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Vicksburg Chemical Company

Dr. Judy Sophianopoulos
Waste Compliance Section
RCRA & FF Branch
U.S. EPA, Region IV
Mailcode 4DW-RCRA
61 Forsyth Street, SW
Atlanta, Georgia 30303

Re: Cedar Chemical Company
Consent Decree Civil Number W92-0008B
SWMU #11, 12 and 15 Interim Revised Corrective Measures Plan

November 21, 2000

Dear Dr. Sophianopoulos:

Please find with this letter a Revised Interim Corrective Measures Plan for the above mentioned SWMUs. This plan envisions a clean-up level for arsenic of 20 mg/kg which is above the Tier I TRG levels set in the Mississippi Brownfields guidance.

The Tier I TRG levels for arsenic are less than one-half mg/kg for un-restricted use and 3.8 mg/kg for restricted use. Both of these levels appear to be below local arsenic levels in this area of Mississippi. As might be imagined, selection of either level increases the volume of material to be remediated substantially and costs to remediate escalate in the same fashion. It may be productive to have an informal discussion with your office and MSDEQ concerning these levels.

Please contact me with any questions there may be concerning this matter.

Sincerely,

Steven T. Boswell
Director of Env. Affairs

STB: pc

xc: Mr. Yoked
Mr. Keen
Mr. Mills, MSDEQ
Mr. Karkkainen, URS-Greiner

P.O. Box 821003 • Vicksburg, MS 39182
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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

Prepared for
Vicksburg Chemical Company
Vicksburg, Mississippi

November 2000

File No. 35092B007C.00-03010

URS Corporation
2822 O'Neal Lane
Baton Rouge, Louisiana 70816
225/751-1873

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ATTACHMENTS

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ATTACHMENTS

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
URS	URS Corporation

1.1 PURPOSE AND ORGANIZATION OF REPORT

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.

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. The tasks include the Preliminary Report, the RFI Work Plan, the Facility Investigation, and the Investigative Analysis Reports (RFI Report). 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.

Additionally, VCC has published documents describing expedited investigative and corrective action activity at various SWMUs. The activity was expedited because of VCC's plans to construct new manufacturing facilities and also utilize some of the SWMU areas for storage, transportation, or other related activity. The following is a tabulation of the publications:

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 ACTIVITY			
Report	**Date**	**Status**	**Comment**
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	Under Review (modified 12-16-99)	Incorporated investigative phase of "Closure Plan SWMUs 1 and 17".
GWA Work Plan Entire Site	June 1996	Under Review (modified 12-16-99)	--
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	--
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.
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	--
RCRA Facility Investigation SWMU 2 – Inactive Landfill Interim Report	October, 2000	Submitted	--

This document is the Interim Revised Corrective Measures Implementation Plan (CMIP). It is based on the RFI Report SWMUs 12, 11 and 15 (April 1998) and a Corrective Measures Study (CMS) (June 1997). The CMS is adopted by reference. The RFI Report describes the activities and the results of analyses of samples obtained during the execution of the RFI Work Plan SWMUs 12, 11 and 15 (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.

The North Plant, in operation since 1961, 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 active operations at the South Plant are a nitric acid unit constructed in 1986, a potassium carbonate (Kcarb) plant constructed in 1995, a phosphate fertilizer plant constructed in 1998, and a multi coat plant constructed in 1999. The manufactured nitric acid is used primarily in the North Plant as a raw material. The potassium carbonate and phosphate fertilizer are commercial products. The multi coat plant coats blended fertilizer to allow slow release in use. 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 submitted in April 1998. 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; see Section 2.1.3 for a discussion of background concentration of arsenic) 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-A.

- All of the drainage systems and sumps (including sump "A" and the sulfur pit) 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 100 cubic yards.

- Wipe samples show arsenic contamination of structural beams, corrugated fiberglass wells and steel floors.

- There is a plume of arsenic contamination in the uppermost aquifer from the MSMA site extending generally to the southeast. An estimate of the concentration plume is presented in Figure 1A. A potentiometric contour map and various geologic contours are presented as Figures 2 through 7. 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 (MW-1A, MW-8, MW-9 and MW-12) exhibit detection of trace concentrations of arsenic. The arsenic contamination in wells MW-1A, MW-8, MW-9 and MW-12 may be due to background concentrations of arsenic in soil, however, that has not yet been established.

2.1 CORRECTIVE ACTION OBJECTIVES

2.1.1 Target Remediation Goals for Soil

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 interim 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. 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 based in part on the values presented in the Mississippi Brownfields Voluntary Cleanup and Redevelopment (Brownfields) Program Tier 1 Target Remediation Goal (TRG) Tables.

Constituent	Concentration in Soil (ppb)	
	Restricted	Unrestricted
Dinoseb	204,000	78,200
Arsenic[1]	3,800	426
Toxaphene	5,200	581
Atrazine	25,800	2,880
Toluene	38,000	38,000

NOTES:

[1] See discussion presented below in Section 2.1.3 on background concentration of arsenic.

2.1.2 Target Remediation Goals for Groundwater

The Interim CMIP is directed at soil and concrete. In order to achieve "clean" closure the groundwater would also need to be addressed. It is proposed with the Interim CMIP that the source of contamination be removed. The groundwater will then be monitored and adequately assessed in the Site Wide Groundwater Assessment to define the extent of the arsenic plume. Remedies, as needed, would be proposed after adequate assessment. The following are values for the same constituents noted above in groundwater as obtained from the Tier 1 TRG Tables:

Constituent	Concentration in Groundwater (ppb)
Dinoseb	7
Arsenic	50
Toxaphene	3
Atrazine	3
Toluene	1,000

2.1.3 Background Concentrations of Arsenic in Soil

The concentration of arsenic in the soil at the Vicksburg site presents an interesting challenge. There is obvious arsenic contamination in the SWMU 11, 12 and 15 area caused during the manufacture of MSMA. It is not obvious, however, how to establish a clean up level. The background level of arsenic on the site is variable, but does exceed the values presented in the MSDEQ Tier 1 TRG Table. This discussion of the literature values on background concentrations of arsenic and the background data obtained attempts to clarify the challenge.

The EPA Region 9 has published remediation goals in a program that is in concept similar to the MDEQ Brownfields Program. In the "Region 9 Preliminary Remediation Goals (PRGs) for 1998", background concentrations are addressed as follows:

> "Before embarking on an extensive sampling and analysis program to determine local background concentrations in the area, one should first compile existing data on the subject. Far too often, there is pertinent information in the literature that gets ignored, resulting in needless expenditures of time and money. An illustrative example of this is naturally occurring arsenic in soils which frequently is higher than the risk-based PRG set at one-in-one-million cancer risk (PRG for residential soils is 0.38 mg/kg):

BACKGROUND CONCENTRATIONS OF SELECTED ELEMENTS IN SOILS						
Trace Element	U.S. Study Data[1]			California Data[2]		
	Range	GeoMean	ArMean	Range	GeoMean	ArMean
Arsenic	<.1-97	5.2 mg/kg	7.2 mg/kg	0.59-11	2.75 mg/kg	3.54 mg/kg
Beryllium	<1-15	0.63 mg/kg	0.92 mg/kg	0.10-2.7	1.14 mg/kg	1.28 mg/kg
Cadmium	<1-10	--	<1	0.05-1.7	0.26 mg/kg	0.36 mg/kg
Chromium	1-2000	37	54	23-1579	76.25 mg/kg	122.08 mg/kg
Nickel	<5-700	13	19	9.0-509	35.75 mg/kg	56.60 mg/kg

[1] Shackle and Hansford, "Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States", USGS Professional Paper 1270, 1984.

[2] Bradford et al, "Background Concentrations of Trace and Major Elements in California Soils", Kearney Foundation Special Report, UC-Riverside and CAL-EPA DTSC, March 1996.

Where anthropogenic "background" levels exceed PRGs and EPA has determined that a response is necessary and feasible, EPA's goals will be to develop a comprehensive response to the widespread contamination. This will often require coordination with different authorities that have jurisdiction over the sources of contamination in the area.

After considering background concentrations in a local area, EPA Region 9 has at times used the non-cancer PRG for arsenic (22 mg/kg) to evaluate sites recognizing that this value tends to be above background levels yet still falls within the range of soil concentrations (0.38-38 mg/kg) that equate the EPA's "permissible" cancer risk (10E-6 to 10E-4)."

The table above that presents the background concentrations of selected elements in soils references "Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States", Shackle and Hansford, USGS Professional Paper 1270, 1984. On page 14 of that reference, a map depicts the location of the arsenic data points. The four points that are nearest the Vicksburg site range from 4.1 to 97 ppm arsenic. The 97 ppm in the highest value reported in the USGS study.

Examination of on site data indicates that there is a variation in the background concentration within the Vicksburg site itself. Two sampling episodes help establish that hypothesis. Six samples were obtained by URS in 1997 to help determine the background concentration of arsenic. The samples were obtained in an area in back of the administration building in the north plant and west of the plant site in the employee picnic area. The samples ware reported on the "B" samples on page 27 of the "Expedited RCRA Facility Investigation Report SWMUs 16, 1 and 17", June 1997.

The following are the statistical procedures which were used in evaluation of the background sampling results:

- The arithmetic mean is:

$$\overline{X} = \sum_{i=1}^{n} = 9.7\ ppm$$

where n is the number of background soil samples and X_I is the detected amount of the compound in each sample.

- The standard deviation of the sample, S, is:

$$S = \sqrt{\sum_{i-1}^{n} \frac{(X_i - \overline{X})^2}{n-1}}$$

- The upper 95 percent confidence limit (UCL) for the Student's t distribution was determined using the sample arithmetic mean, the sample standard deviation, and $t_{(n-1, 0.025)}$. The value for $t_{(n-1,0.025)}$ was obtained from a standard percentile table for the Student's t distribution. For six background samples $t_{(5, 0.025)} = 2.571$. The UCL was determined from these values:

$$UCL = \overline{X} + t_{(n-1, 0.025)} \frac{S}{\sqrt{n}} = 11.8 ppm$$

As the second sampling episode of note, 17 soil samples were obtained within the SWMU 2 Hill Area. Depth of the samples ranged from two feet below surface to nearly 40 feet below surface. Even though this area was used as a landfill, its use and initial closure and capping predates the production of arsenic based pesticides. Analysis of the soil revealed that arsenic did not exceed 4.46 ppm. The arithmetic mean is 2.02 ppm.

Based on the EPA practice in California, the wide range of values near Vicksburg presented in the USGS study and the variation of background sample concentrations found or the Vicksburg site it is suggested that a clean up value of 20,000 ppb be established for arsenic. Although this is higher than values obtained while attempting to determine by sampling and analysis the background, it does parallel the EPA practice in California.

2.2 APPROACH

The approach to corrective action consists of the following course of action:

- Excavate and dispose offsite approximately 3,500 cubic yards of soil and asphalt contaminated by greater than 20,000 ppb arsenic. After treatment, the soil is not hazardous by characteristic. Prior to treatment some of the material may be hazardous by characteristic. Treatment consists of

solidification/stabilization. A delineation of the excavation area is depicted on Figure 1-A;

- Clean excavated concrete of soil contaminated with arsenic and use for erosion control at the VCC site. The concrete is not hazardous by listing or characteristic;
- Backfill the excavation;
- Clean or demolish all the drainage systems and sumps; and
- Monitor for airborne arsenic during excavation.

The corrective measures are discussed in Section 3.0 "Corrective Measures Conceptual Design".

2.3 PROJECT MANAGEMENT PLAN

The Project Management Plan consists of the following elements:

- Project task definition; and
- Specific personnel positions within the project organizational structure.

2.3.1 Project Task Definition

For the corrective measures, VCC has retained the services of URS as an independent engineering firm to develop the CMIP. URS will provide construction management services, to the extent necessary, inspection and monitoring to implement the CMIP. VCC will provide internal implementation supplemented by construction contractors. The 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 are met.

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. URS will act as VCC's agent for that assistance provided for in the implementation of the CMIP.

2.3.1.3 URS Corrective Measures Task Manager

The URS Task Manager will develop the plans and oversee remediation work implementing the CMIP on behalf of VCC. The URS CMIP Task Manager is Mr. Richard D. Karkkainen. He is also the URS Project Manager to handle day to day coordination and administration.

2.3.1.4 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 URS' 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 URS 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, and the corporate health and safety officer in response to additional information obtained regarding the potential hazards to field personnel.

3.1 REQUIRED ACTIVITY

The required activity is to deal with corrective measures by incorporating elements of the following for each remediation area, as necessary and appropriate:

- Excavate and dispose offsite 3,500 cubic yards of material. The soil and asphalt would be solidified, stabilized onsite prior to landfilling offsite.
- Remove arsenic contaminated soil from concrete that is excavated. Use the concrete for erosion control within the VCC site.
- Backfill the excavation.
- Clean all the drainage systems and sumps. During the excavation noted above some portions of the system may be removed.
- Monitor for airborne arsenic.

The following are discussions of the excavation and backfill activities (Section 3.2), the treatment process (Section 3.3), and the air monitoring (Section 3.4).

3.2 EXCAVATION AND BACKFILL

Approximately 3,500 cubic yards of material will be excavated. The material will be excavated in sections approximately 100 cubic yards in volume. Any concrete excavated will be cleaned of soil and removed from the immediate site and placed on the VCC site for erosion control. The soil and asphalt will be treated by solidification/stabilization as described in the following paragraphs and in Section 3.3. The objective is to accomplish the tasks efficiently but not necessarily quickly. Spread of soil by erosion or air during excavation must be avoided. The rate of excavation must not exceed the rate of treating the soil, curing the treated soil, and transporting it to offsite disposal.

In the following discussion, treatment will occur in batches. Each batch will roughly conform in volume to the following:

100 cubic yards soil
10 cubic yards fly ash or kiln dust
4,800 gallons water
55 gallons ferrous sulfate

The following steps describe the sequence of construction. Refer to Figure 1-A to understand the locations of the areas (Mixing Basins A & B, Sections I - IV) described.

1.0 Execute 35' x 30' x 4' for temporary Mixing Basin A

- If there is dusting during excavation, wet the soil.
- Separate concrete from soil and clean concrete with a hydroblaster. Collect water in Basin A. Pump water from Basin A to portable 6,000 gallon storage tank.
- Haul cleaned concrete to storage yard for erosion control material.
- Cover the soil with a tarpaulin.

2.0 Place 10 cubic yards fly ash or kiln dust in Mixing Basin A.

3.0 Mix 4,800 gallons water with 55 gallons ferrous sulfate in the portable 6,000 gallon storage tank.

4.0 Excavate Section I (approximately 100 cubic yards of soil).

- If there is dusting during excavation, wet the soil.
- Separate concrete from soil and clean concrete with a hydroblaster.
- Haul cleaned concrete to storage yard for erosion control material.
- Place the soil in Mixing Basin A.

5.0 Mix the soil and fly ash/kiln dust with a back hoe.

- Add 4,800 gallons water mixed with the ferrous sulfate from the portable storage tank.
- Continue mixing with back hoe.
- Pump the slurry to the Section I area for curing. Allow the material to cure for two days. Perform TCLP extraction on a sample and test the

extract for arsenic. When test results show arsenic less than 5 ppm ship treated soil offsite.

6.0 Execute Steps 2.0 and 3.0.

7.0 Add the stockpiled soil excavated to create Mixing Basin A back to Mixing Basin A.

8.0 Execute Steps 5.0, 2.0 and 3.0.

9.0 Excavate Section II (approximately 100 cubic yards soil, including that in the drains, Sump A and the Sulfur Pit) as noted in Step 4.0.

10.0 Execute Steps 5.0, 2.0, and 3.0.

11.0 Backfill Section II after QA verification samples are obtained and analyzed.

12.0 Excavate Section III as noted in Step 4.0.

13.0 Execute Steps 5.0, 2.0 and 3.0.

14.0 Backfill Section III after QA verification samples are obtained and analyzed.

15.0 Excavate Section IV as noted in Step 4.0, but do so in 3 increments (each increment approximately 100 cubic yards soil). This excavation is Mixing Basin B.

16.0 Execute Steps 5.0, 2.0, and 3.0 between each increment.

17.0 Excavate to 4 feet within Section V, as noted in Step 4.0, but do so in 6 increments (each increment approximately 100 cubic yards soil).

18.0 Execute Steps 5.0, 2.0 and 3.0 between each increment.

19.0 Excavate to 8 feet within Section V as noted in Step 4.0 from the same 6 increments and also Mixing Basin A.

20.0 Execute steps 5.0, 2.0 and 3.0 between each increment.

21.0 Begin backfilling Section V after QA verification samples are obtained and analyzed.

3.3 THE TREATMENT PROCESS

The arsenic contaminated soil that is excavated will 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

Kinds of Wastes	Stabilization/Solidification Process
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)
(Specific process variation dependent) metal-containing wastes, auto shredder fluff, incinerator-bottom ash, 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 B.

The optimum mix (by weight) proposed from the study consists of the following:

- 100 parts waste;
- 9 parts cement plus 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 has been tested for VCC by two remediation contractors. Stabilized samples were sent for Toxicity Characteristics Leaching Procedure and analysis of arsenic. The samples passed. The mix used in the field will vary somewhat from the mix noted, because structural stability afforded by the cement is not needed for offsite disposal.

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/or fly ash cement and/or kiln dust to the waste and mix as thoroughly as possible.
- 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.
- Transport the waste to the final repository.

3.4 AIR MONITORING

During modified Level D field activities, 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. The following table lists air monitoring action levels for Level D and C work.

AIR MONITORING ACTION LEVELS FOR LEVEL C AND D WORK			
Contaminant	**Instrument**	**Reading**	**Action Taken**
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

NOTES:

* Sustained reading above background (for 15 minutes continuous) which shall not be exceeded within worker breathing zones or exclusion zones.

** Mounted at breathing zone elevations down wind and immediately adjacent to work zone.

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, and 3.3 - a discussion of the required construction sequence of events and the treatment processes to be utilized for arsenic contaminated soil.

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 is based on 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 degree of certainty, that the construction activity encompassed by the CMIP will meet 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

URS will be retained by VCC to provide quality assurance services. Personnel described below will be utilized:

- The Project Manager is the official representative of URS and will report to the VCC Project Director. He will function as an agent of VCC to manage schedule and budget.

- The CQA Officer will have day to day responsibility for quality assurance monitoring, inspection, and testing and will report to the Project Manager or may be 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 activity
  - 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

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 CQA 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 are understood and to review material and equipment storage locations

Progress Meetings are typically held 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
- Review monitoring and inspection activities and test results

- Define and discuss any 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
- Set up and maintain air monitoring

The work described in these sections will be conducted as part of the CQA 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 for Excavation

The corrective action excavation that is required is discussed in Section 3. During the corrective action, sampling and analysis will take place. Verification sampling and analysis is to take place in order to provide assurance that the Corrective Action Objectives, that of remaining soil have a concentration of arsenic less than 20,000 ppb, is 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 total arsenic.
Four samples. One per color shaded area in Figure 1-A.	Obtain the four samples from composite samples selected for total arsenic analysis.	Analyze TCLP extract for total arsenic.

The above noted verification sampling is for extent of contamination. Therefore, if the result of a verification sample does not meet the Corrective Action Objective (total arsenic less than 20,000 ppb) 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 that the TCLP extract from the waste to be transported offsite be less than 5,000 ppb total arsenic.

The solidified/stabilized arsenic waste will be tested for:

- TCLP arsenic

The treatment will take place in an excavation where mixing with a backhoe will blend contaminated arsenic soil with reagents. Further homogenization and blending will occur as the mixer is pumped with a chopper/slurry pump to the curing pile. The treatment capacity is performed in batches of 100 cubic yards.

Samples will be taken for TCLP extraction on the basis of one sample per one-half days production or 500 cubic yards, whichever is less.

4.2.4.3 Air Monitoring Quality Assurance

During modified Level D excavation activities, 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. The CQA Officer will setup a personal sampling pump downwind and adjacent to the excavation. The pump will be set at a flow rate of 2 liters per minute. Samples will be collected on 0.8 micrometer pore size filters (37 mm diameter). The samples will be analyzed for arsenic and the breathing zone exposure determined. If determination is less than 5 micrograms per cubic meter of air, the work will continue unabated. If the reading is greater than 5 micrograms per cubic meter of air revise construction procedures to avoid the generation of dust and upgrade to Level C. If the revisions are successful and a subsequent determination is made that the reading is less than 5 micrograms per cubic meter of air, then work may proceed at Modified Level D. Modifications to construction should be made until readings are reduced to less than 5 micrograms per cubic meter of air.

4.2.4.4 Backfill Quality Assurance

Assurance that backfill is in accordance with the plans shall be accomplished by the use of construction quality evaluation.

Construction quality evaluation shall be performed on all components of the construction. These evaluations will become part of the CQA program. Construction evaluation testing shall include visual observations of the work. 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.

4.2.5 Documentation

The CQA Officer will document activities associated with the excavation, verification testing, solidification/stabilization, and backfilling 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, weekly reports of construction activities, and a final summary technical report on the construction project.

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 CQA Report

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 CQA Report will provide an evaluation of the construction project. The report will certify the results of the various field tests and laboratory tests performed and assess whether or not the constructed project is in compliance with the plans and specifications.

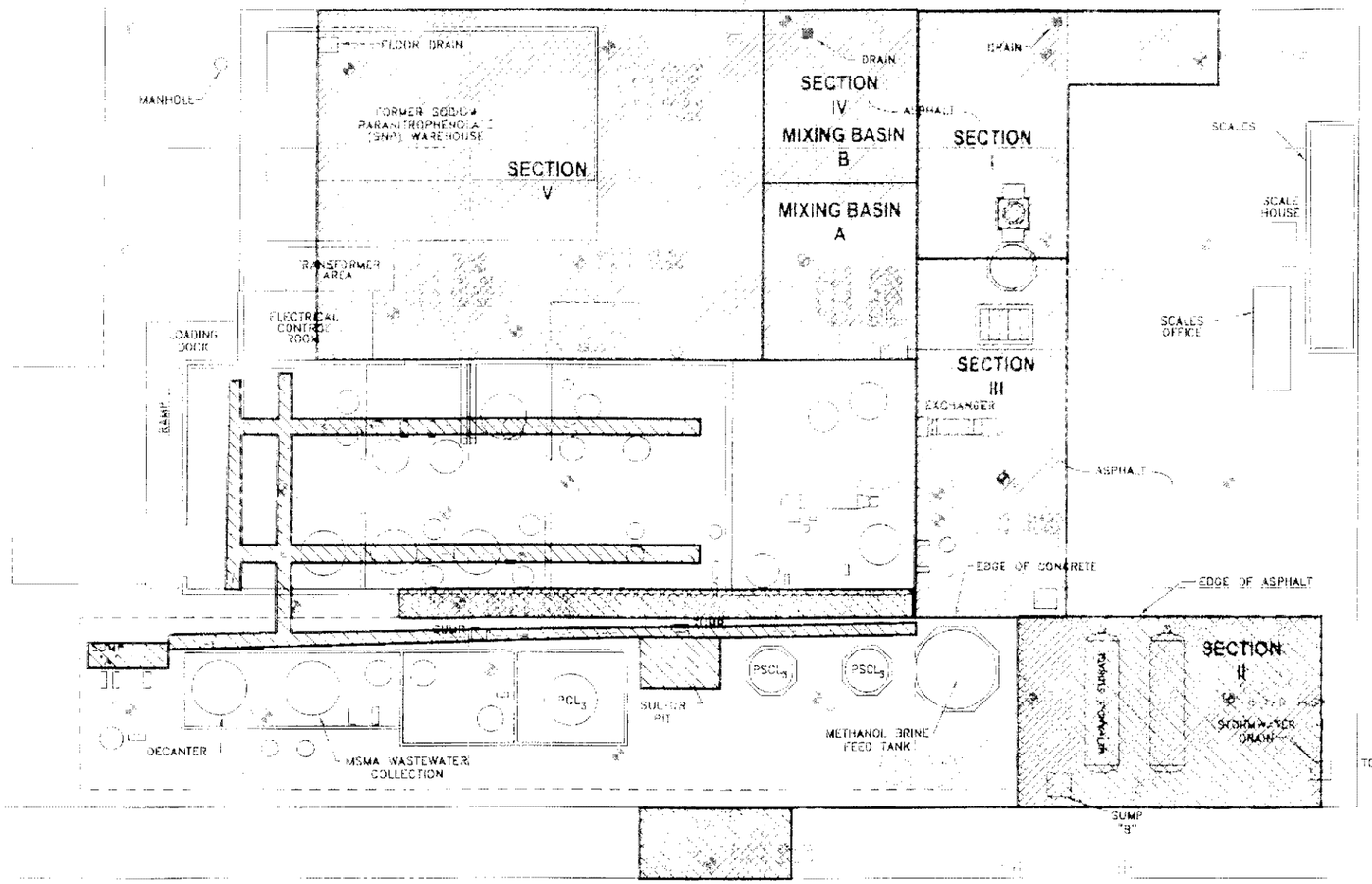
4.3 PROJECT SCHEDULE

The proposed schedule for the project, noted as a deadline for completion of each item, is as follows:

- January 15, 2001 – U.S. EPA and MSDEQ approve Interim Revised Corrective Measures Implementation Plan
- February 15, 2001 – Issue bid documents to prospective contractors.
- March 15, 2001 – Hold bid walk.
- April 15, 2001 – Evaluate bids
- May 15, 2001 – Mobilize for construction
- July 30, 2001 - Demobilize

The proposed schedule is heavily dependent on two variables:

- Agency approval
- Weather during the construction period.



APPROXIMATE
SCALE: 1 INCH = 30 FEET

30' 0 30'

N

LEGEND

SYMBOL OF SAMPLE LOCATION	ANALYTE LIST	DESCRIPTION	NUMBER OF SAMPLE LOCATIONS	NUMBER OF SAMPLES
	SEE FIGURE 2			
*	SEE FIGURE 2			
*	5	CONCRETE OR ASPHALT AND/OR SOIL (ARSENIC ONLY)	9	25 SOIL 9 WATER
*	5	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:
5 = 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:
5 = ARSENIC

* DID NOT PENETRATE CONCRETE AT FOLLOWING:

LOCATION	CONCRETE DEPTH EXCEEDS (FROM GROUND SURFACE)
A	55 INCHES
N	16 INCHES
FF	28 INCHES
YY	28 INCHES

* SECOND CONCRETE FOUNDATION AT 24" AT LOCATIONS [illegible]
* DID NOT PENETRATE RUBBLE BENEATH ASPHALT AT LOCATION 5 & 6
* TWO CONCRETE CORES ANALYZED AT LOCATION 4 (0'-8" & 8"-58")
* FIVE WIPE SAMPLES OF SUPERSTRUCTURE ANALYZED FOR ARSENIC (LOCATIONS NOT NOTED, SEE WRITTEN TEXT OF REPORT)
* EXCAVATE TO 0.5 FT
* EXCAVATE TO 4 FT
* EXCAVATE TO 2 FT
* EXCAVATE TO 1 FT
* [illegible] SECTION II

REV	DESCRIPTION OF REVISION	BY	DATE
△			
△			
△			
△			
△			

VICKSBURG CHEMICAL
VICKSBURG, MISSISSIPPI

URS
2822 O'Neal Lane
Baton Rouge, Louisiana 70816
225/751-1873

REFERENCE DRAWINGS

SCALE: 1"=30'
DESIGNED
DRAWN: PCG
CHECKED
PEER REVIEWED
DATE: 9/5/03

SWMUs 11, 12, & 15 EXCAVATION AREAS

EXCAVATION AREAS BY SECTION

REVISION △
PROJECT 35092B007C
FIGURE 1-A

VICKSBURG CHEMICAL
VICKSBURG, MISSISSIPPI

Woodward-Clyde Consultants
Engineering & Scientific Applied to the Earth & its Environment
2811 Fleur Drive
Baton Rouge, Louisiana 70813

AS SHOWN

GAT

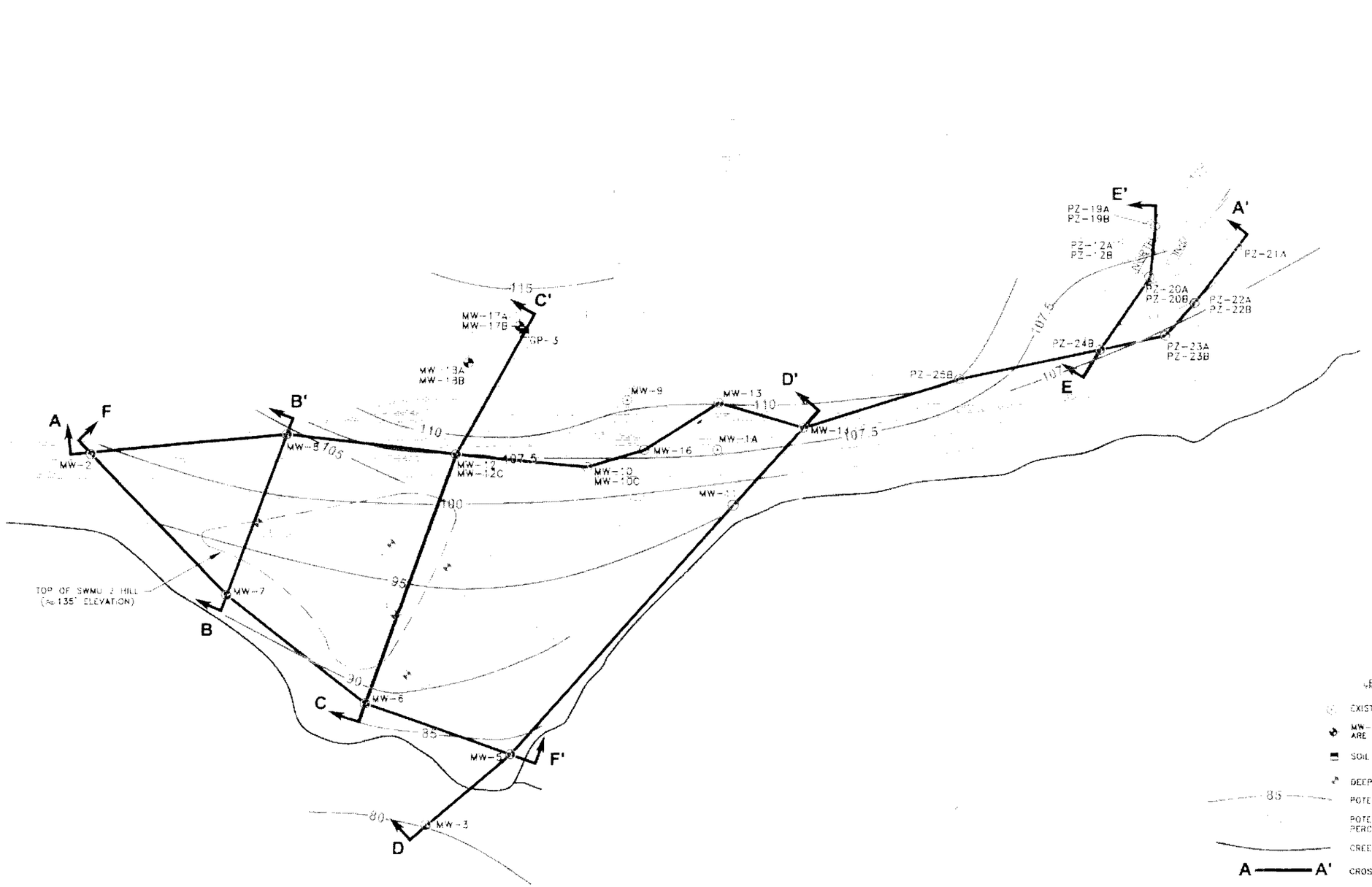
RDK

2/13/88

SWMU 11, 12, 13 EXPECTED RI - ESTIMATE OF GROUNDWATER PLUME

PHASE I GROUNDWATER SAMPLING
ARSENIC CONCENTRATIONS (ug/l)
NOTED ON SAMPLING BASE MAP

1B



REV.	DESCRIPTION OF REVISION	BY	DATE
1	ADD SWMU 2 BORINGS	PDG	8/17/00

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VICKSBURG, MISSISSIPPI

URS
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Baton Rouge, Louisiana 70816
225/751-1873

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SCALE: 1"=300'
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DRAWN: PDG
CHECKED
PEER REVIEWED
DATE: 8/17/00

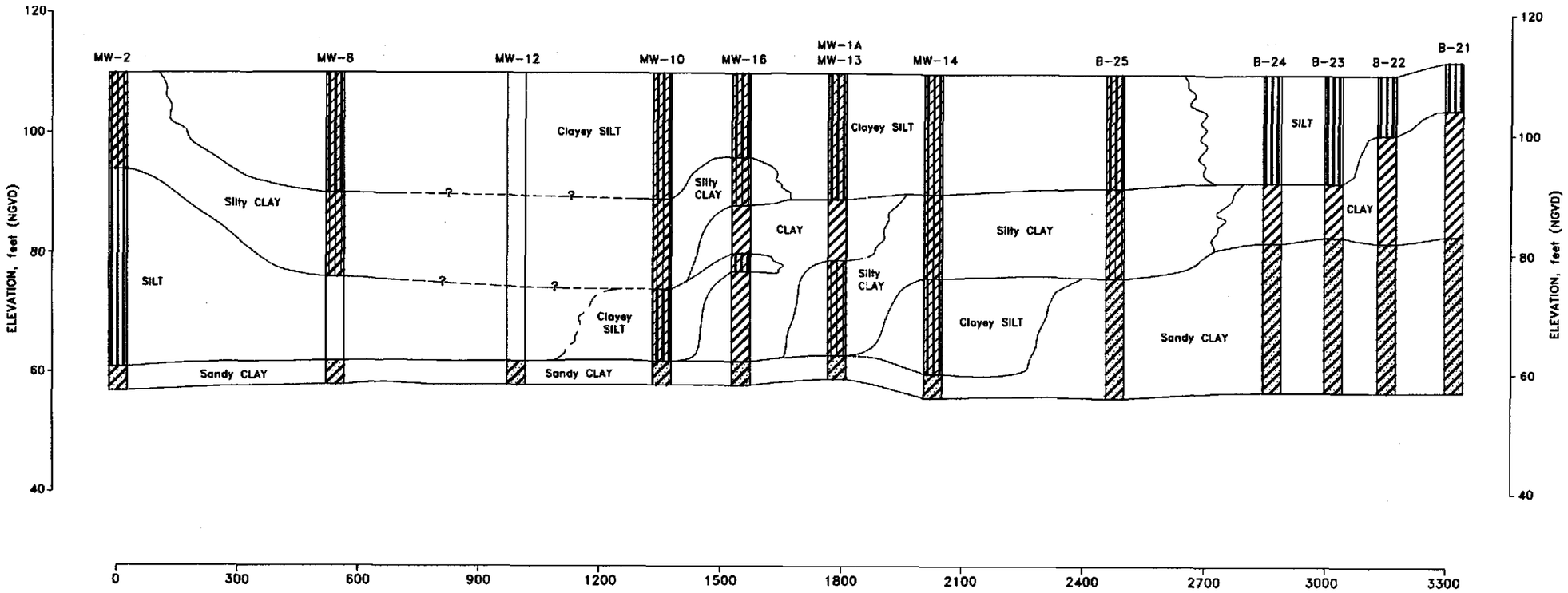
SWMU 2 REPORT

POTENTIOMETRIC CONTOURS
WITH CROSS SECTION LOCATIONS

REVISION: 1
PROJECT: 35092B007C
FIGURE: 2

A
WEST

A'
EAST



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Baton Rouge, Louisiana 70816
225/751-1873

REFERENCE DRAWINGS

SCALE: AS SHOWN
DESIGNED:
DRAWN: PCG
CHECKED: RDR
PEER REVIEWED:
DATE: 8/18/00

SWMU 2 REPORT

CROSS-SECTION A-A'

REVISION: △
PROJECT: 3596B007C
FIGURE: 3

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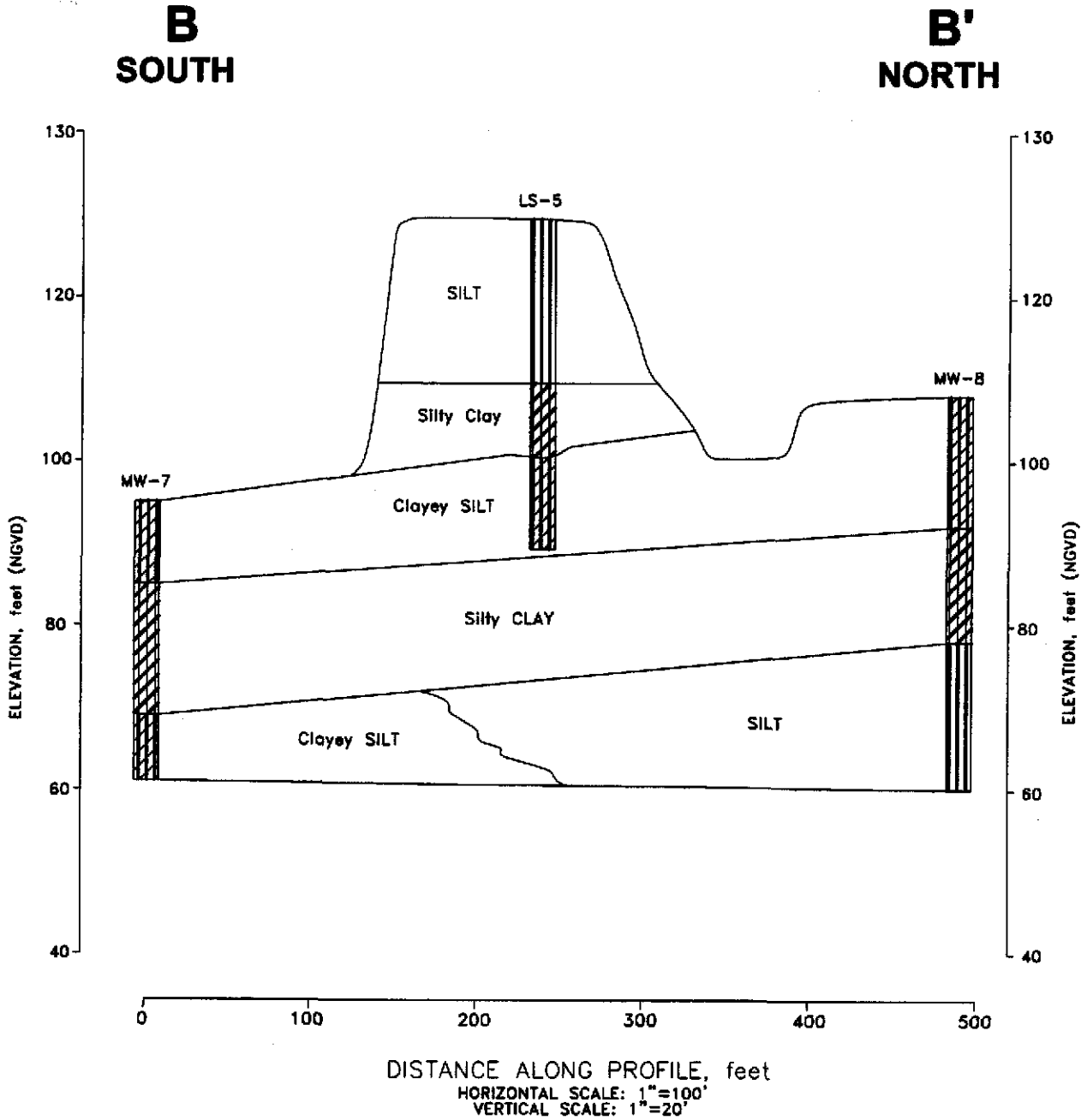

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VICKSBURG CHEMICAL CORPORATION VICKSBURG, MISSISSIPPI	URS 2822 O'Neal Lane Baton Rouge, Louisiana 70816 225/751-1873	SWMU 2 REPORT	PROJ. NO. 3096B007C
	SCALE: AS SHOWN; DRAWN BY: PCG; DATE: 8/18/00; CHKD. BY: RDR; DATE:	CROSS-SECTION B-B'	FIGURE 4

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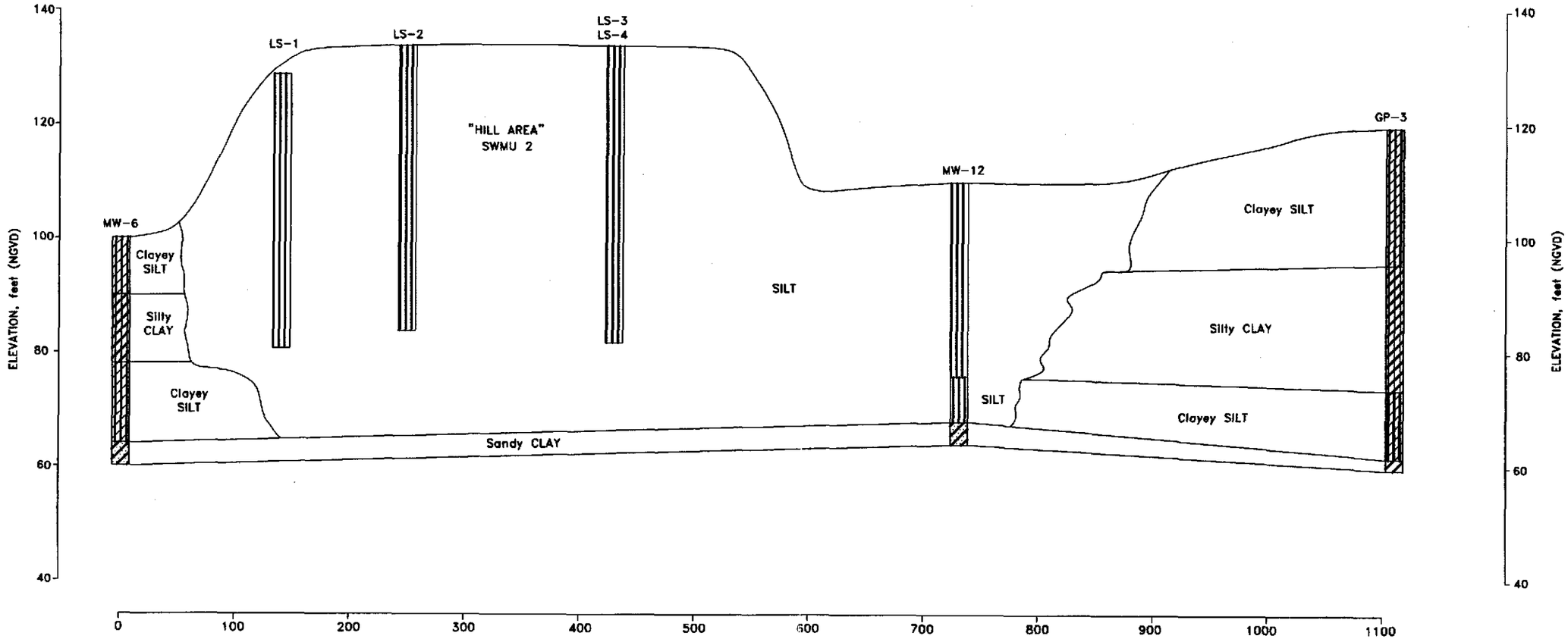
C
SOUTH

C'
NORTH



DISTANCE ALONG PROFILE, feet
HORIZONTAL SCALE: 1"=100'
VERTICAL SCALE: 1"=20'

LEGEND

- CLAY
- Silty CLAY
- SILT
- Sandy CLAY
- Clayey SILT

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REV	DESCRIPTION OF REVISION	BY	DATE
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DATE: 8/18/00

SWMU 2 REPORT

CROSS-SECTION C-C'

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PROJECT: 35096B007C
FIGURE: 5

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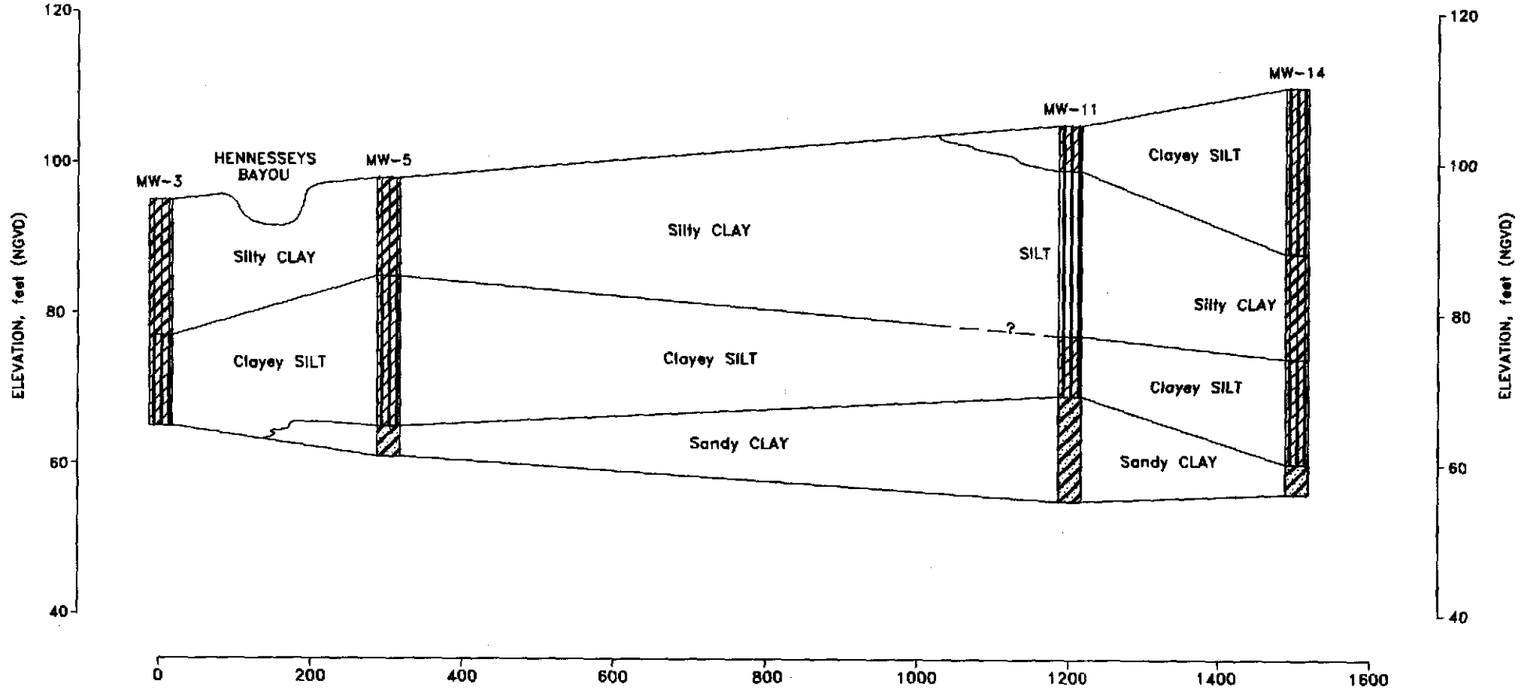

LEGEND

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- Sandy CLAY
- Clayey SILT

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VICKSBURG CHEMICAL CORPORATION
VICKSBURG, MISSISSIPPI

URS
2822 O'Neal Lane
Baton Rouge, Louisiana 70816
225/751-1873

REFERENCE DRAWINGS

SCALE: AS SHOWN
DESIGNED
DRAWN: PCG
CHECKED
PEER REVIEWED
DATE: 8/18/00

SWMU 2 REPORT

CROSSS-SECTION D-D'

REVISION: △
PROJECT: 35096B007C
FIGURE: 6

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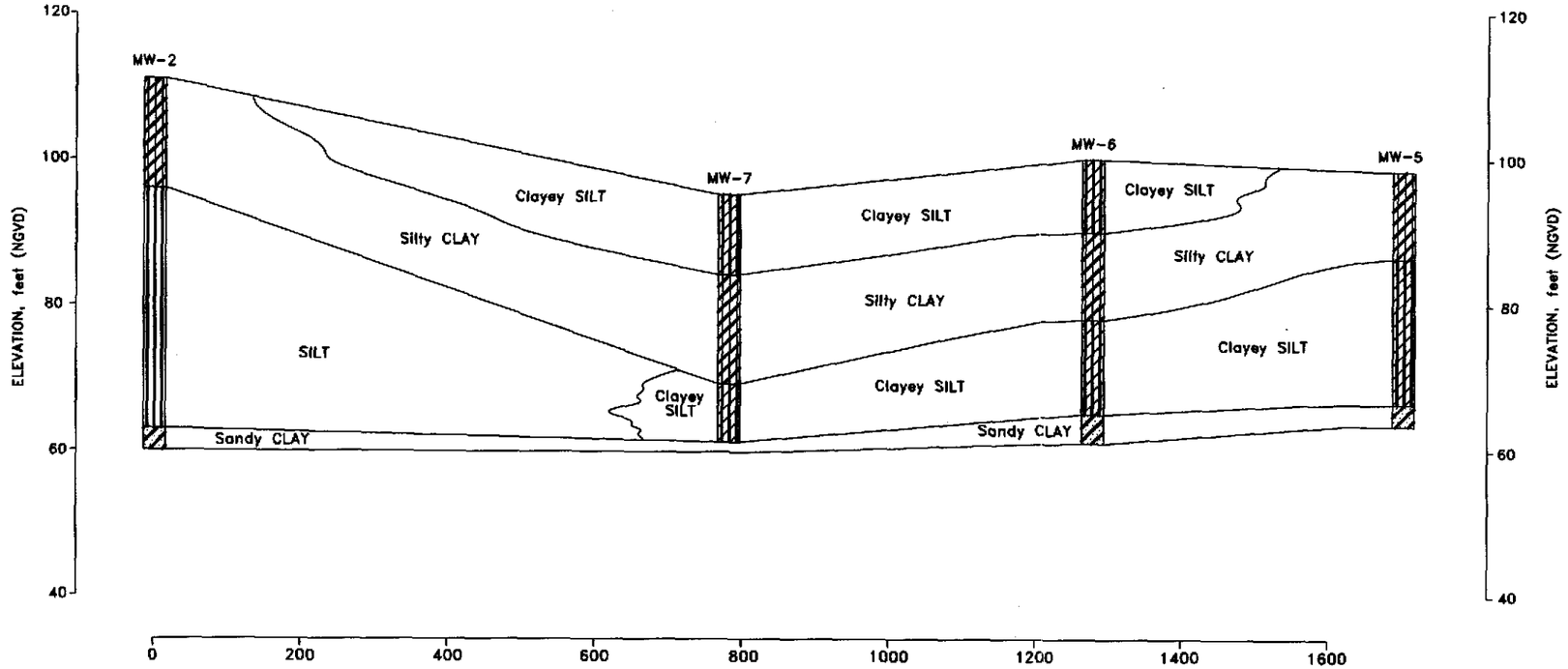

LEGEND

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VICKSBURG CHEMICAL CORPORATION
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REFERENCE DRAWINGS

SCALE: AS SHOWN
DESIGNED:
DRAWN: PCG
CHECKED: ROK
PEER REVIEWED:
DATE: 8/18/00

SWMU 2 REPORT

CROSS-SECTION F-F'

REVISION: △
PROJECT: 35096B007C
FIGURE: 7

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ATTACHMENT A

HEALTH AND SAFETY PLAN
FOR
VICKSBURG CHEMICAL SITE
VICKSBURG, MISSISSIPPI

Prepared for

Project 35092B007C

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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

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10/22/93
Date

Tanya Pawley
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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 employees 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

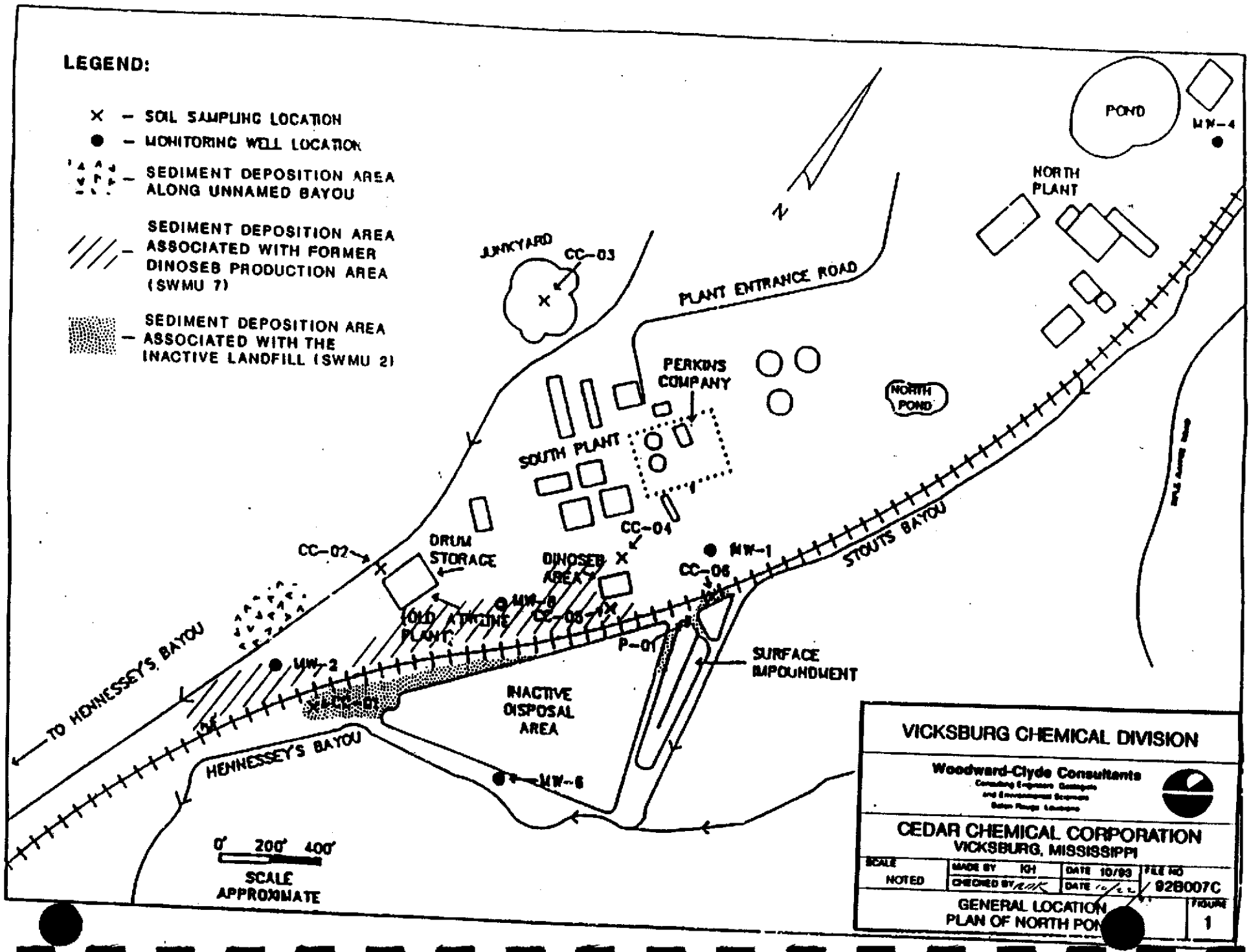
I, _____(print name), have received a copy of the Safety Plan for the Interim Measures, Groundwater Assessment, and RFI Field Investigation Workplans for VCC, Vicksburg, Mississippi and Corrective Measures Implementation Plans. I have read the plan, understand it, and agree to comply with all of its 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:
X – 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 ATRAZINE PLANT
CC-05
P-01
MW-2
SURFACE IMPOUNDMENT
TO HENNESSEY'S BAYOU
INACTIVE DISPOSAL AREA
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 IGH
DATE 10/93
CHECKED BY
DATE
FILE NO 92B007C
GENERAL LOCATION PLAN OF NORTH POND
FIGURE 1

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APPENDIX A
OF
ATTACHMENT 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.

URS

APPENDIX B
OF
ATTACHMENT A

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.

URS

APPENDIX C
OF
ATTACHMENT A

CHEMICAL INFORMATION SHEETS

Genium Publishing Corp.
One Genium Plaza
Schenectady, NY 12304-4690
(518) 377-8854

Material Safety Data Sheet Collection

Anhydrous Ammonia

MSDS No. 1

Date of Preparation: 8/85 Revision: 8

Section 1 - Chemical Product and Company Identification

Product/Chemical Name: Anhydrous Ammonia
Chemical Formula: NH_3
CAS Number: 7664-41-7
Synonyms: am-fol; ammonia, anhydrous; ammonia, anhydrous, liquefied; ammonia gas; ammoniac; ammoniaca; ammoniak; amoniak; aqua ammonia; aqueous ammonia; nitro-sil; R 717; Spirit of Hartshorn
Derivation: Prepared by using atmospheric nitrogen and a hydrogen source at high temperatures (752 °F (400 °C) - 11,732 °F (6500 °C)) and pressures (100 to 900 atm) in the presence of an iron catalyst (modified Haber reduction process).
General Use: Used in the manufacture of nitric acid, explosives, hydrazine, pesticides, urea, ammonium nitrate, ammonium salts, nylon, detergents; as refrigerant, cotton defoliant, fertilizer, neutralizing agent in petroleum industry; in metal treating operations, *e.g.*, nitriding; for hydrogenation of fats and oils; source of pure nitrogen; in rubber industry for stabilization of raw latex; catalyst to make synthetic resin; in water treatment, against tastes and odors; on citrus fruit to control fungal growth; in veterinary medicine as an antacid and respiratory stimulant.
Vendors: Consult the latest *Chemical Week Buyers' Guide*. (73)

Section 2 - Composition / Information on Ingredients

Anhydrous ammonia, ca 100 % vol

OSHA PELs
8-hr TWA: 50 ppm (35 mg/m^3)
Vacated 1989 final Rule Limit:
STEL: 35 ppm (27 mg/m^3)

ACGIH TLVs
TWA: 25 ppm (17 mg/m^3)
STEL: 35 ppm (24 mg/m^3)

NIOSH REL
10-hr TWA: 25 ppm (18 mg/m^3)
STEL: 35 ppm (27 mg/m^3)

IDLH Level
300 ppm

DFG (Germany) MAK
TWA*: 20 ppm (14 mg/m^3)
Category I: Local irritants

Peak Exposure Limit:
40 ppm (28 mg/m^3), 5 min, momentary value, 8/shift

*Embryo/Fetus Risk of Damage Classification C: There is no reason to fear risk of damage to the developing embryo or fetus when MAK and BAT values are observed.

Section 3 - Hazards Identification

ANSI Signal Word: Danger!

☆☆☆☆☆ Emergency Overview ☆☆☆☆☆

Anhydrous ammonia is an easily liquified colorless gas with a pungent, irritating odor. It is toxic by inhalation and ingestion. Due to its extreme alkalinity, it is corrosive and causes severe burns. Exposure may result in respiratory distress and, at high levels, may be fatal. This combustible gas can form explosive mixtures with air, and can violently react with many other chemicals. When heated to decomposition, anhydrous ammonia emits toxic fumes of ammonia and nitrogen oxides (NO_x).

Wilson Risk Scale
R 1
I 3
S 2*
K 4
*Skin absorption

HMIS
H 2*†
F 1
R 0
PPE‡
*Chronic effects
†3 (liquid)
‡Sec. 8

Potential Health Effects

Primary Entry Routes: Inhalation, ingestion, skin and/or eye contact/absorption
Target Organs: Eyes, skin, respiratory system, brain
Acute Effects
Inhalation: Dyspnea, bronchospasms, laryngitis, chest pain, excessive salivation, pink frothy sputum, urine retention, elevated blood pressure, corrosion of nose, throat and respiratory tract, fluid in the lungs (can be delayed), inflammation of and fluid accumulation in the larynx, changes in brain energy metabolism, coma, convulsions, and even death from kidney failure or spasm can result from inhalation of anhydrous ammonia. Concentrations of 2500-4500 ppm for 30 minutes can be fatal. **Eye:** Contact with liquid or exposure to high gas concentrations (> 1700 ppm) causes tearing, eyelid redness and swelling, extreme irritation, permanent corneal damage, cataract formation, glaucoma-like symptoms, temporary/permanent blindness. **Skin:** Contact with liquid or exposure to high gas concentrations may cause blisters, burns, and frostbite (liquid only). Percutaneous absorption may take place through damaged tissue, and lead to systemic effects. **Ingestion:** Nausea, vomiting, swelling of the lips, mouth and larynx

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and systemic effects (see Inhalation) can result. **Carcinogenicity:** IARC, NTP, and OSHA do not list anhydrous ammonia as a carcinogen.

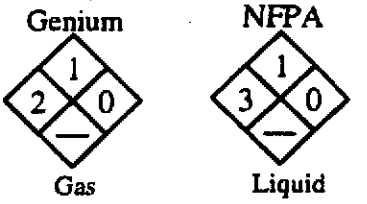
Medical Conditions Aggravated by Long-Term Exposure: Impaired lung or liver function, corneal disease, glaucoma. **Chronic Effects:** Repeated inhalation may result in asthma, chronic bronchitis, dilation of and fiber formation in the bronchial tubes, headache and prolonged sleepiness. Repeated skin contact can result in dermatitis.

Section 4 - First Aid Measures

Inhalation: Remove exposed person to fresh air and support breathing as needed. **Eye Contact:** *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. **Skin Contact:** *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. For reddened or blistered skin, consult a physician. **Ingestion:** Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center. Unless the poison control center advises otherwise, have the *conscious and alert* person drink 1 to 2 glasses of water or milk. *Do not* induce vomiting. ***After first aid, get appropriate in-plant, paramedic, or community medical support.*** **Note to Physicians:** Serum ammonia levels are not clinically useful in managing exposures; instead, monitor blood gases and evaluate clinically for pulmonary edema and respiratory distress, with treatment as appropriate. Consider esophagoscopy if patient has oral or pharyngeal burns. Gastric lavage is contraindicated. For eye exposure, irrigate until conjunctival sack pH is < 8.5. If ingestion is significant, observe for signs of esophageal stricture.

Section 5 - Fire-Fighting Measures

Flash Point: *Not applicable, combustible gas* ***Burning Rate:*** *1 mm/min*
LEL: 16% v/v **UEL:** 25% v/v **Autoignition Temperature:** 1204 °F (651 °C)



Flammability Classification: Combustible gas. **Extinguishing Media:** Use carbon dioxide or dry chemical to extinguish flame at gas valve. **Unusual Fire or Explosion Hazards:** Containers may explode in heat of fire. Ammonia can form explosive mixture with air, and may decompose to flammable hydrogen and nitrogen gas at temperatures greater than 840 °F (450 °C); reacts exothermically with acids. Contact with many incompatibles (see Sec. 10) can generate explosive products. **Hazardous Combustion Products:** Heating anhydrous ammonia to decomposition can produce fumes of ammonia, and nitrogen oxides (NO_x). **Fire-Fighting Instructions:** *Do not* release runoff from fire control methods to sewers or waterways. Use water spray to protect personnel shutting off gas. Remove cylinders from fire. **Fire-Fighting Equipment:** Because fire may produce toxic thermal decomposition products, wear a self-*contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode.*

Section 6 - Accidental Release Measures

Spill /Leak Procedures: Isolate spill for 330-660 ft (100-200 m) in all directions. Fully encapsulating, vapor protective clothing should be worn for spills and leaks with no fire. *Do not* touch or walk through spilled material. Aerosol from leak of liquid ammonia may lower air temperature considerably. Use water spray to reduce vapors or divert vapor cloud drift, and then stop leak if possible. If possible, turn leaking containers so that gas escapes rather than liquid. Prevent entry into waterways, sewers, basements or confined areas. *Do not* direct water at spill or source of leak. Isolate area until gas has dispersed. **Small Spills:** Absorb liquid anhydrous ammonia with vermiculite, earth, sand or similar material.

Large Spills, Containment: For large spills, consider downwind evacuation of at least 1000 ft (300 m). *Do not* release into sewers or waterways. **Cleanup:** Spills can be neutralized with dilute acid. **Regulatory Requirements:** Follow applicable *OSHA regulations (29 CFR 1910.120).*

Section 7 - Handling and Storage

Handling Precautions: Avoid vapor inhalation, and skin and eye contact. Use only with ventilation sufficient to reduce airborne concentrations to non-hazardous levels (see Sec. 2). Wear protective gloves, goggles, and clothing (see Sec. 8). Ground and bond all containers during transfers to prevent static sparks. Use non-sparking tools to open and close containers. Liquid ammonia will attack some plastics, rubbers and coatings. **Storage Requirements:** Store outside, out of direct sunlight, away from drinking water wells, or in a tightly closed container in a cool, well-ventilated area, away from heat, ignition sources and incompatibles (see Sec. 10). Periodically inspect materials. Equip drums with appropriate pressure-relief devices. *Do not* use copper, brass, bronze or galvanized steel in contact with ammonia. **Regulatory Requirements:** Follow applicable OSHA regulations (29 CFR 1910.101, 111) for combustible gases.

Section 8 - Exposure Controls / Personal Protection

Ventilation: Provide general or local exhaust ventilation systems to maintain airborne concentrations as low as possible. Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.

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Section 8 - Exposure Controls / Personal Protection, *continued*

Engineering Controls: Consider installation of sprinklers protection for protection against vapors. **Administrative Controls:** Implement medical surveillance procedures for workers, including chest x-ray, examination of eyes, skin and respiratory. **Respiratory Protection:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. For concentrations ≤ 250 ppm, use chemical cartridge respirator with green cartridge, or supplied air (SA) respirator; ≤ 300 ppm, SA respirator in continuous flow mode, or powered air-purifying respirator with green cartridge, or chemical cartridge respirator with full facepiece and green cartridge, or air-purifying full-facepiece respirator with chin-style front- or back-mounted green cartridge, or SCBA with full facepiece, or SA respirator with full facepiece; > IDLH, or emergency, SCBA with full facepiece operated in pressure-demand or other positive-pressure mode, or SA respirator with full facepiece operated in pressure-demand or other positive-pressure mode combined with SCBA. For escape, use air-purifying full facepiece respirator with green cartridge, or escape-type SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas. **Protective Clothing/ Equipment:** Wear chemically protective gloves, boots, aprons, and gauntlets of butyl rubber, Teflon™, Trellchem HPS™, or Responder™ (breakthrough time (BT) >8 hr), if possible, or alternatively, nitrile rubber (BT >4 hr), and neoprene (BT >1 hr), to prevent skin contact. Polyvinyl chloride, polyethylene, polyvinyl alcohol, Barricade™ and Chemrel™ (BT <1 hr) may degrade after contact and are *not* recommended. Wear splash-proof chemical safety goggles and face shield (8-inch minimum), per OSHA eye- and face-protection regulations (29 CFR 1910.133). Contact lenses are not eye protective devices. Appropriate eye protection must be worn instead of, or in conjunction with contact lenses. **Safety Stations:** Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in work area. **Contaminated Equipment:** Separate contaminated work clothes from street clothes. Launder before reuse. Remove this material from your shoes and clean personal protective equipment. **Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9 - Physical and Chemical Properties

Physical State: Gas
Appearance and Odor: Colorless; strong, pungent, and irritating odor
Odor Threshold Range: 0.32 - 46.8 ppm
Vapor Pressure: 7,510 mm Hg at 77 °F (25 °C)
Vapor Density (Air=1): 0.59
Formula Weight: 17.03
Density: 0.771 g/L at 760 mm Hg (gas)
pH: 11.6 (1.0 N aqueous solution)
Water Solubility: 31% at 77 °F (25 °C)
Other Solubilities: 10% in ethanol at 77 °F (25 °C); 16% in methanol at 77 °F (25 °C); soluble in chloroform and ether.
Boiling Point: -28 °F (-33.35 °C)
Freezing Point: -107.86 °F (-77.7 °C)
Viscosity: 0.255 centipoise at -28.3 °F (-33.5 °C)
Refractive Index: 1.325 at 61.7 °F (16.5 °C)/D
Surface Tension: 23.4 dynes/cm at 39.4 °F (4.1 °C)
Ionization Potential: 10.18 eV
Henry's Law Constant (H): 0.76 atm-m^3/mole
Octanol/Water Partition Coefficient: log K_{ow} = -1.14

Section 10 - Stability and Reactivity

Stability: Anhydrous ammonia is stable at room temperature in closed containers under normal storage and handling conditions. **Polymerization:** Hazardous polymerization cannot occur. **Chemical Incompatibilities:** Include acids; strong oxidants; interhalogens; chlorine or chlorine bleach; boron halides; 1,2-dichloroethane; ethylene oxide; chloroformamidnium nitrate; oxygen + platinum; magnesium perchlorate; nitrogen trichloride; heavy metals and their compounds; chlorine azide; bromine; iodine; iodine + potassium; tellurium halides; pentaborane; silver compounds; hypochlorites; air + hydrocarbons; germanium derivatives; stibine; 1-chloro-2,4-dinitrobenzene; ethanol + silver nitrate; 2-, or 4-chloronitrobenzene; acetaldehyde; acrolein; boron; chlorosilane; hexachloromelamine; sulfur; hydrazine + alkali metals; potassium ferricyanide; potassium mercuric cyanide; nitrogen dioxide; phosphorus pentoxide; tetramethylammonium amide. **Conditions to Avoid:** Heat, ignition sources, contact with oxidizing agents, combustible materials and incompatibles. **Hazardous Decomposition Products:** Thermal oxidative decomposition of anhydrous ammonia can produce fumes of ammonia and nitrogen oxides (NO_x).

Section 11- Toxicological Information

Toxicity Data:*

Genetic Effects:
Bacteria - *E. Coli*, 1500 ppm/3 hr resulted in mutations (-S9).
Multiple Dose Toxicity Data:
Rat, inhalation, 300 ppm/6 hr/5 days, intermittently, caused other changes in blood, other degenerative changes in brain and coverings.

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Section 11- Toxicological Information, *continued*

Tumorigenicity:
Rat, oral, 1680 mg/kg/24 weeks, continuously, resulted in gastrointestinal tumors.

Cytogenetic Analysis:
Rat, inhalation: 19800 µg/m^3/16 weeks

Acute Oral Effects:
Man, oral, TD_{Lo}: 15 µL/kg, caused changes in structure/function of esophagus.
Rat, oral, LD_{50}: 350 mg/kg

Acute Inhalation Effects:
Human, inhalation, LC_{Lo}: 5000 ppm/5 min.
Human, inhalation, TC_{Lo}: 20 ppm, caused ulcerated nasal septum, conjunctive irritation, structural/functional change in trachea.
Rat, inhalation, LC_{50}: 2000 ppm/4 hr

* See NIOSH, *RTECS* (BO0875000), for additional toxicity data.

Section 12 - Ecological Information

Ecotoxicity: Crayfish, LC_{100}=80 ppm/3 days; fathead minnow, TLm=8.2 ppm/96 hr; goldfish/yellow perch, LC_{60}=2.0-2.5 ppm/1-4 day. **Environmental Fate:** Anhydrous ammonia has a very high vapor pressure and will rapidly evaporate from water and soil. In surface water, it may sorb to suspended sediments provided that conditions are oxidizing. Ammonia does not bioconcentrate. **Environmental Degradation:** Biological nitrification (conversion to nitrate) will rapidly occur in soil and water under aerobic conditions. In the atmosphere, ammonia will rapidly combine with sulfate ion and be removed via wet deposition, though some may be oxidized to nitrogen oxides (NO_x) and nitrate (NO_3), contributing to rainfall acidity.

Section 13 - Disposal Considerations

Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Consider dilution with water, cautious neutralization with hydrochloric acid (HCl), and discharge to sewer. Follow applicable Federal, state, and local regulations.

Section 14 - Transport Information

DOT Transportation Data (49 CFR 172.101):

Shipping Name: Ammonia, anhydrous
Shipping Symbols: I; D
Hazard Class: 2.3; 2.2
ID No.: UN1005
Packing Group: —
Label: POISON GAS, CORROSIVE MATERIAL; NONFLAMMABLE GAS
Special Provisions (172.102): 8; 13

Packaging Authorizations
a) Exceptions: None
b) Non-bulk Packaging: 173.304
c) Bulk Packaging: 173.314; 173.315

Quantity Limitations
a) Passenger, Aircraft, or Railcar: Forbidden
b) Cargo Aircraft Only: 25 kg

Vessel Stowage Requirements
a) Vessel Stowage: D
b) Other: 40, 57

Section 15 - Regulatory Information

EPA Regulations:
RCRA Hazardous Waste (40 CFR 261.33): Not listed
Listed as a CERCLA Hazardous Substance (40 CFR 302.4) per CWA Section 311(b)(4)
CERCLA Final Reportable Quantity (RQ), 100 lb. (45.35 kg)
Listed as a SARA Toxic Chemical (40 CFR 372.65)
Listed as a SARA EHS (Extremely Hazardous Substance) (40 CFR 355), Threshold Planning Quantity (TPQ): 500 lb.

OSHA Regulations:
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1)
OSHA Process Safety TQ: 10,000 lb.
OSHA Specifically Regulated Substances (29 CFR 1910.111)

Section 16 - Other Information

References: 1, 73, 103, 124, 136, 149, 176, 190, 208, 209, 216, 217, 218, 222, 223, 224, 227, 228, 230

Prepared By..... HM Spliethoff, MS
Industrial Hygiene Review..... DJ Wilson, CIH
Medical Review..... G Kelafant, MD

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Material Safety Data Sheets Collection:

Sheet No. 296
Arsenic and Compounds

Issued: 4/90

Section 1. Material Identification

Arsenic Description: Obtained from flue dust of copper and lead smelters as white arsenic (arsenic trioxide). Reduction with charcoal and sublimation in an N_2 current yields pure arsenic. Metallic arsenic is used for hardening copper, lead, and alloys; as a doping agent in germanium and silicon solid-state products, special solders, and medicine; and to make gallium arsenide for dipoles and other electronic devices. Arsenic compounds are used in manufacturing certain types of glass; in textile printing, tanning, taxidermy, pharmaceuticals, insecticides and fungicides, pigment production, and antifouling paints; and to control sludge formation in lubricating oils. Arsenic trioxide is the source for 97% of all arsenic products.

R 1
I 4
S 2
K 0

Genium

HM
H
F 2
R
PP
* Se

Other Designations: CAS No. 7440-38-2; arsen; arsenic black; As; gray arsenic; metallic arsenic.
Manufacturer: Contact your supplier or distributor. Consult the latest *Chemicalweek Buyers' Guide*(73) for a suppliers list.

Section 2. Ingredients and Occupational Exposure Limits

Arsenic and soluble compounds, as As

OSHA PEL
8-hr TWA: 0.5 mg/m³,* 0.01 mg/m³†

ACGIH TLV, 1989-90
TLV-TWA: 0.2 mg/m³

NIOSH REL, 1987
Ceiling: 0.002 mg/m³

Toxicity Data‡
Man, oral, TD_{Lo}: 76 mg/kg administered intermittently over a 12-year period affects the liver (tumors) and blood (hemorrhage)
Man, oral: 7857 mg/kg administered over 55 years produces gastrointest (in the structure or function of the esophagus), blood (hemorrhage), and skin and appendage (dermatitis) changes
Rat, oral, TC_{Ln}: 605 µg/kg administered to a 35-week pregnant rat affects fertility (pre- and post-implantation mortality)

* Organic compounds.
† Inorganic compounds.
‡ See NIOSH, *RTECS* (CG0525000), for additional mutative, reproductive, tumorigenic, and toxicity data.

Section 3. Physical Data*

Boiling Point: sublimes at 1134 °F/612 °C
Melting Point: 1497 °F/814 °C
Vapor Pressure: 1 mm at 702 °F/372 °C (sublimes)
Atomic Weight: 74.92
Density: 5.724 at 57 °F/14 °C
Water Solubility: Insoluble†

Appearance and Odor: A brittle, crystalline, silvery to black metalloid. Odorless.

* This data pertains to arsenic only.
† Arsenic is soluble in nitric acid (HNO_3).

Section 4. Fire and Explosion Data

Flash Point: None reported	Autoignition Temperature: None reported	LEL: None reported	UEL: None reported

Extinguishing Media: Use dry chemical, CO_2, water spray, or foam to fight fires.
Unusual Fire or Explosion Hazards: Flammable and slightly explosive in the form of dust when exposed to heat or flame.
Special Fire-fighting Procedures: Since fire may produce toxic fumes, wear a self-contained breathing apparatus (SCBA) with a full facepiec operated in the pressure-demand or positive-pressure mode. Be aware of runoff from fire control methods. Do not release to sewers or waterwa

Section 5. Reactivity Data

Stability/Polymerization: Arsenic is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur.
Chemical Incompatibilities: Arsenic can react vigorously on contact with powerful oxidizers such as bromates, peroxides, chlorates, iodates, lithium, silver nitrate, potassium nitrate, potassium permanganate, and chromium (VI) oxide. This material is also incompatible with halogens, bromine azide, palladium, dirubidium acetylide, zinc, and platinum.
Hazardous Products of Decomposition: Thermal oxidative decomposition of arsenic and its compounds produces irritating or poisonous gase

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Section 6. Health Hazard Data

Carcinogenicity: The IARC, NTP, and OSHA list arsenic as a human carcinogen (Group 1). This evaluation applies to arsenic and arsenic compounds as a whole, and not necessarily to all individual chemicals within the group. Studies report that both the trivalent and pentavalent compounds are strongly implicated as causes of skin, lung, and lymphatic cancers. Experimental studies have shown that arsenic has tumorigenic and teratogenic effects in laboratory animals.
Summary of Risks: Arsenic compounds are irritants of the skin, mucous membranes, and eyes. The moist mucous membranes are most sensitive to irritation. Prolonged contact results in local hyperemia (blood congestion) and later vesicular or pustular eruption. Epidermal carcinoma is a reported risk of exposure. Peripheral neuropathy (degenerative state of the nervous system) is common after acute or chronic arsenic poisoning. Symptoms include decreased sensation to touch, pinprick, and temperature; loss of vibration sense; and profound muscle weakness and wasting. Other complications of acute and chronic arsenic poisoning are encephalopathy (*alterations of brain structure*) and toxic delirium.
Medical Conditions Aggravated by Long-Term Exposure: Damage to the liver, nervous, and hematopoietic (responsible for the formation of blood or blood cells in the body) system may be permanent. Pulmonary and lymphatic cancer may also occur.
Target Organs: Liver, kidneys, skin, lungs, lymphatic system.
Primary Entry Routes: Inhalation, ingestion of dust and fumes, via skin absorption.
Acute Effects: Acute industrial intoxication is more likely to arise from inhalation of arsine. However, with corrosive arsenical vapors, conjunctivitis, eyelid edema, and even corneal erosion may result. Inhalation may result in nasal irritation with perforation of the septum, cough, chest pain, hoarseness, pharyngitis, and inflammation of the mouth. If ingested, metallic or garlic taste, intense thirst, nausea, vomiting, abdominal pain, diarrhea, and cardiovascular arrhythmias (heartbeat irregularities) may occur. Symptoms generally occur within 30 minutes, but may be delayed for several hours if ingested with food. Acute poisoning may result in acute hemolysis (breakdown of red blood cells).
Chronic Effects: Chronic symptoms include weight loss, hair loss, nausea, and diarrhea alternating with constipation, palmar and plantar hyperkeratoses (thickening of the corneous layer of skin on palms and soles of feet), and skin eruptions, and peripheral neuritis (inflammation of the nerves). Leukemia, bone marrow depression, or aplastic anemia (dysfunctioning of blood-forming organs) may occur after chronic exposure.
FIRST AID
Eyes: Flush immediately, including under the eyelids, gently but thoroughly with flooding amounts of running water for at least 15 min.
Skin: *Quickly* remove contaminated clothing. After rinsing affected skin with flooding amounts of water, wash it with soap and water.
Inhalation: Remove exposed person to fresh air and support breathing as needed.
Ingestion: Never give anything by mouth to an unconscious or convulsing person. If ingested, have a *conscious* person drink 1 to 2 glasses of water, then induce repeated vomiting until vomit is clear.
After first aid, get appropriate in-plant, paramedic, or community medical support.
Physician's Note: If emesis is unsuccessful after two doses of Ipecac, consider gastric lavage. Monitor urine arsenic level. Alkalinization of urine may help prevent disposition of red cell breakdown products in renal tubular cells. If acute exposure is significant, maintain high urine output and monitor volume status, preferably with central venous pressure line. Abdominal X-rays should be done routinely for all ingestions. Chelation therapy with BAL, followed by n-penicillamine is recommended, but specific dosing guidelines are not clearly established.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Notify safety personnel of spill, evacuate all unnecessary personnel, remove all heat and ignition sources, and provide adequate ventilation. Cleanup personnel should protect against dust inhalation and contact with skin and eyes. Use nonsparking tools. With a clean shovel, scoop material into a clean, dry container and cover. Absorb liquid material with sand or noncombustible inert material and place in disposal containers. Do not release to sewers, drains, or waterways. Follow applicable OSHA regulations (29 CFR 1910.120).
Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

EPA Designations*
RCRA Hazardous Waste (40 CFR 261.33): Not listed
Listed as a CERCLA Hazardous Substance† (40 CFR 302.4), Reportable Quantity (RQ): 1 lb (0.454 kg) [† per Clean Water Act, Sec. 307(a); per Clean Air Act, Sec. 112]
SARA Extremely Hazardous Substance (40 CFR 355): Not listed
Listed as a SARA Toxic Chemical (40 CFR 372.65)

OSHA Designations‡
Air Contaminant (29 CFR 1910.1000, Subpart Z): Not listed

* Designations for arsenic only.
‡ Listed as arsenic organic compounds (as As).

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133).
Respirator: Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a NIOSH-approved respirator. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA.
Warning: Air-purifying respirators do *not* protect workers in oxygen-deficient atmospheres.
Other: Wear impervious gloves, boots, aprons, and gauntlets to prevent skin contact.
Ventilation: Provide general and local explosion-proof ventilation systems to maintain airborne concentrations below the OSHA PELs, ACGIH TLVs, and NIOSH REL (Sec. 2). Local exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by controlling it at its source.[103]
Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.
Contaminated Equipment: Never wear contact lenses in the work area; soft lenses may absorb, and all lenses concentrate, irritants. Remove this material from your shoes and equipment. Launder contaminated clothing before wearing.
Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Store in closed, properly labeled, containers in a cool, well-ventilated area away from all incompatible materials (Sec. 5) and heat and ignition sources. Protect containers from physical damage.

Engineering Controls: Avoid inhalation or ingestion of dust and fumes, and skin or eye contact. Practice good personal hygiene and housekeeping procedures. Use only with adequate ventilation and appropriate personal protective gear. Institute a respiratory protection program with training, maintenance, inspection, and evaluation. All engineering systems should be of maximum explosion-proof design and electrically grounded and bonded. Provide preplacement and annual physical examination with emphasis on the skin, respiratory system, and blood.

Transportation Data (49 CFR 172.101, .102)

DOT Shipping Name: Arsenic, solid
DOT Hazard Class: Poison B
ID No.: UN1558
DOT Label: Poison
DOT Packaging Requirements: 173.366
DOT Packaging Exceptions: 173.364

IMO Shipping Name: Arsenic, metallic
IMO Hazard Class: 6.1
IMO Label: Poison
IMDG Packaging Group: II
ID No.: UN1558

MSDS Collection **References:** 7, 26, 38, 53, 73, 85, 87, 88, 89, 100, 103, 109, 123, 124, 126, 127, 130, 136, 138
Prepared by: MJ Allison, BS; **Industrial Hygiene Review:** DJ Wilson, CIH; **Medical Review:** MJ Hardies, MD M4

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Material Safety Data Sheet Collection

Arsenic Trioxide

MSDS No. 194
Date of Preparation: 6/86 Revision: A 4/9

Section 1 - Chemical Product and Company Identification

Product/Chemical Name: Arsenic Trioxide
Chemical Formula: As_2O_3
CAS Number: 1327-53-3
Synonyms: arsenic oxide, arsenic (III) oxide, arsenic sesquioxide, arsenicum album, arsenious acid, arsenious acid anhydride, arsenious oxide, arsenious trioxide, arsenite, arsenolite, arsenous acid, arsenous acid anhydride, arsenous anhydride, claudelite, claudetite, crude arsenic, diarsenic trioxide, white arsenic
Derivation: By smelting of copper and lead concentrates, adding pyrite or galena to yield arsenic trioxide vapor and condensation to yield 90 to 95% pure arsenic trioxide. Re-sublimation will yield 99 +%. Available in crystals (monoclinic-*claudetite*; cubic-*arsenolite*) and amorphous lumps.
General Use: No longer produced in the US, but it is imported. Used in the manufacture of other arsenic compounds, glass (decolorizer), Paris green, enamels, weed killers, insecticides, and rodenticides; for preserving hides and wood, and as a textile mordant. Formerly used in veterinary medicine.
Vendors: Consult the latest *Chemical Week Buyers' Guide*. (73)

Section 2 - Composition / Information on Ingredients

Arsenic trioxide, ca 95 to 99+% wt (various purities are available).
Trace Impurities: 10,000 to 20,000 ppm antimony, 300 to 600 ppm lead and iron, 100 to 800 ppm copper, 300 ppm zinc, and 15 ppm cadmium, selenium, mercury, and tellurium.

OSHA PEL
Inorganic compounds, as As
8-hr TWA: 0.01 mg/m^3

NIOSH REL
Inorganic compounds, as As
15-min Ceiling: 0.002 mg/m^3

DFG (Germany) MAK
None established

ACGIH TLV
Inorganic compounds, as As
8-hr TWA: 0.01 mg/m^3

IDLH Level
5 mg/m^3 as As

Section 3 - Hazards Identification

☆☆☆☆☆ Emergency Overview ☆☆☆☆☆

Arsenic trioxide exists as odorless, tasteless, white or transparent, amorphous lumps or crystalline powder. It is irritating to the eyes, skin, and respiratory tract. Severe acute and chronic toxicity occurs via all routes of exposure and includes peripheral nervous system damage, anemia, and possible cancer of the respiratory tract and skin. Arsenic trioxide is easily absorbed through the skin. It is not combustible.

Wilson Risk Scale
R 1
I 4
S 1*
K 1
*Skin absorption

HMIS
H 3*
F 0
R 0
*Chronic effects
PPE†
†Sec. 8

Potential Health Effects

Primary Entry Routes: Inhalation, eye and skin contact/absorption.
Target Organs: Kidneys, liver, lungs, skin, lymphatic system, peripheral nervous system, bone marrow.
Acute Effects
Inhalation: Symptoms include irritation of the respiratory tract, headache, coughing, difficulty breathing, chest pains, and pulmonary edema (fluid in lungs).
Eye: Irritation of the eye and conjunctiva.
Skin: Irritation of the skin.
Ingestion: Symptoms generally occur within 30 to 60 minutes but may be delayed for several hours if ingested with food. Symptoms include a metallic or garlic taste in the mouth, nausea and vomiting, abdominal pain, difficulty swallowing, and profuse, watery, sometimes bloody diarrhea, dehydration, intense thirst, fluid-electrolyte disturbances, severe hypotension (low blood pressure), metabolic acidosis, hemolysis (breakage of red blood cells), pancytopenia (reduction in all formed blood elements), anemia, Mee's lines (transverse white lines in the nails), peripheral neuropathy (damage to the peripheral nerves resulting in sensation and motor disturbances) with muscle wasting, tingling sensations, and burning pain in a "stocking and glove" distribution. Brain damage (1 to 6 months post exposure) may also occur. Human fatal dose = 1 to 2.5 mg/kg.
Carcinogenicity: The following agencies list arsenic trioxide (as arsenic compounds) as a carcinogen: EPA-A (Human carcinogen with sufficient epidemiological evidence to support a casual association between exposure and cancer), IARC-1 (carcinogenic to humans, sufficient evidence of carcinogenicity), DFG MAK-A1 (capable of inducing malignant tumors as shown by experience with humans), NIOSH-X (carcinogen defined with no further categorization), and OSHA-X (Carcinogen defined with no further categorization). The ACGIH lists arsenic trioxide *production* as TLV-A2 (Suspected human carcinogen).
Medical Conditions Aggravated by Long-Term Exposure: Blood or liver disorders.

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Chronic Effects: Symptoms include nasal, eye, and skin irritation, tearing, photophobia (sensitivity to light), hair loss, perforation of the nasal septum (tissue between the nostrils), hoarse voice, cirrhosis of the liver (rare), nausea and vomiting (infrequent), aplastic anemia (anemia characterized by defective functioning of blood-forming organs such as bone marrow and caused by exposure to chemicals or x-rays), and painful ulceration of the wrists, scrotal skin, lips, and nostrils.
Other: Ingestion of arsenic trioxide has caused premature birth with subsequent death. Arsenic trioxide can be passed to an infant through breast milk.

Section 4 - First Aid Measures

Inhalation: Remove exposed person to fresh air and support breathing as needed.
Eye Contact: *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water for at least 15 minutes. Consult a physician or ophthalmologist if pain or irritation persist.
Skin Contact: *Quickly* remove contaminated clothing. *Do not* shake arsenic trioxide dusts off clothing! Rinse with flooding amounts of water to remove loose material followed by a thorough soap and water wash. For reddened or blistered skin, consult a physician.
Ingestion: Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center. Unless the poison control center advises otherwise, have the *conscious and alert* person drink 1 to 2 glasses of water, then induce vomiting.
After first aid, get appropriate in-plant, paramedic, or community medical support.
Note to Physicians: Support respiratory and cardiovascular function. Assure adequate hydration and renal function: alkalinization of the urine may prevent disposition of red blood cell products from hemolysis in renal tubular cells.
Special Precautions/Procedures: Chelation therapy may be indicated if urine arsenic levels exceed 200 µg/liter or higher.

Section 5 - Fire-Fighting Measures

Flash Point: Noncombustible.
Autoignition Temperature: Noncombustible.
LEL: None reported.
UEL: None reported.
Extinguishing Media: Use agents suitable for surrounding fire.
Unusual Fire or Explosion Hazards: *None reported.*
Hazardous Combustion Products: Arsenic trioxide fumes and arsine gas.
Fire-Fighting Instructions: Do not release runoff from fire control methods to sewers or waterways.
Fire-Fighting Equipment: Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode.

Section 6 - Accidental Release Measures

Spill /Leak Procedures: Notify safety personnel, isolate and ventilate area, deny entry, and stay upwind.
Small Spills: *Do not* sweep! Carefully scoop up or vacuum (with appropriate filter) and place in suitable container.
Large Spills
Containment: Flush spill to containment area with water for later reclamation or disposal. Neutralize spill with agricultural lime, crushed limestone, or sodium bicarbonate. *Do not* release into sewers or waterways.
Cleanup: Damp mop any residue with dilute sodium bicarbonate solution.
Regulatory Requirements: Follow applicable OSHA regulations (29 CFR 1910.120).

Section 7 - Handling and Storage

Handling Precautions: Use only with adequate ventilation. Wear appropriate PPE to prevent inhalation and skin/eye contact.
Storage Requirements: Store in a cool, dry, well-ventilated area away from incompatibles (Sec. 10). Floors and shelves should be made of an impermeable material to prevent absorption of arsenic trioxide.
Regulatory Requirements: Follow 29 CFR 1910.1018.

Section 8 - Exposure Controls / Personal Protection

Engineering Controls: Enclose all processes where possible to prevent dispersion of dusts into work area.
Ventilation: Provide general or local exhaust ventilation systems to maintain airborne concentrations below OSHA PEL (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.(103)
Administrative Controls: Consider preplacement and periodic medical exams of exposed workers. Measurement of arsenic levels in urine can be indicative of exposure. Advise against seafood ingestion for 48 to 72 hr prior to testing.
Respiratory Protection: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. The following recommendations are for inorganic arsenic compounds. For any detectable concentration, use a SCBA with a full facepiece operated in pressure-demand or other positive-pressure mode or any supplied-air respirator with a full facepiece operated in pressure demand or other positive pressure mode in combination with an auxiliary SCBA. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical

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certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas. Due to the potential skin irritation associated with respirator use and arsenic dust exposure, workers should be allowed to leave work area every two hours to wash face and obtain a clean respirator.

Protective Clothing/Equipment: Wear chemically protective gloves, boots, aprons, and gauntlets to prevent prolonged or repeated skin contact. Butyl rubber and polycarbonate have been suggested as suitable materials for PPE. Barrier creams such as those which are silicone-based will provide some protection against absorption of arsenic trioxide through the skin. Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Contact lenses are not eye protective devices. Appropriate eye protection must be worn instead of, or in conjunction with contact lenses.

Safety Stations: Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in work area.

Contaminated Equipment: Separate contaminated work clothes from street clothes. *Do not* shake or blow arsenic trioxide dust off clothing! Launder before reuse. Laundry personnel should be informed of the health hazards associated with arsenic trioxide and provided with PPE to protect against exposure. Remove arsenic trioxide from your shoes and PPE.

Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using arsenic trioxide, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9 - Physical and Chemical Properties

Physical State: Solid

Appearance and Odor: White or transparent crystals (monoclinic - *claudetite*), (cubic - *arsenolite*); or amorphous lumps; odorless; tasteless

Vapor Pressure: 66 mm Hg at 406.4 °F (312 °C)

Formula Weight: 197.82

Density (H_2O=1, at 4 °C): 4.15 g/cm^3 (*claudetite*), 3.856 g/cm^3 (*arsenolite*)

Water Solubility: 1.82 % (*claudetite*), 1.2 % (*arsenolite*) at 68 °F (20 °C). Soluble in 15 parts water at 212 °F (100 °C).

Other Solubilities: Soluble in alkali hydroxide or carbonate solutions, acids, and glycerol; insoluble in alcohol, chloroform and ether.

Boiling Point: 869 °F (465 °C), sublimes

Melting Point: 595.4 °F (313 °C), *claudetite*; 527 °F (275 °C) *arsenolite*

Refractive Index: 1.871, 1.92, 2.01 (*claudetite*); 1.755 (*arsenolite*)

Henry's Law Constant: 1.7 x 10^{-12} atm/m^3/mole

Section 10 - Stability and Reactivity

Stability: Arsenic trioxide is stable at room temperature in closed containers under normal storage and handling conditions.

Polymerization: Hazardous polymerization does not occur.

Chemical Incompatibilities: Tannic acid, infusion cinchona, and other vegetable astringent fusions and decoctions, acids (form volatile, highly toxic arsine gas), halogens (rubidium chloride, chlorine trifluoride, fluorine, sodium chlorate, hydrogen fluoride), aluminum, zinc fillings (explodes upon heating), sodium nitrate, and mercury. Corrosive to many metals in the presence of moisture.

Conditions to Avoid: Exposure to incompatibles, elevated temperatures, and dispersion into air.

Hazardous Decomposition Products: Thermal oxidative decomposition of arsenic trioxide can produce arsenic trioxide fumes and arsine gas.

Section 11 - Toxicological Information

Toxicity Data:*

Acute Oral Effects:

Human, oral, LD_{Lo}: 1429 µg/kg

Human, oral, LD_{Lo}: 29 mg/kg caused changes in sleep, muscle weakness, hypermotility, and diarrhea.

Rat, oral, LD_{50}: 14600 µg/kg

Multiple Dose Toxicity Data:

Rat, inhalation: 31 µg/m^3/24 hr administered continuously for 22 weeks produced toxic effects of the brain and coverings.

Reproductive Effects:

Woman, oral: 600 mg/kg taken in the 30th week of pregnancy resulted in premature birth with subsequent death.

Mouse, inhalation: 28,500 µg/m^3/4 hr administered from 9 to 12 days of pregnancy produced cytologic effects (including somatic cell genetic material) and specific developmental abnormalities of the musculoskeletal system.

Mutagenicity:

Human, HeLa cell: 500 µmol caused DNA inhibition.

Human, lymphocyte: 2 µg/cm^3 caused sister chromatid exchange.

* See NIOSH. *RTECS* (CG3325000). for additional toxicity data.

Section 12 - Ecological Information

Ecotoxicity: Salmon, LC_{50} = 8, 330 mcg/L/48 hr; pink salmon, LC_{100} = 7,195 mcg/L/ 7 days; fathead minnow, LC_{50} = 109 mg/L/96 hr

Environmental Fate: Arsenic trioxide adsorbs strongly to soil and sediment in water, especially those soils/sediment which contain clay or are high in ferrous and aluminum oxides. Its half-life in soil is ~ 6.5 years. In water, inorganic trivalent arsenic is slowly oxidized to pentavalent arsenic at neutral pH. Oxidation is more rapid in strong acid or base solutions. Arsenic trioxide may also undergo reduction, methylation, and demethylation conversion to alkyl arsines which are volatile and can lead to

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dissipation into the atmosphere. Arsenic trioxide may be found bound to particulates in air (generally < 2 µm in diameter) and transported by wind and air currents. Deposition will eventually occur (dry or precipitation). Typical residence time in air is ~ 9 days (varies depending on particle size and weather conditions).
Bioconcentration: BCF = 4 (*Lepomis macrochirus* at 28 days), 10 (*Daphnia magna* at 21 days).

Section 13 - Disposal Considerations

Disposal: Arsenic trioxide is a poor candidate for incineration. For small quantities, dissolve in a minimum amount of hydrochloric acid. Add to water until a white precipitate forms. Add 6 M hydrochloric acid again. Saturate with hydrogen sulfide. Filtrate, wash the precipitate, dry, package, and return to supplier. Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.
Disposal Regulatory Requirements: Follow 29 CFR 1910.1018.
Container Cleaning and Disposal: Triple rinse containers. Dispose of rinse water as described above.

Section 14 - Transport Information

DOT Transportation Data (49 CFR 172.101):

Shipping Name: Arsenic trioxide
Shipping Symbols: –
Hazard Class: 6.1
ID No.: UN1561
Packing Group: II
Label: Poison
***Special Provisions* (172.102):** –

Packaging Authorizations
a) Exceptions: None
b) Non-bulk Packaging: 173.212
c) Bulk Packaging: 173.242

Quantity Limitations
a) Passenger, Aircraft, or Railcar: 25 kg
b) Cargo Aircraft Only: 100 kg

Vessel Stowage Requirements
a) Vessel Stowage: A
b) Other: –

Section 15 - Regulatory Information

EPA Regulations:
Listed as a RCRA Hazardous Waste (40 CFR 261.33): P012
CERCLA Hazardous Substance (40 CFR 302.4) listed specific per RCRA, Sec. 3001 and CWA, Sec. 311 (b)(4)
CERCLA Reportable Quantity (RQ), 1 lb (0.454 kg)
Listed (as arsenic compounds) as a SARA Toxic Chemical (40 CFR 372.65)
SARA EHS (Extremely Hazardous Substance) (40 CFR 355), Threshold Planning Quantity (TPQ): 100/10,000 lb*
OSHA Regulations:
Listed (as inorganic arsenic compounds as As) as an Air Contaminant (29 CFR 1910.1000, Table Z-1, Z-1-A)
OSHA Specifically Regulated Substance (29 CFR 1910.1018, *arsenic compounds*)

* The lower quantity applies only if the solid exists in powdered form with a particle size of < 100 microns, or is handled in solution or molten form, or meets the NFPA rating of 2, 3, or 4 for reactivity. If the solid does not meet any of these criteria, it is subject to the upper quantity.

Section 16 - Other Information

References: 73, 103, 124, 136, 149, 176, 189, 190, 197, 200, 201, 204, 205

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Industrial Hygiene Review ..... RE Langford, PhD, CIH
Medical Review ..... R Teichman, MD

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Material Safety Data Sheet Collection

Atrazine **MSDS No. 1039**

Date of Preparation: 3/97

Section 1 - Chemical Product and Company Identification

Product/Chemical Name: Atrazine
Chemical Formula: $C_8H_{14}ClN_5$
CAS Number: 1912-24-9
Synonyms: AAtrex; Atranex; Atred; 2-chloro-4-ethylamino-6-isopropylamino-s-triazine; 6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine; Cristina; Gesaprial; Griffex; Primatol; Purge; Vecta
Derivation: Prepared by the reaction of cyanuric chloride with one equivalent of ethylamine followed by one equivalent of isopropylamine in the presence of an acid-binding agent; by reaction of 2,6-dichloro-4-ethylamino-*s*-triazine with isopropylamine.
General Use: Herbicide; plant growth regulator (inhibits photosynthesis); and weed control agent for corn, etc. and for non-crop and industrial sites.
Vendors: Consult the latest *Chemical Week Buyers' Guide.* (73)

Section 2 - Composition / Information on Ingredients

Atrazine, ca 100% wt

OSHA PEL
Vacated 1989 Final Rule Limit:
8-hr TWA: 5 mg/m^3

NIOSH REL
10-hr TWA: 5 mg/m^3

DFG (Germany) MAK
TWA: 2 mg/m^3, *total dust* (*total inspirable dust fraction*)

ACGIH TLV
TWA: 5 mg/m^3

Section 3 - Hazards Identification

☆☆☆☆☆ Emergency Overview ☆☆☆☆☆

Atrazine is an odorless, white, crystalline (sand-like) substance or powder which is often mixed with liquid in herbicides. It is irritating to the eyes and may cause dermatitis and skin sensitization. Based on animal data, exposure to high concentrations affects the nervous system and can cause liver injury. IARC classifies atrazine as a possible carcinogen. It is a noncombustible substance, but may be dissolved in a flammable carrier.

Wilson Risk Scale
R 1
I 2
S 2
K 0

HMIS
H 2*
F 0
R 0
PPE†
*Chronic effects
†Sec. 8

Potential Health Effects

Primary Entry Routes: Inhalation, ingestion, skin and/or eye contact
Target Organs: Eyes, skin, respiratory system, central nervous system, liver, kidney
Acute Effects *Note! Because adverse effects in humans have not been reported, the following symptoms are from animal data.*
Inhalation: Atrazine presents a low inhalation hazard due to its low vapor pressure. Dust inhalation may produce dyspnea (difficulty breathing). Exposure to high concentrations may produce systemic effects similar to those produced when ingested (see below).
Eye: Contact may cause irritation.
Skin: Contact may cause irritation.
Ingestion: Ingestion of large amounts may cause dyspnea (difficulty breathing), weakness, incoordination, anorexia (loss of appetite), muscle spasms, salivation, hypothermia, and liver injury.
Carcinogenicity: NTP and OSHA do not list atrazine as a carcinogen. IARC classifies it as Group 2B (possibly carcinogenic to humans). The ACGIH classifies it as TLV-A4 (not classifiable as a human carcinogen).
Medical Conditions Aggravated by Long-Term Exposure: None reported.
Chronic Effects: Repeated skin contact may cause dermatitis and sensitization.
Other: Conflicting results are reported for the mutagencity of atrazine. Human mutagenic data is reported (see Sec. 11). Atrazine is not a genetic hazard based on a weight of evidence approach. During dietary studies, no teratogenic effects were observed in rats receiving 100 ppm. At maternal doses of 800 to 2000 mg/kg, embryotoxic effects were seen. Atrazine was not teratogenic at maternally toxic dose levels in rabbits (75 mg/kg/day on gestational days 7 to 19) and in rats (70 mg/kg/day on gestational days 6 to 15). See Sec. 11 for additional reproductive effects data.

Section 4 - First Aid Measures

Inhalation: Remove exposed person to fresh air and support breathing as needed. If breathing has stopped, perform mouth-to-mouth resuscitation. Keep the affected person warm and at rest. Get medical attention immediately.

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Eye Contact: *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician or ophthalmologist if pain and/or irritation develop.

Skin Contact: *Quickly* remove contaminated clothing, flush exposed area with water for at least 15 minutes, and get medical attention immediately.

Ingestion: If victim is conscious, have victim drink water or milk and induce vomiting. Never give anything by mouth to an unconscious or convulsing person. Keep them warm and get medical attention immediately.

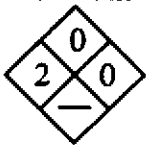
After first aid, get appropriate in-plant, paramedic, or community medical support.

Note to Physicians: Urinary metabolites include 2-chloro-4-ethylamino-6-amino-*s*-traizaine and N-dealkylated atrazine.

Special Precautions/Procedures: Preliminary medical exam to detect chronic diseases of CNS, liver, heart, kidneys, lung and skin, as well as endocrinological or immunological disturbances should be given to susceptible individuals.

Section 5 - Fire-Fighting Measures

Genium



Flash Point: None reported

Autoignition Temperature: None reported

LEL: None reported

UEL: None reported

Flammability Classification: Noncombustible solid

Extinguishing Media: Use an agent suitable for type of surrounding fire.

Unusual Fire or Explosion Hazards: Atrazine is often dissolved in a liquid "carrier" which may be flammable. Also, storage containers may explode in a fire.

Hazardous Combustion Products: Upon decomposition, poisonous gases, such as hydrogen chloride and nitrogen oxide, may be produced.

Fire-Fighting Instructions: Do not release runoff from fire control methods to sewers or waterways.

Fire-Fighting Equipment: Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode.

Section 6 - Accidental Release Measures

Spill /Leak Procedures: Notify safety personnel and isolate and ventilate area. Restrict persons not wearing protective equipment from area of spill or leak until clean-up is complete.

Small Spills: Carefully scoop up powdered material and deposit in sealed containers. Absorb liquid containing atrazine in vermiculite, dry sand, earth, or similar material.

Large Spills

Containment: For large spills, dike far ahead of liquid spill for later disposal. Cover dry spills with plastic sheet to prevent further dispersion. *Do not* release into sewers or waterways. Immediately call your fire department.

Cleanup: Use a vacuum or a wet method to reduce dust during clean-up. *Do not* dry sweep. Use water spray to "knock down" dust.

Regulatory Requirements: Follow applicable OSHA regulations (29 CFR 1910.120).

Section 7 - Handling and Storage

Handling Precautions: Avoid dust inhalation and skin and eye contact. Use with ventilation sufficient to reduce airborne concentrations to nonhazardous levels (see Sec. 2). Avoid contamination of food, feed, and water supplies.

Storage Requirements: Store in tightly closed containers in a cool, well-ventilated area away from heat and ignition sources and strong acids and bases. Transfer atrazine from drums or other storage containers to process containers.

Section 8 - Exposure Controls / Personal Protection

Engineering Controls: Where feasible, enclose operations to prevent dust dispersion into the work area.

Ventilation: Provide general or local exhaust ventilation systems to maintain airborne concentrations below OSHA PELs (see Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.(103)

Administrative Controls: Consider preplacement and periodic medical exams with emphasis on the skin, liver, and nervous system. Prior to working with atrazine, train workers on its proper handling and storage.

Respiratory Protection: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved full facepiece respirator with a pesticide cartridge. Select respirator based on its suitability to provide adequate worker protection for given working conditions, level of airborne contamination, and presence of sufficient oxygen. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas.

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Protective Clothing/Equipment: Wear chemically protective gloves, boots, aprons, and gauntlets to prevent skin contact; data suggest Tyvek, cotton, or cotton and cotton/polyester soil repellent finished fabric provide barrier protection. Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Contact lenses should not be worn when working with this chemical. Appropriate eye protection must be worn instead of contact lenses.
Safety Stations: Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in wor
Contaminated Equipment: Separate contaminated work clothes from street clothes. *Do not* take contaminated work clothes home; they should be laundered by those aware of the hazards of atrazine.
Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9 - Physical and Chemical Properties

Physical State: Crystalline solid
Appearance and Odor: Colorless or white, odorless
Vapor Pressure: 3 x 10^{-7} mm Hg at 68 °F (20 °C)
Formula Weight: 215.68
Specific Gravity (H_2O=1, at 4 °C): 1.19
Corrosivity: Noncorrosive
Water Solubility: 70 ppm at 77 °F (25 °C); 28 mg/L at 68 °F (20 °C)
Other Solubilities: Ether: 12,000 ppm; chloroform: 52,000 ppm; methanol: 18,000 ppm
Boiling Point: Decomposes
Melting Point: 340 °F (173 °C)
Octanol/Water Partition Coefficient: log K_{ow} = 2.75

Section 10 - Stability and Reactivity

Stability: Atrazine is stable (shelf-life: 3 years) at room temperature in closed containers under normal storage and handling conditions. It is stable in neutral, slightly acidic, or basic media.
Polymerization: Hazardous polymerization cannot occur.
Chemical Incompatibilities: Strong acids and strong bases.
Hazardous Decomposition Products: Thermal oxidative decomposition of atrazine-containing chemicals can produce hydrogen chloride and nitrogen oxide.

Section 11 - Toxicological Information

Toxicity Data:*

Eye Effects:
Rabbit: 6320 µg caused severe irritation.

Skin Effects:
Mammal (unspecified species): 500 mg caused mild irritation.

Acute Dermal Effects:
Rabbit, skin, LD_{50}: 7500 mg/kg
Rat, skin, LD_{50}: >12500 mg/kg

Acute Inhalation Effects:
Rat, inhalation, LD_{50}: 5200 mg/m^3/4 hr

Acute Oral Effects:
Rat, oral, LD_{50}: 672 mg/kg
Mice, oral, LD_{50}: 850 mg/kg

Multiple Dose Toxicity Data:
Rat, oral: 20 mg/kg/day/6 months, 40% died with signs of respiratory distress and paralysis of the limbs.

Tumorigenicity:
Rat, oral, TD_{Lo}: 33,775 mg/kg/2 yr administered continuously produced leukemia and uterine tumors.
Mouse, oral: 9000 mg/kg/78 weeks administered intermittently produced tumors of respiratory system and liver.

Genetic Effects:
Human, lymphocyte: 100 mg/L caused DNA damage.
Human, fibroblast: 3 mmol/L caused unscheduled DNA synthesis.

Cytogenetic Analysis:
Human lymphocyte: 1 mg/L

Reproductive Effects:
Rat, oral, TD_{Lo}: 700 mg/kg/administered to a female on gestational days 6 to 15 caused maternal effects and specific developmental abnormalities of the musculoskeletal system.
Rabbit, oral: 975 mg/kg administered to female on gestational days 7 to 19 produced specific developmental abnormalities of the musculoskeletal system.

* See NIOSH, *RTECS* (XY5600000), for additional toxicity data.

Section 12 - Ecological Information

Ecotoxicity: Rainbow trout (*Salmo gairdnerii*), LC_{50} = 4.5 - 8.8 mg/L/96 hr (conditions unspecified). *Anas platyrhynchos* (6 mo old, female mallards), oral, LD_{50}: >2000 mg/kg. *Colinis virginianus* (bobwhite quail), oral, LD_{50}: 5760 mg/kg (8 day dietary diet). *Lepomis machrochirus* (bluegill), LC_{50}: 16.0 mg/L/96 hr; conditions of bioassay not specified.
Environmental Fate: Leaching is limited by its adsorption to certain soil constituents. Volatilization is not expected to be environmentally important. In soil and water, atrazine may hydrolyze in either acidic or basic types yet is fairly resistant t hydrolysis at neutral pHs. This rate can be dramatically increased by the addition of humic materials. Atrazine has the po to photolyze from surface soils. Bioconcentration and volatilization of atrazine are not expected to be environmentally important. In the air, atrazine reacts with photochemically-produced hydroxyl radicals with an estimated half-life of 2.6 hours.

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Soil Adsorption/Mobility: If released to soil, atrazine has a moderate to high mobility. Adsorption is not irreversible and desorption often occurs readily, depending on temperatures, moisture and pH.

Section 13 - Disposal Considerations

Disposal: For small quantities, consider hydrolysis with acid or bases (10% wt/vol aqueous sodium hydroxide). Heating speeds hydrolysis. When hydrolysis is complete, dilute with copious amounts of water and wash down the sewer (with approval from local municipality). For large quantities, consider incineration with a caustic wet scrubber to remove nitrogen oxides and hydrochloric acid from product gases.

Container Cleaning and Disposal: Handle empty containers carefully as hazardous residues may still remain.

Section 14 - Transport Information

DOT Transportation Data (49 CFR 172.101):

Shipping Name: Triazine pesticides, solid, toxic
Shipping Symbols: –
Hazard Class: 6.1
ID No.: UN2763
Packing Group: III
Label: 6.1
Special Provisions (172.102): –

Packaging Authorizations
a) **Exceptions:** 173.153
b) **Non-bulk Packaging:** 173.213
c) **Bulk Packaging:** 173.240

Quantity Limitations
a) **Passenger, Aircraft, or Railcar:** 100 kg
b) **Cargo Aircraft Only:** 200 kg

Vessel Stowage Requirements
a) **Vessel Stowage:** A
b) **Other:** 40

Section 15 - Regulatory Information

EPA Regulations:
RCRA Hazardous Waste (40 CFR 261.33): Not listed.
RCRA Hazardous Waste Classification (40 CFR 261.21-.24): Not classified.
CERCLA Hazardous Substance (40 CFR 302.4): Not listed.
Listed as a SARA Toxic Chemical (40 CFR 372.65).
SARA EHS (Extremely Hazardous Substance) (40 CFR 355): Not listed.

OSHA Regulations:
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A, Vacated 1989 Final Rule Limit)

Section 16 - Other Information

References: 73, 99, 103, 136, 167, 190, 197, 209, 211

Prepared By ..... J Sawyer, MS/MJ Wurth, BS
Industrial Hygiene Review ..... DJ Wilson, CIH
Medical Review ..... T Thoburn, MD, MPH

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Material Safety Data Sheet

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GENIUM PUBLISHING CORP.

No. 22

CALCIUM OXIDE
(Revision C)
Issued: September 1978
Revised: April 1989

SECTION 1. MATERIAL IDENTIFICATION

Material: CALCIUM OXIDE

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.

NFPA

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
8-hr TWA: 5 mg/m³

ACGIH TLV, 1988-89
TLV-TWA: 2 mg/m³

Toxicity Data
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

GENIUM PUBLISHING CORPORATION
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GENIUM PUBLISHING CORP.

NO. 410

CARBON TETRACHLORID

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

APPROVALS: MIS J.M. Nielsen

CRD

Industrial Hygiene and Safety 12-9-80

MEDICAL REVIEW: 16 Dec. 1980

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GENIUM PUBLISHING CORP.

No. 53

CHLORINE
(Revision B)
Issued: July 1979
Revised: April 1988

SECTION 1. MATERIAL IDENTIFICATION

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 Torrs (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	LOWER	UPPER
*	*	% by Volume	*	*

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.

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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 w rkers 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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GENIUM PUBLISHING CORP.

No. 315

CHLOROFORM
(Revision D)
Issued: August 1979
Revised: April 1988

SECTION 1. MATERIAL IDENTIFICATION

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	1
R	0	I	3
PPG*		S	2
*See sect. 8		K	0

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: MJ Hardies, MD

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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
ammable Limits: LEL- n/d UEL- n/d
tinguishing 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/m³.

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

from Genium's Reference Collection

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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

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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 catharsis, 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
Medical Review: W Silverman, MD

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METHANEARSONIC ACID, SODIUM SALT

MSA

Common Synonyms	Solid	Colorless crystal, solution may be red or green	Odorless
Disodium methane arsonate Monosodium methane arsonate MSMA DSMA Disodium methyl arsonate Monosodium methyl arsonate	Solid may flash or burn in water; solid and solution are corrosive		

Solid discharge if involved
Avoid contact with solid and solution
Isolate and remove discharged material
Notify local health and pollution control agencies

Fire	Not flammable POISONOUS GASES ARE PRODUCED WHEN HEATED With oxidizers and combustible burning reactions
Exposure	CALL FOR MEDICAL AID SOLID OR SOLUTION Irritating to skin and eyes If swallowed, the victim vomits, vomiting, or loss of consciousness Avoiding contact 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)

Issue a "Warning" water
Use as shore
Should be removed
Chemical and physical treatment

2. LABEL

2.1 Category: Poison
2.2 Class: 6

3. CHEMICAL DESIGNATIONS

3.1 DOT Compatibility Class: Not listed
3.2 Formula: $CH_3AsO(OH)(ONa)$
$CH_3AsO(ONa)_2 \cdot 6H_2O$
3.3 BOD/UIR Designations: 0.1/1557
3.4 DOT ID No.: 1557
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 darken red or green over
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: Substance poisoning by chronic cause early tests, burning of throat and stomach, and intestinal pain. Acute toxicity evidenced by headache, vomiting, stupor, convulsions, paralysis. About 1 ounce to 1 pound must be taken to cause these symptoms.
5.3 Treatment of Exposure: INGESTION cause vomiting; give water and repeat; 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: Data not available
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: Data not available
5.8 Vapor (Gas) Irritant Characteristics: None
5.9 Liquid or Solid Irritant Characteristics: Prolonged contact may cause skin sensitivity
5.10 Odor Threshold: Not pertinent
5.11 IDLH Value: Data not available

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: The solid disodium salt (DSMA) contains water of 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 RAS 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: 142 (DSMA); 252 (DSMA hexahydrate)
12.3 Boiling Point at 1 atm: Decomposes
12.4 Freezing Point:
(DSMA) 243°F
= 117°C = 390°K
(DSMA) 137°F = 58°C = 332°K
12.5 Critical Temperature: Not pertinent
12.6 Critical Pressure: Not pertinent
12.7 Specific Gravity:
(DSMA) 1.9 at 20°C (solid)
(MSMA solutions) 1.4-1.5 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: 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

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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METHYL PARATHION

MPT

Common Synonyms
Metacid MPT
Parathion Methyl
Methyl Parathion
O, O-Dimethyl O-p-nitrophenyl thiophosphate
Parathion-methyl

Solid crystals with a mild or brown odor. Fusion eggs or garlic odor

Solid and liquid form in water, solution floats on water forming floatings down to 65°F

AVOID CONTACT with LIQUID. Keep people away.
Wear chemical protective suit with self-contained breathing apparatus.
Stop leak if possible.
Call for assistance.
Isolate and remove combustible material.
Notify local health and pollution control agencies.

Fire

Combustible.
POISONOUS GASES ARE PRODUCED IN FIRE AND WHEN HEATED.
Containers may explode in fire.
Wear chemical protective suit with self-contained breathing apparatus.
Withdraw from area immediately if container is discolored.
Extinguish with water.
Cool exposed containers with water.

Exposure

CALL FOR MEDICAL AID.
LIQUID OR SOLID.
POISONOUS IF SWALLOWED OR IF SKIN IS EXPOSED.
Wear protective clothing and gloves.
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.
Induce vomiting.
Have victim vomit repeatedly.
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.
Solution is causing to decompose.
May be dangerous if it enters water intakes.
Notify local health and wildlife officials.
Notify operators of nearest water intakes.

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook)
Issue warning-poison.
Water contaminant.
Restrict access.
Shield the released.
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: $(CH_3O)_2PSOC_6H_4NO_2$-p
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 (at shipping): Solid (dust, or solution)
4.2 Color: Colorless solid or brownish liquid
4.3 Odor: Characteristic, like rotten eggs or garlic

5. HEALTH HAZARDS

5.1 Personal Protective Equipment: Approved mask or respirator; natural rubber gloves, coveralls; protective clothing; goggles
5.2 Symptoms Following Exposure: Exposure to fumes from a fire, or to the liquid, causes nausea, 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: Speed is essential. INGESTION: call a doctor. If victim is not breathing, immediately institute artificial respiration by mouth-to-mouth, mouth-to-nose, or mouth-to-pharyngeal method, when victim is convulsing, give milk, water, or salt-water and induce vomiting immediately. SKIN OR EYES: flood and wash exposed areas thoroughly 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 C.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: Drums may rupture violently
6.7 Ignition Temperature: Data not available
6.8 Electrical Hazard: Not pertinent
6.9 Burning Rate: Data not available
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: Not decomposed in 5 days at 40°C
7.2 Reactivity with Common Materials: Is absorbed in cases, etc., which must be replaced to eliminate possible hazard.
7.3 Stability During Transport: Decomposes above 50°C with possible explosive force.
7.4 Neutralizing Agents for Acids and Caustics: Apply caustic or acids with study and water stone dissolver.
7.5 Polymerization: Not pertinent
7.6 Inhibitor of Polymerization: Not pertinent
7.7 Water Reactivity: Reactant to Products: Data not available
7.8 Reactivity Group: Data not available

8. WATER POLLUTION

8.1 Aquatic Toxicity:
1.0 ppm/96 hr/sheepshead/TL_m/fresh water
0.3 ppm/96 hr/mosquitofish/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); 80% in xylene
9.2 Storage Temperature: Below 80°F
9.3 Inert Atmosphere: no requirement
9.4 Venting: Pressure-vacuum

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)
A-X-Y

11. HAZARD CLASSIFICATIONS

11.1 Code of Federal Regulations: Poison, 6
11.2 IMO Hazard Rating for Bulk Water Transportation: not listed
11.3 NFPA Hazard Classification:

Category	Classification*	
Health Hazard (Blue)	4	4
Flammability (Red)	3	3
Reactivity (Yellow)	2	2

*Fire division for oxidizer, assigned 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

From Genium's Reference Collection
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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	
H	3
F	0
R	1
PPG*	
*See sect. 8	

R	1
I	4
S	4
K	0

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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Section 1. Material Identification

Nitrogen Dioxide (NO_2) Description: Occurs from combustion of fossil fuels, fermentation of animal feed in silos, as a by-product of chemical manufacture (explosives, dyes, lacquers), and whenever nitric acid acts on metals or contacts organic material. Derived commercially by oxidation of nitric acid. Available as a pressurized liquid which contains an equilibrium of nitrogen dioxide (NO_2) and nitrogen tetroxide (N_2O_4). Used as an intermediate in sulfuric and nitric acid production, nitration of organic compounds and explosives, in bleaching flour, in the manufacture of oxidized cellulose compounds (hemostatic cotton), as a component of fuel for jet propulsion (proposed use), and as a polymerization inhibitor.

Other Designations: CAS No. 10102-44-0, nitrito. Since NO_2 and N_2O_4 are always found together at normal environmental temperatures, *dinitrogen tetroxide, nitrogen peroxide, and nitrogen tetroxide are used as synonyms for* NO_2.

Manufacturer: Contact your supplier or distributor. Consult latest *Chemical Week Buyers' Guide*[73] for a suppliers list.

Cautions: Nitrogen dioxide is a strong oxidizer which causes corrosive nitric acid formation on contact with mucous membranes and moist skin and can produce severe pulmonary edema (fluid in lungs) leading to death.

R 1
I 4
S 3*
K 2
* Skin absorption

NFPA
0
3 0
OX

HMIS
H 3†
F 0
R 0
PPE‡
† Chronic Effects
‡ Sec. 8

Section 2. Ingredients and Occupational Exposure Limits

Nitrogen dioxide, ca 99.5%

1991 OSHA PEL
15-min STEL: 1 ppm (1.8 mg/m³)

1990 IDLH Level
50 ppm

1990 NIOSH REL
STEL: 1 ppm (1.8 mg/m³)

1992-93 ACGIH TLVs
TWA: 3 ppm (5.6 mg/m³)
STEL: 5 ppm (9.4 mg/m³)

1990 DFG (Germany) MAK
TWA: 5 ppm (9 mg/m³)
Category 1: local irritants
Peak Exposure Limit: 10 ppm, 5 min momentary value, 8 per shift

1985-86 Toxicity Data*
Human, inhalation, TC_{Lo}: 90 ppm/40 min caused cough, difficulty breathing, and other changes.
Human, inhalation, LC_{Lo}: 200 ppm/1 min; no toxic effect noted
Rat, inhalation, TC_{Lo}: 85 µg/m³/24 hr (1 to 22 days of pregnancy) produced fetotoxicity including fetal death.
Rat, inhalation: 27 ppm/3 continuous hours caused gene mutation in mammalian cells.

* See NIOSH, *RTECS* [QW9800000 (QW9805000, *liquid*)], for additional mutation, reproductive, and toxicity data.

Section 3. Physical Data

Boiling Point: 69.8 °F (21 °C)
Melting Point: 15.3 °F (-9.3 °C)
Vapor Pressure: 400 mm Hg at 176 °F (80 °C), 720 mm Hg at 68 °F (20 °C)
Saturated Vapor Density (Air = 1.2 kg/m³; 0.075 lb/ft³): 1.866 kg/m³; 0.116 lb/ft³
Refraction Index: 1.40 at 68 °F (20 °C)
Odor Threshold: 0.058 to 0.4 ppm
Molecular Weight: 46.01
Density: 1.49 at 32 °F (0 °C)
Water Solubility: Decomposes to form nitric acid and nitric oxide.
Other Solubilities: Soluble in sulfuric and nitric acids, alkalies, chloroform, and carbon disulfide
Ionization Potential: 9.75 eV

Appearance and Odor: Colorless or bluish-white solid, yellow liquid, or brownish-red gas with an irritating, acrid odor.

Section 4. Fire and Explosion Data

Flash Point: Nonflammable	**Autoignition Temperature:** Nonflammable	**LEL:** None reported	**UEL:** None reported

Extinguishing Media: Nitrogen dioxide is nonflammable but enhances combustion of organic matter and other combustible materials (carbon, sulfur, phosphorus). Use extinguishing media appropriate to surrounding fire.
Unusual Fire or Explosion Hazards: Cylinder may explode in heat of fire. Mixture with fuels may explode.
Special Fire-fighting Procedures: Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Structural firefighters' protective clothing is not effective for fires involving nitrogen dioxide. Apply cooling water to sides of container until well after fire is out. Stay away from ends of tanks. For massive fire in cargo area, use monitor nozzles or unmanned hose holders; if this is impossible, withdraw from area and let fire burn. Do not release runoff from fire control methods to sewers or waterways.

Section 5. Reactivity Data

Stability/Polymerization: Nitrogen dioxide is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur.
Chemical Incompatibilities: NO_2 is corrosive to wet steel, reacts with alkalies to form nitrates and nitrites, and decomposes in water to form nitric acid and nitric oxide. It is incompatible with metals, ammonia, acetic anhydride, alkenes, acetonitrile + indium, barium oxide, carbon dichloride, carbon disulfide, chloroform, dimethyl sulfoxide, iron oxide, formaldehyde, fluorine, cyclohexane, nitrobenzene, sulfuryl chloride, trichloroethane, and ozone.
Conditions to Avoid: Avoid contact with organic materials and other incompatibles.
Hazardous Products of Decomposition: Thermal oxidative decomposition of nitrogen dioxide can produce other nitrogen oxide (NO_x) gases.

Section 6. Health Hazard Data

Carcinogenicity: The IARC,[164] NTP,[169] and OSHA[164] do not list nitrogen dioxide as a carcinogen.
Summary of Risks: Nitrogen dioxide is a strong oxidizer which causes severe burns of the eyes, skin (if moist), and mucous membranes of the respiratory tract as it forms nitric acid in contact with water/moisture. Death due to pulmonary edema (fluid in lungs) is common after severe exposures. Nitrogen dioxides' toxicity is mainly due to the peroxidation of lipids causing severe cell membrane damage. This results in decreased resistance to pulmonary infection by adversely affecting the mucociliary system, macrophages, and antibodies. Chronic pulmonary fibrosis may occur after repeated exposures to low concentrations. Animal studies have shown lesions representative of emphysema in humans.

Continue on next page

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Section 6. Health Hazard Data, *continued*

Medical Conditions Aggravated by Long-Term Exposure: Chronic respiratory diseases. **Target Organs:** Eyes, skin, respiratory and cardiovascular systems. **Primary Entry Routes:** Inhalation, eye and skin contact. **Acute Effects:** Brief exposures to 250 ppm can cause cough, frothy sputum, and increased difficulty breathing; within 1 to 2 hr victim may develop pulmonary edema, cyanosis (bluish skin and lip color due to lack of oxygenated blood), loud wheezing, rapid heart beat with increased respiration rate. Sometimes only cough, difficulty breathing will occur with symptoms subsiding over 2 to 3 weeks, but may be followed by a second stage of increasingly severe symtoms characterized by fever, chills, increasingly difficult respiration, cyanosis, and recurring pulmonary edema. Death may occur in initial or secondary stage. A mild initial stage does not indicate a mild or absence of second stage; indeed, a mild first stage may be followed by a severe secondary stage resulting in death. If the second stage is survived, recovery usually occurs within 2 to 3 weeks. However, some do not fully recover and suffer varying degrees of impaired lung function. Contact with the eyes may cause corneal irritation and conjunctivitis. Contact with moist skin is irritating and may cause burns (formation of nitric acid). Sudden bursts of the compressed liquid can produce frostbite. **Chronic Effects:** Chronic pulmonary fibrosis leading to obstruction of the bronchioles (*bronchiolitis obliterans*) may be severe. Yellow-brown staining of the skin & teeth may occur from repeated exposure but is generally due to the formation of nitric acid.

FIRST AID *Rescuers entering areas of potentially dangerous NO_2 levels need to wear a SCBA (Sec. 8) to prevent becoming a secondary victim.* **Eyes:** *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately. **Skin:** If frostbite occurs, rewarm at 42 °C (107 °F) until skin color and temperature are completely normal. **Inhalation:** Remove exposed person to fresh air and support breathing as needed. **Ingestion:** *Unlikely*! NO_2 is a gas above 69.8 °F but if it occurs have that *conscious and alert* person drink water to dilute. *Do not induce vomiting.* **Note to Physicians:** Effects may be delayed for 48 to 72 hours, keep under observation. Pulmonary function tests may reveal obstructive and restrictive defects. In its early stages, bronchiolitis obliterans is reversible with corticosteroids for up to 12 months.

Section 7. Spill, Leak, and Disposal Procedures

Spill/Leak: Immediately notify safety personnel, isolate and ventilate area, deny entry, and stay upwind. Keep combustibles away from leak. NO_2 is a strong oxidizer and can create a fire. Use water spray to disperse vapors and personnel. Be aware that runoff will contain nitric acid and must be contained. Cleanup personnel should protect against inhalation and skin contact. If cold liquid is spilled, allow to vaporize. If cylinder cannot be repaired in place, remove to a safe, outside location and fix or allow gas to empty. Follow applicable OSHA regulations (29 CFR 1910.120).
Ecotoxicity Values: Mosquito fish, TLm =72 ppm/96 hr (fresh water); cockle, LC_{50} = 330 to 1000 ppm/48 hr (salt water).
Disposal: Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.
EPA Designations
Listed as a RCRA Hazardous Waste (40 CFR 261.33): No. P078
Listed as a CERCLA Hazardous Substance* (40 CFR 302.4): Final Reportable Quantity (RQ), 10 lb (4.54 kg) [* per RCRA, Sec. 3001 & CWA, Sec. 311 (b)(4)]
Listed as a SARA Extremely Hazardous Substance (40 CFR 355), TPQ: 100 lb
SARA Toxic Chemical (40 CFR 372.65): Not listed
OSHA Designations
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)
Listed as a Process Safety Hazardous Chemical (29 CFR 1910.119), TQ: 250 lb

Section 8. Special Protection Data

Goggles: Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy. **Respirator:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. For < 25 ppm, use any supplied-air respirator (SAR) operated in a continuous-flow mode. For < 50 ppm, use any SAR or SCBA with a full facepiece. *Never* wear a respirator with charcoal filters as NO_2 supports combustion of charcoal! For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas. **Other:** Wear chemically protective gloves, boots, aprons, or gauntlets to prevent skin contact. Polyvinylidine chloride/polyethylene have breakthrough times (BT) of > 4 hr and are recommended as suitable materials for PPE. Polyvinyl chloride and fluorocarbon rubber have BT's of < 1 hr and are not recommended. **Ventilation:** Provide general and local exhaust ventilation systems to maintain airborne concentrations below the OSHA PEL (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.[103]
Safety Stations: Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.
Contaminated Equipment: Separate contaminated work clothes from street clothes. Launder contaminated work clothing before wearing. Remove this material from your shoes and clean personal protective equipment. **Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9. Special Precautions and Comments

Storage Requirements: Prevent physical damage to containers. Store in a cool, dry, well-ventilated area away from organic, combustible, and reducing, materials and other incompatibles (Sec. 5). NO_2 can be stored in steel containers when moisture content is < 0.1%. Outside or detached storage is preferred. **Engineering Controls:** To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control airborne contaminants and to maintain concentrations at the lowest practical level. Only stainless steel fittings should be used for equipment.
Administrative Controls: Prohibit entrance of silos for 6 weeks after filling (fermentation yields high levels of NO_2). Consider preplacement or periodic medical exams of exposed workers with emphasis on the respiratory tract, skin, and teeth.

Transportation Data (49 CFR 172.101)

DOT Shipping Name: Dinitrogen tetroxide, liquefied
DOT Hazard Class: 2.3
ID No.: UN1067
DOT Label: Poison Gas, Oxidizer
DOT Packing Group: --
Special Provisions (172.102): 1, B7, B12, B14, B45, B46, B61, B66, B67, B77

Packaging Authorizations
a) Exceptions: --
b) Non-bulk Packaging: 173.336
c) Bulk Packaging: 173.314

Vessel Stowage Requirements
a) Vessel Stowage: D
b) Other: 40, 43

Quantity Limitations
a) Passenger, Aircraft, or Railcar: Forbidden
b) Cargo Aircraft Only: Forbidden

MSDS Collection **References:** 26, 73, 89, 100, 101, 103, 124, 126, 127, 132, 133, 136, 140, 148, 149, 153, 159, 163, 164, 167, 171, 174, 180
Prepared by: M Gannon, BA; **Industrial Hygiene Review:** DJ Wilson, CIH; **Medical Review:** AC Darlington, MPH, MD

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NITROGEN TETROXIDE

NOX

Common Synonyms	Liquefied compressed gas Red-brown	Strong, unpleasant chemical odor
Nitrogen peroxide Nitrogen dioxide Red fumes of nitrogen Tetroxide of nitrogen Dinitrogen tetroxide	Dries and reacts with metal. Poisonous brown vapor is produced.	

AVOID CONTACT WITH LIQUID AND VAPOR. Keep people away.
Wear goggles, self-contained breathing apparatus, and rubber overclothing (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 explosion on contact with combustibles.
POISONOUS GASES ARE PRODUCED IN FIRE AND WHEN HEATED.
Wear goggles, self-contained breathing apparatus, and rubber overclothing (including gloves).
Flood discharge area with water.
Stop flow of gas or liquid.
Cool exposed 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 Methods Handbook)
Issue warning/evacuation, as circumstances, water contaminated, corrosive
Personal safety
Evacuate area

2. LABEL

2.1 Category: Poison gas; Oxidizer
2.2 Class: 2 and 5

3. CHEMICAL DESIGNATIONS

3.1 CG Compatibility Class: 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 and Basic Liquid
4.2 Color: Red-brown at ambient temperature; colorless below about 14°F
4.3 Odor: Pungent, acrid, mildly 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, bodily exhaustion, mental confusion, lethargy, bluish skin, and weak, rapid pulse. Severe NOX exposures with gas shortages in lungs, unconsciousness, coma and death by suffocation can result, usually within a few hours after onset of pulmonary edema.
5.3 Treatment of Exposure: INHALATION: remove patient to fresh air and have him breathe as deeply as possible and a doctor; artificial respiration may be necessary; give oxygen if coughing starts; physician may administer morphine (10 mg.) EYES AND SKIN: flush with copious tap or clean water for at least 15 min.
5.4 Threshold Limit Value: 5 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 cannot be detected even at low concentrations.
5.9 Liquid or Solid Irritant Characteristics: Severe skin irritant. Causes severe and long-lasting burns on short contact and is very irritating 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: Poisonous nitric gas may be formed.
6.6 Behavior in Fire: Does not burn, but supports combustion of combustible materials such as wood. May cause fire or explosion on contact with other materials.
6.7 Ignition Temperature: Not flammable
6.8 Electrical Hazards: 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: Combines 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 soda ash or lime.
7.5 Polymerization: Not pertinent
7.6 Inhibitor of Polymerization: Not pertinent
7.7 Water Rate (Reaction) to Products: Data not available
7.8 Reactivity Group: Data not available

8. WATER POLLUTION

8.1 Aquatic Toxicity:
72 ppm/96 hr/mosquito fish/TL_m/fresh water
330-1000 ppm/48 hr/oysters/LC_{50}/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 containers shall be equipped with overpressure relief systems.
9.3 Inert Atmosphere: No requirement
9.4 Venting: Pressure relief valves on containers

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-4-4-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
Poisons	4
Water Pollution	
Human Toxicity	3
Aquatic Toxicity	3
Aesthetic Effect	4
Reactivity	
Other Chemicals	2
Water	0
Self Reaction	

11.3 NFPA Hazard Classification:

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: Gaseous
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:
11.2°F = −11.2°C = 262°K
12.5 Critical Temperature:
317.5°F = 158.5°C = 431.6°K
12.6 Critical Pressure:
1470 psia = 100 atm = 10.1 MN/m²
12.7 Specific Gravity:
1.45 at 68°F (Gas)
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.) 1.322
12.12 Latent Heat of Vaporization:
170 Btu/lb = 99.1 cal/g = 4.15 × 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: 69.5 cal/g
12.18 Limiting Viscosity: Data not available
12.19 Reid Vapor Pressure: 30 psia

6. FIRE HAZARDS (Continued)

6.11 Electrostatic Air to Fuel Ratio: Data not available
6.12 Flame Temperature: Data not available

Material Safety Data Sheet

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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	
PPE*		
	R	1
	I	--
	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	
Indust. Hygiene/Safety	4/87
Medical Review	4/87

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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

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/m^3* (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	LOWER	UPPER
40°F (4°C) CC	896°F (480°C)	% by Volume	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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SECTION 6. HEALTH HAZARD INFORMATION | TLV

Toluene is not considered a carcinogen by the NTP, IARC, or OSHA. SUMMARY OF RISKS: Vapors of toluene may cause irritation of the eyes, nose, upper respiratory tract, and skin. Exposure to 200 ppm for 8 hours causes mild fatigue, weakness, confusion, lacrimation (tearing) and paresthesia (a sensation of prickling, tingling, or creeping on the skin that has no objective cause). Exposure to higher concentrations may cause headache, nausea, dizziness, dilated pupils, and euphoria, and, in severe cases, may cause unconsciousness and death. The liquid is irritating to the eyes and skin. Contact with the eyes may cause transient corneal damage, conjunctival irritation, and burns if not promptly removed. Repeated and/or prolonged contact with the skin may cause drying and cracking. It may be absorbed through the skin in toxic amounts. Ingestion causes irritation of the gastrointestinal tract and may cause effects resembling those from inhalation of the vapor. Chronic overexposure to toluene may cause reversible kidney and liver injury. FIRST AID: EYE CONTACT: Immediately flush eyes, including under eyelids, with running water for at least 15 minutes. Get medical attention if irritation persists.* SKIN CONTACT: Immediately flush skin (for at least 15 minutes) while removing contaminated shoes and clothing. Wash exposed area with soap and water. Get medical attention if irritation persists or if a large area has been exposed.* INHALATION: Remove victim to fresh air. Restore and/or support breathing as required. Keep victim warm and quiet. Get medical help.* INGESTION: Give victim 1 to 2 glasses of water or milk. Contact a poison control center. Do not induce vomiting unless directed to do so. Transport victim to a medical facility. Never give anything by mouth to a person who is unconscious or convulsing. * GET MEDICAL ASSISTANCE = In plant, paramedic, community. Get medical help for further treatment, observation, and support after first aid, if indicated.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

SPILL/LEAK: Notify safety personnel of large spills or leaks. Remove all sources of heat and ignition. Provide maximum explosion-proof ventilation. Limit access to spill area to necessary personnel only. Remove leaking containers to safe place if feasible. Cleanup personnel need protection against contact with liquid and inhalation of vapor (see sect. 8). WASTE DISPOSAL: Absorb small spills with paper towel or vermiculite. Contain large spills and collect if feasible, or absorb with vermiculite or sand. Place waste solvent or absorbent into closed containers for disposal using nonsparking tools. Liquid can be flushed with water to an open holding area for handling. Do not flush to sewer, watershed, or waterway. COMMENTS: Place in suitable container for disposal by a licensed contractor or burn in an approved incinerator. Consider reclaiming by distillation. Contaminated absorbent can be buried in a sanitary landfill. Follow all Federal, state, and local regulations. TLm 96: 100-10 ppm. Toluene is designated as a hazardous waste by the EPA. The EPA (RCRA) HW No. is U220 (40 CFR 261). The reportable quantity (RQ) is 1000 lbs/454 kg (40 CFR 117).

SECTION 8. SPECIAL PROTECTION INFORMATION

Provide general and local exhaust ventilation to meet TLV requirements. Ventilation fans and other electrical service must be nonsparking and have an explosion-proof design. Exhaust hoods should have a face velocity of at least 100 lfm (linear feet per minute) and be designed to capture heavy vapor. For emergency or nonroutine exposures where the TLV may be exceeded, use an organic chemical cartridge respirator if concentration is less than 200 ppm and an approved canister gas mask or self-contained breathing apparatus with full facepiece if concentration is greater than 200 ppm.

Safety glasses or splash goggles should be worn in all work areas. Neoprene gloves, apron, face shield, boots, and other appropriate protective clothing and equipment should be available and worn as necessary to prevent skin and eye contact. Remove contaminated clothing immediately and do not wear it until it has been properly laundered.

Eyewash stations and safety showers should be readily available in use and handling areas.

Contact lenses pose a special hazard; soft lenses may absorb irritants and all lenses concentrate them.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

STORAGE SEGREGATION: Store in a cool, dry, well-ventilated area away from oxidizing agents, heat, sparks, or open flame. Storage areas must meet OSHA requirements for class IB flammable liquids. Use metal safety cans for handling small amounts. Protect containers from physical damage. Use only with adequate ventilation. Avoid contact with eyes, skin, or clothing. Do not inhale or ingest. Use caution when handling this compound because it can be absorbed through intact skin in toxic amounts. SPECIAL HANDLING/STORAGE: Ground and bond metal containers and equipment to prevent static sparks when making transfers. Do not smoke in use or storage areas. Use nonsparking tools. ENGINEERING CONTROLS: Preplacement and periodic medical exams emphasizing the liver, kidneys, nervous system, lungs, heart, and blood should be provided. Workers exposed to concentrations greater than the action level (50 ppm) should be examined at least once a year. Use of alcohol can aggravate the toxic effects of toluene.

COMMENTS: Emptied containers contain product residues. Handle accordingly!

Toluene is designated as a hazardous substance by the EPA (40 CFR 116). DOT Classification: Flammable liquid. UN1294.

Data Source(s) Code: 1-9, 12, 16, 20, 21, 24, 26, 34, 81, 82. CR

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Approvals J.O. Reinecke, 11/86.

Indust. Hygiene/Safety DW 12-86

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Material Safety Data Sheet Collection

Toxaphene

MSDS No. 977

Date of Preparation: 10/95

Section 1 - Chemical Product and Company Identification

Product/Chemical Name: Toxaphene
Chemical Formula: $C_{10}H_{10}Cl_8$
CAS Number: 8001-35-2
Synonyms: Alltex, camphechlor, chlorinated camphene, chlorocamphene, Cristoxo-90, Estonox, Geniphene, Melipax, octachlorocamphene, Phenatox, polychlorocamphene, Strobane-T
Derivation: Produced by chlorination of camphene to 67-69% chlorine.
General Use: Although formerly widely used as an agricultural insecticide, today it has only conditional/restricted uses for existing stock, such as for cattle dips, pineapples in Peurto Rico, bananas in the Virgin Islands, and emergency use on corn, cotton, and small grains and the US. Available as a dust containing 20% toxaphene, emulsifiable formulas containing up to 8 lb/gallon, oil solutions (90% toxaphene) and wettable powders containing 40% toxaphene.
Vendors: Consult the latest *Chemical Week Buyers' Guide.* (73)

Section 2 - Composition / Information on Ingredients

Toxaphene, ca 100 %wt

OSHA PELs
8-hr TWA: 0.5 mg/m^3 (skin)
Vacated 1989 Final Rule Limit
STEL: 1 mg/m^3 (skin)

ACGIH TLVs
8-hr TWA: 0.5 mg/m^3 (skin)
STEL: 1 mg/m^3 (skin)

NIOSH REL
Ca; lowest feasible concentration
LOQ: 0.01 mg/m^3 (skin)

IDLH Level
200 mg/m^3

DFG (Germany) MAK
TWA: 0.5 mg/m^3
Category III: Substances with systemic effects
Onset of effect: > 2 hr
Half-life: > shift length (strongly cumulative)

Peak Exposure Limit:
5 mg/m^3, 30 min average value, 1/shift

Section 3 - Hazards Identification

☆☆☆☆☆ Emergency Overview ☆☆☆☆☆

Toxaphene exists as an amber, waxy solid with a pleasant pine odor. It is irritating to the skin and is toxic to the central nervous system, many times resulting in convulsions. It is a possible human carcinogen. Toxaphene may be found in water as well as oil solutions. Oil solutions can present an increased health hazard and may also be flammable.

Wilson Risk Scale	
R	1
I	3
S	2*
K	1

*Skin absorption

HMIS	
H	3*
F	0
R	0

*Chronic effects
PPE†
†Sec. 8

Potential Health Effects

Primary Entry Routes: Inhalation, skin contact/absorption.
Target Organs: Skin, central nervous system (CNS).
Acute Effects
Inhalation: Symptoms include nausea and vomiting, salivation, muscle spasms followed by convulsions, and possibly death due to respiratory failure. Allergic bronchopneumonia was observed in two workers after using toxaphene, but this does not appear to be a common effect.
Skin: Irritation and allergic dermatitis may occur. Skin absorption can occur, especially when toxaphene is in a solution form. Two cases of aplastic anemia have been seen after skin absorption, however, the toxaphene was in a lindane mixture and it is not known which (or if both) chemical was responsible.
Ingestion: The estimated oral lethal dose is 2 to 7 grams; 10 mg/kg causes non-fatal convulsions in some individuals and no symptoms in others.
Carcinogenicity: The following agencies classify the carcinogenicity of toxaphene: IARC (group 2B, possibly carcinogenic to humans with limited human evidence in the absence of sufficient animal evidence), NIOSH-X (carcinogen defined with no further categorization), NTP (group 2, reasonably anticipated to be a carcinogen with limited human evidence or sufficient animal evidence), and EPA (group 2, probable human carcinogen with limited human epidemiological evidence and sufficient animal evidence). OSHA does not list toxaphene as a carcinogen.
Medical Conditions Aggravated by Long-Term Exposure: Skin and central nervous system disorders including epilepsy.
Chronic Effects: Animal studies have demonstrated the inducement of liver cancer by chronic exposure to toxaphene. It is not known whether or not the same effect will occur in humans. Chromosomal aberrations (mutations) have been seen in humans (lymph cell cultures) exposed to toxaphene.

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Section 4 - First Aid Measures

Inhalation: Remove exposed person to fresh air and support breathing as needed.
Eye Contact: *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water for at least 15 minutes. Consult a physician or ophthalmologist if pain or irritation persist.
Skin Contact: *Quickly* remove contaminated clothing. Rinse with flooding amounts of water followed by a thorough soap and water wash. For reddened or blistered skin, consult a physician.
Ingestion: Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center. Unless the poison control center advises otherwise, have the *conscious and alert* person drink 1 to 2 glasses of water, then induce vomiting. *Note*: Do not induce vomiting if toxaphene is found in an oil solution.
After first aid, get appropriate in-plant, paramedic, or community medical support.
Note to Physicians: Treatment is symptomatic and supportive.

Section 5 - Fire-Fighting Measures

Flash Point: Although toxaphene is a noncombustible solid, it is commercially available in formulations (solutions, emulsifiables) that are combustible. Flash points have been given for the following solutions: 60% (275 °F/135 °C), CC; 90% (239 °F/115 °C), TCC; and Strobane-T90 (95 °F/35 °C), TCC. The most commonly used solvent appears to be xylene.

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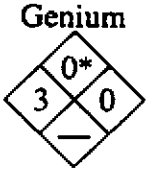

Autoignition Temperature: Varies according to formulation.
LEL: Varies according to formulation.
UEL: Varies according to formulation.
Extinguishing Media: Use agents suitable for the *solvent* in the toxaphene formulation.
Unusual Fire or Explosion Hazards: Hazards may vary according to specific formulation. Consult the MSDS on the particular solvent involved.
Hazardous Combustion Products: Carbon oxide(s), chlorine, and hydrogen chloride gas.
Fire-Fighting Instructions: *Do not* release runoff from fire control methods to sewers or waterways.
Fire-Fighting Equipment: Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode.

*The fire rating for toxaphene is "0" for the pure compound, but can be a "1" or "2" depending on the solvent used.

Section 6 - Accidental Release Measures

Spill /Leak Procedures: Notify safety personnel, isolate and ventilate area, deny entry, and stay upwind. Shut off all ignition sources. Cleanup personnel should protect against inhalation and skin contact.
Small Spills: Carefully scoop up or vacuum (with appropriate filter) and place in suitable containers. If toxaphene is in solution, take up with earth, sand, vermiculite, or other absorbent, noncombustible material.
Large Spills
Containment: Flush with water to containment area for later disposal. *Do not* release into sewers or waterways.
Regulatory Requirements: Follow applicable OSHA regulations (29 CFR 1910.120).

Section 7 - Handling and Storage

Handling Precautions: Use only with adeqaute ventilation and appropriate PPE.
Storage Requirements: Store in a cool, dry, well-ventilated area away from heat, ignition sources, and incompatibles (Sec. 10). Preferably, store in glass or polyolefin containers. If metal containers are used, they must be lined with polyolefin.

Section 8 - Exposure Controls / Personal Protection

Engineering Controls: Enclose all processes to prevent dust dispersion into work area. Metal piping must be lined (polyolefin recommended) to prevent corrosion, especially from emulsifiable formulations.
Ventilation: Provide general or local exhaust ventilation systems to maintain airborne concentrations below OSHA PELs (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.(103)
Administrative Controls: Consider preplacement and periodic medical exams of exposed workers with emphasis on the skin and central nervous system. Exams should be performed *at least* annually.
Respiratory Protection: Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. For any detectable concentration, wear any SCBA with a full facepiece and operated in pressure-demand or other positive-pressure mode, or any supplied-air respirator with a full facepiece in combination with an auxiliary SCBA operated in pressure-demand or other positive-pressure mode. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas.

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Protective Clothing/Equipment: Wear chemically protective gloves, boots, aprons, and gauntlets to prevent prolonged or repeated skin contact. Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Contact lenses are not eye protective devices. Appropriate eye protection must be worn instead of, or in conjunction with contact lenses.

Safety Stations: Make emergency eyewash stations, safety/quick-drench showers, and washing facilities available in wor

Contaminated Equipment: Separate contaminated work clothes from street clothes. Launder before reuse. Remove toxaphene from your shoes and clean personal protective equipment.

Comments: Never eat, drink, or smoke in work areas. Practice good personal hygiene after using toxaphene, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

Section 9 - Physical and Chemical Properties

Physical State: Solid

Appearance and Odor: Amber, waxy, with a pine odor.

Odor Threshold: 2.366 mg/m^3

Vapor Pressure: 0.2 to 0.4 mm Hg at 68 °F (20 °C)

Formula Weight: 414 (average)

Specific Gravity (H_2O=1, at 4 °C): 1.65 at 77 °F (25 °C)

Water Solubility: 0.0003 g/100 g at 68 °F (20 °C)

Other Solubilities: Soluble in petroleum oils, alcohol, acetone, hexane; > 450 g/100 mL in benzene, carbon tetrachloride, ethylene dichloride, and xylene; 280 g/100 mL in kerosene.

Boiling Point: Decomposes at 155 °C (dechlorination)

Melting Point Range: 149 to 194 °F (65 to 90 °C)

Octanol/Water Partition Coefficient: log Kow = 3.3 (+/- 0.4

Henry's Law Constant: 6.3 x 10^{-2} to 4.98 x 10^{-3} atm-m^3/mo

Section 10 - Stability and Reactivity

Stability: Toxaphene is stable at room temperature in closed containers under normal storage and handling conditions.

Polymerization: Hazardous polymerization does not occur.

Chemical Incompatibilities: Toxaphene is corrosive to iron and certain other metalsand incompatible with strong oxidizers. It dechlorinates in the presence of alkalis and upon exposure to sunlight, releasing hydrogen chloride gas.

Conditions to Avoid: Exposure to heat and incompatibles.

Hazardous Decomposition Products: Thermal oxidative decomposition of toxaphene can produce carbon oxide(s), chlorine, and hydrogen chloride gas.

Section 11 - Toxicological Information

Toxicity Data:*

Acute Dermal Effects:

Human, skin, TD_{Lo}: 675 mg/kg caused allergic dermatitis.

Rabbit, skin, LD_{50}: 1025 mg/kg caused excitement, affected food intake, and caused regional or general arteriolar or venous dilation.

Reproductive Effects:

Rat, oral: 280 mg/kg administered to males (10 weeks prior to mating) had an effect on spermatogenesis.

Rat, oral: 150 mg/kg administered from 7 to 16 days of pregnancy resulted in specific developmental abnormalities of the musculoskeletal system.

Acute Oral Effects:

Rat, oral, LD_{50}: 50 mg/kg

Human, oral, LD_{Lo}: 28 mg/kg caused somnolence, coma, and convulsions or effect on seizure threshold.

Multiple Dose Toxicity Data:

Dog, oral: 385 mg/kg administered intermittently for 13 weeks caused changes in liver weight and biochemical effects (phosphatases).

Tumorigenicity:

Mouse, oral: 6.6 g/kg administered continuously for 80 weeks resulted in liver tumors.

Mutagenicity:

S. typhimurium: 100 µg/plate (+ S9)

Human, lymphocyte: 10 µmol/L caused sister chromatid exchange.

* See NIOSH, *RTECS* (XW5250000), for additional toxicity data.

Section 12 - Ecological Information

Ecotoxicity: *Salmo gairdneri* (rainbow trout), LC_{50} = 10.6 µg/L/96 hr; *Pimephales promelas* (fathead minnow), LC_{50} = 18 µg/L/96 hr; *Micropterus salmoides* (largemouth bass), LC_{50} = 2 µg/L/96 hr.

Environmental Fate: If released to soil, toxaphene is very persistent and can remain for 1 to 14 years, depending upon conditions. Leaching to groundwater is not significant, as it strongly adsorbs to soil. Volatilization can occur from soil surfaces and biodegradation will occur, especially under anaerobic conditions such as flooded soil. In water, evaporation is expected to be significant with a half-life of 6 hr from a model river 1 m deep, flowing 1 m/sec with a wind speed of 3 m/sec. Bioconcentration is high in aquatic organisms with a BCF of 3,100 to 33,000 for fish, 400 to 1,200 for shrimp, and 6,902 for algae. In the air, toxaphene will photolyze slowly, but most will react with photochemically-produced hydroxyl radicals with an estimated half-life of 4 to 5 days.

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Section 13 - Disposal Considerations

Disposal: Dissolve in a flammable solvent and atomize in a suitable incinerator equipped with an afterburner and scrubber. Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

Section 14 - Transport Information

DOT Transportation Data (49 CFR 172.101):

Shipping Name: Organochlorine pesticides, solid, toxic, n.o.s.
Shipping Symbols: –
Hazard Class: 6.1
ID No.: UN2761
Packing Group: II
Label: Poison
Special Provisions (172.102): –

Packaging Authorizations
a) Exceptions: None
b) Non-bulk Packaging: 173.212
c) Bulk Packaging: 173.242

Quantity Limitations
a) Passenger, Aircraft, or Railcar: 25 kg
b) Cargo Aircraft Only: 100 kg

Vessel Stowage Requirements
a) Vessel Stowage: A
b) Other: 40

Section 15 - Regulatory Information

EPA Regulations:
Listed as a RCRA Hazardous Waste (40 CFR 261.33): P123
Listed as a CERCLA Hazardous Substance (40 CFR 302.4) per RCRA, Sec. 3001; CWA, Sec. 311 (b)(4); CWA, Sec. 307(a)
CERCLA Reportable Quantity (RQ), 1 lb (0.454 kg)
Listed as a SARA Toxic Chemical (40 CFR 372.65)
Listed as a SARA EHS (Extremely Hazardous Substance) (40 CFR 355), Threshold Planning Quantity (TPQ): 500/10,000 lb
OSHA Regulations:
Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1, Z-1-A)

Section 16 - Other Information

References: 73, 103, 124, 167, 176, 189, 190, 197, 201, 203

Prepared By ..... M Gannon, BA
Industrial Hygiene Review ..... RE Langford, PhD, CIH
Medical Review ..... T Thoburn, MD, MPH

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Material Safety Data Sheet

From Genium's Reference Collection
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GENIUM PUBLISHING CORP.

No. 518

XYLENE (Mixed Isomers)
(Revision D)
Issued: November 1980
Revised: August 1988

SECTION 1. MATERIAL IDENTIFICATION

Material Name: XYLENE (Mixed Isomers)

Description (Origin/Uses): Used as a raw material for the production of benzoic acid, phthalic anhydride, isophthalic and terephthalic acids and their dimethyl esters in the manufacture of polyester fibers; in sterilizing catgut; with Canadian balsam as oil-immersion in microscopy; and as a cleaning agent in microscopic techniques.

Other Designations: Dimethylbenzene; Xylol; C_8H_{10}; CAS No. 1330-20-7

Manufacturer: Contact your supplier or distributor. Consult the latest edition of the *Chemicalweek Buyers' Guide* (Genium ref. 73) for a list of suppliers.

Comments: Although there are three different isomers of xylene (*ortho*, *meta*, and *para*), the health and physical hazards of all three isomers are very similar. This MSDS is written for a xylene mixture of all three isomers, which is usually commercial xylene.

NFPA

HMIS			
H	2		
F	3	R	1
R	0	I	3
PPG*		S	2
*See sect. 8		K	3

SECTION 2. INGREDIENTS AND HAZARDS

Xylene (Mixed Isomers), CAS No. 1330-20-7*

*o-Xylene, CAS No. 0095-47-6
m-Xylene, CAS No. 0108-38-3
p-Xylene, CAS No. 0106-42-3

**Check with your supplier to determine if there are additions, contaminants, or impurities (such as benzene) that are present in reportable quantities per 29 CFR 1910.

***Immediately dangerous to life and health.

**** See NIOSH, *RTECS* (No. ZE2100000), for additional data with references to reproductive, irritative, and mutagenic effects.

%

**

EXPOSURE LIMITS

IDLH*** Level: 1000 ppm

OSHA PEL
8-Hr TWA: 100 ppm, 435 mg/m³

ACGIH TLVs, 1987-88
TLV-TWA: 100 ppm, 435 mg/m³
TLV-STEL: 150 ppm, 655 mg/m³

Toxicity Data**
Human, Inhalation, TC_{Lo}: 200 ppm
Man, Inhalation, LC_{Lo}: 10000 ppm/6 Hrs
Rat, Oral, LD_{50}: 4300 mg/kg

SECTION 3. PHYSICAL DATA

Boiling Point: 275°F to 293°F (135°C to 145°C)*
Melting Point: -13°F (-25°C)
Evaporation Rate: 0.6 Relative to BuAc = 1
Specific Gravity (H_2O = 1): 0.86

Water Solubility (%): Insoluble
Molecular Weight: 106 Grams/Mole
% Volatile by Volume: Ca 100
Vapor Pressure: 7 to 9 Torrs at 68°F (20°C)
Vapor Density (Air = 1): 3.7

Appearance and Odor: A clear liquid; aromatic hydrocarbon odor.

*Materials with wider and narrower boiling ranges are commercially available.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temperature	Flammability Limits in Air	LOWER	UPPER
81°F to 90°F (27°C to 32°C)	867°F (464°C)	% by Volume	1%	7%

Extinguishing Media: Use foam, dry chemical, or carbon dioxide. Use water sprays to reduce the rate of burning and to cool containers.

Unusual Fire or Explosion Hazards: Xylene vapor is heavier than air and may travel a considerable distance to a low-lying source of ignition and flashback.

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

Xylene is stable in closed containers during routine operations. It does not undergo hazardous polymerization.

Chemical Incompatibilities: This material may react dangerously with strong oxidizers.

Conditions to Avoid: Avoid any exposure to sources of ignition and to strong oxidizers.

Hazardous Products of Decomposition: Carbon monoxide (CO) may be evolved during xylene fires.

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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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Medical Review: MJ Hardies, MD

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URS

APPENDIX D
OF
ATTACHMENT A

INCIDENT REPORT FORM

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 _____

URS

APPENDIX E
OF
ATTACHMENT A

HNU PHOTOIONIZATION DETECTOR

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

STUDY ON THE STABILIZATION OF ARSENIC WASTES

Utilized by
Project 35092B007C

HWRIC RR-073

Stabilization of Arsenic Wastes

by

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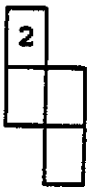
ABBREVIATIONS

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.

STABILIZATION OF ARSENIC WASTES

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 cont-aminated 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]	WASTE: 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:

$HAsO_2(aq) \text{ ----> } H^+(aq) + AsO_2^-(aq) \quad K = 2.1\times10^{-9}$

Dissociation of arsenic acid:

$H_3AsO_4(aq) \text{ ----> } H+(aq) + H_2AsO_4^-(aq) \quad K_1 = 5.0\times10^{-3}$

$H_2AsO_4^-(aq) \text{ ----> } H^+(aq) + HAsO_4^{2-}(aq) \quad K_2 = 8.3\times10^{-6}$

$HAsO_4^{2-}(aq) \text{ ----> } H^+(aq) + AsO_4^{3-}(aq) \quad K_3 = 6.0\times10^{-10}$

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:

$$FeAsO_4(s) + 3\ OH^-(aq) \text{ -----> } Fe(OH)_3(s) + AsO_4^{3-}(aq) \qquad (1)$$

$$K = K_{sp}[FeAsO_4] \,/\, K_{sp}[Fe(OH)_3] = 5\times10^{+15}$$

and

$$AlAsO_4(s) + 3\ OH^-(aq) \text{ -----> } Al(OH)_3(s) + AsO_4^{3-}(aq) \qquad (2)$$

$$K = K_{sp}[AlAsO_4] \,/\, K_{sp}[Al(OH)_3] = 1\times10^{+17}$$

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.

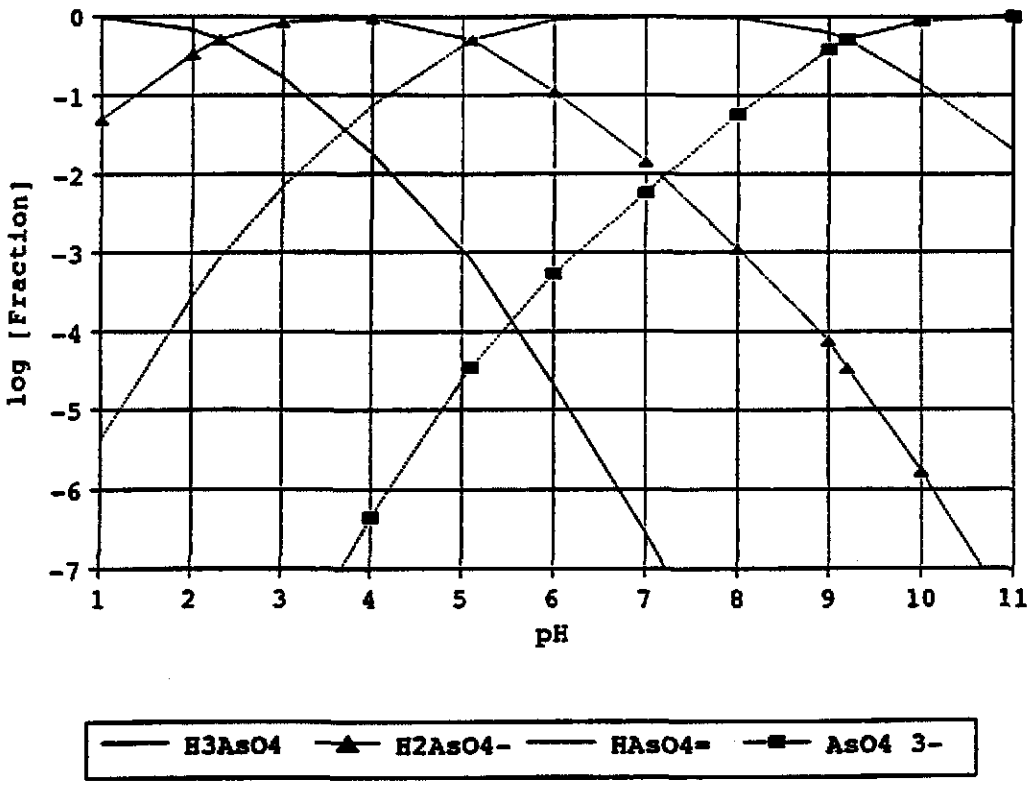


Figure 2-1. Principal Species Analysis for Arsenic Acid

STABILIZATION OF ARSENIC WASTES

$FeAsO_4(s)$ 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

$$FeAsO_4(s) \; <\!\!-\!\!-\!\!-\!\!-\!\!-\!\!> \; Fe^{3+}(aq) + AsO_4^{3-}(aq) \qquad (4)$$

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:

$$FeAsO_4(s) + H^+(aq) \; <\!\!-\!\!-\!\!-\!\!-\!\!-\!\!> \; Fe^{3+}(aq) + HAsO_4^{2-}(aq) \qquad (5)$$

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

$$K_{sp}(FeAsO_4)/K_{sp}(Fe(OH)_3) = 1.4 \times 10^{+17}$$

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

$$BaSO_4(s) \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq) \qquad (7)$$

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.

$$\underset{\text{tricalcium aluminate}}{C_3A} + \underset{\text{gypsum}}{3C\bar{S}H_2} + \underset{\text{water}}{26H} \text{ ------> } \underset{\text{ettringite}}{C_6A\bar{S}_3H_{32}} \qquad (10)$$

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

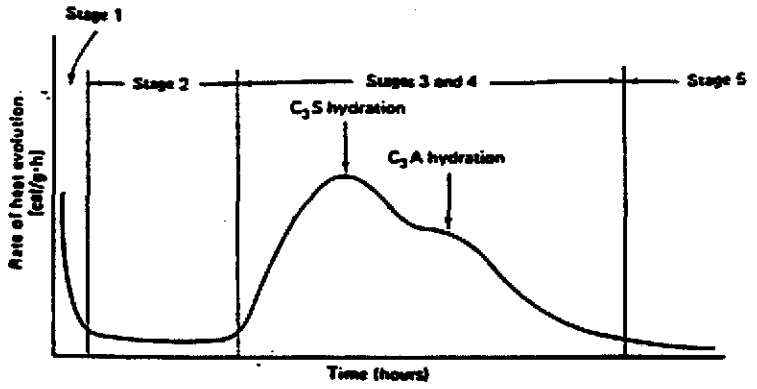


Figure 2-2. Rate of Heat Evolution During the Hydration of Portland Cement. (Mindness and Young, 1981)

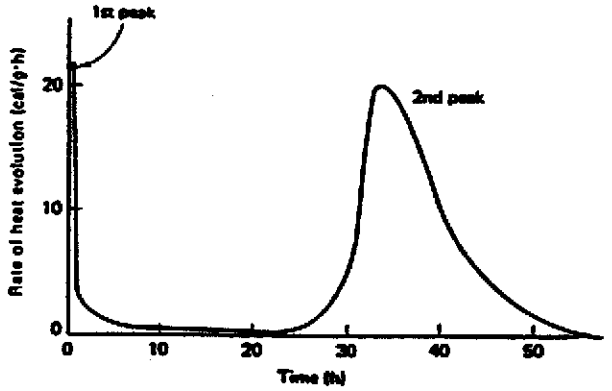


Figure 2-3. Rate of Heat Evolution During the Hydration of Tricalcium Aluminate with Gypsum. (Mindness and Young, 1981)

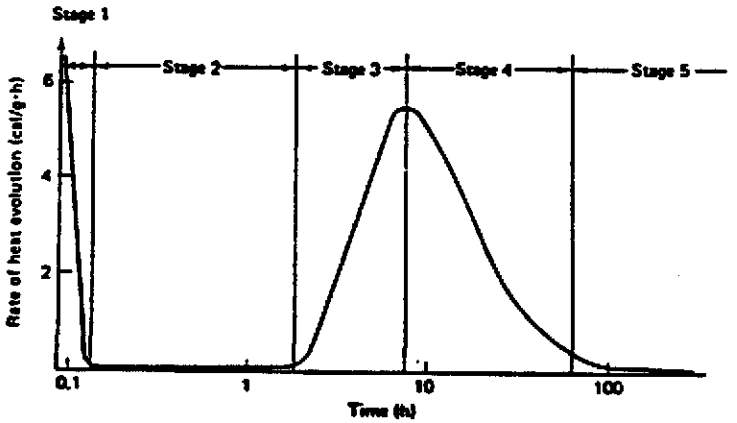


Figure 2-4. Rate of Heat Evolution during the Hydration of Tricalcium Silicate with Gypsum. (Mindness and Young, 1981)

amount of gypsum available. More gypsum prolongs the occurrence of a second heat peak and allows ettringite to remain stable.

$$2C_3A + C_6A\bar{S}_3H_{32} + 4H \longrightarrow 3C_4A\bar{S}H_{12} \quad (11)$$

$2C_3A$: 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).

$$C_4A\bar{S}H_{12} + 2C\bar{S}H_2 + 16H \longrightarrow C_6A\bar{S}_3H_{32} \quad (12)$$

$C_4A\bar{S}H_{12}$: 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).

$$C_3A + 21\,H \longrightarrow C_4AH_{13} + C_2AH_8 \quad (13)$$

C_3A: tricalcium aluminate; 21 H: water; C_4AH_{13} + C_2AH_8: calcium aluminate hydrates

$$C_4AH_{13} + C_2AH_8 \longrightarrow 2C_3AH_6 + 9H \quad (14)$$

C_4AH_{13} + C_2AH_8: 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.

$$2C_3S + 6H \longrightarrow C_3S_2H_3 + 3CH \quad (15)$$

$2C_3S$: tricalcium silicate; 6H: water; $C_3S_2H_3$: C-S-H; 3CH: calcium hydroxide

$$2C_2S + 4H \longrightarrow C_3S_2H_3 + CH \quad (16)$$

$2C_2S$: 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.

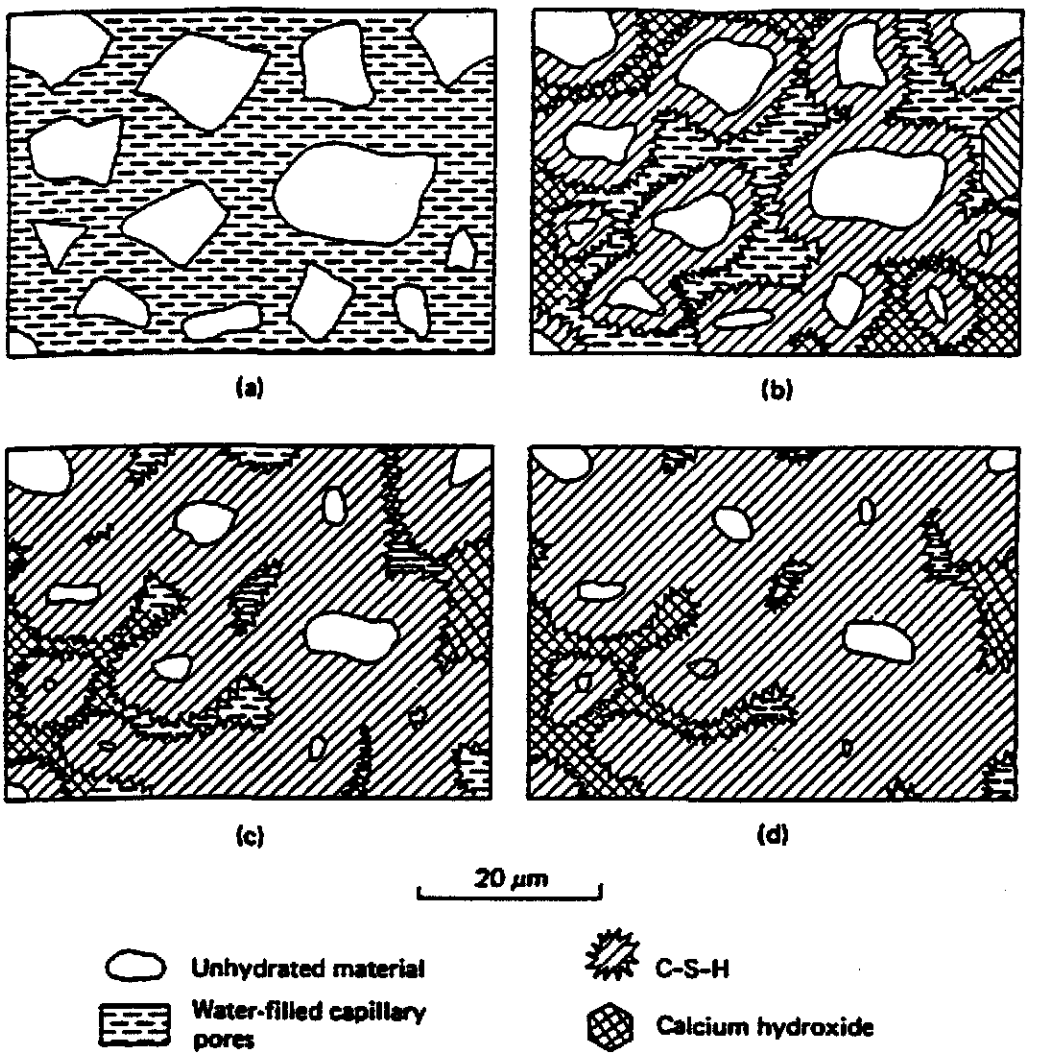


Figure 2-5. Schematic Outline of Microstructural Development of Portland Cement Paste. (Calcium Sulfoaluminates are included as part of C-S-H although they crystalize as separate phases.) (a) Initial (b) 7 days (c) 28 days (d) 90 days (Mindness and Young, 1981)

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

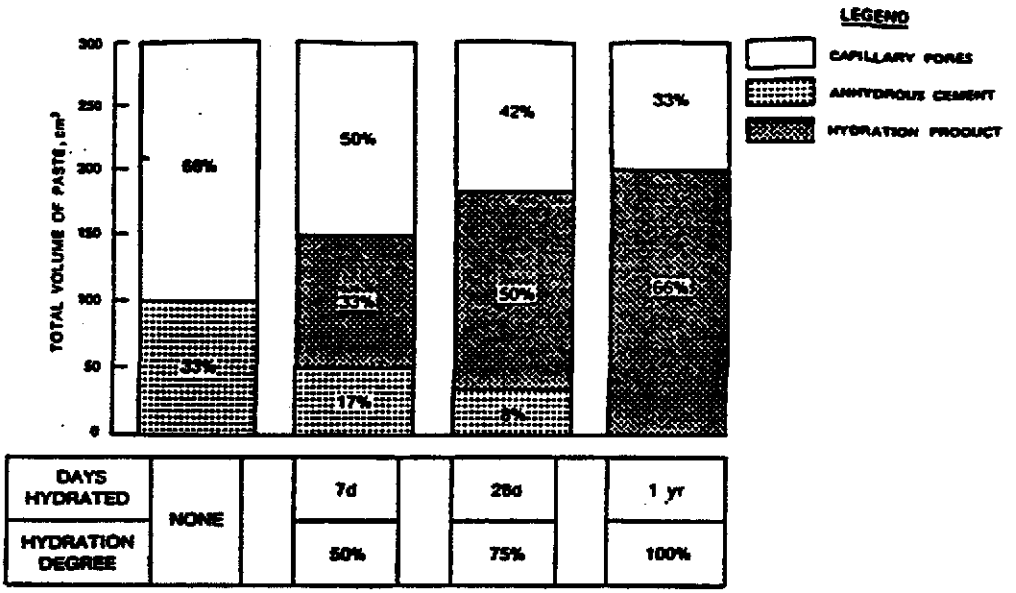


Figure 2-6. Changes in Capillary Pore Sapce with the Degree of Hydration for a Cement Paste with Water/Cement = 0.66 (Mehta, 1987)

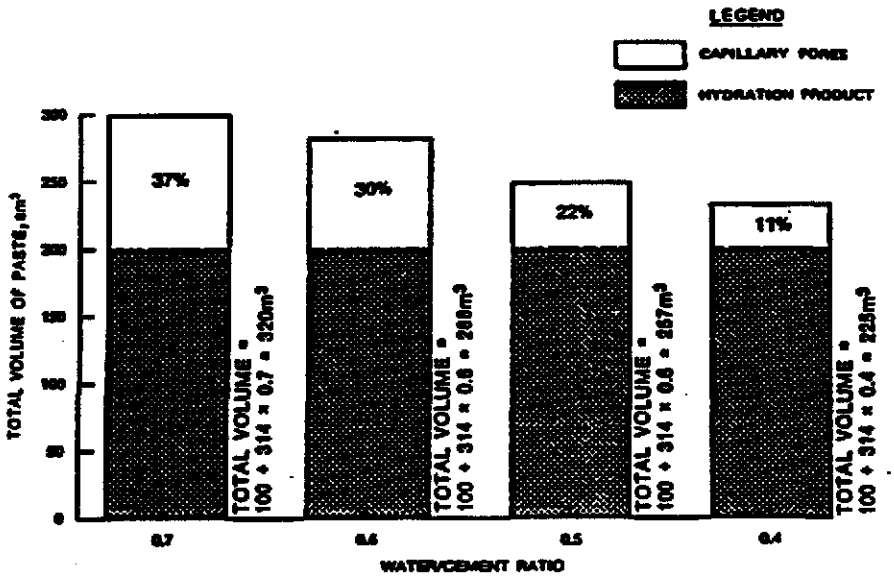


Figure 2-7. Changes in Capillary Pore Space for a Fully Hydrated Cement Paste with Variable Water/Cement Ratios, Based on Equal Amounts of Portland Cement. (Mehta, 1987)

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]

	Leachate Concentration (mg/L)				
Binder[2]	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

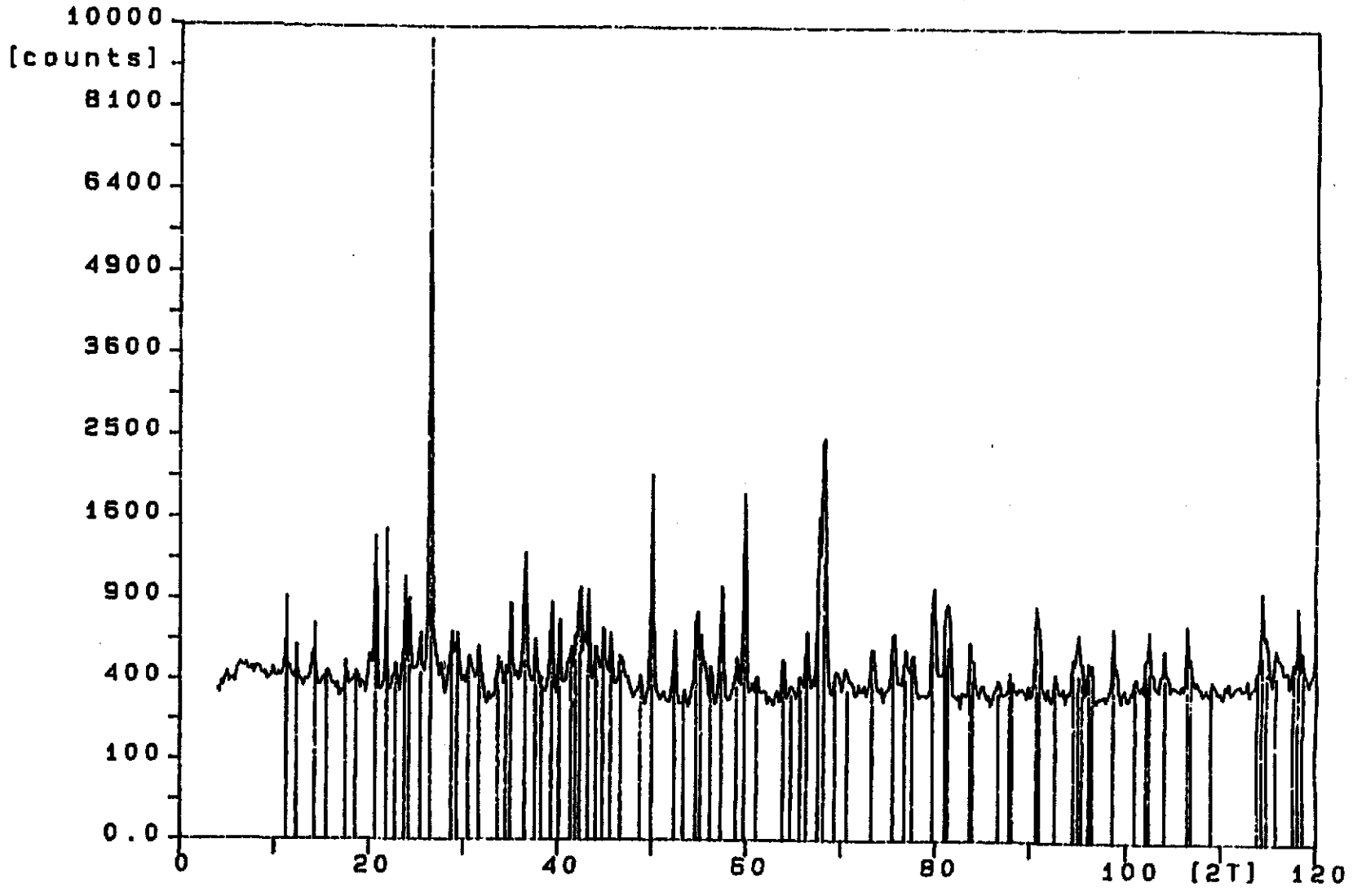


Figure 3-1. X-Ray Diffraction Pattern of D004/D005 Waste

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°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

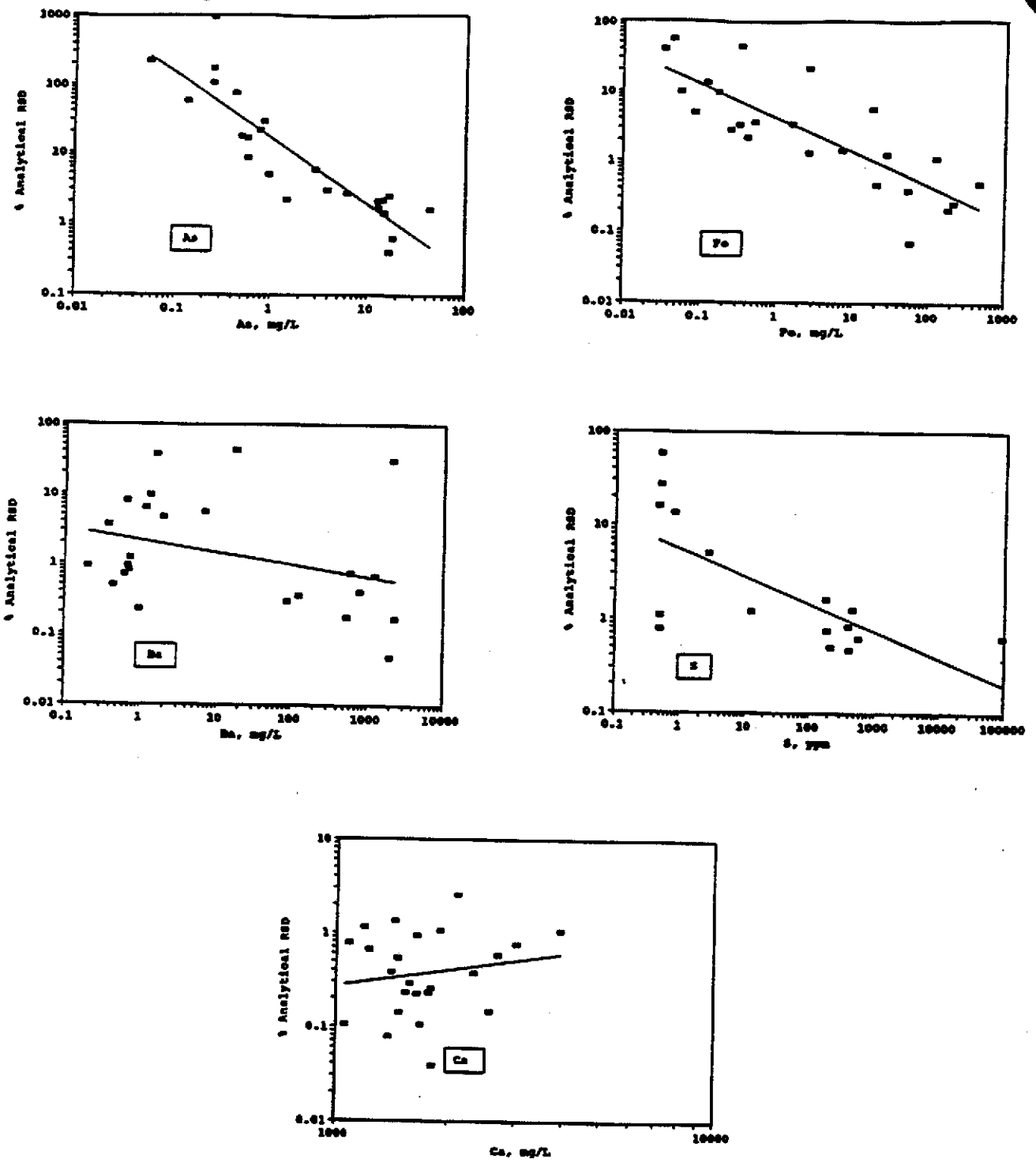


Figure 3-2. ICAP Replicate Relative Standard Deviation as a Function of Concentration with Regression Lines.

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.

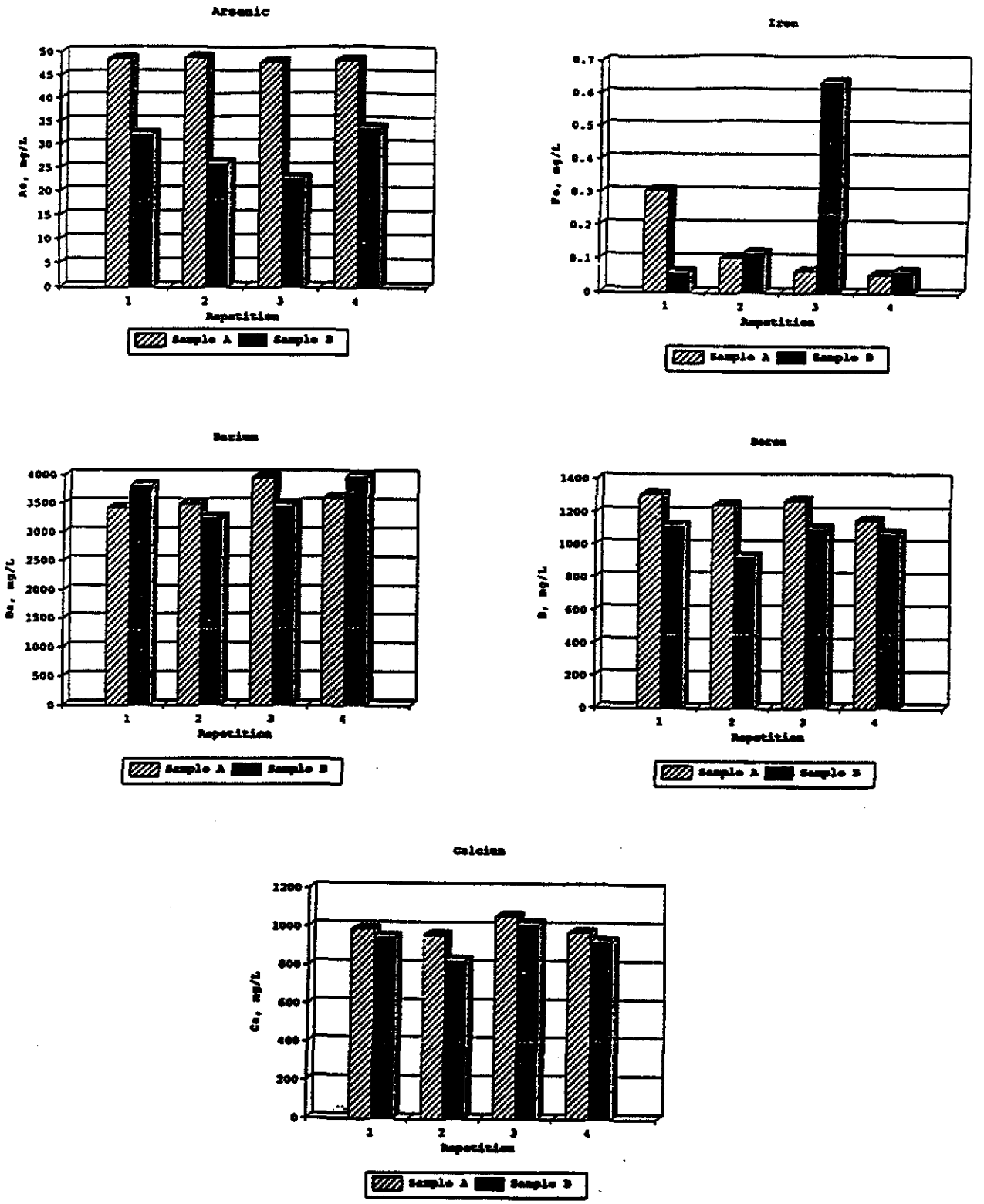


Figure 3-3. TCLP Repeatability Replication Study

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)		Barium (mg/L)	
	Sample 1	Sample 2	Sample 1	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.

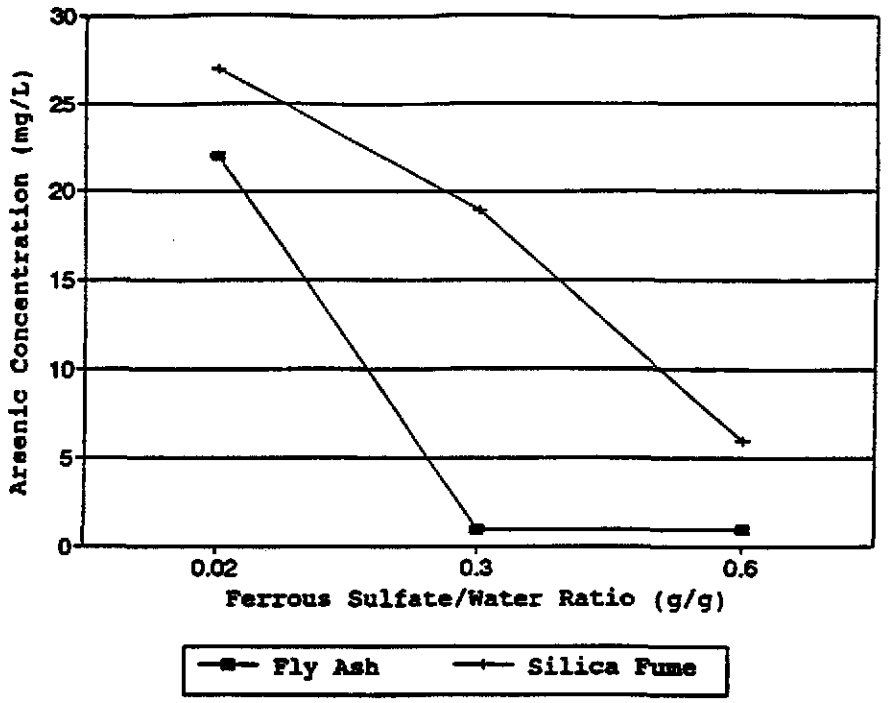


Figure 4-1. TCLP Results for Arsenic

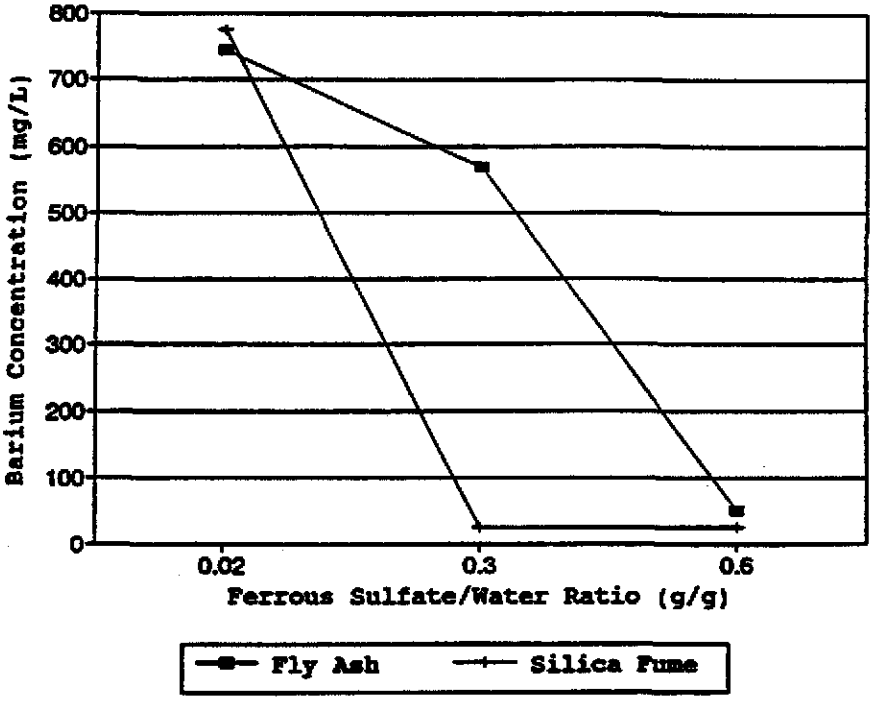


Figure 4-2. TCLP Results for Barium

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.

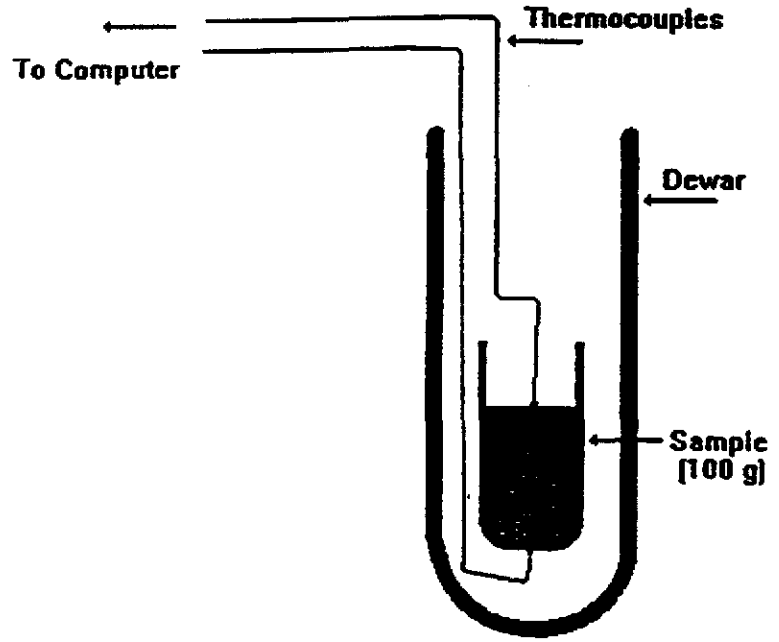


Figure 4-3. Calorimetric Heat of Hydration Apparatus

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 $\pm$ 50-millivolt range was used with 16-bit analog-to-digital resolution. After conversion to temperature, a relative precision of $\pm$ 0.01^{o}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 $\pm$ 0.1^{o}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	
	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.
1.5	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
	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.
3.0	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	
	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.
1.0	Fly Ash	6.	Fly Ash	16.
	Na_2SO_4	10.	Na_2SO_4	10.
	SO_4/binder	0.451	SO_4/binder	0.17
	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.
2.0	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.

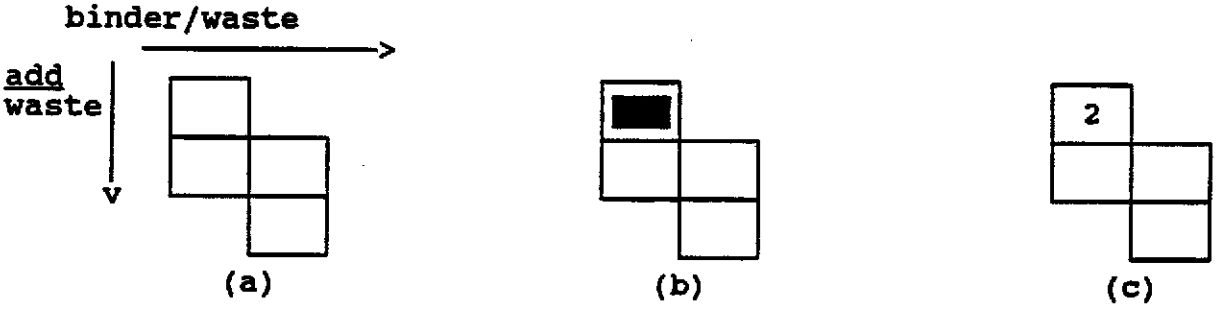


Figure 5-1. Legend of Mix Designs

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).

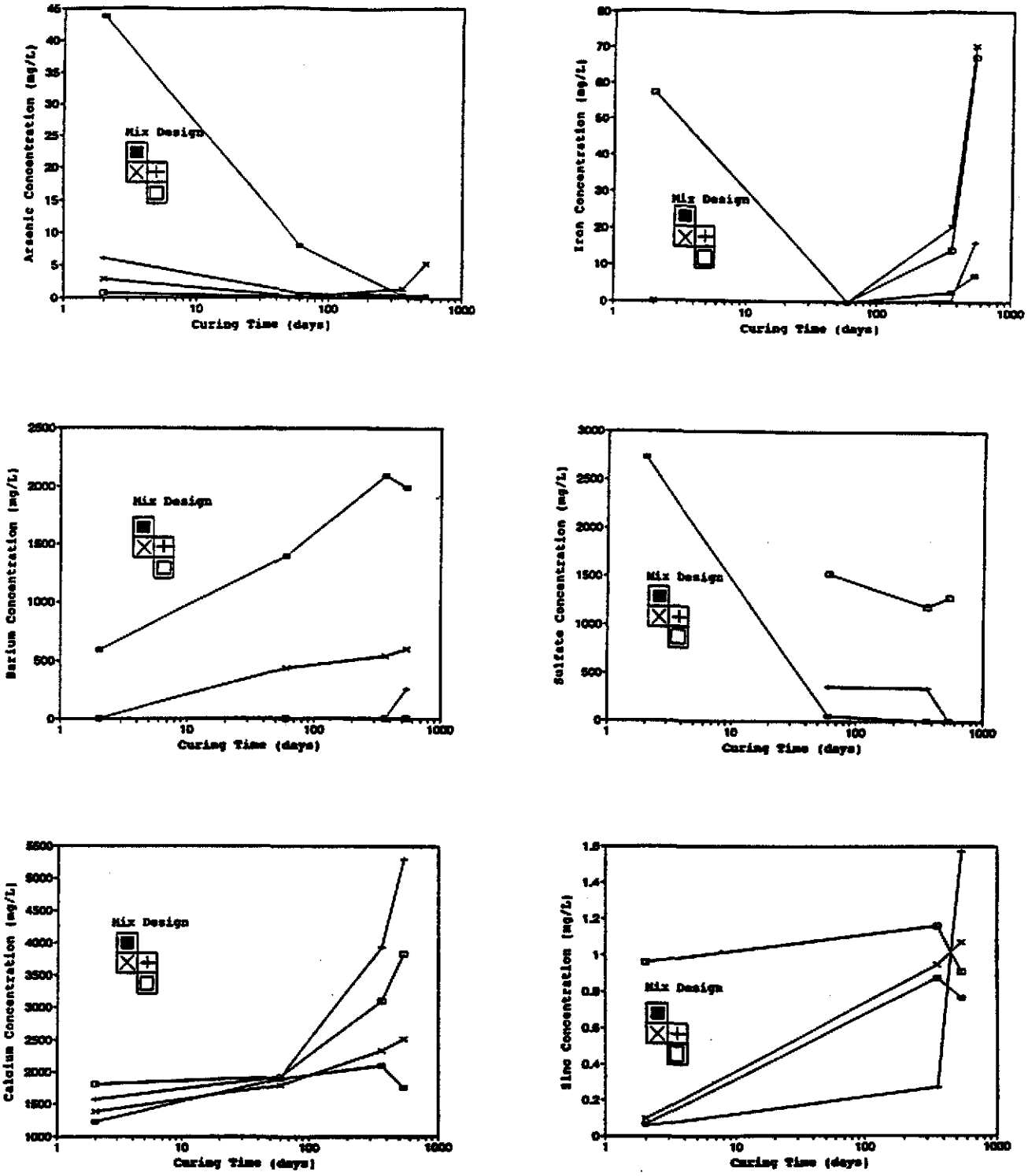


Figure 5-2. Stabilization with Ferrous Sulfate. Mix designs given in Table 4-2.

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

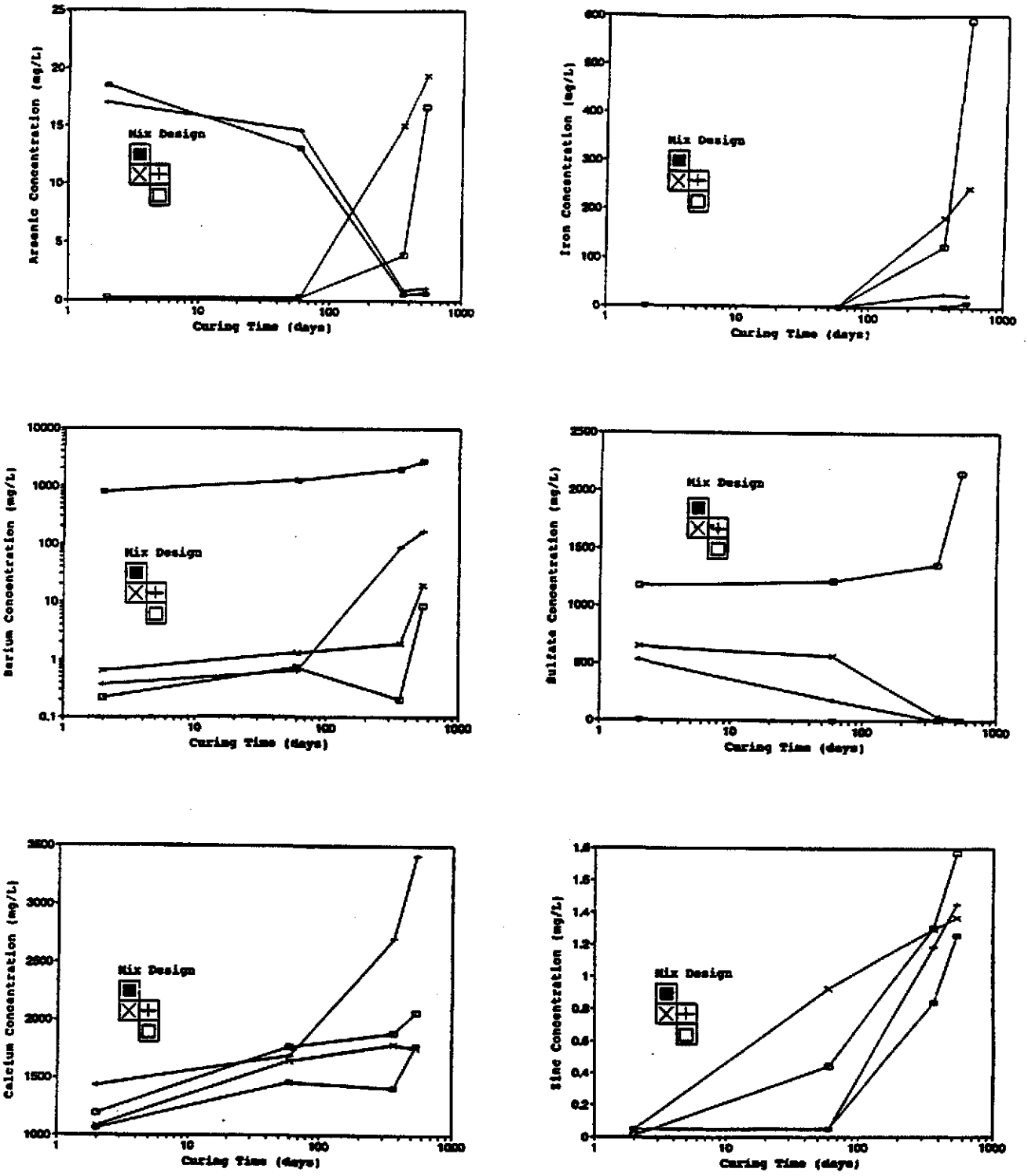


Figure 5-3. TCLP Results for Ferric Sulfate Stabilization. Mix designs defined in Table 4-3.

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.

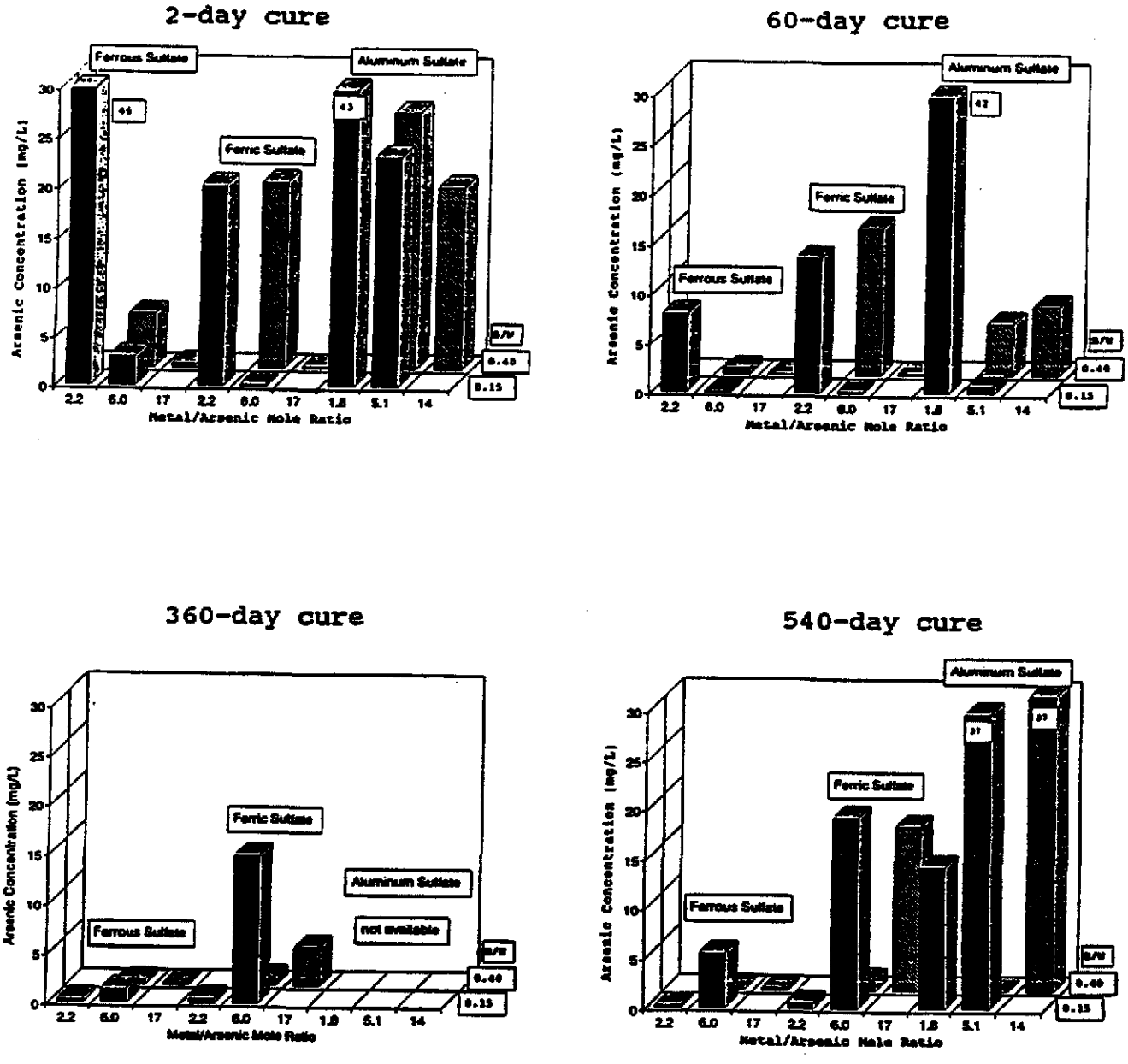


Figure 5-4. Comparison of TCLP Data for Arsenic.

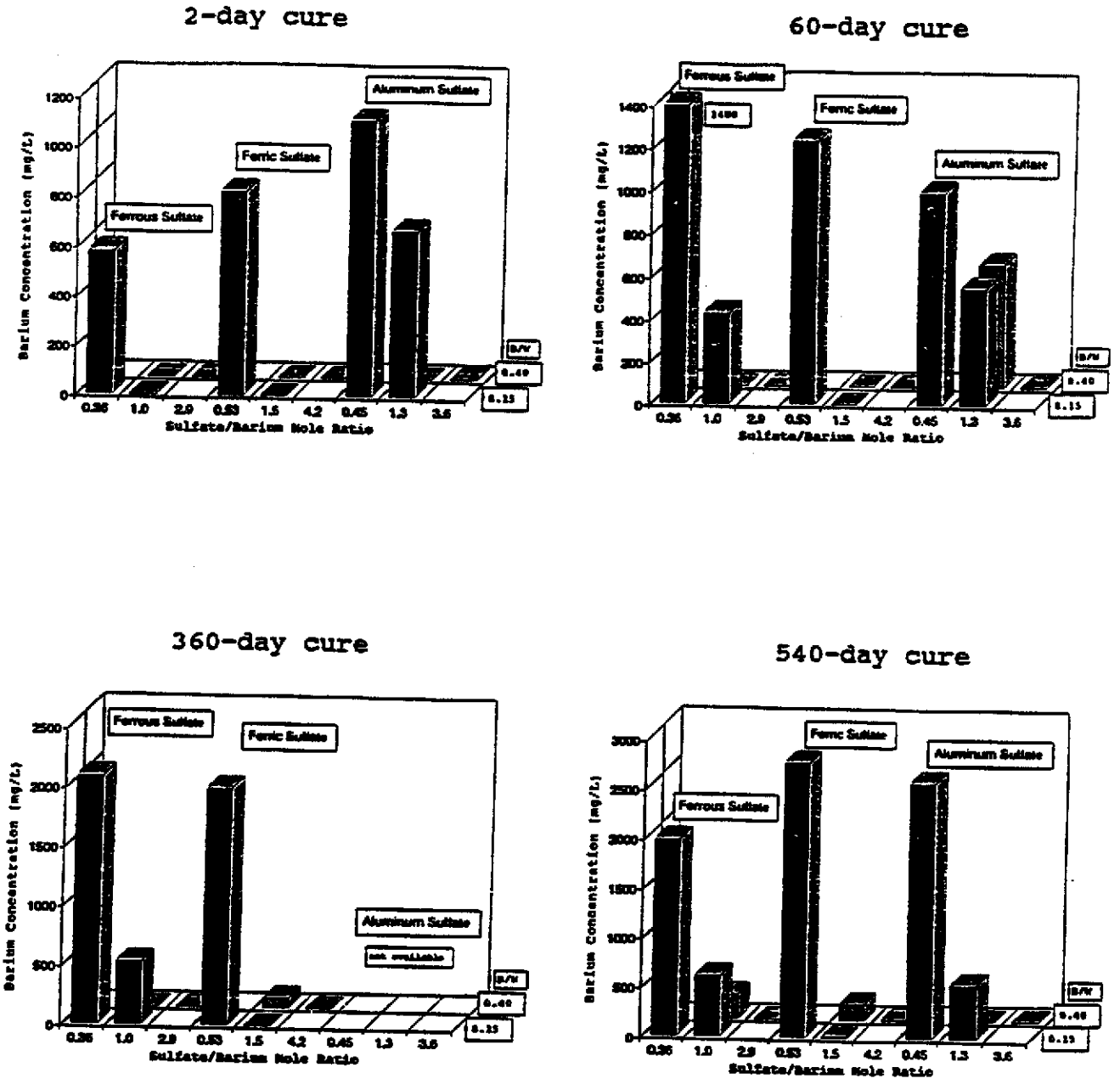


Figure 5-5. Comparison of TCLP Data for Barium.

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.

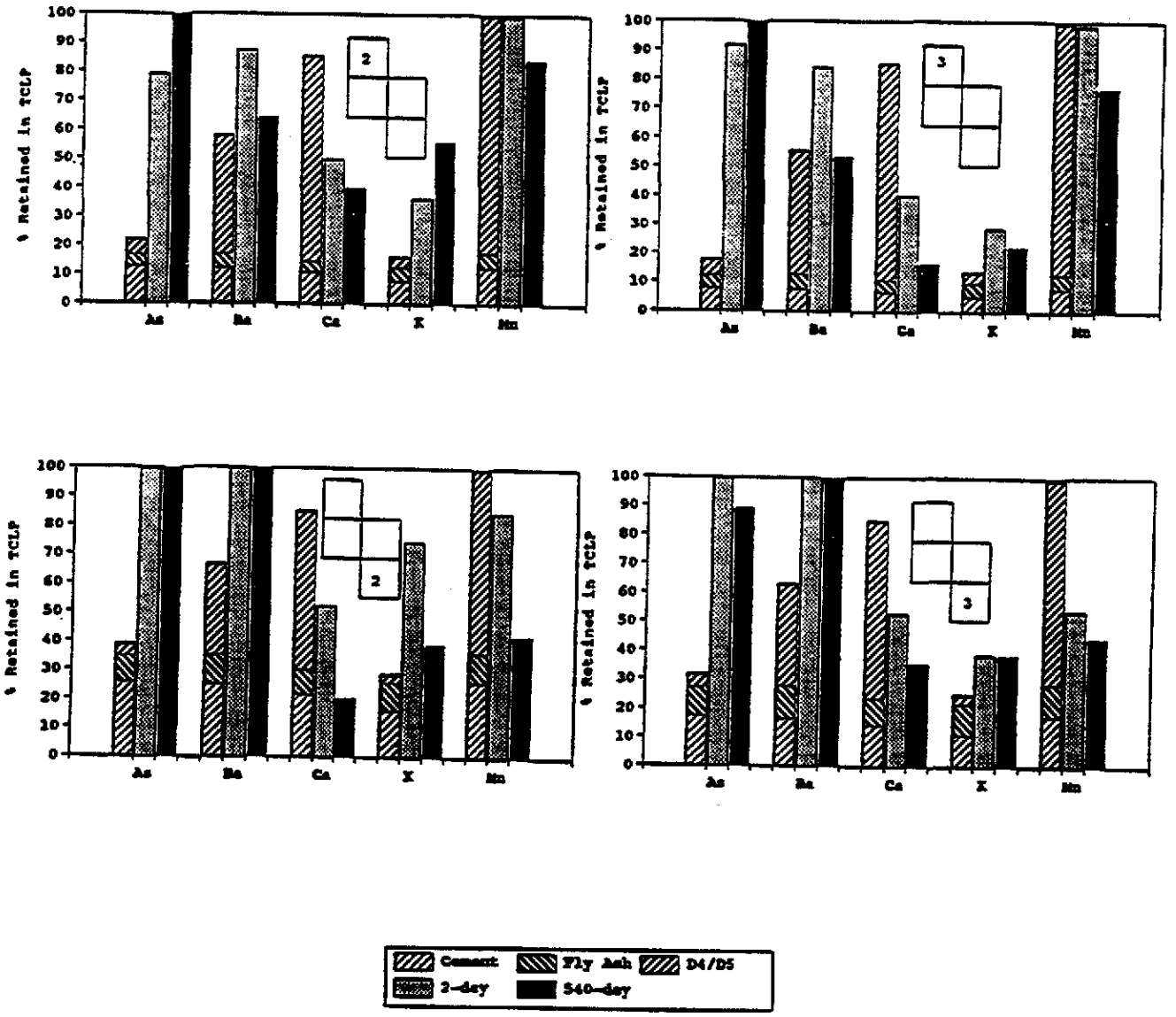


Figure 5-6. Percent Extraction by TCLP

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

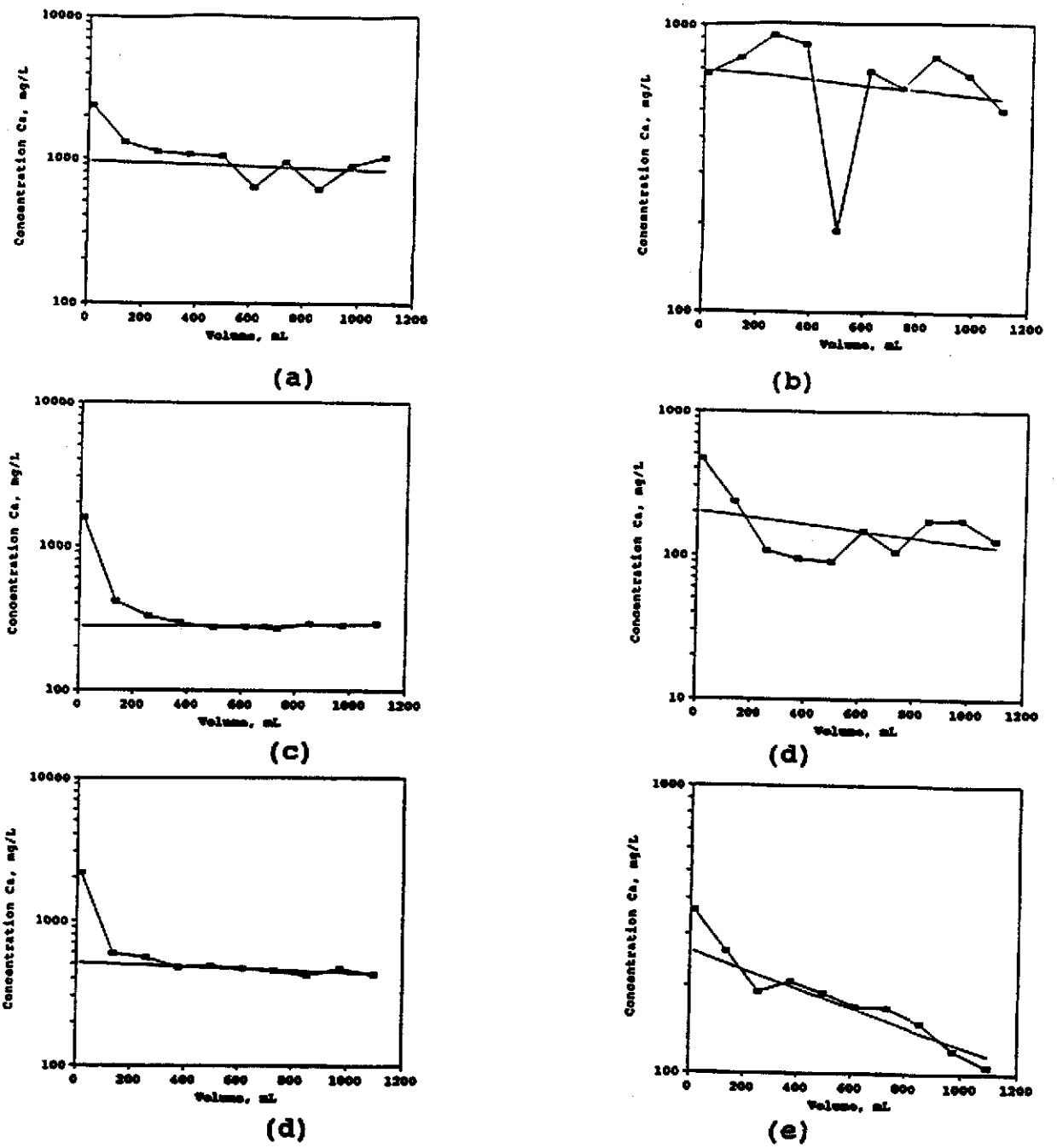


Figure 5-7. Column Extraction Data for Calcium.
(a) Mix US1 (Table 4-2), pH 3.00 Eluant.
(b) Mix US4, pH 3.00 Eluant.
(c) Mix US1, DI H_2O Eluant.
(d) Mix US4, DI H_2O Eluant.
(e) Mix US1, pH 8.77 Eluant.
(f) Mix US4, pH 8.50 Eluant.
All samples cured for two days.

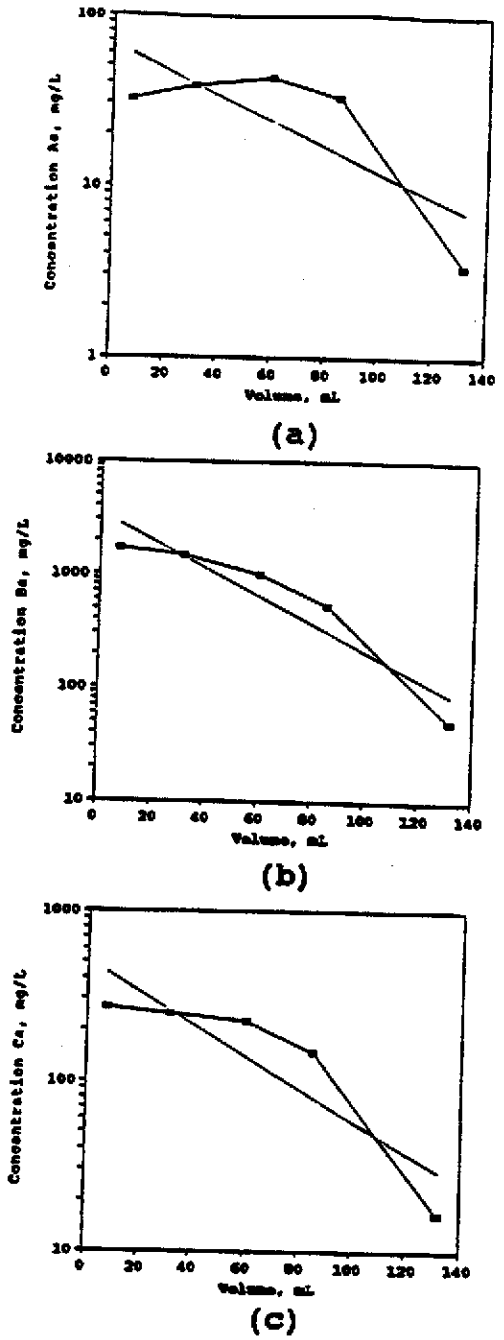


Figure 5-8. Column Extraction Data, 390-day Cure, Mix US1, DI H_2O Eluant.

(a) Arsenic (b) Barium (c) Calcium

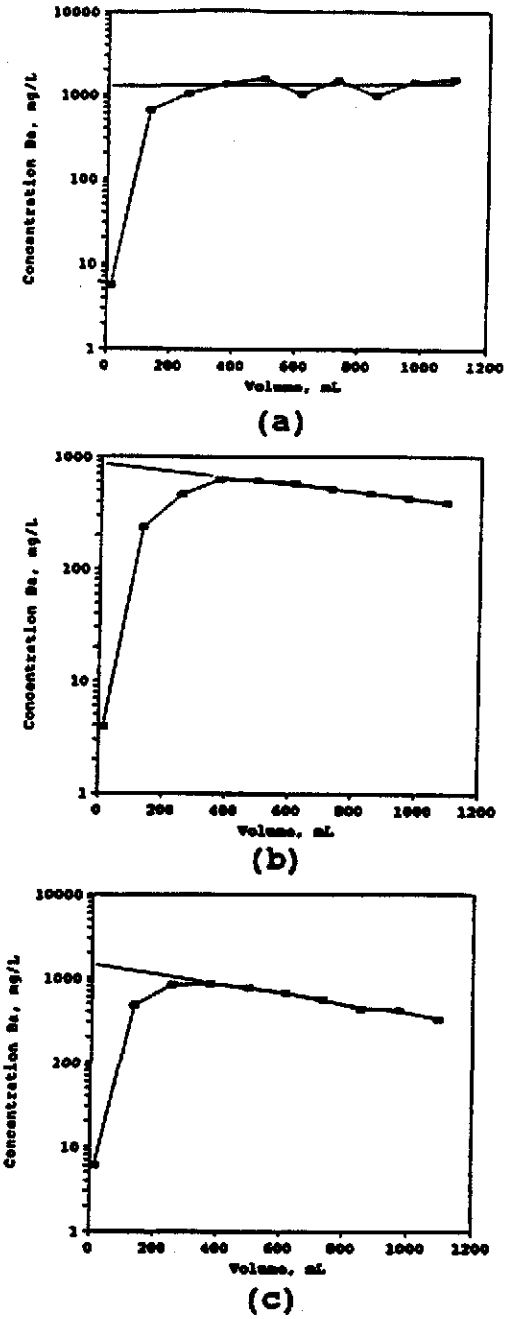


Figure 5-9. Column Extraction Data for Barium, Mix US1, 2-day Cure.

(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.

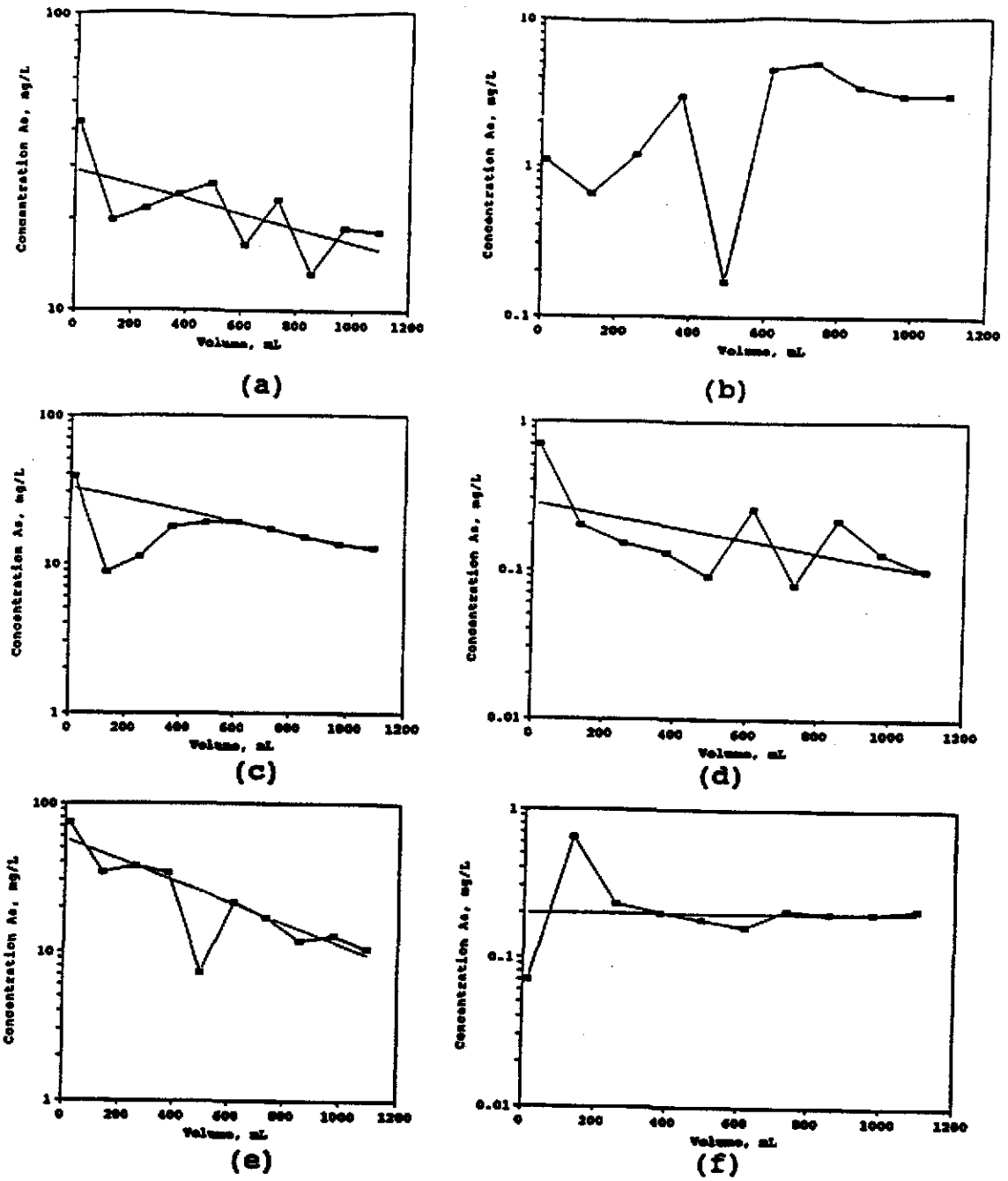


Figure 5-10. Column Extraction Data for Arsenic.

(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.

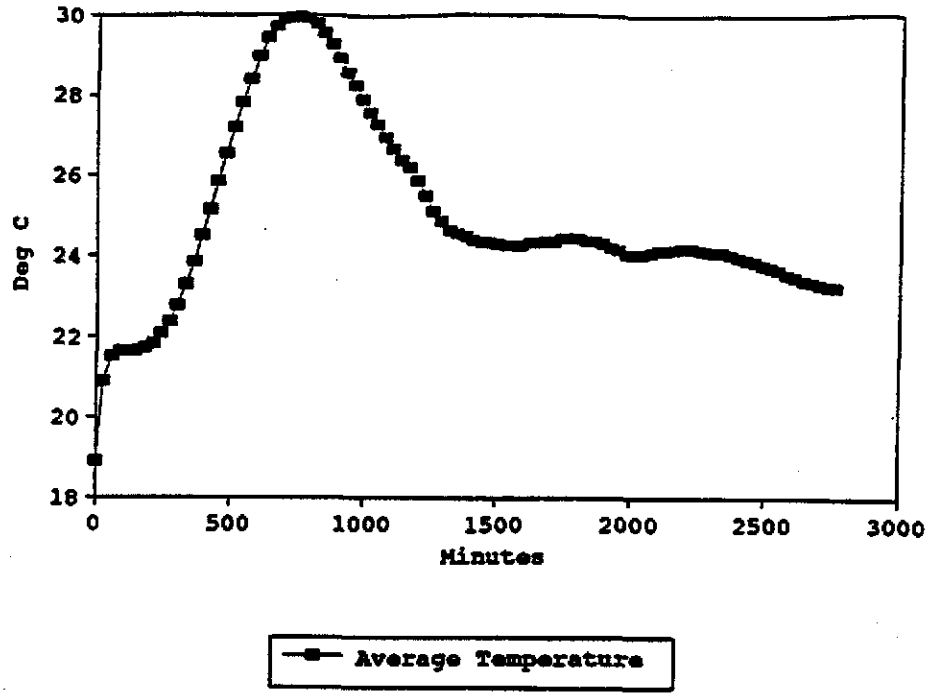


Figure 5-11. Calorimetric Curve for Cement-Sand Mix

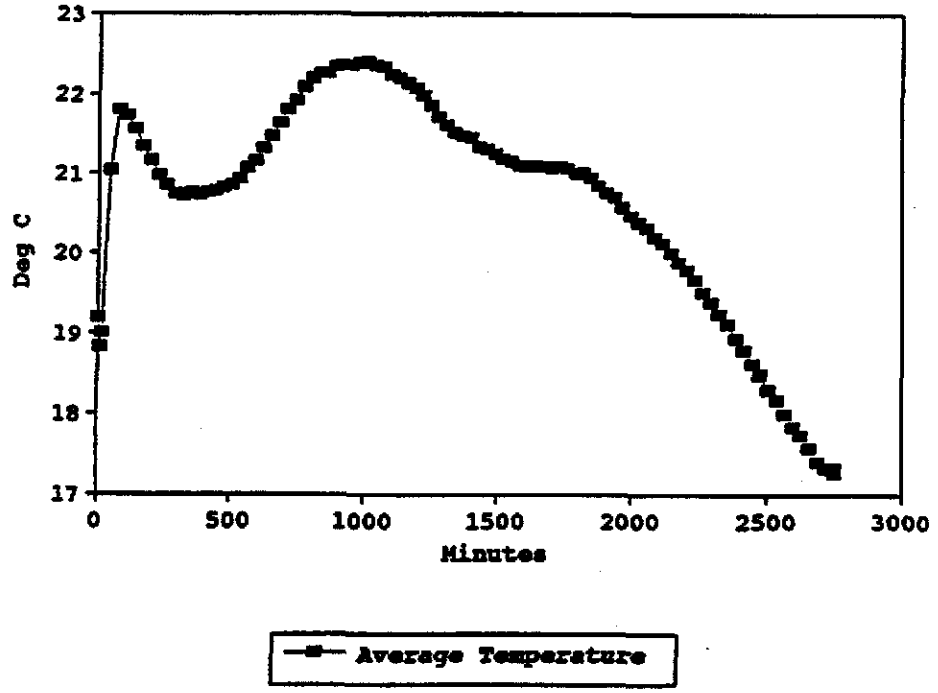


Figure 5-12. Calorimetric Curve for Cement, Fly Ash & Sand Mix

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

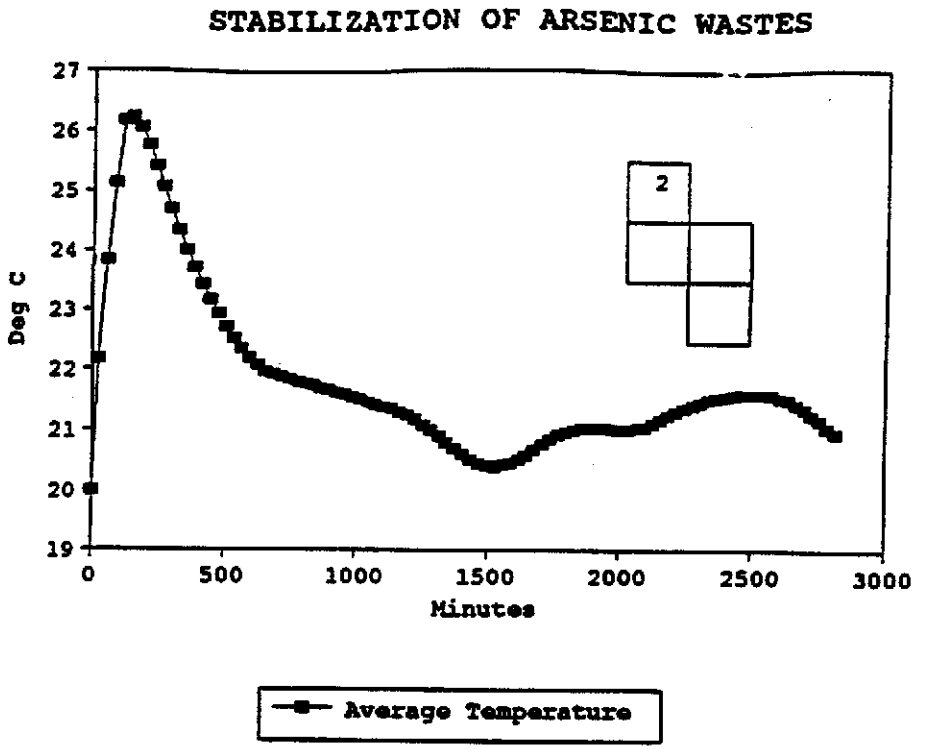


Figure 5-13. Calorimetric Curve for Mix Design US1. (Appendix A)

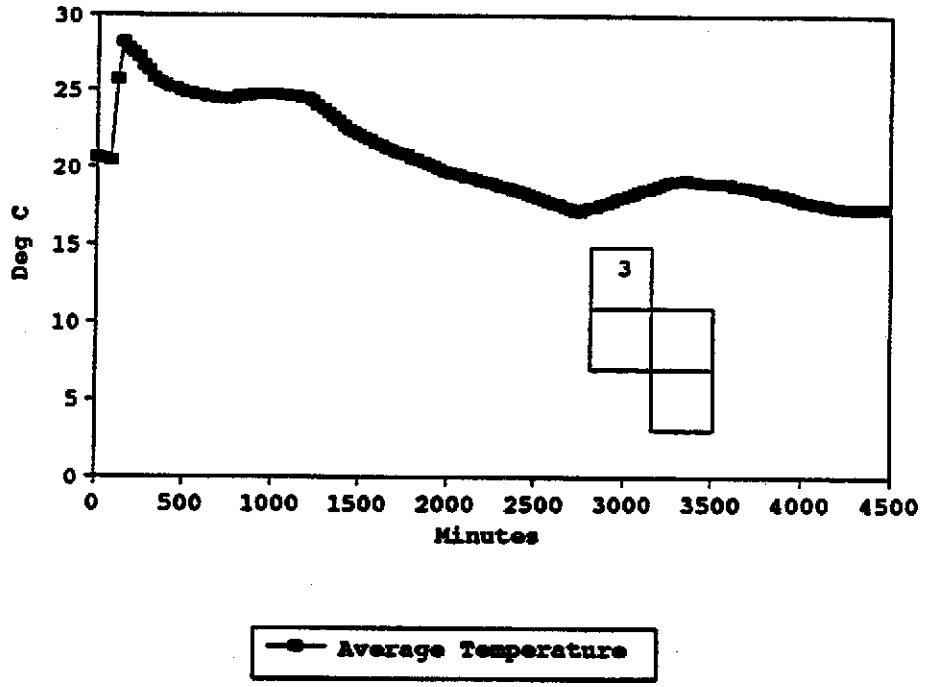


Figure 5-14. Calorimetric Curve for Mix Design F1. (Appendix A)

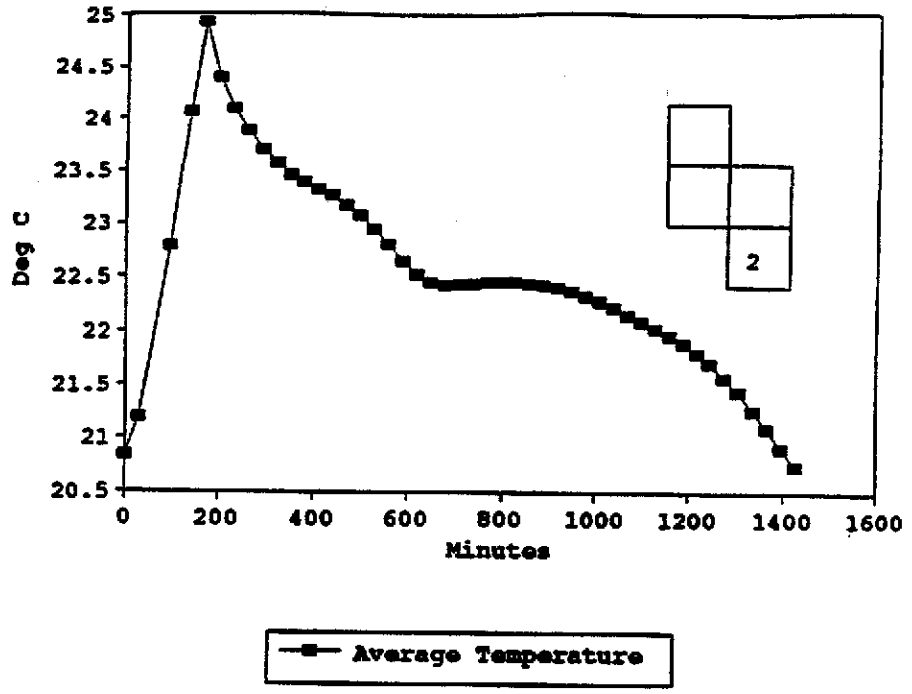


Figure 5-15. Calorimetric Curve for Mix Design US4. (Appendix A)

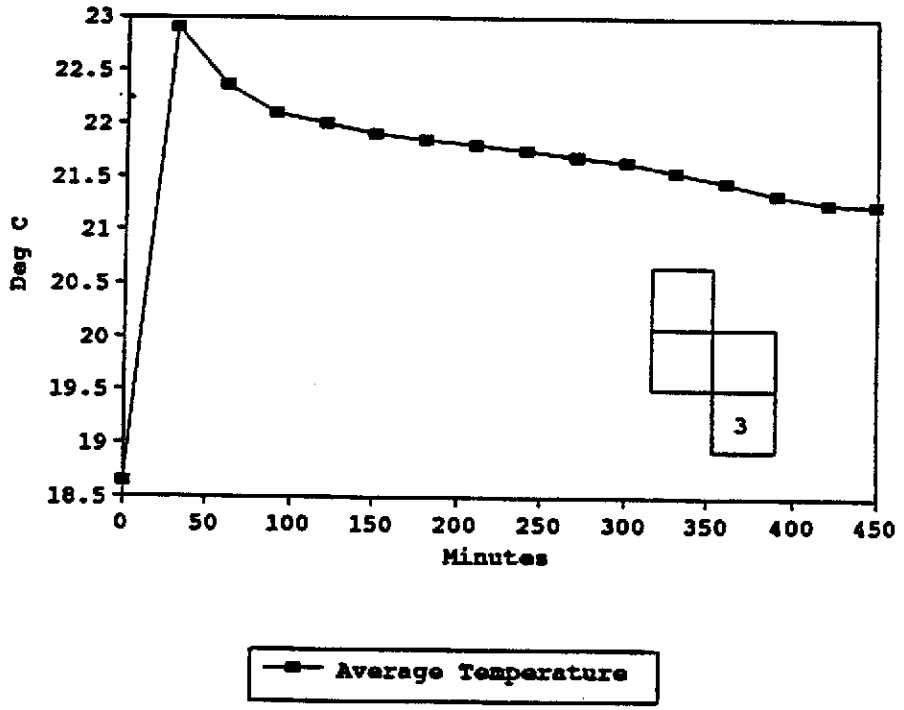


Figure 5-16. Calorimetric Curve for Mix Design F4. (Appendix A)

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)

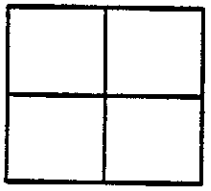
FB1x Series		
Metal	Cure Time 2-days	60-days
As	52.6	61.4
Ca	1580	1890
Fe	0.08	0.36
S	311	3890

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

Binder
F006/Arsenate Waste
0.15 0.40

$\frac{Fe^{+3}}{As}$ mole ratio = 1.1

$\frac{Fe^{+2}}{As}$ mole ratio = 2.0



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.

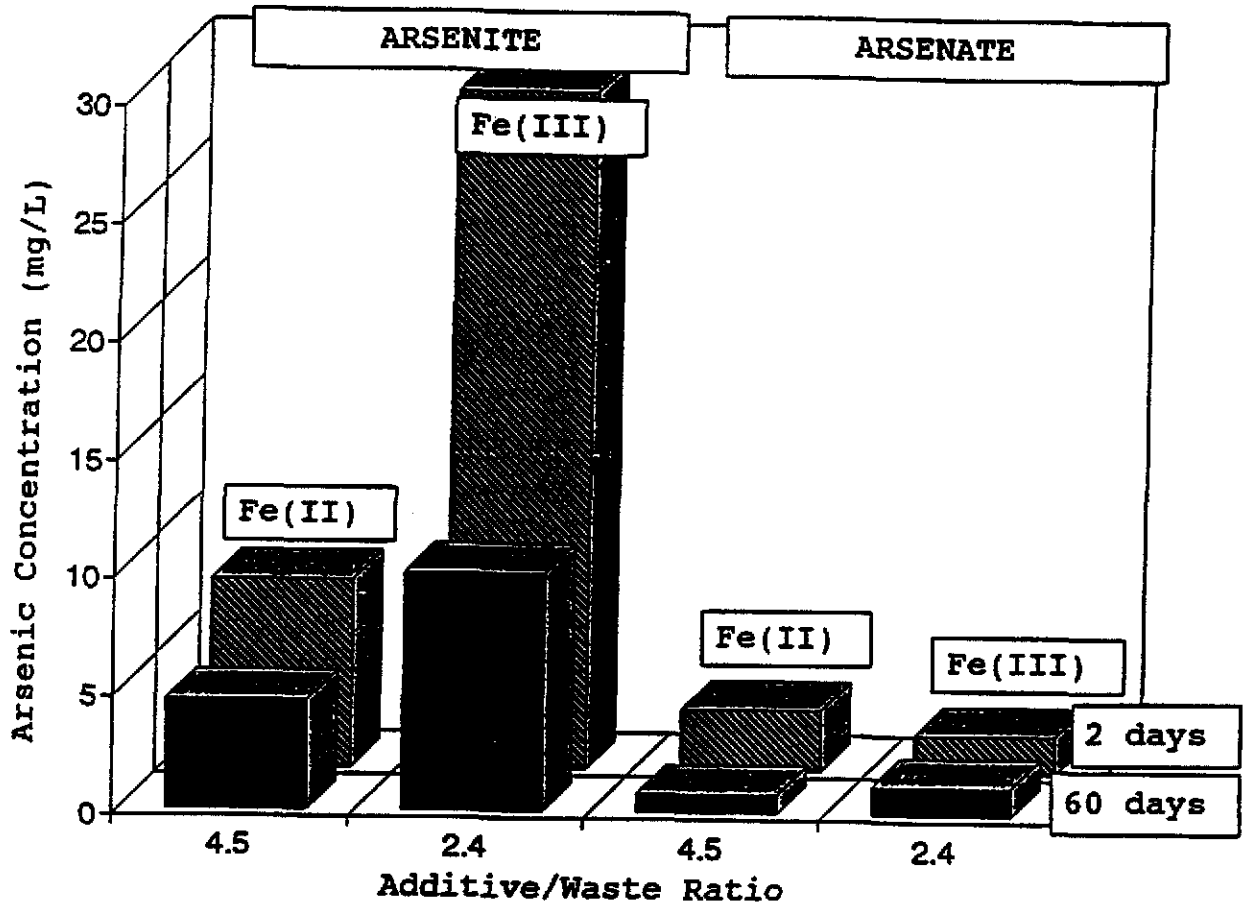


Figure 5-17. **Two-Day and Sixty-Day Stabilization of Modified Arsenate and Arsenite Waste Using Ferrous Sulfate and Ferric Sulfate Additives. Binder/Waste = 0.15**

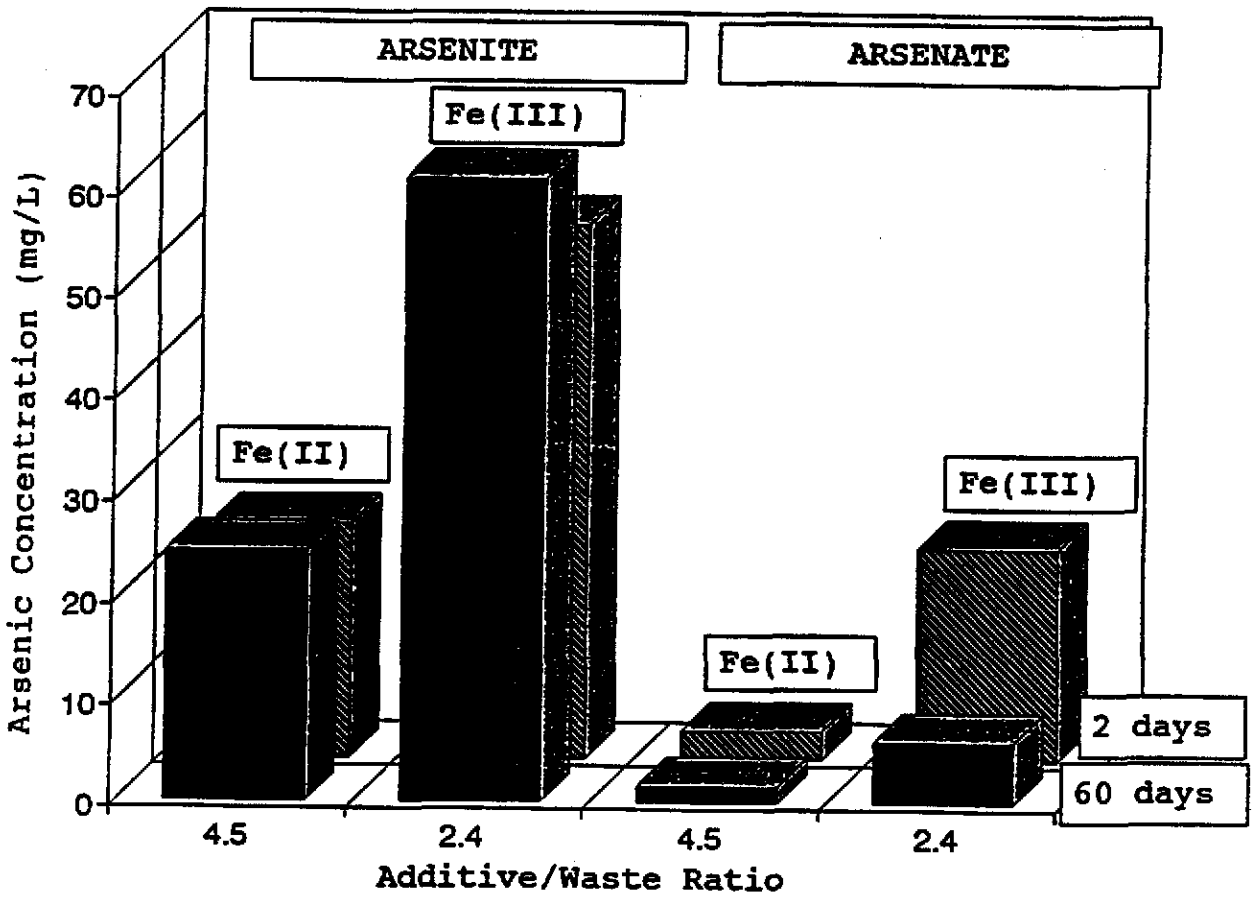


Figure 5-18. Two-Day and Sixty-Day Stabilization of Modified Arsenate and Arsenite Waste Using Ferrous Sulfate and Ferric Sulfate Additives. Binder/Waste = 0.40

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

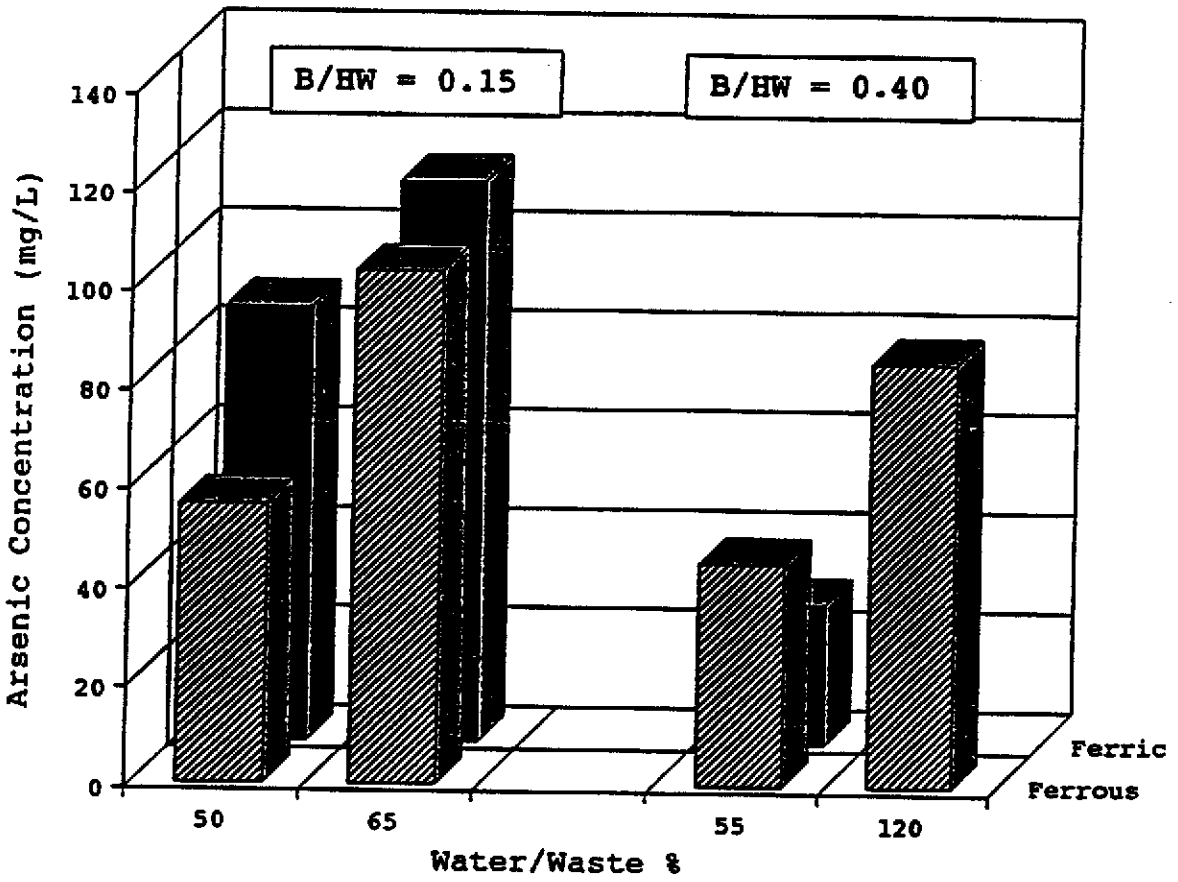


Figure 5-19. Arsenite Pretreatment by Air Oxidation, TCLP Results

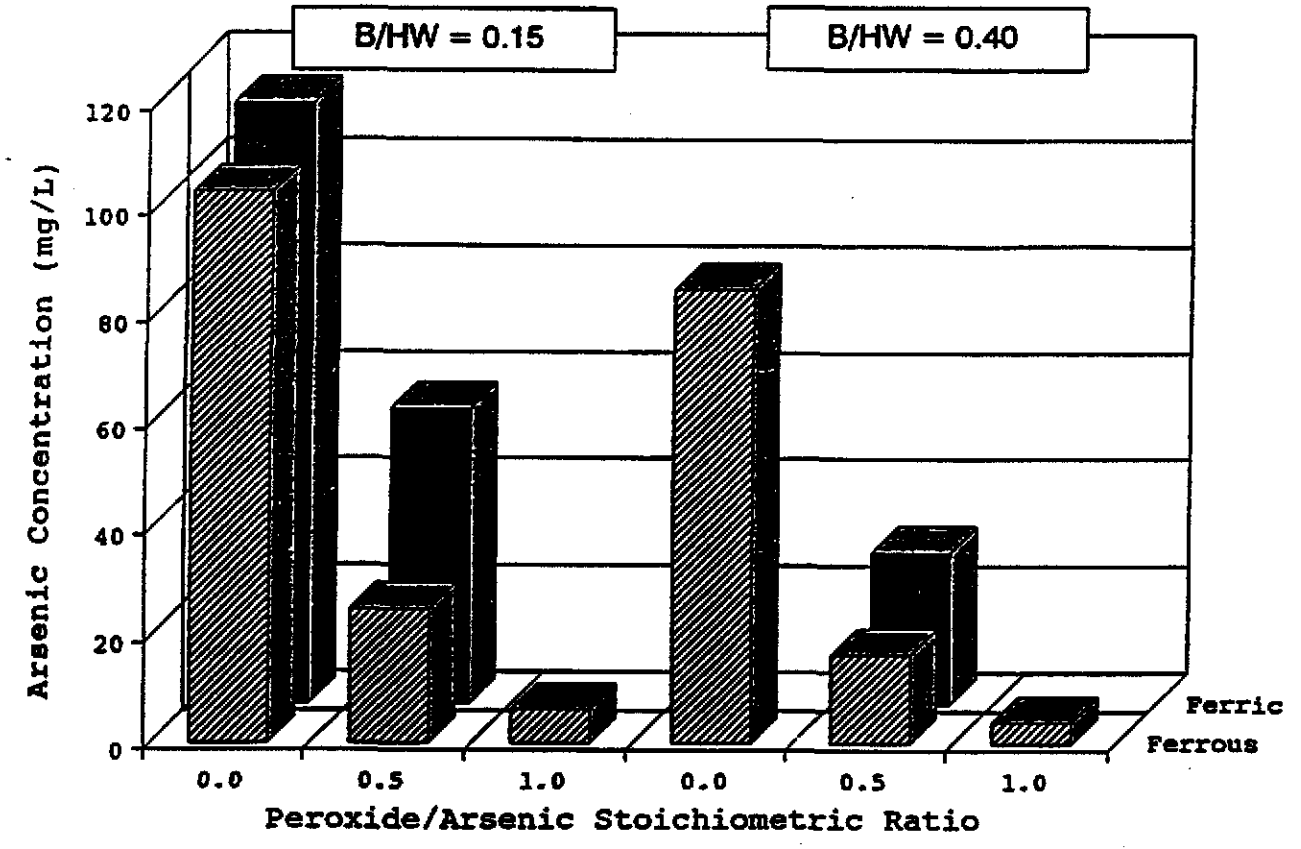


Figure 5-20. Arsenite Pretreatment by Peroxide Oxidation, TCLP Results

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	
1.5	IA1x Series		IA3x Series	
	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
3.0	IA2x Series		IA4x Series	
	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.

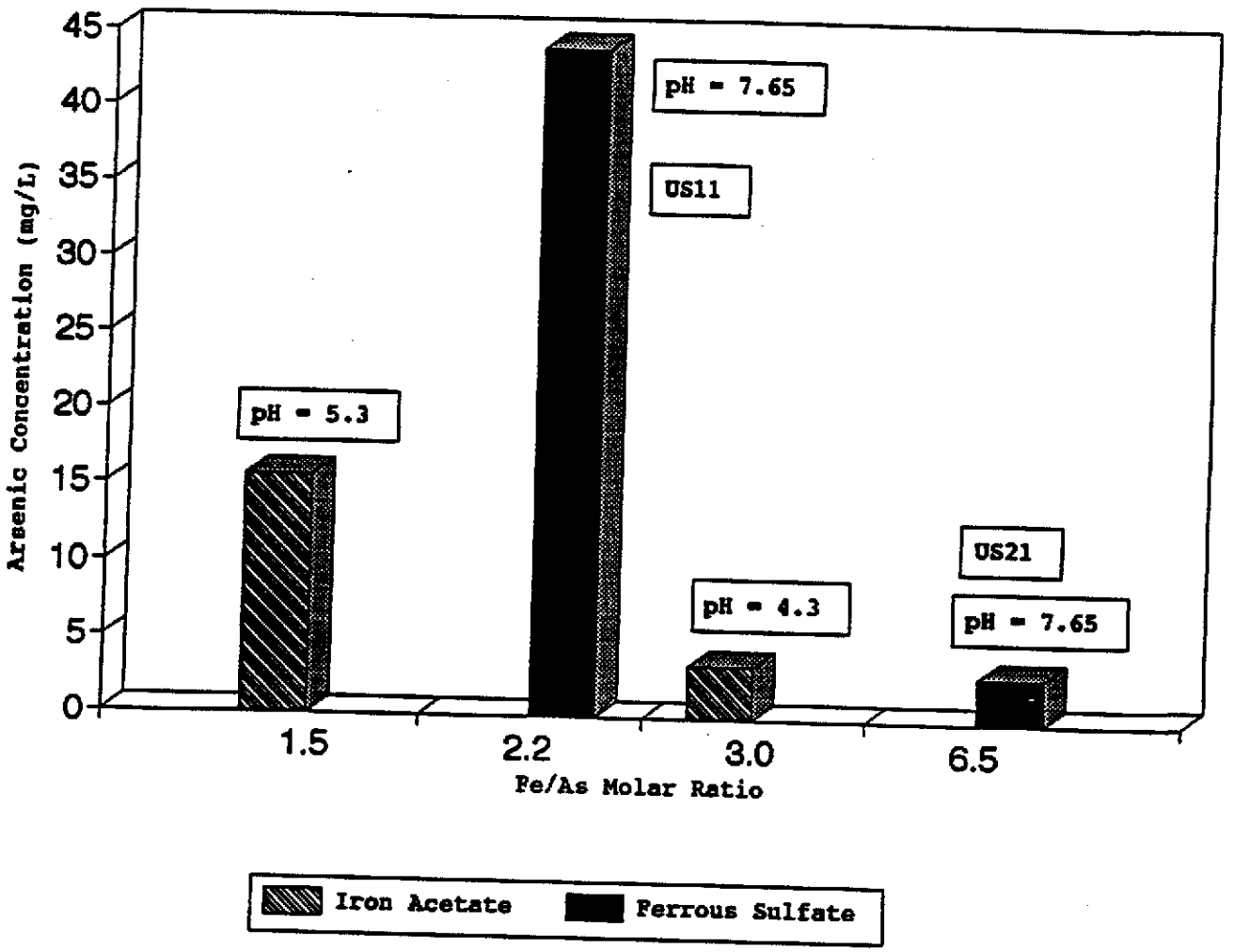


Figure 5-21. TCLP Arsenic Results for Ferrous Sulfate and Ferrous Acetate Stabilizations

Table 5-13. TCLP Results Using Sodium Sulfate

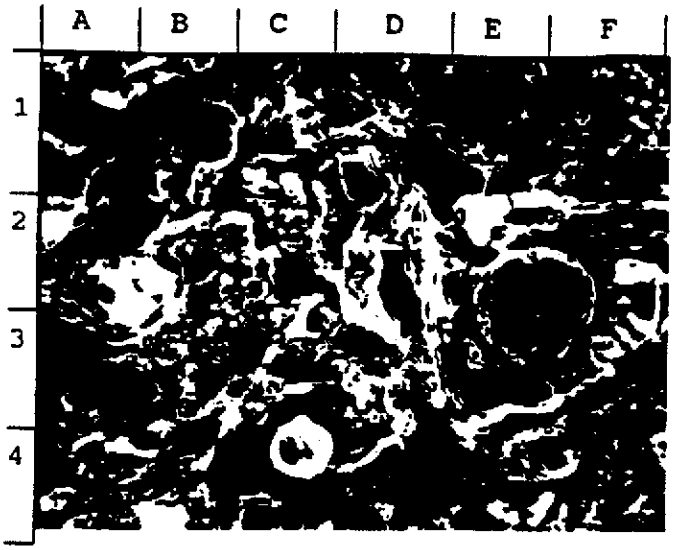
Mole Ratio SO_4^{2-}/Ba^{2+}	Binder/Waste Mass Ratio = 0.15		Binder/Waste Mass Ratio = 0.40	
1.0	SS1x Series		SS3x Series	
	Arsenic	27.7	Arsenic	33.1
	Barium	0.582	Barium	80.6
	Iron	<0.02	Iron	0.125
	Sulfate	35.5	Sulfate	2.28
	Calcium	384.	Calcium	2370
	Extract pH	5.26	Extract pH	4.5
2.0	SS2x Series		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

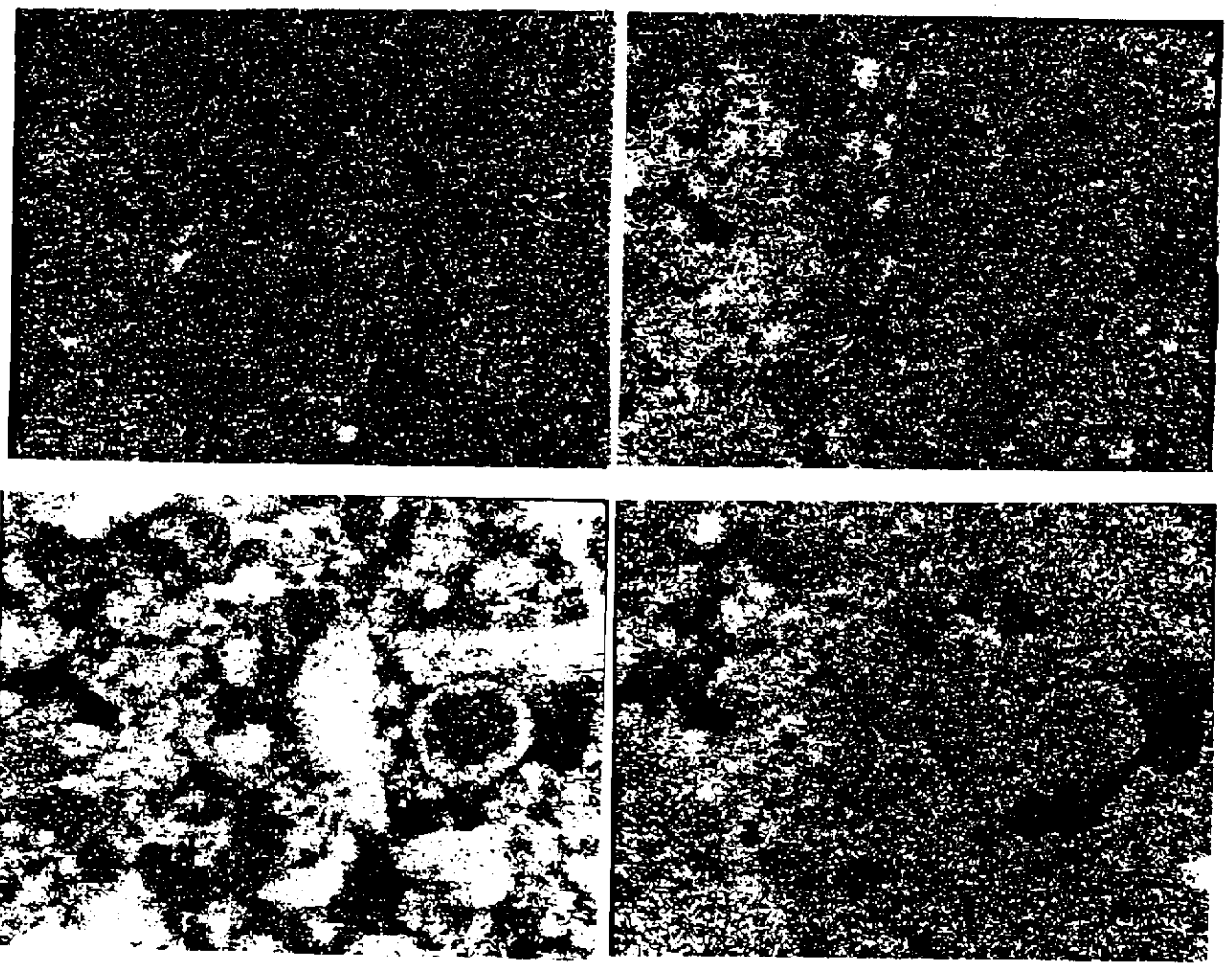
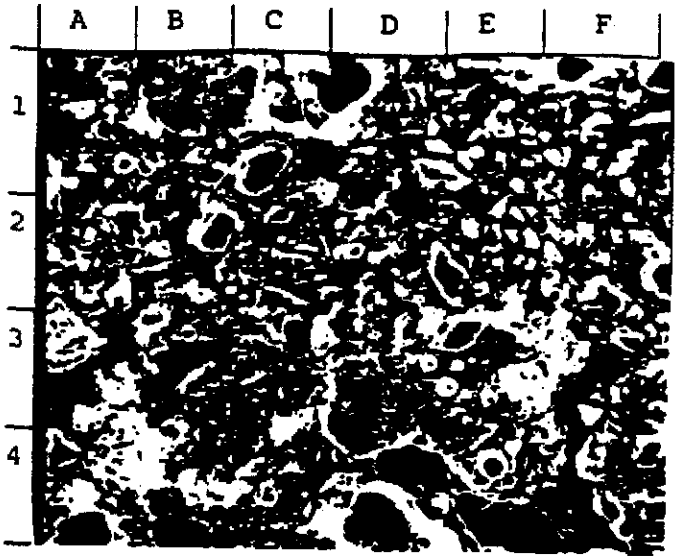


Figure 5-22. SEM Data for Sample SEM1, 2-day Cure Time

STABILIZATION OF ARSENIC WASTES



Magnification 130x

Photo	
As	Fe
Ba	S

Key

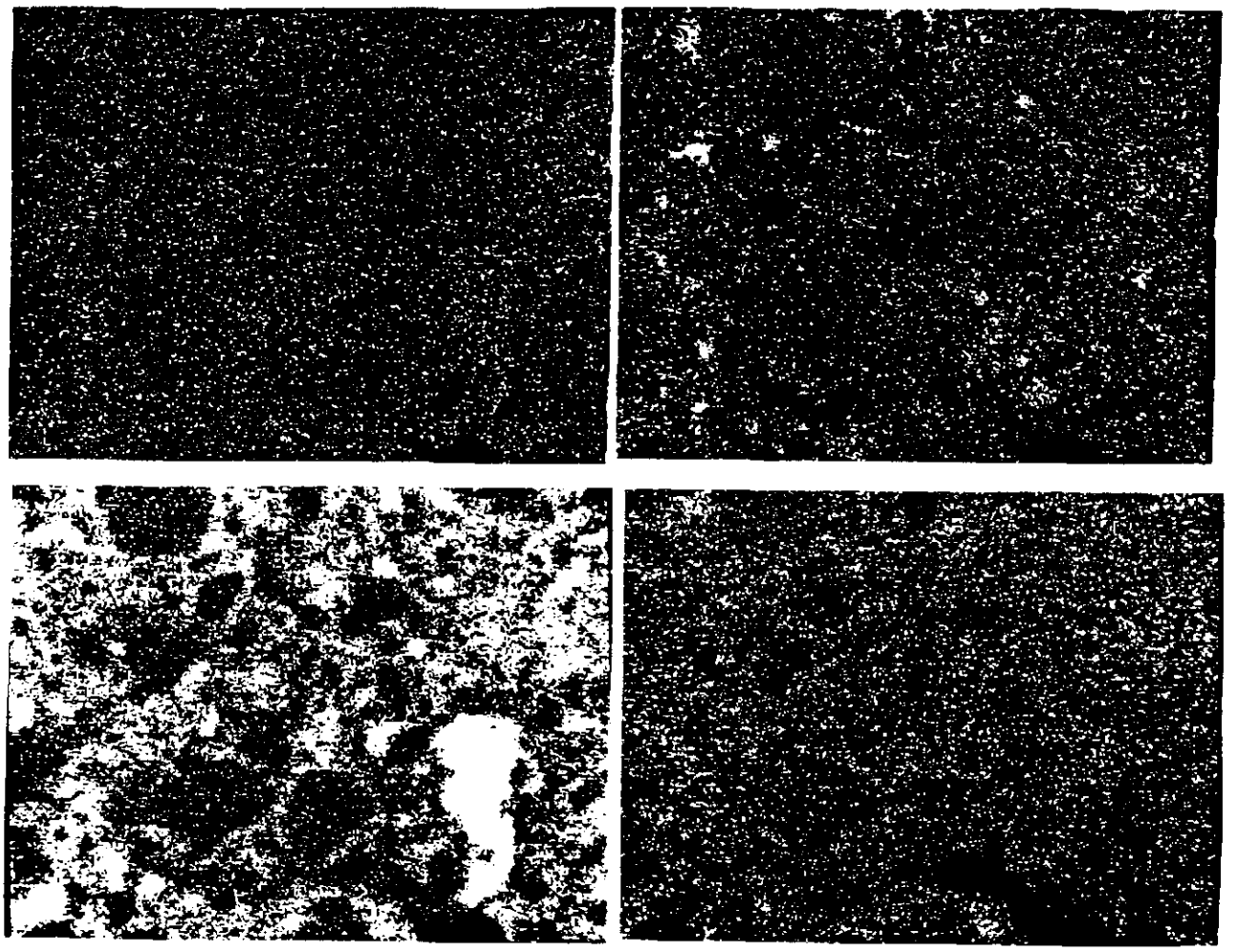
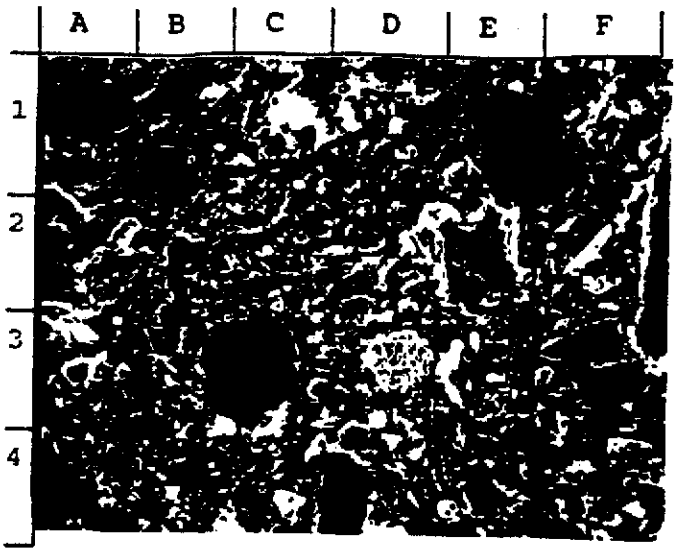


Figure 5-23. SEM Data for Sample SEM2, 60-day Cure Time

STABILIZATION OF ARSENIC WASTES



Magnification 130x

Photo	
As	Fe
Ba	S

Key

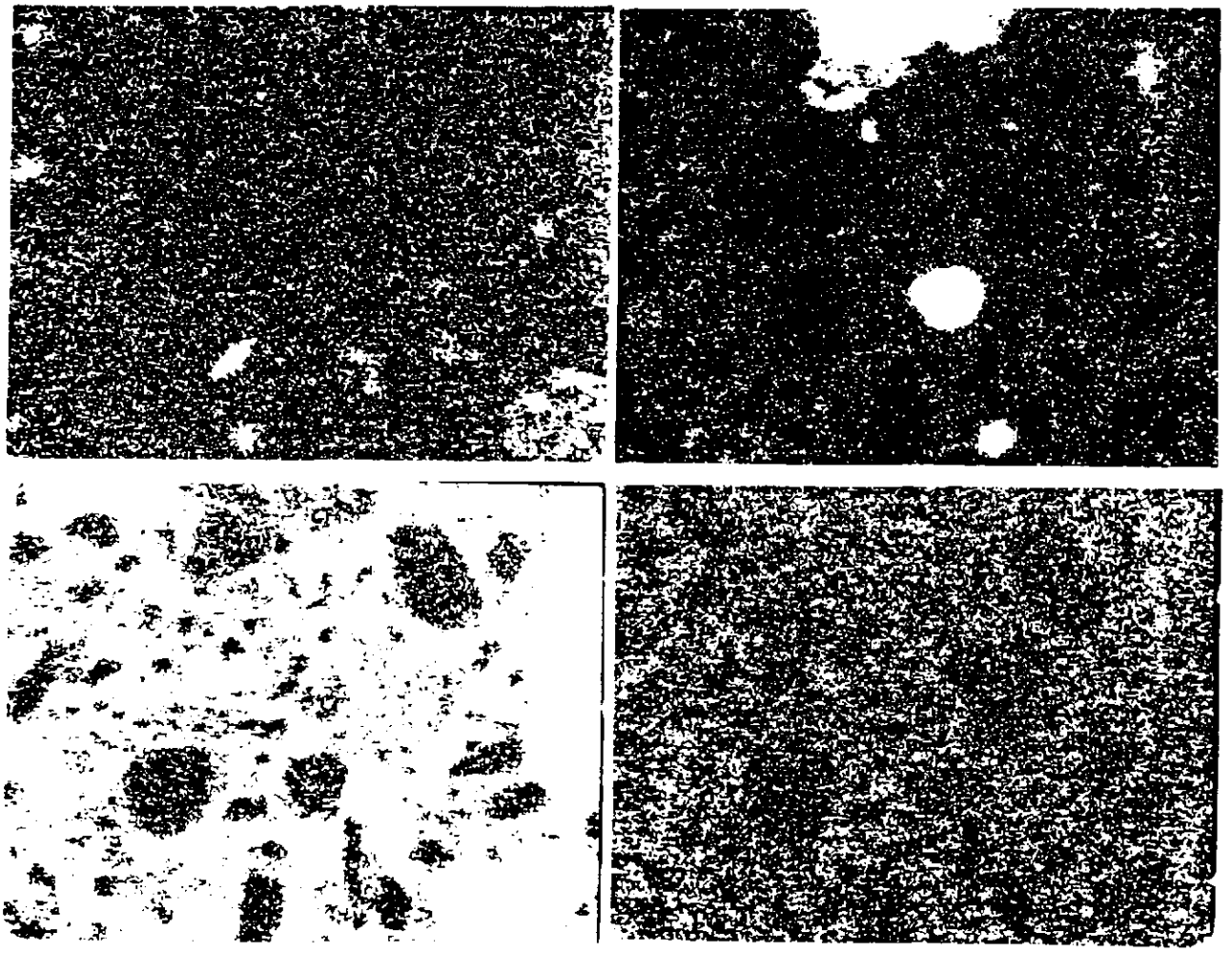


Figure 5-24. SEM Data for Sample SEM3, 365-day Cure Time

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.

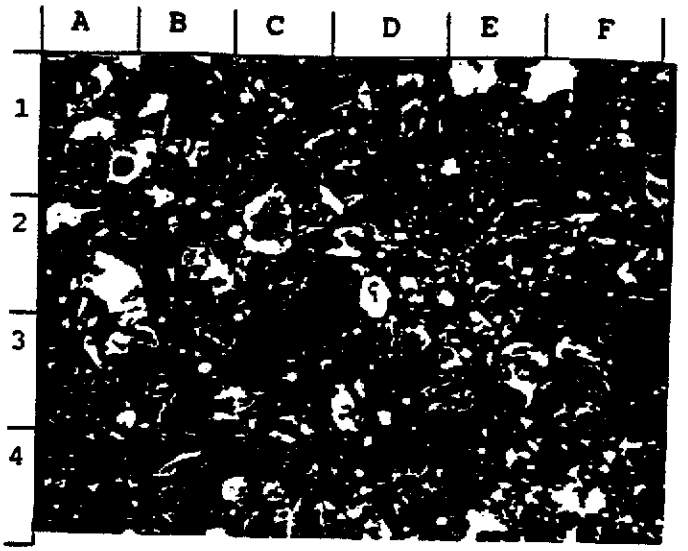
In Figure 5-22, sample SEM1 is shown. The arsenic dot map is essentially featureless, typical of the arsenic distributions observed in this study. This sample has a cure time of two days, so that the CH gel phase is still present in significant amounts. Large zones of gel phase can be identified at locations 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

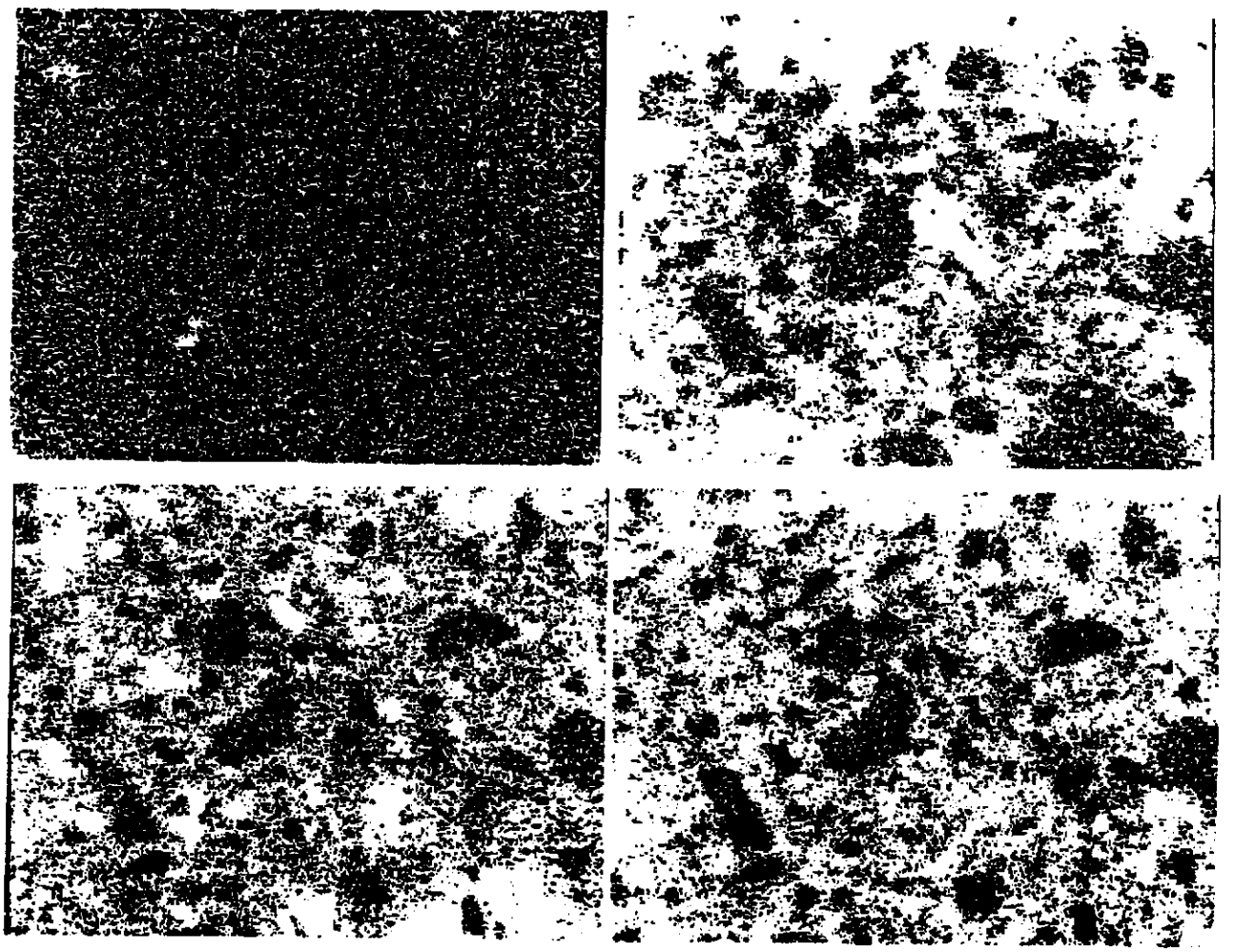


Figure 5-25. SEM Data for Sample SEM4, 2-day Cure Time

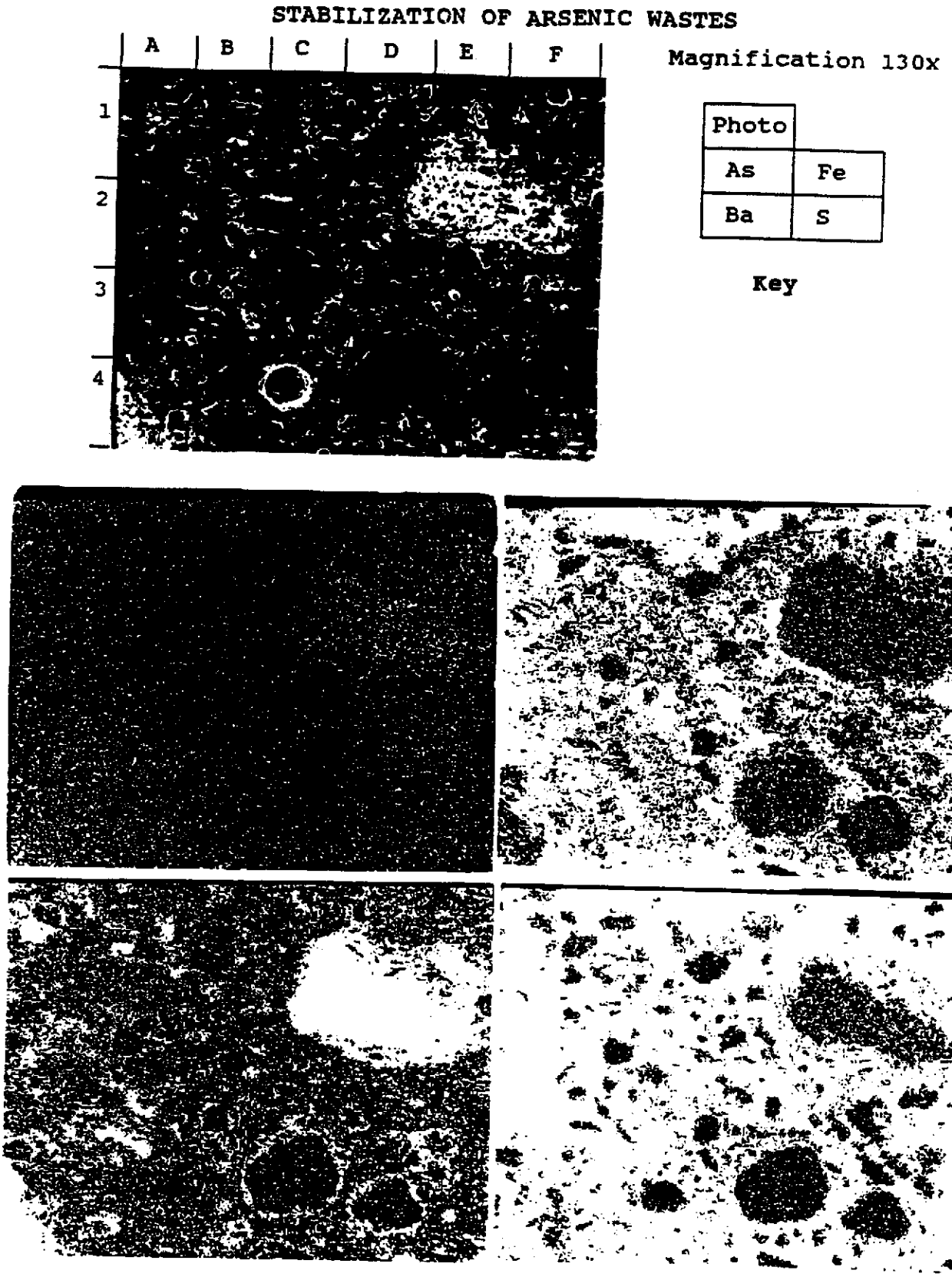


Figure 5-26. SEM Data for Sample SEM5, 2-day Cure Time

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.

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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	0.026	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.

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
	Metal (mg/L)	MIX F1x Cure Time(days) 2	60	365	540
2.2 (0.36)	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)	2	Cure Time(days) 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)	2	Cure Time(days) 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)	2	Cure Time(days) 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)	2	Cure Time(days) 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		

RCRA FACILITY INVESTIGATION EXPEDITED WORKPLAN
SWMU 12 - FORMER MSMA SALT UNLOADING AREA
SWMU 11 - FORMER MSMA PRODUCTION AREA
SWMU 15 - FORMER METHYL PARATHION PRODUCTION AREA

VICKSBURG CHEMICAL COMPANY
VICKSBURG, MISSISSIPPI

Prepared for
Vicksburg Chemical Company
Vicksburg, Mississippi

Cedar Chemical Corporation
Memphis, Tennessee

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LIST OF ATTACHMENTS

Health and Safety Plan

LIST OF ACRONYMS

Acronym	Meaning
CCC	Cedar Chemical Corporation
VCC	Vicksburg Chemical Company
RFI	RCRA Facility Investigation
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
SWMU	Solid Waste Management Unit
AOC	Area of Concern
PECMT	Preinvestigation - Evaluation of Corrective Measures Technologies
EPA	United States Environmental Protection Agency
MSDEQ	Mississippi Department of Environmental Quality
CMS	Corrective Measures Study
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
bgs	below ground surface
TCL	Toxic Compound List
TAL	Toxic Analyte List

1.0
INTRODUCTION

Vicksburg Chemical Company (VCC) has retained Woodward-Clyde Consultants (WCC) to perform activities associated with a RCRA corrective action program. The corrective action program is in response to a Consent Decree. 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 a Corrective Measures Study.

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 five separate tasks which includes the Preliminary Report (submitted as a separate document and 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. 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.

This document is an RFI Expedited Work Plan and is limited to the following areas:

- SWMU 12, Former MSMA Unloading Area;
- SMWU 11, Former MSMA Production Area; and
- SWMU 15, Former Methyl Parathion Production Area.

The location of the SWMUs are presented on Figure 1.

This work plan includes or incorporates by reference the following plans presented in the RFI Work Plan (submitted in June 1996):

- Data Collection Quality Assurance Plan
- Data Management Plan
- Health and Safety Plan

This work plan also includes or incorporates by reference the plans presented in the Closure Plan for SWMU 1 and SWMU 17.

The RCRA corrective action program for SWMUs 12, 11 and 15 is expected to be very similar to that for SWMUs 16, 1 and 17. An RFI Report, Corrective Action Measures Study, RCRA Corrective Measures Implementation Plan and Application for Corrective Action Management Unit were published and initially submitted to the U.S. EPA and MSDEQ in June 1997.

This RFI Expedited Work Plan is guided by the information contained in the Amended and Supplemental Preliminary Report (Report of Current Conditions) and is expedited because of VCC's plans to consider construction of a new manufacturing facilities in the South Plant and potentially utilize some of the area to be investigated for storage, transportation and manufacturing.

The RCRA Facility Investigation is intended to obtain information to characterize the nature and extent of releases of hazardous waste or constituents, if any. This information will be used to determine whether a Corrective Measures Study (CMS) will be necessary. The purpose of a CMS is to develop and evaluate the corrective action alternatives and to recommend the corrective measure or measures to be taken at the facility.

2.0
RFI EXPEDITED WORK PLAN STRATEGY

The Amended and Supplemental Preliminary Report provides an overview of the investigations and analyses undertaken to characterize the potential contaminants of concern as well as the environmental setting and to determine those areas requiring additional investigation. Completed work tasks include:

- Compiled site background information
- Reviewed facility's history and file data
- Characterized the facility's environmental setting
- Established boundaries of SWMUs and AOCs
- Identified surface SWMUs not requiring further investigation
- Characterized waste sources to fullest extent possible
- Identified potential receptor population

The RFI Expedited Work Plan objectives, strategy, and approach are presented herein. Several plans are needed to insure an accurate and complete field investigation of the facility. These plans include by reference the RFI Work Plan (submitted in June 1996) and any modifications of that plan needed to comply with deficiencies to the plan provided by the U.S. EPA and MSDEQ.

2.1 RFI EXPEDITED WORK PLAN OBJECTIVES

The primary objectives for the RFI Expedited Work Plan shall be to provide procedures for collecting information as necessary to protect human health and the environment. A secondary objective is for evaluation of areas for new manufacturing facilities in the South Plant and potentially utilize some of the area to be investigated for storage, transportation and manufacturing. Specifically, the objectives are to:

- Identify specific constituents of concern.
- Determine whether or not the areas to be investigated are releasing hazardous constituents into the environment.

- If a release of hazardous constituents is occurring, identify the source(s) of contamination.
- Determine the horizontal and vertical extent of contamination.
- Evaluate migration rates, pathways, and potential receptors.
- Provide data for the evaluation of remedial alternatives and associated health risk assessments for the site.

These objectives will be obtained by establishing data quality objectives to be met during the investigation and then implementing the RFI Expedited Work Plan as discussed in the Section 4.0 Project Schedule. For quality objectives, quality assurance and quality control (QA/QC) procedures will be followed as delineated in the Data Collection Quality Assurance Plan.

2.2 RFI WORK PLAN RATIONALE

The rationale which forms the basis for the Expedited Work Plan is based on VCC's knowledge of the SWMUs requiring further investigation. For example, it is known that the Inactive Landfill (SWMU 2) is associated with waste disposal practices (SWMU 2 is not included within the Expedited Work Plan). In addition, several former production areas have been identified as requiring further investigation based on current information as discussed in the *Preliminary Report*.

The location of each SWMU is shown in Figure 1. SWMU boundaries were defined in the Preliminary Report. The environmental setting and potential receptors/pathways were presented in the Preliminary Report. The information to be gathered during the Expedited RFI and GWA (after the GWA Work Plan is approved) includes the following:

- The vertical and horizonal extent of releases that have or are occurring within the SWMU boundaries which could potentially impact human health or the environment.

- The transport mechanisms, rates, and pathways for migration of hazardous constituents from SWMU areas.

For the former production areas, it is necessary to determine if hazardous constituents are migrating out of the SWMU area through surface water or groundwater. If there are indications of release, the vertical and horizontal extent of established constituents of concern will be assessed and data will be gathered to determine flow directions and pathways.

Storage areas will be approached from the standpoint that the type of hazardous constituents stored in the units are known. The extent of contamination, if any, will therefore be assessed, in the overall RFI (which will incorporate data obtained in this Expedited RFI) followed by a study of migration rates, pathways, and potential receptors. Groundwater contamination and plume migration will not be considered in the Expedited RFI but will be considered in the overall RFI and GWA.

The field investigation will proceed in phases. Phase I will focus on areas of surficial contamination within the SWMUs or AOCs that are suspected or confirmed to have a release. The density of sampling is approximately on sample per 2,500 square feet of area investigated. This Expedited RFI Work Plan should be considered a part of the overall Phase I program.

The following table is a summary of the total surficial contamination sampling to be executed during Phase I (more specific information on the sampling under the Expedited RFI is included in Section 3.1):

SWMU Number	Sample Points	Samples	Analyte Lists
1/17 - Container Storage - Off-Spec Storage*	12	34	A
2 - Landfill	10	23	B
4 - Activated Carbon Treatment	6	6	B
5 - South Plant Drainage	16	16	C
7/20 - Former Dinoseb Production Area/Railroad Car Loading/Unloading Station	21	42	A
8 - Dinoseb Loading/Unloading Area	2	6	A
11/12/15 MSMA-Methyl Production Area*	57	105	A, B, C, D, G
13 - West Drainage	9	9	C
14 - Toxaphene	3	6	C

SWMU Number	Sample Points	Samples	Analyte Lists
16 - Atrazine - Production and Warehouse*	35	57	C
18 - Blue Tank	3	3	C
30 - Waste Oil	3	3	E
34 - Junkyard	6	6	F

LEGEND:

* Part of the Expedited RFI (sampling density generally has been increased to expedite investigation by precluding a need for Phase II shallow or surface sampling)
A Atrazine, cyanazine, arsenic, dinoseb, toxaphene, toluene
B TCL, TAL, atrazine, cyanazine, dinoseb
C Atrazine, cyanazine, arsenic, dinoseb, toxaphene
D TLC, dioxin, TAL, atrazine, cyanazine, dinoseb
E BTEX, TPH
F BTEX, TPH, atrazine, cyanazine, arsenic, dinoseb, toxaphene
G Arsenic

A Phase II investigation will be executed for those areas where additional information is needed. The primary objective of Phase II is to establish the vertical and horizontal extent of contamination, if it is not adequately established in Phase I. The Phase II work may, for example, identify locations for monitor wells for individual SWMUs where there is evidence of releases.

Based on the data gathered for the Phase I investigation, there may be a need for a limited Phase II investigation. During the Groundwater Assessment and the RFI covering the entire plant site the data gathered for Phase I and Phase II report will be further considered for the placement of monitor wells.

3.0
SITE CHARACTERIZATION PLAN

The overall approach is designed to accomplish the objectives as stated in Section 2.1. The primary purpose of the sampling will be to determine if the areas to be investigated are releasing hazardous constituents of concern into the environment. A secondary purpose is for evaluation of areas for new manufacturing facilities in the South Plant and potentially utilize some of the area to be investigated for storage, transportation and manufacturing. To accomplish this, the effort will involve specific field sampling, data assessment, and development of a field investigation report which summarizes the results of the work.

The general locations of the areas to be investigated are depicted in Figure 1. The specific sample locations for SWMU 11, SWMU 12 and SWMU 15 are depicted on Figure 2.

3.1 SAMPLING RATIONALE

For each sample point there will be two or three samples taken:

- A core of the concrete (if the sample point is a former production or storage area).
- A composite sample of the first six inches of soil beneath the concrete referred to as the shallow sample.
- A sample of soil generally 12 inches or deeper beneath the concrete referred to as the deep sample.

The total number of samples to be submitted for analysis shall be, as a minimum, as follows:

SWMU Number	Sample Description	Sample Points	Number of Samples	Analyte List
11, 12, 15 MSMA and Methyl Parathion	Sludge/Sediment (from drains, sumps and pits)	10 sludge/sediment	10	D
	Concrete and Soil	4 concrete and soil	12	D

SWMU Number	Sample Description	Sample Points	Number of Samples	Analyte List
11, 12, 15 MSMA and Methyl Parathion	Concrete and Soil	2 concrete and soil	6	G
	Soil (underneath concrete)	18 soil	36	G
	Wipe	5 paper	5	G
	QA/QC	Matrix spike, matrix spike duplicate	8	5-G 3-D

LEGEND:

A Atrazine, Cyanazine, Arsenic, Dinoseb, Toxaphene, Toluene
B TCL, TAL, Atrazine, Cyanazine, Dinoseb
C Atrazine, Cyanazine, Arsenic, Dinoseb, Toxaphene
D TCL, Dioxin, TAL, Atrazine, Cyanazine, Dinoseb
E BTEX, TPH
F BTEX, TPH, Atrazine, Cyanazine, Arsenic, Dinoseb, Toxaphene
G Arsenic

3.2 ANALYTICAL RATIONALE

The soil and concrete samples submitted for analysis will be analyzed for atrazine, cyanazine, arsenic, dinoseb and toxaphene. Many samples will be analyzed for the Target Compound List (TCL) and Target Analyte List (TAL). The TCL/TAL parameters provide scientifically valid data that is more defensible than protocols for Appendix IX constituents. The following paragraphs are discussions of the list TCL/TAL parameters presented in the RFI Work Plan and the list of Appendix IX constituents.

Most Superfund site investigations involve analyzing for TCL organics and TAL metals. The list is an expanded version of the Clean Water Act (CWA) Priority Pollutant List. (These lists are often referred to as the Hazardous Substance List). On July 9, 1987, the EPA finalized new groundwater monitoring requirements for TSD facilities. These new requirements specify monitoring for a list of 252 organic, metallic and inorganic analytes contained in Appendix IX of 40 CFR Part 264 when a contamination plume is present. Although the regulation is specific for groundwater analysis, the analytes can be determined in other matrices.

Comparison of the TCL/TAL analytes with the Appendix IX analytes reveals that the TCL and TAL parameters include 9 parameters that are not included in the Appendix IX listing. These parameters consist of benzoic acid in the semivolatile fraction, endrin ketone in the pesticide/PCB fraction, and aluminum, calcium, iron, magnesium, manganese, potassium, and sodium in the inorganic fraction. The concentration of aluminum, calcium, iron, and magnesium can be particularly informative with regard to providing insight to results reported for several of the other metals.

Even though the Appendix IX Ground Water Monitoring List appears to be a diverse list of compounds the usefulness of the list is suspect. Consider, for example the following subset of compounds found in Appendix IX:

- Safrole
- Isosafrole
- Phenacetin
- 2-Acetylaminofluorene
- Aramite®
- Sym-Trinitrobenzene

Safrole is a constituent of several essential oils and most notable sassafras, i.e., root beer, in which it is the major compound amounting to about 75 percent (Merck, page 8175). Isosafrole is a minor compound of sassafras (Merck, page 5075). Phenacetin or acetophenetidin is an analgesic and antipyretic pharmaceutical and is employed as a stabilizer in hydrogen peroxide in hair bleaching preparations (Sittig, page 817). Sym-Trinitrobenzene is an explosive more powerful and brisant but less sensitive to shock than TNT (2,4,6-trinitrotoluene).

The majority of the organic parameters in the Appendix IX List can be analyzed employing the two general GC/MS Methods 8240 and 8270 for the volatiles and semivolatiles, respectively; however, the compounds enumerated as being characterized with Method 8240 cannot be determined from a single analytical run as the chemical and physical properties of these compounds are widely divergent. In actual fact, the properties vary continuously from the well behaved compounds to the highly polar water soluble compounds. Consequently,

these compounds must be considered in terms of at least two distinct categories according to the required sample preparation conditions summarized as follows:

Compound Category/Sample Matrix	Purge Temperature
Well Behaved Compounds:	
Water	Ambient
Low Soil	4°C
High Soil	Ambient
Highly Polar Water Soluble Compounds:	
Water	85°C
Low Soil	85°C
High Soil	85°C

Thus, the analysis of Appendix IX volatiles for a single sample requires a minimum of two discrete determinations provided that all the compounds are amenable to purge and trap isolation. If this is not the case, then at least one additional analytical run must be performed.

In the summary, the TCL/TAL is a listing of analytes for which: (1) analytical methods are established based on available laboratory data and judgment of technical experts, and (2) analytical methods have been rewritten in standard format, subjected to editorial review, extensive revisions, and validated in numerous EPA and contractor laboratories throughout the country. Precision and accuracy criteria for these protocols have been established in terms of analytical data required on real world samples.

No such accreditation can be stated for the Appendix IX parameters which are not also included in the TCL or TAL given in the RFI Work Plan. The following are some of the reasons that such accreditation is not possible at this time:

- Regulations apply to Appendix IX parameters only to monitor well groundwater samples; however, it appears that regulations were established without any serious consideration of how any required analytical measurements would be performed.

- Validated analytical methods are not available for a number of Appendix IX parameters even in water and no deliberative attempt has been made by the agency to develop analytical methods for the Appendix IX parameters.

- The suggested analytical methods for characterizing the Appendix IX parameters are provided in SW-846; however, the only justification for inclusion of a significant number of the Appendix IX parameters in existing SW-846 analytical methods seems to have been some type of extrapolation, i.e., according to someone's judgment, the method should work.

- The suggested Appendix IX analytical methods are not even necessarily analytical fraction specific, i.e., both purgeable volatile and semivolatile extractable analytical methods are quoted for some specific parameters.

  Regulatory flexibility concerning permissible analytical methods for a given parameter may be desirable. Further, it may be technically feasible to analyze certain parameters in either the purgeable volatile or semivolatile analytical fractions. However, this raises concern as to whether the data from the two methods would be comparable.

- The SW-846 analytical methods posses one or more of the following shortcomings with respect to the characterization of a given Appendix IX parameter:
  - Parameter not enumerated in the list of the method's target parameters.
  - Characteristic masses not provided for the parameter.
  - Chromatographic retention time value not provided for the parameter.
  - Only an estimated chromatographic retention time provided for the parameter.
  - QA accuracy and precision criteria are not provided for the parameter.

- The only practical quantitation limits quoted in SW-846 for Appendix IX organic compounds are for those compounds included in the TCL.

- Authentic analytical standards are not readily available for all of the Appendix IX parameters.

- EPA laboratory control standards are not available for a substantial number of the Appendix IX parameters.

- The SW-846 document is an evolving one, i.e., analytical methods are currently being modified, deleted, and/or added.

- The regulations apply to Appendix IX parameters only to monitoring well groundwater samples and water analytical methods do not necessarily translate to soil matrices.

- Required method detection limits are not specific in the regulations even for groundwater samples. There is confusion with the concept of detection and quantitation limits associated with Appendix IX parameters.

  For example, with regard to the Practical Quantitation Limits (PQLs) quoted in the Appendix IX Ground Water Monitoring List, variation in quantitation limits for a given parameter by a factor of 800, simply due to the application of different analytical methods, is acceptable. Variation in quantitation limits quoted for a given parameter by a factor of 50 to 100 is common.

Use of the TCL and TAL given in the Expedited RFI Work Plan in lieu of the Appendix IX list of parameters for the analysis of soil sample collection during Phase I of the RFI will provide laboratory data that is valid and defensible.

3.3 SAMPLING PROCEDURES

The following procedures will be employed to sample the soil and concrete under concrete. The sampling locations, noted in Figure 2 are approximate. If there is a crack near the sample point the field sampler is to sample near the crack. A concrete saw, concrete drill or geoprobe will be used to remove a small section or plug of the concrete. The concrete samples will be wrapped in aluminum foil.

Samples of soil underneath the concrete will be obtained utilizing a geoprobe. The geoprobe contained a clear plastic tube. A new tube is used for each thrust of the geoprobe. Each thrust penetrates to 2 feet thereby filling the plastic tube with a continuous 2-foot core that is examined and logged prior to sectioning and placing in sample bottles. Following the removal of the soil probe and logging, the sample is extracted from the plastic tube. The soil samples are transferred to sample bottles, appropriately labeled, and placed on ice for transport to the laboratory. All equipment is cleaned in accordance with the decontamination procedures before collection of each sample.

Sample points are to be chosen near to locations of joints and/or cracks where contamination could most likely accumulate if released. As a point of reference, according to guidance provided in OSWER 9476-00-8.C a clean closure demonstration may be made with one sample per 2500 ft^2. The areal locations meet the criterion noted. The mobility of pesticides in soil underneath the concrete will be limited; therefore, the highest concentrations would likely be found in areas where there are cracks just below the concrete/soil interface.

All equipment will initially be decontaminated before use and again after each sample is collected. The following decontamination procedures will be employed:

- Washing in tap water and a detergent (Alconox) solution. Brush, if necessary, to remove particulate matter and surface films
- Rinsing thoroughly with tap water
- Rinsing with distilled, deionized water
- Rinsing twice with pesticide - grade solvent
- Rinsing with organic - free water
- Allow to air dry as long as possible

After decontaminating, the sample equipment will be wrapped in aluminum foil for protection until its subsequent use. All wash fluids will be containerized for later disposal by VCC.

3.4 DOCUMENTATION OF SAMPLE ACQUISITION

All information pertinent to field observations and sampling will be recorded. Entries will include at least the following:

- Sketch of the container storage area with measurements
- A grid of the site area
- Purpose of sampling
- Number and approximate volume of samples taken
- Location of sampling point on grid
- Description of sampling point
- Date and time of collection
- Collector's sample identification number(s)
- References, such as maps or photographs of the sampling site
- Field observations
- Weather conditions

The documentation in the logbook will be sufficient to reconstruct the sampling situation without relying on the collector's memory.

Proper sample preservation is important in retaining the sample characteristics prior to analysis. Sample preservation is documented on the chain-of-custody form and also in the field logbook. The proposed analytical methods required that the sample be kept on ice until transferred to the laboratory.

Once the sample has been transferred to an appropriate laboratory sample container, sample tags will be completed and affixed to the sample container. The concrete samples will be wrapped in aluminum foil.

3.4.1 Sample Tagging

Each sample will be tagged and sealed properly immediately after collection. Sample tags are necessary to prevent misidentification of samples. The tag will include at least the following information:

- Name of collection
- Date and time of collection
- Place of collection
- Collector's sample number, which uniquely identifies the sample

3.4.2 Chain-of-Custody

In addition in the field logbook, each sample will be recorded on a chain-of-custody record. An identifying code will be assigned to each sample and this code will be used on the chain-of-custody and in the logbook to ensure that the sample description is identifiable. A brief description of the sampling point will also be placed on the chain-of-custody form.

Chain-of-custody forms will become the permanent records of all sample handling and shipment. If standard sampling procedures are not used, a written justification of each deviation will be placed in the project file. Upon completion of sampling, the sample will be prepared for shipment in accordance with the applicable sampling instruction, including preservation, labeling, and logging.

The person collecting a sample will initiate the document(s) at the source of sample and start the chain-of-custody procedure.

The sample will be kept in a limited access or locked storage at the proper temperature until custody is relinquished from the site and formal documentation of the transfer is completed.

Upon transfer of the custody, the person involved will verify sample numbers and condition and will document the sample acquisition and transfer. The field sampler will properly package the samples, indicate method of shipping, obtain documentation of the shipment, such as certified mail receipt or bill of lading number, and sample identification records (one

of each with the shipment, one of each by mail to the laboratory, and one of each returned with field records).

On transfer of custody of the samples to the transport agency, the field sample custodian will sign and retain a copy of the chain-of-custody, witness the transport company custody signature, and send two copies of the chain-of-custody, witness the transport company custody signature, and send two copies of the chain-of-custody with the samples. On arrival at the laboratory, the sample custodian will sign for custody and return a copy of the completed chain-of-custody to VCC. Custody procedures will then proceed according to the procedures of the selected testing laboratory.

3.4.3 Analytical Methods and Parameters

A summary of the parameter and possible methods to be employed by the offsite laboratory are as follows:

Toxaphene, Atrazine and Cyanazine	EPA SW-846, Method 8080
Dinitrobutyl Phenol (Dinoseb)	EPA SW-846, Method 8150
Arsenic	TAL, SOW
BTEX	TAL, SOW
TCL/TAL	See Table 1

3.5 EVALUATION OF DATA

Upon completion of the field investigation of Phase I and Phase II, if necessary, the next step will involve the analysis of data collected during the first task. Methods, procedures and data base tools, detailed in the Data Management Plan, will be implemented to the extent necessary to ascertain trends, constituents of concern, and indications of potential release.

The analysis of data will be summarized and presented to the VCC in a report. The report will discuss the sampling and analytical results and present the data in a concise manner along with conclusions and recommendations. In the event that a release or potential release of established contaminants of concern is not indicated, the report could include recommendations for no further action. If a potential release is indicated, recommendations would include submittal of conceptual plans for corrective action.

4.0
PROJECT SCHEDULE

4.1 RFI SCHEDULE

The estimated schedule (assuming a Phase II follow-up investigation) is as follows:

- December 10, 1997 - Establish and mark sample points and clear space for sampling.
- December 15, 16 and 17, 1997 - Mobilize, sample and send samples for analyses.
- February 9, 1998 - Receive results of Phase I analysis and begin Expedited RFI Report.
- February 23 and 24, 1998 - Mobilize for Phase II, sample and send samples for analyses.
- April 6-10, 1998 - Receive results of Phase II analysis and finalize Expedited RFI Report for review by VCC.
- April 20-24, 1998 - Complete Expedited Corrective Measure Study for review by VCC.
- April 27 through May 1, 1998 - VCC complete review. Publish copies of three reports and one application for submittal to the U.S. EPA and MSDEQ.

The rationale, approach, and strategy for the Expedited RFI discussed above will be implemented in accordance with the referenced Data Collection Quality Assurance Plan and Data Management Plan, where appropriate. The Health and Safety Plan is appropriate for

all of the WCC work on the VCC site. Changes in the procedures outlined will be documented.

4.2 RFI FIELD INVESTIGATION REPORT

A report will be compiled at the conclusion of the field investigation. The report will include the following:

- Discussion of relevant work accomplished to date
- Summary of findings
- Conclusions
- Supporting analytical and field data

In addition, the report will include discussion of results, and any new significant issues that would impact the RFI. The report will have appropriate drawings, tables, figures, maps, cross-sections, and other diagrams as needed to allow for a clear understanding of the nature and extent of any contaminations that may exist at the site.

5.0
PROJECT MANAGEMENT PLAN

The Project Management Plan consists of the following elements:

- Project task definition
- Specific personnel positions within the project organizational structure

5.1 PROJECT TASK DEFINITION

Vicksburg Chemical Corporation (VCC) has retained the services of Woodward-Clyde Consultants (WCC) to develop the Expedited RFI Field Investigation Plan.

5.2 PROJECT PERSONNEL

Duties of key personnel are described

5.2.1 Vicksburg Chemical Project Director

The Vicksburg Chemical Project Director is Steve Boswell and is the official representative for VCC. He is in charge of administration of the work and the completion of the project.

5.2.2 Woodward-Clyde Consultants Project Manager

The WCC Project Manager will develop the plans required and oversee implementing of the work plan on behalf of Vicksburg Chemical, and will be the primary contact with the Vicksburg Chemical. The WCC Project Manager is Richard D. Karkkainen.

5.2.3 Expedited RFI Field Investigation Site Coordinator

Richard D. Karkkainen will handle day to day work plan activities. He will coordinate efforts with personnel from Petra, Inc. who will perform the sampling and he will oversee and assist their implementation.

5.2.4 WCC Health and Safety Officer

A WCC Health and Safety (H&S) officer will be responsible for the administration and implementation of site Health and Safety for work plan activities. 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
  - personnel protective equipment
  - respiratory protection equipment usage and fit testing, and
  - emergency response including site evacuation, dealing with fire and medical situations

- Be responsible for the maintenance of separate exclusion, contamination reduction, and support zones as described in the Contractor's H&S Plan when appropriate.

- Ensure that personnel exposure air monitoring is properly conducted and recorded when appropriate.

- Maintain a record keeping system which will include daily records of all site activity, waste quantities produced, waste transportation activity information, laboratory results, and other information as required when appropriate.

TABLES

TABLE 1

TCL/TAL ANALYTES

	Volatiles	CAS Number	Quantitation Limits** Water (µg/L)	Low Soil/Sediments (µg/Kg)
1.	Chloromethane	74-87-3	10	10
2.	Bromomethane	74-83-9	10	10
3.	Vinyl Chloride	75-01-4	10	10
4.	Chloroethane	75-00-3	10	10
5.	Methylene Chloride	75-09-2	5	5
6.	Acetone	67-64-1	10	10
7.	Carbon Disulfide	75-15-0	5	5
8.	1,1-Dichloroethane	75-35-4	5	5
9.	1,1-Dichloroethane	75-34-3	5	5
10.	1,2-Dichloroethane (Total)	540-59-0	5	5
11.	Chloroform	67-66-3	5	5
12.	1,2-Dichloroethane	107-06-2	5	5
13.	2-Butanone	78-93-3	10	10
14.	1,1,1-Trichloroethane	71-55-6	5	5
15.	Carbon Tetrachloride	56-23-5	5	5
16.	Vinyl Acetate	108-05-4	10	10
17.	Bromidichloromethane	75-27-4	5	5
18.	1,2-Dichloropropane	78-87-5	5	5
19.	cis-1,3-Dichloropropane	10061-01-6	5	5
20.	Trichloroethane	79-01-6	5	5
21.	Dibromochloromethane	124-48-1	5	5
22.	1,1,2-Trichloroethane	79-00-5	5	5
23.	Benzene	71-43-2	5	5
24.	trans-1,3-Dichloropropane	10061-02-6	5	5
25.	Bromoform	75-25-2	5	5
26.	4-Methyl-2-pentanone	108-10-1	10	10
27.	2-Hexanone	591-78-6	10	10
28.	Tetrachloroethane	127-18-4	5	5
29.	Toluene	108-88-3	5	5

TABLE 1 (Continued)

TCL/TAL ANALYTES

	Volatiles	CAS Number	Quantitation Limits** Water (µg/L)	Low Soil/Sediment* (ug/Kg)
30.	1,1,2,2-Tetrachloroethane	79-34-5	5	5
31.	Chlorobenzene	108-90-7	5	5
32.	Ethyl Benzene	100-41-4	5	5
33.	Styrene	100-42-5	5	5
34.	Xylenes (Total)	1330-20-7	5	5
35.	Phenol	108-95-2	10	330
36.	bis-2-Chloroethyl ether	111-44-4	10	330
37.	2-Chlorophenol	95-57-8	10	330
38.	1,3-Dichlorobenzene	541-73-1	10	330
39.	1,4-Dichlorobenzene	104-46-7	10	330
40.	Benzyl Alcohol	100-51-6	10	330
41.	1,2-Dichlorobenzene	95-50-1	10	330
42.	2-Dichlorobenzene	95-48-7	10	330
43.	bis(2-Chloroiscopropyl)ether	108-60-1	10	330
44.	4-Methylphenol	106-44-5	10	330
45.	N-Nitroso-di-n-dipropylamine	621-64-7	10	330
46.	Hexachloroethane	67-72-1	10	330
47.	Nitrobenzene	98-95-3	10	330
48.	Isophorone	78-59-1	10	330
49.	2-Nitrophenol	88-75-5	10	330
50.	2,4-Dimethylphenol	105-67-9	10	330
51.	Benzoic Acid	65-85-0	50	1600
52.	bis(2-Chloroethoxy)methane	111-91-1	10	330
53.	2,4-Dichlorophenol	120-83-2	10	330
54.	1,2,4-Trichlorobenzene	120-82-1	10	330
55.	Naphathalene	91-20-3	10	330
56.	4-Chloroanile	106-47-8	10	330
57.	Hexachlorobutadiene	87-68-3	10	330
58.	4-Chloro-3-methylphenol (para-chloro-meta-cresol)	59-50-7	10	330
59.	2-Methylnaphthalene	91-57-6	10	330

TABLE 1 (Continued)

TCL/TAL ANALYTES

	Volatile	CAS Number	Quantitation Limits** Water (µg/L)	Low Soil/Sediment[b] (µg/Kg)
60.	Hexachlorocyclopentadiene	77-47-4	10	330
61.	2,4,6-Trichlorophenol	88-06-2	10	330
62.	2,4,5-Trichlorophenol	95-95-4	50	1600
63.	2-Chloranaphthalene	91-58-7	10	330
64.	2-Nitroaniline	88-74-7	50	1600
65.	Dimethylphthalate	131-11-3	10	330
66.	Acenaphthalene	208-96-8	10	330
67.	2,6-Dinitrotoluene	606-20-2	10	330
68.	3-Nitroaniline	99-09-2	50	1600
69.	Acenaphthene	83-32-9	10	330
70.	2,4-Dinotrophenol	50	1600	
71.	4-Nitrophenol	50	1600	
72.	Dibenzofuran	10	330	
73.	2,4-Dinitrotoluene	10	330	
74.	4-Dithylphthalate	10	330	
75.	4-Chlorophenyl-phenyl-ether			
76.	Fluorene	86-73-7	10	330
77.	4-Nitroaniline	100-01-6	50	1600
78.	4,6-Dinitro-2-methylphenol	534-52-1	50	1600
79.	N-nitrosodiphenylamine	86-30-6	10	330
80.	4-Bromophenyl-phenylether	101-55-3	10	330
81.	Hexachlorobenzene	118-74-1	10	330
82.	Pentachlorophenol	87-86-5	50	1600
83.	Phenanthrene	85-01-8	10	330
84.	Anthracene	120-12-7	10	330
85.	Di-n-butylphthalate	84-74-2	10	330
86.	Fluoranthene	206-44-0	10	330
87.	Pyrene	129-00-0	10	330
88.	Butyl Benzyl Phthalate	85-68-7	10	330
89.	3,3-Dichlorobenzidine	91-94-1	20	660
90.	Benzo(a)anthracene	56-55-3	10	330

TABLE 1 (Continued)

TCL/TAL ANALYTES

	Semivolatiles	CAS Number	Quantitation Limits** Water (µg/L)	Low Soil/Sediment[b] (µg/Kg)
91.	Chrysene	218-01-9	10	330
92.	bis(2-Ethylhexyl)phthalate	117-81-7	10	330
93.	Di-n-octylphthalate	117-84-0	10	330
94.	Benzo(b)fluoranthene	205-99-2	10	330
95.	Benzo(k)fluoranthane	207-08-9	10	330
96.	Benzo(a)pyrene	50-32-8	10	330
97.	Ideno(1,2,2-cd)pyrene	193-39-5	10	330
98.	Dibenz(a,h)anthracene	53-70-3	10	330
99.	Benzo(g,h,i)perylene	191-24-2	10	330
100.	alpha-BHC	319-84-6	0.05	8.0
101.	beta-BHC	319-85-7	0.05	8.0
102.	delta-BHC	319-86-8	0.05	8.0
103.	gamma-BHC(Lindane)	58-89-9	0.05	8.0
104.	Heptachlor	76-44-8	0.05	8.0
105.	Aldrin	309-00-2	0.05	8.0
106.	Heptachlor Epoxide	1024-57-3	0.05	8.0
107.	Endosulfan I	959-98-8	0.05	8.0
108.	Dieldrin	60-57-1	0.10	16.0
109.	4,4'-DDE	72-55-9	0.10	16.0
110.	Endrin	72-20-8	0.10	16.0
111.	Endosulfan II	33213-65-9	0.10	16.0
112.	4,4'-DDD	75-54-8	0.10	16.0
113.	Endosulfan Sulfate	1031-07-8	0.10	16.0
114.	4,4'-DDT	50-29-3	0.10	16.0
115.	Methoxychlor	72-43-5	0.5	80.0
116.	Endrin ketone	53494-70-5	0.10	16.0
117.	alpha-Chlordane	5103-71-9	0.5	80.0
118.	gamma-Chlordane	5103-74-2	0.5	80.0
119.	Toxaphene	8001-35-2	1.0	160.0
120.	Aroclor-1061	12674-11-2	0.5	80.0
121.	Aroclor-1221	11104-28-2	0.5	80.0
122.	Aroclor-1232	11141-16-5	80.0	
123.	Aroclor-1242	53469-21-9	80.0	
124.	Aroclor-1248	12672-29-6	80.0	
125.	Aroclor-1254	11097-69-1	1.0	160.0
126.	Aroclor-1260	11096-82-5	1.0	160.0

TARGET ANALYTE LIST (TAL) METALS

Analyte	Contract Required Detection Limits* Water (µg/l)	Soil (mg/kg)
Aluminum	200	20
Antimony	60	6.0
Arsenic	10	1.0
Barium	200	20
Beryllium	5	0.5
Cadmium	5	0.5
Calcium	5000	500
Chromium	10	1.0
Cobalt	50	0.5
Copper	25	2.5
Iron	100	10
Lead	3	0.5
Magnesium	5000	500
Manganese	15	1.5
Mercury	0.2	0.1
Nickel	40	4.0
Potassium	5000	500
Selenium	5	0.5
Silver	10	1.0
Sodium	5000	500
Thallium	10	1.0
Vanadium	50	5.0
Zinc	20	2.0

[a] Meduim Soil/Sediment quantitation limits for Volatile TCL Compounds are 125 times the individual Low Soil/Sediment instrument detection limits.

[b] Medium Soil/Sediment quantitation limits for Semivolatile TCL Compounds are 15 times the individual Low Soil/Sediment quantitation limit.

[c] Medium Soil/Sediment quantitation limits for Pesticide/PCB TCL Compounds are 15 times the individual Low Soil/Sediment quantitation limit.

* Specific quantitation limits are highly matrix dependent. The quantitation limits listed herein are provided for quidance and may not always be achievable.

** Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis are required by the contract, will be higher.

Source: Statement of Work for Organic Analysis Multi-Media Multi-Concentation SOW 2/88, Revisions, 9/88, 4/89, and 5/89, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C., May 1989.

TABLE 2

APPENDIX IX - GROUND WATER MONITORING LIST

Cross-Reference Number from TCL Table 1 or M for TAL	Common Name[2]	Number	PQL (μg/L)[6]
69	Acenaphthene	83-32-9	200
66	Acenaphthylene	208-96-8	10
6	Acetone	67-64-1	200
	Acetophenone	98-86-2	100
	Acetonitrile; MethylCyanide	75-05-8	100
	2-Acetylaminofluorene; 2-AAF	53-96-3	10
	Acrolein	107-02-8	5
	Acrylonitrile	107-13-1	5
105	Aldrin	309-00-2	0.05
	Allyl Chloride	107-05-1	5
	4-Aminobiphenyl	92-67-1	10
	Aniline	62-53-3	10
84	Anthracene	120-12-7	200
M	Antimony	(Total)	300
	Aramite	140-57-8	10
M	Arsenic	(Total)	500
M	Barium	(Total)	20
23	Benzene	71-43-2	2
90	Benzo(a)anthracene; Benzantracene	56-55-3	200
94	Benzo(b)fluoranthene	205-99-2	200
95	Benzo(k)fluoranthene	207-08-9	200
99	Benzo(g,h,i)perylene	191-24-2	200
96	Benzo(a)pyrene	50-32-8	200
40	Benzyl Alcohol	100-51-6	20
M	Beryllium	(Total)	3
100	alpha-BHC	319-84-6	0.05
101	beta-BHC	319-85-7	0.05
102	delta-BHC	319-86-6	0.1
103	gamma-BHC; Lindane	58-89-9	0.05
52	Bis(2-chloroethoxy)methane	111-91-1	10
36	Bis(2-chloroethyl)ether	111-44-4	10

TABLE 2 (Continued)

APPENDIX IX - GROUND WATER MONITORING LIST

Cross-Reference Number from TCL Table 1 or M for TAL	Common Name[2]	Number	PQL (μg/L)[6]
	Bis(2-chloromethylethyl)ether; 2,2'-Dichlorodiisopropyl ether	108-60-1	100
92	Bis(2-ethylhexyl)phthalate	117-81-7	20
17	Bromodichloromethane	75-27-4	1
25	Bromoform; Tribromomethane	75-25-2	2
80	4-Bromophenyl phenyl ether	101-55-3	5
88	Buty benzyl phthalate; Benxyl butyl phthalate	85-68-7	10
M	Cadmium	(Total)	40
7	Carbon Disulfide	75-5-0	5
15	Carbon Tetrachloride Chlordane	56-23-5 57-74-9	1 0.1
56	p-Chloroaniline	106-47-8	20
31	Chlorobenzilate Chlorobenzilate	108-90-7 510-15-6	2 10
58	p-Chloro-m-cresol	59-50-7	5
4	Chloroethane; Ethyl Chloride	75-00-3	5
11	Chloroform	67-66-3	0.5
63	2-Chloroanphthalene	91-58-7	10
37	2-Chlorophenol	95-57-8	5
75	4-Chlorophenyl phenyl ether Cnloroprene	7005-72-3 126-99	10 50
M	Chromium	(Total)	70
91	Chrysene	218-01-9	200
M	Cobalt	(Total)	70
M	Copper m-Cresol	(Total) 108-39-4	10 10
42	o-Cresol	95-48-7	10

TABLE 2 (Continued)

APPENDIX IX - GROUND WATER MONITORING LIST

Cross-Reference Number from TCL Table 1 or M for TAL	Common Name[2]	Number	PQL (μg/L)[6]
44	p-Cresol Cyanide 2,4-D' 2,4-Dichlorophenoxyacetic acid	106-44-5 57-12-5 94-75-7	10 40 10
112	4,4'-DDD	72-54-8	0.1
109	4,4'-DDE	72-55-9	0.005
114	4,4'-DDT Diallate	50-29-3 2303-64-9	0.1 10
98	Dibenz(a,h)anthracene	53-70-3	200
72	Dibenxofuran	132-64-9	10
21	Dibromochloromethane; 1,2-Dibromo-3-chloropropane DBCP 1,2-Dibromoethane; Ethylene dibromide	124-48-1 96-12-8 106-93-4	1 100 10 5
85	Di-n-butyl phthalate	84-74-2	5
41	o-Dichlorobenzene	95-50-1	2
38	m-Dichlorobenznee	541-73-1	5
39	p-Dichlorobenzene	106-46-7	2
89	3,3'-Dichlorobenzidine trans-1,4-Dichloro-2-butene Dichlorodifluoromethane	91-94-1 110-57-6 75-34-3	20 5 10
9	1,1-Dichloroethane	75-34-3	1
12	1,2-Dichloroethane; Ethylene dichloride	107-06-2	0.5
8	1,1-Dichloroethylene; Vinylidene chloride trans-1,2-Dichloroethylene	75-35-4 156-60-5	1 1
53	2,4-Dichlorophenol 2,6-Dichlorophenol	120-83-2 87-65-0	5 10
18	1,2-Dichloropropane	78-87-5	0.5
19	cis-1,3,Dichloropropane	10061-01-5	20
24	trans-1,3-Dichloropropene	10061-02-6	5
108	Dieldrin	60-57-1	0.05

TABLE 2 (Continued)

APPENDIX IX - GROUND WATER MONITORING LIST

Cross-Reference Number from TCL Table 1 or M for TAL	Common Name[2]	Number	PQL (μg/L)[6]
74	Diethyl phthalate	84-66-2	5
	O,O-Diethyl O-2,pyranzinyl phosophorothioate; Thionazin	297-97-2	10
	Dimethoate	60-51-5	10
	p-(Dimethylamino)azobenzene	60-11-7	10
	7,12-Dimehtylbenz(a)anthracene	57-97-6	10
	3-3'-Dimethylbenzidine	119-93-7	10
	alpha, alpha-Dicmehtylphenethylamine	122-09-8	10
50	2,4-Dimethyphenol	105-67-9	5
65	Dimethyl phthalate	131-11-3	5
	m-Dinotrobenzene	99-65-0	10
78	4,6-Dinitro-o-cresol	534-52-1	150
70	2,4-Dinitrophenol	51-28-5	150
73	2,4-Dinitrotoluene	121-14-2	0.2
67	2,6-Dinitrotoluene	606-20-2	10
	Dinoseb; DNBP; 2-sec-Butyl-4,6-dinitrophenol	88-85-7	1 10
93	Di-n-octyl phthalate	117-84-0	30 10
	1,4-Dioxane	123-91-1	150
	Diphenylamine	122-39-4	10
	Disulfoton	298-04-4	2 10
107	Endosulfan I	959-98-8	0.1 10
111	Endosulfan II	33213-65-9	0.05
113	Endosulfan Sulfate	1031-07-8	0.5 10
110	Endrin	72-20-8	0.1 10
	Endrin Aldehyde	7421-93-4	0.2 10

TABLE 2 (Continued)

APPENDIX IX - GROUND WATER MONITORING LIST

Cross-Reference Number from TCL Table 1 or M for TAL	Common Name[2]	Number	PQL (μg/L)[6]
32	Ethylbenzene	100-41-4	2
			5
	Ethyl Methacrylate	97-63-2	10
			5
	Ethyl Methanesulfonate	62-50-0	10
	Famphur	52-85-7	10
86	Fluoranthene	206-44-0	200
			10
76	Fluorene	86-73-7	200
			10
104	Heptachlor	76-44-8	0.05
			10
106	Heptachlor Epoxide	1024-57-3	1
			10
81	Hexachlorobenzene	118-74-1	0.5
			10
57	Hexachlorobutadiene	87-68-3	5
			10
60	Hexachlorocyclopentadiene	77-47-4	5
			10
46	Hexachloroethane	67-72-1	0.5
			10
	Hexachlorophene	70-30-4	10
	Hexachloropropene	188-71-7	10
27	2-Hexanone	591-78-6	50
97	Ideno(1,2,3-od)pyrene	193-39-5	200
			10
	Isobutyl Alcohol	78-83-1	50
	Isodrin	465-73-6	10
48	Isophorone	78-69-1	60
	Isosafroie	120-58-1	10
	Kepone	143-50-0	10
M	Lead	(Total)	40
			1,000
			10

TABLE 2 (Continued)

APPENDIX IX - GROUND WATER MONITORING LIST

Cross-Reference Number from TCL Table 1 or M for TAL	Common Name[2]	Number	PQL (μg/L)[6]
M	Mercury	(Total	2
	Methacrylonitrile	126-98-7	5
			5
	Methapyrilene	91-80-5	10
115	Methyoxychlor	72-43-5	2
			10
2	Methyl bromide (Bromomethane)	74-83-9	20
			10
1	Methyl chloride (Chloromethane)	74-87-9	1
			10
	3-Methylcholanthrene	58-49-5	10
	Methylene bromide (Dibromomethane)	74-95-3	15
			5
5	Methylene chloride (Dichloromethane)	75-09-2	5
			5
	Methyl ethyl ketone; MEK	78-93-3	10
			100
	Methyl Iodide (Iodomethane)	74-88-4	40
			5
	Methyl methacrylate	80-62-6	2
			5
	Methyl methanesulfonte	66-27-3	10
59	2-Methylnaphthalene	91-67-8	10
	Methyl parathlon; Parathlon methyl	298-00-0	0.5
			10
26	4-Methyl-2-pentanone; Methyl isobutyl ketone	108-10-1	5
			50
55	Naphthalene	91-20-3	200
			10
	1,4-Naphthoquinone	130-15-4	10
	1-Naphthylamine	134-32-7	10
	2-Naphthylamine	91-59-8	10
M	Nickel	(Total)	50
			400
64	o-Nitroaniline	88-74-4	50
68	m-Nitroaniline	99-09-2	50
77	p-Nitroaniline	100-01-6	50

TABLE 2 (Continued)

APPENDIX IX - GROUND WATER MONITORING LIST

Cross-Reference Number from TCL Table 1 or M for TAL	Common Name[2]	Number	PQL (μg/L)[6]
47	Nitrobenzene	98-95-3	40 10
49	o-Nitrophenol	88-75-5	5 10
71	p-Nitrophenol	100-02-7	10 50
	4-Nitroquinoline-1-oxide	56-57-5	10
	N-Nitrosodi-n-butylamine	924-16-3	10
	N-Nitrosodiethylamine	55-18-5	10
	N-Nitrosodimethylamine	62-75-9	10
79	N-NItrosodiphenylamine	86-30-6	10
45	N-Nitrosodipropylamine; Di-n-propyl-nitrosamine	521-64-7	10
	N-Nitrosomethylethylamine	10595-95-6	10
	N-Nitrosomorpholine	59-89-2	10
	N-Nitrosopiperidine	100-75-4	10
	N-Nitrosopyrrolldine	930-55-2	10
	5-Nitro-o-toluidine	99-55-8	10
	Parathion	56-38-2	10
	Polychlorinated biphyenyls: PCBs	Note 7	50 100
	Polychlorinated dibenzo-p-dioxins; PCDDs	Note 8	0.01
	Polychlorinated dibenzofurans; PCDFs	Note 9	0.01
	Pentachlorobenzene	608-93-5	10
	Pentachloroethane	76-01-7	5 10
	Pentachloronitrobenzene	82-68-8	10
82	Pentachlorophenol	87-86-5	5 50
	Phenacetin	62-44-2	10
83	Phenanthrene	85-01-8	200 10

TABLE 2 (Continued)

APPENDIX IX - GROUND WATER MONITORING LIST

Cross-Reference Number from TCL Table 1 or M for TAL	Common Name[2]	Number	PQL (μg/L)[6]
35	Phenol	108-95-2	1
			10
	p-Phenylenedizmine	106-50-3	10
	Phorate	298-02-2	5
			10
	2-Picoline	109-06-8	5
			10
	Pronamide	23950-58-5	10
	Propionitrile; Ethyl cyanide	107-12-0	60
			5
87	Pyrene	129-00-0	200
			10
	Pyridine	110-86-1	5
			10
	Safrole	94-59-7	10
M	Selenium	(Total)	750
			20
			20
M	Silver	(Total)	70
			100
	Silvex; 2,4,5-TP	93-72-1	2
33	Styrene	100-42-5	1
			5
	Sulfide	18496-25-8	10,000
	2,4,5-T; 2,4,5-Trichlorophenol-xyacetic acid	93-76-5	2
	2,3,7,8-TCDD; 2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	0.005
	1,2,4,5-Tetrachlorobenzene	95-94-3	10
			5
	1,1,1,2-Tetrachloroethane	630-20-5	5
			5
30	1,1,2,2-Tetrachloroethane	79-34-5	0.5
			5
28	Tetrachloroethylene; Perchloroethylene; Tetrachlorothene	127-18-4	0.5
			5
	2,3,4,6-Tetrachlorophenol	58-90-2	10
	Tetraethyl dithiopyrophosphate; Sulfotepp	3689-24-5	10

TABLE 2 (Continued)

APPENDIX IX - GROUND WATER MONITORING LIST

Cross-Reference Number from TCL Table 1 or M for TAL	Common Name[2]	Number	PQL (μg/L)[6]
M	Thallium	(Total)	400 1,000
	Tin	(Total	10 8,000
29	Toluene	108-88-3	2 5
	o-Toluidine	95-53-4	10
119	Toxaphene	8001-35-2	2 10
54	1,2,4-Trichlorobenzene	120-82-1	10
14	1,1,1-Trichloroethane; Methylchloroform	71-55-8	5
22	1,1,2-Trichloroethane	79-00-5	0.2 5
20	Trichloroethylene; Trichloroethene	79-01-6	1 5
	Trichlorofluoromethane	75-69-4	10 5
62	2,4,5-Trichlorophenol	95-95-4	10
61	2,4,6-Trichlorophenol	88-06-2	5 10
	1,2,3-Trichloropropane	96-18-4	10 5
	O,O,O-Triethyl phosphorothloate	126-68-1	10
	sym-Trinitrobenzene	99-35-4	10
M	Vanadium	(Total)	80 2,000 40
16	Vinyl acetate	108-05-4	5
3	Vinyl chloride	75-01-4	2 10
34	Xylene (total)	1330-20-7	5 5
M	Zinc	(Total)	20 50

TABLE 2 (Continued)

APPENDIX IX - GROUND WATER MONITORING LIST

[1] The regulatory requirements pertain only to the list of substances; the right hand columns (Methods and PQL) are given for informational purposes only. See also footnotes 5 and 6.

[2] Common names are those widely used in government regulations, scientific publications, and commerce; synonyms exist for many chemicals.

[3] Chemical Abstracts Service registry number. Where "Total" is entered, all species in the groundwater that contain this element are included.

[4] CAS index names are those used in the 9th Cumulative Index.

[5] Suggested Methods refer to analytical procedure numbers used in EPA Report SW-846 "Test Methods for Evaluating Solid Waste", third edition, November 1986. Analytical details can be found in SW-846 and in documentaiton on file at the agency. CAUTION: The methods listed are representative SW-846 procedures adn may not always be the most suitable method(s) for monitoring an analyte under the regulations.

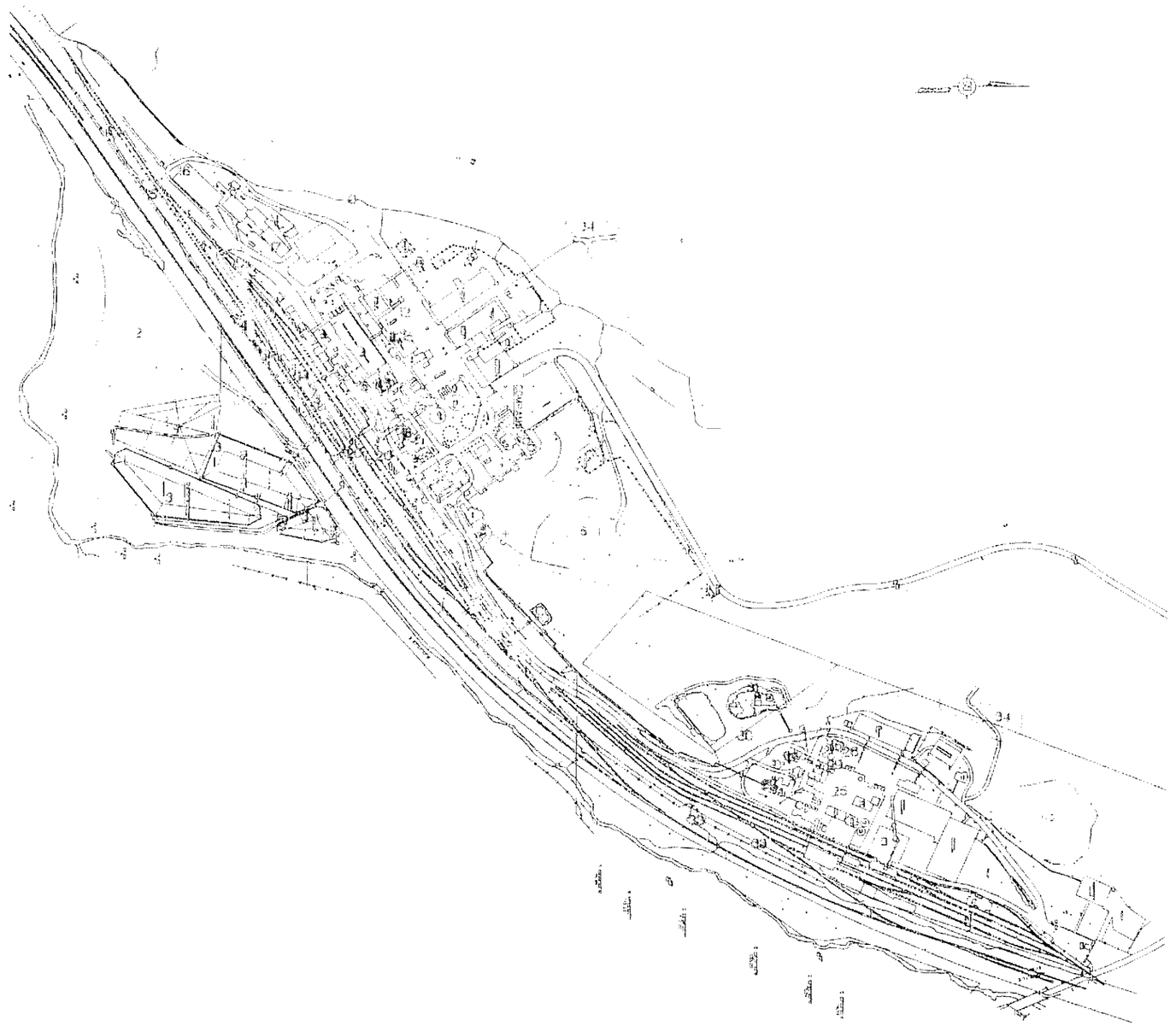
[6] Practical Quantitation Limits (PQLs) are the lowest concentrations in groundwaters that can be reliably determined within specified limits of precision and accuracy by teh indicated methods under routine laboratory operation conditions. The PQLs listed are generally stated to one significant figure. CAUTION: The PQL values in many cases are based only on a general estimate for the method and not on a determination for individual compounds; PQLs are not a part of the regulation.

[7] Polychlorinated biphenyls (CAS RN 1336-36-3); this category contains congener chemicals, including constituents of Aroclor-1016 (CAS RN 12674-11-2); Aroclor-1221 (CAS RN 11104-28-4), Aroclor-1232 (CAS RN 11141-16-5); Aroclor -1242 (CAS RN 53469-21-9), Aroclor-1248 (CAS RN 12672-29-6), Aroclor-1254 (CAS RN 11097-6-1), and Aroclor-1260 (CAS RN 11-96-82-5). The PQL shown is an average value for PCB congeners.

[8] This category contains congener chemicals, including tetrachlorodibenzo-p-dioxins (see also 2,3,7,9-TCDD), pentachlorodibenzo-p-dioxins, and hexachlorodibenzo-p-dioxins. The PQL shown is an average for PCDD congeners.

[9] This category contains congener chemicals, including tetrachlorobenzofurand, pentachlorodibenzofurans, and hexachlorodibenzofurans. The PQL shown in an average value for PCDF congeners.

FIGURES



SWMU NUMBER	SOUTH PLANT
1	CONTAINER (DRUM) STORAGE AREA
2	INACTIVE LANDFILL
3	SURFACE IMPOUNDMENT (SOUTH PLANT)
4	ACTIVATED CARBON TREATMENT UNITS
5	SOUTH PLANT DRAINAGE SYSTEMS
6	WASTEWATER STORAGE (HILL) TANKS
7	FORMER DINOSEB PRODUCTION AREA
8	DINOSEB LOADING/UNLOADING AREA
9	DINOSEB DRUMMING AREA
11	FORMER MSMA PRODUCTION AREA
12	FORMER MSMA SALT UNLOADING AREA
13	SOUTH PLANT DRAINAGE DITCHES
14	FORMER TOXAPHENE PRODUCTION AREA
15	FORMER METHYL PARATHION PRODUCTION AREA
16	FORMER ATRAZINE PRODUCTION AREA
17	RETURNED PRODUCT STORAGE AREA
18	FORMER BLUE TANK AREA
20	RAILROAD CAR UNLOADING STATION

	NORTH PLANT
22	NORTH PLANT NEUTRALIZATION SYSTEM
23	EQUALIZATION, NEUTRALIZATION POND (NORTH PLANT)
25	NORTH PLANT WASTEWATER PIPES
28	C-10 SCRUBBER
29	OIL COLLECTION UNIT
30	NORTH PLANT WASTE OIL ACCUMULATION AREA
31	NO. 6 FUEL OIL AREA
33	NORTH PLANT DRAINAGE DITCHES

	BOTH PLANTS
34	SURPLUS EQUIPMENT STORAGE (JUNKYARD)

AOC NUMBER	AOC NAME
1	FISH POND (NORTH PLANT)
2	DRUM STORAGE AREA
3	NEUTRALIZATION TANKS (SOUTH PLANT)
4	CHEMICAL CRYPT (SEPTIC TANKS)

SCALE
200 0 200 400 FEET

NO.	REVISION	DATE	INITIAL

SWMU 16,1,&17 RFI REPORT; CMS; CMIP

WOODWARD-CLYDE CONSULTANTS
Consulting Engineers, Geologists and Environmental Scientists
Baton Rouge, Louisiana

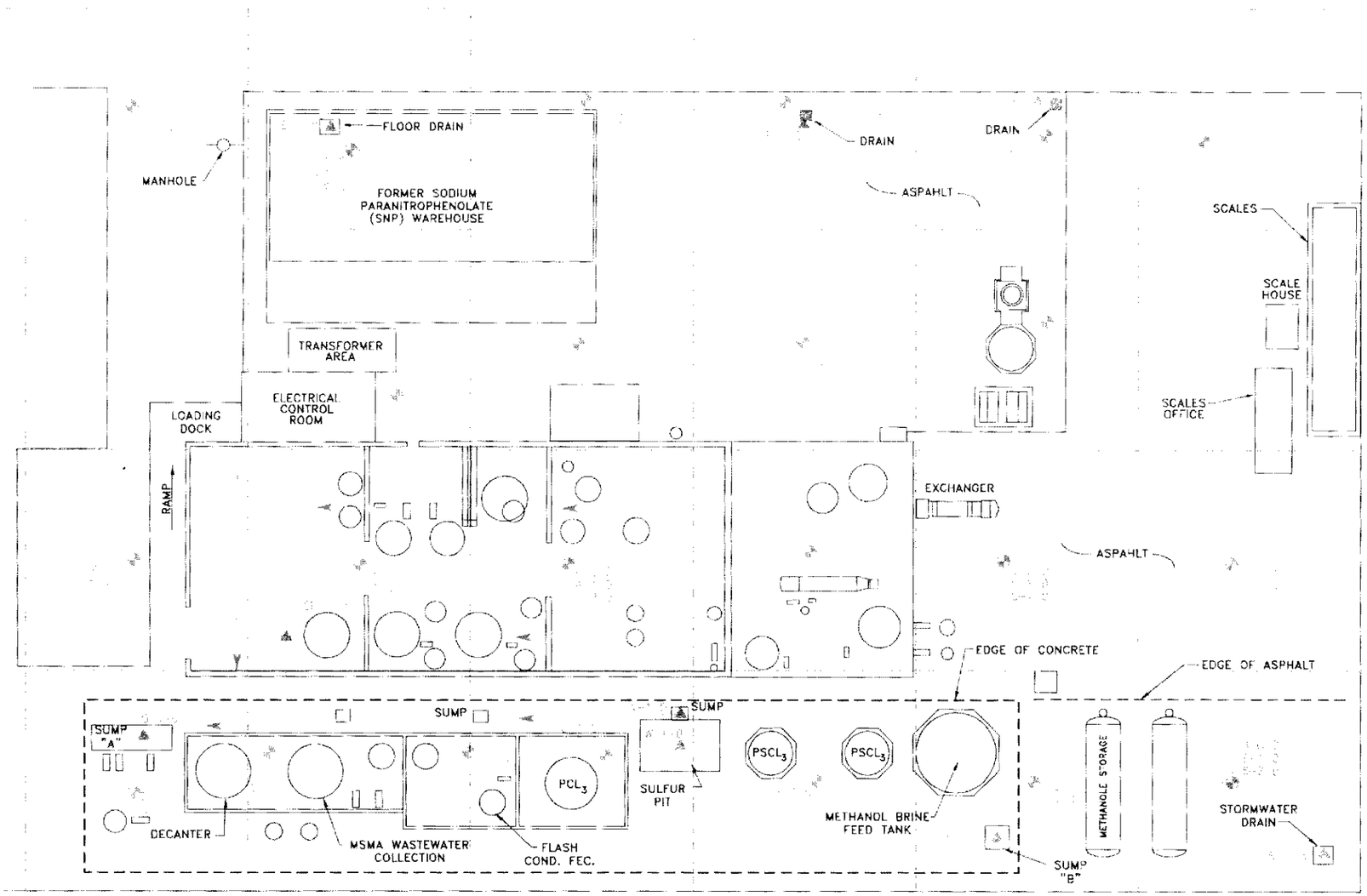
CEDAR CHEMICAL CORPORATION
VICKSBURG CHEMICAL DIVISION
VICKSBURG, MISSISSIPPI

SCALE:	MADE BY: GT	DATE: 4/6/92	FILE NO.
1" = 200'	CHECKED BY: RAK	DATE: [illegible]	96B315

LOCATION OF SOLID WASTE MANAGEMENT UNITS

FIGURE 1

Location: Baton Rouge File name: S:\26007099.DWG Last edited: 02/21/95 @ 11:13



NOTES:

- SAMPLE ID = LOCATION - TYPE - PARAMETERS
  LOCATION:
  ALPHABETIC = SOIL, SLUDGE OR SEDIMENT
  NUMERIC =CONCRETE/SOIL

  TYPE:
  C = CONCRETE
  1 = 0-12"
  2 = 12"-24" SOIL

- QA/QC
  8 ms/msd (4 SOIL - ANALYTE LIST G
  1 CONCRETE - ANALYTE LIST D
  2 SOIL - ANALYTE LIST D
  1 WIPE - ANALYTE LIST G)

- CONTAINER REQUIREMENTS
  - CONCRETE SAMPLE - WRAP N ALUMINUM FOIL
  - SOIL SAMPLE - ONE 16 OUNCE AND ONE 2 OUNCE

SYMBOL OF SAMPLE LOCATION	NUMBER OF SAMPLE LOCATIONS	NUMBER OF SAMPLES	ANALYTE LIST	LEGEND
▲	10	10	D	SLUDGE/SEDIMENT SAMPLE LOCATION (TCL, TAL, ATRAZINE, CYANAZINE, DINOSEB, DIOXIN)
✕	18	36	G	SOIL SAMPLE LOCATION - SHALLOW & DEEP (ARSENIC ONLY), MAY BE BENEATH CONCRETE OF ASPHALT
	2	6	G	CONCRETE AND SOIL SAMPLE - MATRIX SAMPLING (ARSENIC ONLY)
✕	4	12	D	CONCRETE SAMPLE AND SOIL SAMPLE REQUIRED BY PROPOSED RFI WORKPLAN (TCL, TAL, ATRAZINE, CYANAZINE, DINOSEB, DIOXIN)

GRID 2500 FT^2

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
DESIGNED	
DRAWN	PCG
CHECKED	
PEER REVIEWED	
DATE	12/8/97

SWMUS 11, 12, 15 EXPEDITED RFI

SAMPLE LOCATIONS & IDENTIFICATION

REVISION △
PROJECT
DRAWING 2

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: Tanya Pawley

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.

WCC Site Safety Officer: Yong Goh

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 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, and occasional 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 less than extractable products 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.

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. Some construction in conjunction with sump closure 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 organic 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 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, 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. 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

\+ 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/pestiide/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 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.

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
		5 - 25 ppm	Upgrade to Level C and Expand Work Zones; Commence additional colorimetric tube sampling
		>25 ppm	Evacuate Area

* 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:	Yong Goh
Field Personnel:	Mike Olson
Subcontractor:	Soil Testing Engineers, Inc.

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

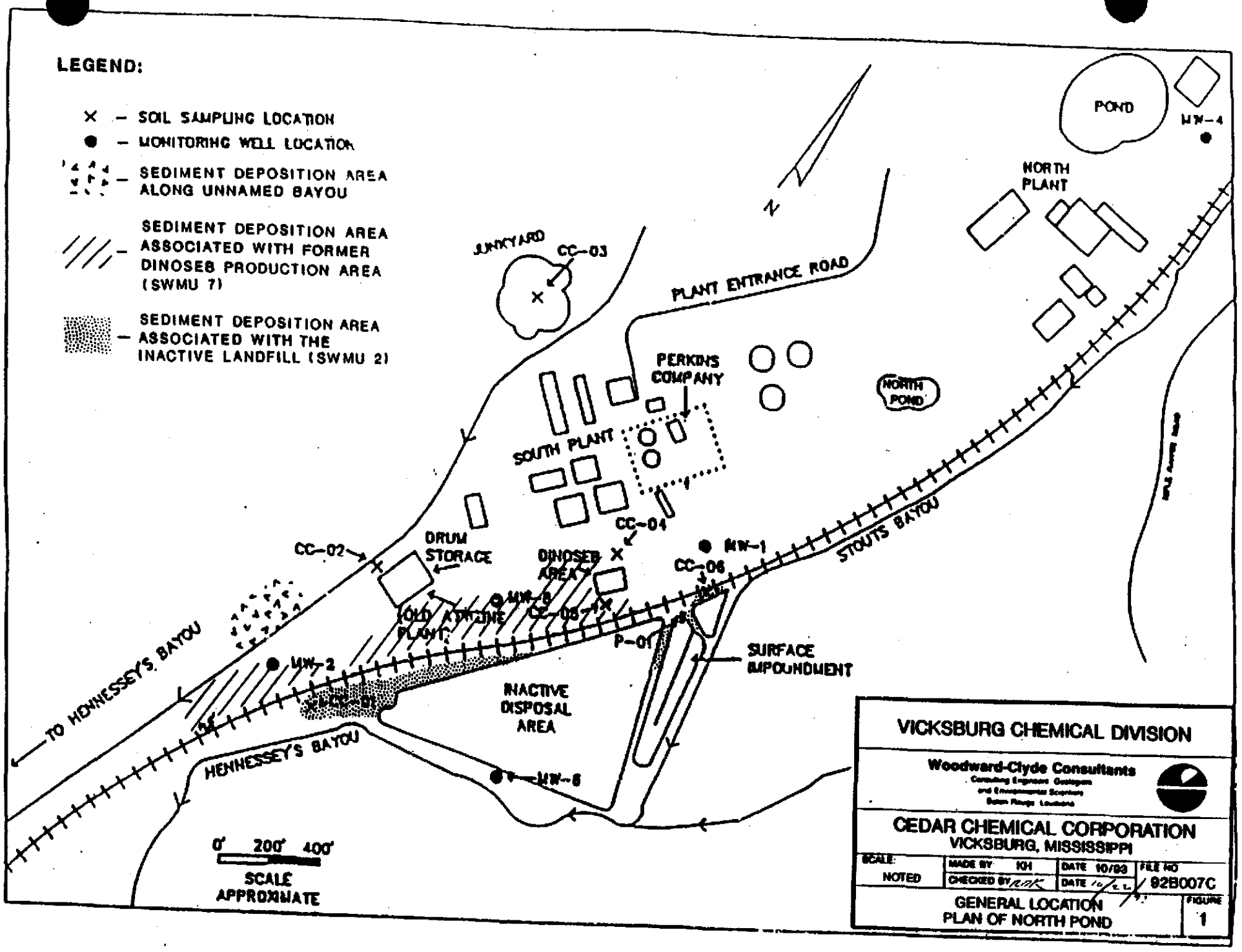
I, _____(print name), have received a copy of the Safety Plan for the Interim Measures, Groundwater Assessment, and RFI Field Investigation Workplans for VCC, Vicksburg, Mississippi (WCC Project No. 90B451C). I have read the plan, understand it, and agree to comply with all of its provisions. I understand 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
CC-02
DRUM STORAGE
DINOSEB AREA
MW-1
CC-06
STOUTS BAYOU
COLD ATMOSPHERE PLANT
MW-5
CC-05
P-01
SURFACE IMPOUNDMENT
TO HENNESSEY'S BAYOU
MW-2
CC-01
INACTIVE DISPOSAL AREA
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
CHECKED BY
DATE
FILE NO 92B007C
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	Acid division	Intro
2-Chloro-4-ethylamino-6-isopropylamino-s-triazine Aatrex Herbicide	Soluble in water,	

AVOID CONTACT WITH SOLID AND DUST
PEOPLE AWAY
Wear goggles and self-contained breathing apparatus
Sand spreading. Use water spray to "handle steam". Dike
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.
Irritating to eyes, nose and throat.
Move victim to fresh air
If in eyes: Hold eyelids open and flush with plenty of water
If breathing is difficult, give oxygen

SOLID
POISONOUS IF SWALLOWED
Irritating to skin and eyes.
Harmful to eyes if swallowed
Flush skin and eyes 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 reviving 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)
Initial containment: Dikes
Shovel up recovered
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 IMO/UN Designation: 6.1/1699
3.4 DOT ID No.: 1699
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 4 tbsp. Gastric and supportive therapy
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 corrosive to eyes and throat
5.9 Liquid or Solid Irritant Characteristics: Causes smarting of the skin and brick-dusted flame on short exposure and may cause severe damage 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: No ignition
6.3 Fire Extinguishing Agents: Not combustible
6.4 Fire Extinguishing Agents Not to be Used: Data not available
6.5 Special Hazards of Combustion: Products of burning hydrogen chloride and toxic oxides of nitrogen may be formed.
6.6 Behavior in Fire: Not combustible
6.7 Ignition Temperature: Not pertinent
6.8 Electrical Hazards: 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 Water Ratio (Reactant to Product): Data not available
7.8 Reactivity Groups: Data not available

8. WATER POLLUTION

8.1 Aquatic Toxicity: 13.0 mg/l /48 hr/Rainbow trout/TL$_m$/fresh water
8.2 Waterfowl Toxicity: >2000 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, 70-80% Mixtures with sodium arsenite and sodium molybdate
9.2 Storage Temperature: Ambient
9.3 Inert Atmosphere: No requirement
9.4 Vent Ings: Open

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)
H

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	
Water Hazard	0
Liquid or Solid Hazard	2
Poisons	0
Water Pollution	
Human Toxicity	3
Aquatic Toxicity	2
Waterfowl Effect	3
Reactivity	
Other Chemicals	1
Water	0
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 (est.)
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.) −3,500 Btu/lb = −8,300 cal/g = −350 K 10³ J/kg
12.14 Heat of Decomposition: Not pertinent
12.15 Heat of Solution: Not pertinent
12.16 Heat of Polymerization: Not pertinent
12.17 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. 22

CALCIUM OXIDE
(Revision C)
Issued: September 1978
Revised: April 1989

SECTION 1. MATERIAL IDENTIFICATION

28

Material: CALCIUM OXIDE

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.

NFPA

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
8-hr TWA: 5 mg/m³

ACGIH TLV, 1988-89
TLV-TWA: 2 mg/m³

Toxicity Data
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/m³* 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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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 CRD J. M. Nielsen

Industrial Hygiene and Safety [signature] 12-9-80

MEDICAL REVIEW: 16 Dec. 1980

Material Safety Data Sheet

From Genium's Reference Collection
Genium Publishing Corporation
1145 Catalyn Street
Schenectady, NY 12303-1836 USA
(518) 377-8855

GENIUM PUBLISHING CORP.

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 Torrs (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
1145 Catalyn Street
Schenectady, NY 12303-1836 USA
(518) 377-8855

GENIUM PUBLISHING CORP.

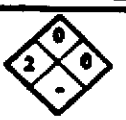
No. 315

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 1
R 0	I 3
PPG*	S 2
*See sect. 8	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 dilute 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: MJ Hundley, MD

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/m³.

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

from Genium's Reference Collection

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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; remove 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
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Medical Review: W Silverman, MD

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METHANEARSONIC ACID, SODIUM SALT

MSA

Common Synonyms	Color	Physical State
Disodium methane arsonate Monosodium methane arsonate MSMA DSMA Disodium methyl arsonate Monosodium methyl arsonate	Colorless and odorless may be red or green	Solid may float or sink in water; may cake and solution may with water.

Skin discharge if possible
Avoid contact with dust and solution
Isolate and remove contaminated materials
Notify local health and pollution control agencies

Fire

Not flammable
POISONOUS GASES ARE PRODUCED WHEN HEATED
Toxic gases are produced during combustion

Exposure

CALL FOR MEDICAL AID

SOLID OR SOLUTION
Irritating to skin and eyes
If swallowed, may cause nausea, vomiting, or loss of consciousness
Avoid contact with solid and dust
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 supplies
Notify local health and wildlife officials
Notify operators of nearby water intakes

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook)

Wear ... respirator, eye goggles, rubber gloves and protective clothing
Stop discharge
Should be removed
Chemical and physical treatment

2. LABEL

2.1 Category: Poison
2.2 Class: 6

3. CHEMICAL DESIGNATIONS

3.1 DS Compatibility Class: Not listed
3.2 Formula: $CH_4AsO(OH)(ONa)$
$CH_4AsO(ONa)_2 \cdot 6H_2O$
3.3 IMO/UN Designation: 6.1/1557
3.4 DOT ID No.: 1557
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, otherwise 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: Solution poisoning by ingestion causes salty taste, burning in mouth and stomach, and intense pain. Death usually followed by hematemia, vomiting, stupor, convulsions, paralysis. About 1 ounce to 1 pound must be taken to cause these symptoms
5.3 Treatment of Exposure: INGESTION: Induce vomiting; give water and repeat; give 4 tbsp. activated, such as sodium sulfate. SKIN: wash with soap and water. EYES: wash with water; consult physician if irritation persists
5.4 Threshold Limit Value: Data not available
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: Data not available
5.8 Vapor (Gas) Irritant Characteristics: None
5.9 Liquid or Solid Irritant Characteristics: Repeated contact may cause skin dermatitis
5.10 Odor Threshold: Not pertinent
5.11 IDLH Value: Data not available

6. FIRE HAZARDS

6.1 Flash Points: 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 Hazards: 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 Inhibition of Polymerization: Not pertinent
7.7 Water Reactivity Hazard to Products: Data not available
7.8 Reactivity Groups: Data not available

8. WATER POLLUTION

8.1 Aquatic Toxicity:
>1000 ppm/48 hr/trout/fresh water/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: The most common salt (DSMA) contains water crystallization. Salts are often shipped as solutions in water with concentrations up to about 50% solids.
9.2 Storage Temperature: Ambient
9.3 Inert Atmospheres: No requirement
9.4 Venting: Open

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

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11. HAZARD CLASSIFICATIONS

11.1 Code of Federal Regulations: Poison, B
11.2 NAS Hazard Rating for Bulk Water Transportation: Not listed
11.3 EPA Hazard Classification: Not listed

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 Physical State at 15°C and 1 atm: Solid or water solution
12.2 Molecular Weight: 162 (DSMA); 292 (DSMA monohydrate)
12.3 Boiling Point at 1 atm: Decomposes
12.4 Freezing Point:
(DSMA) 243°F = 117°C = 390°K
(DSMA) 127°F = 53°C = 326°K
12.5 Critical Temperature: Not pertinent
12.6 Critical Pressure: Not pertinent
12.7 Specific Gravity:
(DSMA) 1.6 at 25°C (solid)
(DSMA solutions) 1.4-1.5 at 25°C (liquid)
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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Medical Review: MJ Hardies, MD

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METHYL PARATHION

MPT

Common Synonyms
Mobam MPT
Penpar Abbam
Nitrox Wofatox
O, O-Dimethyl O-p-nitrophenyl thiophosphate
Dimethoxythion
Parathion-methyl

Solid crystals with a faint or strong garlic odor

Solid and liquid cans in water, dilution forms an oily boiling (freezing) point is 35°F.

AVOID CONTACT with LIQUID. Keep people away.
Wear chemical protective suit with self-contained breathing apparatus.
Stop flow of material.
Let dry if possible.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

Combustible.
POISONOUS GASES ARE PRODUCED IN FIRE AND WHEN HEATED.
Containers may explode in fire.
Wear chemical protective suit with self-contained breathing apparatus.
Move undamaged containers from area if it can be done without risk.
Dike for later disposal.
Do not get water inside containers.
Cool exposed containers with water.

Exposure

"CALL FOR MEDICAL AID."

LIQUID OR SOLID
POISONOUS IF SWALLOWED OR IF SKIN IS EXPOSED.
Prevent skin contact.
Prevent eye contact.
Wear protective clothing and gloves.
Avoid breathing dust.
Wash skin with soap and water.
In case of contact with material, immediately flush eyes with plenty of water for at least 15 minutes.
Remove contaminated clothing and shoes.
IF SWALLOWED and victim is CONSCIOUS, have victim drink water (two glasses at most).
Induce vomiting.
IF SWALLOWED and victim is UNCONSCIOUS OR HAVING CONVULSIONS, do nothing except maintain open airway.

Water Pollution

HARMFUL TO AQUATIC LIFE IN VERY LOW CONCENTRATIONS
Dissolves in moving to groundwater.
May be dangerous if it enters water intakes.
Notify local health and wildlife officials.
Notify operators of nearest water intakes.

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook)
Wear protective clothing.
Stop discharge.
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 given
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 (crystals, or powder)
4.2 Color: Colorless solid or greenish liquid
4.3 Odor: Characteristic, like rotten eggs or garlic

5. HEALTH HAZARDS

5.1 Personal Protective Equipment: Approved mask or respirator; neutral rubber gloves, overboots, protective clothing goggles.
5.2 Symptoms Following Exposure: Exposure to fumes from a fire, or to the liquid, causes headache, blurred vision, constricted pupils of the eyes, weakness, nausea, vomiting, diarrhea, and dizziness in the victim. Muscle twitch and convulsions may follow. Symptoms may develop over a period of 2 hrs.
5.3 Treatment of Exposure: Shock is common. INGESTION: Call a doctor. If victim is not breathing, immediately institute artificial respiration by mouth-to-mouth, resuscitator, or oxygen-administering method. When victim is convulsing, give nothing, water, or stimulants and induce vomiting immediately. SKIN OR EYES: Flood area with copious amount of 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} under 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: Positive 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: 110°F O.C.
6.2 Flammable Limits in Air: Data not available
6.3 Fire Extinguishing Agents: Foam
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 before volatility
6.7 Ignition Temperature: Data not available
6.8 Electrical Hazard: Not pertinent
6.9 Burning Rate: Data not available
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: Will decompose in 6 days at 45°C
7.2 Reactivity with Common Materials: Is dissolved in xylene, etc., which must be released to atmosphere outside hazard.
7.3 Stability During Transport: Decomposes above 50°C with possible explosive force.
7.4 Neutralizing Agents for Acids and Caustics: Apply neutral or mild ash slurry and yellow stains oxidizer.
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:
1.0 ppm/96 hr/bluegill/TL_m/fresh water
0.2 ppm/96 hr/mosquitofish/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), 80% in xylene
9.2 Storage Temperature: Below 50°F
9.3 Inert Atmosphere: No requirement
9.4 Venting: Pressure-vacuum

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)
A-X-Y

11. HAZARD CLASSIFICATIONS

11.1 Code of Federal Regulations: Poison, B
11.2 DOT Hazard Rating for Bulk Water Transportation: Not listed
11.3 NFPA Rating Classification:

Category	Classification*
Health Hazard (Blue)	4
Flammability (Red)	3
Reactivity (Yellow)	2

*Four (above for division, missing for zero)

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 = 19°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

JUNE 1985

Material Safety Data Sheet

From Genium's Reference Collection
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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	
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	LOWER	UPPER
*	*	% by Volume	*	*

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

Corrosion Symptoms Nitrogen dioxide Nitrogen dioxide Red vapors of nitrogen Bubbles of nitrogen Dinitrogen tetroxide	Liquified compressed Poisonous gas Strong oxidizer Stays and reacts with water. Poisonous fumes when in produced.

AVOID CONTACT WITH LIQUID AND VAPOR. Keep people away.
Wear goggles, self-contained breathing apparatus, and rubber overclothing (including gloves).
Stop discharge if it burns.
Evacuate area in case of large discharge.
Notify local health and pollution control agencies.

Fire

Not flammable.
Non-metal fire and corrosion on contact with combustibles.
POISONOUS GASES ARE PRODUCED IN FIRE AND WHEN HEATED.
Wear goggles, self-contained breathing apparatus, and rubber overclothing (including gloves).
Keep discharge area with water.
Stop flow of gas or vapor.
Cool exposed 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 ON 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 HAZARDS

(See Response Methods Handbook)
Wear self-contained, air supplied mask, water spray/fog, protective clothing
Restrict access
Evacuate area

2. LABEL

2.1 Category: Poison gas; Oxidizer
2.2 Stripe: 2 and 5

3. CHEMICAL REACTIONS

3.1 Oil Compatibility Class: Not listed
3.2 Formula: N_2O_4
3.3 BIO/UN Designation: 2/1067
3.4 IMCO ID No.: 1067
3.5 CAS Registry No.: 10102-44-0

4. OBSERVABLE CHARACTERISTICS

4.1 Physical State (at STP and 1 atm): Liquid
4.2 Color: Red-brown at ambient temperatures; Gaseous fumes above 140°F
4.3 Odor: Pungent, acrid, mildly irritating

5. HEALTH HAZARDS

5.1 Personal Protective Equipment: Rubber gloves; safety goggles and face shield; protective clothing; hood 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, few symptoms appear at time of exposure. After symptom-free period of 5-72 hours, pulmonary edema gradually develops, causing fatigue, restlessness, coughing, difficulty in breathing, frothy expectoration, mental confusion, lethargy, bluish skin, and weak, fast pulse. Since NOX interferes with gas exchange in lungs, unconsciousness, coma and death by suffocation can result, usually within a few hours after onset of pulmonary edema.

5.3 Treatment of Exposure (INHALATION): Remove person to fresh air and have him breathe as deeply as possible; call a doctor; administer oxygen mist for 24-48 hours; have victim give oxygen if coughing starts; physician may administer morphine (10 mg.) EYES AND SKIN: flush with water for at least 15 min.

5.4 Threshold Limit Value: 5 ppm
5.5 Short Term Exposure 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 on skin/tissue even at low concentrations.
5.9 Liquid or Solid Irritant Characteristics: Severe skin irritant. Causes severe and sometimes burns on skin contact and is very irritating to the eyes.
Odor Threshold: 5 ppm
IDLH Value: 50 ppm

6. FIRE HAZARDS

6.1 Flash Points (see Flammable Limits in Air) 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: Produces 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 explosion 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. Also reacts readily with air to form more nitrogen dioxide.
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. Does not react with air or soil.
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 (96-hr) TL$_m$ (mosquito fish)/TL$_m$ (fresh water)
350-1000 (96-hr) TL$_m$ (mosquito)/LC$_{50}$ (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 must be stainless with moisture-free vapor systems.
9.3 Inert Atmospheric Requirement
9.4 Venting: Pressure relief valves on containers

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-1-J-O

11. HAZARD CLASSIFICATIONS

11.1 Code of Federal Regulations: Poison, A
11.2 IMCO Hazard Rating for Bulk Water Transportation:

Category	Rating
Fire	0
Health	
Vapor Inhalation	4
Liquid or Solid Contact	4
Poisons	4
Water Pollution	
Human Toxicity	3
Aquatic Toxicity	3
Aquatic Effect	4
Reactivity	
Other Chemicals	2
Water	0
Self Reaction	0

11.3 NFPA Hazard Classification:

Category	Classification
Health Hazard (Blue)	3
Flammability (Red)	0
Reactivity (Yellow)	0
	Oxy

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 Physical State at 15°C and 1 atm: Gaseous
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: 11.3°F = −11.5°C = 262°K
12.5 Critical Temperature: 317.9°F = 159.9°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): (gas) 1.322
12.12 Latent Heat of Vaporization: 170 Btu/lb = 39.1 cal/g = 4.15 X 10⁷ 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: 62.8 cal/g
12.18 Limiting Value: Data not available
12.19 Reid Vapor Pressure: 30 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

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No. 205

POTASSIUM NITRATE

Issued: January 1987

SECTION 1. MATERIAL IDENTIFICATION

22

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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Material Safety Data Sheet

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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/m^3* (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	LOWER	UPPER
40°F (4°C) CC	896°F (480°C)	% by Volume	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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SECTION 6. HEALTH HAZARD INFORMATION | TLV

Toluene is not considered a carcinogen by the NTP, IARC, or OSHA. SUMMARY OF RISKS: Vapors of toluene may cause irritation of the eyes, nose, upper respiratory tract, and skin. Exposure to 200 ppm for 8 hours causes mild fatigue, weakness, confusion, lacrimation (tearing) and paresthesia (a sensation of prickling, tingling, or creeping on the skin that has no objective cause). Exposure to higher concentrations may cause headache, nausea, dizziness, dilated pupils, and euphoria, and, in severe cases, may cause unconsciousness and death. The liquid is irritating to the eyes and skin. Contact with the eyes may cause transient corneal damage, conjunctival irritation, and burns if not promptly removed. Repeated and/or prolonged contact with the skin may cause drying and cracking. It may be absorbed through the skin in toxic amounts. Ingestion causes irritation of the gastrointestinal tract and may cause effects resembling those from inhalation of the vapor. Chronic overexposure to toluene may cause reversible kidney and liver injury. FIRST AID: EYE CONTACT: Immediately flush eyes, including under eyelids, with running water for at least 15 minutes. Get medical attention if irritation persists.* SKIN CONTACT: Immediately flush skin (for at least 15 minutes) while removing contaminated shoes and clothing. Wash exposed area with soap and water. Get medical attention if irritation persists or if a large area has been exposed.* INHALATION: Remove victim to fresh air. Restore and/or support breathing as required. Keep victim warm and quiet. Get medical help.* INGESTION: Give victim 1 to 2 glasses of water or milk. Contact a poison control center. Do not induce vomiting unless directed to do so. Transport victim to a medical facility. Never give anything by mouth to a person who is unconscious or convulsing. * GET MEDICAL ASSISTANCE - In plant, paramedic, community. Get medical help for further treatment, observation, and support after first aid, if indicated.

SECTION 7. SPILL, LEAK, AND DISPOSAL PROCEDURES

SPILL/LEAK: Notify safety personnel of large spills or leaks. Remove all sources of heat and ignition. Provide maximum explosion-proof ventilation. Limit access to spill area to necessary personnel only. Remove leaking containers to safe place if feasible. Cleanup personnel need protection against contact with liquid and inhalation of vapor (see sect. 8). WASTE DISPOSAL: Absorb small spills with paper towel or vermiculite. Contain large spills and collect if feasible, or absorb with vermiculite or sand. Place waste solvent or absorbent into closed containers for disposal using nonsparking tools. Liquid can be flushed with water to an open holding area for handling. Do not flush to sewer, watershed, or waterway. COMMENTS: Place in suitable container for disposal by a licensed contractor or burn in an approved incinerator. Consider reclaiming by distillation. Contaminated absorbent can be buried in a sanitary landfill. Follow all Federal, state, and local regulations. TLm 96: 100-10 ppm. Toluene is designated as a hazardous waste by the EPA. The EPA (RCRA) HW No. is U220 (40 CFR 261). The reportable quantity (RQ) is 1000 lbs/454 kg (40 CFR 117).

SECTION 8. SPECIAL PROTECTION INFORMATION

Provide general and local exhaust ventilation to meet TLV requirements. Ventilation fans and other electrical service must be nonsparking and have an explosion-proof design. Exhaust hoods should have a face velocity of at least 100 lfm (linear feet per minute) and be designed to capture heavy vapor. For emergency or nonroutine exposures where the TLV may be exceeded, use an organic chemical cartridge respirator if concentration is less than 200 ppm and an approved canister gas mask or self-contained breathing apparatus with full facepiece if concentration is greater than 200 ppm.

Safety glasses or splash goggles should be worn in all work areas. Neoprene gloves, apron, face shield, boots, and other appropriate protective clothing and equipment should be available and worn as necessary to prevent skin and eye contact. Remove contaminated clothing immediately and do not wear it until it has been properly laundered.

Eyewash stations and safety showers should be readily available in use and handling areas.

Contact lenses pose a special hazard; soft lenses may absorb irritants and all lenses concentrate them.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

STORAGE SEGREGATION: Store in a cool, dry, well-ventilated area away from oxidizing agents, heat, sparks, or open flame. Storage areas must meet OSHA requirements for class IB flammable liquids. Use metal safety cans for handling small amounts. Protect containers from physical damage. Use only with adequate ventilation. Avoid contact with eyes, skin, or clothing. Do not inhale or ingest. Use caution when handling this compound because it can be absorbed through intact skin in toxic amounts. SPECIAL HANDLING/STORAGE: Ground and bond metal containers and equipment to prevent static sparks when making transfers. Do not smoke in use or storage areas. Use nonsparking tools. ENGINEERING CONTROLS: Preplacement and periodic medical exams emphasizing the liver, kidneys, nervous system, lungs, heart, and blood should be provided. Workers exposed to concentrations greater than the action level (50 ppm) should be examined at least once a year. Use of alcohol can aggravate the toxic effects of toluene.

COMMENTS: Emptied containers contain product residues. Handle accordingly!

Toluene is designated as a hazardous substance by the EPA (40 CFR 116). DOT Classification: Flammable liquid. UN1294.

Data Source(s) Code: 1-9, 12, 16, 20, 21, 24, 26, 34, 81, 82. CR

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Approvals J.O. Reference, 11/86.

Indust. Hygiene/Safety 12-86

Medical Review Oct 86

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TOXAPHENE

TXP

Common Synonyms
Chlorocamphene

Water Value or In Action
Solid sinks in water, solution floats on water.

Use drainage if possible. Keep people away.
Call fire department.
Avoid contact with solid and solution.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

Solid not flammable, but readily dissolves in combustible liquid.
HYDROGEN CHLORIDE GAS ARE PRODUCED IN FIRE.
Use water spray, carbon dioxide, dry chemical, and foam extinguishing (limited) (Foam).
Extinguish with foam, dry chemical or carbon dioxide.
Water may be ineffective on fire.
Cool exposed containers with water.

C

Exposure

CALL FOR MEDICAL AID.

SOLID OR SOLUTION
POISONOUS IF SWALLOWED.
[illegible] AVOID CONTACT.
FLUSH [illegible] 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 raise victim's head and clothing.

Water Pollution

HARMFUL TO AQUATIC LIFE IN VERY LOW CONCENTRATIONS.
Solution is toxic to organisms.
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 respiratory protection, rubber boots and gloves.
Shovel up material.
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: Not listed
3.2 Formula: $C_{10}H_{10}Cl_8$
3.3 IMO/UN Classification: Not listed
3.4 DOT ID No.: 2761
3.5 CAS Registry No.: 8001-35-2

4. OBSERVABLE CHARACTERISTICS

4.1 Physical State (as shipped): 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 stomach (fast). Symptoms include convulsions, leg and back muscle spasms, nausea, vomiting, hyperexcitability, tremors, shivering, clonic convulsions, then intense convulsions of all skeletal muscles. Lethal doses cause respiratory failure. Respiration, inhibited as a result of the tonic form convulsions, is first arrested because of tetanic muscular contractions, then convulsive in both amplitude and rate as the muscles relax.

5.3 Treatment of Exposure: If symptoms of poisoning appear, promptly remove the contaminated materials from the stomach by inducing vomiting with warm salty or soapy water (if the victim is conscious) or wash the skin with soap and water. Keep person warm and quiet. Call a physician.

5.4 Threshold Limit Value: 0.5 mg/m³

5.5 Short Term Inhalation Limits: Not pertinent

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: The solid is non-volatile. For solutions, see water-system.

5.9 Liquid or Solid Irritant Characteristics: Minimum hazard if soaked on clothing and allowed to remain. May cause smarting and reddening of the skin.

5.10 Odor Threshold: Not pertinent

5.11 IDLH Value: 200 mg/m³

6. FIRE HAZARDS

6.1 Flash Points: 64°F C.C. (solution)
6.2 Flammable Limits in Air: 1.1%-6.0% (solution only)
6.3 Fire Extinguishing Agents: Foam, 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 produced when burned.
6.6 Behavior in Fire: Solution in xylene may produce corrosive products when heated.
6.7 Ignition Temperature: 600°F (solution)
6.8 Electrical Hazard: Not pertinent
6.9 Burning Rate: 3.0 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 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:
0.05 ppm/96 hrs/sunfish/100% dil/fresh water
0.02 ppm*/48 hrs/goldfish/100% dil/fresh water
0.0005 ppm/24 hr/trout/100% dil/salt water
*Time based not complete.
8.2 Waterfowl Toxicity: 32.0 mg/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: 65% dust formulations; 90% solution in xylene
9.2 Storage Temperature: Ambient
9.3 Inert Atmosphere: No requirement
9.4 Venting: Sealed 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 49
11.2 DOT Hazard Zoning 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—194°F
= 65—90°C = 338—363°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
12.18 Limiting Value: Data not available
12.19 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

Material Safety Data Sheet

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GENIUM PUBLISHING CORP.

No. 318

XYLENE (Mixed Isomers)
(Revision D)
Issued: November 1980
Revised: August 1988

SECTION 1. MATERIAL IDENTIFICATION

Material Name: XYLENE (Mixed isomers)

Description (Origin/Uses): Used as a raw material for the production of benzoic acid, phthalic anhydride, isophthalic and terephthalic acids and their dimethyl esters in the manufacture of polyester fibers; in sterilizing catgut; with Canadian balsam as oil-immersion in microscopy; and as a cleaning agent in microscopic techniques.

Other Designations: Dimethylbenzene; Xylol; C_8H_{10}; CAS No. 1330-20-7

Manufacturer: *Contact your supplier or distributor. Consult the latest edition of the Chemicalweek Buyers' Guide* (Genium ref. 73) for a list of suppliers.

Comments: Although there are three different isomers of xylene (*ortho*, *meta*, and *para*), the health and physical hazards of all three isomers are very similar. This MSDS is written for a xylene mixture of all three isomers, which is usually commercial xylene.

NFPA

HMIS	
H	2
F	3
R	0
PPG*	
*See sect. 8	

R	1
I	3
S	2
K	3

SECTION 2. INGREDIENTS AND HAZARDS

Xylene (Mixed Isomers), CAS No. 1330-20-7*

o-Xylene, CAS No. 0095-47-6
m-Xylene, CAS No. 0108-38-3
p-Xylene, CAS No. 0106-42-3

*Check with your supplier to determine if there are additions, contaminants, or impurities (such as benzene) that are present in reportable quantities per 29 CFR 1910.

**Immediately dangerous to life and health.

**** See NIOSH, *RTECS* (No. ZE2100000), for additional data with references to reproductive, irritative, and mutagenic effects.

%

**

EXPOSURE LIMITS

IDLH** Level: 1000 ppm

OSHA PEL
8-Hr TWA: 100 ppm, 435 mg/m³

ACGIH TLVs, 1987-88
TLV-TWA: 100 ppm, 435 mg/m³
TLV-STEL: 150 ppm, 655 mg/m³

Toxicity Data**
Human, Inhalation, TC_{Lo}: 200 ppm
Man, Inhalation, LC_{Lo}: 10000 ppm/6 Hrs
Rat, Oral, LD_{50}: 4300 mg/kg

SECTION 3. PHYSICAL DATA

Boiling Point: 275°F to 293°F (135°C to 145°C)*
Melting Point: -13°F (-25°C)
Evaporation Rate: 0.6 Relative to BuAc = 1
Specific Gravity (H_2O = 1): 0.86

Water Solubility (%): Insoluble
Molecular Weight: 106 Grams/Mole
% Volatile by Volume: Ca 100
Vapor Pressure: 7 to 9 Torrs at 68°F (20°C)
Vapor Density (Air = 1): 3.7

Appearance and Odor: A clear liquid; aromatic hydrocarbon odor.

*Materials with wider and narrower boiling ranges are commercially available.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method	Autoignition Temperature	Flammability Limits in Air	LOWER	UPPER
81°F to 90°F (27°C to 32°C)	867°F (464°C)	% by Volume	1%	7%

Extinguishing Media: Use foam, dry chemical, or carbon dioxide. Use water sprays to reduce the rate of burning and to cool containers.

Unusual Fire or Explosion Hazards: Xylene vapor is heavier than air and may travel a considerable distance to a low-lying source of ignition and flashback.

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

Xylene is stable in closed containers during routine operations. It does not undergo hazardous polymerization.

Chemical Incompatibilities: This material may react dangerously with strong oxidizers.

Conditions to Avoid: Avoid any exposure to sources of ignition and to strong oxidizers.

Hazardous Products of Decomposition: Carbon monoxide (CO) may be evolved during xylene fires.

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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

INCIDENT REPORT FORM

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

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.