gasoline leaks from underground storage tanks is attributable to indigenous microorganisms.

Most biodegradation processes in soil are carried out under aerobic conditions because biodegradation in the presence of oxygen produces more energy and faster pollutant destruction than anaerobic processes. To effect these degradations, microorganisms can induce enzymes to catalyze the transformation of the chemical.

In addition to using pollutants as its primary supply of carbon and energy, a microbial mixture may co-metabolize a pollutant when enzymes used to degrade the primary substrata also catalyze the decomposition of the contaminant.

Anaerobic biodegradation occurs in the absence of oxygen under reducing conditions. In the absence of oxygen, anaerobic microorganisms combine with nitrate, sulfate, or carbon dioxide to yield cell proteins, methane, nitrate or nitrogen, or hydrogen sulfide. Anaerobic processes are slower than aerobic ones, produce less energy, and have not been applied consistently.

Most bioremediation to date has focused on treatment of petroleum hydrocarbons. Many synthetic organic compounds can also be biodegraded or transformed by microorganisms. Biodegradation of chloroaromatic compounds has been studied extensively (Reineke and Knackmuss, 1988). Many were thought to be resistant to biodegradation; however, bacteria able to degrade all but the most complex molecules have been discovered during the last twenty years. Chlorobenzenes are the simplest chloroaromatic compounds and, until recently, were not considered to be biodegradable. Bacteria have been isolated that are capable of growing on chlorobenzene (Reineke and Knackmuss, 1984; Nishino et. al., 1992), 1,4-dichlorobenzene (Schraa et. al., 1986; Spain and Nishino, 1987), 1,3-dichlorobenzene (deBont et. al., 1986), 1,2-dichlorobenzene (Haigler and Spain, 1989), 1,2,4-trichlorobenzene (van der Meer et. al., 1987), and 1,2,4,5-tetrachlorobenzene (Sander et. al., 1991). The metabolic pathways for degradation of the isomeric chlorobenzenes are remarkably similar (Spain, 1990) and lead to mineralization with release of the halogens as hydrochloric acid (HCl). Bacteria able to degrade chlorobenzene may not be ubiquitous; therefore, recently contaminated sites may require extended acclimation periods or inoculation with competent strains. The design of the system must also include the capacity for neutralization of the acid

produced during chlorobenzene degradation if contaminant concentrations are high or if a vapor-phase system is used.

Chlorinated solvents are among the most common contaminants at waste sites and in groundwater. They are so volatile that they are seldom a problem in shallow soil and surface water. When their volatilization from a contaminated matrix is inhibited, they can be very persistent because they are relatively stable and resist biodegradation.

Trichloroethylene was considered inert to bacterial degradation until the discovery that cultures grown on methane (methylotrophs) could also oxidize TCE (Wilson and Wilson, 1985). The initial step in methane degradation is an oxidation catalyzed by methane monoxygenase. The enzyme is very nonspecific and can also catalyze the oxidation of a wide variety of organic compounds.

Reductive dehalogenation is catalyzed by a variety of anaerobic microbial systems. An example is shown in the following equation:

$$CCl_4 \text{ (carbon tetrachloride)} + 2H \rightarrow CHCl_3 \text{ (chloroform)} + HCl$$

Methanogenic systems, the most widely studied, can dehalogenate contaminants ranging from PCBs to tetrachloroethylene. The reactions seem to be specific for certain isomers in some systems. The enzymology of the reactions is poorly understood at present.

Highly chlorinated substrates tend to be more susceptible to reductive dehalogenation than their lower chlorinated analogs. Therefore, tetrachloroethylene is dehalogenated more rapidly than trichloroethylene, which is, in turn, more readily attacked than vinyl chloride.

The following table is presented to depict the relative biodegradability of common contaminants:

CHEMICAL CLASS:	BIODEGRADABILITY STATUS:
Hydrocarbons and Derivatives	
Gasoline, BTEX, fuel oils	Established, aerobic, full-scale
Polycyclic aromatic hydrocarbons, creosote, PCP	Established, aerobic, full-scale
Alcohols, ketones, esters, ethers	Established, aerobic, full-scale
Halogenated Aliphatics	
Highly chlorinated	Developing, co-metabolized by methanotrophs, anaerobic microbes
Less chlorinated	Developing, aerobic
Halogenated Aromatics	
Highly chlorinated	Emerging, aerobic and anaerobic
Less chlorinated	Established, aerobic, pilot scale
Polychlorinated Biphenyls	
Highly chlorinated	Emerging, anaerobic co-metabolism
Less chlorinated	Developing, aerobic, pilot scale
Pesticides	Developing, anaerobic, fungi
Nitroaromatics	Developing, aerobic and anaerobic
Metals	Not generally applicable, although toxicity and mobility may be changed
Dioxins	Not applicable
Legend: Established:	biodegradable and treated full-scale.
Developing:	shown to biodegrade in laboratory and field (pilot studies).
Emerging:	promising results in the laboratory.
Not applicable:	not degraded by known microorganisms.

Landfarming, which involves biological degradation, may be a viable alternative in the study of alternatives because of the large amount of land in the south plant and the time available to achieve degradation. Another option is to biologically degrade organic compounds to below clean up levels in a liquids solids contactor. A liquid solids contractor is an aerobic reactor that uses high speed mixers. The objective is not 100% degradation of organics but rather degradation of objectionable leachable compounds to safe action levels. The residuals would then be treated and/or stabilized by conventional methods to appropriate levels.

EPA's Region 10 has evaluated composting as an ex-situ solid phase biological treatment technology to degrade nitroaromatic and nitramine compounds in soils. Treatability studies at two National Priority List sites — the Umatilla Army Depot Activity site in Hermiston, Oregon and the U.S. Naval Submarine Base site in Bangor, Washington — demonstrate that composting is a treatment alternative to incineration for remediating these compounds.

Composting mixes natural organic amendments, such as manure, wood chips, alfalfa, vegetable processing wastes and cotton gin wastes with 30 to 70 percent contaminated soil and adds water to 50 percent of moisture holding capacity. The process utilizes native aerobic thermophilic microorganisms and requires no inoculation. Composting operates under mesophilic [30 to 35 degrees Centigrade (C)] and thermophilic (50 to 55 degrees C) conditions, with thermophilic conditions being optimum.

Composting residues will support the growth of vegetation after treatment, unlike incineration ash or soils treated by solidification/stabilization. The final volume increase in soil is approximately 50 to 100 percent, similar to stabilization/solidification technologies. Composting is suitable for soils and sludges. Composting does not appear to be particularly sensitive to soil type.

Some pilot effort would be required to optimize the method. VCC is presently conducting a pilot effort in a Temporary Unit. The details of the Temporary Unit and the plans to conduct the pilot effort are described in "Request for Temporary Unit" May 1995.

4.9 SOIL REMEDIATION - SOIL FLUSHING

Soil flushing is the enhanced in situ mobilization of contaminants in a contaminated soil for the purpose of their recovery and treatment. Soil flushing uses water, water enhanced with surfactants or other chemicals, or gaseous mixtures to accelerate one or more geochemical dissolution reactions. The process accelerates a number of subsurface contaminant transport mechanisms that are found in conventional groundwater pumping.

In general, soil flushing is most effective in homogeneous, permeable soils, such as, sands or certain silty sands. The process may be effective also in the recovery of mobile degradation products formed after soil treatment with chemical oxidizing agents and in the

enhancement of oil recovery operations. Effective application of the process requires a sound understanding of the manner in which target contaminants are bound to soils and of hydrogeologic transport. Depending on the matrix, organic, inorganic, and radioactive contaminants are amenable to soil flushing.

The following is a useful table of information to evaluate the effectiveness of soil flushing based on the characteristics of the site and the characteristics of the contaminant:

Critical Success Factor	Units	Success Less Likely	Success Somewhat Likely	Success More Likely
SITE RELATED				
Dominant Contaminant Phase	Phase	Vapor	Liquid	Dissolved
Soil Hydraulic Conductivity	cm/sec.	Low ($<10^{-5}$)	Medium (10^{-5}-10^{-3})	High ($>10^{-3}$)
Soil Surface Area	m^2/kg	High (>1)	Medium (0.1 - 1)	Small (<0.1)
Carbon Content	% Weight	High (>10%)	Medium (1 - 10%)	Small (<1%)
Fractures in Rock	---	Present	---	Absent

Critical Success Factor	Units	Success Less Likely	Success Somewhat Likely	Success More Likely
CONTAMINANT RELATED				
Water solubility	mg/l	Low (<100)	Medium (100 - 1,000)	High (>1,000)
Sorption Characteristics Soil Sorption Constant	l/kg	High (>10,000)	Medium (100 - 10,000)	Low (<100)
Vapor Pressure	mm Hg	High (>100)	Medium (10 - 100)	Low (<10)
Liquid Viscosity	cPoise	High (>20)	Medium (2 - 20)	Low (<2)
Liquid Density	g/cm^3	Low (<1)	Medium (1-2)	High (>2)

In situ soil flushing accelerates the in situ mobilization of contaminants from a contaminated soil for recovery and treatment. Depending on the matrix, organic, inorganic, and radioactive contaminants are amenable to soil flushing.

The process uses water, enhanced water, or gaseous mixtures to accelerate geochemical dissolution such as:

- adsorption/desorption
- acid/base reactions
- solution/precipitation reactions
- oxidation/reduction reactions
- ion pairing or complexation

In addition, soil flushing accelerates a number of subsurface contaminant transport mechanisms that are found in conventional groundwater pumping, including:

- advection
- dispersion, as expressed by the dispersivity coefficient
- molecular diffusion
- depletion via volatilization or solubilization

The fluids can be applied and/or drawn from the groundwater in the immediate area. They can be introduced to the soil either through spraying, surface flooding, subsurface leach field, or subsurface injection.

Once the infiltrated or percolated mixture has flushed the contaminants to a certain location, the contaminated fluids must be recovered. Conventional soil flushing recovery techniques are:

- well-and-capture in the vadose zone; and
- pump and treat systems in the saturated zone.

The treatment system is configured to remove specific contaminants of concern. For organic contaminants, in most cases, the treatment system will consist of air stripping, carbon

adsorption, and/or biological treatment units. For inorganic treatment, the systems will usually include standard precipitation systems, electrochemical exchange, ion exchange, and/or ultrafiltration systems. For many sites, the contaminants of concern will include organics and inorganics in the same waste stream. For these cases, process treatment trains will be configured to provide appropriate removals. In all cases, one of the key concerns, and the primary contributor to long term operation and maintenance, will be the volume and quality of sludge generated from the process treatment system.

Soil flushing generally requires a relatively large volume of water to be flushed through the soil to be effective. Even under favorable soil conditions, at least 10 pore volumes of water is commonly expected to be required.

Soil flushing requires construction and operation of equipment and devices, some of which are subsurface and some of which are aboveground. Relatively high capital costs are required. Relatively high operation and maintenance costs are required.

4.10 SOIL REMEDIATION - SOIL WASHING

Soil washing is an ex situ, water-based process that employs chemical and physical extraction and separation processes to remove organic, inorganic, and radioactive contaminants from soil. It is often employed as a pretreatment process in the reduction of the volume of feedstock for other remediation processes.

The contaminated soil is excavated and staged, pretreated to remove oversized material, and washed with water and, possibly, other cleaning agents to separate and segregate the contaminants. The process recovers a clean soil fraction and concentrates the contaminants in another soil portion.

The principal advantage of soil washing lies in its ability to concentrate contaminants in a residual soil as a pretreatment step, facilitating the application of other remediation processes. In reducing the volume of soil that must be treated, soil washing can reduce the overall cost. Soil washing performance is highly sensitive to site conditions. The process is most effective when applied to soils and sediments containing large proportions of sand and gravel and is relatively ineffective when applied to soils having a high silt and clay content.

Soil washing is an ex situ process employing chemical and physical extraction and separation techniques to remove a broad range of organic, inorganic, and radioactive contaminants from soils. The process entails excavation of the contaminated soil, mechanical screening to remove various oversize materials, separation processes to generate coarse and fine grained fractions, treatment of those fractions (soil washing), and management of the generated residuals. It is a separation and volume reduction process, typically used in conjunction with other technologies. By concentrating the contaminants in a smaller volume for further treatment, it enables more overall cost-effective treatment.

Surficial contaminants are removed through abrasive scouring and scrubbing action in a step using a washwater that is sometimes augmented by surfactants or other agents. The soil is then separated from the spent washing fluid, which carries with it some of the contaminants. The recovered soils consist of a clean, coarse fraction, sands and gravels (>230 mesh or >63 microns (μm)), a contaminated fine fraction, silts and clays (<230 mesh or <63 μm), and a contaminated organic/humic fraction. The contaminated fines typically carry the bulk of the chemical contaminants and generally require further treatment using another remediation process, such as, thermal destruction, thermal desorption, or bioremediation.

Soil washing may be used effectively to treat soils containing a wide variety of organic, inorganic, and radioactive contaminants, including:

- petroleum and fuel residues
- radionuclides
- heavy metals
- polychlorinated biphenyls (PCBs)
- pentachlorophenol (PCP)
- pesticides
- cyanides
- creosote
- semivolatiles
- volatiles

Soil washing is most appropriate for treating noncomplex soils that contain at least 50% sand and gravel, such as, coastal sandy soils and soils with glacial deposits and is relatively

ineffective in treating soils that are rich in clay and silt sized particles. Further, soils with a relatively high cation exchange capacity (the capacity to exchange cations for those in the polluting substance) tend to bind pollutants more tightly, which can limit the ability of the soil washing process to effectively separate the pollutant from the soil.

Studies have shown that soils contaminated with fuel oil, jet fuel, and waste oil from underground tank system releases can be effectively treated by soil washing. Removal efficiencies for residual metals and hydrocarbons of 90 to 98% have been achieved when heat and surfactants are added to the washwater. Although studies have shown that soil washing can be effective in removing gasoline and diesel fuels from soils, thermal desorption, biodegradation, vapor extraction, or other processes may be more effective and appropriate.

Soil washing can be used to remove volatile organic compounds (VOCs) and other materials having a relatively high vapor pressure or water solubility quotient. Removals of 90 to 99% or more of VOCs can be achieved by simple water washing. Removal rates for semivolatile organic materials tend to be lower, on the order of 40 to 90%, and the addition of surfactants to the washwater is often required to aid in the washing and/or separation.

The following table of information shows the general effectiveness of soil washing in removing various types of chemical groups:

		Matrix	
	Contaminant Groups	**Sandy/Gravelly Soils**	**Silty/Clay soils**
Organic	Halogenated volatiles	†	–
	Halogenated semivolatiles	–	–
	Nonhalogenated volatiles	†	–
	Nonhalogenated semivolatiles	–	–
	PCBs	–	–
	Pesticides (halogenated)	–	–
	Dioxins/Furans	–	–

	Contaminant Groups	Matrix	
		Sandy/Gravelly Soils	Silty/Clay soils
Inorganic	Volatiles metals	†	–
	Nonvolatile metals	†	–
	Asbestos	‡	‡
	Radioactive materials	–	–
	Inorganic corrosives	–	–
	Inorganic cyanides	–	–
Reactive	Oxidizer	–	–
	Reducers	–	–

† Good to Excellent Applicability: High probability that technology will be successful
– Moderate to Marginal Applicability: Exercise care in choosing technology
‡ Not Applicable: Expert opinion that technology will not work
Source: U.S. EPA 1990

Site characterization is the first and most important step in determining whether soil washing may be effectively applied. Removal efficiencies are highly dependent on the specific blend of physical and chemical characteristics of the soil and the contaminants and on the spatial distribution of pollutants throughout the soil. Among the extensive data required for site characterization are the site geology and hydrogeology, soil type and composition versus depth, soil chemistry, and variability of contaminants in the soil. It is important to know how the soil type and contaminant concentrations change with latitude and depth in order to develop an accurate profile of the feedstock soil and to guide sampling efforts in collecting representative soils for further characterization and for bench and pilot testing. The following table of information summarizes key soil parameters that should be measured:

Parameter	Purpose and Comment
Key Physical	
Particle Size Distribution:	
>2 mm	Oversize pretreatment requirements
0.25 - 2 mm	Effective soil washing
0.063 - 0.25 mm	Limited soil washing
<0.063 mm	Clay and silt fraction -difficult soil washing
Cation Exchange Capacity	A measure of soils ability to attract and bind pollutants in exchange for naturally occurring ions or elements

Parameter	Purpose and Comment
Other Physical Type, physical form, handling properties Moisture content	Affects pretreatment and transfer requirements Affects pretreatment and transfer requirements
Key Chemical Organics Concentration Volatility	Determine contaminants and assess separation and washing efficiency, hydrophobic interaction, washing fluid compatibility, changes in washing fluid with changes in contaminants. May require preblending for consistent feed.
Partition coefficient	Use the jar test protocol to determine contaminant partitioning
Metals	Concentration and species of constituents (specific jar test) will determine washing fluid compatibility, mobility of metals posttreatment.
Humic acid	Organic content will affect adsorption characteristics of contaminants on soil. Important in marine/wetland sites.
Other Chemical pH, buffering capacity	May affect pretreatment requirements, compatibility with equipment materials of construction, wash fluid compatibility.

Bench and pilot scale tests on representative contaminated soil samples are generally required if the technology appears promising for a site. The tests are used to determine whether soil washing can be used to effectively remove the contaminants and determine the requirements for soil feedstock preparation. In addition, these tests provide the basis for gauging the performance capabilities of commercially available systems at a particular site.

Whether soil washing should be applied depends upon key, individual site characteristics - the soil's mix of contaminants, the soil's unique chemistry which may impact adsorption/desorption, particle size distribution, and specific gravity. For example, it can generally be said that the higher the percentage of sand and gravel in the soil or sediment, the more effective is soil washing. Soil washing can be a very cost-effective, stand-alone soil treatment process and, in addition, can be used as a volume reduction and feedstock preparation step for other more complex soil-treatment technologies. In both cases, residuals from the treatment process must be anticipated and properly managed.

Most commercially available soil washing systems utilize mechanical screening devices to remove oversize material, separation systems to generate coarse and fine grained fractions, treatment units for washing, systems for scrubbing the separated fraction, equipment for rinsing and dewatering, and water treatment and recycling system for water management. The specifications for each system are largely driven by individual site characteristics.

Soil washing involves the use of wet, mechanical scrubbing and screening processes to separate particles that contain contaminants from those that do not. In this sense, it is a volume reduction or pretreatment technology. It exploits the tendency of contaminants to adhere to the organic matter (leaves, roots, and twigs) and the fine grained soil fraction (silt and clay), rather than the coarse grained mineral fraction (sand and gravel). In addition, or, in some cases, alternatively, contaminants may be removed from the soil as a result of being solubilized in the washwater.

Simply stated, soil washing entails the following steps:

- excavation and staging of contaminated soil or sediment
- pretreatment of the soil to remove large objects and oversized clods and material
- washing the soil with water to separate and segregate the contaminants
- recovering a clean soil fraction that can be redeposited on site or otherwise beneficially used
- treating the contaminated washwater and discharge or recycle

The process frees contaminants and concentrates them in a residual portion of the soil (typically 5 to 40% of the original soil, by volume), where the contaminants can be subsequently treated by other remediation techniques. The washwater is treated by conventional wastewater treatment techniques and then recycled.

The soil washing process begins with the excavation and preparation of the feedstock soil. Soil preparation can involve the mechanical screening of the feedstock to remove rocks, debris, and other oversized material. Most soil washing systems cannot accept feed materials that are larger than 50 mm (2 in.) in diameter.

In the second stage, the contaminants are separated and concentrated. This is accomplished primarily through active mixing of the soil with water or an amended water-based washing fluid, separation of the soil from the spent fluid, and recovery of the soil in two distinct fractions. One is a relatively high-volume, coarse sand and gravel fraction (>230 mesh or >63 micron (μm)) that is clean and suitable for use as onsite fill, and the other is usually a smaller volume, fine silt and clay fraction (<230 mesh or <63 μm) that typically carries the bulk of the chemical contaminants. A third fraction, contaminated, naturally occurring organic material, may be separated from the coarse soil fraction by specific gravity separation.

Surficial contamination that is attached to sand and gravel fractions through forces of adhesion and compaction is removed from the coarse fraction by abrasive scouring or scrubbing action. This washing step is sometimes augmented by adding to the washwater a basic leaching agent, surfactant, pH adjustment, or chelating agent (such as ethylene diamine tetra-acetic acid (EDTA)) to help remove organics or heavy metals. After washing, the coarse soil fraction may be rewashed to further remove residual contaminants and washwater additives. The spent washwater and rinsewater are treated to remove the contaminants prior to recycling back to the treatment unit. Fines and wastewater treatment solids are handled separately.

Soil washing will usually not be cost-effective in treating soils having a high percentage of clay and silt (e.g., more than 30 to 50%); high humic content in the soil makes separation of contaminants very difficult. It may be relatively ineffective in treating soils contaminated with a high concentration of mineralized metals or hydrophobic organics. Hydrophobic contaminants can be difficult to separate from soil particles into the aqueous washing fluid. Soil washing costs would be relatively very high.

4.11 SOIL REMEDIATION - DEHALOGENATION

Dehalogenation is an ex situ technology in which an alkaline polyethylene glycol (APEG) reagent is used to dehalogenate halogenated aromatic compounds in a batch reactor. Potassium polyethylene glycol is the most common APEG reagent. Contaminated soils and the reagent are mixed and heated in a treatment vessel. In the APEG process, the reaction causes the polyethylene glycol to replace halogen molecules and render the compound nonhazardous or less toxic, for example, the reaction with chlorinated organics causes replacement of a chlorine molecule and results in a reduction in toxicity. Dehalogenation can be used in combination with other technologies. Treatment of the wastewater generated by the process may include chemical oxidation, biodegradation, carbon adsorption, or precipitation.

The target contaminant groups for glycolate dehalogenation are halogenated SVOCs and pesticides. The technology can be used but may be less effective against selected halogenated VOCs. The technology is amenable to small-scale applications.

Factors that may limit the applicability and effectiveness of the process include:

- The technology is generally not cost-effective for large waste volumes.
- Media water content above 20% requires excessive reagent volume.
- Concentrations of chlorinated organics greater than 5% require large volumes of reagent.

When the technology appears promising for a site, treatability tests should be conducted to identify parameters such as water, alkaline metals, and humus content in the soils; the presence of multiple phases; and total organic halides that could affect processing time and cost.

This technology uses standard equipment. The reaction vessel must be equipped to mix and heat the soil and reagents. A detailed engineering design for continuous feed, full-scale

treatment system is currently complete. It has been estimated that a full-scale system can generally be fabricated and placed in operation in 12 months.

Costs to use APEG treatment, if applicable, are relatively high. Advances are currently being made to the APEG technology. These advances employ water rather than costly polyethylene glycol to wet the soil and require shorter reaction times and less energy. These advances should greatly enhance the economics of the process.

4.12 SOIL REMEDIATION - VITRIFICATION - ABOVEGROUND

Vitrification is a technology that utilizes thermal energy to accomplish stabilization and/or solidification.

Stabilization refers to processes that reduce the risk posed by a waste by converting the contaminants into a less soluble, mobile, or toxic form. The physical nature of the waste is not necessarily changed.

Solidification refers to processes that encapsulate the waste in a monolithic solid of high-structural integrity. The encapsulation may be that of fine waste particles (microencapsulation) or of a large block or container of wastes (macroencapsulation). Solidification does not necessarily involve a chemical interacting between the waste and the solidifying reagents, but may mechanically bind the waste in the monolith. Contaminant migration is restricted by decreasing the surface area exposed to leaching and/or by isolating the waste within an impervious capsule.

Vitrification processes are solidification processes that employ heat to melt and convert waste materials into glass or other glass and crystalline products. Waste materials, such as heavy metals and radionuclides, are actually incorporated into the glass structure which is, generally, a relatively strong, durable material that is resistant to leaching.

Vitrification involves glass formers, stabilizers, and fluxes. Silica is the principal glass former and provides the basic matrix of the vitrified product. In waste management, silicates and borosilicates are used. Fluxes, primarily sodium oxide that generally exist within the waste material, reduce the melting temperature and, when molten, increase electrical

conductivity, thereby enhancing process efficiency. Stabilizers are employed to increase the durability of the glass and to decrease the conductivity of the molten pool.

The high temperatures employed, 1,200°C or higher, cause the glass formers, fluxes, stabilizers, and wastes to melt together to form a glass matrix. The high temperatures also destroy any organic constituents with very few byproducts, which are treated with an offgas treatment system that generally accompanies the vitrification processes. There are three basic technology variations that differ in the kind of heating employed - electrical processes, thermal processes, and plasma systems.

The process results in a relatively strong and durable material that is capable of lasting for thousands of years.

Vitrification products are commonly composed of oxides that can be classified into one of three primary groups: 1) glass formers, 2) stabilizers, and 3) fluxes (Tooley, 1974).

For most glasses, the principal glass-forming constituent is silica (SiO_2)(U.S. EPA, 1992b). Glass formers provide the basic silicon-oxygen tetrahedron matrix of vitrified products. Other glass formers such as phosphates and borates exist, but waste remediation technologies are generally limited to silicate and borosilicate glasses.

Fluxes reduce the melting temperature and viscosity of the oxides within the glass matrix, as well as increase the electrical conductivity of glasses when molten. Therefore, fluxes become important to the processibility of the vitrified product, especially for electrically heated vitrification processes. The primary flux constituent is sodium oxide (Na_2O), but the flux can also contain potassium oxide (K_2O), lithium oxide, and other alkaline oxide chemicals. Fluxes can be added in more common chemical forms, such as soda ash (Na_2CO_3), and be allowed to decompose to their oxide form during processing. They can also be added in chemical forms that include glass formers, such as sodium silicate (Na_2SiO_3).

Stabilizers are most responsible for increasing the durability and decreasing the electrical conductivity of molten glasses. The primary constituents stabilizers are calcium oxides (CaO) and other alkaline earth oxides. Alumina (Al_2O_3) can also act as a modifier. Stanek (1977)

shows the relative impact of stabilizers on electrical conductivity in relation to other constituents.

When heated, the constituents decompose to their oxide form, fuse, and melt together to form a glass matrix. For example, in a simple system, the fusion of SiO_2 and Na_2CO_3 occurs when Na_2CO_3 decomposes to form Na_2O and CO_2, and Na_2O fluxes with SiO_2 to form a melt at less than the melting temperature of SiO_2. The sodium interferes with some of the silicon-oxygen-silicon bonds, thus disrupting the polymerization of units of tetrahedral structure of SiO_2 and reducing the melting temperature and viscosity of the mixture. Similarly, the addition of a stabilizer, such as CaO, can lower the melting point, yet maintain the durability of the glass (U.S. EPA, 1992b).

In most vitrification processes, the glass product can be designed with specific compositions in order to obtain specific physical and chemical properties. Waste constituents, such as lead or chromium, also enter into the formation of the glass product. These constituents can act as glass formers, replacing silica in the structure or acting as stabilizers and fluxes and interfering with the bonds of silicon and oxygen ions. Consequently, the waste constituents become part of the glass, making them more resistant to chemical attack than if they were merely encapsulated within the glass.

The high temperature of the vitrification process also destroys organic constituents. Most vitrification processes operate at 1,200°C (2,200°F) or higher, a temperature capable of destroying any organic contaminant. The organic contaminants decompose into carbon dioxide (CO_2), water (H_2O), and hydrogen chloride (HCl) when interacted with oxygen as the gases exit the vitrification process.

Problems with implementation are associated with the water and organics within the soil and the control of the release of the vapor stream. The high operating temperatures and the rapidity with which wastes must reach the temperatures can cause uncontrollable rapid creation of vapor streams. Vitrification is a process that has virtue for incinerator fly ash, soils contaminated mostly with heavy metals and radioactive wastes.

4.13 SOIL REMEDIATION - EXCAVATION AND OFFSITE DISPOSAL

This alternative technology assumes that contaminated soil is excavated and transported offsite for disposal.

Since it is assumed that there would be no offsite treatment and only disposal in a RCRA landfill, there is no incremental increase in effectiveness over retaining material onsite. In particular there is a decrease in effectiveness over treating some of the contaminated soil onsite.

The capital cost of excavation, transportation and offsite disposal would be relatively very high.

This alternative would require excavation and transportation offsite of thousands of truck loads of soil. This amount of activity would be highly disruptive onsite and would create short term environmental and safety concerns. The offsite traffic flow would cause additional safety problems. Additionally disposal is not a permanent solution as compared to some of the alternatives that treat or destroy constituents.