FINAL

SITE INVESTIGATION WORK PLAN
PHASE I

AMES STREET SITE
ROCHESTER, NEW YORK

Prepared by:

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ASEA BROWN BOVERI

AMES STREET SITE
SITE INVESTIGATION WORK PLAN - PHASE 1

TABLE OF CONTENTS

TABLE OF CONTENTS

Section Title Page No.

AMES STREET SITE
SITE INVESTIGATION WORK PLAN - PHASE 1

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

ABB Environmental Services (ABB-ES), at the request of Combustion Engineering, Inc. has prepared this Work Plan for subsurface investigations at the former Taylor Instruments facility at 95 Ames Street (Ames Street Site), Rochester, Monroe County, New York (Figure 1-1). The Work Plan presents the technical approach and rationale, as well as the methodologies, that will be used to conduct soil and groundwater sampling at the Ames Street Site. The tasks presented in this plan compose Phase 1 of a planned two-phase voluntary investigation and site restoration.

Phase 1 is designed to identify concentrations of site-related chemicals in overburden soils that represent soil contact hazards or that may act as sources of contamination to groundwater. To accomplish this, soil sampling is targeted to areas of concern (AOCs) across the site. The AOCs were developed based on evaluation of historical records, previous environmental data from the site, and discussions with New York State Department of Environmental Conservation (NYSDEC) and the New York State Department of Health (including meetings on September 13 and October 6 and 30, 1995). Additional site knowledge obtained during observation of the demolition and removal of site structures, foundation slabs, and underground storage tanks (completed in December, 1995) has been incorporated in the development of the AOCs.

Phase 1 will also include perimeter groundwater sampling to assess groundwater quality leaving the site. Three geologic borings extending into bedrock are planned to characterize subsurface geology in addition to data from soil borings at the AOCs.

In general, the potential impact from historic operations will be assessed through analysis of soil and groundwater for three types of chemical compounds:

1. volatile organic compounds (VOCs) from petroleum-based products and cleaning/degreasing solvents.
2. mercury, used in elemental form in the manufacture of various mercury-filled instruments.
3. metals and cyanide used as part of electroplating processes at a specific area of the site.

Phase 1 is designed to provide sufficient information about subsurface conditions at the site to:

- characterize site geology
- complete a risk assessment, setting usage-based soil and groundwater quality goals for comparison to soil and groundwater analytcial data

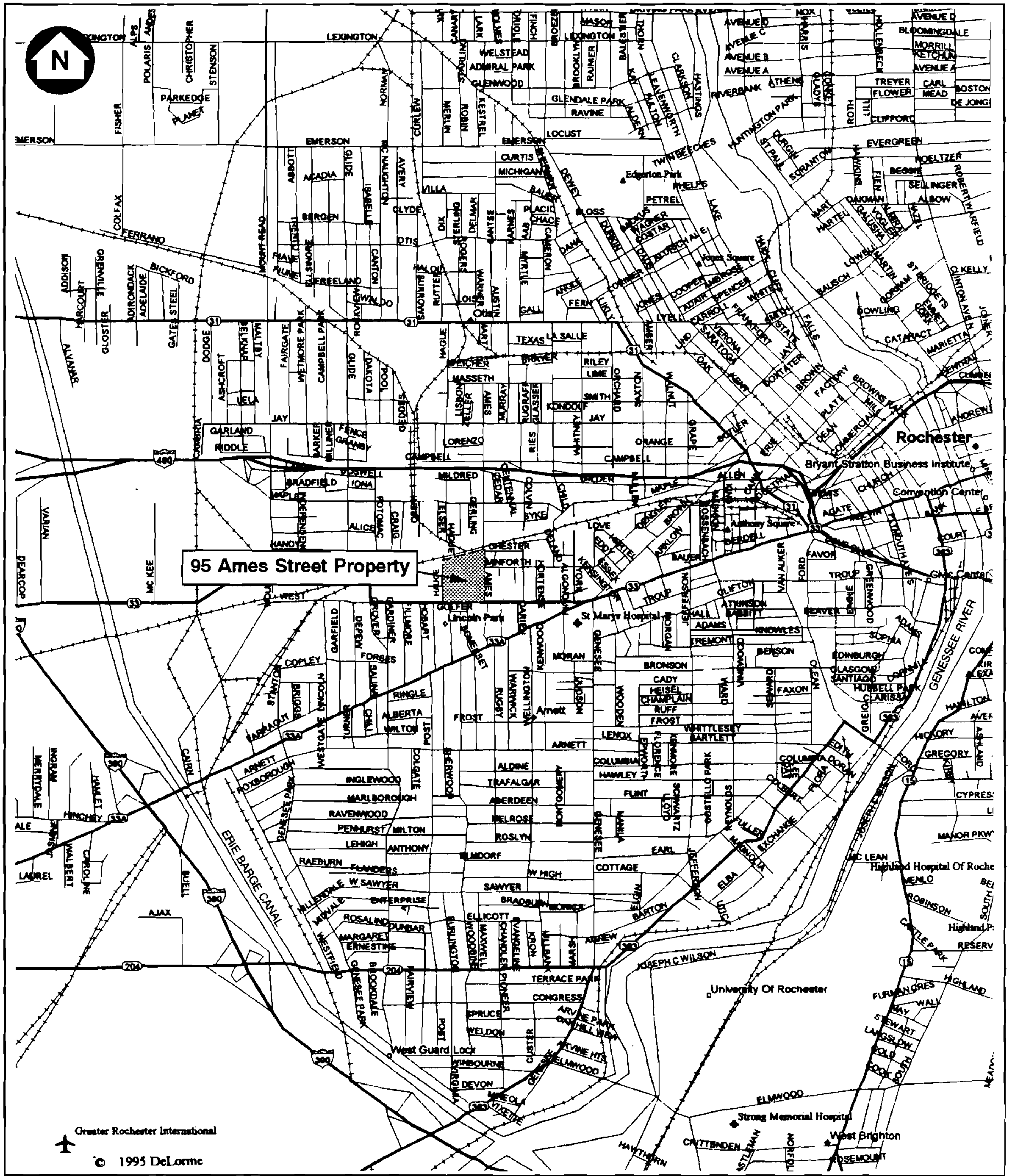
- provide sufficient soil data from each AOC for comparison to soil quality goals
- assess groundwater quality along the downgradient perimeter of the site

Soil borings to be completed within the AOCs and geologic borings located apart from potential contaminant sources will provide a comprehensive database to characterize site geology. Soil samples from all borings within the AOCs and groundwater samples from the perimeter borings will be analyzed using a field-based laboratory for target contaminants of concern (COCs) to evaluate impact. Fixed-base (offsite) laboratories will be used to confirm on-site laboratory results and to provide data on mercury speciation needed to assess potential risk to human health.

The Phase 1 Report will present the results of the soil and groundwater analyses and the risk assessment. This information will be used to develop the Phase 2 Work Plan. Depending on the results of Phase 1, Phase 2 may include soil excavation or treatment and/or further groundwater investigations. It is possible that additional work beyond Phase 2 will be required to complete site restoration to site-specific usage-based goals.

The Work Plan is organized with task descriptions in the body of the report and supporting documentation attached as appendices. Section 2 presents general site history and setting. Section 3 summarizes previous investigations and/or sampling conducted at the site. Section 4 summarizes the selection process used to identify areas for investigation in Phase 1 and site-related. Section 5 presents the scope of work to be completed in Phase 1, including a summary of the analytical program. Section 6 introduces the format of the Phase 1 report, and Section 7 presents the project schedule.

Appendix A and Appendix B are the site-specific Quality Assurance Project Plan (QAPjP) and the site-specific Health and Safety Plan (HASP), respectively. In addition, five sections from the Background Documents, provided to NYSDEC on October 17, 1995, have been included in a separately bound volume as appendices: Historical Building Usage Table (Appendix C), First Floor Analytical Data and Map (Appendix D), Potential Areas of Concern Table (Appendix E), Soil Data and Map (Appendix F) and Outline of the External Site Investigation (Appendix G).



Approximate
Scale in Miles
0 0.5 1

FIGURE 1-1
SITE LOCATION MAP
SITE INVESTIGATION WORK PLAN - PHASE I
95 AMES STREET
ROCHESTER, NEW YORK

ABB Environmental Services, Inc.

2.0 SITE HISTORY

The following sections summarize the history of industrial operations at the former Taylor Instruments facility on Ames Street.

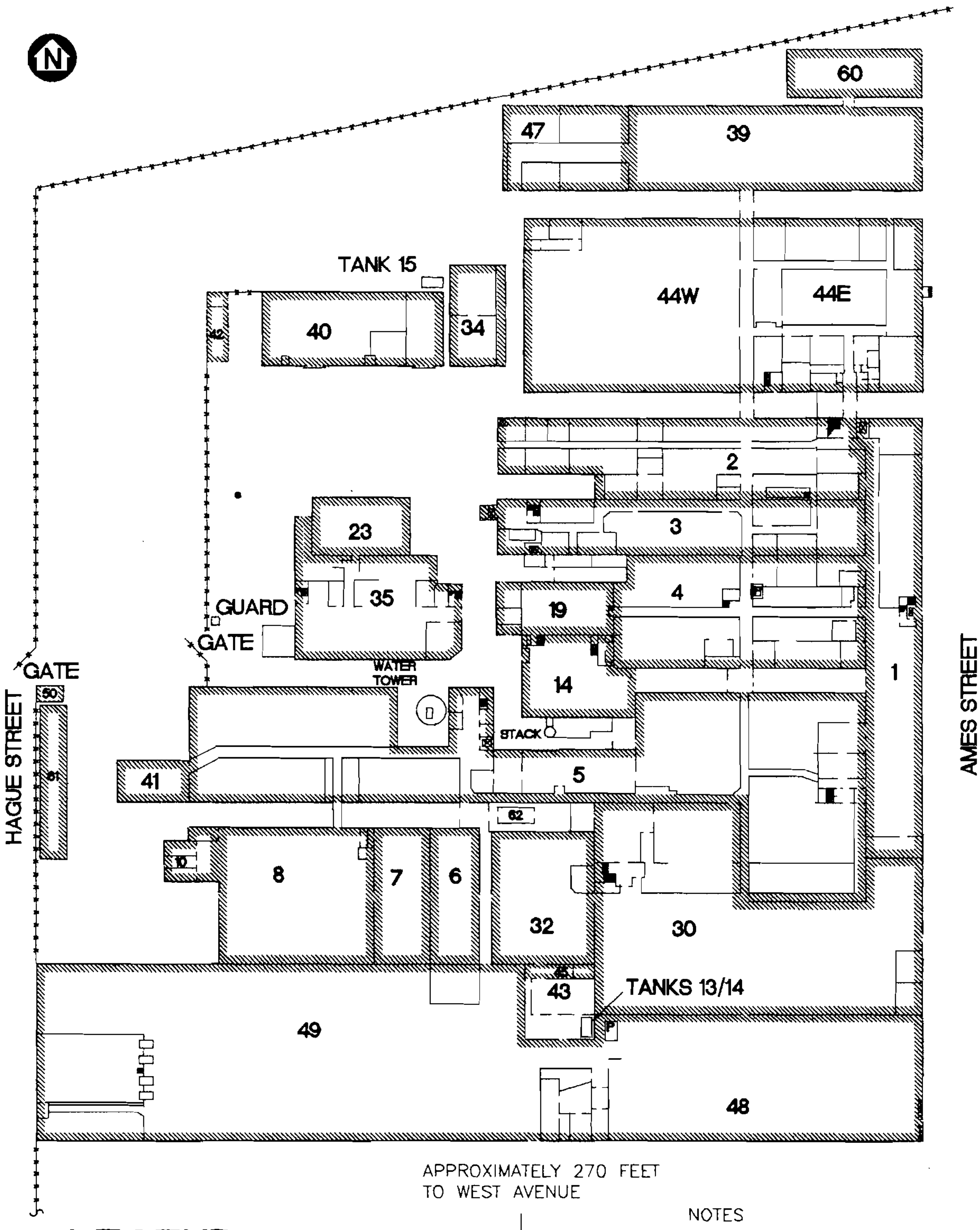
2.1 General History

In 1904, the Taylor Brothers Company purchased a portion of what is now the Ames Street Site, and construction of the original buildings began shortly thereafter. The building numbering convention (e.g., 1, 2, 3) appears to have been used from the beginning, and indicates the general sequence of initial construction. Both the number of buildings and the overall size of the facility expanded from the original Ames Street frontage, replacing houses and small businesses, until the plant property reached to Hague Street on the west and the railroad easement on the north (approximately 1934), and to West Avenue on the south (approximately 1948) (see Figure 2-1). Over the years a number of buildings were erected and later removed, so that although the last building number is 60, only approximately 26 buildings existed as of 1992.

In 1982, Taylor Instruments Company merged with the Ritter Pfaudler Company to form Sybron Corporation (Sybron). Taylor Instruments operated as a division of Sybron until 1983, when it was sold to Combustion Engineering. In January 1990, Asea Brown Boveri, Ltd. (ABB) acquired Combustion Engineering, including the business now known as Kent-Taylor. Title to the property continues to be held by Combustion Engineering, a wholly-owned subsidiary of ABB.

In 1991, ABB began construction of a new facility south of Rochester to house the Kent-Taylor manufacturing operations. The transfer of operations began in 1992 and was completed in 1993. Under the direction of the facility environmental manager at the time, a variety of old and unused chemicals and wastes were removed from the 95 Ames Street facility and recycled and/or disposed of off-site. The intent of these "close-up" procedures was to remove everything that was hazardous and not physically part of a structure. Following close-up, ABB's corporate real estate department, through the title holder Combustion Engineering, assumed responsibility for the property.

Once Kent-Taylor made the decision to move to a new facility, ABB's corporate real estate department actively began to market the property. A number of prospective purchasers expressed serious interest in the site but no buyer was found. Prospective purchasers expressed significant concerns about the environmental condition of the buildings and the underlying property.



APPROXIMATELY 270 FEET
TO WEST AVENUE

NOTES

1. INTERIOR LAYOUT IS FOR GROUND FLOOR AREA

LEGEND

P DEGREASING EQUIPMENT PIT

-x-x- FENCE

EXISTING STRUCTURE

0 50 100 200

FIGURE 2-1
BUILDING LOCATIONS
COMBUSTION ENGINEERING PROPERTY
95 AMES STREET ROCHESTER, NEW YORK

ABB Environmental Services, Inc.

In late 1993, some initial site characterization work was done. In 1994, ABB-ES, another ABB subsidiary, began the final phase of an asbestos abatement project at the facility and, simultaneously, a characterization of building materials (e.g., concrete, wood) for disposal. After completing this characterization, which involved significant interaction with NYSDEC's Region 8 Hazardous Waste staff, the demolition contract was let and demolition activities were initiated in May 1995.

Currently (February 1996), the demolition project is nearing completion. All buildings (except one that will remain through the site investigation), asbestos, hazardous and non-hazardous building wastes have been completely removed. Installation of asphalt paving over the former building areas will be completed in the spring of 1996.

2.1.1 Manufacturing Processes and Building Use History

The original products produced at the facility were mercury-filled thermometers, barometers and related simple instruments. Manufacturing operations changed little during World War I and World War II, as product lines were varied only slightly to meet military needs. For the most part, production continued on fluid-filled instruments until the early 1960's. At that time, a shift away from the fluid-filled instruments towards electronics-based instrumentation occurred. By 1965, all "liquid in glass" (i.e., thermometers and barometers) manufacturing had ceased. With the advent of computers, the various operations required for printed circuit board manufacture and assembly were introduced. By 1992, mercury-filled instruments, and consequently mercury-handling operations, represented a very minor aspect of facility operations.

In addition to mercury, other chemicals and industrial materials considered potentially environmentally significant were also used. Most prominent among these were petroleum fuels and oils, metal-bearing plating solutions and paints and organic solvents. These materials were used in operations by the early 1900's, and their use continued until 1992.

Appendix C provides a summary of known usage information for each building on a floor-by-floor basis, as assembled from a number of historical sources. In addition to this summary, the following sections provide some detail relative to the most significant operations at the facility. Also, it is known that the facility was connected to the combined municipal sewer at all times during its history.

Mercury-Filled Instrument Manufacturing and Mercury Use

There were two major types of mercury-containing instruments manufactured at the site: "liquid-in-glass" instruments and "solid-filled" thermometer systems. All liquid-in-glass instruments, thermometers, sphygmomanometers and barometers, were manufactured in a similar fashion. Glass tubes were purchased from an outside source, cut to the desired length and fitted with glass "bulbs" at one end. The instrument was then filled with mercury, in some cases under a vacuum. Solid filled thermometer systems typically involved filling narrow stainless steel or other “solid” capillary tubes (some to 200 feet long) with either a varsol/kerosene mixture or mercury, typically under vacuum or pressure. Both types of instruments used elemental mercury exclusively.

Mercury coming into the plant was generally shipped in durable metal containers. From the shipping or initial storage areas, it was brought to a refining operation located for many years on the third floor of Building 2. In this operation, the commercial-grade mercury was further purified to make it suitable for use in instrumentation.

Manufacturing of both types of instruments occasionally resulted in mercury being spilled at the work area. During plant demolition, concrete slabs in some areas were removed as hazardous waste due to their mercury content and several hundred pounds of liquid mercury were removed from between the floorboards of second and third floors of buildings. Overall, the occurrence of mercury in concrete and wood floors in the buildings as observed during demolition is consistent with the known manufacturing history. Buildings 1, 2, 4, 20, 30, 35, 40 and 44 were most impacted by these mercury releases.

Because mercury was a valuable raw material, significant efforts were made to collect the spilled liquid and to recover it from instruments broken or rejected during manufacture. Beginning in approximately 1940 and lasting until the mid 1960’s, broken or rejected instruments were routinely collected and brought to a reclamation area located in the northwest corner of Building 40. Reclamation consisted of heating the scrap materials so as to volatilize the mercury, which was then re-condensed and recovered (a process known as “retorting”). Although enough mercury was recovered to make this operation worthwhile, evidently the process was not completely effective in extracting mercury from the small capillaries in the scrap instruments; mercury is still visible in a percentage of the scrap (“glass shards”) found in close proximity to this building.

Electroplating

Electroplating operations began at the plant around 1914 to 1915 and are believed to have been conducted in the same area of Building 4 throughout the site’s history. Electroplating processes involved various acids, cyanides, alkaline cleaners and metals, including chromium, copper, brass, tin, lead, nickel, silver, cadmium, gold and zinc. Plating tanks and baths were set around the concrete-floored room. In and beneath the floors were a series of troughs and drains carrying discharges from the process, as well as leaks, drips, and spills, to the plant sewer system. A series of tunnels beneath the plating area floor served both to convey liquids to the sewer system and to allow fumes to be drawn from the plating area and exhausted from the building. At the time of demolition, most floors and tunnels appeared to be original, although several patched areas were obvious.

In later years, measures to improve the operations included eliminating the use of cyanides and most "hard" (hexavalent) chromium and enhancing management practices to minimize spills and excessive dripping. These measures were implemented primarily in response to increasingly strict effluent discharge requirements, and the efficiency of the drainage systems in conveying process-related liquids to the sewer, which resulted in exceedances of those effluent discharge requirements.

Solvent Degreasing

Major solvent vapor degreasing occurred in two areas, one in Building 4 and the other in Building 48. Both operations used tricholoethene (TCE) and began operation in the mid-1960s. Other smaller desk top-scale degreasing units were also used at various locations at various times.

Each of the two major areas included one vapor degreaser located in a concrete sump designed, in part, to contain any spills. Both sumps exhibited staining. The third unit was a conveyor degreaser set at floor level in Building 48. Nearby this unit was distillation equipment used to reclaim spent TCE. Fresh TCE was stored in Tanks 13 and 14, in an interior "courtyard" outside the Building 48 area, and in Tank 15, behind Building 40. TCE drawn from Tank 15 was dispensed in the Building 40 garage into smaller containers for use in many minor degreasing operations throughout the plant.

Several spills onto the concrete floors of the two vapor degreasing areas have been noted. Both sumps were connected to the plant sewer system.

Machining

Small parts machining operations occurred in various locations of Buildings 2, 3, 30, 44, 48 and 49 over the years. For the most part machines were self-contained, and the operations used the typical quantities of lubricant and cooling oils and fluids. The lack of significant oil staining on the concrete in most areas indicates the operations were either not very dirty and/or housekeeping was good.

Buildings 48 and 49 housed the most extensive machining operations and were expressly built for that purpose. An advanced (at the time) oiler system consisting of a rooftop filtration plant, a central collection sump, and a piping network was used to collect and clean used cutting oil and re-distribute it to each machine. Existence of this system is most likely the reason very little evidence of oil releases was noted during demolition of these buildings.

Chemical and Waste Storage and Handling

Manufacturing operations utilized numerous chemicals and some hazardous materials, and generated a number of hazardous waste streams. Bulk chemicals were stored in underground and aboveground tanks, in drums and other smaller containers. Buildings 12, 34 and 42 were all significant storage areas. However, with the exception of mercury, which was used in relatively large quantities, overall chemical throughput was low, consistent with the manufacture of small precision instruments.

Detailed records relative to waste generation and handling at the facility prior to approximately 1980 are not available. Based on interviews of facility personnel, available documentation, and observations during demolition, materials, such as coal slag, ash, and glass scrap and shards were used as fill for construction of both buildings and utilities. There is no information developed to date suggesting that waste materials other than this "fill" were disposed of at the site.

2.2 Site Description

The Ames Street Site covers approximately 13 acres north of West Avenue in the city of Rochester. The site is bounded on the south by West Avenue, the west by Hague Street, east by Ames Street and to the north by Conrail railroad tracks. The site is in the final stages of demolition. Final grading plans, to be completed in the spring, call for asphalt paving over the entire site with a maximum slope of 3 percent. There are no identified wetlands or surface water bodies on-site.

The area within one-half mile of the site is primarily mixed residential and light industrial. Rochester Gas and Electric has a leased facility on the west side of Hague Street. South of West Avenue and east of Ames Street is predominantly residential.

2.2.1 Site Geology

The surficial geology of the site area is dominated by Late Pleistocene glacially-deposited stratified sands and silty sands. According to previous investigations, overburden on the site ranges from 14 to 28 feet thick (Lozier, 1983). The overburden consists of 3 to 9 feet of fill overlying the glacial till. The fill material consists largely of clayey silt and includes at various locations coal slag, ash, building debris, and refuse (e.g., bottles, etc.). The till is composed of dense silt and sand with some gravel and rock fragments. The till is characterized as a red-brown basal till overlying the bedrock and a laterally discontinuous layer of yellow-brown ablation till overlying the basal till in some areas. The ablation till is generally slightly more sandy and less dense than the basal till.

Bedrock underlying the overburden has been identified as the upper Silurian-age Lockport dolomite (Rickard and Fisher, 1970). Regionally this formation consists of flat to very gently dipping medium- to thick-bedded fine-grained dolomite with interbedded shales (Williams, 1990). The highest bedrock elevations were observed in the southeast sloping toward the northwest (Lozier, 1983).

2.2.2 Hydrogeology

Groundwater is present within the overburden between 5 and 10 feet below the ground surface with a 4- to 5-foot seasonal fluctuation (Lozier, 1983). According to the Water Resources Investigations Report -- Groundwater-water Availability in the Genesee River Basin, New York and Pennsylvania, prepared by the United States Department of the Interior Geologic Survey (1986), the overburden yields less than 1 gallon per minute and the underlying bedrock less than 50 gallons per minute.

Overburden groundwater flow is believed to be generally from the south and west to the north and east. This general flow direction was described in the Lozier report and confirmed by water level measurements made on October 25, 1995 by ABB-ES. According to the Lozier report, hydraulic conductivities range from $1.6x10^{-5}$ to $8.8x10^{-5}$ centimeters per second (cm/s) with a geometric mean value of $5.2x10^{-5}$ cm/s. Using Lozier's measured hydraulic gradient of 0.0095 feet per foot and an representative porosity of 0.15, average horizontal groundwater velocity in the overburden is estimated at 3.4 feet per year.

3.0 SUMMARY OF PREVIOUS ENVIRONMENTAL INVESTIGATION

Since 1982, several environmental investigation efforts have been undertaken at the Ames Street Site. Soil sampling has also occurred relative to facility maintenance and demolition issues. This section describes the rationale and scope of each known effort. Except for the mercury contamination area north of Buildings 34 and 40, soil sampling locations and analyses are provided on a figure and table in Appendix F. (Sampling locations and results from the area north of Buildings 34 and 40 can be found in the various reports and correspondence submitted to NYSDEC at the time of the investigation.)

In addition to the work described below, a large number of building materials samples (e.g., wood, concrete) were collected during 1993 and 1994 to characterize wastes for disposal during plant demolition. Since all the building materials will have been removed by the time the Phase 1 field work begins, these analytical results will not be discussed in this report. However, these results were evaluated in selecting Areas of Concern (AOCs) for Phase 1 (see Section 4.0), and are included as Appendix D.

3.1 CLASS 4 AREA INVESTIGATIONS (1981-1986)

Mercury contamination in the area north of former Buildings 34 and 40, now referred to as the "Class 4 area", was first identified in 1981 (see Figure 2-1). Glass instrument shards, some containing visible mercury, were observed on the surface and in shallow subsurface soil. In late 1981, Taylor's consultant, Lozier, installed borings and wells to provide soil and groundwater samples in the immediate shard areas. Results showed total mercury concentrations up to 52,000 milligrams per kilogram (mg/kg) in shallow soil in the shard areas with much lower levels outside the areas (Lozier, 1983). NYSDEC became involved in early 1982, and another round of investigation, including installation of additional soil borings and shallow monitoring wells and lysimeters, was completed late that year. By the end of this field effort, a thorough characterization of soil within the 1/2 acre area was completed. The investigation also detected mercury in groundwater above the Class GA standards, primarily at the source areas.

NYSDEC subsequently approved installation of asphalt paving over the entire area as a remedial measure, and this was completed in late 1982 and early 1983. Quarterly groundwater monitoring was initiated and continued until September 1986, by which time mercury concentrations had generally fallen to below the Class GA standard. The area continues to be listed as a "Class 4" on the New York Registry of Inactive Hazardous Waste Sites (Registry), indicating the site is properly closed and requires continued management.

3.2 WATER TOWER AREA INVESTIGATION (1984-1985)

Discovery of glass shards in the area beneath the former water tower near the center of the property led to a soil investigation in late 1984 and early 1985. Approximately 16 samples from depths of 2 to 10 feet were collected and analyzed for mercury by the EP Toxicity method. Mercury concentrations in the extractions ranged from non-detectable up to 0.0094 milligrams per liter (mg/l). NYSDEC accepted the characterization and approved installation of asphalt paving in order to close the site. This was completed in late 1986, and the location was deleted from the Registry in approximately 1990.

3.3 BUILDING 4 SAMPLING (1987)

According to a 1987 Taylor interoffice memorandum, an "area under the old zinc cyanide tank will have to be excavated because of poor structural integrity." The memo describes "several core samples and the soil underneath" composited and analyzed by the EP Toxicity method for cadmium, chromium, lead and mercury to determine if the material constituted a hazardous waste. The results were below the EP Toxicity limits, and apparently no further sampling was performed.

3.4 BUILDING 8 SAMPLING (1989)

According to a 1989 Combustion Engineering interoffice memorandum, a composite sample of soil from several locations beneath Building 8 was collected to characterize soil to be excavated during a construction project. Samples were presumably collected just beneath the floor slab. According to the EP Toxicity results, the soil was determined to be non-hazardous, based on Resource Conservation and Recovery Act metals. The total concentration of each metal ranged from 0.7 mg/kg for chromium to 231 mg/kg for copper.

3.5 TANK CLOSURES

Tank 2. In September 1986 this 1000-gallon gasoline underground storage tank (ust), was suspected to have leaked several hundred gallons of gasoline. With NYSDEC's concurrence, Taylor sampled nearby wells and lysimeters that had been installed for the NYSDEC Class 4 area investigation. No evidence of groundwater impact was found, and on this basis NYSDEC allowed the tank to be closed in place with no further groundwater or soil sampling or remediation. The Taylor correspondence file also indicates that "a 12/23/86 inspection of the tank site by the Rochester Fire Department revealed no significant soil contamination", although the scope of this inspection is not discussed.

Tank 2 was removed during demolition activities in November 1995. The tank had been closed by filling it with concrete. Samples were collected from the excavation and excavated material. Results indicated VOC levels beneath the STARS guidance values for gasoline contaminated soils. However, VOCs were present in a water sample that was collected from standing water in the excavation. The excavation has been backfilled. ABB-ES plans to investigate groundwater in this area as part of the site-wide investigation. It is unclear whether the presence of VOCs is a result of the 1986 release or from other potential sources in the immediate area. SVOCs detected in the soil are believed to be indicative of coal combustion by-products historically used as fill

Tank 16. This 3,000 gallon underground tank used to store paint thinner was removed in early 1993 by ABB Kent-Taylor. The initial set of soil samples from the excavation sidewalls showed levels of toluene, xylene and 4-methyl-2-pentanone above the NYSDEC Spill Technology and Remediation Series guidelines. At NYSDEC's request, additional soil was removed from the excavation and a second set of samples was obtained. These samples indicated the impacted soil had been removed, and tank closure was granted.

Tanks 11/12. These former xylene and toluene tanks were removed in December 1995. After initial field PID screening, unsaturated contaminated soil was excavated. This soil was shipped off site for proper disposal. Analytical results indicate that standing water in the excavation and surrounding soils (bottom and east sidewall) remain impacted. The extent of remaining contamination is unclear. Additional investigation is planned for this AOC. The excavation has been lined with polyethylene plastic sheeting and temporarily backfilled.

Tanks 17/18/19. These three 54-gallon tanks were removed in December 1995. Sampling of sidewalls and bottom of the excavation indicated remaining contamination at the bottom of the excavation. An additional three feet was excavated and the bottom resampled in January 1996. The contaminated soil was shipped off site for proper disposal. Analytical results indicate no remaining contaminated soil. The excavation was backfilled and no further investigation is planned.

3.6 SITE INVESTIGATION (1993)

In May 1993, ABB-ES conducted a limited site investigation to establish the general environmental condition of the property through selected sampling of potentially suspect areas. Outside the buildings, ABB-ES used a drill rig to collect soil samples from borings completed near each existing underground tank; the former Building 42 solvent recovery/drum storage area, the former Tank 15 area, and several other locations. Inside the buildings, shallow soils samples were collected by hand from beneath floor slabs in several areas, including the plating and degreasing areas, Building 30 mercury filling room, Building

12 and the former Tank 13 and 14 locations.

Results of field screening, field lab analysis and off-site lab analysis of the samples indicated the presence of mercury, metals and VOCs in some areas, and led to a report to NYSDEC regarding suspected releases from Tank 9 and former Tanks 13/14. The results suggested the need for further work in some areas and formed the basis for selection of some of the AOCs described in Section 4.0 of this workplan.

3.7 SUB-SLAB SOIL SAMPLING (1993)

During a September 1993 effort to sample concrete and other materials for waste characterization, several soil samples (that may have contained floor material) from beneath floor slabs were collected to augment the information from the May 1993 work. Samples were analyzed in a field laboratory for mercury only, with results ranging from not detected to 360 mg/kg.

3.8 SAMPLING DURING DEMOLITION (1995)

Plans for plant demolition included the possibility of removing obvious contaminant source, or limited areas of impacted soil, if encountered. In addition, regulatory requirements require sampling during underground tank closures.

Two areas of impacted soil were excavated during demolition activities in 1995. One area is located at the west end of former Building 49, where hydraulic pistons for the loading docks apparently leaked oil into the surrounding soil. The second area included apparently VOC-impacted soil around an old brick structure found several feet below grade between former Buildings 5 and 8. At both locations, ABB-ES collected soil samples from the excavation sidewalls to evaluate whether the impacted material was completely removed. Results indicated that all contaminated soils had been removed at these locations.

In November 1995, a 25,000 gallon underground storage tank was removed during the demolition project. While the tank itself appeared to be intact, visible material that appeared to be fuel oil was observed in the excavation. Notification was provided to NYSDEC. The liquid material was subsequently removed by a vacuum truck. Approximately 150 tons of soil were removed and sent off-site for treatment and/or disposal. The remaining soil was sampled. Analytical results indicate that soil above NYSDEC guidance values was removed. No further investigation is planned for this AOC.

4.0 POTENTIAL AREAS OF CONCERN AND CHEMICALS OF CONCERN

This section presents the Phase 1 potential AOCs and COCs identified for investigation at the Ames Street Site and the basis for the identifications.

4.1 AREAS OF CONCERN

ABB-ES reviewed all available site information, historical use information, and previous environmental analytical data to identify areas of the site that would be most likely to exhibit impact from historical plant operations. This information, supplemented by observations of shallow soils during demolition of the plant buildings, were used to develop AOCs that will be investigated during Phase 1.

Types of AOCs include:

- broad areas of potential soil impact (e.g. areas of the site containing glass shards as fill *or* soils beneath a building where soil impact was observed during removal of ground level floors)
- potential point sources such as underground storage tanks
- potential non-point background sources (e.g. soils beneath floors that were removed as hazardous waste due to elevated concentrations of COCs)

Table 4-1 and Figure 4-1 (attached at end of report) summarize the AOCs that will be investigated during Phase 1. A complete listing of all site features evaluated during selection of Phase 1 AOCs is located in Appendix E. Table 4-1 is organized as follows:

COLUMN	DATA PRESENTED
1	Area number and site description
2	Historical usage summary based on interviews with current and former employees; fire insurance maps from 1913,1934,1952,1986,1979, and 1988; mercury vapor/mercury problem reports and measurements circa 1946 to 1949 and 1963; Building Floor Area Report, July 1990, Rev 1 (8/14/90); and handwritten notes, circa 1982 to 1983, on "Places Where Mercury Has Been Used and Probably Spilled.
3	Results of concrete and wood floor analyses from the overlying first floor collected during four stages of building material characterization (see Appendix D)

TABLE 4-1

AREA OF CONCERN SUMMARY
AMES STREET INVESTIGATION WORK PLAN - PHASE 1

	POTENTIAL AREA OF CONCERN	HISTORICAL USAGE	OVERLYING FLOOR ANALYTICAL RESULTS	VISUAL OR SCREENING EVIDENCE DURING DEMOLITION	AVAILABLE SOIL ANALYTICAL RESULTS	PHASE I AREA OF CONCERN? [RATIONALE]	PLANNED PHASE I ACTIONS	PHASE I CHEMICALS OF CONCERN
1	Areas underlying floors removed as *characteristic* hazardous waste due to mercury.	Various mercury-intensive operations, e.g., instrument manufacturing.	Contained total mercury at concentrations exceeding 550 mg/kg.	Floors largely in good condition - no visual evidence of mercury in underlying soil.	Concentrations of mercury range from ND to 360 mg/kg in several isolated samples.	**Yes** [Elevated mercury results in floors indicate need to look at underlying soils.]	Shallow Soil Sampling	Mercury
2	Areas underlying Building 5 floors removed as hazardous waste.	Painting operations, paint chemical and waste use/generation.	Total VOC concentrations ranged from ND to 4,000 ug/kg.	Floors in good condition - no visual evidence of VOC impacts in soils.	None	**Yes** [Potential for VOC concentrations in underlying soil]	Shallow Soil Sampling	VOCs
3	Area underlying former electroplating area floors removed as hazardous waste. Building 4.	Metal plating and degreasing.	Concentration ranges: VOCs 7 to 312 ug/kg Cr^{+3} ND - 34 mg/kg Cr^{+6} 1.4 - 68 mg/kg Cd 1.2 - 26 mg/kg Pb ND - 0.76 mg/kg CN ND - 98 mg/kg Floors/debris not characteristic hazardous waste based on TCLP results.	Floors in fair condition but evidence of historical deterioration/patching - no visual evidence of releases to soil.	Metal concentration ranges: Cd ND - 260 mg/kg Cr^{+3} ND - 6,000 mg/kg Cr^{+6} ND - 6,300 mg/kg Pb ND - 500 mg/kg Ni ND - 5,500 mg/kg Zn 40 - 12,000 mg/kg No VOC results available.	**Yes** [Use history; floor condition may have allowed soil impacts.]	Shallow Soil Sampling	VOCs, Metals and Cyanide
4	Area underlying Building 34	Chemical/waste drum storage (also adjacent to former TCE use/storage area)	Floor materials removed as listed hazardous waste due to low levels of VOCs, CN, metals.	Floors in fair-to-good condition, but staining, drum rings visible. Some shards observed during demolition	Six shallow soil samples showed TCE ranged from ND to 910 ug/kg.	**Yes** [Presence of VOCs in soil suggests potential impact.]	Shallow Soil Sampling	VOCs, Mercury
5	Area underlying Building 40 garage area.	TCE dispensing/degreasing; garage maintenance operations. Floor drain to sewer present.	Total VOCs ranged from 32 to 9,000 ug/kg.	Floors largely intact, some limited staining; Glass shards observed during removal of floors	None	**Yes** [Known bulk TCE use]	Shallow Soil Sampling	VOCs, Mercury
6	Area near and underlying former Building 42	1940's-era solvent recovery operations (north end) and waste drum storage. Minimal knowledge of actual operations or locations.	No sampling.	Floors intact;no shards observed during floor removal	Eight soil samples with PCE in one at 280 ug/kg, TCE ranging from 4 to 260 ug/kg and BTEX up to 1,000 ppm	**Yes** [History of bulk chemical operation and known soil impacts]	Shallow Soil Sampling	VOCs
7	Area underlying Building 12	Oil and chemical storage in subgrade vaulted concrete building. Possible soil floor.	No sampling of concrete.	No visible impacts	Shallow soil samples contained TCE/1,1,1-TCA /PCE ranging from 10 to 200 ug/kg and TEX ranging from 14 to 8,970 ug/kg	**Yes** [History of bulk chemical storage and existing soil data indicate potential for soil impact]	Shallow Soil Sampling	VOCs
8	Area where glass shards were observed during demolition and in previous studies	Broken instruments observed.	NA - shards apparently deposited prior to floor construction, or no floors over areas.	Shards easily identifiable visually, liquid mercury observed occaisionally Shard density varies from absent to foot+ near-surface fill layer.	1980 Soil samples (from different shard areas) show total mercury concentrations ranging from 20 to 12,800 mg/kg.	**Yes** [History and existing soil data indicate potential for mercury in associated/underlying soils]	Soil Sampling	Mercury

TABLE 4-1

AREA OF CONCERN SUMMARY
AMES STREET INVESTIGATION WORK PLAN - PHASE 1

POTENTIAL AREA OF CONCERN	HISTORICAL USAGE	OVERLYING FLOOR ANALYTICAL RESULTS	VISUAL OR SCREENING EVIDENCE DURING DEMOLITION	AVAILABLE SOIL ANALYTICAL RESULTS	PHASE I AREA OF CONCERN? [RATIONALE]	PLANNED PHASE I ACTIONS	PHASE I CHEMICALS OF CONCERN
9 Degreasing area, Building 48.	TCE vapor degreasing	TCE from ND - 11,000 ug/kg .	Floors in fair-to-good condition but stained; no obvious soil impact.	One soil sample showed TCE 11,000 ug/kg, PCE 97 ug/kg .	**Yes** [History of bulk chemical use and existing soil data suggest potential soil impact]	Shallow soil sampling	VOCs
10 Area beneath Building 2.	Various mercury-intensive operations	Some overlying floor areas (AOC-1g,1h) contained total mercury above 550 mg/kg.	Floors in good condition. Mercury observed in shallow soils beneath floors, especially associated with subsurface drainlines/air tunnels.	None	**Yes** mercury present in soils	Shallow soil sampling	Mercury
11 Area beneath Building 44.	Various mercury-intensive operations	Some overlying floor areas contained total mercury above 550 mg/kg (AOCs-1i,1j,1k,1l,13e)	Floors in good condition. Mercury observed in drainlines beneath floors.	None	**Yes** mercury observed in drainlines of unknown integrity	Shallow soil sampling	Mercury
12 Areas underlying floors removed as *listed* hazardous waste due to mercury.	Various mercury-intensive storage and handling areas.	Some overlying floor areas contained total mercury above 550 mg/kg and all overlying areas correspond to NYSDEC listed areas due to mercury operations.	Floors in good condition. No obvious impact to underlying soils	None	Yes Investigate to assess impact beneath a NYSDEC *listed* mercury storage area.	Shallow soil sampling	Mercury
Storage Tanks							
Tank 1/9 (USTs)	Tank 1:Fuel oil storage (25,000 gal.) Tank 9: Gasoline storage (1,000 gal.) Visually impacted soil around fill port reported to NYSDEC in 1993.	NA	Visually stained soil present around bottom of Tank 1.	Prior samples contained TPH up to 64,000 mg/kg and BTEX between 3 mg/kg and 12 mg/kg. Results during demolition found no residual impact to soils in immediate underlying soils.	No	None	None
Tank 2 (UST)	Gasoline storage (1,000 gal) adjacent to Tank 15. Tank known to have leaked, cleanup/tank closure done under Fire Dept./ NYSDEC supervision in 1986.	NA	VOCs detected in soils around tank.	See results for Tank 15.	**Yes** [Existing soil data indicates potential soil impact]	Soil sampling	VOCs
Tank 15 (AST)	TCE storage (8,000 gal.), adjacent to Tank 2. Removed 1992.	NA	TBD (slab/foundation to be removed)	Samples adjacent to Tank 15/Tank 2 area showed 0.4 mg/kg to 930 mg/kg TCE, and BTEX from 2 mg/kg to 60 mg/kg.	**Yes** [Existing soil data indicates potential soil impact]	Soil sampling	VOCs

TABLE 4-1

AREA OF CONCERN SUMMARY
AMES STREET INVESTIGATION WORK PLAN - PHASE 1

POTENTIAL AREA OF CONCERN	HISTORICAL USAGE	OVERLYING FLOOR ANALYTICAL RESULTS	VISUAL OR SCREENING EVIDENCE DURING DEMOLITION	AVAILABLE SOIL ANALYTICAL RESULTS	PHASE I AREA OF CONCERN? [RATIONALE]	PLANNED PHASE I ACTIONS	PHASE I CHEMICALS OF CONCERN
Tank 10 (AST)	Various organic solvent/paint thinner storage (285 gal.)	NA	Storage vault. No tanks present or staining observed during demolition.	None	No. [Aboveground storage vaults with no tanks present or indications of releases to concrete.]	None	None
Tanks 13/14	TCE storage (1,500 and 1,000 gal.) Removed 1992.	NA	Some soil staining present.	PCE/TCE/1,2-DCE present in nearby soils from 0.2 mg/kg to 150 mg/kg, BTEX from 70 to 270 mg/kg.	Yes. [Existing soil data indicates potential soil impact]	Soil sampling	VOCs
Tank 11/12 (USTs)	Toluene/xylene storage (200 gal. each).	NA	Visually stained soils were removed during tank excavation.	No VOCs detected in four samples beneath tanks.	Yes. [Need to determine if soils are contaminated beyond lateral boundary of tank excavation.]	Soil sampling	VOCs
18 Areas underlying hydraulic hoists, elevator pistons, and machine oil sumps, cutting oil storage locations.	As described, locations of bulk oil-containing equipment.	Oils did not contain PCBs, floors managed as non-hazardous solid waste.	Oil-stained soils were removed during demolition from one area (AOC-18a)	Soils results show no residual impact beyond area of removed soils.	No. [No remaining impact]	None	None
19 Sewerlines and buried pipes	Potential for contamination via floor drains in chemical use areas	None available	Shallow pipes removed during demoition. Mercury observed in shallow soils beneath Building 2 and in pipes beneath Building 44. Some sewers left in place.	Low concentrations of mercury in water in sewers leaving site.	Yes. [AOCs established as footprint of Building 2 (AOC-10) and Building 44 (AOC-11).]	Soil Sampling	Mercury
20 Areas identified during demolition	NA	NA	Soils examined during the removal of ground-level floors and inground pipes resulted in the creation of AOC-10 and AOC-11.	None	Yes. [AOCs 10 and 11 identified during demolition and extent of glass shards in soil (see AOC-8) partially determined.]	Soil Sampling	Mercury

Notes:
1) Only first floor use/condition of floor considered because focus is underlying soil.
2) All mercury results expressed as total mercury.
3) NA = Not available. ND = Not Detected.
4) TBD = To Be Determined.
5) IRM = Interim Remedial Measure.

4	Observations, both visual and screening by PID and mercury vapor analyzer, made during building demolition and tank and sewer pipe removal (demolition is not yet complete and additions to this data are expected prior to Phase 1 on-site work)
5	Results of soil analyses from May 1993 site investigation (see Appendix F)
6	Findings of the data review, including yes or no decision for Phase 1 sampling and rationale for decision
7	COCs detected in flooring or soils in the area that will be analyzed during Phase 1

4.2 POTENTIAL CHEMICALS OF CONCERN

Potential COCs can be grouped into three categories based on the information developed during the selection of the Phase 1 AOCs: (1)VOCs, (2) mercury, and (3) metals/cyanide.

VOCs of concern are primarily aromatic hydrocarbons associated with petroleum products (fuel oil, gasoline),toluene or xylene (stored in product form), and chlorinated hydrocarbons used in cleaning and degreasing operations (e.g. TCE and PCE). Mercury was used in large quantities over the lifetime of the facility in the manufacture of various mercury-filled instruments throughout large areas of the building complex. Metals and cyanide are COCs at a specific area of the site where electroplating activities were carried out.

The potential COCs are presented in Table 4-2. In addition to identified COCs, selected other samples will be subjected to target compound list analyses as discussed in Section 5.5 to ensure that there are no additional site-related compounds that should be considered COCs.

The COCs listed are site-related compounds and metals detected in floors or soils at the site during previous site sampling events. Vinyl chloride is included as a possible degradation product of chlorinated compounds at the request of NYSDEC. Significant new site-related metals and VOCs identified by off-site laboratory analysis during the Phase 1 field investigations will be added to the calibration standards for the field laboratory in Phase 1.

TABLE 4-2

CHEMICALS OF CONCERN
AMES STREET SITE INVESTIGATION WORK PLAN - PHASE 1

Parameter	Analytes
VOCs	Tetrachloroethene Trichloroethene 1,1-Dichloroethene 1,2-Dichloroethene 1,1,1-Trichloroethane Benzene Toluene Ethyl Benzene Xylenes Acetone 4-Methyl-2-pentanone Vinyl Chloride
Metals	Mercury
	Cadmium Chromium (trivalent) Chromium (hexavalent) Lead Zinc Nickel
Other	Cyanide

5.0 SCOPE OF WORK

The following sections describe the activities planned as part of the Phase 1 site investigation. The field investigations will be conducted in accordance with the specifications presented in the QAPP (ABB-ES, August 1995)) and the site-specific QAPjP (Appendix A). Quality Assurance/Quality Control (QA/QC) procedures for sample handling, sample shipment, and data validation are presented in the program QAPP (ABB-ES, August 1995) and QA/QC sample frequencies are presented in the site-specific QAPjP (Appendix A). Health and safety procedures for all on-site activities are presented in Appendix B, the Site-Specific HASP.

5.1 AOC INVESTIGATIONS - PHASE 1 SOIL BORING PROGRAM

The scope of work that will be completed during Phase 1 consists principally of a boring program targeted to the identified AOCs. Borings will be drilled at each AOC to collect soil samples for field and laboratory analysis. The primary objective of the soil sampling program is to provide data for comparison to usage-based soil quality goals to identify which AOCs will require further action. To accomplish this, a minimum number of borings will be drilled at each AOC and soil samples from each boring will be analyzed for specific COCs. Target COCs have been identified for each AOC based on AOC type, previous environmental data, and demolition observations as detailed in Table 4-1. Some selected soil samples may also be analyzed for speciation and bioavailability. Additionally, the soil boring observations will be used to characterize the physical setting. Three geologic borings are planned (outside the AOCs) to further characterize the overburden and shallow bedrock at the site.

5.1.1 Boring Location and Rationale

The final location and number of borings planned for each AOC will depend on the size of the AOC, site history, and analytical results generated during the field investigation. The AOCs vary in size from the locations of former underground storage tanks to broad areas of potential impact beneath former buildings or related to contaminated fill (glass shards). AOCs targeted for different COCs often overlap or are located in close proximity. For example, AOC-2 (consisting of soils beneath former painting operations) is potentially impacted by VOCs and is located partially within AOC-8, a large area of potentially mercury-contaminated fill soils. Because of this complexity, a minimum number of borings have been assigned specific locations within each AOC to provide an initial understanding of soil concentrations. These assigned borings and the rationale for locations are listed in Table 5-1. Figure 5-1 (attached at end of report) shows the location of each boring.

TABLE 5-1

SOIL BORING SUMMARY
AMES STREET INVESTIGATION WORK PLAN - PHASE 1

AREA OF CONCERN	DEDICATED SOIL BORINGS	NOTES ON BORING LOCATION/RATIONALE
AOC-1 1a, 1b, 1c	3	These areas are located apart from other mercury AOCs in the southern portion of the site. One initial boring will be drilled at each to determine if mercury is present in soils. Up to three additional borings will be located based on field results to provide additional data on distribution in soils.
AOC-1 1d, 1e, 1n, 1m	4	These four mercury AOCs are located within a large potential area of impact from glass shard fill (AOC-8). One initial boring will be drilled within each AOC. Other dedicated borings will be located nearby to assess the overall impact within AOC-8.
AOC-2 2a, 2b, 2c	8	Eight borings will be drilled to assess impact from VOCs. The borings at AOC-2a and 2b are located at former degreasing operations. Borings at AOC-2c include locations of former drum storage and paint storage areas.
AOC-3 3a, 3b, 3c	7	AOC-3 is an area including former electroplating operations. Seven dedicated borings will collect samples for off-site analysis of metals/CN. Soils will be also analyzed for VOCs from the borings located within AOC-3b. Boring locations include the former location of a zinc cyanide tank and concrete floor containing elevated levels of metals.
AOC-4	4	Four borings will be drilled initially to assess impact from VOCs/mercury. Up to 2 additional borings will be located downgradient of the AOC based on field results.
AOC-5	2	Two borings will be drilled initially to assess impact from VOCs/mercury. One is located at a former TCE dispensing area.
AOC-6	2	Two borings will be located to determine impact from VOCs at this former 1940s-era solvent recovery/storage area. VOCs will also be screened in adjacent AOC-1n borings.
AOC-7	1	One boring will be drilled to determine impact from VOCs beneath the floor of this former oil/chemical storage area. Downgradient boring(s) in AOC-10 will provide additional information on potential impact.
AOC-8	6	A minimum of 6 borings will be drilled within this large area of suspected impact from glass shards. Three of these borings are at specific locations of shards observed during demolition and three are located to provide spatial information on overall soil impact within the AOC. These borings are in addition to more than 10 borings at smaller AOCs within the boundary of AOC-8 that will include screening for mercury. Up to 4 additional borings may be added based on field results.
AOC-9	1	One initial boring will be drilled at this former degreasing area. Additional borings may be drilled to examine the extent of impact based on field results from this AOC or at adjacent T-13/14
AOC-10 10, 1f, 1g, 1h	4	Four borings will be drilled beneath Building 2 to assess the distribution of mercury, observed in shallow soils during demolition. This AOC includes AOC- 1f, 1g and 1h, areas of mercury-impacted concrete floor.

TABLE 5-1 (cont'd.)

AREA OF CONCERN	DEDICATED SOIL BORINGS	NOTES ON BORING LOCATION/RATIONALE
AOC-11 11, 1i, 1j 1k, 1l, 12e	7	At least seven borings will be drilled beneath Building 44 to assess impact from mercury. Mercury was observed in excavated drainlines in shallow soils during demolition. This AOC includes smaller mercury AOCs 1i, 1j, 1k, 1l, (impacted concrete floor) and 12e (a NYSDEC listed area for Hg).
AOC-12 12a, 12b, 12c, 12d	6	These AOCs are considered listed areas for mercury under NYSDEC. Two borings will be drilled at AOC-12a, a receiving area for mercury shipments to the site. At least 4 borings will be drilled at AOC-12b, 12c, and 12d in Building 3.
T-1/9	1	One boring will be drilled at the downgradient edge of these former fuel tanks to assess if any VOCs remain in soils below the excavated depth (12 ft bgs)
T-2/15	1	One boring will be drilled downgradient adjacent to the location of these former tanks. Up to two additional borings will be added to assess the extent of VOC-impacted soils, if any.
T-11/12	1	One boring will be drilled at the location of former tanks 11/12 to assess if VOCs remain below the level of excavated soils. The downgradient boring in AOC-1m will provide additional information on potential impact.
T-13/14	1	One initial boring will be drilled at the location of these former TCE storage tanks. Additional borings may be drilled downgradient based on field results from this boring or adjacent AOC-9.
Total	60	Minimum soil borings to be completed during Phase I

Additional borings may be completed, if required to assess the feasibility of remedial measures such as soil excavation or treatment. The number and location of these additional borings will be determined in the field. The project team will continually evaluate the analytical findings generated by the on-site field laboratory and revise the conceptual model for the site accordingly. Factors that will be used to decide on additional sampling include; the nature of contaminants found at an AOC, the distribution and concentration of chemicals vertically within the overburden soils, and the existence of quality goals for a compound. A budget for Phase 1 has been established that will allow the completion of up to 20 additional borings.

Three geologic borings will be drilled to provide additional information about the overburden and bedrock geology at the Ames Street Site. The geologic borings will be drilled in areas near the northern, eastern and south-western areas of the site, respectively, to provide representative coverage. Each boring will be drilled outside an AOC to avoid the potential for contamination of the upper bedrock groundwater system.

5.1.2 Soil Sampling

In each soil boring, samples will be collected continuously at 2-foot intervals starting at the top of the original fill and ending at boring refusal or bedrock, whichever comes first. Borings will be advanced using conventional hollow-stem augers. Drilling, sampling, and decontamination procedures are described in the QAPP (ABB-ES, August 1995). In addition to PID screening for VOCs, a mercury vapor analyzer will be used to assist in selecting samples for analysis.

A minimum of two soil samples will be selected from each boring for analysis. The selection criteria will depend on the COCs at each AOC. In general, the sampling is intended to identify soils that may have concentrations of site chemicals above soil quality goals. The following paragraphs describe the COC-specific selection criteria:

<u>Mercury AOCs</u> Samples for mercury analysis will be collected from every split spoon and visually inspected for the presence of free mercury. Samples will be submitted to the field laboratory and analyzed sequentially. If mercury is detected, samples will be run from shallow to deep until concentrations are less than the method detection limit (0.1 parts per million) or until the overburden soil has been fully characterized. If no mercury is detected in the first two shallow soil samples, a third sample will be selected from the surface of the first less permeable layer or the overburden/bedrock interface, whichever is encountered first. This sample is intended to evaluate the potential for elemental mercury to move down through the water/soil column and accumulate on less permeable layers.

<u>VOC AOCs</u> Samples from each boring will be screened for the presence of VOCs using a PID. A minimum of two samples from each boring will be selected for field analysis; one each from both the saturated and unsaturated zones. As at other AOCs, the unsaturated zone samples are intended to identify soils that may have concentrations of site chemicals above soil quality goals. Saturated zone VOC samples are intended to identify site chemicals that may be migrating via overburden groundwater flow. Samples will be selected from the most likely impacted areas, based on PID meter screening results and visual observations. If there is no visual or PID evidence of VOCs, one sample from the original fill material and one from near the overburden bedrock interface will be selected.

<u>Metals/Cyanide AOCs</u> Two samples will be collected from the unsaturated zone of each boring. One sample will be selected from 2 feet below the top of the original fill in order to avoid the upper layers that may have been disturbed by demolition activities and therefore not representative of the original fill. A second sample will be collected for analysis at the water table or at the base of the fill, whichever is encountered first, to characterize the vertical distribution of metals.

<u>Geologic borings</u>. Soil samples will be collected continuously at 2-foot intervals using either conventional hollow-stem auger or drive and wash drilling techniques. Each boring will be backfilled with a cement/bentonite grout mixture following sampling. The upper ten feet of bedrock will be drilled using "N" size rock core bit and barrel. Overburden and bedrock drilling and split-spoon sampling procedures are outlined in the QAPP (ABB-ES, August 1995).

5.1.3 Analysis

Chemical analysis for selected VOCs and mercury will be performed at an on-site field laboratory as a rapid and cost-effective means of data acquisition. Field analysis will provide same-day results to assist in decision making about future boring locations. Samples from each AOC will be analyzed for the COC list chemicals (Table 4-1) targeted for that specific AOC. Details of the field analytical program are provided in Section 5.4. Five percent of the total VOC and mercury samples field analyzed, will be split and sent for off-site analysis. For the VOC splits, the analytes of interest will include all VOCs from the Target Compound List (TCL) for VOCs, plus up to ten library search compounds. The metals analysis will be done at an off-site laboratory for the Target Analyte List (TAL) inorganics and will also include hexavalent and trivalent chromium, which are site-specific COCs. Section 5.4 and the site-specific QAPjP (Appendix A) describe the analytical methodology for both on-site and off-site laboratory analysis. Table 5-2 contains a breakdown of anticipated soil analyses for each AOC.

TABLE 5-2

SOIL ANALYTICAL PROGRAM
AMES STREET SITE INVESTIGATION WORK PLAN - PHASE 1

		FIELD ANALYSIS		OFF-SITE ANALYSIS			MERCURY
AREAS OF CONCERN	COCs	VOCs[1]	MERCURY	VOCs[2]	MERCURY	METALS[3]	SPEC./BIO[4]
AOC 1 (a-n)	Mercury		X		5%		TBD
AOC 2 (a-d)	VOCs	X		5%			
AOC 3(a)	Select metals		X			X	
AOC 3(b)	VOCs, Select metals	X	X	5%		X	
AOC 3(c)	Select metals		X			X	
AOC 4	VOCs, mercury	X	X	5%			
AOC 5	VOCs, mercury	X	X	5%			
AOC 6	VOCs	X		5%			
AOC 7	VOCs	X		5%			
AOC 8	Mercury		X		5%		TBD
AOC 9	VOCs	X		5%			
AOC 10	Mercury		X		5%		
AOC 11	Mercury		X		5%		
AOC 12	Mercury		X		5%		
Tank 1/9	VOCs	X		5%			
Tank2	VOCs	X		5%			
Tank 15	VOCs	X		5%			
Tank 13/14	VOCs	X		5%			
Tank 11/12	VOCs	X		5%			

NOTES:

COCs = Chemicals of Concern
VOCs = Volatile Organic Compounds
UNK = Unknown
TBD = To Be Determined

1 - Field laboratory analysis for the following:

Tetrachloroethene
Trichloroethene
1,1-Dichloroethene
1,2-Dichloroethene
1,1,1-Trichloroethan
Benzene
Toluene
Ethylbenzene
Xylenes
4-Methyl-2-Pentanone
Acetone
Vinyl Chloride

2 = Off-site laboratory analysis for Target Compound List (TCL) VOCs plus up to 10 library search compounds.

3 = Off-site laboratory analysis for Target Analyte List (TAL) inorganics plus trivalent and hexavalent chromium.

4 = Analysis for mercury speciation and bioavailability. Number and location of samples will be dependent on mercury concentrations measured by on-site laboratory.

Additional split samples may be collected for mercury speciation and bioavailability analysis in areas with high mercury concentration. The rationale for conducting these analyses is discussed in Section 5.3.4.

5.2 GROUNDWATER SAMPLING

Groundwater sampling will be performed at existing monitoring wells and at temporary well points to be installed along the northern and eastern boundaries of the Ames Street Site. The intent of the groundwater sampling program is to characterize overburden groundwater quality along the down-gradient site perimeter for comparison to groundwater quality goals, and to determine the optimal location for permanent monitoring wells that may be installed during Phase 2. At least eight existing monitoring wells and a minimum of 20 temporary well points will be sampled. The location of each monitoring well and planned temporary well point is shown on Figure 5-1.

5.2.1 Temporary Well Point Locations

A total of 20 temporary well points are planned along the northern and eastern boundary of the Ames Street Site as part of the groundwater sampling program to provide a relatively inexpensive means of providing groundwater samples. Additional well points may be added after the initial 21 points have been sampled and analyzed, to trace chemicals detected back to possible on-site sources. The location and distribution of the initial 20 well points is based on:

1) Groundwater flow. A prior investigation conducted within the northwest portion of the Ames Street Site showed an interpreted north and east groundwater flow direction in the overburden groundwater system (see Section 2.2.2). In addition, analytical results from previous groundwater samplings show the presence of chemicals suspected of having migrated toward the northeast from possible sources on-site. Based on the location of the different AOCs at the site relative to the predominant groundwater flow direction, the northern and eastern property boundary are considered to be hydraulically downgradient of the site.

2) Dispersion. Assuming 50 feet as a conservative estimate of average source area width, an average distance to the property boundary of 100 feet, and estimates of flow velocity from previous investigations (Lozier, 1983), a minimum hypothetical plume width of approximately 75 feet is estimated as a result of dispersion mechanisms. Based on this width, spacing of the initial 21 temporary well points was set at 60 foot intervals along the northern and eastern property boundaries (see Figure 5-1).

3) Location of AOCs The location of the AOCs is concentrated within the central and northern sections of the Ames Street Site. The position of all AOCs relative to that of the interpreted groundwater flow, exposes approximately 700 feet of the eastern, and nearly all of the northern boundary of the site, as areas of potential off-site migration. The temporary well points are located in these areas.

5.2.2 Groundwater Sampling and Analysis.

Temporary wells will be installed using a conventional augering. Two inch ID PVC with 5-foot wellscreens will be installed in an open auger hole and backfilled with clean sand. The bottom of the screen will be placed at least 5-feet below the top of the water table. Following installation, the wells will be purged and sampled similar to the existing site monitoring wells. After sampling, the PVC will be removed and the remaining open borehole filled with bentonite grout.

Groundwater samples will also be collected from at least eight existing on-site overburden monitoring wells (see Figure 5-1) in conjunction with the temporary well point sampling. Procedures for groundwater sampling will follow those in the United States Environmental Protection Agency (USEPA) Region I guidance for low-flow purge and sampling (USEPA, 1994) and the "clean-hands technique" for water sampling of mercury. These procedures are outlined in the site-specific QAPjP (Appendix A).

Samples from both temporary well points and existing monitoring wells will be analyzed at the on-site field laboratory for selected VOCs and mercury. All water samples will be split for off-site analysis of Target Compound List VOCs. Ten percent of these will also be analyzed off-site for mercury. Table 5-3 is a summary of the analytical groundwater program. Section 5.5 describes the analytical methodology to be employed for the on-site analysis.

5.3 RISK ASSESSMENT AND DERIVATION OF RISK-BASED GOALS

A human health risk assessment (HHRA) will be performed for the Ames Street Site. The HHRA activities will be conducted consistent with NYSDEC guidance and guidance developed for the federal Superfund program. Because the purpose of the HHRA is to provide the information required to develop risk-based soil and groundwater quality goals for the site, the risk assessment will be documented in the Site Investigation Report - Phase 1 but a separate formal baseline risk assessment report will not be prepared. The risk-based soil and groundwater quality goals for the site will be derived based on the site-specific risk assessment information.

TABLE 5-3

GROUNDWATER ANALYTICAL PROGRAM
AMES STREET SITE INVESTIGATION WORK PLAN - PHASE 1

SAMPLE SOURCE	NO. OF SAMPLES[1]	FIELD ANALYSIS		OFF-SITE ANALYSIS[3]	
		VOCs[2]	MERCURY	VOCs[1]	MERCURY
Temporary Well Points	20	20	20	100 %	10 %
Existing Monitoring Wells	8	8	8	1	1

NOTES:

VOCs = Volatile Organic Compounds

1 = Minimum of 20 temporary well point samples; additional samples may be collected to further delineate the distribution of VOCs and mercury.

2 - Field laboratory analysis for the following:

Tetrachloroethylene	Ethylbenzene
Trichloroethylene	Xylenes
1,1-Dichloroethylene	2-Butanone
1,2-Dichloroethylene	2- Hexanone
1,1,1-Trichloroethane	4-Methyl-2-Pentanone
Benzene	Acetone
Toluene	Vinyl Chloride

3 = Off-site laboratory analysis for Target Compound List (TCL) VOCs and SVOCs (including search for tentatively identified compounds) and Target Analyte List (TAL) metals.

No ecological risk assessment is proposed since the site is and will continue to be an industrial/commercial property without significant habitat, and no surface water or sediments are present at the site.

Risk-based soil and groundwater quality goals at the site will be developed based on the current and foreseeable uses of the property, using a methodology similar to that in NYSDEC's Revised TAGM - Determination of Soil Cleanup Objectives and Cleanup Levels TAGM HWR-94-4046, except that: the human health levels will be based on the planned future use of the site, i.e. as a commercial or an industrial property and on the current and reasonably foreseeable uses of the underlying groundwater; achieving background levels of contaminants will not be a site goal, unless merited by the risk analyses; and no goal will be set lower than the site-specific quantitation level for a contaminant. The future land uses, which are the basis of the goals, will be enforced via deed restrictions and no other land uses will be implemented without further review by NYSDEC.

The HHRA will include the following tasks:

- data evaluation and summarization
- identification of HHRA chemicals of potential concern (CPCs)
- exposure assessment (for both current and future land uses)
- toxicity assessment
- risk characterization
- derivation of risk-based goals

5.3.1 Data Evaluation and Summarization

The Phase 1 analytical results will be compiled and evaluated for suitability of use in the risk assessment. The data will be summarized by media and by separate areas of concern (AOCs). The product of this task will be a series of media-specific data summaries to be used in determining exposure point concentrations.

5.3.2 Identification of HHRA Chemicals of Potential Concern

HHRA CPCs are those chemicals which are included in the quantitative risk assessment. CPCs are COCs most likely to be risk contributors based on their toxicity, frequency of occurrence and their concentrations in soil or groundwater.

5.3.3 Exposure Assessment

The exposure assessment involves:

- characterization of the exposure setting (including current and future land use)
- identification of exposure pathways (including receptor identification)
- identification of exposure point concentrations
- quantification of exposures (including speciation and bioavailability issues potentially important for mercury or other CPCs)
- summary of exposures by receptor and land use

The exposures will be estimated for reasonable maximum exposure scenarios. Under current land use there is very limited exposure potential and the future use will be industrial/commercial with virtually the entire site being paved or covered by buildings. The only foreseeable potential soil exposures are those associated with construction activities during site redevelopment and more limited periodic below-ground maintenance activities. Exposure to potentially hazardous vapors potentially entering buildings through basement walls and/or floors will also be considered. Table 5-4 presents theoretically possible exposure pathways and identifies those pathways and receptors to be evaluated. A groundwater receptor analysis will be conducted to determine if there are any potential receptors for groundwater by any environmental pathway. Figure 5-2 presents the theoretically possible mercury migration pathways and exposure pathways for the site. The Phase I investigation will determine which of these pathways are in fact complete or likely to be complete given the planned use of the site. In particular, information will be gathered to determine 1) if there is mercury contamination in groundwater, and if so, if it is volatile; 2) if there are any potable or non-potable uses of the groundwater; 3) if there is mercury at depth such that partitioning between soil, soil gas and groundwater is occurring. Only those pathways which are determined to be complete will be evaluated quantitatively.

Quantification of exposures to soil and groundwater may include an assessment of bioavailable mercury as discussed below.

5.3.4 Toxicity Assessment

The toxicity assessment will identify available information on the potential toxic effects of CPCs and the relationship between exposure (and dose) and likelihood and/or severity of adverse human health effects associated with potential exposures. The toxic effects associated with each of the CPCs will be summarized. The dose-response values for the CPCs will be obtained from USEPA's Integrated Risk

TABLE 5-4

SUMMARY OF POTENTIAL EXPOSURE PATHWAYS AND RECEPTORS
AMES STREET SITE INVESTIGATION WORK PLAN - PHASE 1

LAND USE	MEDIUM	RECEPTOR	EXPOSURE ROUTES	SELECTED FOR EVALUATION?	RATIONALE
Current	Soils	Trained site investigators/workers	Ingestion Dermal Inhalation (dust and/or vapors)	No	Current workers are operating under a health and safety plan.
	Soils	Trespassers	Ingestion Dermal Inhalation (dust and/or vapors)	No	Access to the site is limited by a fence and ground surfaces are paved/covered by buildings.
	Groundwater	Area residents	Ingestion Dermal Inhalation of vapors	Yes	Neighboring residences are served by remote public water supply. This will only be addressed if a potentially complete exposure pathway is identified.
	Groundwater	Site investigators/workers	Ingestion	No	There is no use of groundwater for potable or non-potable uses on site.
	On-site Surface Water/ Sediment	Trespassers, Site workers	Ingestion Dermal Inhalation	No	No surface water/sediment present on site.

TABLE 5-4 (cont'd)

LAND USE	MEDIUM	RECEPTOR	EXPOSURE ROUTES	SELECTED FOR EVALUATION?	RATIONALE
Future	**Soils**	Residents	Ingestion Dermal Inhalation (dust and/or vapors)	No	Property will be in industrial or commercial use with virtually total paving/building coverage and deed restrictions which prevent exposure to soils.
	Soils	Construction Workers/ Below-Ground Maintenance Workers		Yes	During and after site redevelopment construction workers/ maintenance workers are potentially exposed to impacted soils
	Soils	Industrial/Commercial workers and site visitors	Ingestion Dermal Inhalation (dust and/or vapors indoors and outdoors)	Yes	After redevelopment basement or other sub-grade areas may be periodically occupied.
	Groundwater	On-site residents On-site workers On-site visitors	Ingestion Dermal Inhalation	No	Area is served by public water supply. Deed restriction will prohibit use of site groundwater as drinking water.
	Groundwater	Area residents	Ingestion Dermal Inhalation	Yes	Area is served by public water supply. This will only be addressed if a potentially complete exposure pathway is identified.

Information System (IRIS), Health Effects Assessment Summary Tables, the Agency for Toxic Substance and Disease Registry and other published scientific literature. The dose-response values used will be Reference Doses (RfD) for non-carcinogenic effects and Cancer Slope Factors (CSFs) for carcinogenic effects. For CPCs that can be present in both bioavailable and non bioavailable forms, published estimates of their bioavailability will generally be used where appropriate. A combination of speciation and in vitro bioavailability testing may be used to determine the relative bioavailability of the mercury which is found in soils at the site.

5.3.5 Risk Characterization

The risk characterization will utilize the toxicity assessment and exposure assessment results to identify the nature and magnitude of risks to human receptors associated with potential exposures to CPCs. The risks will be evaluated by comparing site concentrations to published soil cleanup levels and/or to site-specific risk-based concentration goals. The site-specific risk-based concentration goals will be associated with acceptable levels of non-carcinogenic (hazard quotient) and carcinogenic risks (excess lifetime cancer risk). The identified risks will be put into context by comparison to commonly used risk management criteria. Uncertainties in the risk characterization will be discussed. In particular, the impact of various assumptions and of uncertain values will be discussed.

5.3.6 Use of Risk-based Mercury Screening Concentrations in the Sampling and Analysis Program

Risk-based screening concentrations for total mercury will be used as a component of a decision process to determine the nature and extent of sampling and analyses that will be conducted for mercury in soil, groundwater and possibly soil gas. These conservative screening concentrations, in general, indicate, for a particular exposure pathway, a concentration below which human health risks would not expected to be significant. If concentrations are above these screening values, some additional sampling and analyses may be required to determine the nature and magnitude of the associated site-specific human health risks and to develop site-specific risk-based goals. Risk-based screening levels will be employed for the following exposure pathways: ingestion of groundwater (if receptors are identified), soil ingestion, and inhalation of vapors potentially released from soil and groundwater into buildings. The following sections describe how each screening level has been derived. Section 5.5 describes how the screening levels will be used to adjust the Phase I analytical program.

5.3.6.1 Setting the Mercury Screening Levels for Groundwater. Due to its potential importance at the site, a multi-step goal setting process for mercury in groundwater will be followed. Initially, mercury concentrations in groundwater at the downgradient property boundary will be compared to the New York groundwater standard for mercury in class GA groundwaters (2 ug/l). If concentrations exceed the standard, it will be determined if there are any complete or potentially complete ingestion exposure pathways for the groundwater and additional well points may be installed to trace contaminants back to a source. If there is a complete or potentially complete ingestion exposure pathway, filtered analyses of groundwater from representative wells will be conducted to determine if the mercury is dissolved and therefore actually representative of potential drinking water ingestion exposures. In addition, a groundwater mercury concentration which theoretically might be associated with vapor migration into basements of buildings at a concentration of concern will be identified through transport modeling. This screening concentration is based on the potential for mercury vapors to be released form groundwater into soil gas in the subsurface soil and subsequently, diffusion-based transport of vapors through subsurface basement walls and/or floors of buildings which might be constructed in the future. This screening concentration would be utilized to identify candidate locations for future soil gas or groundwater monitoring activities if they are deemed necessary. This soil gas monitoring would be conducted to determine if indeed soil gas contains mercury vapor at concentrations of potential concern.

5.3.6.2 Setting the Mercury Screening Levels for Soil. Risk-based soil screening levels will be employed for the following exposure pathways: soil ingestion and inhalation of vapors potentially released from soil and groundwater into buildings. These screening levels are discussed in the following paragraphs.

Initially, a default human toxicity-based soil screening level for **soil ingestion** based on an industrial/commercial land use will be identified. The total mercury levels measured in soil at various AOCs will be compared to this screening level. If, in a given area, no total mercury levels are found above the screening level, no mercury speciation or bioavailability testing will be necessary for soils in that area. However, although not strictly necessary, some samples with total mercury concentrations below the screening level will be evaluated with respect to speciation and bioavailability to provide a complete picture of site conditions. It will be assumed that mercury in that area is not of significance with respect to soil ingestion. Investigations and evaluation of other exposure pathways will also be conducted in these areas. In areas where total mercury levels are above the soil ingestion screening level, mercury speciation and possibly bioavailability analysis will be conducted in order to develop the soil ingestion component of a site-specific, future site use, risk-based goal.

Based upon a literature review, the initial soil ingestion mercury screening concentration will be 200 mg/kg. This number, representing an exposure which is acceptable for a lifetime exposure, was published by USEPA Region III as a screening level for soils in an industrial setting (USEPA, 1995). This number is based on the reported toxicity of methyl mercury, which is considered the most toxic form of mercury via the ingestion exposure route. It assumes that a 70 kg adult is exposed via incidental ingestion of 100 mg soil per day (half of which comes from the site), 250 days per year for a period of 25 years. The background information supporting this screening level is presented in Appendix H. Given the planned commercial/industrial use of the property and the planned paving of virtually the entire property, ingestion exposures associated with soil concentrations below this screening level should not be a public health concern. As a confirmation of the utility of this screening level for this site, ABB-ES has also calculated a soil ingestion screening concentration specifically for a construction worker. This screening level is 165 mg/kg. It assumes a 70 kg adult is exposed via incidental ingestion of 118 mg soil per day (half of which is derived from the site), 5 days per week for an entire year. The derivation of this screening concentration is shown in Appendix I. A screening concentration for the construction worker dust inhalation scenario will not be incorporated into the decision tree for determining which chemical analyses will be conducted. A preliminary evaluation indicates that such a screening level would be well above the 200 mg/kg soil ingestion screening value, and therefore would not be a factor in determining if further chemical analyses be conducted.

In those areas where no total mercury concentrations are found above the screening level, no further sampling and analysis will be required to determine the human health risk associated with soil ingestion exposure. In that case, the soil ingestion screening level would become the soil ingestion component of the mercury soil goal at the site as discussed below. It should be noted that the total mercury analytical method will have a detection limit of 0.1 mg/kg , even though the soil ingestion screening level is substantially higher than that.

A human toxicity-based soil screening level based on potential **inhalation of vapors released from groundwater and subsurface soil into buildings** will be identified. This screening level represents a mercury soil concentration which would be protective for two exposure pathways: direct migration of vapors from soil into buildings; and leaching of mercury from soil to groundwater with subsequent partitioning of mercury to soil gas followed by diffusion-based migration into buildings. These pathways are depicted in figure 5-2. The screening concentration will be based on a target indoor air concentration for mercury which is equal to the OSHA Permissible Exposure Limit (PEL) and will utilize EPA approved modeling techniques for leaching to groundwater as well as partitioning of vapors between groundwater, soil gas and buildings. The total mercury levels measured in soil at various AOCs will be compared to this screening level. Areas where this soil screening level is exceeded may be targeted for mercury soil gas analysis to determine if this potential mercury migration pathway is a significant pathway at this site.

5.3.7 Development of Risk-Based Goals

Site-specific risk-based goals will be developed once the Phase I data are obtained.. The current and future uses of the property (with associated potential receptors and institutional controls), the toxicity, fate, and transport characteristics of the CPCs and the speciation and bioavailability of the CPCs will be considered. Direct soil contact, potential leaching of CPCs to groundwater, and inhalation of CPCs potentially released to indoor air (vapors) and outdoor air (vapors and soil particulates) will be considered in developing soil and groundwater goals. The construction worker and maintenance worker exposure scenarios will likely be the basis of the direct soil contact calculations since other exposures to soil will be precluded by industrial/commercial use, paving, and institutional controls. The groundwater quality goals will reflect current and foreseeable uses of the groundwater, any potential direct groundwater exposures and will consider potential migration of vapors form groundwater into buildings. It should be noted that exceedance of risk-based goals is expected to trigger some action to eliminate or minimize medium-specific and route-specific exposure may be warranted. Such actions may involve removal, treatment, engineering controls, health and safety protection measures, and /or institutional controls.

5.3.7.1 Setting a Site-Specific Risk- and Future Use-based Mercury Groundwater Goal. The site-specific risk- and future use-based mercury groundwater goal will be developed in a manner consistent with accepted risk assessment practices. If it is determined that a potentially complete exposure pathway for potable or non-potable use of groundwater exists, one component of the groundwater goal would be the Class GA groundwater standard of 2 ug/liter. Another component of the groundwater site goal could involve a concentration which would be protective of potential vapor migration from the subsurface through basement walls and/or floors if no potable or non-potable use of the groundwater are identified. Potential exposures to vapors released from groundwater may be controlled by means other than reducing concentrations The process which will be employed to derive the mercury groundwater site goal is diagrammed in Figure 5-3.

5.3.7.2 Setting a Site-Specific Risk- and Future Use-based Mercury Soil Goal. When total mercury in soil are found above the screening levels, then site-specific goals will be derived through quantification of potential future exposures to mercury in soil and other media potentially impacted by release of mercury from soil. This quantification may include an assessment of speciation and bioavailability of mercury in soils.

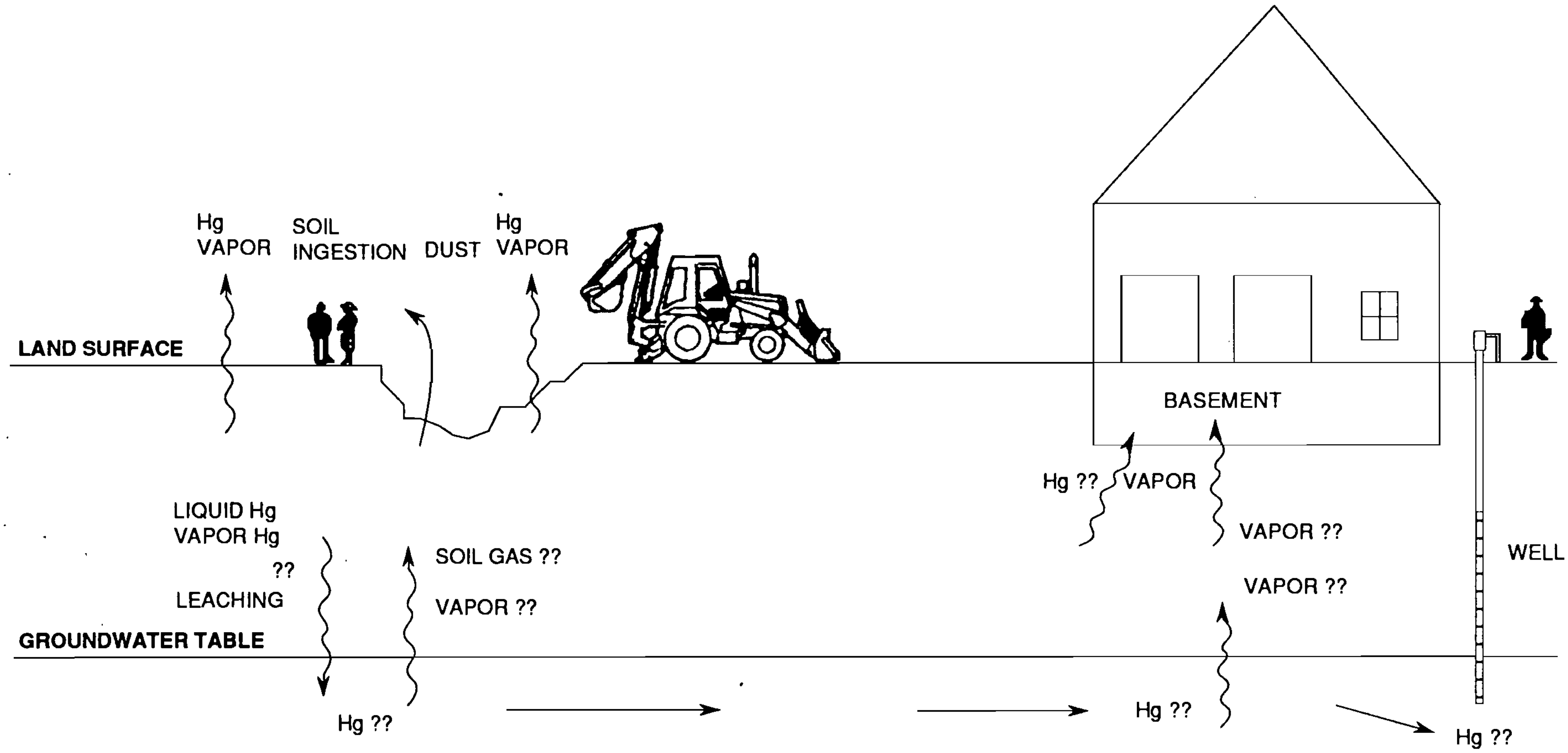
The mercury soil goal will be identified through the development of health risk-based concentrations for each potentially complete exposure pathway (e.g. ingestion of soil, inhalation of dust). The risk-based soil concentrations for each of the pathways will be referred to as the "components" of the mercury soil goal. The mercury soil goal will be set at the lowest mercury soil concentration that is represented by one of the components, unless that particular component will be controlled by some engineering or institutional control measures, a process which is shown graphically in Figure 5-4. In such a case, the next lowest concentration among the components would become the mercury soil goal. The four components of the mercury soil goal include:

1) soil ingestion by a construction worker;

2) inhalation of soil particulates (dust) by a construction worker; 3) inhalation of mercury vapors by a construction worker; and 4) inhalation of vapors by a future on-site worker (mercury released from soil to soil gas and/or potentially leaches from soil to groundwater with subsequent release of vapors to soil gas and into buildings). The allowable risk-based concentration for each of these pathways would be derived using standard risk assessment procedures and readily available, USEPA -endorsed fate and transport modeling techniques. This modeling is required for the estimation of exposures since monitoring of many of these potential exposures is impossible (no construction is ongoing and there are no intact buildings where indoor air monitoring could be conducted).

The Class GA groundwater standard and the vapor migration- based groundwater screening concentration (if soil gas monitoring confirms its validity) will be used to set a site-specific soil goal that is intended to protect the underlying groundwater. The methodology for setting this groundwater protection soil goal will be based upon NYSDEC's revised TAGM HWR-94-4046.

POTENTIAL HUMAN HEALTH EXPOSURE PATHWAYS*



* PHASE I INVESTIGATION WILL DETERMINE WHICH EXPOSURE PATHWAYS ARE COMPLETE.

FIGURE 5-2
MERCURY SOIL ANALYSIS FLOW CHART
SITE INVESTIGATION - PHASE I
95 AMES STREET
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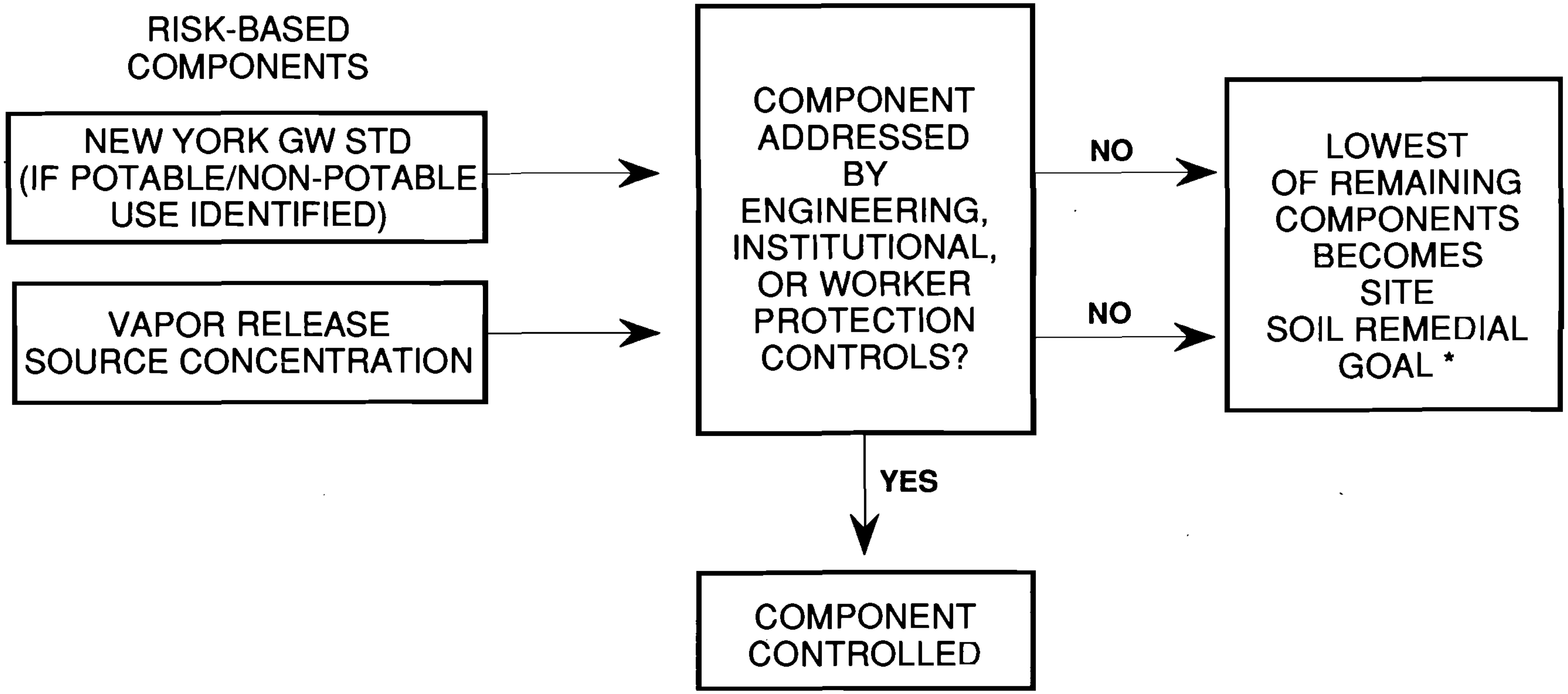
DERIVATION OF GROUNDWATER SITE GOAL FOR MERCURY



RISK-BASED COMPONENTS

NEW YORK GW STD (IF POTABLE/NON-POTABLE USE IDENTIFIED)

VAPOR RELEASE SOURCE CONCENTRATION

COMPONENT ADDRESSED BY ENGINEERING, INSTITUTIONAL, OR WORKER PROTECTION CONTROLS?

NO

NO

LOWEST OF REMAINING COMPONENTS BECOMES SITE SOIL REMEDIAL GOAL *

YES

COMPONENT CONTROLLED

* GOAL WILL NOT BE SET
BELOW BACKGROUND NOR
PRACTICAL QUANTITATION LIMIT

FIGURE 5-3
SITE INVESTIGATION WORKPLAN
SITE INVESTIGATION - PHASE I
95 AMES STREET
ROCHESTER, NEW YORK

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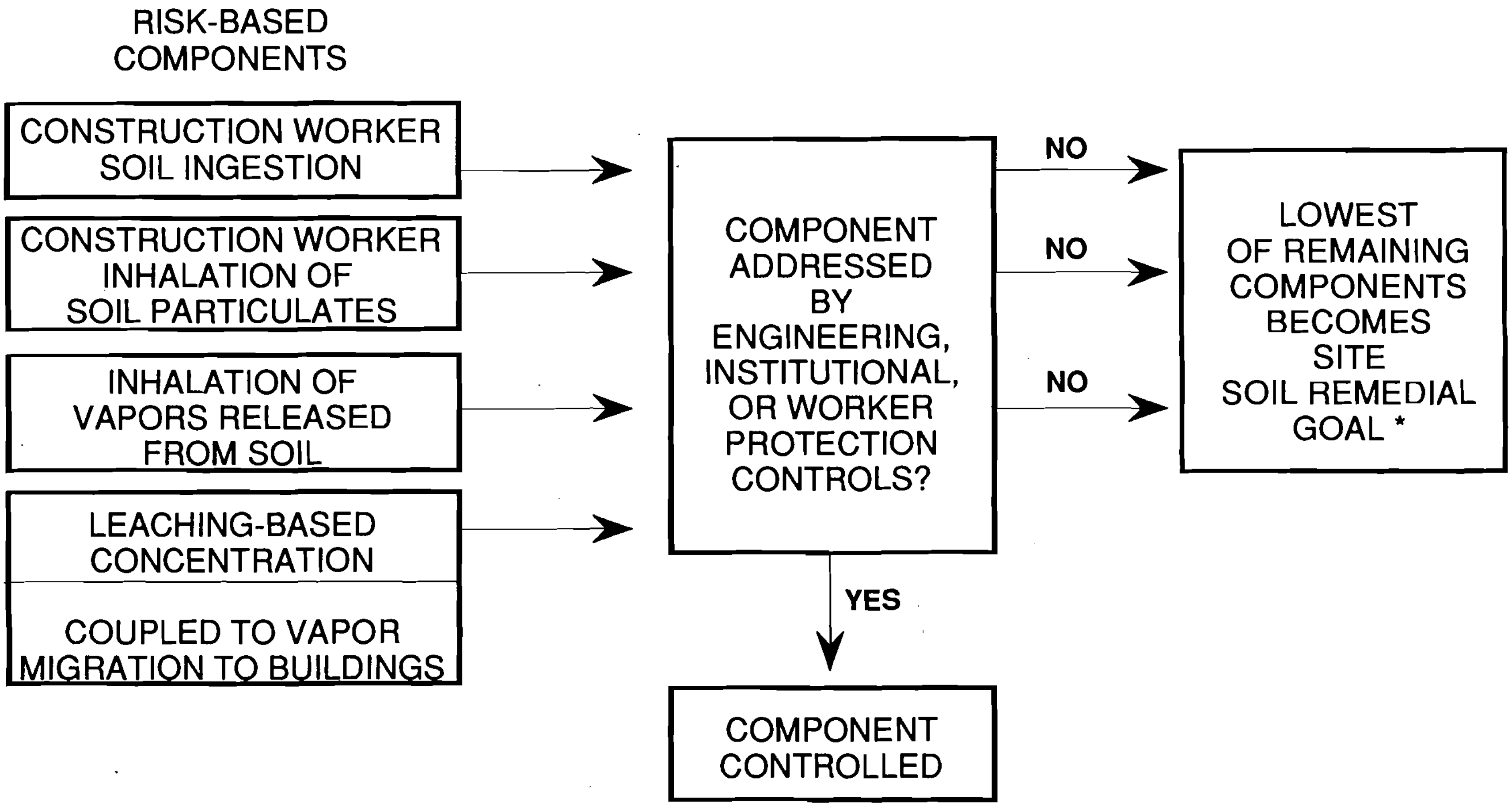
DERIVATION OF SOIL SITE GOAL FOR MERCURY



* GOAL WILL NOT BE SET BELOW BACKGROUND NOR PRACTICAL QUANTITATION LIMIT

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FIGURE 5-4
SITE INVESTIGATION WORKPLAN
SITE INVESTIGATION - PHASE I
95 AMES STREET
ROCHESTER, NEW YORK

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Depending on the results of the speciation analysis, it may be necessary to adjust the soil ingestion exposures to coincide with the medium of exposure (soil) and the chemical species present because they are different than the media and mercury species which are involved in the derivation of the oral RfD for mercuric chloride (provided methyl mercury is not present at the site). Appendix A of USEPA's Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), Interim Final (USEPA, 1989) recommends adjustment of exposure estimates if the site-related exposure involves a medium which is different from the medium of exposure assumed by the RfD. Such an adjustment is appropriate here, since the site exposure is to soil while the RfD exposures involve water or mercuric chloride itself. In addition, if the chemical species (or mix of species) is different than the chemical species used in the RfD development (mercuric chloride), it may be more or less bioavailable than the species in the RfD development and therefore may have a significantly different toxicity based on administered dose. In such a case, adjustment of the exposure to reflect the reduced or enhanced bioavailability is appropriate. This adjustment would be accomplished via the application of a bioavailability adjustment factor (BAF) to soil ingestion exposure estimates. The approach for derivation of the BAF for mercury in site soils, including speciation analysis and in vitro bioavailability testing is described in Appendix J.

Mercury speciation analytical results will be reviewed and evaluated to determine if in vitro bioavailability testing will be conducted. In those areas where the speciation techniques clearly indicate the mercury species in soil are insoluble species which are reported in the literature to be not bioavailable via ingestion (such as elemental mercury or mercury sulfides), it will be concluded that for soil ingestion, the mercury is not of toxicological significance. As stated in Casarett and Duoll's Toxicology: The Basic Science of Poisons, Fifth Edition, "metallic mercury, such as may be swallowed from a broken thermometer, is only slowly absorbed by the gastrointestinal tract (0.01 percent) at a rate related to vaporization of the elemental mercury and is generally thought to be of no toxicological consequence." No in vitro bioavailability testing will be conducted for samples taken in such areas.

Speciation and bioavailability testing will not be conducted for any inhalation exposures. There are published inhalation toxicity values for the volatile mercury species. Therefore, no adjustments due to matrix differences or mercury speciation differences will need to be made.

While not planned at this time, laboratory tests to determine site-specific bioavailability of other CPCs may be conducted.

5.4 DATA QUALITY OBJECTIVES

As stated in Section 5.1, soil sampling will be performed at the various AOCs to characterize the distribution of VOCs, mercury, and/or selected metals in subsurface soils. The intent of the soil sampling program is to provide soil quality data for comparison to usage-based soil quality goals.

Groundwater samples will be collected down-gradient at the property boundary and from available on-site monitoring wells. The purpose of the groundwater evaluation is to characterize groundwater quality on-site and provide data for comparison to usage-based quality goals.

Data quality objectives (DQOs) are qualitative and quantitative statements developed by the data users to specify the quality of data needed from a particular data activity to support specific decisions. DQOs are based on the concept that the intended use of the data determines the quality of the data required. As such, DQOs for this Phase 1 voluntary investigation have been developed to ensure that the data used to support decisions are of sufficient quality for the intended data uses (see Appendix A).

5.4.1 Overview

In accordance with USEPA guidance, the DQOs are developed after considering the intended data uses, the COCs, the detection limits to meet criteria concentrations (e.g., risk-based or regulatory standards), and analytical QA and QC requirements and documentation. DQOs for the site investigation are presented in the site-specific QAPjP in Appendix A.

5.4.2 Intended Data Uses

Phase 1 investigation analytical data collected at the Ames Street Site must be adequate for the following primary data uses:

- to characterize the soils beneath each AOC
- to compare to usage-based soil quality goals
- to evaluate groundwater quality on-site
- to compare to usage-based groundwater quality goals
- to provide useable data to conduct a risk assessment to set soil and groundwater quality site goals

5.4.3 Chemicals of Concern

The COCs identified in Section 4.0 are summarized below, and include VOCs, metals, and inorganics:

VOCs

tetrachloroethene (PCE)
TCE
1,2-dichloroethene (1,2-DCE)
1,1-dichloroethene (1,1-DCE)
1,1,1-trichloroethane (TCA)
benzene
toluene
ethylbenzene
xylenes
acetone
4-methyl-2-pentanone (methyl isobutyl ketone)
vinyl chloride

Metals and Inorganics

mercury (elemental, bioavailable, speciation)
cadmium
chromium, trivalent
chromium, hexavalent
lead
nickel
zinc
cyanide

Analytical protocols for identifying and quantifying concentrations of the above mentioned COCs meet the DQOs for this project and are presented in Section 5.4 and Appendix A.

5.4.4 Sample Quantitation Limits

Concentrations detected in the soil and groundwater samples collected as part of the Phase 1 site investigation will be compared to use-based soil and groundwater quality goals established by the Phase 1 risk assessment. Since these quality goals are not yet established, quantitation limits for Phase 1 will be determined by other existing regulatory-based soil and groundwater standards.

5.5 ANALYTICAL PROGRAM

Selection of analytical procedures to be used for this program and the required analytical deliverables were chosen to support the DQOs and to provide technically and legally defensible data.

The detailed sampling program is described in Sections 5.1 (soil) and 5.2 (groundwater), and the associated analytical methods and parameters are described in the site-specific QAPjP (Appendix A). Off-site laboratory chemical analysis will be conducted at a frequency of 5 percent of all soil samples and 10 percent of all groundwater samples provided to a laboratory certified by the New York State Department of Health.

On-site chemical analysis will be conducted at a DQO Level III (consistent with off-site analysis) for selected VOCs by USEPA SW-846 modified methods 8010/8020/8015 and mercury by USEPA SW846 modified methods 7470/7471. Off-site chemical analysis will be performed for the TCL list of SVOCs by method 8270, VOCs by methods 8240/8260, the TAL list of metals by methods 6010/7000s, cyanide by method 9010, and mercury by methods 7470/7471. A few soil samples will be submitted for special mercury analyses being conducted to assess the bioavailability of mercury in soils with respect to potential ingestion of soil . These specialized analytical method are summarized below; details of these methods are provided in the site-specific QAPjP (Appendix A of the Phase I Workplan). The analytical program is also summarized in Table A-2 in the site-specific QAPjP.

The sampling and analysis for mercury in soils will be conducted consistent with the decision tree presented in Figure 5-5. The decision tree presents a tiered approach for determining what analysis for mercury will be conducted. The approach is intended to focus mercury speciation and bioaccessibility analysis on areas where total mercury concentrations (per USEPA SW846 methods 7470/7471) are above a risk-based soil ingestion screening concentration of 200 mg/kg. Given the planned commercial future use of the property and the planned paving of virtually the entire property, ingestion exposures associated with soil concentrations below this screening level should not be a public health concern, and no further analysis will be required for samples in AOCs where concentrations are below the screening concentration.

If, however, the total mercury soil concentration at a given location is greater than the soil ingestion screening level, additional analysis will be conducted to identify and quantify the mercury species which are present. The speciation analysis will be conducted via sequential extractions, electron microprobe analysis and heavy mineral separations and identification and quantification of the various mercury species. Species to be identified and quantified will include, but not be limited to, elemental mercury, mercury oxide, acid soluble mercury (including inorganic mercury, salts), organic mercury, and mercuric sulfide. If the two sequential extraction procedures indicate clearly that only species that are non-bioavailable via ingestion (elemental mercury and/or mercury sulfides) are present in soil, the electron microprobe analysis and the heavy mineral separation techniques may

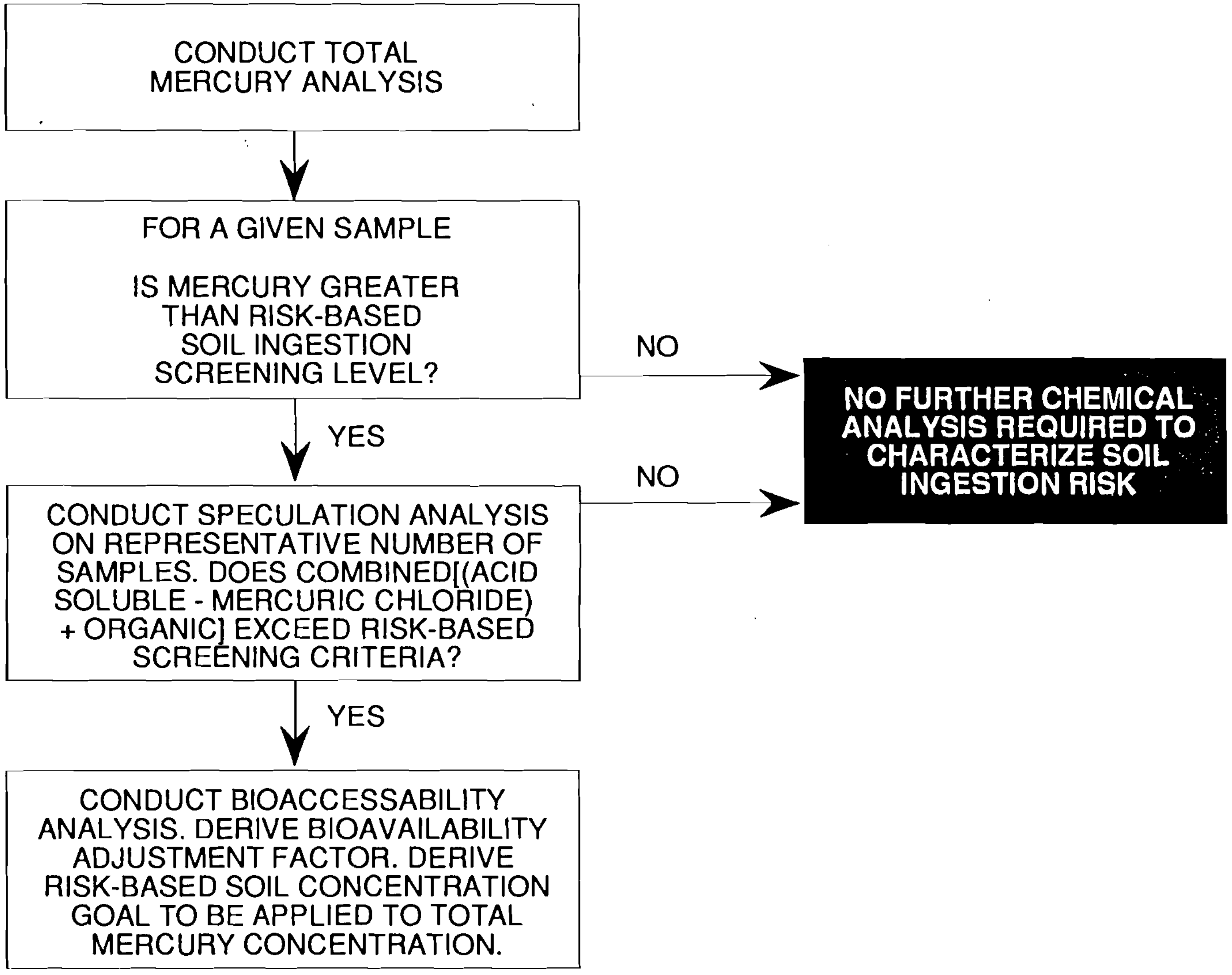

FIGURE 5-5
MERCURY SOIL ANALYSIS FLOW CHART
SITE INVESTIGATION - PHASE I
95 AMES STREET
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not be implemented. Since the literature indicates that elemental mercury and mercuric sulfide are very poorly absorbed and have very low toxicity via the oral route, if these species are the only species present , no further analysis will be required and it will be assumed that the exposure associated with ingestion of the relevant soil is not of public health concern. However, if the potentially bioavailable mercury species are present (organic mercury such as methylmercury, inorganic salts other than sulfides), then the total concentration of those species will be compared to the soil ingestion screening level. If the screening level is not exceeded, it will be assumed ingestion exposure to those soils is not of public health concern and no further analysis will be required.

If the combined organic mercury and inorganic mercury (not including sulfides or elemental mercury) exceeds the 200 mg/kg screening value, samples will be submitted for an *in Vitro* bioaccessibility test conducted in a manner similar to the test described by Ruby et al (1993). and described in Appendix J. In this test, relative bioaccessibility of mercury in soil from the property is determined relative to mercuric chloride in a water medium. The relative bioaccessibility of mercury in site soils and the mercuric chloride in water will be used to develop a bioavailability adjustment factor (BAF) which will be used to develop a site-specific mercury soil concentration goal .

5.6 DATA VALIDATION

Both off-site and on-site analytical results will undergo an evaluation to determine data usability. Details of the data validation process are included in the site-specific QAPjP (Appendix A).

6.0 PHASE 1 REPORT

Following completion of all field activities and the receipt of analytical results from the laboratory, ABB-ES will prepare a Site Investigation Phase 1 Report summarizing the data and presenting the findings.

The report will be presented in two, separately-bound volumes. Volume 1 will contain the report and Volume 2 will contain the appendices. The Site Investigation Report will include the following:

EXECUTIVE SUMMARY
1.0 PURPOSE
2.0 BACKGROUND INFORMATION
    2.1 SITE DESCRIPTION
    2.2 SITE HISTORY
    2.3 PREVIOUS INVESTIGATIONS
3.0 SCOPE OF WORK
    3.1 SOIL BORINGS
    3.2 GROUNDWATER SAMPLING
    3.3 RISK ASSESSMENT
    3.4 LABORATORY ANALYSIS AND DATA VALIDATION
4.0 SITE CHARACTERIZATION
    4.1 GEOLOGY AND HYDROGEOLOGY
        4.1.1 Geology
        4.1.2 Hydrogeology
    4.2 SUBSURFACE SOIL ANALYTICAL RESULTS
        4.2.1 Area of Concern 1
        4.2.2 Area of Concern 2
        4.2.3 Etc.
    4.3 GROUNDWATER ANALYTICAL RESULTS
5.0 RISK ASSESSMENT RESULTS
6.0 CONCLUSIONS AND RECOMMENDATIONS

REFERENCES
APPENDICES

The appendices will include the field data sheets, laboratory deliverables, and other supporting documentation.

ABB will provide five copies of the Volume 1 Draft Site Investigation Report - Phase 1 for review by NYSDEC. After incorporation of comments, ABB-ES will issue five copies of the final Site Investigation Report - Phase 1 and three copies of Volume 2 for NYSDEC.

7.0 SCHEDULE

The proposed schedule for the Ames Street Site Investigation is provided in Figure 7-1.

As shown, the on-site work will begin as soon as the Work Plan Addendum is completed. ABB-ES anticipates that the on-site work will take 25 working days to complete; however, activities included in the addendum could increase the length of this task. The final off-site laboratory data should be received within one month of the end of the on-site work. This data will not be available for use until data validation is completed (approximately two weeks after the final data package is received.

At this time, ABB-ES anticipates delivery of the draft Ames Street Site Investigation Report - Phase 1 the last week in March.

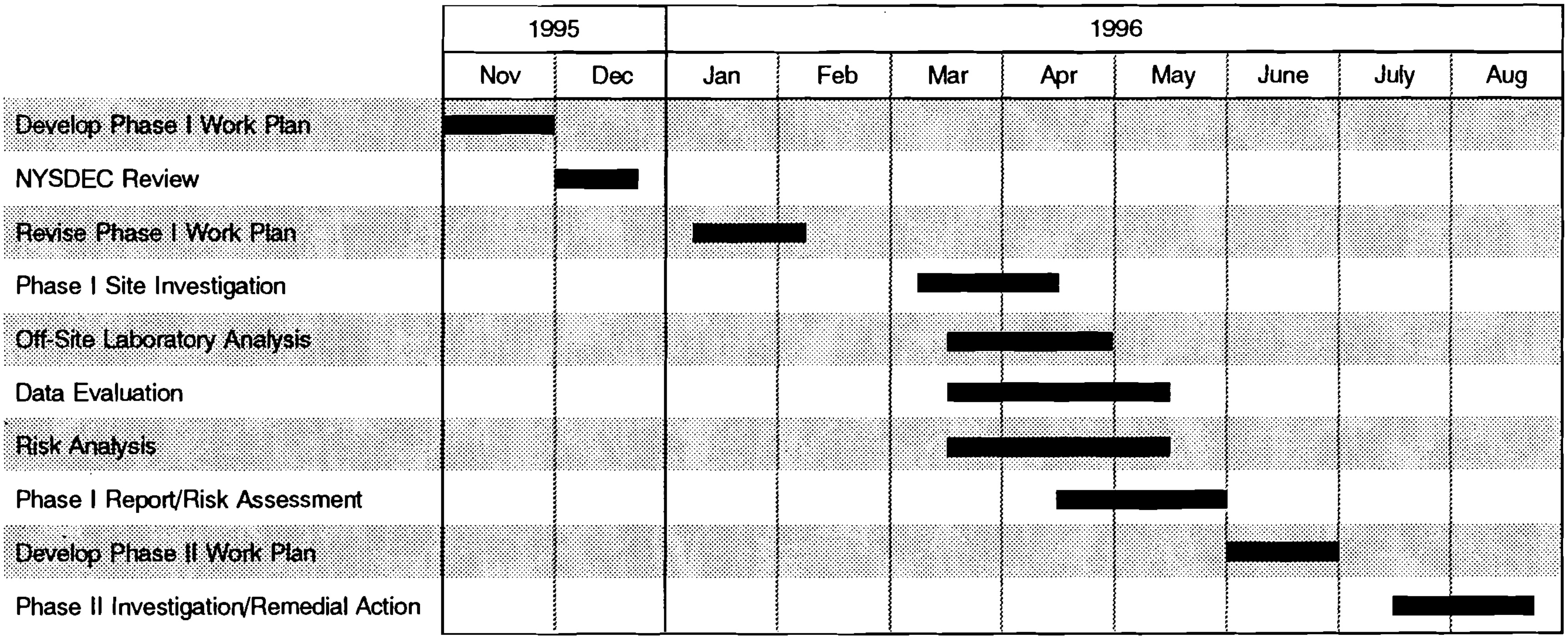

FIGURE 7-1
SCHEDULE
SITE INVESTIGATION WORK PLAN - PHASE I
95 AMES STREET
ROCHESTER, NEW YORK

ABB Environmental Services, Inc.

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Agency for Toxic Substances and Disease Registry, Toxicological profile for MERCURY, Draft, February 19, 1993

EPA Region III Risk-Based Concentration Table, January 31, 1995

Lozier Architects and Engineers, 1983. *Phase 1 Mercury Contamination*, prepared forTaylor Instrument Company.

Rickard, Lawrence V. and Donald W. Fisher, 1970. *Geologic Map of New York*, Finger Lakes Sheet.

Ruby, M.V., Davis, A., Link, T.E., Schoof, R., Chaney, R. L., Freeman, G.B., and P. Bergstrom, *Development of an in Vitro Screening Test To Evaluate the in Vivo Bioaccessibility of Ingested Mine-Waste Lead*, Environmental Science & Technology, Vol. 27, No. 13, 1993.

Williams, R.E., 1990. *Dolomite Products Company, Inc. Quarry-Gates Center, New York, Geologic Report of Proposed Operation for 1990-1993*: Dolomite Products Company, Inc., Rochester, New York, February 1990.

United States Department of the Interior Geological Survey, 1986. Water-Resources Investigation Report 86-4048, *Ground-Water Availability in the Genesee River Basin, New York and Pennsylvania*, John C. Kammerer and William A. Hobba, Junior.

ABB	Asea Brown Boveri
ABB-ES	ABB Environmental Services, Inc.
AOCs	areas of concern
BAF	Bioavailability Adjustment Factor
BTEX	benzene, toluene, ethyl benzene, and xylene
Cd	cadmium
Cr	chromium
COCs	Chemicals of Concern
CPCs	Chemicals of Potential Concern
CSFs	Cancer Slope Factors
DCE	dichloroethene
DQOs	Data Quality Objectives
HASP	Health and Safety Plan
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
IRIS	Integrated Risk Informations System
NYSDEC	New York State Department of Environmental Conservation
PCBs	poly-chlorinated biphenyls
PCE	tetrachloroethene
QA	quality assurance
QAPP	Quality Assurance Program Plan
QAPjP	Quality Assurance Project Plan
QC	quality control
RfD	Reference Dose
Sybron	Sybron Corporation
SVOCs	semivolatile organic compounds
TCA	trichloroethane
TCE	trichloroethene
TPH	total petroleum hydrocarbons

USEPA	United States Environmental Protection Agency
USTs	underground storage tanks
VOCs	volatile organic compounds

APPENDIX A

SITE-SPECIFIC QUALITY ASSURANCE PROJECT PLAN

ATTACHMENTS:

1 - Low Flow Standard Operating Procedures
2 - Clean Hands Sampling
3 - ABB-ES' Standard Operating Procedure No. FGC00202
4 - ABB-ES' Standard Operating Procedure No. FXRFS00102
5 - Mercury Analyzer Manufacturer Documentation
6 - Bioavailability Reference

QUALITY ASSURANCE PROJECT PLAN
AMES STREET SITE INVESTIGATION - PHASE 1

This site-specific Quality Assurance Project Plan (QAPjP) is designed to identify the sections of the "Draft Quality Assurance Program Plan (QAPP), NYSDEC Superfund Standby Contract, Contract Number D002472" (ABB-ES, 1995) that apply to the activities described in the Site Investigation Work Plan - Phase 1. This QAPjP will also describe any variations to those procedures, and specify the analytical data quality objectives (DQOs) for the site and associated analytical methods used for the laboratory analysis of environmental samples.

Project Organization. Figure A-1 presents the Ames Street Site Investigation project team organization. Roles and responsibilities of personnel are those described in the QAPP.

General Procedures and Practices. The general procedures used to conduct the site investigation at the Ames Street Site will be taken from the following sections of the QAPP:

Section 5.0	Sample Custody
Section 6.0	Calibration Procedures
Section 9.0	Internal Quality Control
Section 10.0	Audits
Section 11.0	Preventive Maintenance
Section 12.0	Data Assessment
Section 13.0	Corrective Action

Field Procedures and Sampling. The following field investigation tasks and associated procedures set forth in Section 4.0 of the QAPP will be used at the Ames Street Site.

Subsection 4.1	Sample Labels and Records
Subsection 4.2	Sample Container and Preservation Requirements
Subsection 4.3	Decontamination Procedures
Subsection 4.4.3	Exploratory Drilling
Subsection 4.5.1	General Soil Sampling Methodology
Subsection 4.5.2.2	Groundwater Sampling (using the Low-Flow sampling technique described below)
Subsection 4.6	TerraProbe/Field Laboratory Analysis
Subsection 4.9	Surveys
Subsection 4.10	Management of Investigation-Derived Wastes

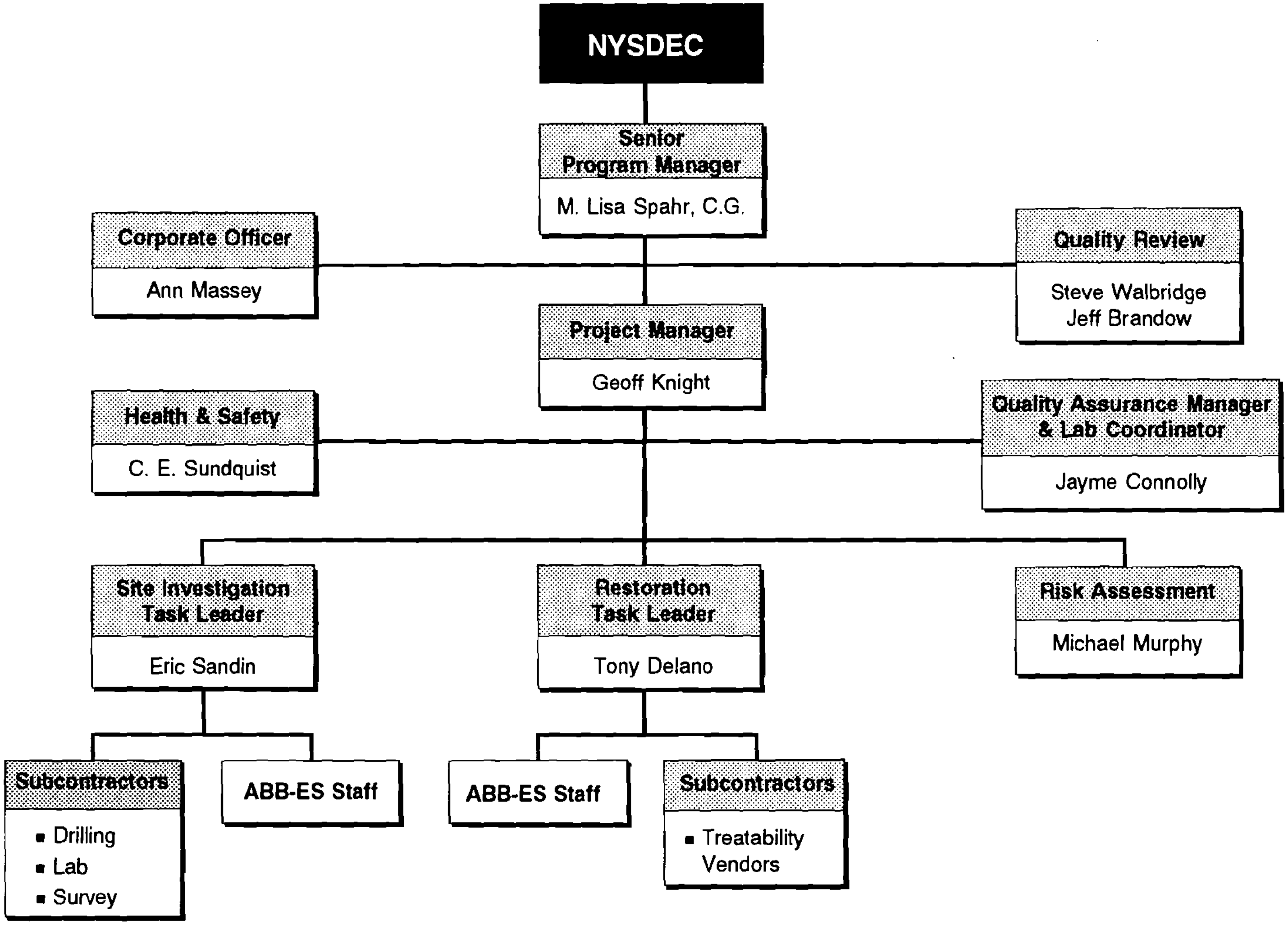


FIGURE A-1
ORGANIZATION CHART
SITE INVESTIGATION - PHASE 1
95 AMES STREET
ROCHESTER, NEW YORK

W9511025D

Low Flow Sampling Technique. The objective of the low flow sampling procedure is the same as the standard groundwater sampling procedure: to collect representative groundwater samples for chemical analysis. Low flow is specifically designed to minimize disturbance of the water column in the well and minimize the stress on the aquifer and drawdown inside the well. Purging and sampling is conducted at low rates (e.g., 0.2 to 0.5 liters per minute) with pump intakes located in the well screen zone in an effort to minimize the entrainment of solids (e.g., silt, clay, and colloids) and minimize mixing of the standing water column inside the well with water from the aquifer.

Bladder pumps approved by USEPA Region I for sampling VOCs will be used, and all sample vessels are filled directly from the pump, eliminating the use of bailers.

The low flow procedure outlined below is based upon the USEPA Region I Draft Final Low Flow SOP, GW 0001 dated August 10, 1994 (Attachment 1), and discussions with the Region I Hydrogeologist. The procedure is limited in scope to purging the well up to the time at which samples are ready to be collected. The procedure for filling sample vessels is covered in the standard groundwater sampling procedure, described in the QAPP.

1) Open the well and measure the depth to water through the opening in the well cap to the nearest 0.01 feet. Leave the probe in the well just out of the water.

2) Hook the pressurized gas line from the control box to the quick connect on the well cap and begin purging. Adjust the pump settings to control the discharge between 0.2 and 0.5 liters per minute. The low end of this range is preferred to minimize turbidity and drawdown.

3) When the discharge rate is stable, record the flow rate and begin measuring and recording time, water level, temperature, pH, specific conductance, dissolved oxygen and turbidity every three to five minutes.

4) Parameters are considered stable when the water level has stabilized within +/- 0.1 foot, temperature, specific conductance, and dissolved oxygen have stabilized to within +/- 10 percent, pH has stabilized to within +/- 0.2 pH units, and turbidity is less than or equal to 10 NTU or stable to within +/- 10 percent if 10 NTU does not appear to be achievable.

5) Purging is complete when parameters are stable as in item 4, and if the volume of water removed due to drawdown is less than 0.3 of the total volume removed during the course of purging the well. If the drawdown volume exceeds 0.3 of the total volume, continue purging until this ratio decreases to less than 0.3, continuing to record all parameters every three to five minutes to assure the stability criteria are still met.

6) Collect samples directly into sample vessels from the pump discharge. When all vessels are filled, shut off the pump and record the time and the total volume purged from the well. Remove the water level probe and disconnect the pressurized gas line. Close and secure the well.

Clean-Hands Sampling Technique. This SOP for collecting water samples for mercury analysis may be followed when performing groundwater sample collection. The technique employs two people, one designated as the "clean-hands person" and the other designated as the "dirty-hands person". This SOP is included as Attachment 2.

Sampling and Analysis Program. The results of the DQO analysis for the Ames Street Site sampling activities are summarized in Table A-1. The analytical data requirements were established using methods described in "Test Methods for Evaluating Solid Waste" (USEPA, 1992). The analytical methods to be used for both on-site and off-site analysis are presented in Table A-2.

On-site volatile organic analysis compound (VOC) analysis will be in accordance with ABB-ES' Standard Operating Procedure No. FGCPT00202, dated 4/14/93 (see Attachment 3). Analysis for VOCs will be performed using a gas chromatograph (GC) equipped with three detectors in series. A photoionization detector (PID) will be used for the identification of selected volatile aromatics, a flame ionization detector (FID) will be used for the non-halogenated volatiles (ketones), and a electrolytic conductivity detector (ELCD) will be used for the identification of the selected halogenated volatiles. The GC will be connected to a purge and trap (P&T) device for sample preparation and instrument delivery. The approximate reporting limits for the selected VOCs are provided in Table A-3. Actual method detection limits will be determined on site at the start of the field program. All quality control protocols described in the SOP will be included as part of the on-site laboratory program so that Level III analytical data quality is achieved. Quality control protocols include routine calibration, method blanks, surrogate standards, matrix spike/matrix spike duplicate samples, laboratory duplicate samples.

Soil samples to be analyzed for mercury will be first analyzed for gross mercury contamination using x-ray fluorescence (XRF). Analytical procedures will be inaccordance with ABB-ES' Standard Operating Procedure No. FXRFS00102 (see Attachment 4). The reporting limit is expected to be approximately 100 mg/kg.

Soil samples with mercury concentrations at or below the reporting limit requiring characterization to levels below 100mg/kg and all groundwater samples will be analyzed analyzed in accordance with instrument manufacturer documentation (provided in Attachment 5) for sample preparation and delivery combined with the cold vapor atomic absorption (CVAA) Method 7470/7471. A Leeman Lab's Automated Mercury Analyzer will be connected to a tabletop atomic absorption (AA) in the field laboratory. The Leeman Mercury Analyzer performs sample preparation and digestion followed by sample introduction to the AA. The reporting limit is expected to be at least 0.1 parts per million

TABLE A-1

ANALYTICAL DATA QUALITY OBJECTIVE LEVELS
AMES STREET SITE INVESTIGATION WORK PLAN - PHASE 1

PARAMETER	USE	DATA QUALITY LEVEL
pH, turbidity, temperature, specific conductivity	To provide background physical data on liquid and groundwater samples.	Level I
PID screening Mercury vapor analyzer screening	To provide qualitative real-time information on air quality in the breathing zone for health and safety decisions and to identify potential contaminated materials.	Level I
On-Site and Off-site VOCs, metals, and Inorganics Surface Soil/Soil Boring/Groundwater Samples	To provide analytical information to evaluate the presence and concentration of organic and inorganic compounds in site media, and compare to applicable state and federal soil quality guidance values.	Level III
Off-site Mercury Speciation/ Bioavailability	To provide analytical data to evaluate mercury speciation and bioaccessibility for risk assessment soil goal.	Level V

NOTES:

Level I:	Qualitative information generated on-site using portable equipment for identification of sampling locations and health and safety monitoring.
Level III:	These data represent laboratory information generated using USEPA-approved procedures, but using methods other than Contract Laboratory Program protocols. These data are both qualitative and quantitative and are used for site characterization, risk assessment, and engineering studies.
Level V:	These data represent fixed base laboratory analysis results using non-standard methods that require development for specific constituents and/or detection limits. Data obtained from these analyses are often used for risk assessment purposes.

TABLE A-2

ANALYTICAL PROGRAM
AMES STREET SITE INVESTIGATION WORK PLAN - PHASE 1

MEDIA & PROGRAM	PARAMETER	METHOD[1]
Soil - On-Site Analysis[2]	Selected VOCs[3] Mercury	8010/8015/8020 - Modified 7471 - Modified X-ray fluorescence
Groundwater - On-Site[2] Analysis	Selected VOCs[3] Mercury	8010/8015/8020 - Modified 7470 - Modified
Soil & Groundwater Off-Site Analysis[4]	TCL SVOCs TCL VOCs Mercury TAL Metals Cyanide Lead	8270 8240/8260 7471/7470 6010/7000s 9010 7421/7420
Special Hg-ingestion Analysis	Mercury	Special Method[5]

NOTES:

1 USEPA, 1986. "Test Methods for Evaluating Solid Waste", SW-846, Third Edition with revisions.

2 On-Site analysis includes adherence to all quality control protocols described in ABB-ES' SOP for "Purge and Trap Analysis of Volatile Organic Compounds by Field Gas Chromatography" SOP No. FGCPT00202, 4/14/93. On-site mercury analysis follows manufacturer's recommendations and methods stated above. (See Appendix A).

3 Selected VOCs include: tetrachloroethene (PCE); trichloroethene (TCE); 1,1-dichloroethene; 1,2-dichloroethene; 1,1,1-trichloroethane; benzene; toluene; ethylbenzene; xylenes; acetone; 4-methyl-2-pentanone.

4 Off-site split-sample analysis being conducted at a frequency of 5 percent for soil samples and 10 percent for groundwater samples. Analysis to be conducted at a New York State Department of Health certified laboratory.

5 Special Hg-ingestion method being performed for risk assessment purposes. Refer to section 5.5 of text for brief explanation of analyses.

TABLE A-3

CHEMICAL OF CONCERN QUANTITATION LEVELS FOR SOIL AMES STREET SITE INVESTIGATION WORK PLAN - PHASE 1

Parameter	Analytes	Estimated Instrumental Quantitation Level	Field Lab Detection Limit (maximum)	TAGM Recommended Soil Cleanup Objectives [1]
VOCs	Tetrachloroethene	5 μg/kg	10 μg/kg	1,400 μg/kg
	Trichloroethene	5 μg/kg	10 μg/kg	700 μg/kg
	1,1-Dichloroethene	5 μg/kg	10 μg/kg	200 μg/kg
	1,2-Dichloroethene	5 μg/kg	10 μg/kg	100 μg/kg
	1,1,1-Trichloroethane	5 μg/kg	10 μg/kg	800 μg/kg
	Benzene	5 μg/kg	10 μg/kg	60 μg/kg
	Toluene	5 μg/kg	10 μg/kg	1,500 μg/kg
	Ethyl benzene	5 μg/kg	10 μg/kg	5,500 μg/kg
	Xylenes	5 μg/kg	10 μg/kg	1,200 μg/kg
	Acetone	5 μg/kg	10 μg/kg	200 μg/kg
	4-Methyl-2-pentanone	5 μg/kg	10 μg/kg	1,000 μg/kg
	Vinyl chloride	5 μg/kg	20 μg/kg	200 μg/kg
Metals	Mercury	0.2 μg/kg	NA	100 μg/kg
	Cadmium	42 μg/kg	NA	1,000 μg/kg
	Chromium (total)	7 μg/kg	NA	10,000 μg/kg
	Lead	42 μg/kg	NA	30,000 μg/kg
	Zinc	2 μg/kg	NA	20,000 μg/kg
	Nickel	15 μg/kg	NA	13,000 μg/kg
Other	Cyanide	1,000 μg/kg	NA	Not available

[1] New York State Department of Environmental Conservation, TAGM, "Determination of Soil Cleanup Objectives and Cleanup Levels"; November 16, 1992.

(ppm) for soil samples and 0.002 ppm for water samples. Quality control protocols include routine instrument calibration, method blanks, matrix spike samples, and laboratory duplicate samples.

On-site soil and groundwater analytical results will be verified by collecting and submitting split samples to an off-site New York State Department of Health-certified laboratory at a frequency of 5 and 10 percent, respectively. Split samples for groundwater collection is being done at a higher frequency due to the limited number of total groundwater samples planned for collection.

Off-site analyses for routine analysis (VOCs, metals, cyanide, elemental mercury) will be performed by a New York Department of Health certified laboratory using method protocols described in USEPA SW-846 (USEPA, 1992).

Soil samples may also be submitted for mercury speciation and bioavailability testing if the total mercury results are greater than the to-be-determined risk-based screening level. The bioavailability testing is similar to that described by Ruby, et.al. (1993). A copy of the bioavailability testing article (Ruby, 1993) is provided in Attachment 6.

Data Reduction, Validation, and Reporting. Both off-site and on-site analytical results will undergo an evaluation to determine data usability. This evaluation will include the following:

- blank contamination to determine potential for laboratory and/or field sampling contamination
- surrogate standard recoveries for organic analyses for analytical accuracy
- field duplicates to assess sampling precision and environmental matrix heterogeneity
- matrix spike/matrix spike duplicate sample results for analytical precision and accuracy, and to assess any potential for matrix interferences
- initial and continuing calibration for on-site analyses only to assess analytical precision and accuracy

Once the data have been reviewed by a chemist, data flags may be determined appropriate to qualify the data before use. All data, unless rejected during data evaluation, will be used for making decisions. As such, both on-site and off-site analytical data will be generated at DQO Levels III and V.

Data generated in the field will be available to the project team on a real-time basis for decision making. The analytical data from the on-site laboratory are generated using existing software that produces text-formatting output from the GC and AA. The data are then converted into database-formatted files using ABB-ES-developed software. This reformatting allows for initial editing and evaluation of the data. Data are both reviewed by the site and project chemists before results are considered “final”. Preliminary (unevaluated) data are available real time and will be used for interpretive purposes.

The data management program proposed for this site investigation is intended to provide an efficient and cost effective method for production and interpretation of data as it is obtained in the field. This program includes procedures that will ensure consistency and validity of the data generated and interpreted.

Sample Identification. Sample identification will adhere to Section 4.1.1 of the QAPP with the following exceptions:

Digits 1,2	All sample identification will be begin with the AOC number (e.g., 01, 02) for soil samples and “KT” for non-AOC related samples, such as groundwater samples.
Digits 11,12	The event number will be the year the samples are collected (96).

ATTACHMENT 1

LOW FLOW STANDARD OPERATING PROCEDURE

OPTIONAL FORM 99 (7-90)

FAX TRANSMITTAL

# of pages ► 6

To Nate Hagelin	From Dick Willey
Dept./Agency ABB	Phone # 617-573-9859
Fax # 207-772-4762	Fax #

NSN 7540-01-317-7368 5099-101 GENERAL SERVICES ADMINISTRATION

SOP #: GW 0001
Region I Low Flow SOP
Revision Number: 0
Date: August 10, 1994
Page 1 of 6

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION I

GROUND WATER SAMPLING PROCEDURE
LOW FLOW PURGE AND SAMPLING

DRAFT FINAL

I. SCOPE & APPLICATION

The purpose of this standard operating procedure (SOP) is to provide information on collecting ground water samples using a pump. The procedure will in most situations provide for the collection of ground water samples with minimum turbidity. This procedure is designed to be used in conjunction with the analyses for the most common types of ground water contaminants (volatile and semi-volatile organic compounds, pesticides, PCBs, metals and inorganic compounds).

II. EQUIPMENT

- Adjustable rate, positive displacement pumps (e.g., centrifugal or bladder pumps constructed of stainless steel or Teflon). Peristaltic pumps may be used only for inorganic sample collection.
- Clear plastic bottom filling bailer may be used to obtain samples of light or dense non-aqueous liquids (LNAPL, DNAPL).
- Tubing - Teflon or Teflon lined polyethylene must be used to collect samples for organic analysis. For samples collected for inorganic analysis, Teflon or Teflon lined polyethylene, PVC, Tygon or polyethylene tubing may be used.
- Water level measuring device, 0.01 foot accuracy, (electronic preferred for tracking water level drawdown during all pumping operations).
- Flow measurement supplies (e.g., graduated cylinder and stop watch).
- Interface probe, if needed.

Use of trademarked names does not imply endorsement by U.S. EPA but is intended only to assist in identification of a specific product.

- Power source (generator, nitrogen tank, etc.).
- Indicator parameter monitoring instruments - pH, turbidity, specific conductance, and temperature. Optional Indicators - eH and dissolved oxygen.
- Decontamination supplies.
- Logbook(s).
- Sample Bottles.
- Sample preservation supplies (as required by the analytical methods).
- Sample tags or labels.
- Well construction data, location map, field data from last sampling event.
- Field Sampling Plan.

III. PRELIMINARY SITE ACTIVITIES

- Check well for damage or evidence of tampering, record pertinent observations.
- Lay out sheet of polyethylene for monitoring and sampling equipment.
- Remove well cap.
- Measure VOCs (volatile organic compounds) at the rim of the well with a PID or FID instrument and record the reading in the field logbook.
- If the well casing does not have a reference point (usually a V-cut or indelible mark in the well casing), make one.
- Measure and record the depth to water (to 0.01 ft) in all wells to be sampled before any purging begins. Care should be taken to minimize disturbance of any particulate attached to the sides or at the bottom of the well.
- Measure and record (as appropriate) the depth of any DNAPL's or LNAPL's with an interface probe. Care should be given to minimize disturbance of any sediment which has accumulated at the bottom of the well. If LNAPL's or DNAPL's are present, a decision needs to be made on whether to collect samples of the free phase liquid(s) and/or the dissolved phase.

IV. SAMPLING PROCEDURE

A positive displacement type pump will be used to purge and sample monitoring wells which have a 2.0 inch I.D. or greater well casing.

Pump, safety cable, tubing and electrical lines will be lowered slowly into the well to a depth corresponding to the center of the saturated screen section of the well. It is also advisable to keep the pump intake at least two feet above the bottom of the well, to prevent mobilization of any sediment present in the bottom of the well.

Measure the water level again with the pump in well before starting the pump. Start pumping the well at 0.2 to 0.5 liters per minute. Ideally, the pump rate should cause little or no water level drawdown in the well (less than 0.3 ft. and the water level should stabilize). The water level should be monitored every three to five minutes (or as appropriate) during pumping. Care should be taken not to cause pump suction to be broken, or entrainment of air in the sample. Record pumping rate adjustments and depths to water. Pumping rates should, if needed, be reduced to the minimum capabilities of the pump (e.g., 0.1 - 0.2 l/min) to avoid pumping the well dry and/or to ensure stabilization of indicator parameters. If the recharge rate of the well is very low and the well is purged dry, then sampling shall commence as soon as the well has recharged to a sufficient level to collect the appropriate volume of samples with the pump.

During purging of the well, monitor the field indicator parameters (turbidity, temperature, specific conductance, pH, etc.) every three to five minutes (or as appropriate). The well is considered stabilized and ready for sample collection once all the field indicator parameter values remain within 10% for three consecutive readings. If the parameters have stabilized, but the turbidity is not in the range of the 5 NTU goal the pump flow rate should be decreased, and measurement of the parameters should continue every three to five minutes. Measurements should be obtained using a flow through cell (preferred method) or taken in a clean container (a glass beaker is ideal).

VOCs samples will be collected first and directly into pre-preserved sample containers. All sample containers should be filled by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

Samples requiring pH adjustment will have their pH checked to assure that the proper pH has been obtained. For VOC samples, this will require that a test sample be collected to determine the amount of preservative that needs to be added to the sample containers prior to sampling.

If filtered metal samples are to be collected, the use of an in-line filter is preferred. A high pressure, in-line 0.45 um particulate filter will be pre-rinsed with approximately 400 ml of deionized water and attached to the discharge end of the pump's tubing. After the sample is filtered, it must be preserved immediately.

As each sample is collected, the sample will be labeled. Those samples (volatile organics, cyanide, etc.) requiring cooling will be placed into an ice cooler for delivery to the laboratory. Metal samples after acidification to a pH less than 2 do not need to be cooled.

After collection of the samples, the pump's tubing may either be dedicated to the well for resampling (by hanging the tubing inside the well), decontaminated or properly discarded.

Measure and record well depth.

Secure the well.

V. DECONTAMINATION

Sampling equipment will be decontaminated prior to use and following sampling of each well. Pumps will not be removed between purging and sampling operations. The pump and tubing (including support cable and electrical wires which are in contact with the sample) will be decontaminated by one of the procedures listed below. Alternative procedures must be approved by the Quality Assurance Office prior to sampling event.

Procedure 1

- Steam clean the outside of the submersible pump.
- Pump hot water from the steam cleaner through the inside of the pump. This can be accomplished by placing the pump inside a three or four inch diameter PVC pipe with end cap. Hot water from the steam cleaner jet will be directed inside the PVC pipe and the pump exterior will be cleaned. The hot water from the steam cleaner will then be pumped from the PVC pipe through the pump and collected into another container. Note: additives or solutions should not be added to the steam cleaner.
- Pump five gallons of non-phosphate detergent solution through the inside of the pump.
- Pump tap water through the inside of the pump to remove all of the detergent solution.

- Pump distilled/deionized water through the pump.

Procedure 2

- The decontaminating solutions can be either be pumped from buckets through the pump or the pump can be disassembled and flushed with the decontaminating solutions. It is recommended that detergent and isopropyl alcohol used in the decontamination process be used sparingly and water flushing steps be extended to ensure that any sediment trapped in the pump is flushed out. The outside of the pump and the electrical wires must be rinsed with the decontaminating solutions, as well. The procedure is as follows:

- Flush the equipment/pump with potable water.

- Flush with non-phosphate detergent solution (five gallons).

- Flush with tap water to remove all of the detergent solution.

- Flush with distilled/deionized water.

- Flush with isopropyl alcohol.

- Flush with distilled/deionized water.

VI. FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not affected the quality of the ground water samples. All field quality control samples must be prepared exactly as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples will be collected for each batch of samples (a batch may not exceed 20 samples). Trip blanks are required for the VOC samples at frequency of one per sample cooler.

- Field duplicate.

- Matrix spike.

- Matrix spike duplicate.

- Equipment blank.

- Trip blank (VOCs)

VII. FIELD LOGBOOK

A field log must be kept each time ground water monitoring activities are conducted in the field. The field logbook should document the following:

- Well identification.
- Well depth, and measurement technique.
- Static water level depth, date, time and measurement technique.
- Presence and thickness of immiscible liquid layers and detection method.
- Collection method for immiscible liquid layers.
- Pumping rate, drawdown, indicator parameters values, and clock time, at three to five minute intervals; calculate or measure total volume pumped.
- Well sampling sequence and time of sample collection.
- Types of sample bottles used and sample identification numbers.
- Preservatives used.
- Parameters requested for analysis.
- Field observations of sampling event.
- Name of sample collector(s).
- Weather conditions.
- QA/QC data for field instruments.

ATTACHMENT 2

CLEAN HANDS SAMPLING STANDARD OPERATING PROCEDURE

STANDARD OPERATING PROCEDURE

CLEAN-HANDS TECHNIQUE (FOR WATER SAMPLING OF MERCURY)
SOP-72

The concentration of many metals in ambient waters is typically very low, and collecting water samples that are representative of ambient conditions requires extreme care to prevent contamination during handling. This SOP outlines procedures for collecting water samples to be analyzed for mercury and its various forms. Water samples are more prone to be contaminated with mercury than other metals and require that specialized clean techniques be used. This SOP is based on a technique used by the University of Wisconsin Trout Lake Station. The following technique is commonly called the "clean-hands technique." It employs two people, one designated as the "clean-hands person" and the other designated as the "dirty-hands person."

INITIAL STEPS AND PRECAUTIONS

Prior to collecting a water sample, the following steps or precautions must be taken to avoid sample contamination:

1. Prior to collecting the sample or handling the sampling equipment or sample bottles, a quick survey of the sampling area should be performed to identify sources of potential contamination to the sample (e.g., sources of dust, engines running, batteries). If there is an obvious source, it should be removed, cleaned, or isolated from the sample handling area.

2. Both the clean-hands and dirty-hands persons will wear lint-free suits that reduce the amount of airborne dust in the immediate vicinity of the sample. These suits can be made of nylon, Tyvek, or a plastic-coated material (e.g., Saranex). These suits should be kept isolated from dust and contamination (in plastic bags) until ready for use and discarded after they have been used once. Avoid bumping into potentially contaminated surfaces.

   Two types of gloves will be used, an inner polyethylene glove and an outer vinyl glove. The inner polyethylene gloves are shoulder length. These gloves provide the first level of isolation (they are relatively clean compared to bare hands) and allow the sampler to put on the outer gloves without significantly contaminating them. These gloves should be taped to the shoulder of the suit or rubber-banded at the upper arm to prevent them from sliding down while working. The vinyl gloves are powder-free, clean-room gloves (e.g., Oak Class 100, powder-free). These gloves come in vacuum-sealed plastic bags containing 50 pairs. Once opened, the entire pack is potentially exposed to contamination. To minimize this potential, open only the end of the bag at the wrist end of the glove (not the fingertip end), and remove only one pair at a time. Keep the unused gloves in the original bag inside of a large Ziploc® bag. When handling the clean gloves, do not touch the fingertips: handle the gloves only around the wrist.

3. At all times, the clean-hands person must avoid touching surfaces that are not known to be clean, including their suit. The clean-hands person should only touch the inner bag and the sample bottle used during sample collection. While sampling, both samplers must be conscious of the potential chains of contamination that can occur. A chain of contamination could involve handling an object that touched another object that touched something contaminated. Unless it is known whether an object is clean (i.e., was cleaned appropriately and isolated from contaminants from the time of cleaning until the time of use), it should be assumed that it is dirty.

SAMPLE COLLECTION PROCEDURE

After the initial steps have been taken, the clean-hands person and the dirty-hands person will use the following procedure to collect the samples:

1. To retrieve the sample bottle, the dirty-hands person will remove the double-bagged bottle from the ice chest and open the outer bag. While the dirty-hands person is holding the outer bag open, the clean-hands person will reach inside, lift the inner bag (but not remove it), open it, remove the sample bottle, and push the inner bag back down inside the outer bag. The dirty-hands person will close the outer bag. See Consideration 1 below.

2. While the clean-hands person holds the bottle, the dirty-hands person will use pliers to loosen the cap on the bottle. See Consideration 2 below.

3. The clean-hands person will remove the cap and, while filling the bottle, will hold the cap in the upright position so that particles cannot land inside the cap. If the cap must be set down, lay down a clean vinyl glove and place the cap upright on it.

4. While the clean-hands person is filling the sample bottle, the dirty-hands person will keep the outer bag closed and prepare the sample tag. When the sample bottle is full, the clean-hands person will replace the cap and the dirty-hands person will use pliers to do the final tightening of the cap.

5. The dirty-hands person will open the outer bag, and the clean-hands person will reach inside, lift the inner bag, place the bottle in the inner bag, and

seal it. Before lowering the bagged bottle into the outer bag, the dirty-hands person will place the sample tag on the inner bag. The clean-hands person will then lower the inner bag into the outer bag, and the dirty-hands person will close the outer bag and place the bagged bottle in the ice chest.

ADDITIONAL CONSIDERATIONS

1. Sample bottles for mercury are made of FEP Teflon® and are double-bagged in Ziploc® bags. Because labels do not stick to Teflon®, each sample bottle has a unique identifier etched on the outside. It is assumed that the exterior of the outer bag is contaminated and that its contents are clean. Therefore, only the dirty-hands person is allowed to handle the outer bag, and only the clean-hands person its contents.
2. It is common for the caps on Teflon® bottles not to seal well, and they will frequently leak if tightened only by hand. Procedures used at the University of Wisconsin Trout Lake Station call for using pliers to tighten the cap. However, the pliers can be another source of metal contamination, and, if possible, should be avoided. If pliers are necessary, put them inside a couple of pairs of gloves to keep metal from contacting the bottle. Avoid tearing the gloves. For larger bottles, the cap diameter is large enough to get a good grip on it, and tightening can be done by hand. For sample bottles with small caps, pliers should be used.
3. Rain has elevated concentrations of mercury relative to most surface water samples and may contaminate a sample. Sampling in the rain should be avoided. If it is necessary to sample in the rain, be careful that rain that contacts surfaces does not get into the sample bottle (e.g., rain that contacts the suit does not splash into or run down your sleeve into the bottle).
4. If there is any question as to whether gloves are clean, change gloves.

ATTACHMENT 3

ABB-ES' STANDARD OPERATING PROCEDURE NO. FGCP00202

STANDARD OPERATING PROCEDURE

Author: Advanced Technology Team
Reviewed by:

Issuing Unit: ABB-ES
SOP No.: FGCPT00202
Date: 04/14/93

SENIOR CHEMIST
(Name & Title)
(Functional Area)

Approved by:
Team Leader
(Name & Title)
(Functional Area)

TITLE: Purge and Trap Analysis of Volatile Organic Compounds by Field Gas Chromatography

PURPOSE: To establish standard operating protocols for the analysis of Volatile Organic Compounds by Purge and Trap Field Gas Chromatography (GC).

SCOPE: This procedure describes the preparation and analysis of soil and water samples for Volatile Organic Compounds using Purge and Trap concentration followed by GC analysis.

REQUIREMENTS: Requirements for the method include either a fully operational Purge and Trap/GC system or the ability to assemble one shipped from the vendor. The SOP also requires that the operator understand basic GC operation (e.g., troubleshooting, data handling systems, interferences, etc.) and have familiarity with the operation of Purge and Trap concentration devices.

The critical components needed for the assembly and operation of the Purge and Trap/GC system are listed. Additional items such as syringes, glassware, ventilation hoods, etc. are not included as they pertain to general GC operation and set-up.

Purge & Trap Device. A Tekmar LSC 2000 or equivalent is recommended for most applications. The Purge and Trap (P&T) is a concentration device for volatiles in both soil and water. A sparger vessel, a removable glass tube, is used to hold either the water or soil sample. A polymer trap is used to trap the volatiles as they are purged from the sample. After the volatiles are purged from the sample, the trap is flash heated and the volatiles are transferred to the GC for separation, identification, and quantitation.

Purge & Trap Run Conditions. Run conditions may be altered in project specific work plans, however, the following settings are recommended for most operations.

- Polymer trap: Supelco (# 3) or as required by the project.
- Purge pressure: 30 psi ± 5 psi.
- Purge: 6 minutes at 30 mL/minute ± 5 mL/minute with a temperature of < 40°C.
- Desorb: 3 minutes at 220°C.
- Bake: 5 minutes at 225°C.
- Mount temperature: off.
- Line and valve temperatures: 180°C.
- Bake gas delay: on for 2 minutes.

Gas Chromatograph. A wide range of temperature programmable gas chromatographs may be used for this method. For most field operations a Hewlett Packard 5890 Series II (or equivalent) temperature programmable GC is recommended. The instrument is durable, easy to assemble, and uses keypad input for operation.

GC Run Conditions. Run conditions may be altered in project specific work plans, however, the following settings are recommended for most operations (e.g., fuels: benzene, toluene, ethylbenzene, xylenes; solvents: VC, DCE, TCE, PCE, etc.)

- Carrier gas: Helium at 99.999% purity with a flow of 10 mL/minute ± 2 mL/minute.
- Injector temperature: 225°C.
- Initial temperature: 40°C.
- Rate: 8°C/minute.
- Final temperature: 180°C.
- Final time: 0 to 15 minutes depending on the retention time of the final peak.

Columns. A number of columns are available for volatile analysis, however, unless otherwise stated in a project specific work plan a DB-624 0.53mm ID megabore column or equivalent will be used. The column may be 30, 60, 75, or 120 meters in length as long as the information is recorded.

Detectors. A variety range of detectors are available for GC operation and specific compound detection. The appropriate selection of detectors is project specific and depends on the project objectives and Data Quality Objectives (DQO's) of the program.

Electron Capture Detector (ECD):

- o Make-up Gas: Helium at 99.999% purity with a flow of 35 mL/minute ± 5 mL/minute.
- o Ionization Gas: Ultra-pure P-5 (95% Argon, 5% Methane) or nitrogen with a flow of 35 mL/minute ± 5 mL/minute.
- o Detector Temperature: 325°C.
- o Special Requirements: Set GC switch to either the argon-methane or nitrogen mode.

Flame Ionization Detector (FID):

- o Make-up Gas: Helium at 99.999% purity with a flow of 35 mL/minute ± 5 mL/minute.
- o Combustion Gases: hydrogen at 99.999% purity with a flow of 25 mL/minute ± 5 mL/minute and 0.1 grade air with a flow of 400 ± 150 mL/minute.
- o Detector Temperature: 275°C.

Electrolytic Conductivity Detector (ELCD):

- Make-up Gas: Helium at 99.999% purity with a flow of 35 mL/minute ± 5 mL/minute.
- Combustion Gases: Hydrogen at 99.999% purity with a flow of 100 mL/minute ± 20 mL/minute.
- Reactor Temperature: 900°C ± 25°C.
- Solvent Flow: n-Propanol flow at 35% ± 5%, this is equivalent to 3.5 turns ± 0.5 turns.

Photoionization Detector (PID):

- Make-up Gas: Helium at 99.999% purity with a flow of 35 mL/minute ± 5 mL/minute.
- Detector Temperature: 275°C.
- Special Requirements: The operating range of the lamp is a power setting between 1 and 10 with normal operation at 5.

PROCEDURE: The procedure can be broken down into nine categories: conventions, calibration, blanks, sample preparation, analysis, identification, quantification, quality control, and reporting.

Conventions. Conventions are established to ensure that documentation and analysis are performed in a consistent manner from operator to operator and project to project. Conventions are established for coding standards, recording logbook entries, performing calculations, and analyzing quality control samples.

Stock Standards. Stock chemical standards will be purchased from Supelco, Inc., Chem Service, Inc., or an equivalent supplier. All standard information will be logged in a bound logbook with the pages sequentially numbered. This information will include, at a minimum:

- o Vendor name supplying standards.
- o Name and concentration of the standard (this can be done by attaching the label from the standard to the logbook).
- o Lot number of the standard.
- o Expiration date of the standard, if listed.

Working Standards. Working chemical standards may either be purchased through an approved vendor or prepared from stock standards. Working standards will be made by diluting neat or prepared stock standards. For standards made from neat solutions, the compound density or weight will be used in calculating the appropriate amount of compound and solvent to be combined. All working standards will be labeled with an identification code (see below), compound or mix name, and concentration. The associated logbook will contain the following information at a minimum:

- o The Stock solution used to make the working standard, including either the information required for logging the stock solution or a reference to where that information can be found.
- o Both a written description and calculation of how the working standard was prepared.

- o The solvent(s) and associated lot number(s) used in preparing the standards.
- o The final concentration of the working standard.
- o The GC code associated with the standard.
- o Standard and stock solutions will be kept refrigerated at less than 10°C when not in use.
- o The surrogate standard is made separately from the working standards.

GC coding system. The GC coding system is used to trace all standards back to the vendor. All standard are required to have the appropriate code assigned when they are prepared and must be labeled accordingly. The GC code will follow the format:

- o FGCXXXXXXWWYZPPPP Where:
- o XXXXXX is the month, day, and year that the standard was made, i.e, 041693 = April 16,1993.
- o WW is the page in the logbook where the standard can be found, i.e., 01 to 99.
- o Y is where the standard fell chronologically on the page, i.e., A through Z.
- o Z is the logbook number where the standard can be found, i.e., 1 through 9.
- o PPPP is the project identifier, i.e., ABB = Asea Brown Boveri, a short character identification of the project from 1 to 4 characters in length.

Logbook entries. While the style and specific requirements for logbook entries will vary between operators and projects, certain information is required for all projects. At a minimum this will include:

- A table of contents listing what and where specific information is located.
- A listing of P&T and GC run conditions and set points.
- A chemical standards preparation section containing the required standards information.
- A run log section containing at a minimum: sample identification, run number or computer file identification, sample amount (weight or volume), spiked surrogate amount and % recovery, standard code for each standard used, amount of standard(s) used, an example calculation for any calculations performed, dilution factor, and a remarks column with any pertinent information (e.g., unusual sample color or odor, unusable blanks, failed standards, coelutions, reruns, etc.).

$$\%Surrogate\ recovery = \left(\frac{calc.\ amt.\ surrogate}{amt.\ surrogate\ added}\right) * 100$$

- An equipment maintenance section containing both routine and equipment malfunction maintenance (e.g., column replacement, electronic parts replacement, lamp replacement or cleaning, etc.)

Calibration. The calibration process for GC involves two steps, the first is compound identification and second is quantitation. Identification is accomplished by matching retention times of peaks. Quantitation for purge and trap analysis will be performed using an external calibration technique. The calibration method will use either a single-level or multilevel external calibration technique depending on the DQOs of the project.

Identification. Compounds are identified by matching the retention times of peaks. The retention time is defined as the period of time from the injection of a mixture onto a column to the elution of the peak of interest. For proper compound identification, a known standard is analyzed on the GC and the compounds of interest retention times are noted. A three percent (note: the 3% retention time window is normalized to the surrogate to adjust for injection variation) retention time window will be used for compound identification.

Single Level Calibration. The single-level external calibration technique requires that a standard containing a known concentration of selected compounds is analyzed. The retention time for each target compound is identified and used for the identification of sample peaks. The peak areas are then used to compute the response factors for the compounds of interest.

Multilevel Calibration. In the multilevel calibration, a minimum of three levels (concentrations) of standards are analyzed. The standard concentrations are selected to cover the concentration range of contaminants expected. This includes a low concentration standard at or near the practical quantitation limit (PQL). In addition, the upper level standard needs to be within the working range of both the detector and the column.

- Approximate working range, ECD: PQL to 40 ppb.
- Approximate working range, FID: PQL to 200 ppb.
- Approximate working range, ELCD: PQL to 40 ppb.
- Approximate working range, PID: PQL to 200 ppb.

PQL. PQL's are determined on an annual basis or as required by project workplans. This is accomplished by analyzing seven replicate low concentration standards near the expected method detection limit (MDL). From these analysis a standard deviation is calculated and multiplied by 3.14 to establish the MDL. This correlates to a student's t of 99% for (n-1). The PQL's are set above the MDL's to present uniform reporting limits (e.g., the MDL's may be calculated to be 0.23, 0.67, 0.45, etc., with the PQL's set at 1.0). Note: The various detectors are sensitive to different amounts (e.g., ng, pcg, μg, etc.) of specific compounds. The detection limits at different concentrations (e.g., μg/L, mg/L, etc.) are dependent on the technique used to achieve them (i.e., whether or not a 5 mL or 25 mL purge is used).

Quantitation. When the quantitation requirements are not defined in the project workplans, the operator can choose (based on operator experience, the selected detectors, and the compounds of interest) one of three options for quantitating sample results. These options include using the average response factor, (the response factor (RF) is calculated by dividing the area counts of a compound by the amount of compound in the standard, Ac/amt), linear regression, or point to point calibration.

$$RF = \frac{\text{area counts}}{\text{amt. of compound}}$$

The average response factor may be used when the relative standard deviation (RSD) of the RF's is less than 30 percent.

$$\%RSD = \left(\frac{S}{\bar{x}}\right) * 100$$

where: S = standard deviation of response factors
x = mean of response factors

When this technique is chosen, the average RF is used for calculating sample results.

Linear regression may be used when a correlation coefficient (r^2) of 0.95 or greater is achieved.

A point to point calibration may be used for non-linear calibrations (i.e., the RSD of the average response factor exceeds 30 percent or the r^2 for linear regression exceeds 0.95). Care must be taken so that the response for the upper calibration point is not equal to or less than the response for the previous calibration point (i.e., the curve may flatten or curve back toward the baseline). Note: If this technique is chosen, then all analytes must be calculated using this technique.

Once a calibration technique is chosen it must be used for all compounds associated with each detector for the length of the project. The initial calibration is valid for twenty-four hours beginning when the last calibration standard run is complete.

<u>Independent Check Standard Verification</u>. After the first initial calibration for a project, an independent check standard will be analyzed when required by project DQO's. The check sample will be obtained from a different source than the stock solution and working standards. The check standard is used to verify the accuracy of the working standards. A percent difference of less than 30 percent is considered acceptable to confirm standard accuracy.

<u>Continuing Calibration</u>. Prior to daily sample analysis, a continuing calibration check standard will be analyzed at or near the mid-level of the current calibration curve. The target analytes must have percent differences of less than 30 percent when compared to the initial calibration.

$$\%D = \left| \frac{calc.\ amt.\ std. - spiked\ amt.\ std.}{spiked\ amt.\ std.} \right| * 100$$

Samples may be analyzed only if no more than one compound per detector, or up to 10 percent of the target compounds, exceed the percent difference criteria of 30 percent. If the above criteria are not met, a second standard is analyzed for the compounds that failed during the initial analysis. If the second standard is unacceptable, a new calibration curve will be prepared. Following analysis of an acceptable continuing calibration standard, samples can be analyzed for a period of 24 hours from the time the standard run was completed.

Blanks. There are three types of banks associated with purge and trap analysis: low level method blanks, medium level method blanks, and cleaning blanks.

Low Level Method Blanks. For routine analysis, a low level method blank must be analyzed before samples are analyzed. A low level method blank consist of 5 mL of analyte free water that has a surrogate added. Method blanks are acceptable if no target compounds are present above the PQL. Samples should not be analyzed until an acceptable method blank is run demonstrating that the instrument is free of interferences. If an acceptable method blank can not be obtained then all associated results will be flagged with a (B).

Medium Level Method Blanks. A medium level blank will be analyzed when medium level extracts are analyzed (see below). The medium level blank consists of 5.0 mL of reagent water, surrogate, and 100 microliters of methanol. The methanol will be from the same source as that used for the medium level extractions. If an acceptable method blank can not be obtained then all associated results will be flagged with a (B).

Cleaning Blanks. A cleaning blank is 5 mL of reagent water only. Blanks will be analyzed after any high level sample to ensure that carryover is not occurring. A high level sample is defined as having a concentration 5 times higher than the highest calibration point. Cleaning blanks will be analyzed until the analysis of further samples will not be affected by carryover. (based on experience, the concentration in the following samples, and the DQO's of the project).

Sample Preparation. Sample analysis and preparation techniques have been adapted from protocols outlined in SW-846 3rd ed. USEPA Purge and Trap methods 8010, 8015, 8020. and 8240 (USEPA 1986).

Water Samples. Rinse a 5 mL syringe with one volume of sample. Draw the sample into the syringe, invert and remove all air adjusting the final volume to 5.0 mL. Add the appropriate amount of surrogate directly to the sample. Deliver the sample to the sparger and start the run. After the desorb and bake cycle, remove spent sample. rinse the sparger with reagent water prior to analyzing subsequent samples.

If high concentrations of VOC's are suspected (indicated by PID headspace results or odor), samples should be diluted to bring the target compound concentrations within the instrument calibration range. Sample volumes of 1 mL (dilutions of 1 to 5) or more may be measured in the 5 mL syringe and reagent water drawn directly into the syringe for a final volume of 5.0 mL. To dilute sample requiring a volume of less than 1 mL add 5.0 mL reagent water to the syringe. Then remove a volume equal to the volume of sample to be added. Add the sample volume and surrogate to the syringe using an appropriate size syringe.

The results of diluted samples must be multiplied by a dilution factor to correct for volume change. Calculate the dilution factor as follows:

$$DF = 5\ mL/X$$

where X = sample volume, mL

If the sample results are still outside the calibration range the sample may be further diluted or flagged with an E (E = estimated).

Soil Samples. Weigh 5 g ± 0.5 g into the sparging vessel and attach to the purge & trap. Add surrogate to 5.0 mL reagent water and add into the sparging vessel and start the purge cycle. After the desorb and bake cycle, remove spent sample, rinse the sparger with reagent water prior to analyzing subsequent samples.

Reagent water. Reagent water or locally purchased distilled or spring water that has been demonstrated to be free of target analytes (i.e, QC analysis) below the PQL's. This is checked daily with method blanks.

Balance check. The field balance will be checked daily with a standard certified weight and the weight recorded. The balance must be accurate to ± 0.1 g. If the balance fails this criteria the balance either needs to be serviced or a new balance obtained.

Medium level soil samples. If the concentration of target compounds and/or other hydrocarbons is suspected to be high, soils will be extracted with methanol. Weigh 4 g ± 0.4 g of sample into a VOA vial and add 10 mL ± 0.5 mL of methanol (alternately, 2.0 g ± 0.2 g. in 5 mL ± 0.2 mL may be used). Cap the tube and shake for approximately 1 minute until the soil and methanol are completely mixed. Centrifuge if required and withdraw 100 μL of supernatant. Add to 5.0 mL of reagent water and surrogate in a 5 mL syringe and proceed with analysis according to the procedure for water.

$$\text{Medium Level DF of } 125 = \frac{5.0\ g}{\frac{X}{Y}} * 100\ uL$$

Where X = the amount of soil extracted (g)
Y = the amount of methanol used for extraction (mL)

For highly contaminated soils less than 100 μL of extract may be used. If the amount of extract needed to bring the concentration of contaminants within the instrument calibration range is less than 2 μL, the extract will be further diluted with methanol.

Medium level blanks are required each day that medium level soil samples are analyzed.

Dry weight. Project specifications may require that VOC concentrations be based on dry weight. Weigh sample drying pan to the nearest 0.1 g. Weigh approximately 10 g of sample. Dry in an oven at 110°C, ± 5°C for approximately 1 hour. Temperature of the oven will be checked at the beginning of each project and the proper setting set. Calculate the solids content from:

$$\%Solids = \left(\frac{A}{B}\right) * 100$$

where A = dry weight of sample, g
B = wet weight of sample, g

Dry weight calculations are performed on all samples when required.

$$dry\ wt. = \frac{X}{Y}$$

where X = final concentration of sample
Y = decimal percent solids

Analysis. The standards and samples are analyzed as outlined in the previous sections. The routine order of analysis is:

- Calibration standard(s) at the start of the project and a continuing calibration standard for each subsequent day (note: a new calibration may have to be run each day if the continuing calibration fails criteria, see calibration section).
- Independent check to verify calibration at the beginning of the project, if required (note: this standard is only analyzed once during the project).
- Method blank and samples.
- Matrix spike and matrix spike duplicate (MS/MSD) samples if required.

Quality Control. The following procedures will be implemented by the field chemist to insure standardization of the operating procedures:

Review. The field chemist will review each chromatogram before analyzing the next sample. The review will include the calculation of surrogate recoveries, comparison of surrogate and target compound retention times to calibration standards, and the evaluation of carryover potential.

Surrogate recoveries. Surrogate recoveries for water samples must be greater than 50 percent and less than 150 percent on at least one detector if dual detector analysis is performed. Water samples with surrogate recoveries of less than 50 percent must be reanalyzed to confirm matrix interferences. Water samples with recoveries greater than 150 percent will be qualified with an (S).

Surrogate recoveries for soil samples must be greater than 30 percent and less than 200 percent on at least one detector if dual detector analysis is performed. Soil surrogate recoveries of less than 30 percent must be reanalyzed to confirm matrix interferences. Soil surrogate recoveries of greater than 200 percent will be qualified with an (S).

Matrix spike. Matrix spike quality control samples will be analyzed when required by project workplans. These are field samples to which target compounds at the mid-calibration concentration are added. The percent recovery of target compounds will be recorded.

Matrix spikes and matrix spike duplicates are analyzed after twenty samples or as required by the project workplans. Matrix spikes are prepared as either water or soil samples with a mid-level standard added immediately after the surrogate.

Matrix spike and matrix spike duplicate results will be calculated and recorded in the GC logbook. Unless specified in the project workplans there will be no action criteria for matrix spike results, the results will be advisory only.

$$\%Recovery = \left| \frac{(sample\ conc. + spike\ conc.) - sample\ conc.}{spike\ conc.} \right| * 100$$

<u>RPD</u>. The relative percent difference (RPD) for the matrix spike and matrix spike duplicates will be calculated and recorded in the project logbook.

$$RPD = \left| \frac{\%R\ MS - \%R\ MSD}{\left(\frac{\%R\ MS + \%R\ MSD}{2} \right)} \right|$$

Reporting. Data from all sample analyses and relevant calibration and blank analyses will be documented in the project GC run logbook. A quality control summary as outlined in project specific workplans will be generated at the completion of the project and will include some or all of the following as required: initial calibrations, continuing calibrations, surrogate recoveries, matrix spikes, matrix spike duplicates, method blanks, dilutions, reanalyses, observations of the field chemist, problems and fixes, unknown peaks, raw data, etc..

REFERENCE:

U.S. Environmental Protection Agency, 1986, "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods; SW-846"; Office of Solid Waste and Emergency Response, Washington, D.C.

ATTACHMENT 4

ABB-ES' STANDARD OPERATING PROCEDURE NO. FXRFS00102

STANDARD OPERATING PROCEDURE

Author: Advanced Technology Team
Reviewed by:

Issuing Unit: ABB-ES
SOP No.: FXRFS00102
Date: 05/12/94

SENIOR CHEMIST
(Name & Title)
(Functional Area)

Approved by:
Team Leader
(Name & Title)
(Functional Area)

TITLE: Field Analysis of Metals by X-ray Fluorescence

PURPOSE: To establish standard operating protocols for the analysis of metals using the Spectrace 9000 X-ray Fluorescence Analyzer (XRF).

SCOPE: This procedure describes the preparation and analysis of soil samples for metals using XRF.

REQUIREMENTS: Requirements for the method include a Spectrace 9000 XRF. The critical components needed for the assembly and operation of the system are listed. Additional items such as gloves, oven, ventilation hoods, etc. are not included as they pertain to general XRF operation.

Instrumentation. Spectrace 9000 Field Portable X-ray Fluorescence Analyzer. The Spectrace is fully self-contained and only requires additional sample cups, mylar, and the independent check standard for operation.

Run Conditions. The following settings are used for routine sample analysis. Some parameters will be changed during daily calibration checks. Allow the XRF to warm up for approximately 30 minutes before use.

- Soils mode
- Acquisition Times: Cd-109 at 300 seconds
  Fe-55 at 20 seconds
  Am-241 at 20 seconds

PROCEDURE: The procedure can be broken down into six categories: conventions, calibration, blanks, sample preparation, analysis, and reporting.

Conventions. Conventions are established to ensure that documentation and analysis are performed in a consistent manner from operator to operator and project to project. Conventions are established for coding standards, recording logbook entries, performing calculations, and analyzing quality control samples.

<u>Standards.</u> Soil reference standards will be purchased through USGS, NIST, or equivalent. All standard information will be logged in a bound logbook with the pages sequentially numbered. This information will include, at a minimum:

- Vendor name supplying standards.
- Name and concentration of the standard
- Lot number of the standard.

Logbook entries. While the style and specific requirements for logbook entries will vary between operators and projects, certain information is required for all projects. At a minimum this will include:

- A table of contents listing what and where specific information is located.
- A listing of XRF run conditions and calibration check results.
- A run log section containing at a minimum: sample identification, run number, an example calculation for any calculations performed, and a remarks column with any pertinent information (e.g., unusual sample color or odor, unusable blanks, failed standards, reruns, etc.).
- An equipment maintenance section containing both routine and equipment malfunction maintenance.

Calibration. The Spectrace is calibrated at the factory. However, three checks are required to ensure that the instrument is operating properly. These checks are performed daily prior to sample analysis.

Energy Calibration Check. Place the safety shield on the probe. Set the acquisition time for each source to 60 sec (180 sec total). Upon completion save results and examine spectra. For each source locate and record the KeV for the major peaks as listed below (use the x12 horizontal magnification).

Source	Peak	Range, KeV
Cd-109	Pb L-alpha	10.54 ± 0.040
	Pb L-beta	12.61 ± 0.040
	Pb L-gamma	14.76 ± 0.040
	Emission	22.10 ± 0.040
Fe-55	S K-alpha	2.31 ± 0.010

	Emission	5.89 ± 0.010
Am-241	Pb L-alpha	10.54 ± 0.050
	Pb L-beta	12.61 ± 0.050
	Emission	59.50 ± 0.20

Perform an energy calibration if any peaks do not meet the requirements and repeat the energy calibration check.

Resolution Check. Set the Cd-109 source acquisition time to 60 sec and the Fe-55 and Am-241 times to 20 sec and measure the pure iron standard supplied with the XRF. Save and examine the Cd-109 spectrum. Record the KeV values measured at the full width at half height. Subtract the left side value from that of the right; the difference must be less than 0.300 KeV. Contact the manufacturer if the resolution is out of specification.

Element X-ray Response Check. The relative intensities of Fe, Mn, and Co are compared using the spectrum obtained in the resolution check (above). From the raw data verify that the Fe intensity is greater than 0.96 and those for Mn and Co are less than 0.003. If the intensities are out of range ensure that the window is clean, reposition the standard and reanalyze.

Target Element Response Check. Standards containing the metals of interest are analyzed using the sample analysis application and acquisition times (see below). The concentrations should be at low, mid, and high levels for some or all of the target elements. The low level standard should be near the instrument detection limit; mid level near the project action level; and the high level near the maximum concentration of the metals on-site.

Continuing Calibration. This is the mid-level standard at or near the action level. This check will be run after every 10 samples.

Blanks. A teflon blank is supplied with the XRF. This must be analyzed under the same application and source acquisition times as in sample analysis (see below). All elements should be at concentrations at or less than 3 times their standard deviation. Reanalyze if any elements are out of range. Check probe window and teflon blank for cleanliness if any are still out and run the Acquire Background program if needed.

Sample Preparation. A representative portion of the sample, approximately 20 to 30 g, is placed in an appropriate container until dry. The sample is then sieved through a 30 to 60 mesh screen and homogenized. Pour enough sample into the sample cup to fill at least halfway; assemble mylar and ring.

Analysis. Lead and copper are both measured using the Cd-109 source. The acquisition times are set at 300 sec for the Cd-109 source and 20 sec for Fe-55 and Am-241.

Reporting. Data from all sample analyses and relevant calibration and blank analyses will be documented in the project XRF logbook. A quality control summary as outlined in project specific workplans will be generated at the completion of the project and will include some or all of the following as required: daily calibration checks, continuing calibrations, reanalyses, observations of the field chemist, problems and fixes, etc..

REFERENCE:

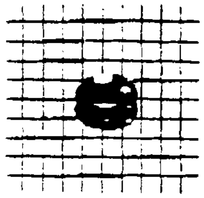
Spectrace 9000 Portable X-ray Fluorescence Analyzer Operating Instructions, Revision 03, January 1992.

ATTACHMENT 5

MERCURY ANALYZER MANUFACTURER DOCUMENTATION

The Leeman Labs' Model PS200 Automated Mercury Analyzer offers exceptional value to any laboratory measuring mercury. Everything is included: a random access PS Series autosampler, an IBM-compatible PC, and Leeman Labs' powerful PS Series software complement an instrument specifically designed for mercury determinations.

The PS200 is an energy-efficient double beam photometer with parts per trillion (ppt) sensitivity. Energy efficiency is achieved by eliminating the monochromator used in AAs. The monochromator serves no function in a dedicated mercury analyzer. In fact, it causes a large energy loss by using narrow slits and by diffracting energy into unused spectral orders.



Since the optical cell need not fit the physical constraints of an AA burner or furnace cavity, it has been optimized for cold vapor determinations. The system has a wide dynamic measuring range, and can be used for determining mercury under USEPA CLP and TCLP protocols. Low ppt sensitivity makes it the ideal companion to our ICP/Echelle Spectrometers.

Unattended Operation

The PS200 completely automates the analysis of prepared samples, freeing time for other laboratory tasks. Up to 88 samples, 6 calibration standards, and 7 QC check standards and/or spiked samples can all be loaded into the autosampler. Even baseline correction is performed automatically. Large reservoirs hold the rinse, reductant and blank solutions.

Autosampler functions are defined through the PS Series software, so that operation can be customized to your needs. You can even interrupt an autosampler batch to run a "rush" sample. Results are easily transmitted to a LIMS.

User-Defined Automation

The PS200 software contains a library of routines known as "macros." These routines not only allow you to customize operation of your instrument, they also simplify training, reduce errors, and enhance consistency of results.

Use macros to reduce multiple steps to a single keystroke. Have the system make intelligent decisions and act on them automatically – saving time and increasing sample throughput. For example:

- Standardize start-up and shut-down procedures for consistent operator-to-operator performance.
- Build in as many standards and control samples as required for your QA/QC needs.
- Set your own limits for out-of-spec readings on control/check samples, and have the system automatically recalibrate and repeat sample determinations as needed.
- Calculate matrix spike recoveries and apply those recovery factors to subsequent samples if desired.
- Calculate for the method of standard additions.

While analytical testing for mercury has become increasingly automated and efficient, sample preparation has remained a tedious and time-consuming procedure. The Leeman Labs AP200 Automated Mercury Sample Preparation System performs all sample preparation steps for mercury determination by cold vapor AA. Sample and standard preparation for the most demanding QA/QC protocol is made simple and easy with the AP200.

Samples and standards are digested, and reagents are precisely added for consistent results. Potassium permanganate additions are made as required under control of a "Complete Oxidation Probe" (COP).

Consistent Results

Leeman Labs AP200 Automated Mercury Preparation System ensures that all samples and standards are treated identically, sample-to-sample and operator-to-operator, for consistent, reliable results.

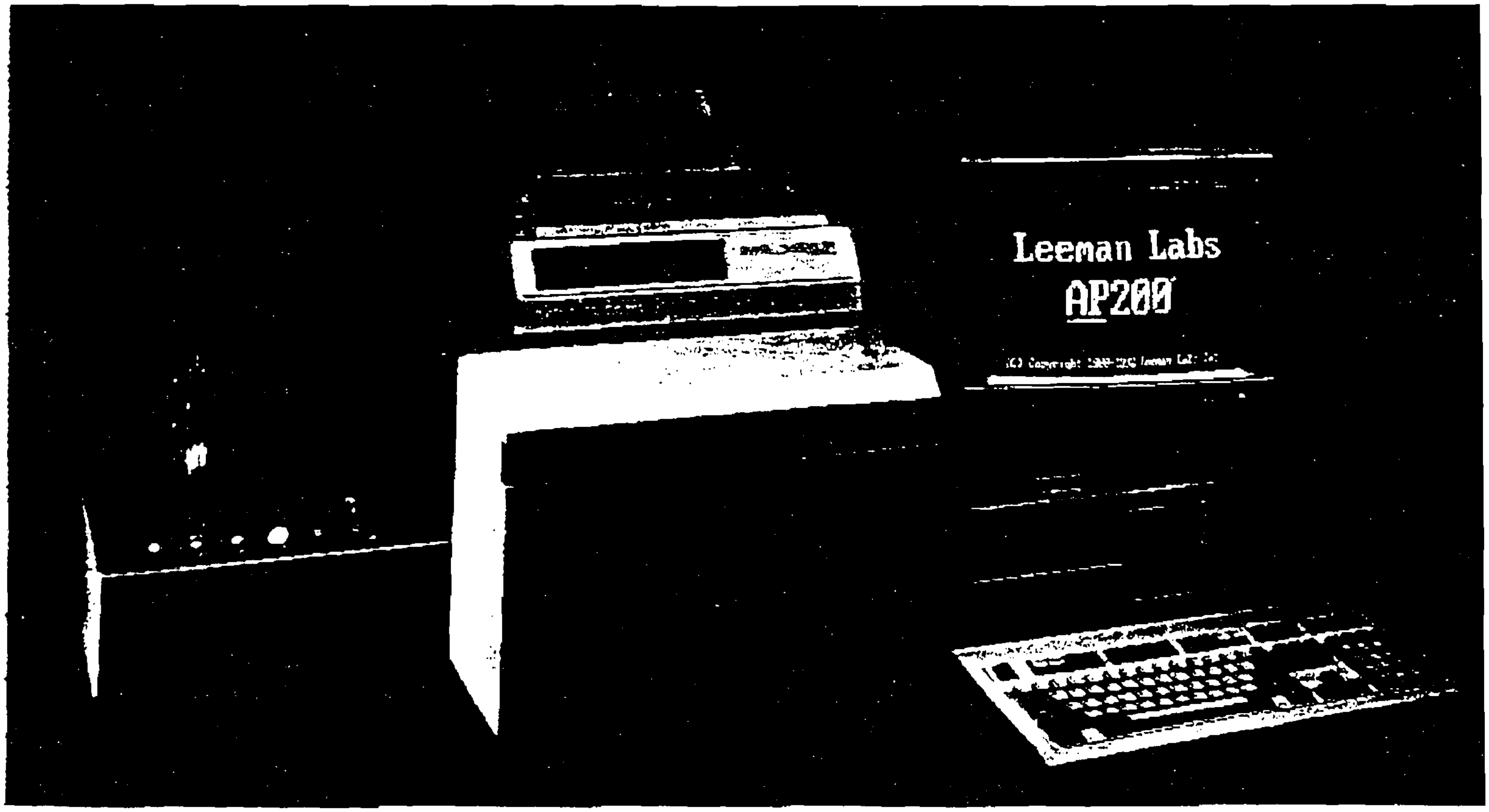
The AP200 is capable of preparing up to 88 samples, 6 calibration standards, and 7 check standards at one time without operator intervention. The samples and standards are placed directly in autosampler cups in a rack that mounts in the enclosed temperature-controlled bath for reagent additions and digestion. Reagent volumes and digestion times are programmed to meet specific sample requirements. COP, a colorimetric detector, ensures that samples receive sufficient potassium permanganate and retain color for a specified time period. This assures complete oxidation of organics in the sample, eliminating their interference with mercury determinations.

Maximum Productivity

The AP200 significantly improves the quality of results and reduces man-hours required for mercury sample preparation. When combined with the PS200 Automated Mercury Analyzer, you have the complete "walk-away" answer for mercury determinations.

Cost Savings

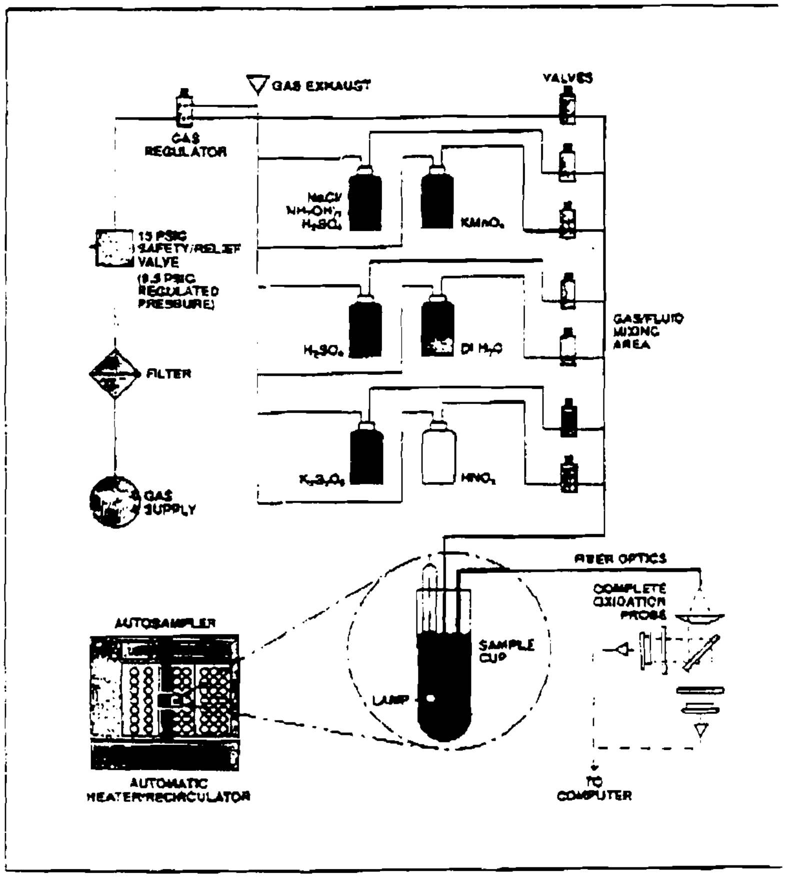
The AP200 not only saves time and labor, it saves operating costs as well. Only 8 mL of sample are required, along with correspondingly reduced amounts of reagents, so reagent costs are 10 times lower than conventional methods. This also means 10 times less hazardous waste for disposal. Also, because of the high degree of reliability associated with automation, fewer samples will need to be reworked or reanalyzed due to errors in preparation.

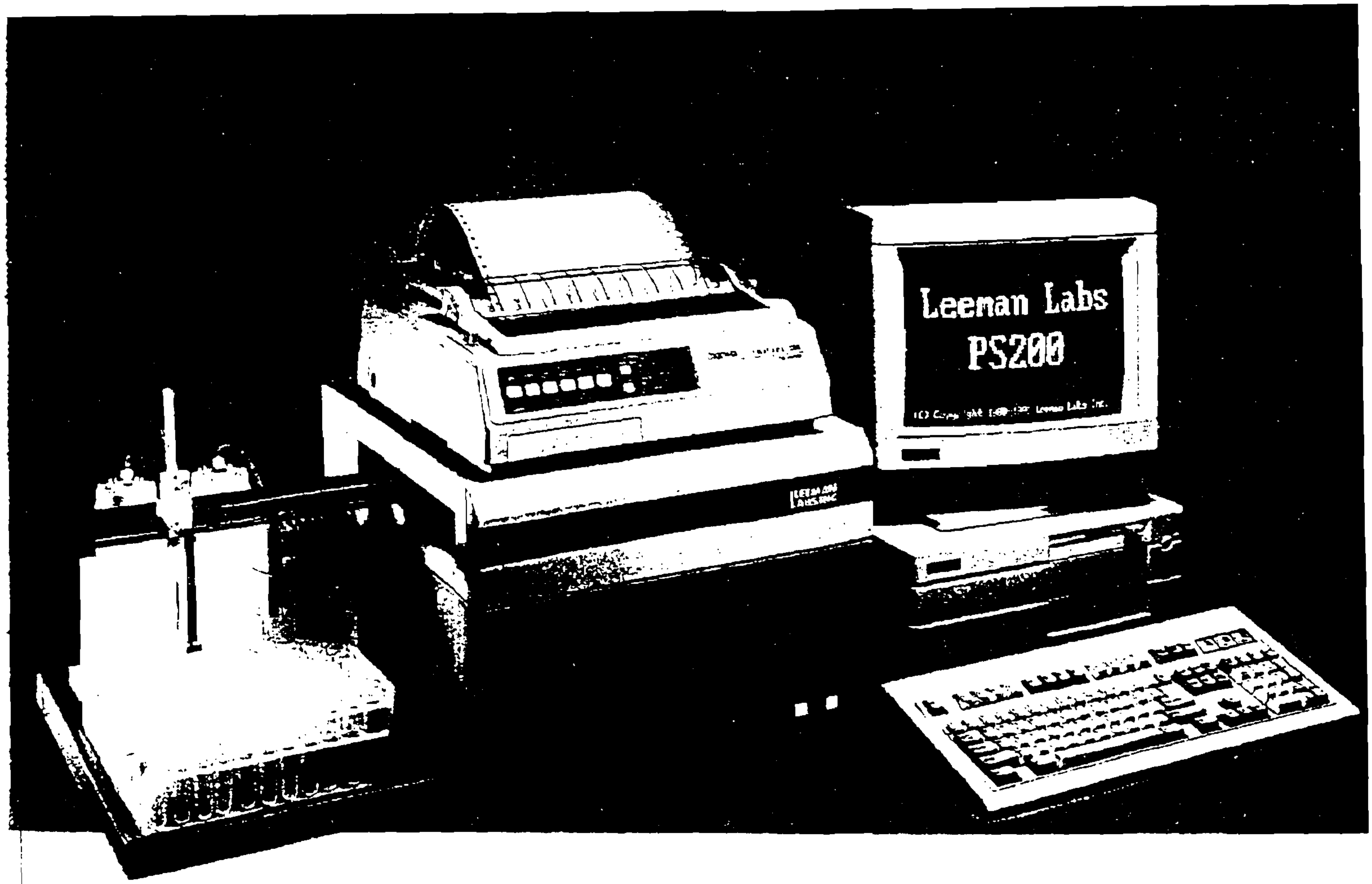


Principles of Operation

The AP200 uses established methodology for the preparation of mercury samples for cold vapor AA. The required 8 mL of sample are placed directly in autosampler cups. (After preparation the racks transfer directly to the autosampler of the PS200 Automated Mercury Analyzer.) Sulfuric acid, nitric acid, and potassium permanganate are precisely added, mixed, and sparged.

The Complete Oxidation Probe examines each cup to determine if the purple color persists for the specified time period. Additional potassium permanganate is added if necessary. Should the purple color continue to disappear, the sample is flagged for operator attention. Potassium persulfate is then added, and the samples are digested for 2 hours at 95° C. After cooling, sodium chloride-hydroxylamine sulfate is added to reduce the excess permanganate. The samples and standards are then ready for Hg determination by cold vapor AA, which commences with the addition of stannous chloride.





Early Warning of High Mercury Levels

One of the problems in mercury analysis occurs when a sample with high mercury content is measured. Adsorption of these high vapor levels results in slow elution from internal surfaces, characterized by long baseline return times. Once a system has been exposed, it can take hours to clean out, during which time the instrument is unavailable for use.

The PS200 detects high mercury levels early - before the vapor has a chance to saturate the system. When the detector senses a rapid rate of signal increase, the system automatically shuts off the flow of carrier gas (argon or nitrogen) to prevent more mercury vapor from flowing into the system. Immediately, rinse solution starts flowing through the liquid sample path to wash out the sample. Throughout this process, the system monitors the detector signal, and waits until it has sufficiently decreased before running the next sample.

The entire procedure typically takes 5 minutes - saving you hours of system flushing, and minimizing downtime.

Analytical Reliability

The PS200 Automated Mercury Analyzer is designed and supported to give you maximum confidence in your results. Leeman Labs offers everything you need for accurate, reliable mercury determinations, including:

- A completely automated system at significantly less cost than an automated cold vapor AA.
- Double beam measurement for accuracy and sensitivity.
- PLASMA-PURE calibration standards.
- Optional pre-shipment testing to specific protocols, including CLP and TCLP.
- Regionally located Sales/Support Centers for quick response.

ATTACHMENT 6

BIOAVAILABILITY REFERENCE

Environ. Sci. Technol. 1993, 27, 2870–2877

Development of an *in Vitro* Screening Test To Evaluate the *in Vivo* Bioaccessibility of Ingested Mine-Waste Lead

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A screening-level *in vitro* test was developed to evaluate the relative solubility of ingested lead (Pb) from different mine wastes in the gastrointestinal (GI) tract. The *in vitro* method, modeled after assay methods for available iron from food, used a laboratory digestion procedure designed to reproduce GI tract chemistry and function. The *in vitro* method was independently calibrated against a rabbit feeding study, demonstrating that only 1–6% of the total Pb in four mine-waste samples with disparate Pb mineralogy was bioaccessible. *In vitro* method development tests indicated that H^+ concentration and Cl^- complexation control dissolution of Pb-bearing minerals in the stomach and that both GI tract enzymes and organic acids are necessary to maintain Pb in the soluble form on entering the small intestine. The experimental results indicate that ingestion of Pb-bearing mine wastes results in limited Pb solubility and that the *in vitro* test provides a screening-level estimate of the maximum available Pb from mine wastes.

Table I. Occurrence of Pb Minerals in Mine-Waste Samples

	sample no.			
Pb phase	BMW-1	BMW-2	BMW-3	BMW-4
anglesite ($PbSO_4$) (%)	59	4	10	
galena (PbS) (%)	26		1	5
lead phosphates[a] (%)	4	7	37	39
manganese-lead oxides[b] (%)		31	7	26
iron-lead oxides[c] (%)	2	29	6	
iron-lead sulfates[d] (%)	2	24	39	
lead oxides [PbO and $Pb(OH)_2$] (%)	1	3		17
lead metallics[e] (%)				2
lead silicates ($PbSiO_3$ and $PbSiO_4$) (%)		2		11
lead barite [$(Ba-Pb)SO_4$] (%)	3			
cerussite ($PbCO_3$) (%)	3			
Pb concn (mg/kg)[f]	3900	1030	5820	1790
As concn (mg/kg)[g]	1380	620	1180	420
Fe concn (%)[g]	6.9	12.3	5.0	5.4
Mn concn (mg/kg)[g]	2200	2000	1100	1200
Zn concn (mg/kg)[g]	6040	NA[i]	NA	1600
Ca concn (%)[g]	0.7	2.9	1.2	0.8
pH[h]	3.7	2.8	3.8	2.6

[a] Lead phosphate grains contain variable compositions of Pb, PO_4, SO_4, and halogens. [b] Manganese-lead oxide particles contain more Mn than Pb, with variable compositions of constituents. [c] Iron-lead oxide particles contain more Fe than Pb, with variable compositions of constituents. [d] Iron-lead sulfate grains contain more Fe than Pb, with variable compositions of constituents. [e] Lead metallics contain elemental Pb with Fe, Mn, As, Cu, and Zn in varying proportions. [f] Determined by digestion (*31*) and atomic absorption spectroscopy (*31*). [g] Determined by X-ray fluorescence. [h] Determined by the saturated paste method (*32*). [i] NA, not analyzed.

Introduction

When assessing risks associated with lead (Pb)-contaminated soils, one exposure pathway typically evaluated is soil ingestion by children. Standard procedures recommended by the U.S. Environmental Protection Agency (EPA) for estimating soil Pb exposures using the Uptake Biokinetic Model assume that a typical child will ingest 100 mg of soil/day and that 30% of the ingested Pb will be absorbed into the systemic circulation (i.e., will be bioavailable) (*1*). However, recently completed animal studies indicate that lead from mine waste is much less bioavailable than lead from other sources (*2–4*). Our previous research has demonstrated that Pb-bearing minerals dissolve slowly and incompletely in the gastrointestinal (GI) tract, due to a variety of geochemical factors (*5*) resulting in Pb forms that are bioaccessible. The limited dissolution of Pb-bearing minerals in the GI tract is most likely responsible for the low bioavailability observed in the animal studies, because Pb absorption has been shown to occur from the soluble phase in the small intestine (*6, 7*).

The geochemical factors controlling dissolution of metals from mine waste include the mineral composition, the degree of encapsulation, and the presence of alteration rinds. Because the solubility of Pb from mine waste is constrained by the composition of the mineral assemblage, site-specific mineralogical data are necessary to characterize the availability of Pb (*2, 5*). Two dominant Pb mineral assemblages—sulfide/sulfate and oxide/phosphate—have been identified in residential soils containing mine waste (*8*). The sulfide/sulfate assemblage consists of galena (PbS) grains altering to the oxidation product anglesite ($PbSO_4$) or enclosed in pyrite (FeS_2) or silicate (SiO_2) matrices, making them unavailable for alteration or dissolution. Precipitation of jarosite $[KFe_3(SO_4)_2(OH_6]$ rinds on Pb-bearing particles was also observed and would retard Pb dissolution, both physically by reduction in the exposed surface area and chemically due to the insoluble nature of jarosite in acidic (pH < 4) media (*9*). The oxide/phosphate assemblage consists of lead phosphates of varying compositions, lead ferromanganese oxides, iron-lead sulfates that are similar in composition to the mineral lead jarosite $[PbFe_6(SO_4)_4(OH)_{12}]$, and lead oxides [PbO and $Pb(OH)_2$, Table I]. These Pb minerals occur in mine waste and soils as a complex set of alteration products

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that are weathering toward more stable lead phosphates. The geochemical controls on Pb dissolution from one of the mine-waste samples (BMW-1) used in this study have been discussed in detail in previous papers (*5, 10*).

The mass of Pb dissolved is also controlled by physiological factors, including gastric pH, the rate of Pb dissolution relative to the residence time of Pb-bearing mine waste in the GI tract, and by *in vivo* sorption and precipitation reactions that may limit dissolved Pb concentrations. Gastric pH, which in humans ranges from a basal level of 1–2 to 4–6 after ingestion of food, with its attendant buffering capacity (*11, 12*), appears to be one of the most important physiological factors in determining the mass of Pb solubilized from a mine waste. Lead that enters the fluid phase in a fasting stomach (assumed pH = 1.3 and high chloride activity) will be present at approximately equimolar concentrations of Pb^{2+} and $PbCl^+$ (*13*). Another critical factor is the residence time in the stomach. The gastric contents are emptied completely into the small intestine within approximately 2 h in humans when fed various test meals (*14*).

On entering the duodenum, $NaHCO_3$ excreted with the pancreatic juices is mixed with the intestinal chyme, resulting in an increase in pH to approximately 7 in humans (*15*). Consequently, dissolved Pb concentrations are likely to decrease in the small intestine due to adsorption to mineral and food-particle surfaces with increasing pH and as a result of precipitation reactions (*16*). For the purpose of this discussion, the fluid or soluble phase within the small intestine is operationally defined as the fraction that can be separated from the solid fraction by relatively low-speed centrifugation, as defined in the methods section. Lead in the soluble small intestinal phase will be distributed between fractions bound by proteins and enzymes (*17, 18*); complexed by amino acids (*19, 20*), low molecular weight carboxylic acids (*21*), and tannins and humic acids released from ingested soil and food, respectively (*16*); adsorbed to suspended particulates in the fluid phase; or present as free lead cations and hydroxide complexes. The distribution of Pb between these forms will control the solubility and, consequently, the mass available for absorption across the intestinal epithelium.

Because of the complexity of the geochemical and physiological factors controlling dissolution of lead from mine waste, it was determined that a rapid, inexpensive *in vitro* method was needed to investigate interactions of the various factors and to compare the relative solubility of Pb from solid sources. The *in vitro* method for estimating Pb availability presented in this paper was modeled after an *in vitro* assay method for available Fe in foodstuffs (*22–26*). The Fe availability method simulates the stomach and small intestinal phases of digestion using solutions of specific pH that contain digestive enzymes (pepsin in the stomach, pancreatic enzymes and bile acids in the small intestine) mixed with the test substrate to reproduce GI tract function and chemistry.

The pH values of 1.3 and 7.0, selected for the gastric and small intestinal incubations, respectively, were based on measurements in fasting rabbit stomachs and small intestines. The strongly acidic stomach solution selected for the *in vitro* method is representative of a fasting child and maximizes Pb dissolution to provide an upper-bound estimate of available Pb that would apply to ingestion of small particles due to mouthing behavior by children several hours after food ingestion or under fasting conditions. Selection of appropriate concentrations for digestive enzymes is problematic because concentrations are highly variable in the human system. The enzyme concentrations selected for the *in vitro* test were those used in refs 23 and 24 for *in vitro* estimation of Fe from food. The method developed herein included the addition of small quantities of organic acids that were determined to be present in the rabbit GI tract.

Gastric mixing rate (the rate at which ingested material is mixed with fluid in the stomach due to peristalsis) will also affect mineral dissolution kinetics and influence the concentrations of Pb solubilized in the stomach. Therefore, mixing of the *in vitro* flask contents employed a mixing rate designed to replicate *in vivo* mixing, as previously determined in Pb dissolution rate experiments (*9*). The test material mass (4 g) and fluid volume (40 mL) for the *in vitro* experiments were based on those found in the stomachs and small intestines of 33 New Zealand White rabbits. The rabbits had been dosed with 2.0 g of mine waste/kg of body weight and weighed, on average, 2.1 kg, resulting in 4.2 g of ingested mine waste (16.4 mg of Pb).

To test the validity of the *in vitro* model, an *in vivo* experiment was conducted to assess the dissolution of Pb from mine waste during passage through the GI tract of New Zealand White rabbits. A mine-waste dose of 2.0 g/kg of body weight was selected to represent the worst-case scenario of a child with pica-for-soil (e.g., a child who intentionally ingests soil), who may ingest up to 10 g of soil/day (*27, 28*). Although differences in digestive anatomy and function between humans and rabbits, such as coprophagy, biliary excretion, and development of Pb absorption mechanisms during growth, must be considered when assessing Pb bioavailability, the primary factors controlling Pb dissolution (i.e., pH, mixing, and transit time) are comparable for humans and rabbits (*5, 11, 12, 14, 29*). Therefore, the rabbit GI tract provides an appropriate model to assess Pb bioaccessibility from a mine waste on ingestion by a child. Values for several important parameters in the *in vitro* model were therefore based on observed values in rabbits, as well as humans.

Methods

Mine-Waste Collection and Characterization. The mine waste used for both the *in vivo* experiment and *in vitro* method development (BMW-1) was blended using five mine-waste samples (waste rock and mine overburden material) collected from one mining site to achieve a desired Pb content (3900 mg/kg of Pb). Before blending, each of the five mine-waste samples was air-dried and sieved to <250 μm using a mechanical sieve shaker, because predominantly smaller particles adhere to children's hands and may be ingested (*30*). The remaining samples (BMW-2–4) were composite samples collected from individual mine-waste piles and treated in an identical manner to BMW-1. Bulk Pb concentrations were determined for each sample by digestion in HNO_3/H_2O_2, followed by atomic absorption spectroscopy (*31*). Bulk arsenic (As), Fe, manganese (Mn), zinc (Zn), and calcium (Ca) concentrations were determined by X-ray fluorescence. Sample pH was determined by the saturated paste method

(*32*). Lead minerals in the mine-waste samples were identified by electron microprobe (JEOL 8600) at the Department of Geological Sciences, University of Colorado at Boulder (Table I). A description of microprobe methods, and more detailed descriptions of the Pb mineralogy, may be found in refs 5 and 8.

***In Vivo* Experiment.** Thirty-six female New Zealand White rabbits, weighing an average of 2.1 kg at 12 weeks, were used in the *in vivo* study undertaken at Battelle Columbus Laboratories (Columbus, OH) and performed in compliance with Good Laboratory Practice Regulations (*33*). Animals were caged in individual stainless steel cages with mesh bottoms. To avoid interactions between the rabbit chow and the mine waste, all of the rabbits were fasted for 16 h prior to dosing and 4 h after. During nonfasting periods, Purina high-fiber rabbit chow was provided *ad libitum*. Deionized (DI) water was available at all times. Twenty-seven rabbits were dosed with 2.0 ± 0.02 g of BMW-1 (in gelatin capsules)/kg of body weight, and three rabbits each were killed at 0.5, 1, 1.5, 3, 6, 8, 16, 24, and 36 h after dosing. One group of three rabbits was given a mass of soluble Pb salts equal to that given to the mine-waste-dosed animals (14.3 mg of lead acetate [$Pb(CH_3CO_2)_2 \cdot 3H_2O$]/kg of body weight) and killed 1 h after dosing. Two groups of three rabbits each served as controls and were killed at 1 and 36 h after dosing.

Whole blood was collected from all rabbits via cardiac puncture after sedation with sodium pentobarbital. Subsequently, a lethal injection of pentobarbital was administered, the stomach and intestines were exposed, and the region below the pyloric valve was clamped to prevent passage of the stomach contents into the duodenum. Measurements of pH were performed using an Orion portable pH meter in conjunction with a Ross semimicro pH electrode. The electrode was inserted through an incision in the stomach wall for measurement of pH in the fundic and pyloric regions of the stomach. These measurements were also taken in the duodenum and ileum by removing the small intestine and gently inserting the probe into either end of the segment. Large intestine measurements were made in the middle of the cecum.

Samples of the contents of the stomach, small intestine, and large intestine were collected from each animal in 50-mL Corning polypropylene centrifuge tubes and centrifuged at approximately 2100*g* for 25 min in a Beckman Model TJ6 centrifuge. Approximately 30–40 mL of stomach material was collected with a spoon through a slit in the stomach wall, and any remaining material was removed from the stomach with a spoon, collected into a disposable beaker, and weighed. The volume of material in the fasted rabbit stomachs was approximately 30 mL, while the volume in fed rabbit stomachs was approximately 60 mL. Entire small intestinal contents (10–20 mL) were extruded into single centrifuge tubes. Approximately 40 mL of large intestinal material was collected with a spoon through a slit in the middle portion of the organ, and the remaining material was collected with a spoon into a disposable beaker and weighed. The fluid phase was decanted, and reagent-grade HNO_3 (17N) was used to acidify the fluid samples (1% v/v). Solid samples were dried to determine percent moisture and digested in HNO_3/H_2O_2 (*31*). A Thermo Jarrel Ash, Video 11E atomic absorption spectrophotometer, equipped with a Model CTF 188 graphite furnace and Smith–Hieftje background correction, was used for analysis of samples with <2 mg/L of Pb, and the same instrument, equipped for flame analysis, was used for samples with >2 mg/L of Pb. Organic acid analyses were performed by capillary electrophoresis at Galbraith Labs (Knoxville, TN).

Analytical quality assurance and quality control (QA/QC) samples consisted of 1 in 20 samples analyzed as matrix spikes and duplicates, calibration verification, continuing calibration verification and blanks, and the use of the method of standard additions when recalcitrant matrices were encountered. Based on quality control limits for acceptable analytical results (*34*), all data were accurate and precise.

***In Vitro* Experiments.** A mine-waste/solution ratio of 1:10 (4.0 ± 0.01 g of mine waste and 40 mL of fluid) was selected for the *in vitro* method because each rabbit was dosed with 2 g of BMW-1/kg of body weight (average of 4.2 g of BMW-1/rabbit), and the 1:10 solid-to-fluid ratio was the average ratio observed in the 36 rabbit stomachs and small intestines. The *in vivo* experiment was designed to minimize interactions between the mine waste and rabbit chow; however, because rabbits practice coprophagy (*35*), some interaction between mine waste and food is inevitable. Therefore, *in vitro* tests were conducted with both mine waste alone (in triplicate) and a mine-waste/rabbit chow mixture (4.0 g of BMW-1, 1.0 g of rabbit chow, 40 mL of fluid), in duplicate. The *in vitro* test was also conducted with an equivalent mass of Pb as lead acetate, in both the presence and absence of Pb-free mine waste, to allow calculation of Pb solubility from BMW-1 relative to lead acetate. Subsequent to method development using BMW-1, three additional mine-waste samples (BMW-2–4, Table I) were subjected to the *in vitro* test to examine Pb availability from mine waste with disparate Pb mineralogies.

A total of 40 mL of type I DI water was adjusted to pH 1.3 with HCl. Mine waste (4 g), pepsin (50 mg, activity of 800–2500 units/mg, Sigma Chemical Co.), and organic acids (acetate [0.5 mL], citrate [0.5 g], lactate [0.42 mL], and malate [0.5 g]) were added, and the flask was placed on a wrist-action shaker in a water bath at 37 °C, representative of GI tract temperature (*23*). The pH was checked at 10-min intervals during the first half hour and at half-hour intervals thereafter, and measured volumes of 12N HCl were added to maintain a pH of 1.3. Aliquots (2 mL) were removed from the reaction flask at 0.5, 1.0, 1.5, and 2.0 h after initiation of the reaction and centrifuged immediately at approximately 2100*g* for 25 min, and the liquid fraction was decanted for Pb analysis. After 2 h, the reaction vessel was titrated to pH 7.0 ± 0.2 by the addition of a dialysis bag (8000 MWCO, Spectra/Por cellulose ester tubing) containing 3 mL of DI and $NaHCO_3$ of equivalent molarity to the calculated acidity (HCl) in the flask. The system required approximately 30 min to reach a pH of 7.0 ± 0.2, after which the dialysis bag was removed and the contents were emptied into the reaction flask. Pancreatin (20 mg, activity equivalent to 4× U.S. Pharmacopeia specifications, Sigma Chemical Co.) and bile extract (70 mg) were added, and the flask was returned to the water bath. Two hours were allowed for the flask contents to reach equilibrium, the fluid volume was measured, and a 10-mL fluid sample was collected by centrifugation for Pb analysis. Fluids were analyzed for Pb using the methods and instrumentation described in the *in vivo* experimental section. GI tract enzymes and

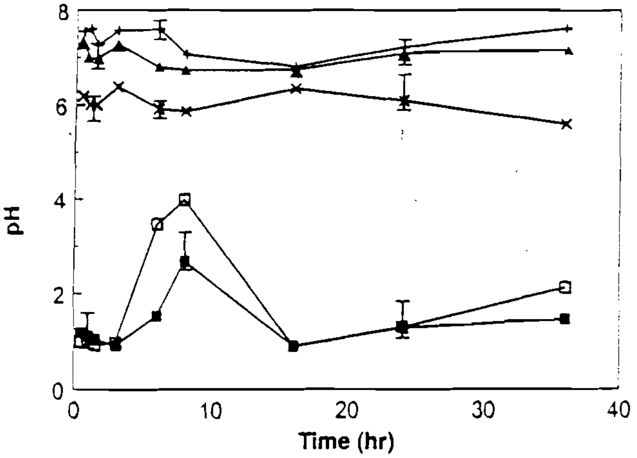

Figure 1. pH variations in rabbit GI tract as a function of time and location: (■) fundic stomach, (□) pyloric stomach, (▲) duodenum, (+) ileum, (×) cecum. Error bars indicate standard deviation for the measured values in three rabbits.

acids were obtained from Sigma Chemical Co. (St. Louis, MO).

Method development testing for the *in vitro* test also included omission of the organic acids, omission of the GI tract enzymes, and omission of both the acids and enzymes (each test in duplicate). A parallel procedure was carried out (in duplicate) with an equimolar amount of a soluble lead acetate [$Pb(CH_3CO_2)_2 \cdot 3H_2O$, 24.5 mg] to evaluate Pb availability from a soluble salt with no matrix present. Finally, the *in vitro* test was conducted with lead acetate (in duplicate) in reaction flasks containing 4 g of low-Pb mine waste (100 mg/kg of Pb). This mine waste was also subjected to the *in vitro* procedure (in duplicate) to determine available Pb. An experimental blank (no solid material in flask) was carried through the procedure during each experiment.

Results

Mineralogy, Metal Concentrations, and Sample pH. Lead mineralogy in samples BMW-1–4 (Table I) was calculated as percent occurrence of Pb-bearing grains and indicates a diverse Pb mineralogy consisting of both sulfate/sulfide and oxide/phosphate phases, consistent with Pb mineralogy observed during a comprehensive study at this site (*8*). Bulk metals data are presented (Table I) for comparison of these mine-waste samples with samples that may be analyzed by the *in vitro* method in the future. Although the bulk concentrations of As, Fe, Mn, Zn, and Ca will have a minimal effect on the dissolution of Pb-bearing phases, the presence of soluble Fe and Ca will decrease the absorption of Pb across the intestinal epithelium (*16*). The acidic pH values determined in these samples (2.6–3.8) are consistent with the high Fe concentrations (5.0–12.3 wt %) and the presence of pyrite and suggest that these materials will have a limited capacity to buffer stomach acids on ingestion.

***In Vivo* pH.** The pH measurements collected in the rabbit GI tracts (36 rabbits) indicate that a pH in the range of 1.0–1.3 exists in the stomach under fasting conditions, increasing to 2.8 and 4.1, respectively, in the fundic and pyloric regions of the stomach on ingestion of food (Figure 1). Small and large intestinal pH values were independent of nutritional status and averaged 6.9 in the duodenum, 7.4 in the ileum, and 5.9 in the cecum. These values are in agreement with the basal gastric pH of 1.0–2.0 (*11, 12*) and with the small intestinal pH of 4.7–7.2 (*15*) for human subjects, validating the use of female New Zealand White rabbits as a GI model for humans with respect to pH. Based on observations in New Zealand White rabbits, pH levels of 1.3 and 7.0 were selected to represent the stomach and small intestinal phases, respectively, in the *in vitro* model.

Table II. Concentrations of Organic Acids in Rabbit GI Tract

organic acid	pK_a	lead-acid log K_{ML},[e] ionic strength 1.0	stomach concn[a] (mg/L)	small intestine[a] (mg/L)
acetate	4.7[b]	2.1	189	212
butyrate	4.9[c]	2.1	<10	<10
citrate	pK_1 3.1[b] pK_2 4.8[b]	4.1	534	<10
lactate	3.8[b]	2.0	174	972
malate	pK_1 2.8[d] pK_2 5.7[d]	2.4	1302	100
succinate	pK_1 4.2[d] pK_2 5.6[d]	2.4	64	<10
tartrate	pK_1 3.1[b] pK_2 4.8[b]	2.6	<10	<10

[a] Determined by capillary electrophoresis. [b] Ref 40. [c] Ref 41. [d] Ref 42. [e] Ref 36.

Organic Acids. Organic acids are known to chelate Pb (*21*) and may increase solubilized Pb concentrations in the small intestine, promoting transport of Pb across the intestinal epithelium (*6*). Therefore, concentrations of organic acids were measured by capillary electrophoresis (Table II) in the stomach and small intestinal fluids of a rabbit from the 6-h post-dose group. The pK_a values for the first proton released from all of the carboxylic acids for which analyses were performed are ≥2.8 (Table II); therefore, these acids will be protonated during fasting stomach conditions (pH 1–2) but may chelate Pb in the stomach in the presence of food (pH 4–6) and in the small intestine (pH 7). Comparison of stability constants (determined at 25 °C and solution ionic strength of 1.0 (*36*) for the lead carboxylate complexes) indicates that citrate, if present, will form the most stable complex with Pb (log K_{ML} = 4.1), while the remaining acids will form complexes of decreasing stability in the order tartrate > malate, succinate > acetate, butyrate > lactate. The ability of organic acids to serve as Pb chelators depends on the ability of the soluble chelator to complex Pb (which is pH dependent due to proton competition for the ligand), the strength of Pb^{2+} binding to individual ligands (e.g., selectivity for Pb), and the activity of competing cations (e.g., Ca^{2+}, Zn^{2+}, or Cu^{2+}) that may displace Pb. Therefore, in the small intestine at pH 7, the K_{ML} values for organic acids (Table II) indicate that nearly all Pb complexed by organic acids would be present as lead citrate complexes; however, this does not eliminate the possibility that Pb would be preferentially complexed by stronger chelators (e.g., enzymes and amino acids) or displaced by competing cations.

Malate and citrate were the most concentrated carboxylic acids in the rabbit stomachs, whereas lactate and acetate were most concentrated in the small intestine (Table II). The decrease in citrate and malate concentrations between the stomach and small intestinal fluid may be due to the absorption of these species in the small intestine or to the formation of stable complexes that are

Table III. Pb Mass (μg) Recovered from Rabbit Fluids and Solids, Reported as Arithmetic Mean, Standard Deviation of Three Samples[a]

time (h)	stomach fluid[b]	small int. fluid[b]	large int. fluid[b]	blood[d]	stomach solids	small int. solids	large int. solids	% total Pb in stomach in fluid phase[h] (%)
0.5	230 ± 170	6.9 ± 6.7	3.0[c]	2.0 ± 0.4	6980 ± 2290	38 ± 20	170 ± 60	3 ± 2
1	260 ± 140	28 ± 34	3.8 ± 2.4[e]	1.5 ± 0.5	6670 ± 2820	480 ± 710	130 ± 47	4 ± 2
1.5	620 ± 250	140 ± 27[e]	–[f]	1.7 ± 0.4	6210 ± 2070	1230 ± 630	690 ± 760	9 ± 4
3	62 ± 53	250 ± 220	32 ± 25	5.4 ± 2.8	850 ± 300	4580 ± 4830	550 ± 530	7 ± 6
6	5.8 ± 3.8	6.1 ± 6.7	53 ± 18	7.1 ± 2.1	62 ± 80	160 ± 230	1170 ± 300	9 ± 6
8	1.6 ± 0.5	1.6 ± 1.0	46 ± 20	7.7 ± 2.8	NA[i]	NA	NA	
16	5.3 ± 1.2	15 ± 6.1	7.2 ± 0.4[e]	3.9 ± 0.8	NA	NA	NA	
24	3.4 ± 2.0	5.3 ± 0.4[e]	8.2 ± 1.0[e]	5.3 ± 1.4	NA	NA	NA	
36	3.4 ± 2.4	3.3 ± 2.1	2.9 ± 0.2[e]	6.4 ± 2.5	NA	NA	NA	
1 (soluble salt dose)[g]	2000 ± 610	810 ± 390	620 ± 58[e]	14 ± 7.9	3400 ± 2300	1150 ± 300	530 ± 400	37 ± 11
1 (blank)	1.4 ± 0.2	0.6 ± 0.4	10 ± 1.4[e]	0.8 ± 0.4	120 ± 44	33 ± 28	180 ± 31	1 ± 0.1
36 (blank)	2.5 ± 1.7	28 ± 0.6[e]	0.7 ± 0.2[e]	2.9 ± 0.4	NA	NA	NA	

[a] Each rabbit dosed with 2.0 g of BMW-1/kg of body weight (average animal weight of 2.1 kg) for an average dose of 4.2 g of BMW-1 (16.4 mg of Pb). [b] Corrected for percent moisture in solids. [c] No error is presented, because only one measurement was obtained. [d] Assuming average rabbit blood volume of 56 mL/kg of body weight (*43*). [e] Error based on two measurements. [f] No fluid available after centrifugation. [g] One hour between dosing and sample collection. [h] Value calculated by dividing the Pb mass in stomach fluid by total Pb mass in stomach. Associated error calculated as standard deviation of Pb mass in stomach fluid divided by total Pb mass in stomach. [i] NA, not analyzed.

not resolved during capillary electrophoresis. Lactic acid, which may be produced in the stomach (*37*), has been observed previously in the small intestines of rabbits (*38*). Because the concentrations of acetate, citrate, lactate, and malate were variable throughout the rabbit GI tract, an average concentration of 500 mg/L for each acid was used during the *in vitro* experiments.

Lead in *in Vivo* Fluid and Solid Samples. Lead analyses were performed on all of the fluid samples and on the solid samples collected from the 0.5–6-h post-dose groups. Solid samples from the 8–36-h post-dose groups were not analyzed, because the solid Pb mass had traversed the small intestine and was no longer available for dissolution and absorption (Table III). Reported data were corrected for percent moisture in the solids and are reported as mass (μg) rather than concentration to account for the varying fluid volumes and solid masses present in each rabbit (Table III). Data are presented with standard deviations for each set of three rabbits and indicate substantial interanimal variability (Table III); observed standard deviations are generally in the range of 30–50%. Lead masses in the 1- and 36-h control rabbits are less than or equivalent to any of the dosed rabbits, indicating that background Pb masses are 1–10 and 30–180 μg in GI tract fluids and solids, respectively (Table III), probably due to low concentrations of Pb (0.75 mg/kg) present in the rabbit feed.

Acidification of the small intestinal fluid with HNO_3, for preservation, resulted in the formation of a flocculent precipitate (believed to be an agglomeration of proteins and enzymes that are present in small intestinal fluid), which was readily resuspended when the pH was raised to >5.0 using NaOH. To evaluate the banding of Pb by the precipitate, three small intestinal fluids were analyzed for Pb concentration, with the precipitate both solubilized and precipitated and removed by centrifugation. Comparison of the Pb concentrations in the fluid samples after solubilization of the precipitate indicates that 63 ± 4% of the total Pb in solution is removed by this precipitation reaction. Furthermore, a dialysis experiment using 12000 MWCO tubing indicated that 93% of Pb in one small intestinal fluid sample was incapable of diffusing out of the dialysis bag in 24 h. These results suggest that a substantial portion (approximately 60–95%) of solubilized small intestinal Pb is bound to a protein or enzyme that is >12000 MW.

Mean solubilized Pb masses from BMW-1 as a function of time and GI tract compartment exhibit the expected profile (Table III), with maximum solubilization in the stomach, small intestine, and large intestine occurring at approximately 1.5, 3, and 6 h, respectively. Maximum solubilized Pb masses decrease in each successive segment of the GI tract, with stomach, small intestinal, and large intestinal masses of 0.62, 0.25, and 0.053 mg recovered, respectively. The decrease in Pb mass in solution between stomach and small intestine is probably due to precipitation or sorption reactions that occur as the pH is increased from 1.3 to 7, whereas the decrease in Pb mass between small and large intestine is most likely due to Pb absorption across the intestinal epithelium. Mean Pb masses in GI tract solids are consistent with the pattern observed in the fluid phase (Table III). Emptying of solid Pb from the stomach into the small intestine is complete within 3 h, during which time Pb in the small intestinal solids reaches a maximum (Table III).

When considering available Pb based on either *in vivo* or *in vitro* results, it should be recognized that absorption of Pb in the small intestine is a nonequilibrium process. Four pools of Pb are present in the small intestine: (1) solubilized Pb, either ionic or bound by small organic ligands (Pb_{sol}); (2) solubilized Pb that is bound to large MW entities (Pb_{bnd}); (3) Pb that was solubilized in the stomach but has sorbed to solid surfaces on entering the small intestine (Pb_{sorb}); and (4) Pb that was insoluble in the stomach (Pb_{insol}). Because Pb_{insol} is unlikely to be solubilized during passage through the small intestine, this fraction of ingested Pb is not bioaccessible. The other three forms of Pb are all available for absorption. Pb_{sol} is immediately available, while Pb_{bnd} and Pb_{sorb} must become unbound or desorbed, respectively, prior to absorption in the small intestine. However, as Pb_{sol} is absorbed, Pb_{bnd} and Pb_{sorb} could be released into solution to regain equilibrium partitioning of Pb between the fluid and solid phases. Therefore, assuming that the binding or adsorption mechanisms are reversible, the entire pool of Pb_{sol}, Pb_{bnd}, and Pb_{sorb} [which is equal to the total Pb

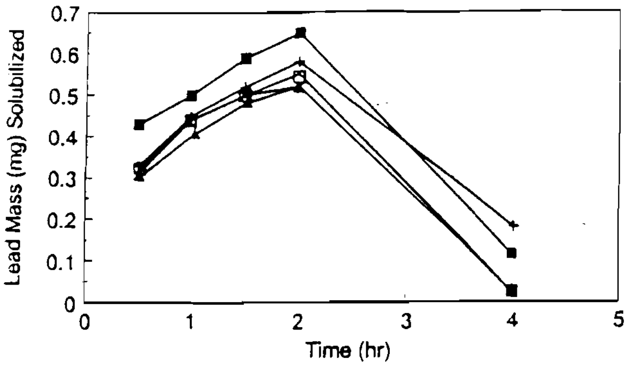

Figure 2. Average Pb mass (mg) solubilized during the *in vitro* method development testing: (■) standard test, (+) rabbit chow present during standard test, (□) no acids present during test, (▲) no enzymes present during test, (×) no enzymes or acids present during test.

in the stomach fluid phase, because surface adsorption of Pb will be negligible at the acidic pH of the stomach (*39*)] is theoretically available for absorption, if the kinetics of Pb absorption across the intestinal epithelium are sufficiently rapid with respect to intestinal transit time and to the kinetics of Pb release or desorption. The mass of Pb present in the Pb_{bnd} and Pb_{sorb} pools and the relative release and desorption kinetics were not evaluated during this study. Consequently, the maximum mass of solubilized Pb in the stomach compared to the mass that is insoluble (e.g., the partitioning ratio from solid to fluid) represents a conservative (upper) estimate of available Pb.

Based on the above reasoning, calculation of *in vivo* Pb solubility from BMW-1 (mass of Pb solubilized divided by total Pb present in the stomach) shows that the solubilized Pb fraction increased from an initial 3% to a maximum of 9% at the 1.5-h time point (Table III). The limited Pb dissolution from mine waste is due to the low solubility of Pb-bearing minerals, kinetic dissolution limitations (*10*), and encapsulation of Pb phases by inert matrices (e.g., silicates, pyrite, and jarosite) (*5*).

A total of 37% of the recovered Pb from $Pb(OAc)_2$ is present in the stomach fluids after 1 h, suggesting that the balance is present in the stomach solids. It is unclear why the bulk of Pb from $Pb(OAc)_2$ was present in the stomach solids. Blood-lead response 1 h after ingestion of $Pb(OAc)_2$ was 9.4 times larger than from an equivalent mass of Pb contained in BMW-1, supporting maximum *in vivo* mine-waste-lead solubility, relative to $Pb(OAc)_2$, of approximately 10%.

Lead in *in Vitro* Fluids. Reproducibility of the *in vitro* method was tested by conducting triplicate experiments using BMW-1, for which the maximum Pb mass solubilized (2-h sample) was 0.65 ± 0.04 mg. The method development tests, consisting of the addition of rabbit chow, the omission of organic acids, the omission of GI tract enzymes, and the omission of both acids and enzymes (each performed in duplicate), resulted in maximum solubilized Pb masses at the 2-h time point of 0.58 ± 0.04, 0.55 ± 0.01, 0.52 ± 0.02, and 0.52 ± 0.02 mg of Pb, respectively (Figure 2). The blank flasks were below the instrument detection limit (IDL, 0.10 mg/L) in each experiment. The method detection limits (IDL × dilution factor × volume in flask) in the mine-waste and method development flasks and the $Pb(OAc)_2$ flask were 0.020 and 0.60 mg, respectively.

The method development experiments indicate that the addition of rabbit chow to the reaction flask causes a slight decrease in the mass of Pb solubilized in the stomach from 0.65 ± 0.04 to 0.58 ± 0.04 mg, while the mass of Pb in the soluble phase during the small intestinal incubation was increased slightly from 0.11 ± 0.04 to 0.18 ± 0.03 mg (Figure 2). The reason for a decrease in stomach-solubilized Pb in the presence of rabbit chow is unknown, while the increase in intestinal solubilized Pb is most likely due to a solubilized component of rabbit chow, probably citrate, amino acids, or suspended organic matter, that is capable of binding Pb and retaining it in solution. The absence of either organic acids or GI tract enzymes, or both components together, results in a 20% decrease in maximum stomach Pb solubility (0.65 ± 0.04 to 0.52 ± 0.02 mg), consistent with the observation that the presence of organic acids in solution may increase the dissolution of Pb-bearing phases (*38*). In addition, both acids and enzymes are necessary to retain Pb in solution during the small intestinal phase (Figure 2). These data suggest that organic acids and GI tract enzymes in the pH 7 environment of the small intestine either bind Pb or inhibit the formation of Pb-bearing precipitates.

Based on the reasoning presented in the *in vivo* results section, the fraction of available Pb *in vitro* from BMW-1 (4 ± 0.2%), determined by dividing the average dissolved Pb mass at 2.0 hr (0.65 mg) by the mass of Pb in the flask (15.6 mg) (Table IV), was in good agreement with the *in vivo* result (9 ± 4%). The comparison of *in vivo* and *in vitro* solubilized Pb masses (1.5 h for *in vivo* and 2.0 h for *in vitro*) were nearly identical: 0.62 versus 0.65 mg for the *in vivo* and *in vitro* systems, respectively (Tables III and IV). The overall rate of Pb dissolution in the stomach (the rate of change in solubilized Pb with time in Table III versus Table IV) was similar in the *in vivo* and *in vitro* systems, although the *in vitro* dissolution rate was more constant (less variability in the rate of Pb dissolution), indicating that dissolution kinetics are important in controlling Pb bioaccessibility from BMW-1.

The $Pb(OAc)_2$ results indicate that, after correction for Pb emanating from the blank mine waste (100 mg/kg of bulk Pb concentration resulted in 0.07 mg in the *in vitro* test), 68% of the Pb from $Pb(OAc)_2$ is bioaccessible *in vitro* in the presence of a mine-waste matrix, while 76% is available when no matrix is present (Table IV). The discrepancy between available Pb from $Pb(OAc)_2$ during *in vitro* (68 or 76%, depending on the matrix present) and *in vivo* (37%) testing could be due to a variety of factors, including (1) pH differences between the systems, (2) lower concentrations of organic acids *in vivo* than used *in vitro*, or (3) incomplete recovery of ingested material during the *in vivo* study. Soluble Pb mass from $Pb(OAc)_2$ in the absence of mine waste decreased by a factor of 2 in the small intestinal simulation (Table IV), while in the presence of mine waste, soluble Pb decreased by a factor of 9. These results suggest that Pb absorption to the mine-waste surface may reduce Pb solubility in the small intestine.

The mine-waste samples BMW-2–4, consisting predominantly of lead phosphates, manganese-lead oxides, iron-lead oxides, and iron-lead sulfates, also resulted in limited bioaccessible Pb when tested by the *in vitro* method (0.5–6%, Table IV). BMW-2, which consists of ferromanganese lead oxides and iron-lead sulfate, produced only 0.5% available Pb during the *in vitro* test and reached equilibrium dissolved Pb concentration prior to collection of the initial sample (0.5 h, Table IV). BMW-3 and BMW-4

Compared to *in Vivo* Results

time (h)	Pb mass (mg) solubilized from mine waste during *in vitro* test					
	BMW-1	BMW-2	BMW-3	BMW-4	Pb(OAc)$_2$/ no mine waste	Pb(OAc)$_2$/ blank mine waste
0.5	0.43 ± 0.04	0.02[a]	0.94[a,b]	0.06[a]	11.0 ± 0.2	10.6 ± 0.2
1.0	0.50 ± 0.02	0.02	1.09[b]	0.09	11.9 ± 0.2	10.4 ± 0.3
1.5	0.59 ± 0.06	0.02	1.30[b]	0.11	11.8 ± 0.3	10.2 ± 0.1
2.0	0.65 ± 0.04	0.02	1.26[b]	0.15	11.4 ± 0.1	10.2 ± 0.1
mass of Pb (mg) solubilized in small intestine simulation	0.11 ± 0.04	<0.008[d]	0.03	0.04	5.3 ± 0.2	1.0 ± 0.1
mass of Pb added to flask (mg)	15.6	4.1	23.3	7.2	15.6	15.6
fraction available Pb *in vitro* (%)	4[d]	0.5[d]	6[d]	2[d]	76[d]	68[d]
fraction available Pb *in vivo*[c] (%)	9[e]				37[e]	

[a] No standard error available because only one test was conducted. [b] Based on detection limit of 0.1 mg/L of Pb by direct-aspiration atomic absorption spectrometry. [c] Method for establishing maximum available Pb *in vivo* same as *in vitro*, using data from Table II. [d] Fraction of bulk Pb mass solubilized during *in vitro* test (4.0 g substrate/40 mL of fluid). [e] Fraction of bulk Pb mass solubilized during *in vivo* feeding study.

(6% and 2% available Pb, respectively) contain greater percentages of Pb minerals such as lead oxides, lead silicates, and anglesite (Table I), which appear to be more soluble than the lead phosphates, ferromanganese lead oxides, and iron-lead sulfates. In addition, BMW-3 reached equilibrium concentration after only 1.5 h, while BMW-4 did not reach equilibrium during the 2-h stomach incubation. These data indicate that dissolution kinetics limit Pb bioaccessibility from the suite of Pb minerals present in BMW-1 and BMW-4 but not from BMW-2 and BMW-3. No discrete Pb mineral phase appears consistently responsible for the available Pb from these mine wastes, a result that was expected, due to the highly variable Pb mineral composition. Factors such as mineral associations, the presence and type of alteration and precipitation rinds, encapsulation of Pb phases in inert minerals (e.g., silicates), and the presence of surface-adsorbed Pb are likely to be of equal or greater importance in controlling Pb bioaccessibility in the GI tract.

Conclusions

This study has demonstrated that an *in vitro* method can be an effective tool in evaluating the geochemical and physiological factors controlling the dissolution of mine-waste Pb in the GI tract.

The rabbit was determined to be an appropriate model for human GI tract conditions, with respect to pH and transit times. In a validation study using female New Zealand White rabbits, average pH values were 1.3 and 3–4 in the stomach under fasting and fed conditions, respectively, and approximately 7 in the small intestine, similar to pH values reported in humans. Acetate, citrate, lactate, and malate are all present in varying concentrations in both human and rabbit GI tracts and may chelate Pb with relative complex formation strengths of citrate > malate > acetate > lactate, thereby increasing Pb solubility and subsequent absorption across the intestinal epithelium by passive diffusion. However, a variety of potential chelating agents (organic acids, amino acids, proteins, enzymes, and tannins) will compete for soluble Pb, and on the basis of two preliminary tests, 60–95% of solubilized Pb in the small intestine appears to be bound to a protein or enzyme >12000 MW. Although a stomach pH of 1.3 was used in the *in vitro* test to maximize Pb dissolution, this stomach acidity would apply only to fasting children. A stomach pH of 3–4, typical when food is in the stomach, would be expected to further reduce Pb bioaccessibility by decreasing the extent of Pb mineral dissolution.

The *in vitro* beaker assay, modeled after an assay method used to determine available Fe from food, was successful in replicating Pb dissolution during the feeding study. Four mine-waste samples with highly variable mineral composition (BMW-1–4) resulted in only 4, 0.5, 6, and 2% bioaccessible Pb, respectively, suggesting that geochemical and physiological factors limit the solubility and, therefore, the availability of Pb from mine waste, regardless of whether the bulk Pb mineralogy consists of the sulfate/sulfide or the oxide/phosphate assemblage. The 4% available Pb from BMW-1 is in good agreement with a 30-day feeding study in Sprague–Dawley rats, using this mine waste, which produced only 3% absolute Pb bioavailability based on blood-lead data (*3*). In addition, method development testing indicates that although HCl concentration is the most important GI component controlling Pb dissolution in the stomach, both organic acids and enzymes are necessary to retain Pb in solution during the small intestinal incubation. Based on these results, the assay appears to provide a useful, rapid, screening-level test to predict maximum available Pb from mine wastes.

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Literature Cited

(1) EPA. *User's Guide for Pb: A PC Software Application of the Uptake/Biokinetic Model Version 5.0*; Department of Research and Development, U.S. Environmental Protection Agency; Washington, DC, 1990.

(2) Freeman, G. B.; Johnson, J. D.; Killinger, J. M.; Liao, S. C.; Feder, P. I.; Davis, A. O.; Ruby, M. V.; Chaney, R. L.; Lovre, S. C.; Bergstrom, P. D. *Fund. Appl. Toxicol.* 1992, *19*, 388–398.

(3) Freeman, G.; Johnson, J.; Liao, S.; Schoof, R.; Bergstrom, P. *Toxicologist* 1993, *13* (1), 301.

(4) Dieter, M. P.; Matthews, H. B.; Jeffcoat, R. A.; Museman, R. F. *J. Toxicol. Environ. Health* 1993, *39*, 79–93.

(5) Davis, A.; Ruby, M. V.; Bergstrom, P. D. *Environ. Sci. Technol.* 1992, *26* (3), 461–468.

(6) Blair, J. A.; Coleman, I. L.; Hilburn, M. E. *J. Physiol.* 1979, *286*, 343–350.

(7) Conrad, M. E.; Barton, J. C. *Gastroenterology* 1978, *74*, 731–740.

(8) Davis, A.; Drexler, J. W.; Ruby, M. V.; Nicholson, A. *Environ. Sci. Technol.* 1993, *27* (7), 1415–1425.

(9) Vlek, P. L. G.; Blom, J. M.; Beek, J.; Lindsay, W. L. *Soil Sci. Soc. Am. Proc.* 1974, *38*, 429.

(10) Ruby, M. V.; Davis, A. O.; Kempton, J. H.; Drexler, J. W.; Bergstrom, P. D. *Environ. Sci. Technol.* 1992, *26* (6), 1242–1248.

(11) Malagelada, J. R.; Longstreth, G. F.; Summerskill, W. H. J.; Go, V. L. W. *Gastroenterology* 1976, *70*, 203–210.

(12) Malagelada, J. R.; Go, V. L. W.; Summerskill, W. H. J. *Dig. Dis. Sci.* 1979, *24*, 101–110.

(13) Hemphill, C. P.; Ruby, M. V.; Beck, B. D.; Davis, A.; Bergstrom, P. D. *Chem. Speciation Bioavailability* 1991, *3* (3/4), 135–148.

(14) Hunt, J. N.; Spurrel, W. R. *J. Physiol.* 1951, *113*, 157–168.

(15) Murthy, S. N. S.; Kostman, J.; Dinoso, V. P. *Dig. Dis. Sci.* 1980, *25*, 289–294.

(16) Chaney, R. L.; Mielke, H. W.; Sterret, S. B. *Environ. Geochem. Health* 1989, *11*, 105–129.

(17) Klotz, I. M.; Urquhart, J. M.; Fiess, H. A. *J. Am. Chem. Soc.* 1952, *74*, 5537-5538.

(18) Richardt, G.; Federolf, G.; Habermann, E. *Biochem. Pharmacol.* 1986, *35* (8), 1331–1335.

(19) Li, N. C.; Manning, R. A. *J. Am. Chem. Soc.* 1955, *77*, 5225–5228.

(20) Quarterman, J.; Humphries, W. R.; Morrison, J. N.; Morrison, E. *Environ. Res.* 1980, *23*, 54–67.

(21) Jugo, S.; Maljkovic, T.; Kostial, K. *Toxicol. Appl. Pharmacol.* 1975, *34*, 259–263.

(22) Narasinga Rao, B. S.; Proabhavati, T. *Am. J. Clin. Nutr.* 1978, *31*, 169–175.

(23) Miller, D. D.; Schricker, B. R.; Rasmussen, R. R.; Van Campen, D. *Am. J. Clin. Nutr.* 1981, *34*, 2248–2256.

(24) Miller, D. D.; Schricker, B. R. In *In Vitro Estimation of Food Iron Bioavailability*; Kies, C., Ed.; ACS Symposium Series 203; American Chemical Society: Washington, DC, 1982; pp 11–24.

(25) Reddy, M. B.; Chidambaram, M. V.; Fonseca, J.; Bates, G. W. *Clin. Physiol. Biochem.* 1986, *4*, 78–86.

(26) Reddy, M. B.; Browder, E. J.; Bates, G. W. In *Essential and Toxic Trace Elements in Human Health and Disease;* Prasad, A., Ed.; Alan Liss Inc.: New York, 1988.

(27) Calabrese, E. J.; Barnes, R.; Stanek, E. J., III; Pastides, J.; Gilbert, C. E.; Veneman, P.; Wang, X.; Laszitity, A.; Kostecki, P. T. *Regul. Toxicol. Pharmacol.* 1989, *10*, 123–137.

(28) Kimbrough, R. D.; Falk, H.; Stehr, P.; Fries, G. *J. Toxicol. Environ. Health* 1984, *14*, 47–93.

(29) Auvergne, A.; Bouyssou, T.; Pairet, M.; Bouillier-Oudot, M.; Ruckebusch; Y.; Candau, M. *Reprod. Nutr. Dev.* 1987, *27* (4), 755–768.

(30) Duggan, M. J.; Inskip, M. J.; Rundle, S. A.; Moorcroft, J. S. *Atmos. Environ.* 1985, *44*, 65–79.

(31) EPA. *Test Methods for Evaluating Solid Waste. Volume 1A: Laboratory Manual, Physical/Chemical Methods*; Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency: Washington, DC, 1986, p 222.

(32) ASA. *Methods for soil analysis. Part 2: Chemical and microbiological properties*; Black, C. A., Ed.; American Society for Agronomy, Inc.: Madison, WI, 1965; pp 914.

(33) EPA. Toxic Substances Control Act, Good Laboratory Practice Standards; U.S. Environmental Protection Agency, 1989, 40 CFR, Part 792.

(34) EPA. *Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses*; Hazardous Site Evaluation Division, U.S. Environmental Protection Agency: Washington, DC, 1988, p 19.

(35) Soave, O.; Brand, C. D. *Cornell Vet.* 1991, *81*, 359–364.

(36) Martell, A. E.; Smith, R. M. In *Critical Stability Constants*; Plenum Press: New York, 1977; Vol. 3.

(37) Argenzio, R. A.; Southworth, M. *Am. J. Physiol.* 1974, *228* (2), 454–460.

(38) Marty, J.; Raynaud, P. *Arch. Sci. Physiol.* 1966, *20* (4), 515–524.

(39) Salim, R.; Cooksey, B. G. *Plant Soil* 1980, *54*, 399–417.

(40) *The Merck Index*, 11th ed.; Budavari, S., Ed.; Merck and Co., Inc.: Rahway, NJ, 1989.

(41) Kemp, D. S.; Vellacio, F. In *Organic Chemistry*; Poulson, S., Ed.; Worth Publishers, Inc.: New York, 1980: pp 327–330.

(42) Streitwieser, A.; Heathcock, C. H. In *Introduction to Organic Chemistry*, 3rd ed.; Macmillan Publishing Co., New York, 1985; p 864.

(43) Armin, J.; Grant, R. T.; Pels, H.; Reeve, E. B. *J. Physiol.* 1952, *116*, 59–73.

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APPENDIX B

HEALTH AND SAFETY PLAN
PART I

HEALTH AND SAFETY PLAN
PART I

AMES STREET FACILITY
ROCHESTER, NEW YORK

Prepared by:
ABB ENVIRONMENTAL SERVICES, INC.
ROCHESTER, NEW YORK

APRIL 1993
Revision 1: July 1995
Revision 2: November, 1995

AMES STREET FACILITY

HEALTH AND SAFETY PLAN
PART I

TABLE OF CONTENTS

AMES STREET FACILITY

HEALTH AND SAFETY PLAN
PART 1

TABLE OF CONTENTS
(continued)

AMES STREET FACILITY

HEALTH AND SAFETY PLAN
PART 1

TABLE OF CONTENTS
(continued)

Section Title Page No.

AMES STREET FACILITY

HEALTH AND SAFETY PLAN
PART II

TABLE OF CONTENTS
(continued)

APPENDICES, Part 2

The following appendices are applicable for the work anticipated at the site (see Health and Safety Plan, Part II):

X A. AUTHORITY AND RESPONSIBILITY OF HEALTH AND SAFETY PERSONNEL

X B. TRAINING PROGRAM

X C. MEDICAL SURVEILLANCE PROGRAM

X D. ENGINEERING CONTROLS

X E. PERSONAL PROTECTIVE LEVEL DETERMINATION

X F. MONITORING EQUIPMENT

X G. ZONATION

X H. WORK PRACTICES

_ I. CONFINED SPACE ENTRY PROCEDURES

_ J. EXCAVATION AND TRENCHING

_ K. TEMPERATURE EXTREMES
    _ HEAT STRESS
    _ COLD STRESS

AMES STREET FACILITY

HEALTH AND SAFETY PLAN
PART II

TABLE OF CONTENTS
(continued)

APPENDICES, Part 2

AMES STREET FACILITY

HEALTH AND SAFETY PLAN
PLAN I

LIST OF FIGURES

AMES STREET FACILITY

HEALTH AND SAFETY PLAN
PLAN I

LIST OF TABLES

1.0 GENERAL

1.1 SCOPE AND PURPOSE

This Health and Safety Plan (HASP) has been prepared in conformance with the ABB Environmental Services, Inc. (ABB Environmental) Health and Safety Program and is intended to meet the requirements of 29 CFR 1910.120. As such, the HASP addresses those activities associated with field and other operations for this project. Compliance with this HASP is required for all ABB Environmental personnel. Contractor personnel entering the site will be supplied with a copy of this HASP for informational purposes.

1.2 PROJECT PERSONNEL

1.2.1 Project Manager

The project manager (PM) is the individual with overall project management responsibilities. Those responsibilities as they relate to health and safety include provision for the development of this site-specific HASP; the necessary resources to meet requirements of this HASP; the coordination of staff assignments to ensure that personnel assigned to the project meet medical and training requirements; and the means and materials necessary to resolve any health and safety issues that are identified or that developed on the project.

As of November, 1995, the PM is Geoff Knight from ABB-ES' Rochester, NY office.

1.2.2 Field Operations Leader/Construction Manager

The Resident Engineer or Field Operations Leader (FOL) is the PM's designee who is on-site and vested with the authority by the PM to carry out day-to-day site operations, including interfacing with the site Health and Safety Officer (HSO).

As of November, 1995, Tony Delano, P.E. from ABB-ES' Rochester office is the FOL.

1.2.3 Health and Safety Officer

The HSO for each field activity is designated by the PM with concurrence of the Health and Safety Supervisor (HSS) or Health and Safety Manager (HSM). The HSO will have at least an indirect line of reporting to the HSM through the HSS for the duration of his/her assignment as project HSO. The HSO is responsible for developing and implementing this site-specific HASP and any activity-specific procedures in accordance with the ABB Environmental Health and Safety Program. The HSO will investigate all accidents, illnesses, and incidents occurring on-site. The HSO will also conduct safety briefings and site-specific training for on-site personnel. The HSO, in consultation with the PM, HSS or HSM, is responsible for updating and modifying this HASP as site or environmental conditions change.

1.2.4 Other ABB Environmental Personnel

Depending on the specific activity being conducted (e.g., soil investigation, demolition, construction, regulatory agency tour), different ABB Environmental personnel may visit or work at the Ames Street site on a one-time, occasional or frequent basis. Regardless of the activity, all ABB Environmental personnel entering the site are subject to the provisions of this HASP.

When a particular site activity may potentially require greater than Level D protection, and for any activity involving sample collection, the "Medical Data Sheet" forms found in Section 8.0 of this HASP must be completed. Site visits, tours or other activities by ABB Environmental personnel for which only Level D protection is required do not require that this form be completed. Prior to each visit, however, the PM or HSO will brief these persons on the HASP components as they may apply to the specific activity or area(s) to be visited as described in Section 3.4.

1.2.5 ABB Environmental Subcontractor Personnel

ABB Environmental subcontractors are generally required under their contract terms to devise a health and safety program for their employees who will enter or work at the site. This program, at a minimum, must comply with local, state and federal requirements (particularly 29 CFR 1910.120) and utilize measures which are at least as protective as those in ABB Environmental's HASP (i.e., this document).

Unless specified in the subcontract agreement, ABB Environmental is not responsible for monitoring a subcontractor's compliance with the subcontractor's or ABB Environmental's HASP or local, state or federal requirements. ABB Environmental does, however, have the contractual right to control subcontractors whom they believe may not be in compliance, through such measures as denying site access, issuing stop work orders, etc. Such measures will be applied at the discretion of the FOL, HSO, PM and other responsible ABB Environmental personnel.

1.2.6 Other Site Visitors

Visitors to the Ames Street site other than ABB Environmental personnel and subcontractors may include:

- Representatives of Combustion Engineering (ABB Environmental's client and the site owner).
- Combustion Engineering contractors (e.g., Nixon, Hargrave, Devans and Doyle [environmental attorneys], Eric Mower and Associates [public relations]).
- Representatives of ABB Kent-Taylor (the former site owner)
- Potential vendors invited to job walks, etc.
- Regulatory agency, City and State government and local utility personnel.

Although ABB Environmental is not strictly speaking responsible for these visitors' health and safety, as agents of Combustion Engineering and professionals knowledgeable of site conditions, ABB Environmental personnel have a responsibility to provide for visitor's health and safety. As described in Section 3.0, a set of procedures has been devised to provide information and guidance to site visitors.

1.3 TRAINING

Training is defined under the ABB Environmental Health and Safety Program, and all ABB Environmental personnel entering potentially contaminated areas of this site must meet the requirements of 29 CFR 1910.120. Personnel without the required training **will not be permitted** in any area with potential for exposure to toxic substances or harmful physical agents (i.e., downrange). Refer to Appendix B for further information.

1.4 MEDICAL SURVEILLANCE

All ABB Environmental personnel entering potentially contaminated areas of the Ames Street Site will be medically qualified for site assignment through a medical surveillance program outlined in the ABB Environmental Health and Safety Program. Personnel who have not received medical clearance **will not be permitted** in any area with potential for exposure to toxic substances or harmful physical agents (i.e., downrange). Refer to Appendix C for further information.

2.0 SITE CHARACTERIZATION AND ANALYSIS

2.1 SITE NAME, LOCATION, AND SIZE

The Ames Street site, the subject of the investigation, is located at 95 Ames Street in Rochester, N.Y. (Figure 2-1). The Site encompasses approximately 14 acres of land and one significant building (Figure 2-2).

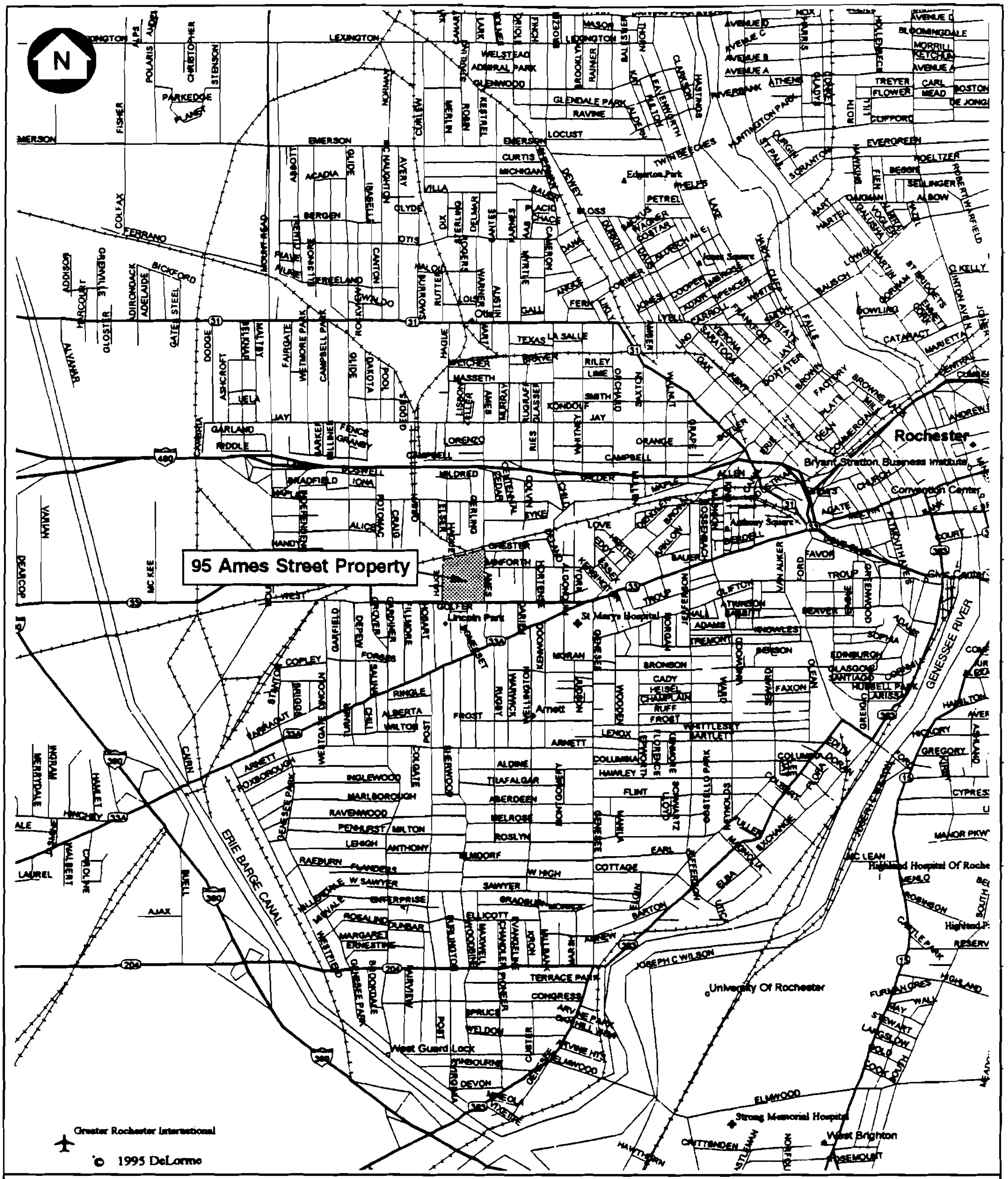
2.2 SITE HISTORY AND LAYOUT

The Ames Street facility was part of the Rochester operations of ABB Kent-Taylor. The property was purchased by Taylor Brothers Company (a predecessor to ABB Kent-Taylor) in 1904; the company occupied the site in 1905 or 1906. Industrial operations at the site, conducted by ABB Kent-Taylor or its predecessor companies, have included the manufacture of thermometers, barometers, compasses, altimeters, process automation equipment, and other related products. The property is currently held under the Combustion Engineering name, with site closure activities being coordinated by the ABB, Inc., Real Estate Director in Norwalk, CT.

As of November, 1995 all structures with the exception of Building 60, at the northeast corner of the property, have been removed and the site graded flat. Site operations are conducted from office trailers located at the Hague Street entrance to the site. Telephone and electric power is available at the trailers, but there is no running water at the site unless arrangements are made with the City of Rochester to utilize fire hydrants in the Hague Street or Ames Street sidewalks. Building 60 is used for storage of field equipment.

2.3 SCOPE OF WORK (WORK PLAN)

ABB Environmental will be performing a number of tasks at the site throughout what is expected to be a project lasting several years. For the most part, ABB Environmental's activities will fall into one of the following categories:



Approximate
Scale in Miles

0 0.5 1

FIGURE 2-1
SITE LOCATION MAP
SITE INVESTIGATION WORK PLAN - PHASE I
95 AMES STREET
ROCHESTER, NEW YORK

ABB Environmental Services, Inc.

W9511023D

CATEGORY	ACTIVITIES
A	Sampling building materials (e.g., wood, concrete) and/or surface and subsurface soil and groundwater potentially contaminated with mercury, solvents, hydrocarbon fuels or other industrial materials.
B	Other investigation-related activities which do not involve direct contact with potentially contaminated materials. Examples: surveying and mapping, geophysical investigation.
C	Overseeing subcontractor activities associated with remediation of soil or groundwater, and routine site security, maintenance and other services.
D	Attending and/or leading site tours and meetings involving the client, client subcontractors, regulatory agencies, government officials, community members, etc.

The Task Analysis section of this HASP (Section 3.0) analyzes each of the above Task Categories, which provides general information regarding potential health and safety hazards and protective measures. Because of the wide variety of activities likely to occur at this site, analysis of specific tasks within each class is not provided. Instead, the FOL/HSO for each field activity will undertake a specific task analysis prior to field work using the following process:

1. Review this entire HASP.

2. Using the forms on the following pages, analyze all contemplated field activities likely for the particular task. The general information in Section 3.0 of this HASP will in many cases provide sufficient information to complete the analysis and select protective measures. The task analysis is to be approved by the PM and HSS.

3. Provide the HASP and completed task analysis forms to the field team for review and signature.

4. Submit a copy of the approved task analysis to the PM. It will be added to the site HASP "library", where it can be readily referred to for future task analyses.

Remember, **each separate field task must be separately analyzed and protective measures approved by the HSS. By itself, this HASP is NOT sufficient for performing field work!**

3.0 TASK ANALYSIS

The following sections provide a general analysis of each task category.

It is important to remember that every individual task analysis should also consider the impact of other tasks or operations being simultaneously conducted. Particularly with respect to Categories C, D and E, which are generally conducted at Level D protection, the presence of other operations on the site may restrict both work in or even access to particular areas.

3.1 CATEGORY A - INVASIVE SAMPLING-TYPE ACTIVITIES

This category clearly has the highest risk potential of the four categories. All contemplated tasks within this category must be carefully analyzed and planned for.

3.1.1 Hazardous Substances

Field investigation activities all have a potential for site personnel to be exposed to low concentrations of organic and inorganic compounds.

Table 3-1 identifies the compounds that are known or suspected to be present on-site, along with the established exposure limits for those substances.

3.1.2 Site Risks

Health Hazards

General observations from the three rounds of sampling conducted at the site as of July, 1995, and plant demolition, are summarized below. A complete list of potential chemical hazards by area at the site is contained in the "Investigation Workplan, Phase 1, Former Taylor Instruments Facility."

Visible or non-visible liquid mercury: Significant concentrations of mercury

TABLE 3-1

CHEMICALS OF CONCERN
AMES STREET SITE INVESTIGATION WORKPLAN - PHASE 1

COMPOUND	EXPOSURE PEL/TWA OR TLV/TWA	LIMITS STEL/CEIL(c) (ppm)
Mercury	0.05 mg/m^3 [skin]	-
Gasoline	300 ppm	-
Toluene	100 ppm	-
Trichloroethylene	50 ppm	200
Naphtha	100 ppm	-
Xylene	100 ppm	150
No. 6 Fuel Oil	-	-
Cadmium	0.005 mg/m^3	-
Chromium	0.5 mg/m^3	-
Cyanide	5 mg/m^3	-
perchloroethylene	25 ppm	-
1,1,1-Trichloroethane	350 ppm	450 ppm
Ethylbenzene	100 ppm	125 ppm
Benzene	1 ppm	5 ppm
Nickel	1 mg/m^3	-
Asbestos	02 f/cc	1 f/cc
PCB	0.5 - 1 mg/m^3	-
Oils/Motor	-	-

PEL/TWA = Permissible Exposure Limit - Time Weighted Average
TLV/TWA = Threshold Limit Value - Time Weighted Average
STEL = Short-term Exposure Limit - The 15-minute time - weighted average which should not be exceeded at any time during the working day.
CEIL = The concentration that should not be exceeded during any part of the working exposure.
ppm = parts per million
[skin] = The potential significant contribution to the overall exposure by the cutaneous route, by direct skin contact with the substance.
mg/m^3 = milligrams per cubic meter
f/cc = fibers per cubic centimeter

may be present on-site. Liquid mercury has been noted at several locations in soil. Soil concentrations of mercury up to 13,000 mg/kg have been detected, and are expected particularly in association with areas where broken instruments ("glass shards") occur in the site soils. Lower levels of mercury can be expected in soils in many other areas.

Elemental mercury, which was the material used by the manufacturing processes and is the form most likely to occur at the Ames Street site, is primarily a health hazard via the inhalation pathway. Mercury vapor monitoring by ABB Environmental and its subcontractors using the Jerome analyzer has found that excavation of the mercury-bearing soils will frequently produce mercury vapor levels above the action level of 0.025 mg/m^3. Installing soil borings, where the exposed surface area of soil is lower, is generally less likely to cause action level exceedances. Holding the Jerome analyzer directly over thermometer shards or highly contaminated soil frequently produces a reading, however, indicating that personnel should continue monitoring when working closely with these materials.

Pre- and post-work urine samples have been collected and analyzed from a number of onsite workers at various times. As of November, 1995, only one individual has not been within normal limits. Although the reason for this exception is unclear (the worker was generally engaged in a high exposure-potential activity) and may not definitely be linked to the individual's work at the Ames Street site, continued caution is certainly warranted.

Solvents and hydrocarbons: Several areas in which chlorinated solvent degreasing activity or storage occurred may contain residual TCE and/or PCE. Previous sampling operations in these areas frequently produced PID readings above the 10 ppm level requiring upgrade to Level C, and brief excursions above the 175 ppm limit for Level B upgrade occurred. Odors were very noticeable.

Sampling near the former Tanks 2/15 and 16/17, using hand augers and the TerraProbe^{SM}, produced PID readings generally below the 10 ppm upgrade level. Odors were still noticeable, however, and significant concentrations of these two solvents are present in soil. Fuel-related hydrocarbons are also present near the former Building 40 and 42 areas, but TerraProbe^{SM} sampling activities produced no PID readings which required Level C. Sampling in Building 12 produced no PID levels above background, and only very low levels of soil contamination.

Metals (including cyanide): The occurrence of heavy metals at the site is believed to be limited to the former electroplating area in former Building 4. Cyanide compounds may also be present in this area. No real-time techniques have been used during previous sampling of these areas, which has been conducted at Level C.

Other materials: *Various oils and greases* (e.g., machine oils, hydraulic fluids) may be present in soil in several areas. These should not constitute a significant health hazard under normal conditions, but dermal/respiratory protection needs to be considered during invasive activity.

Safety Hazards

In the absence of significant site activity, such as building demolition or soil excavation, there should be very few safety hazards outside of those normally posed by working with drilling rigs and other heavy equipment used in site investigation. Due to the lack of a convenient power source, the use of hand tools, i.e., jackhammers, generators, etc. should be also be considered in the hazard analysis.

"Slip, trip and fall" hazards may be numerous at the Ames Street site. A maintenance contractor is available for debris removal or other duties if necessary to minimize such hazards for a particular task or area.

The locations of underground utilities and structures are believed to be well known, and maps are available from the PM. Although caution should still be exercised, there are no known active electric, water or gas lines within the fenced area of the site.

Cold stress in the winter is a distinct possibility, as is heat stress during warm months when Level C or greater protection is needed.

Conclusion/Risk Assessment

In general, the overall health risks for Category A activities will be low to moderate, and due primarily to the potential presence of mercury and solvent/hydrocarbon vapors. The overall safety risk is moderate and due primarily to the hazards associated with working with heavy equipment. Work conducted in proximity to other site activities, however, can significantly alter the nature of or increase the level of hazard. Cold and heat stress also need to be considered for certain operations.

3.1.3 Protective Measures

Protective measures will be undertaken to minimize the potential health and safety risks for field personnel engaged in Category A activities.

Engineering Controls

It is anticipated that engineered controls will rarely be used. Fans or blowers may be useful for vapor control in some instances; opening windows has also proven to be easy and effective. Use of water to control dust must be carefully evaluated, due to the potential need to containerize runoff, and is not recommended. Prior to subsurface drilling, boring locations should be compared to available site utility maps and reviewed by the PM.

Levels of Protection

The following paragraphs describe typical levels of protection utilized for various Category A activities, for each type of known contaminant.

Mercury and metals: To prevent dermal exposure and spreading of mercury via foot traffic, the immediate areas where visible mercury is present, and where significant concentrations are known to exist, should not be entered unless, at a minimum, boot covers are worn. Invasive work requires Level C, or at a minimum modified Level D, protection.

Solvents/hydrocarbons: For soil/groundwater sampling, Level C protection will probably not be necessary unless large-diameter boreholes are opened or bulk soil excavation occurs. Highly invasive activities, such as excavation, will probably require Level C, and potentially Level B, protection.

Typical levels of personal protection for Category A activities are as follows:

ACTIVITY	TYPICAL LEVEL OF PROTECTION
Surface Soil Sampling	Modified Level D
TerraProbe Activities	Level D/Modified Level D
Well Sampling	Modified Level D

Modified Level D consists of Level D personal protective equipment, boot covers and Tyvek coveralls. Levels of protection may be changed at the discretion of the HSO, as warranted by a change in site conditions.

Respirator cartridges, if Level C becomes necessary, will be approved for respiratory protection against organic vapors (magenta/yellow cartridge) or mercury vapors with high efficiency filters (part #466204 and #492924). Refer to Appendix E for details of protection and personal protective equipment and Appendix O for further information on respiratory protection. Task activities may require upgrade per assigned action levels (see below).

3.1.4 Monitoring

Monitoring of the work environment will be undertaken to ensure that Immediately Dangerous to Life or Health (IDLH) or other dangerous conditions are identified. At a minimum, this monitoring will include evaluations for combustible atmospheres, and hazardous concentrations of airborne contaminants.

Air Sampling

To the extent feasible, the presence of airborne contaminants will be evaluated through the use of direct reading instrumentation. Information gathered will be used to ensure the adequacy of the levels of protection being used and may be used as the basis for upgrading or downgrading the levels of protection in conformance with action levels provided in this HASP and at the direction of the task HSO.

In general, due to the prevalence of mercury at the Ames Street site, the Jerome analyzer should be used to monitor for mercury vapors during the initial stages of any invasive sampling at any location at the Ames Street site. Subsequent use of the analyzer can depend on the initial readings, visual observations, and the specific area being investigated.

Depending on the task, the following sampling equipment will be used. Refer to Appendix F for information on the calibration and maintenance of the equipment.

1. Jerome Mercury Vapor Analyzer
2. Photoionization Detector (PID)
3. Draeger Tubes - benzene 5/c
4. Explosimeter

For solvents/hydrocarbons: Monitor the breathing zone with the PID. If levels steadily exceed background, monitor for benzene using the 5/c benzene Draeger Tube. If benzene levels exceed 0.5 ppm, upgrade to Level C. If benzene levels are $\geq$10 ppm, upgrade to Level B. If benzene levels are $\leq$0.5 ppm, continue work at Level D/Modified Level D until the PID reads $\geq$10 ppm then upgrade to Level C. If PID $\geq$175 ppm, upgrade to Level B.

Monitor the borehole opening with explosimeter.

For mercury vapors: Monitor continuously with the Jerome Mercury Vapor Analyzer (MVA) and upgrade accordingly.

The action levels for upgrade are as follows:

Level D/Modified Level D acceptable if:

- PID reads < 10 ppm; and
- Benzene 5/c Draeger Tube reads < 0.5 ppm; or
- MVA reads < 0.025 mg/m^3

Level C required if:

- PID reads between 10 and 175 ppm; and/or
- MVA reads ≥ 0.025 mg/m^3; and/or
- Benzene 5/c Draeger Tube reads < 10 ppm.

Level B required if:

- PID reads ≥ 175 ppm; or
- ≥ 2.5 mg/m^3 on the MVA; and/or
- Benzene 5/c Draeger Tube reads ≥ 10 ppm.

If the explosimeter reads 10%, use non-sparking tools. If the explosimeter reads 20%, stop work, eliminate all ignition sources, and evacuate the area.

Personal Monitoring

Personal air sampling for mercury has been conducted to some extent by the plant demolition contractor. Results indicated that exposure above the PEL was likely; however, the activities monitored involved significant handling of liquid mercury which are not expected to be repeated again at the site. In general, personal air sampling will not be necessary, however, the HSM should be consulted relative to the specifics of the particular task and make the final evaluation.

Urine monitoring for mercury should be considered for Category A activities which involve sampling or working in suspect or known mercury-containing areas for extended periods. The need for this type of personal monitoring should be discussed with the HSM on a task-by-task basis.

3.2 CATEGORY B - NON-INVASIVE ACTIVITIES

This category involves generally more limited risk potential than Category A, principally because the risk for chemical exposure is lower. Because Category B activities are frequently performed concurrently with Category A activities, however, a task analysis should be made so that personnel involved in the non-invasive activity do not work within the exclusion zone for invasive activity.

3.2.1 Hazardous Substances

Category B activities generally pose little potential for chemical exposure, because they are by definition non-invasive. Following complete paving of the site, this work is very unlikely to pose an exposure hazard.

3.2.2 Site Risks

Health Hazards

Visible or non-visible liquid mercury: As described in Section 3.1, mercury may pose risks to work in certain areas. Mercury vapors should not pose a problem for any Category B activity.

Solvents and hydrocarbons: These should not pose a hazard during Category B activities except.

Metals (including cyanide): Similarly, metals exposure should not be an issue.

Other materials: For in-building work, the hazards posed by asbestos, PCBs and various oils and greases should be considered if activities occur in areas where they are present. For most Category B activities in the buildings, however, and all outdoor activities, these materials will pose little if any hazard.

Safety Hazards

In the absence of significant site activity, such as soil sampling or excavation, there should be very few safety hazards outside of those normally posed by working with the particular tools required for the task. As previously indicated, however, "slip, trip and fall" hazards are present and numerous. Although heat stress is unlikely to be a problem, cold stress may during the winter.

Conclusion/Risk Assessment

In general, the overall health risks for Category B activities will be low, based on the limited potential presence for chemical exposure. Work conducted in proximity to other site activities (particularly Category A), however, can significantly alter the nature of or increase the level of hazard.

3.2.3 Protective Measures

Protective measures will be undertaken to minimize the potential health and safety risks for field personnel engaged in Category A activities.

Engineering Controls

Engineering controls will rarely be useful for strictly Category B activities. They may, however, be useful if Category A and B activities are being performed in close proximity and simultaneously.

Levels of Protection

Mercury/metals: The areas where significant mercury or metals is present should not be entered unless, at a minimum, boot covers are used. Depending on the activity, gloves and coated Tyvek may be added. Protection or decontamination of non-disposable equipment also needs to be considered.

Typical levels of personal protection for Category B activities are as follows:

ACTIVITY	TYPICAL LEVEL OF PROTECTION
Activities in paved areas	Level D
Simple entry into areas of possible mercury/metals contamination	Level D w/boot covers
Work in areas of known mercury/metals contamination	Modified Level D*

*Modified Level D consists of Level D personal protective equipment, Tyvek coveralls and boot covers. Levels of protection may be changed at the discretion of the HSO, as warranted by a change in site conditions.

3.2.4 Monitoring

When working at or near areas with possibly significant mercury or solvent contamination, initial monitoring of work areas should be conducted. Monitoring can probably be performed only occasionally, based on expected low readings. Action levels and upgrade criteria should duplicate those described in Section 3.1.

Monitoring is not required for Category B activities involving only work in paved areas. Personal air or other sampling is unlikely to be warranted for any Category B activity.

3.3 CATEGORY C - SUBCONTRACTOR OVERSIGHT

Risk potential for this category of activity is highly variable based on the exact nature of the subcontractor's activities. Thorough evaluation of the subcontractor's scope of work and ABB Environmental personnel oversight responsibilities, and pre-work consultation with the subcontractor, are necessary to provide adequate protection. Entry into the exclusion zone while work is being performed generally will require protection equivalent to the subcontractor personnel actually performing the work. Contractor activities may include soil removal and construction. During these activities, ABB Environmental personnel may engage in the following:

- video tape and photograph activities;
- evaluate dust and dust control procedures;
- evaluate soil protection measures;
- observe soil/waste removal;
- evaluate other environmental issues; and
- observe job progress

When conducting these activities, ABB Environmental Services personnel will follow certain procedures which are described below.

3.3.1 Hazardous Substances

Because a number of subcontractor activities will consist of actual removal of materials containing or contaminated with hazardous substances, there is a potentially significant risk of exposure to both contractor and ABB Environmental oversight personnel. Due to the disturbance required to remove or abate hazardous materials, significant airborne or dermal hazards may develop.

3.3.2 Site Risks

Health Hazards

Visible mercury: Contractor operations which involve remediation/removal of mercury (visible or not) clearly pose risks to oversight personnel. Risk will probably be dependent primarily on proximity to the work area, and whether significant dust is produced. Pre-work inspections of these areas may pose a dermal contact hazard.

Mercury vapors: Although mercury vapor levels both in ambient air, and during environmental sampling, have been relatively low, remediation or removal operations in mercury-contaminated areas must be considered likely to produce significant vapor concentrations.

Solvents and hydrocarbons: Similar to mercury, work in these areas during remediation/removal may produce vapor levels requiring respiratory protection, and are also likely to produce significant dust. Detailed pre-work inspections may pose dermal or inhalation hazards.

Metals (including cyanide): Again, potentially significant dermal and/or inhalation hazards may be generated by remediation/removal work.

Other materials: Due to oils' and greases' typically low volatility and low contact hazard, remediation/removal of these materials should pose little hazard to oversight personnel.

Safety Hazards

Category C activities pose potentially significant safety hazards due to the heavy equipment typically utilized, and the expected nature of the activity (e.g., building demolition). Vehicle/equipment traffic, falling objects, "slip, trip and fall", loud/sustained noise, high-intensity light (e.g., metal cutting), poorly lit areas in building and other hazards associated with heavy construction activity can be expected.

The following general procedures should be followed when ABB Environmental personnel are to conduct inspection activities:

1) ABB Environmental personnel must notify the work area foreman of their presence when approaching the work area.
2) The foreman will indicate where it is safe for ABB Environmental personnel to conduct inspection activities.
3) At all times during inspection, ABB Environmental personnel should be visible to the work area foreman.
4) The foreman should be notified when ABB Environmental personnel are to leave the area.

Conclusion/Risk Assessment

In general, the overall health and safety risks for Category C activities will be moderate. Although significant contaminant disturbance and construction-related safety hazards will be prominent, ABB Environmental personnel in an oversight/observation role will often be able to reduce the level of hazard without significant effect on their job performance (e.g., by simply moving away and making the foreman aware of their planned activities). However, the level of hazard will also depend significantly on subcontractor work practices, which are typically less easily controlled than our own.

3.3.3 Protective Measures

Protective measures will be undertaken to minimize the potential health and safety risks for field personnel engaged in Category C activities.

Engineering Controls

Engineering controls may frequently be useful for Category C activities, but will typically be implemented by the subcontractor. For this reason, it is important for each task analysis to include evaluation of the subcontractor's scope of work and planned control measures. If ABB Environmental is to implement controls, compatibility with the subcontractor's operations should also be considered.

The simplest method of controlling hazard exposure to ABB Environmental personnel is to simply design and conduct oversight/observation activities in order to minimize it. For many operations, it may not be truly necessary for ABB Environmental to be in the active work area or exclusion zone to provide adequate general oversight. Observation can also be limited to the extent that it is truly necessary, rather than being a casual or "general interest" activity. The HSO for each task should initiate discussion between the PM, CM and/or field staff to devise an approach that balances health and safety concerns with oversight requirements.

Levels of Protection

Typical levels of personal protection for Category C activities are as follows:

ACTIVITY	TYPICAL LEVEL OF PROTECTION
Oversight of activities not involving remediation/removal of hazardous materials	Level D
Oversight of hazardous material remediation/removal	Modified Level D

Modified Level D for Category C activities consists of Level D personal protective equipment, Tyvek coveralls and boot covers. Levels of protection may be changed at the discretion of the HSO, as warranted by a change in site conditions.

If vapor levels exceed criteria for upgrade to Level B, and engineering control is not possible, the need for direct oversight/observation should be re-evaluated.

3.3.4 Monitoring

Monitoring of the work environment should be performed whenever remediation/removal of hazardous materials is occurring. Such monitoring can be coordinated or supplied by the subcontractor, but action criteria must, at a minimum, remain consistent with that presented in Section 3.1

Because Category C activities are frequently of significant duration (i.e., weeks or months), the need for personal air monitoring, or urine monitoring for mercury, should be discussed with the HSO and HSM as part of the specific task analysis.

3.4 CATEGORY D - VISITOR TOURS AND MEETINGS

The health and safety risk potential for ABB Environmental personnel engaged in Category D activities is typically low, and is largely based on the presence of concurrent site operations which visitors may want to observe. Nevertheless, Category D activities require a significant focus on health and safety for another reason: based on ABB Environmental's position as general contractor for the site and the persons generally most knowledgeable of site conditions, our personnel have a duty to inform visitors of site hazards and assist in avoiding them.

Procedures designed to ensure visitors are duly informed of potential hazards are presented following the Category D hazard analysis. ABB Environmental personnel must be careful, however, to evaluate the activity visitors are to engage in. For purposes of this HASP, Category D is intended to cover walking tours for general observation, potential subcontractor jobwalks, and other activities which <u>do not</u> involve observation, inspection or other direct involvement with site operations. For example, visitors wishing to observe active remediation/removal of hazardous materials are engaging in Category C activity, for which the guidance of Section 3.3 must be followed.

3.4.1 Hazardous Substances

In general, Category D activities have limited potential for personnel to be exposed to low concentrations of inorganic compounds.

3.4.2 Site Risks

Health Hazards

Visible mercury: A frequent target of site tours are areas at which liquid mercury or glass shards are visible. These areas clearly present a dermal and/or inhalation exposure hazard.

Metals (including cyanide): Contact with potentially impacted soil is clearly a possible hazard.

Solvents and hydrocarbons: A dermal or inhalation hazard may exist in the exclusion zone.

Safety Hazards

Category D activities will pose few safety hazards to ABB Environmental personnel not already covered in previous sections. Again, "slip, trip and fall" hazards are of greatest concern. Because visits will generally be planned to avoid active site operations, these operations should pose little hazard. Site visitors must follow the same procedures as those described for category C activities for entering work areas.

Conclusion/Risk Assessment

In general, the overall health and safety risks to ABB Environmental personnel for Category D activities will be low.

3.4.3 Protective Measures

Protective measures will be undertaken to minimize the potential health and safety risks for field personnel engaged in Category D activities.

Engineering Controls

Engineering controls will rarely be useful or necessary.

Levels of Protection

Typical levels of personal protection for Category D activities are as follows:

ACTIVITY	TYPICAL LEVEL OF PROTECTION
Walking tours, meetings, other activities in which areas containing hazardous materials are not entered.	Level D
Entering areas containing hazardous materials. NOTE: ENTRY INTO THESE AREAS BY VISITORS SHOULD BE CAREFULLY CONTROLLED.	As per activity

3.4.4 Monitoring

Monitoring of the work environment should not be necessary, based on the site knowledge developed to date and the nature of Category D activities.

Because Category D activities are frequently of very short duration, personal monitoring is neither necessary or, in general, feasible.

3.5 SPECIAL PROCEDURES FOR SITE VISITORS

This section describes administrative procedures established for site visitors which Combustion Engineering, ABB Environmental and their subcontractors should implement.

[NOTE: As of November, 1995, the Ames Street site is not subject to requirements of 29 CFR 1910.120, the OSHA hazardous waste site operations standard. The standard's requirements, for example training requirements for persons entering "exclusion zones" or "contaminated" areas, are therefore not applicable. Should the Ames Street site become "recognized" as a hazardous waste site by a governmental body, the standard would apply and the procedures described below may require modification.]

3.5.1 Visitor Entry Forms

The following three pages contain forms on which visitor-related procedures are based. ABB Environmental personnel should utilize these forms as follows.

"Safety Information and Procedures for Visitors to the Ames Street Site"

This form is intended to provide visitors with basic information about potential health and safety hazards at the site, and provide rules/procedures that visitors are to follow.

It is preferable that visitors review this form prior to arrival at the site. ABB Environmental personnel inviting or scheduling visitors (e.g., potential vendors or subcontractors) should ensure the two-page form is sent/FAXed to them in advance.

Because ABB Environmental personnel will often lead site tours or walkthroughs of specific areas, it is important that the Safety Procedures are known and understood. Of particular importance are rules regarding safety equipment (hard hat, sturdy shoes) and the need for escort at all times.

"Visitor Log and Signature Form"

This form serves as a permanent record that visitors were informed of potential hazards, and should be completed and signed by anyone entering the site who is not an ABB Environmental or Combustion Engineering employee or subcontractor.

When possible, the "Additional Hazard Information" section should be completed in advance by ABB Environmental, noting hazards due to current site operations and specific to areas the visitors will access. For example, if a tour of glass shard areas is planned, an appropriate note under "Summary of other potential hazards..." would be "Significant concentrations of mercury may be present in the shard areas; dermal protection (boot covers and gloves) required."

3.5.2 Visitor Entry Procedures

Specific procedures for bringing visitors to the site are described below. Compliance with procedures can be verified through use of the "Site Visitor Checklist".

1. Notify visitors in advance of the requirements for site entry, i.e., personal protective gear, attending the safety briefing, traveling with an escort. Send or FAX the "Safety Information..." form (2 pages) prior to their visit.

   As representative of the site owner, ABB Environmental may deny entry to persons who are unauthorized, uninvited, or who cannot or refuse to follow safety procedures. **Remember, Combustion Engineering and ABB Environmental could be held liable for injuries which occur on the site, regardless of who's at fault!** If you are unsure whether to allow entry, contact the PM, CM or HSO.

2. Prior to visitor arrival, plan their route through the facility. To the extent possible, plan a route which avoids known or potential hazards. Walk the route yourself and note the location(s) of water, debris and other "slip, trip and fall" hazards. Re-familiarize yourself with areas which may contain hazardous materials and appropriate protective measures.

3. Upon arrival, confirm visitors have reviewed the "Safety Information..." and have brought their own personal protective gear.

4. Deliver a safety briefing to the visitor(s):

   a) ***Briefly review the "Safety Information..." sheet***, with particular emphasis on the Safety Procedures.

b) ***Describe health and safety hazards specific to the area(s) which will be visited.*** Using the site plan, show the route which will be traveled, noting any physical hazards (dim lighting, water, etc.) Describe hazardous materials which may be present.

c) ***Review the MSDSs for chemicals of concern (the MSDS for mercury should ALWAYS be reviewed.)*** Point out the health hazards and appropriate protective measures.

d) ***Describe current site operations, locations and potential hazards.*** Emphasize that visitors must not interfere in any way with these operations.

e) ***Review any additional protective measures which will be used.*** If measures or equipment (e.g., booties, gloves) beyond the standard hard hat and safety shoes are needed to access certain areas, describe their use. Include how to don, how to remove, where to dispose of.

5. Have all visitors complete and sign the "Visitor Log and Signature Form".

6. Escort visitors at all times. [NOTE: Under certain conditions, visitors can be allowed into the site without an escort. Unescorted visitors must be approved by the PM, CM or HSO.]

4.0 DATA SHEETS

xposure Risk

used for hardening metals such
id lead, and as a doping agent in
products of silicon and germa-
salts are used in making her-
denticides, in semiconductors,
echnics.

roperties

metals; tarnish when exposed
in several allotropic modifica-
50°C; bp 1380°C; sublimes.

ard

allotropic forms, yellow arsenic
human poison. The fatal dose is
-2 mg/kg body weight. All arse-
nds are toxic, the toxicity vari-
oxidation state of the metal and
es. Thus the trivalent inorganic
of arsenic, such as arsenic
arsenic trioxide, and arsine.
oxic—more poisonous than the
pentavalent salts. The organic
mpound Lewisite is a severe blis-
t that can penetrate the skin and
ge at the point of exposure.
s used as a poison gas in World
s soluble arsenic sulfide exhibits
e toxicity.
is absorbed into the body
astrointestinal route and inhala-
acute symptoms include fever,
nal disturbances, irritation of
ry tract, ulceration of the nasal
id dermatitis. Chronic exposure
pigmentation of the skin, pe-
ropathy, and degeneration of
idneys.
c effects of arsenic are attributed
ng properties with sulfur. It
lexes with coenzymes. This in-
production of adenosine triphos-
), which is essential for energy
abolism. 2,3-Dimercapto-1-pro-
antidote against acute intoxica-
ithioerythritol is reported to be
ctive and less toxic antidote
1989).

Arsenic is carcinogenic to humans. Ingestion by an oral route has caused an increased incidence of tumors in the liver, blood, and lungs.

Exposure Limits

TLV-TWA 0.2 mg(As)/m^3 (ACGIH), 0.5 mg(As)/m^3 (MSHA), 0.01 mg(As)/m^3 (OSHA); ceiling 0.002 mg(As)/m^3/15 min (NIOSH); carcinogenicity: Human Sufficient Evidence (IARC).

34.6 CHROMIUM

Symbol Cr; at. wt. 52.00; at. no. 24; CAS [7440-47-3]; a transition metal, contains partially filled *d* orbitals; exhibits valences from 1 to 6, commonly occurs in +3 and +6 oxidation states

Uses and Exposure Risk

Chromium is used in the manufacture of its alloys, such as chrome–steel or chrome–nickel–steel. It is also used for chromeplating of other metals, for tanning leather, and in catalysts. It occurs in chromite ores ($FeO \cdot Cr_2O_3$).

Physical Properties

Grayish, hard, lustrous metal; density 7.14; melts at 1900°C; boils at 2642°C; reacts with dilute HCl and H_2SO_4; attacked by alkalies.

Health Hazard

The toxicity of chromium alloys and compounds varies significantly. Chromium metal does not exhibit toxicity. Divalent and trivalent compounds of chromium have a low order of toxicity. Exposure to the dusts of chromite or ferrochrome alloys may cause lung diseases, including pneumoconiosis and pulmonary fibrosis.

Among all chromium compounds only the hexavalent salts are a prime health hazard. Occupational exposure to these compounds can produce skin ulceration, dermatitis, perforation of the nasal septa, and kidney damage. The examples of hexavalent salts are the chromates and dichromates of sodium, potassium, and other metals. The water-soluble hexavalent chromium salts are absorbed into the bloodstream through inhalation. Many chromium(VI) compounds are carcinogenic, causing lung cancers in animals and humans.

Exposure Limits

TLV-TWA: chromium metal 0.5 mg/m^3 (ACGIH and MSHA), 1 mg/m^3 (OSHA); Cr(II) and Cr(III) compounds 0.5 mg/m^3 (ACGIH); Cr(VI) compounds, water soluble and certain water insoluble, 0.05 mg/m^3 (ACGIH).

34.7 SELENIUM

Symbol Se; at. wt. 78.96; at. no. 34; valences 2, 4, and 6; CAS [7782-49-2]; a Group VIA metal

Uses and Exposure Risk

Selenium is used in the manufacture of colored glass, in photocells, in semiconductors, as a rectifier in radio and television sets, and as a vulcanizing agent in the manufacture of rubber.

Physical Properties

Dark red to bluish-black amorphous solid, or dark red or gray crystals; exists in several allotropic forms; density 4.26–4.28 for amorphous, 4.26–4.81 for crystals; mp 170 to 217°C (crystals); bp 685°C; amorphous form becomes elastic at 70°C.

Health Hazard

The toxicity of selenium and its compounds varies substantially. Sodium selenite is highly toxic; many sulfur compounds of selenium are much less toxic. The target organs are the respiratory tract, liver, kidneys, blood, skin, and eyes. The sign of acute poisoning is a garlic-like odor in the

Arsenic and its compounds are on the Community Right To Know List.

THR: Poison by most routes. See also ARSENIC COMPOUNDS and SULFIDES. Dangerous fire hazard when exposed to heat or by spontaneous chemical reaction, i.e., in air. Vigorous reaction with oxidizing materials. When heated to decomposition it emits toxic fumes of As.

CAC500 ***HR: 3***

CADIA DEL PERRO

NIOSH: EU 9500000

PROP: Aqueous extract from the dried leaves of the plant (JNCIAM 46,1131,71).

SYNS:

K. IXINA
KRAMERIA IXINA

TOXICITY DATA:	CODEN:
scu-rat TDLo:300 mg/kg/1Y-I: NEO	JNCIAM 46,1131,71
ims-rat TDLo:45 g/kg/1Y-I:ETA	JNCIAM 46,1131,71
skn-ham TDLo:53950 mg/kg/65W-I:CAR	JNCIAM 53,1259,74
scu-rat TD :990 mg/kg/55W-I: NEO	JNCIAM 52,1579,74

THR: An experimental carcinogen, tumorigen and neoplastigen. When heated to decomposition it emits acrid smoke and fumes.

CAD000 ***HR: 3***

CADMIUM

CAS: 7440-43-9 NIOSH: EU 9800000
mf: Cd mw: 112.40

PROP: Hexagonal crystals, silver-white, malleable metal. Mp: 320.9°, bp: 767 ± 2°, d: 8.642, vap press: 1 mm @ 394°.

SYNS:

C.I. 77180
COLLOIDAL CADMIUM
KADMIUM (GERMAN)

TOXICITY DATA:	CODEN:
cyt-ham:ovr 1 µmol/L	CGCGBR 26,251,80
orl-rat TDLo:220 mg/kg (1-22D preg):REP,TER	TOLED5 11,233,82
orl-rat TDLo:23 mg/kg (1-22D preg):REP,TER	PSEBAA 158,614,78
ivn-rat TDLo:1250 µg/kg (14D preg):REP,TER	JJATDK 1,264,81
ims-rat TDLo:40 mg/kg/4W-I: CAR	JEPTDQ 1(1),51,77
ims-rat TD :70 mg/kg:ETA	BJCAAI 18,124,64
ims-rat TD :63 mg/kg:ETA	NATUAS 193,592,62
ims-rat TD :45 mg/kg/4W-I: NEO	NCIUS* PH-43-64-886,SEPT,71
ihl-man TCLo:88 µg/m³/8.6Y: KID	AEHLAU 28,147,74
ihl-hmn LCLo:39 mg/m³/20M	AIHAAP 31,180,70
unk-man LDLo:15 mg/kg	85DCAI 2,73,70
orl-rat LD50:225 mg/kg	TXAPA9 41,667,77
ipr-rat LD50:4 mg/kg	TXAPA9 41,667,77
scu-rat LD50:9 mg/kg	TXAPA9 41,667,77
ivn-rat LD50:1800 µg/kg	JJATDK 1,264,81
unr-rat LD50:1140 mg/kg	GTPZAB 22(5),6,78
orl-mus LD50:890 mg/kg	41HTAH -,14,78
ihl-mus LCLo:170 mg/m³	NTIS** PB158-508
unr-mus LD50:890 mg/kg	GTPZAB 22(5),6,78
orl-rbt LDLo:70 mg/kg	AMPMAR 34,127,73
scu-rbt LDLo:6 mg/kg	PROTA* -,-,55
ivn-rbt LDLo:5 mg/kg	JOGBAS 35,693,28
ims-ham LDLo:25 mg/kg	NCIUS* PH-43-64-886

IARC Cancer Review: Animal Sufficient Evidence IMEMDT 11,39,76; IMEMDT 2,74,73. Cadmium and its compounds are on the Community Right To Know List. Reported in EPA TSCA Inventory. EPA Genetic Toxicology Program.

OSHA PEL: TWA 0.1 mg(Cd)/m^3; CL 0.6 mg(Cd)/m^3 (fume)
ACGIH TLV: TWA 0.01 mg(Cd)/m^3 (dust). Human carcinogen
DFG BAT: Blood 1.5 µg/dL; Urine 15 µg/dL
NIOSH REL: (Cadmium) Reduce to lowest feasible level

THR: A human poison by inhalation and possibly other routes. Poison experimentally by ingestion, inhalation, intraperitoneal, subcutaneous, intramuscular, and intravenous routes. In humans inhalation causes an excess of protein in the urine. An experimental carcinogen, tumorigen, neoplastigen, and teratogen. Experimental reproductive effects. Mutagenic data. The dust ignites spontaneously in air and is flammable and explosive when exposed to heat, flame, or by chemical reaction with oxidizing agents; metals; HN_3; Zn; Se; and Te. Explodes on contact with hydrazoic acid. Violent or explosive reaction when heated with ammonium nitrate. Vigorous reaction when heated with nitryl fluoride. When heated strongly it emits toxic fumes of Cd. See also CADMIUM COMPOUNDS. For further information, see Vol. 3, No. 5 of *DPIM Report*.

CAD250 ***HR: 3***

CADMIUM(II) ACETATE

CAS: 543-90-8 NIOSH: EU 9810000
DOT: 2570
mf: $C_2H_4O_2 \cdot 1/2Cd$ mw: 116.25

PROP: Monoclinic, colorless crystals; odor of acetic acid. Mp: 256°, bp: decomp. d: 2.341.

SYNS:

ACETIC ACID, CADMIUM SALT
BIS(ACETOXY)CADMIUM
CADMIUM ACETATE (DOT)
CADMIUM DIACETATE
C.I. 77185

TOXICITY DATA:	CODEN:
cyt-hmn:lym 10 nmol/L	MUREAV 85,236,81
otr-ham:emb 1 µmol/L	CNREA8 39,193,79
dnd-ham:emb 1 µmol/L	CNREA8 39,193,79

GASOLINES: CASINGHEAD

GCS

Common Synonyms	Watery liquid	Colorless	Gasoline odor
Natural gasoline	Floats on water. Flammable, irritating vapor is produced.		

Stop discharge if possible. Keep people away
Shut off ignition sources and call fire department
Stay upwind and use water spray to "knock down" vapor
Isolate and remove discharged material
Notify local health and pollution control agencies

Fire

FLAMMABLE.
Flashback along vapor trail may occur.
Vapor may explode if ignited in an enclosed area.
Extinguish with dry chemical, foam or carbon dioxide
Water may be ineffective on fire
Cool exposed containers with water

Exposure

CALL FOR MEDICAL AID

VAPOR
Irritating to eyes, nose and throat.
If inhaled will cause dizziness, headache, difficult breathing or loss of consciousness.
Move to fresh air
If breathing has stopped, give artificial respiration
If breathing is difficult, give oxygen

LIQUID
Irritating to skin and eyes.
If swallowed, will cause nausea or vomiting
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.
Fouling to shoreline.
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-high flammability
Evacuate area
Disperse and flush

2. LABEL

2.1 **Category:** Flammable liquid
2.2 **Class:** 3

3. CHEMICAL DESIGNATIONS

3.1 **CG Compatibility Class:** Miscellaneous Hydrocarbon Mixtures
3.2 **Formula:** Not pertinent
3.3 **IMO/UN Designation:** 3.1/1257
3.4 **DOT ID No.:** 1257
3.5 **CAS Registry No.:** Data not available

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Gasoline

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Protective goggles, gloves.
5.2 **Symptoms Following Exposure:** INHALATION causes irritation of upper respiratory tract; central nervous system stimulation followed by depression of varying degrees ranging from dizziness, headache, and incoordination to anesthesia, coma, and respiratory arrest; irregular heartbeat is dangerous complication. ASPIRATION causes severe lung irritation with coughing, gagging, dyspnea, substernal distress, and rapidly developing pulmonary edema; later, signs of bronchopneumonia and pneumonitis, acute onset of central nervous system excitement followed by depression. INGESTION causes irritation of mucous membranes of throat, esophagus, and stomach; stimulation followed by depression of central nervous system; irregular heartbeat.
5.3 **Treatment of Exposure:** Seek medical attention. INHALATION: maintain respiration; give oxygen if needed. ASPIRATION: enforce bed rest; administer oxygen. INGESTION: do NOT induce vomiting; lavage carefully if appreciable quantity was ingested; guard against aspiration into lungs. EYES: wash with copious quantity of water. SKIN: wipe off and wash with soap and water.
5.4 **Threshold Limit Value:** 300 ppm
5.5 **Short Term Inhalation Limits:** 500 ppm for 30 min.
5.6 **Toxicity by Ingestion:** Grade 2; LD_{50} = 0.5 to 5 g/kg
5.7 **Late Toxicity:** None
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary.
5.9 **Liquid or Solid Irritant Characteristics:** Minumum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
5.10 **Odor Threshold:** 0.25 ppm
5.11 **IDLH Value:** Data not available

6. FIRE HAZARDS

6.1 **Flash Point:** <0°F O.C.
6.2 **Flammable Limits in Air:** 1.3%-7.1%
6.3 **Fire Extinguishing Agents:** Dry chemical, foam, or carbon dioxide
6.4 **Fire Extinguishing Agents Not to be Used:** Water may be ineffective
6.5 **Special Hazards of Combustion Products:** None
6.6 **Behavior in Fire:** Vapor is heavier than air and may travel a considerable distance to a source of ignition and flash back.
6.7 **Ignition Temperature:** Data not available
6.8 **Electrical Hazard:** Class I, group D
6.9 **Burning Rate:** 4 mm/min.
6.10 **Adiabatic Flame Temperature:** Data not available
6.11 **Stoichiometric Air to Fuel Ratio:** Data not available
6.12 **Flame Temperature:** Data not available

7. CHEMICAL REACTIVITY

7.1 **Reactivity With Water:** No reaction
7.2 **Reactivity with Common Materials:** No reaction
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent
7.7 **Molar Ratio (Reactant to Product):** Data not available
7.8 **Reactivity Group:** 33

8. WATER POLLUTION

8.1 **Aquatic Toxicity:**
90 ppm/24 hr/juvenile American shad/TL_m/fresh water
91 ppm/24 hr/juvenile American shad/TL_m/salt water
8.2 **Waterfowl Toxicity:** Data not available
8.3 **Biological Oxygen Demand (BOD):** 8%, 5 days
8.4 **Food Chain Concentration Potential:** None

9. SHIPPING INFORMATION

9.1 **Grades of Purity:** Composition depends on location of oil well
9.2 **Storage Temperature:** Ambient
9.3 **Inert Atmosphere:** No requirement
9.4 **Venting:** Open (flame arrester) or pressure-vacuum

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-T-U-V-W

11. HAZARD CLASSIFICATIONS

11.1 **Code of Federal Regulations:** Flammable liquid
11.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	**Rating**
Fire	4
Health	
Vapor Irritant	1
Liquid or Solid Irritant	0
Poisons	1
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	2
Aesthetic Effect	1
Reactivity	
Other Chemicals	0
Water	0
Self Reaction	0

11.3 **NFPA Hazard Classification:**

Category	**Classification**
Health Hazard (Blue)	1
Flammability (Red)	3
Reactivity (Yellow)	0

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 **Physical State at 15°C and 1 atm:** Liquid
12.2 **Molecular Weight:** Not pertinent
12.3 **Boiling Point at 1 atm:** 58—275°F = 14—135°C = 287-408°K
12.4 **Freezing Point:** Not pertinent
12.5 **Critical Temperature:** Not pertinent
12.6 **Critical Pressure:** Not pertinent
12.7 **Specific Gravity:** 0.871 at 15°C (liquid)
12.8 **Liquid Surface Tension:** 19-23 dynes/cm = 0.019—0.023 N/m at 20°C
12.9 **Liquid Water Interfacial Tension:** 49—51 dynes/cm = 0.049—0.051 N/m at 20°C
12.10 **Vapor (Gas) Specific Gravity:** 3.4
12.11 **Ratio of Specific Heats of Vapor (Gas):** Not pertinent
12.12 **Latent Heat of Vaporization:** 130—150 Btu/lb = 71—81 cal/g = 3.0—3.4 X 10^5 J/kg
12.13 **Heat of Combustion:** —18,720 Btu/lb = —10,400 cal/g = —435.4 X 10^5 J/kg
12.14 **Heat of Decomposition:** Not pertinent
12.15 **Heat of Solution:** Not pertinent
12.16 **Heat of Polymerization:** Not pertinent
12.25 **Heat of Fusion:** Data not available
12.26 **Limiting Value:** Data not available
12.27 **Reid Vapor Pressure:** Data not available

NOTES

Mercury and its compounds are on the Community Right To Know List.

NIOSH REL: (To Inorganic Mercury) TWA 0.05 mg(Hg)/m^3

THR: Poison by intravenous and intramuscular routes. When heated to decomposition it emits very toxic fumes of NO$_x$, Na$_2$O and Hg vapors. See also MERCURY COMPOUNDS.

MCV750 *HR: 3*

MERCUROPHYLLINE

CAS: 8012-34-8 NIOSH: OV 8650000

SYNS:

MERCUPURIN

MERCUZANTHIN

TOXICITY DATA:	CODEN:
ivn-hmn TDLo:28 mg/kg:CVS	JAMAAP 117,1806,41
ipr-rat LD50:121 mg/kg	THERAP 10,936,55
scu-mus LD50:163 mg(Hg)/kg	JPETAB 105,336,52
ivn-mus LD50:1410 mg/kg	JPETAB 99,149,50
ivn-cat LDLo:250 mg/kg	JPETAB 99,149,50
ivn-rbt LDLo:177 mg/kg	JPETAB 99,149,50

Mercury and its compounds are on the Community Right To Know List.

ACGIH TLV: TWA 0.1 mg(Hg)/m^3 (skin)
NIOSH REL: (To Inorganic Mercury) TWA 0.05 mg(Hg)/m^3

THR: Poison by subcutaneous, intraperitoneal and intravenous routes. Human systemic effects by intravenous route: cardiac arrythmias. When heated to decomposition it emits toxic fumes of Hg. See also MERCURY COMPOUNDS.

MCW000 *HR: 3*

MERCUROUS CHLORIDE

CAS: 7546-30-7 NIOSH: OV 8750000
mf: Cl$_2$Hg$_2$ mw: 472.09

PROP: White, odorless, tasteless, heavy powder or crystals. Sublimes @ 400°, d: 7.150. Insol in H$_2$O, alc and ether. Protect from light. Sunlight causes it to decomp into mercuric chloride and metallic Hg.

SYNS:

CALOGREEN
CALOMEL
CALOMELANO (ITALIAN)
CALOSAN
CHLORURE MERCUREUX (FRENCH)
C.I. 77764
CLORURO MERCUROSO (ITALIAN)
CYCLOSAN
KALOMEL (GERMAN)
MERCUROCHLORIDE (DUTCH)
MERCURY(I) CHLORIDE
MERCURY MONOCHLORIDE
MERCURY PROTOCHLORIDE
MILD MERCURY CHLORIDE
PRECIPITE BLANC
QUECKSILBER(I)-CHLORID (GERMAN)
QUECKSILBER CHLORUER (GERMAN)
SUBCHLORIDE OF MERCURY

TOXICITY DATA:	CODEN:
mrc-bcs 50 mmol/L	MUREAV 77,109,80
sce-ham:ovr 3200 nmol/L	ENMUDM 7,381,85
orl-rat LD50:166 mg/kg	GTPZAB 25(7),27,81
skn-rat LD50:1500 mg/kg	GTPZAB 25(7),27,81
orl-mus LD50:180 mg/kg	GTPZAB 25(7),27,81
ipr-mus LD50:10 mg/kg	GTPZAB 25(7),27,81

Mercury and its compounds are on the Community Right To Know List. EPA Genetic Toxicology Program. Reported in EPA TSCA Inventory.

ACGIH TLV: TWA 0.1 mg(Hg)/m^3 (skin)
NIOSH REL: (To Inorganic Mercury) TWA 0.05 mg(Hg)/m^3

THR: Poison by ingestion and intraperitoneal routes. Moderately toxic by skin contact. Mutagenic data. A fungicide. An FDA over-the-counter drug. Incompatible with bromides; iodides; alkali chlorides; sulfates; sulfites; carbonates; hydroxides; lime water; ammonia; golden antimony sulfide; cyanides; copper salts; hydrogen peroxide; iodine; iodoform; lead salts; silver salts; sulfides. When heated to decomposition it emits very toxic fumes of Cl$^-$ and Hg. See also MERCURY COMPOUNDS.

MCW250 *HR: 3*

MERCURY

CAS: 7439-97-6 NIOSH: OV 4550000
DOT: 2809
af: Hg aw: 200.59

PROP: Silvery, heavy, mobile liquid. A liquid metallic element. Mp: −38.89°, bp: 356.9°, d: 13.534 @ 25°, vap press: 2 × 10^{-3} mm @ 25°. Solid: tin-white, ductile, malleable mass which can be cut with a knife.

SYNS:

COLLOIDAL MERCURY
KWIK (DUTCH)
MERCURE (FRENCH)
MERCURIO (ITALIAN)
MERCURY, METALLIC (DOT)
NCI-C60399
QUECKSILBER (GERMAN)
QUICK SILVER
RCRA WASTE NUMBER U151
RTEC (POLISH)

TOXICITY DATA:	CODEN:
cyt-man-unr 150 µg/m^3	AEHLAU 34,461,79
ihl-rat TCLo:890 ng/m^3/24H (16W male):REP	GISAAA 45(3),72,80
ihl-rat TCLo:7440 ng/m^3/24H (16W male):REP	GISAAA 45(3),72,80
ipr-rat TDLo:400 mg/kg/14D-I: ETA	ZEKBAI 61,511,57
ihl-man TDLo:44300 µg/m^3/8H: CNS,LIV,MET	JOCMA7 20,532,78
ihl-wmn TCLo:150 µg/m^3/46D: CNS,GIT	AEHLAU 33,186,78
skn-man TDLo:129 mg/kg/5H-C:EAR,CNS,SKN	DERAAC 172,48,86
ihl-rbt LCLo:29 mg/m^3/30H	AMIHBC 7,19,53

Mercury and its compounds are on the Community Right To Know List.

OSHA PEL: CL 0.1 mg/m^3
ACGIH TLV: TWA 0.05 mg(Hg)/m^3 (vapor, skin)
DFG MAK: 0.01 ppm (0.1 mg/m^3)
NIOSH REL: (To Inorganic Mercury) TWA 0.05 mg(Hg)/m^3

DOT Classification: Corrosive Material; Label: Corrosive

THR: Poison by inhalation. An experimental tumorigen. Corrosive to skin, eyes and mucous membranes. Human systemic effects by inhalation: wakefulness, muscle weakness, anorexia, headache, tinnitus, hypermotility, diarrhea, liver changes, dermatitis, fever. An experimental teratogen. Experimental reproductive effects. Human mutagenic data. Used in dental applications, electronics, and chemical synthesis.

May explode on contact with 3-bromopropyne: alkynes + silver perchlorate; ethylene oxide; lithium; methylsilane + oxygen (explodes when shaken); peroxyformic acid; chlorine dioxide; tetracarbonylnickel + oxygen. May react with ammonia to form an explosive product. Mixtures with methyl azide are shock- and spark-sensitive explosives. The vapor ignites on contact with boron diiodophosphide. Reacts violently with acetylenic compounds (e.g., acetylene, sodium acetylide, 2-butyne-1,4-diol + acid); metals (e.g., aluminum; calcium; potassium; sodium; rubidium; exothermic formation of amalgams); Cl_2; ClO_2; CH_3N_3; Na_2C_2; nitromethane. Incompatible with methyl azide: oxidants. When heated to decomposition it emits toxic fumes of Hg. See also MERCURY COMPOUNDS. For further information, see Vol. 1, No. 3 of *DPIM Report*.

MCW350 ***HR: 3***

MERCURY(II) ACETYLIDE

CAS: 37297-87-3

mf: C_2Hg mw: 224.61

Mercury and its compounds are on the Community Right To Know List.

THR: A shock- and heat-sensitive explosive. Upon decomposition it emits toxic fumes of Hg. See also MERCURY COMPOUNDS and ACETYLIDES.

MCW400 ***HR: 3***

MERCURY(II) aci-DINITROMETHANIDE

mf: $C_2H_2HgN_4O_8$ mw: 410.65

Mercury and its compounds are on the Community Right To Know List.

THR: An explosive detonator. Upon decomposition it emits toxic fumes of Hg and NO_x. See also MERCURY COMPOUNDS.

MCW500 ***HR: 3***

MERCURY AMIDE CHLORIDE

CAS: 10124-48-8 NIOSH: OV 7020000

DOT: 1630

mf: ClH_2HgN mw: 252.07

H_2NHgCl

PROP: White, pulverized lumps or powder.

SYNS:

AMINOMERCURIC CHLORIDE
AMMONIATED MERCURY
MERCURIC AMMONIUM CHLORIDE, SOLID
MERCURIC CHLORIDE, AMMONIATED
MERCURY AMINE CHLORIDE
MERCURY AMMONIATED
WHITE MERCURY PRECIPITATED
WHITE PRECIPITATE

Mercury and its compounds are on the Community Right To Know List. Reported in EPA TSCA Inventory.

ACGIH TLV: TWA 0.1 mg(Hg)/m^3 (skin)
NIOSH REL: (To Inorganic Mercury) TWA 0.05 mg(Hg)/m^3

DOT Classification: Poison B, Label: Poison

THR: A poison. Explosive reaction with halogens or amine metal salts. When heated to decomposition it emits very toxic fumes of Cl^-, NO_x, and Hg. See also MERCURY COMPOUNDS.

MCW509 ***HR: 3***

MERCURY(II) ORTHOARSENATE

CAS: 7784-37-4 NIOSH: OV 7040000

mf: $AsHO_4 \cdot Hg$ mw: 340.52

DOT: 1623

SYN: MERCURIC ARSENATE (DOT)

Arsenic and its compounds, as well as mercury and its compounds, are on the Community Right To Know List.

OSHA PEL: TWA 0.01 mg(As)/m^3
ACGIH TLV: TWA 0.1 mg(Hg)/m^3 (skin)
NIOSH REL: (To Inorganic Mercury) TWA 0.05 mg(Hg)/m^3; (To Inorganic Arsenic) CL 0.002 mg(As)/m^3/15M

DOT Classification: Poison B; Label: Poison

THR: Poison. When heated to decomposition it emits toxic fumes of Hg and As. See also MERCURY COMPOUNDS and ARSENIC COMPOUNDS.

MCX000 ***HR: 3***

MERCURY(I) AZIDE

CAS: 38232-63-2 NIOSH: OV 7045000

mf: Hg_2N_6 mw: 485.22

SYNS:

MERCUROUS AZIDE (DOT)
MERCURY AZIDE

Mercury and its compounds are on the Community Right To Know List.

ACGIH TLV: TWA 0.1 mg(Hg)/m^3 (skin)

DOT Classification: Forbidden

THR: Poison. Explodes on heating in air. When heated to decomposition it emits very toxic fumes of NO_x and Hg. See also AZIDES and MERCURY COMPOUNDS.

NAPHTHA: VM & P

NVM

Common Synonyms

Petroleum solvent
Light naphtha
Painter's naphtha

Watery liquid — Colorless — Gasoline-like odor

Floats on water. Flammable, irritating vapor is produced.

Stop discharge if possible. Keep people away.
Shut off ignition sources and call fire department.
Stay upwind and use water spray to "knock down" vapor.
Avoid contact with liquid and vapor.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

FLAMMABLE.
Flashback along vapor trail may occur.
Vapor may explode if ignited in an enclosed area.
Extinguish with foam, dry chemical or carbon dioxide.
Cool exposed containers with water.

Exposure

CALL FOR MEDICAL AID

VAPOR
Irritating to eyes, nose and throat.
If inhaled, will cause dizziness or loss of consciousness.
Move to fresh air.
If breathing has stopped, give artificial respiration.
If breathing is difficult, give oxygen.

LIQUID
Irritating to skin and eyes.
If swallowed, will cause nausea or vomiting.
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

Effect of low concentrations on aquatic life is unknown.
Fouling to shoreline.
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-high flammability
Evacuate area
Disperse and flush

2. LABEL

2.1 **Category:** Flammable liquid
2.2 **Class:** 3

3. CHEMICAL DESIGNATIONS

3.1 **CG Compatibility Class:** Miscellaneous Hydrocarbon Mixtures
3.2 **Formula:** Not applicable
3.3 **IMO/UN Designation:** 3.2/1255
3.4 **DOT ID No.:** 1255
3.5 **CAS Registry No.:** Data not available

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Like gasoline

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Goggles or face shield (as for gasoline).
5.2 **Symptoms Following Exposure:** Vapor irritates respiratory tract, causes coughing and mild depression. Aspiration causes severe lung irritation with coughing, gagging, and rapidly developing pulmonary edema. Ingestion irritates mouth and stomach, causes nausea, vomiting, swelling of abdomen, cardiac arrhythmias.
5.3 **Treatment of Exposure:** INHALATION: maintain respiration if required. INGESTION: do NOT induce vomiting; observe for pneumonia; support if central nervous system depression occurs. ASPIRATION: enforce rest; administer oxygen; call a doctor. EYES: flush with water for at least 15 min. SKIN: wipe off, wash with soap and water.
5.4 **Threshold Limit Value:** ~~Data not available~~ 300 ppm
5.5 **Short Term Inhalation Limits:** 500 ppm for 30 min.
5.6 **Toxicity by Ingestion:** Grade 1; LD_{50} = 5 to 15 g/kg
5.7 **Late Toxicity:** None
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary.
5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
5.10 **Odor Threshold:** Data not available
5.11 **IDLH Value:** 10,000 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** 20-55°F C.C.
6.2 **Flammable Limits in Air:** 0.9%-6.7%
6.3 **Fire Extinguishing Agents:** Foam, carbon dioxide, or dry chemical
6.4 **Fire Extinguishing Agents Not to be Used:** Water may be ineffective
6.5 **Special Hazards of Combustion Products:** Not pertinent
6.6 **Behavior in Fire:** Vapor is heavier than air and may travel long distances to a source of ignition and flash back.
6.7 **Ignition Temperature:** 450°F
6.8 **Electrical Hazard:** Class I, Group D
6.9 **Burning Rate:** 4 mm/min.
6.10 **Adiabatic Flame Temperature:** Data not available
6.11 **Stoichiometric Air to Fuel Ratio:** Data not available
6.12 **Flame Temperature:** Data not available

7. CHEMICAL REACTIVITY

7.1 **Reactivity With Water:** No reaction
7.2 **Reactivity with Common Materials:** No reaction
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent
7.7 **Molar Ratio (Reactant to Product):** Data not available
7.8 **Reactivity Group:** 33

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** Data not available
8.2 **Waterfowl Toxicity:** Data not available
8.3 **Biological Oxygen Demand (BOD):** Data not available
8.4 **Food Chain Concentration Potential:** None

9. SHIPPING INFORMATION

9.1 **Grades of Purity:** Petroleum hydrocarbons (90%) plus aromatic hydrocarbons such as benzene and toluene (10%)
9.2 **Storage Temperature:** Ambient
9.3 **Inert Atmosphere:** No requirement
9.4 **Venting:** Open (flame arrester) or pressure-vacuum

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-T-U-V-W

11. HAZARD CLASSIFICATIONS

11.1 **Code of Federal Regulations:** Flammable liquid
11.2 **NAS Hazard Rating for Bulk Water Transportation:** Not listed
11.3 **NFPA Hazard Classification:**

Category	**Classification**
Health Hazard (Blue)	1
Flammability (Red)	3
Reactivity (Yellow)	0

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 **Physical State at 15°C and 1 atm:** Liquid
12.2 **Molecular Weight:** Not pertinent
12.3 **Boiling Point at 1 atm:** 200—300°F = 93—149°C = 366—422°K
12.4 **Freezing Point:** Not pertinent
12.5 **Critical Temperature:** Not pertinent
12.6 **Critical Pressure:** Not pertinent
12.7 **Specific Gravity:** 0.75 at 20°C (liquid)
12.8 **Liquid Surface Tension:** 19—23 dynes/cm = 0.019—0.023 N/m at 20°C
12.9 **Liquid Water Interfacial Tension:** 39—51 dynes/cm = 0.039—0.051 N/m at 20°C.
12.10 **Vapor (Gas) Specific Gravity:** Data not available
12.11 **Ratio of Specific Heats of Vapor (Gas):** (est.) 1.030
12.12 **Latent Heat of Vaporization:** 130—150 Btu/lb = 71—81 cal/g = $3.0—3.4 \times 10^5$ J/kg
12.13 **Heat of Combustion:** (est.) —18,200 Btu/lb = —10,100 cal/g = $—424 \times 10^5$ J/kg
12.14 **Heat of Decomposition:** Not pertinent
12.15 **Heat of Solution:** Not pertinent
12.16 **Heat of Polymerization:** Not pertinent
12.25 **Heat of Fusion:** Data not available
12.26 **Limiting Value:** Data not available
12.27 **Reid Vapor Pressure:** 0.12 psia

NOTES

OILS, FUEL: 6

OSX

Common Synonyms

Bunker C oil
Residual fuel oil
No. 6

Thick liquid   Black   Tar odor

Usually floats on water.

Stop discharge if possible.
Call fire department.
Avoid contact with liquid.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

Combustible.
Extinguish with dry chemical, foam or carbon dioxide.
Water may be ineffective on fire.
Cool exposed containers with water.

Exposure

CALL FOR MEDICAL AID.

LIQUID
Irritating to skin and eyes.
Harmful 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

Dangerous to aquatic life in high concentrations.
Fouling to shoreline.
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)

Mechanical containment
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:** Miscellaneous Hydrocarbon mixture
3.2 **Formula:** Not listed
3.3 **IMO/UN Designation:** 3.3/1223
3.4 **DOT ID No.:** 1223
3.5 **CAS Registry No.:** Data not available

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Dark
4.3 **Odor:** Tarry; like kerosene

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Protective gloves; goggles or face shield.
5.2 **Symptoms Following Exposure:** INGESTION: gastrointestinal irritation. ASPIRATION: pulmonary , irritation is normally minimal but may become more severe several hours after exposure.
5.3 **Treatment of Exposure:** INGESTION: do NOT lavage or induce vomiting. ASPIRATION: treatment probably not required; delayed development of pulmonary irritation can be detected by serial chest x-rays; consider prophylactic antibiotic regime if condition warrants. EYES: wash with copious quantity of water. SKIN: wipe off and wash with soap and water.
5.4 **Threshold Limit Value:** Data not available
5.5 **Short Term Inhalation Limits:** Not pertinent
5.6 **Toxicity by Ingestion:** Grade 1; LD_{50} = 5 to 15 g/kg
5.7 **Late Toxicity:** Data not available
5.8 **Vapor (Gas) Irritant Characteristics:** None
5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
5.10 **Odor Threshold:** Data not available
5.11 **IDLH Value:** Data not available

6. FIRE HAZARDS

6.1 **Flash Point:** > 150°F C.C.
6.2 **Flammable Limits in Air:** 1%-5%
6.3 **Fire Extinguishing Agents:** Dry chemical, foam, or carbon dioxide
6.4 **Fire Extinguishing Agents Not to be Used:** Water may be ineffective
6.5 **Special Hazards of Combustion Products:** Not pertinent
6.6 **Behavior in Fire:** Not pertinent
6.7 **Ignition Temperature:** 765°F
6.8 **Electrical Hazard:** Not pertinent
6.9 **Burning Rate:** 4 mm/min.
6.10 **Adiabatic Flame Temperature:** Data not available
6.11 **Stoichiometric Air to Fuel Ratio:** Data not available
6.12 **Flame Temperature:** Data not available

7. CHEMICAL REACTIVITY

7.1 **Reactivity With Water:** No reaction
7.2 **Reactivity with Common Materials:** No reaction
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent
7.7 **Molar Ratio (Reactant to Product):** Data not available
7.8 **Reactivity Group:** 33

8. WATER POLLUTION

8.1 **Aquatic Toxicity:**
2400 ppm/48 hr/juvenile American shad/TL_m/fresh water
2417 mg/l/48 hr/juvenile American shad/TL_m/salt 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:** Commercial
9.2 **Storage Temperature:** Elevated
9.3 **Inert Atmosphere:** No requirement
9.4 **Venting:** Open (flame arrester)

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-T-U

11. HAZARD CLASSIFICATIONS

11.1 **Code of Federal Regulations:** Combustible liquid
11.2 **NAS Hazard Rating for Bulk Water Transportation:** Not listed
11.3 **NFPA Hazard Classification:**

Category	Classification
Health Hazard (Blue)	0
Flammability (Red)	2
Reactivity (Yellow)	0

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 **Physical State at 15°C and 1 atm:** Liquid
12.2 **Molecular Weight:** Not pertinent
12.3 **Boiling Point at 1 atm:**
415—> >1093°F
= 212—> >588°C = 485—> >861°K
12.4 **Freezing Point:**
25 to 55°F
= −4 to +13°C = 269 to 286°K
12.5 **Critical Temperature:** Not pertinent
12.6 **Critical Pressure:** Not pertinent
12.7 **Specific Gravity:** 0.95 (approx.) at 20°C (liquid)
12.8 **Liquid Surface Tension:** (est.) 25 dynes/cm = 0.025 N/m at 20°C
12.9 **Liquid Water Interfacial Tension:** (est.) 50 dynes/cm = 0.05 N/m at 20°C
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:** −18,000 Btu/lb = −10,000 cal/g = −418.68 X 10^5 J/kg
12.14 **Heat of Decomposition:** Not pertinent
12.15 **Heat of Solution:** Not pertinent
12.16 **Heat of Polymerization:** Not pertinent
12.25 **Heat of Fusion:** Data not available
12.26 **Limiting Value:** Data not available
12.27 **Reid Vapor Pressure:** Data not available

NOTES

TOLUENE

TOL

Common Synonyms

Toluol
Methylbenzene
Methylbenzol

Watery liquid — Colorless — Pleasant odor

Floats on water. Flammable, irritating vapor is produced.

Stop discharge if possible. Keep people away.
Shut off ignition sources and call fire department.
Stay upwind and use water spray to "knock down" vapor.
Avoid contact with liquid and vapor
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

FLAMMABLE.
Flashback along vapor trail may occur.
Vapor may explode if ignited in an enclosed area.
Wear goggles and self-contained breathing apparatus.
Extinguish with dry chemical, foam, or carbon dioxide.
Water may be ineffective on fire.
Cool exposed containers with water.

Exposure

CALL FOR MEDICAL AID.

VAPOR
Irritating to eyes, nose and throat.
If inhaled, will cause nausea, vomiting, headache, dizziness, difficult breathing, or loss of consciousness.
Move to fresh air.
If breathing has stopped, give artificial respiration.
If breathing difficult, give oxygen.

LIQUID
Irritating to skin and eyes.
If swallowed, will cause nausea, vomiting or loss of consciousness.
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

Dangerous to aquatic life in high concentrations.
Fouling to shoreline.
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-high flammability
Evacuate area

2. LABEL

2.1 **Category:** Flammable liquid
2.2 **Class:** 3

3. CHEMICAL DESIGNATIONS

3.1 **CG Compatibility Class:** Aromatic Hydrocarbon
3.2 **Formula:** $C_6H_5CH_3$
3.3 **IMO/UN Designation:** 3.2/1294
3.4 **DOT ID No.:** 1294
3.5 **CAS Registry No.:** 108-88-3

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Pungent; aromatic, benzene-like; distinct, pleasant

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Air-supplied mask; goggles or face shield; plastic gloves.
5.2 **Symptoms Following Exposure:** Vapors irritate eyes and upper respiratory tract; cause dizziness, headache, anesthesia, respiratory arrest. Liquid irritates eyes and causes drying of skin. If aspirated, causes coughing, gagging, distress, and rapidly developing pulmonary edema. If ingested causes vomiting, griping, diarrhea, depressed respiration.
5.3 **Treatment of Exposure:** INHALATION: remove to fresh air, give artifical respiration and oxygen if needed; call a doctor. INGESTION: do NOT induce vomiting; call a doctor. EYES: flush with water for at least 15 min. SKIN: wipe off, wash with soap and water.
5.4 **Threshold Limit Value:** 100 ppm
5.5 **Short Term Inhalation Limits:** 600 ppm for 30 min.
5.6 **Toxicity by Ingestion:** Grade 2; LD_{50} = 0.5 to 5 g/kg
5.7 **Late Toxicity:** Kidney and liver damage may follow ingestion.
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary.
5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
5.10 **Odor Threshold:** 0.17 ppm
5.11 **IDLH Value:** 2,000 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** 40°F C.C.; 55°F O.C.
6.2 **Flammable Limits in Air:** 1.27%-7%
6.3 **Fire Extinguishing Agents:** Carbon dioxide or dry chemical for small fires, ordinary foam for large fires.
6.4 **Fire Extinguishing Agents Not to be Used:** Water may be ineffective
6.5 **Special Hazards of Combustion Products:** Not pertinent
6.6 **Behavior in Fire:** Vapor is heavier than air and may travel a considerable distance to a source of ignition and flash back.
6.7 **Ignition Temperature:** 997°F
6.8 **Electrical Hazard:** Class I, Group D
6.9 **Burning Rate:** 5.7 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:** 32

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** 1180 mg/l/96 hr/sunfish/TL_m/fresh water
8.2 **Waterfowl Toxicity:** Data not available
8.3 **Biological Oxygen Demand (BOD):** 0%, 5 days; 38% (theor), 8 days
8.4 **Food Chain Concentration Potential:** None

9. SHIPPING INFORMATION

9.1 **Grades of Purity:** Research, reagent, nitration-all 99.8 + %; industrial: contains 94 + %, with 5% xylene and small amounts of benzene and nonaromatic hydrocarbons; 90/120: less pure than industrial.
9.2 **Storage Temperature:** Ambient
9.3 **Inert Atmosphere:** No requirement
9.4 **Venting:** Open (flame arrester) or pressure-vacuum

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-T-U

11. HAZARD CLASSIFICATIONS

11.1 **Code of Federal Regulations:** Flammable liquid
11.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	3
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poisons	2
Water Polution	
Human Toxicity	1
Aquatic Toxicity	3
Aesthetic Effect	2
Reactivity	
Other Chemicals	1
Water	0
Self Reaction	0

11.3 **NFPA Hazard Classification:**

Category	Classification
Health Hazard (Blue)	2
Flammability (Red)	3
Reactivity (Yellow)	0

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 **Physical State at 15°C and 1 atm:** Liquid
12.2 **Molecular Weight:** 92.14
12.3 **Boiling Point at 1 atm:** 231.1°F = 110.6°C = 383.8°K
12.4 **Freezing Point:** −139°F = −95.0°C = 178.2°K
12.5 **Critical Temperature:** 605.4°F = 318.6°C = 591.8°K
12.6 **Critical Pressure:** 596.1 psia = 40.55 atm = 4.108 MN/m^2
12.7 **Specific Gravity:** 0.867 at 20°C (liquid)
12.8 **Liquid Surface Tension:** 29.0 dynes/cm = 0.0290 N/m at 20°C
12.9 **Liquid Water Interfacial Tension:** 36.1 dynes/cm = 0.0361 N/m at 25°C
12.10 **Vapor (Gas) Specific Gravity:** Not pertinent
12.11 **Ratio of Specific Heats of Vapor (Gas):** 1.069
12.12 **Latent Heat of Vaporization:** 155 Btu/lb = 86.1 cal/g = 3.61 X 10^5 J/kg
12.13 **Heat of Combustion:** −17,430 Btu/lb = −9686 cal/g = −405.5 X 10^5 J/kg
12.14 **Heat of Decomposition:** Not pertinent
12.15 **Heat of Solution:** Not pertinent
12.16 **Heat of Polymerization:** Not pertinent
12.25 **Heat of Fusion:** 17.17 cal/g
12.26 **Limiting Value:** Data not available
12.27 **Reid Vapor Pressure:** 1.1 psia

6. FIRE HAZARDS (Continued)

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

JUNE 1985

TRICHLOROETHYLENE

TCL

Common Synonyms

Trichloroethylene
Triclene; Algylen
Chlorylen
Gemalgene
Trethylene
Trichloran; Trilene

Watery liquid — Colorless — Sweet odor

Sinks in water. Irritating vapor is produced.

Stop discharge if possible. Keep people away.
Avoid contact with liquid and vapor.
Call fire department.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

Combustible.
POISONOUS GASES ARE PRODUCED IN FIRE.

Wear goggles and self-contained breathing apparatus.
Extinguish with dry chemical, carbon dioxide, or foam.

Exposure

CALL FOR MEDICAL AID

VAPOR
Irritating to eyes, nose and throat.
If inhaled, will cause nausea, vomiting, difficult breathing, or loss of consciousness.

Move to fresh air.
If breathing has stopped, give artificial respiration.
If breathing is difficult, give oxygen.

LIQUID
Irritating to skin and eyes.
If swallowed, will cause nausea, vomiting, difficult breathing, or loss of consciousness.

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

Effect of low concentrations on aquatic life is unknown.
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)

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:** Halogenated hydrocarbon
3.2 **Formula:** $CHCl=CCl_2$
3.3 **IMO/UN Designation:** 9.0/1710
3.4 **DOT ID No.:** 1710
3.5 **CAS Registry No.:** 79-01-6

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Chloroform-like; ethereal

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Organic vapor-acid gas canister; self-contained breathing apparatus for emergencies; neoprene or vinyl gloves; chemical safety goggles; face-shield; neoprene safety shoes; neoprene suit or apron for splash protection.
5.2 **Symptoms Following Exposure:** INHALATION: symptoms range from irritation of the nose and throat to nausea, an attitude of irresponsibility, blurred vision, and finally disturbance of central nervous system resulting in cardiac failure. Chronic exposure may cause organic injury. INGESTION: symptoms similar to inhalation. SKIN: defatting action can cause dermatitis. EYES: slightly irritating sensation and lachrymation.
5.3 **Treatment of Exposure:** Do NOT administer adrenalin or epinephrine; get medical attention for all cases of overexposure. INHALATION: remove victim to fresh air; if necessary, apply artificial respiration and/or administer oxygen. INGESTION: have victim drink water and induce vomiting; repeat three times; then give 1 tablespoon epsom salts in water. EYES: flush thoroughly with water. SKIN: wash thoroughly with soap and warm water.
5.4 **Threshold Limit Value:** 50 ppm
5.5 **Short Term Inhalation Limits:** 200 ppm for 30 min.
5.6 **Toxicity by Ingestion:** Grade 3; LD_{50} = 50 to 500 mg/kg
5.7 **Late Toxicity:** Data not available
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary.
5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
5.10 **Odor Threshold:** 50 ppm
5.11 **IDLH Value:** 1,000 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** 90°F C.C.; practically nonflammable
6.2 **Flammable Limits in Air:** 8.0%-10.5%
6.3 **Fire Extinguishing Agents:** Water fog
6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent
6.5 **Special Hazards of Combustion Products:** Toxic and irritating gases are produced in fire situations.
6.6 **Behavior in Fire:** Not pertinent
6.7 **Ignition Temperature:** 770°F
6.8 **Electrical Hazard:** Not pertinent
6.9 **Burning Rate:** Not pertinent
6.10 **Adiabatic Flame Temperature:** Data not available
6.11 **Stoichiometric Air to Fuel Ratio:** Data not available
6.12 **Flame Temperature:** Data not available

7. CHEMICAL REACTIVITY

7.1 **Reactivity With Water:** No reaction
7.2 **Reactivity with Common Materials:** No reaction
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent
7.7 **Molar Ratio (Reactant to Product):** Data not available
7.8 **Reactivity Group:** 36

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** 660 mg/l/40 hr/daphnia/kill/fresh water
8.2 **Waterfowl Toxicity:** Data not available
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; dry cleaning; degreasing; extraction
9.2 **Storage Temperature:** Ambient
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:** ORM-A
11.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	1
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poisons	2
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	2
Aesthetic Effect	2
Reactivity	
Other Chemicals	1
Water	0
Self Reaction	1

11.3 **NFPA Hazard Classification:**

Category	Classification
Health Hazard (Blue)	2
Flammability (Red)	1
Reactivity (Yellow)	0

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 **Physical State at 15°C and 1 atm:** Liquid
12.2 **Molecular Weight:** 131.39
12.3 **Boiling Point at 1 atm:** 189°F = 87°C = 360°K
12.4 **Freezing Point:** −123.5°F = −86.4°C = 186.8°K
12.5 **Critical Temperature:** Not pertinent
12.6 **Critical Pressure:** Not pertinent
12.7 **Specific Gravity:** 1.46 at 20°C (liquid)
12.8 **Liquid Surface Tension:** 29.3 dynes/cm = 0.0293 N/m at 20°C
12.9 **Liquid Water Interfacial Tension:** 34.5 dynes/cm = 0.0345 N/m at 24°C
12.10 **Vapor (Gas) Specific Gravity:** 4.5
12.11 **Ratio of Specific Heats of Vapor (Gas):** 1.116
12.12 **Latent Heat of Vaporization:** 103 Btu/lb = 57.2 cal/g = 2.4×10^5 J/kg
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
12.25 **Heat of Fusion:** Data not available
12.26 **Limiting Value:** Data not available
12.27 **Reid Vapor Pressure:** 2.5 psia

NOTES

m-XYLENE

XLM

Common Synonyms

1, 3-Dimethylbenzene
Xylol

Watery liquid — Colorless — Sweet odor

Floats on water. Flammable, irritating vapor is produced.

Stop discharge if possible. Keep people away.
Call fire department.
Avoid contact with liquid and vapor.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

FLAMMABLE
Flashback along vapor trail may occur.
Vapor may explode if ignited in an enclosed area.
Wear self-contained breathing apparatus.
Extinguish with foam, dry chemical, or carbon dioxide.
Water may be ineffective on fire.
Cool exposed containers with water

Exposure

CALL FOR MEDICAL AID.

VAPOR
Irritating to eyes, nose, and throat.
If inhaled, will cause headache, difficult breathing, or loss of consciousness.
Move to fresh air.
If breathing has stopped, give artificial respiration.
If breathing is difficult, give oxygen.

LIQUID
Irritating to skin and eyes.
If swallowed, will cause nausea, vomiting, or loss of consciousness.
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.
Fouling to shoreline.
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-high flammability
Evacuate area
Should be removed
Chemical and physical treatment

2. LABEL

2.1 **Category:** Flammable liquid
2.2 **Class:** 3

3. CHEMICAL DESIGNATIONS

3.1 **CG Compatibility Class:** Aromatic Hydrocarbon
3.2 **Formula:** $m\text{-}C_6H_4(CH_3)_2$
3.3 **IMO/UN Designation:** 3.2/1307
3.4 **DOT ID No.:** 1307
3.5 **CAS Registry No.:** 108-38-3

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Like benzene; characteristic aromatic

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Approved canister or air-supplied mask; goggles or face shield; plastic gloves and boots.
5.2 **Symptoms Following Exposure:** Vapors cause headache and dizziness. Liquid irritates eyes and skin. If taken into lungs, causes severe coughing, distress, and rapidly developing pulmonary edema. If ingested, causes nausea, vomiting, cramps, headache, and coma; can be fatal. Kidney and liver damage can occur.
5.3 **Treatment of Exposure:** INHALATION: remove to fresh air; administer artificial respiration and oxygen if required; call a doctor. INGESTION: do NOT induce vomiting; call a doctor. EYES: flush with water for at least 15 min. SKIN: wipe off, wash with soap and water.
5.4 **Threshold Limit Value:** 100 ppm
5.5 **Short Term Inhalation Limits:** 300 ppm for 30 min.
5.6 **Toxicity by Ingestion:** Grade 3; LD_{50} = 50 to 500 g/kg
5.7 **Late Toxicity:** Kidney and liver damage.
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary.
5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
5.10 **Odor Threshold:** 0.05 ppm
5.11 **IDLH Value:** 10,000 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** 84°F C.C.
6.2 **Flammable Limits in Air:** 1.1%-6.4%
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:** Not pertinent
6.6 **Behavior in Fire:** Vapor is heavier than air and may travel considerable distance to a source of ignition and flash back.
6.7 **Ignition Temperature:** 986°F
6.8 **Electrical Hazard:** Class I, Group D
6.9 **Burning Rate:** 5.8 mm/min.
6.10 **Adiabatic Flame Temperature:** Data not available
6.11 **Stoichiometric Air to Fuel Ratio:** Data not available
6.12 **Flame Temperature:** Data not available

7. CHEMICAL REACTIVITY

7.1 **Reactivity With Water:** No reaction
7.2 **Reactivity with Common Materials:** No reaction
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent
7.7 **Molar Ratio (Reactant to Product):** Data not available
7.8 **Reactivity Group:** 32

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** 22 ppm/96 hr/bluegill/TL_m/fresh water
8.2 **Waterfowl Toxicity:** Data not available
8.3 **Biological Oxygen Demand (BOD):** 0 lb/lb, 5 days; 0% (theor.), 8 days
8.4 **Food Chain Concentration Potential:** Data not available

9. SHIPPING INFORMATION

9.1 **Grades of Purity:** Research: 99.99%; Pure: 99.9%; Technical: 99.2%
9.2 **Storage Temperature:** Ambient
9.3 **Inert Atmosphere:** No requirement
9.4 **Venting:** Open (flame arrester) or pressure-vacuum

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-T-U

11. HAZARD CLASSIFICATIONS

11.1 **Code of Federal Regulations:** Flammable liquid
11.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	3
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poisons	2
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	3
Aesthetic Effect	2
Reactivity	
Other Chemicals	1
Water	0
Self Reaction	0

11.3 **NFPA Hazard Classification:**

Category	Classification
Health Hazard (Blue)	2
Flammability (Red)	3
Reactivity (Yellow)	0

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 **Physical State at 15°C and 1 atm:** Liquid
12.2 **Molecular Weight:** 106.18
12.3 **Boiling Point at 1 atm:** 269.4°F = 131.9°C = 405.1°K
12.4 **Freezing Point:** −54.2°F = −47.9°C = 225.3°K
12.5 **Critical Temperature:** 650.8°F = 343.8°C = 617.0°K
12.6 **Critical Pressure:** 513.8 atm = 34.95 psia = 3.540 MN/m^2
12.7 **Specific Gravity:** 0.864 at 20°C (liquid)
12.8 **Liquid Surface Tension:** 28.6 dynes/cm = 0.0286 N/m at 20°C
12.9 **Liquid Water Interfacial Tension:** 36.4 dynes/cm = 0.0364 N/m at 30°C
12.10 **Vapor (Gas) Specific Gravity:** Not pertinent
12.11 **Ratio of Specific Heats of Vapor (Gas):** 1.071
12.12 **Latent Heat of Vaporization:** 147 Btu/lb = 81.9 cal/g = 3.43×10^5 J/kg
12.13 **Heat of Combustion:** −17,554 Btu/lb = −9752.4 cal/g = -408.31×10^5 J/kg
12.14 **Heat of Decomposition:** Not pertinent
12.15 **Heat of Solution:** Not pertinent
12.16 **Heat of Polymerization:** Not pertinent
12.25 **Heat of Fusion:** 26.01 cal/g
12.26 **Limiting Value:** Data not available
12.27 **Reid Vapor Pressure:** 0.34 psia

NOTES

POLYCHLORINATED BIPHENYL

PCB

Common Synonyms			
PCB Chlorinated biphenyl Arochlor Halogenated waxes Polychloropolyphenyls	Oily liquid to solid powder Sinks in water.	Light yellow liquid, or white powder	Weak odor

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

Fire	Combustible. Extinguish with water, foam, dry chemical, or carbon dioxide.
Exposure	CALL FOR MEDICAL AID. **LIQUID OR SOLID** Irritating to skin and eyes. Flush affected areas with plenty of water. IF IN EYES, hold eyelids open and flush with plenty of water.
Water Pollution	HARMFUL TO AQUATIC LIFE IN VERY LOW CONCENTRATIONS. May be dangerous if it enters water intakes. Notify local health and wildlife officials. Notify operators of nearby water intakes.

1. RESPONSE TO DISCHARGE

(See Response Methods Handbook)

Issue warning-water contaminant
Should be removed
Chemical and physical treatment

2. LABEL

2.1 **Category:** None
2.2 **Class:** Not pertinent

3. CHEMICAL DESIGNATIONS

3.1 **CG Compatibility Class:** Not listed
3.2 **Formula:** $(C_{12}H_{10-n})Cl_n$
3.3 **IMO/UN Designation:** Not listed
3.4 **DOT ID No.:** 2315
3.5 **CAS Registry No.:** 1336-36-3

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid or solid
4.2 **Color:** Pale yellow (liquid); colorless (solid)
4.3 **Odor:** Practically odorless

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Gloves and protective garments.
5.2 **Symptoms Following Exposure:** Acne from skin contact.
5.3 **Treatment of Exposure:** SKIN: wash with soap and water.
5.4 **Threshold Limit Value:** 0.5 to 1.0 mg/m^3
5.5 **Short Term Inhalation Limits:** Data not available
5.6 **Toxicity by Ingestion:** Grade 2; oral rat LD_{50} = 3980 mg/kg
5.7 **Late Toxicity:** Causes chromosomal abnormalities in rats, birth defects in birds
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause severe irritation of eyes and throat and cause eye and lung injury. They cannot be tolerated even at low concentrations.
5.9 **Liquid or Solid Irritant Characteristics:** Contact with skin may cause irritation.
5.10 **Odor Threshold:** Data not available
5.11 **IDLH Value:** 5 to 10 mg/m^3

6. FIRE HAZARDS

6.1 **Flash Point:** >286°F
6.2 **Flammable Limits in Air:** Data not available
6.3 **Fire Extinguishing Agents:** Water, foam, dry chemical, or carbon dioxide
6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent
6.5 **Special Hazards of Combustion Products:** Irritating gases are generated in fires.
6.6 **Behavior in Fire:** Not pertinent
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:** 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:**
0.278 ppm/96 hr/bluegill/TL_m/fresh water
0.005 ppm/336-1080 hr/pinfish/TL_m/salt water
8.2 **Waterfowl Toxicity:** LD_{50} 2000 ppm (mallard duck)
8.3 **Biological Oxygen Demand (BOD):** Very low
8.4 **Food Chain Concentration Potential:** High

9. SHIPPING INFORMATION

9.1 **Grades of Purity:** 11 grades (some liquid, some solids) which differ primarily in their chlorine content (20%-68% by weight)
9.2 **Storage Temperature:** Ambient
9.3 **Inert Atmosphere:** No requirement
9.4 **Venting:** Open

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

II

11. HAZARD CLASSIFICATIONS

11.1 **Code of Federal Regulations:** ORM-E
11.2 **NAS Hazard Rating for Bulk Water Transportation:** Not listed
11.3 **NFPA Hazard Classification:** Not listed

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 **Physical State at 15°C and 1 atm:** Solid
12.2 **Molecular Weight:** Not pertinent
12.3 **Boiling Point at 1 atm:** Very high
12.4 **Freezing Point:** Not pertinent
12.5 **Critical Temperature:** Not pertinent
12.6 **Critical Pressure:** Not pertinent
12.7 **Specific Gravity:** 1.3—1.8 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
12.25 **Heat of Fusion:** Data not available
12.26 **Limiting Value:** Data not available
12.27 **Reid Vapor Pressure:** Data not available

NOTES

OILS, MISCELLANEOUS: MOTOR

OMT

Common Synonyms

Crankcase oil
Lubricating oil
Transmission oil

Oily liquid — Yellow-brown — Lube oil odor

Floats on water.

Stop discharge if possible.
Call fire department.
Avoid contact with liquid.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

Combustible.
Extinguish with dry chemical, foam or carbon dioxide.
Water may be ineffective on fire.
Cool exposed containers with water.

Exposure

CALL FOR MEDICAL AID.

LIQUID
Irritating to skin and eyes.
Harmful 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

Effect of low concentrations on aquatic life is unknown.
Fouling to shoreline.
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)

Mechanical containment
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:** Miscellaneous Hydrocarbon Mixtures
3.2 **Formula:** Not applicable
3.3 **IMO/UN Designation:** 3.3/1270
3.4 **DOT ID No.:** 1270
3.5 **CAS Registry No.:** Data not available

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Yellow fluorescent
4.3 **Odor:** Characteristic

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Protective gloves; goggles or face shield.
5.2 **Symptoms Following Exposure:** INGESTION: minimal gastrointestinal irritation; increased frequency of bowel passage may occur. ASPIRATION: pulmonary irritation is normally minimal but may become more severe several hours after exposure.
5.3 **Treatment of Exposure:** INGESTION: do NOT lavage or induce vomiting. ASPIRATION: treatment probably not required; delayed development of pulmonary irritation can be detected by serial chest x-rays. EYES: wash with copious amounts of water. SKIN: wipe off oil and wash with soap and water.
5.4 **Threshold Limit Value:** Data not available
5.5 **Short Term Inhalation Limits:** Data not available
5.6 **Toxicity by Ingestion:** Grade 1; LD_{50} = 5 to 15 g/kg
5.7 **Late Toxicity:** Data not available
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary.
5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
5.10 **Odor Threshold:** Data not available
5.11 **IDLH Value:** Data not available

6. FIRE HAZARDS

6.1 **Flash Point:** 275—600°F C.C.
6.2 **Flammable Limits in Air:** Data not available
6.3 **Fire Extinguishing Agents:** Dry chemical, foam, or carbon dioxide
6.4 **Fire Extinguishing Agents Not to be Used:** Water may be ineffective
6.5 **Special Hazards of Combustion Products:** Not pertinent
6.6 **Behavior in Fire:** Not pertinent
6.7 **Ignition Temperature:** 325—625°F
6.8 **Electrical Hazard:** Not pertinent
6.9 **Burning Rate:** 4 mm/min.
6.10 **Adiabatic Flame Temperature:** Data not available
6.11 **Stoichiometric Air to Fuel Ratio:** Data not available
6.12 **Flame Temperature:** Data not available

7. CHEMICAL REACTIVITY

7.1 **Reactivity With Water:** No reaction
7.2 **Reactivity with Common Materials:** No reaction
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent
7.7 **Molar Ratio (Reactant to Product):** Data not available
7.8 **Reactivity Group:** 33

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** Data not available
8.2 **Waterfowl Toxicity:** Data not available
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 viscosities
9.2 **Storage Temperature:** Ambient
9.3 **Inert Atmosphere:** No requirement
9.4 **Venting:** Open (flame arrester)

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-T-U

11. HAZARD CLASSIFICATIONS

11.1 **Code of Federal Regulations:** Not listed
11.2 **NAS Hazard Rating for Bulk Water Transportation:** Not listed
11.3 **NFPA Hazard Classification:** Not listed

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 **Physical State at 15°C and 1 atm:** Liquid
12.2 **Molecular Weight:** Not pertinent
12.3 **Boiling Point at 1 atm:** Very high
12.4 **Freezing Point:** —29.9°F = —34.4°C = 238.8°K
12.5 **Critical Temperature:** Not pertinent
12.6 **Critical Pressure:** Not pertinent
12.7 **Specific Gravity:** 0.84—0.96 at 15°C (liquid)
12.8 **Liquid Surface Tension:** 36-37.5 dynes/cm = 0.036—0.0375 N/m at 20°C
12.9 **Liquid Water Interfacial Tension:** 33—54 dynes/cm = 0.033—0.054 N/m at 20°C
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:** —18,486 Btu/lb = —10,270 cal/g = —429.98 X 10^5 J/kg
12.14 **Heat of Decomposition:** Not pertinent
12.15 **Heat of Solution:** Not pertinent
12.16 **Heat of Polymerization:** Not pertinent
12.25 **Heat of Fusion:** Data not available
12.26 **Limiting Value:** Data not available
12.27 **Reid Vapor Pressure:** Data not available

NOTES

JANUARY 1991

BENZENE

BNZ

Common Synonyms

Benzol
Benzole

Watery liquid — Colorless — Gasoline-like odor

Floats on water. Flammable, irritating vapor is produced. Freezing point is 42°F.

Avoid contact with liquid and vapor. Keep people away.
Wear goggles and self-contained breathing apparatus.
Shut off ignition sources and call fire department.
Stop discharge if possible.
Stay upwind and use water spray to "knock down" vapor.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

FLAMMABLE.
Flashback along vapor trail may occur.
Vapor may explode if ignited in an enclosed area.
Wear goggles and self-contained breathing apparatus.
Extinguish with dry chemical, foam, or carbon dioxide.
Water may be ineffective on fire.
Cool exposed containers with water.

Exposure

CALL FOR MEDICAL AID.

VAPOR
Irritating to eyes, nose and throat.
If inhaled, will cause headache, difficult breathing, or loss of consciousness.
Move to fresh air.
If breathing has stopped, give artificial respiration.
If breathing is difficult, give oxygen.

LIQUID
Irritating to skin and eyes.
Harmful 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.

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-high flammability
Restrict access

2. LABEL

2.1 **Category:** Flammable liquid
2.2 **Class:** 3

3. CHEMICAL DESIGNATIONS

3.1 **CG Compatibility Class:** Aromatic Hydrocarbon
3.2 **Formula:** C_6H_6
3.3 **IMO/UN Designation:** 3.2/1114
3.4 **DOT ID No.:** 1114
3.5 **CAS Registry No.:** 71-43-2

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Aromatic; rather pleasant aromatic odor; characteristic odor

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Hydrocarbon vapor canister, supplied air or a hose mask; hydrocarbon-insoluble rubber or plastic gloves, chemical goggles or face splash shield; hydrocarbon-insoluble apron such as neoprene.
5.2 **Symptoms Following Exposure:** Dizziness, excitation, pallor, followed by flushing, weakness, headache, breathlessness, chest constriction. Coma and possible death.
5.3 **Treatment of Exposure:** SKIN: flush with water followed by soap and water; remove contaminated clothing and wash skin. EYES: flush with plenty of water until irritation subsides. INHALATION: remove from exposure immediately. Call a physician. IF breathing is irregular or stopped, start resuscitation, administer oxygen.
5.4 **Threshold Limit Value:** 10 ppm
5.5 **Short Term Inhalation Limits:** 75 ppm for 30 min.
5.6 **Toxicity by Ingestion:** Grade 3; LD_{50} = 50 to 500 mg/kg
5.7 **Late Toxicity:** Leukemia
5.8 ***Vapor (Gas) Irritant Characteristics:*** *If present in high concentrations, vapors may cause irritation of eyes or respiratory system. The effect is temporary.*
5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin
5.10 **Odor Threshold:** 4.68 ppm
5.11 **IDLH Value:** 2,000 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** 12°F C.C.
6.2 **Flammable Limits in Air:** 1.3%-7.9%
6.3 **Fire Extinguishing Agents:** Dry chemical, foam, or carbon dioxide
6.4 **Fire Extinguishing Agents Not to be Used:** Water may be ineffective
6.5 **Special Hazards of Combustion Products:** Not pertinent
6.6 **Behavior in Fire:** Vapor is heavier than air and may travel considerable distance to a source of ignition and flash back
6.7 **Ignition Temperature:** 1097°F
6.8 **Electrical Hazard:** Class I, Group D
6.9 **Burning Rate:** 6.0 mm/min.
6.10 **Adiabatic Flame Temperature:** Data not available
6.11 **Stoichiometric Air to Fuel Ratio:** Data not available
6.12 **Flame Temperature:** Data not available

7. CHEMICAL REACTIVITY

7.1 **Reactivity With Water:** No reaction
7.2 **Reactivity with Common Materials:** No reaction
7.3 **Stability During Transport:** Stable
7.4 **Neutralizing Agents for Acids and Caustics:** Not pertinent
7.5 **Polymerization:** Not pertinent
7.6 **Inhibitor of Polymerization:** Not pertinent
7.7 **Molar Ratio (Reactant to Product):** Data not available
7.8 **Reactivity Group:** 32

8. WATER POLLUTION

8.1 **Aquatic Toxicity:**
5 ppm/6 hr/minnow/lethal/distilled water
20 ppm/24 hr/sunfish/TL_m/tap water
8.2 **Waterfowl Toxicity:** Data not available
8.3 **Biological Oxygen Demand (BOD):** 1.2 lb/lb, 10 days
8.4 **Food Chain Concentration Potential:** None

9. SHIPPING INFORMATION

9.1 **Grades of Purity:**

Industrial pure	99 + %
Thiophene-free	99 + %
Nitration	99 + %
Industrial 90%	85 + %
Reagent	99 + %

9.2 **Storage Temperature:** Open
9.3 **Inert Atmosphere:** No requirement
9.4 **Venting:** Pressure-vacuum

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-T-U-V-W

11. HAZARD CLASSIFICATIONS

11.1 **Code of Federal Regulations:** Flammable liquid
11.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	3
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poisons	3
Water Pollution	
Human Toxicity	3
Aquatic Toxicity	1
Aesthetic Effect	3
Reactivity	
Other Chemicals	2
Water	1
Self Reaction	0

11.3 **NFPA Hazard Classification:**

Category	Classification
Health Hazard (Blue)	2
Flammability (Red)	3
Reactivity (Yellow)	0

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 **Physical State at 15°C and 1 atm:** Liquid
12.2 **Molecular Weight:** 78.11
12.3 **Boiling Point at 1 atm:** 176°F = 80.1°C = 353.3°K
12.4 **Freezing Point:** 42.0°F = 5.5°C = 278.7°K
12.5 **Critical Temperature:** 552.0°F = 288.9°C = 562.1°K
12.6 **Critical Pressure:** 710 psia = 48.3 atm = 4.89 MN/m^2
12.7 **Specific Gravity:** 0.879 at 20°C (liquid)
12.8 **Liquid Surface Tension:** 28.9 dynes/cm = 0.0289 N/m at 20°C
12.9 **Liquid Water Interfacial Tension:** 35.0 dynes/cm = 0.035 N/m at 20°C
12.10 **Vapor (Gas) Specific Gravity:** 2.7
12.11 **Ratio of Specific Heats of Vapor (Gas):** 1.061
12.12 **Latent Heat of Vaporization:** 169 Btu/lb = 94.1 cal/g = 3.94×10^5 J/kg
12.13 **Heat of Combustion:** −17,460 Btu/lb = −9698 cal/g = -406.0×10^5 J/kg
12.14 **Heat of Decomposition:** Not pertinent
12.15 **Heat of Solution:** Not pertinent
12.16 **Heat of Polymerization:** Not pertinent
12.25 **Heat of Fusion:** 30.45 cal/g
12.26 **Limiting Value:** Data not available
12.27 **Reid Vapor Pressure:** 3.22 psia

NOTES

ETHYLBENZENE

ETB

Common Synonyms	Liquid	Colorless	Sweet, gasoline-like odor
Phenylethane EB	Floats on water. Flammable, irritating vapor is produced.		

Avoid contact with liquid and vapor. Keep people away.
Wear goggles, self-contained breathing apparatus, and rubber overclothing (including gloves).
Shut off ignition sources and call fire department.
Stop discharge if possible.
Stay upwind and use water spray to "knock down" vapor.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

FLAMMABLE.
Flashback along vapor trail may occur.
Vapor may explode if ignited in an enclosed area.
Wear goggles, self-contained breathing apparatus, and rubber overclothing (including gloves).
Extinguish with dry chemical, foam, or carbon dioxide.
Water may be ineffective on fire.
Cool exposed containers with water.

Exposure

CALL FOR MEDICAL AID.

VAPOR
Irritating to eyes, nose and throat.
If inhaled, will cause dizziness or difficult breathing.
Move to fresh air.
If breathing has stopped, give artificial respiration.
If breathing is difficult, give oxygen.

LIQUID
Will burn skin and eyes.
Harmful 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.
Fouling to shoreline.
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)
Mechanical containment
Should be removed
Chemical and physical treatment

2. LABEL

2.1 **Category:** Flammable liquid
2.2 **Class:** 3

3. CHEMICAL DESIGNATIONS

3.1 **CG Compatibility Class:** Aromatic hydrocarbon
3.2 **Formula:** $C_6H_5CH_2CH_3$
3.3 **IMO/UN Designation:** 3.3/1175
3.4 **DOT ID No.:** 1175
3.5 **CAS Registry No.:** 100-41-4

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Aromatic

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Self-contained breathing apparatus; safety goggles.
5.2 **Symptoms Following Exposure:** Inhalation may cause irritation of nose, dizziness, depression. Moderate irritation of eye with corneal injury possible. Irritates skin and may cause blisters.
5.3 **Treatment of Exposure:** INHALATION: if ill effects occur, remove victim to fresh air, keep him warm and quiet, and get medical help promptly; if breathing stops, give artificial respiration. INGESTION: induce vomiting only upon physician's approval; material in lung may cause chemical pneumonitis. SKIN AND EYES: promptly flush with plenty of water (15 min. for eyes) and get medical attention; remove and wash contaminated clothing before reuse.
5.4 **Threshold Limit Value:** 100 ppm
5.5 **Short Term Inhalation Limits:** 200 ppm for 30 min.
5.6 **Toxicity by Ingestion:** Grade 2; LD_{50} = 0.5 to 5 g/kg (rat)
5.7 **Late Toxicity:** Data not available
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause moderate irritation such that personnel will find high concentrations unpleasant. The effect is temporary.
5.9 **Liquid or Solid Irritant Characteristics:** Causes smarting of the skin and first-degree burns on short exposure; may cause secondary burns on long exposure.
5.10 **Odor Threshold:** 140 ppm
5.11 **IDLH Value:** 2,000 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** 80°F O.C.; 59°F C.C.
6.2 **Flammable Limits in Air:** 1.0%-6.7%
6.3 **Fire Extinguishing Agents:** Foam (most effective), water fog, carbon dioxide or dry chemical.
6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent
6.5 **Special Hazards of Combustion Products:** Irritating vapors are generated when heated.
6.6 **Behavior in Fire:** Vapor is heavier than air and may travel considerable distance to the source of ignition and flash back.
6.7 **Ignition Temperature:** 860°F
6.8 **Electrical Hazard:** Not pertinent
6.9 **Burning Rate:** 5.8 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:** 32

8. WATER POLLUTION

8.1 **Aquatic Toxicity:** 29 ppm/96 hr/bluegill/TL_m/fresh water
8.2 **Waterfowl Toxicity:** Data not available
8.3 **Biological Oxygen Demand (BOD):** 2.8% (theor.), 5 days
8.4 **Food Chain Concentration Potential:** None

9. SHIPPING INFORMATION

9.1 **Grades of Purity:** Research grade: 99.98%; pure grade: 99.5%; technical grade: 99.0%
9.2 **Storage Temperature:** Ambient
9.3 **Inert Atmosphere:** No requirement
9.4 **Venting:** Open (flame arrester) or pressure-vacuum

10. HAZARD ASSESSMENT CODE

(See Hazard Assessment Handbook)

A-T-U

11. HAZARD CLASSIFICATIONS

11.1 **Code of Federal Regulations:** Flammable liquid
11.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	Rating
Fire	3
Health	
Vapor Irritant	2
Liquid or Solid Irritant	2
Poisons	2
Water Polution	
Human Toxicity	1
Aquatic Toxicity	3
Aesthetic Effect	2
Reactivity	
Other Chemicals	1
Water	0
Self Reaction	0

11.3 **NFPA Hazard Classification:**

Category	Classification
Health Hazard (Blue)	2
Flammability (Red)	3
Reactivity (Yellow)	0

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 **Physical State at 15°C and 1 atm:** Liquid
12.2 **Molecular Weight:** 106.17
12.3 **Boiling Point at 1 atm:** 277.2°F = 136.2°C = 409.4°K
12.4 **Freezing Point:** —139°F = —95°C = 178°K
12.5 **Critical Temperature:** 651.0°F = 343.9°C = 617.1°K
12.6 **Critical Pressure:** 523 psia = 35.6 atm = 3.61 MN/m²
12.7 **Specific Gravity:** 0.867 at 20°C (liquid)
12.8 **Liquid Surface Tension:** 29.2 dynes/cm = 0.0292 N/m at 20°C
12.9 **Liquid Water Interfacial Tension:** 35.48 dynes/cm = 0.03548 N/m at 20°C
12.10 **Vapor (Gas) Specific Gravity:** Not pertinent
12.11 **Ratio of Specific Heats of Vapor (Gas):** 1.071
12.12 **Latent Heat of Vaporization:** 144 Btu/lb = 80.1 cal/g = 3.35×10^5 J/kg
12.13 **Heat of Combustion:** —17,780 Btu/lb = —9877 cal/g = -413.5×10^5 J/kg
12.14 **Heat of Decomposition:** Not pertinent
12.15 **Heat of Solution:** Not pertinent
12.16 **Heat of Polymerization:** Not pertinent
12.25 **Heat of Fusion:** Data Not Available
12.26 **Limiting Value:** Data Not Available
12.27 **Reid Vapor Pressure:** 0.4 psia

6. FIRE HAZARDS (Continued)

6.11 **Stoichiometric Air to Fuel Ratio:** Data Not Available
6.12 **Flame Temperature:** Data Not Available

TETRACHLOROETHYLENE

12.17 SATURATED LIQUID DENSITY

Temperature (degrees F)	Pounds per cubic foot
35	103.400
40	103.099
45	102.900
50	102.599
55	102.299
60	102.000
65	101.700
70	101.400
75	101.099
80	100.799
85	100.500
90	100.200
95	99.910
100	99.610
105	99.320
110	99.020
115	98.730
120	98.429
125	98.139
130	97.839
135	97.549
140	97.250
145	96.959
150	96.669
155	96.370
160	96.080

12.18 LIQUID HEAT CAPACITY

Temperature (degrees F)	British thermal unit per pound-F
0	.198
10	.200
20	.201
30	.202
40	.203
50	.204
60	.205
70	.206
80	.207
90	.208
100	.210
110	.211
120	.212
130	.213
140	.214
150	.215
160	.216
170	.217
180	.218
190	.220
200	.221
210	.222

12.19 LIQUID THERMAL CONDUCTIVITY

Temperature (degrees F)	British thermal unit-inch per hour-square foot-F
	NOT PERTINENT

12.20 LIQUID VISCOSITY

Temperature (degrees F)	Centipoise
55	.958
60	.929
65	.900
70	.873
75	.848
80	.823
85	.800
90	.777
95	.756
100	.736
105	.716
110	.698
115	.680
120	.663
125	.647
130	.631
135	.616
140	.601
145	.588
150	.574
155	.561
160	.549
165	.537
170	.526
175	.515

12.21 SOLUBILITY IN WATER

Temperature (degrees F)	Pounds per 100 pounds of water
68.02	.016

12.22 SATURATED VAPOR PRESSURE

Temperature (degrees F)	Pounds per square inch
60	.236
70	.318
80	.425
90	.561
100	.732
110	.948
120	1.217
130	1.548
140	1.953
150	2.446
160	3.042
170	3.756
180	4.607
190	5.616
200	6.805
210	8.199
220	9.824
230	11.710
240	13.890
250	16.390
260	19.260
270	22.520
280	26.230

12.23 SATURATED VAPOR DENSITY

Temperature (degrees F)	Pounds per cubic foot
60	.00702
70	.00929
80	.01216
90	.01575
100	.02022
110	.02571
120	.03242
130	.04055
140	.05032
150	.06199
160	.07583
170	.09215
180	.11130
190	.13360
200	.15940
210	.18910
220	.22330
230	.26230
240	.30660
250	.35680
260	.41330
270	.47680
280	.54790

12.24 IDEAL GAS HEAT CAPACITY

Temperature (degrees F)	British thermal unit per pound-F
0	.108
25	.110
50	.113
75	.116
100	.118
125	.120
150	.122
175	.125
200	.127
225	.129
250	.131
275	.132
300	.134
325	.136
350	.138
375	.139
400	.141
425	.142
450	.143
475	.144
500	.146
525	.147
550	.148
575	.148
600	.149

TRICHLOROETHANE

TCE

Common Synonyms

1,1,1-Trichloroethane
Methylchloroform
Aerothene
Chlorothene

Watery liquid | Colorless | Sweet odor

Sinks in water. Irritating vapor is produced.

Stop discharge if possible. Keep people away.
Avoid contact with liquid and vapor.
Call fire department.
Isolate and remove discharged material.
Notify local health and pollution control agencies.

Fire

Combustible.
POISONOUS GASES ARE PRODUCED IN FIRE.
Wear goggles and self-contained breathing apparatus.
Extinguish with dry chemical, carbon dioxide, or foam.

Exposure

CALL FOR MEDICAL AID.

VAPOR
Irritating to eyes, nose and throat.
If inhaled, will cause dizziness or difficult breathing.
Move to fresh air.
If breathing has stopped, give artificial respiration.
If breathing is difficult, give oxygen.

LIQUID
Irritating to skin and eyes.
If swallowed, may produce nausea.
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

Effect of low concentrations on aquatic life is unknown.
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)

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:** Halogenated hydrocarbon
3.2 **Formula:** CH_3CCl_3
3.3 **IMO/UN Designation:** Not listed
3.4 **DOT ID No.:** 2831
3.5 **CAS Registry No.:** 71-55-6

4. OBSERVABLE CHARACTERISTICS

4.1 **Physical State (as shipped):** Liquid
4.2 **Color:** Colorless
4.3 **Odor:** Chloroform-like; sweetish

5. HEALTH HAZARDS

5.1 **Personal Protective Equipment:** Organic vapor-acid gas canister; self-contained breathing apparatus for emergencies; neoprene or polyvinyl-alcohol-type gloves; chemical safety goggles and face shield; neoprene safety shoes (or leather safety shoes plus neoprene footwear); neoprene or polyvinyl alcohol suit or apron for splash protection.

5.2 **Symptoms Following Exposure:** INHALATION: symptoms range from loss of equilibrium and incoordination to loss of consciousness; high concentration can be fatal due to simple asphyxiation combined with loss of consciousness. INGESTION: produces effects similar to inhalation and may cause some feeling of nausea. EYES: slightly irritating and lachrymatory. SKIN: defatting action may cause dermatitis.

5.3 **Treatment of Exposure:** Get medical attention for all eye exposures and any other serious overexposures. Do NOT administer adrenalin or epinephrine; otherwise, treatment is symptomatic. INHALATION: remove victim to fresh air; if necessary, apply artificial respiration and/or administer oxygen. INGESTION: have victim drink water and induce vomiting. EYES: flush thoroughly with water. SKIN: remove contaminated clothing and wash exposed area thoroughly with soap and warm water.

5.4 **Threshold Limit Value:** 350 ppm
5.5 **Short Term Inhalation Limits:** 1,000 ppm for 60 min. in man
5.6 **Toxicity by Ingestion:** Grade 1; LD_{50} = 5 to 15 g/kg (rat, mouse, rabbit, guinea pig)
5.7 **Late Toxicity:** Data not available
5.8 **Vapor (Gas) Irritant Characteristics:** Vapors cause a slight smarting of the eyes or respiratory system if present in high concentrations. The effect is temporary.
5.9 **Liquid or Solid Irritant Characteristics:** Minimum hazard. If spilled on clothing and allowed to remain, may cause smarting and reddening of the skin.
5.10 **Odor Threshold:** 100 ppm
5.11 **IDLH Value:** 1,000 ppm

6. FIRE HAZARDS

6.1 **Flash Point:** Data not available
6.2 **Flammable Limits in Air:** 7%-16%
6.3 **Fire Extinguishing Agents:** Dry chemical, foam, or carbon dioxide
6.4 **Fire Extinguishing Agents Not to be Used:** Not pertinent
6.5 **Special Hazards of Combustion Products:** Toxic and irritating gases are generated in fires.
6.6 **Behavior in Fire:** Not pertinent
6.7 **Ignition Temperature:** 932°F
6.8 **Electrical Hazard:** Not pertinent
6.9 **Burning Rate:** (est.) 2.9 mm/min.
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:** Reacts slowly, releasing corrosive hydrochloric acid.
7.2 **Reactivity with Common Materials:** Corrodes aluminum, but reaction is not hazardous.
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:** 36

8. WATER POLLUTION

8.1 **Aquatic Toxicity:**
75-150 ppm/*/pinfish/TL_m/salt water
*Time period not specified.
8.2 **Waterfowl Toxicity:** Data not available
8.3 **Biological Oxygen Demand (BOD):** Data not available
8.4 **Food Chain Concentration Potential:** None

9. SHIPPING INFORMATION

9.1 **Grades of Purity:** Uninhibited; inhibited; industrial inhibited; white room; cold cleaning
9.2 **Storage Temperature:** Ambient
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:** ORM-A
11.2 **NAS Hazard Rating for Bulk Water Transportation:**

Category	**Rating**
Fire	1
Health	
Vapor Irritant	1
Liquid or Solid Irritant	1
Poisons	2
Water Pollution	
Human Toxicity	1
Aquatic Toxicity	3
Aesthetic Effect	2
Reactivity	
Other Chemicals	1
Water	0
Self Reaction	0

11.3 **NFPA Hazard Classification:**

Category	**Classification**
Health Hazard (Blue)	2
Flammability (Red)	1
Reactivity (Yellow)	0

12. PHYSICAL AND CHEMICAL PROPERTIES

12.1 **Physical State at 15°C and 1 atm:** Liquid
12.2 **Molecular Weight:** 133.41
12.3 **Boiling Point at 1 atm:** 165°F = 74°C = 347°K
12.4 **Freezing Point:** <−38°F = <−39°C = <234°K
12.5 **Critical Temperature:** Not pertinent
12.6 **Critical Pressure:** Not pertinent
12.7 **Specific Gravity:** 1.31 at 20°C (liquid)
12.8 **Liquid Surface Tension:** 25.4 dynes/cm = 0.0254 N/m at 20°C
12.9 **Liquid Water Interfacial Tension:** (est.) 45 dynes/cm = 0.045 N/m at 20°C
12.10 **Vapor (Gas) Specific Gravity:** 4.6
12.11 **Ratio of Specific Heats of Vapor (Gas):** 1.104
12.12 **Latent Heat of Vaporization:** 100 Btu/lb = 56 cal/g = 2.4×10^5 J/kg
12.13 **Heat of Combustion:** (est.) 4700 Btu/lb = 2600 cal/g = 110×10^5 J/kg
12.14 **Heat of Decomposition:** Not pertinent
12.15 **Heat of Solution:** Not pertinent
12.16 **Heat of Polymerization:** Not pertinent
12.25 **Heat of Fusion:** Data not available
12.26 **Limiting Value:** Data not available
12.27 **Reid Vapor Pressure:** 4.0 psia

NOTES

[illegible]

[illegible]

SUBSTANCE: NICKEL

TRADE NAME: [illegible] NI

DESCRIPTION: [illegible] metal, powder or cubic [illegible].

EXPOSURE LIMITS:
This substance is regulated by OSHA and/or ACGIH. See MSDS

FIRE AND EXPLOSION HAZARD:
No fire hazard in solid form; however, [illegible] in dust, powder, or [illegible] form. Never smoke when using this product or handle near an open flame or sparks. If it catches fire, do not try to stop the fire yourself. Seek the help of firefighting personnel. Containers may rupture when exposed to fire.
FOR SMALL FIRES: Use dry sand, graphite, [illegible] sodium chloride, [illegible] or appropriate metal extinguishing powder. Do not apply water to burning material.

HEALTH AND FIRST AID:
INHALATION:
SHORT TERM EFFECTS: May cause irritation. May cause allergic reactions. Additional effects may include coughing, fever, asthma and lung damage.
LONG TERM EFFECTS: In addition to effects from short term exposure, perforation of the nose, runny nose and lack of sense of smell may occur. May also cause cancer.
SKIN CONTACT:
SHORT TERM EFFECTS: May cause irritation. May cause allergic reactions. Additional effects may include redness and swelling of the eyes, redness and swelling of the mouth, redness and swelling of the gums, rash, itching, fever, asthma and lung damage.
LONG TERM EFFECTS: Same effects as short term exposure.
EYE CONTACT:
SHORT TERM EFFECTS: May cause irritation.
LONG TERM EFFECTS: No information is available.
INGESTION:
SHORT TERM EFFECTS: No information available on significant adverse effects.
LONG TERM EFFECTS: May cause reproductive effects.
FIRST AID: Remove from exposure area. If breathing has stopped, perform artificial respiration or CPR. Flush skin/eyes with water for 15 minutes. If vomiting occurs, keep head below hips to prevent aspiration. Get medical attention immediately. See MSDS for further recommendations.

REACTIVITY:
Stable under normal temperatures and [illegible]. [illegible] with [illegible], [illegible] and [illegible]. See MSDS for complete listing.

SPILL AND LEAK:
[illegible]

[illegible]

[illegible]

[illegible] protective equipment [illegible]

[illegible] PROTECTIVE EQUIPMENT [illegible]

[illegible] protective clothing [illegible]
may be needed when working in high or unknown concentrations. [illegible]
[illegible] recommendations [illegible]

Occupational Health Services, Inc.
For Emergency Source Information contact: (615) 366-2000

[illegible]

[illegible]

[illegible]

[illegible] state will depend on the [illegible]

EXPOSURE LIMITS:
This substance regulated by OSHA and/or ACGIH. See MSDS.

FIRE AND EXPLOSION HAZARDS:
[illegible] fire hazard. [illegible] open flame or sparks. If it catches fire, leave the area immediately. Do not try to put out the fire yourself. Seek the help of firefighting personnel.
FOR SMALL FIRES: Use dry chemical, carbon dioxide, water spray or regular foam.
FOR LARGE FIRES: Use water spray, fog or regular foam.

HEALTH AND FIRST AID:
INHALATION:
SHORT TERM EFFECTS: May cause sores, nose bleeds and suffocation.
LONG TERM EFFECTS: May cause lack of appetite, nausea, headache, weakness and dizziness.
SKIN CONTACT:
SHORT TERM EFFECTS: May cause suffocation.
LONG TERM EFFECTS: May cause rash, itching, lack of appetite, nausea, headache, weakness and dizziness.
EYE CONTACT:
SHORT TERM EFFECTS: May cause irritation. May cause effects as reported in short term inhalation. Additional effects may include suffocation.
LONG TERM EFFECTS: No information is available.
INGESTION:
SHORT TERM EFFECTS: May cause rash, drooling, nausea, vomiting, chest pain, gasping, irregular heartbeat, headache, weakness, dizziness, giddiness, confusion, anxiety, excitation, muscle spasm, blurred vision, bluish skin color, lung congestion, paralysis, convulsions, unconsciousness and death.
LONG TERM EFFECTS: In addition to effects from short term exposure, lack of appetite [illegible]
FIRST AID: Remove from exposure area. If breathing has stopped, perform artificial respiration or CPR. Flush skin/eyes with water for 15 minutes. If vomiting occurs, keep head below hips to prevent aspiration. Get medical attention immediately. See MSDS for further recommendations.

REACTIVITY:
[illegible] hazard. May react dangerously with oxidizers, acids and other chemicals. See MSDS for complete listing.

SPILL AND LEAK:
Do not touch spilled material. Stop leak if you can do it without risk [illegible]

[illegible]

[illegible]

[illegible] unnecessary people away. [illegible]

[illegible]

[illegible] NIOSH recommendations [illegible]

Occupational Health Services, Inc.
For Emergency Source Information Contact: [illegible]

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[illegible]
[illegible]

SUBSTANCE: ASBESTOS

CAS#: 1332-21-4   RTECS#: [illegible]

DESCRIPTION: Fibers or filaments which may be white, gray, green, brown, or yellow in color.

EXPOSURE LIMITS:
This substance regulated by OSHA under 29 CFR 1910.1001.

FIRE AND EXPLOSION HAZARDS:
No fire hazard. In case of surrounding fire [illegible] (seek the help of firefighting personnel).
FOR SMALL FIRES: Use dry chemical, carbon dioxide, water spray or regular foam.
FOR LARGE FIRES: Use water spray, fog or regular foam.

HEALTH AND FIRST AID:
INHALATION:
SHORT TERM EFFECTS: May cause irritation. Additional effects may include coughing and chest pain.
LONG TERM EFFECTS: In addition to effects from short term exposure, fever, lack of appetite, weight loss, difficulty breathing, weakness, bluish skin color, lung effects and heart failure may occur. May also cause cancer.
SKIN CONTACT:
SHORT TERM EFFECTS: May cause irritation.
LONG TERM EFFECTS: Same effects as short term exposure.
EYE CONTACT:
SHORT TERM EFFECTS: May cause irritation.
LONG TERM EFFECTS: Same effects as short term exposure.
INGESTION:
SHORT TERM EFFECTS: May cause gastrointestinal irritation. Additional effects may include digestive disorders.
LONG TERM EFFECTS: No information available on significant adverse effects.
FIRST AID: Remove from exposure area. If breathing has stopped, perform artificial respiration or CPR. Flush skin/eyes with water for 15 minutes. If vomiting occurs, keep head below hips to prevent aspiration. Get medical attention immediately. See MSDS for further recommendations.

REACTIVITY:
Stable under normal conditions. See MSDS for complete listing of incompatible substances.

SPILL AND LEAKS:
Sweep up and place in suitable clean, dry containers for reclamation and later disposal. Do not flush spilled material into sewer. Keep unnecessary people away.

This material or its components, if spilled, may be reportable under CERCLA [illegible] 304. See MSDS for specific reportable quantities, if applicable.

[illegible]

SAFETY EQUIP. AND PROCEDURES (R-1)

You should wear protective clothing, gloves and safety goggles. A respirator may be needed when working in field or unknown concentrations. See NIOSH or OSHA/NIOSH recommendations. If an accident occurs, contact safety personnel.

Occupational Health Services, Inc.
For Emergency Source Information Contact: 1-615-366-2000

5.0 SITE CONTROL

5.1 ZONATION

The general zonation protocols that should be employed at hazardous waste sites are described in Appendix G. The site-specific zonation that will be used for this project is described as follows:

Exclusion Zone: area within a 15-foot radius of each drilling/sampling location during drilling or sampling (when a borehole or well is open).

Contaminant Reduction Zone: area beyond the 15-foot exclusion zone at each drilling/sampling location where equipment and personnel decontamination will occur, not to occur beyond 50-feet in any area from the drilling/sampling locations.

Support Zone: all areas beyond the contaminant reduction zone.

5.2 COMMUNICATIONS

When radio communication is not used, the following air horn signals will be employed:

HELP	EVACUATION	ALL CLEAR
Three Short Blasts (. . .)	Three Long Blasts (_ _)	Alternating Long and Short Blasts (_ . _ .)

5.3 WORK PRACTICES

General work practices to be used during ABB Environmental projects are described in Appendix H. Specific work practices necessary for this project or those that are of significant concern are described as follows:

All ABB-ES personnel, subcontractors, or third party representatives should be aware of the previously detected presence of mercury. These personnel should also be aware of the potential for the contaminants to exist in airborne form.

6.0 DECONTAMINATION/DISPOSAL

All personnel and/or equipment leaving contaminated areas of the site will be subject to decontamination, which will take place in the contamination reduction zone.

6.1 PERSONNEL DECONTAMINATION

Decontamination procedures are followed by all personnel leaving hazardous waste sites. Under no circumstances (except emergency evacuation) will personnel be allowed to leave the exclusion and contaminant reduction zones prior to decontamination. A typical personnel decontamination station is shown in Appendix L, Figure L-1. Generalized procedures for removal of protective clothing are as follows:

1. Drop tools, monitors, samples, and trash at designated drop stations (i.e., plastic containers or drop sheets).

2. Step into the designated shuffle pit area and scuff feet to remove gross amounts of dirt from outer boots.

3. Scrub outer boots and outer gloves with decon solution or detergent and water. Rinse with water.

4. Remove tape from outer boots and remove boots; discard tape and boots in disposal container.

5. Remove tape from outer gloves and remove gloves; discard tape and gloves in disposal container.

6. If the worker has left the Exclusion Zone to change the air tank on the SCBA or the canister on the air-purifying respirator, this will be the last step in the decontamination procedure. The tank or cartridge should be exchanged, new outer gloves and boot covers donned, and the joints taped; the worker then returns to duty.

7. Remove outer garments and discard in disposal container.

8. Remove respirator and place or hang in the designated area.

9. Remove inner gloves and discard in disposal container.

10. If the site requires use of a decontamination trailer, all personnel must shower before leaving the site at the end of the work day.

NOTE: Disposable items (i.e., Tyvek coveralls, inner gloves, and latex overboots) will be changed daily unless there is reason to change sooner. Dual respirator canisters will be changed daily, unless more frequent changes are deemed appropriate by site surveillance data or personnel assessment.

Maximum and minimum decontamination layouts for PPE Levels A through C are shown in Figures L-2 through L-6.

Pressurized sprayers or other designated equipment will be available in the decontamination area for washdown and cleaning of personnel, samples, and equipment.

Respirators will be decontaminated daily and taken from the drop area. The masks will be disassembled, the cartridges set aside, and all other parts placed in a cleansing solution. Parts will be pre-coded (e.g., #1 on all parts of Mask #1). After an appropriate time in the solution, the parts will be removed and rinsed with tap water. Old cartridges will be marked to indicate length of use (i.e., if it is possible to evaluate the remaining utility of the cartridge), or discarded in the contaminated trash container for disposal. In the morning, the masks will be reassembled and new cartridges installed, if appropriate. Personnel will inspect their own masks and readjust the straps for proper fit.

6.2 SMALL EQUIPMENT DECONTAMINATION

Small equipment will be protected from contamination as much as possible by draping, masking, or otherwise covering the instruments with plastic (to the extent feasible), without hindering operation of the unit. For example, the PI meter can be placed in a clear plastic bag to allow for reading the scale and operating the knobs. The PI meter can be partially wrapped, keeping the sensor tip and discharge port clear.

The contaminated equipment will be taken from the drop area and the protective coverings will be removed and disposed of in appropriate containers. Any dirt or obvious contamination will be brushed or wiped with a disposable paper wipe. The units can then be taken inside in a clean plastic tub, wiped off with damp disposable wipes, and dried. The units will be checked, standardized, and recharged as necessary for the next day's operation, and then prepared with new protective coverings.

6.3 HEAVY EQUIPMENT DECONTAMINATION

It is anticipated that drilling rigs and backhoes will become contaminated during borehole and test-pitting activities. They will be cleaned with high-pressure water or steam, followed by a soap and water wash and rinse. Loose material will be removed with a brush. The person performing this activity will usually be at least at the level of protection used during the personnel and monitoring equipment decontamination.

6.4 DISPOSAL OF DECONTAMINATED MATERIALS

All protective gear, decontamination fluids (for both personnel and equipment), and other disposable materials will be disposed of at each site.

Decontamination fluids identified to be contaminated by site contaminants (i.e., Liqui-nox, used to decontaminate sampling equipment such as split spoons and groundwater sampling pumps) will be stored in DOT-approved 55-gallon drums. Contaminated disposable materials (e.g., gloves and Tyveks) will be double-bagged and stored as is, or placed in DOT-approved 55-gallon drums.

7.0 EMERGENCY/CONTINGENCY PLAN

This section identifies the emergency contingency plan that has been developed for operations at this site. Other sections provide further information to be used under emergency conditions. Refer to Appendix D for emergency telephone numbers, routes to emergency medical facilities, and emergency signals.

7.1 PERSONNEL ROLES, LINES OF AUTHORITY, AND COMMUNICATION

The site HSO is the primary authority for directing operations under emergency conditions. All communications both on- and off-site will be directed through the HSO. Should the HSO be injured, the Health and Safety Designee (HSD) will assume HSO responsibilities. These responsibilities include:

- Investigate all accidents, illnesses, and incidents occurring on an assigned site and report the findings to the HSM or HSS.
- Assume the role of on-site coordinator during emergency response activities.
- Accompany all USEPA, OSHA, and other government agency, and client personnel visiting an assigned site in response to health and safety issues.
- The HSO or HSD will immediately notify the HSM after a stop work order is executed. Authorization to resume work, after such a stoppage, will only be issued by the HSO after consultation and approval from the HSM or HSS.

7.2 EVACUATION

7.2.1 Withdrawal Upwind

The work party will continually note general wind directions while on-site. (A windsock may be set up near the work site for visual determinations.) When conditions warrant moving away from the work site, the crew will relocate upwind a distance of approximately 100 feet or farther, as indicated by site monitoring instruments. Donning an SCBA and a safety harness and line, the HSO and a member of the crew (the buddy system must be used) may return to the work site to determine if the condition noted was transient or persistent. If persistent, an alarm should be activated to notify on-site personnel of the situation and the need to leave the site or don an SCBA. An attempt to decrease emissions should be made only if greater respiratory protection is donned. The HSS and client will be notified of conditions. When site access is restricted, thus hindering escape, the crew may be instructed to evacuate the site rather than move upwind, especially if withdrawal upwind moves the crew away from escape routes.

7.2.2 Site Evacuation

When conditions warrant site evacuation, the work party will proceed upwind of the work site and notify the HSO and field office of site conditions. If the decontamination area is upwind and greater than 500 feet from the work site, the crew will pass quickly through decontamination to remove contaminated outer suits. If the hazard is toxic gas, respirators will be retained. The crew will proceed to the field office to assess the situation. If instrumentation indicates an acceptable condition, respirators may be removed. As more information is received from the field crew, it will be relayed to the appropriate agencies. The advisability and type of further response action will be coordinated and carried out by the HSO.

7.2.3 Evacuation of Surrounding Area

When the HSO determines that conditions warrant evacuation of downwind residences and commercial operations, local agencies will be notified and assistance requested. Designated on-site personnel will initiate evacuation of the immediate off-site area without delay.

7.3 EMERGENCY MEDICAL TREATMENT/FIRST AID

Any personnel injured on-site will be rendered first aid as appropriate and transported to competent medical facilities for further examination and/or treatment. The preferred method of transport would be through professional emergency transportation means; however, when this is not readily available or would result in excessive delay, other transport will be authorized. Under no circumstances will injured persons transport themselves to a medical facility for emergency treatment.

8.0 ADMINISTRATION

8.1 PERSONNEL AUTHORIZED DOWNRANGE

Personnel authorized to participate in downrange activities at this site have been reviewed and certified for site operations by the PM/CM and the HSS. Certification involves the completion of appropriate training, a medical examination, and a review of this site-specific HASP. All persons entering the site must use the buddy system, and check in with the Field Team Leader and/or HSO before going downrange.

For each field activity, the HSO will complete the "Authorized Personnel" section of the "Task Analysis and Protective Measures" form.

8.2 MEDICAL DATA SHEET

The Medical Data Sheet will be completed by all on-site personnel and kept in the Support Zone during site operations. It is not a substitute for the Medical Surveillance Program requirements consistent with the ABB Environmental Corporate Health and Safety Program for Hazardous Waste Sites. This data sheet will accompany any personnel when medical assistance or transport to hospital facilities is required. If more space is required, use the back of this sheet.

MEDICAL DATA SHEET

Task/Activity:

Name:

Address:

Home Telephone: Area Code ( )

Age: Height: Weight:

In Case of Emergency contact:

Address:

Telephone: Area Code ( )

Do you wear contact lenses: Yes ( ) No ( )

Allergies:

List medication(s) taken regularly:

Particular sensitivities:

Previous/current medical conditions or exposures to hazardous chemicals:

Name of Personal Physician:

Telephone: Area Code ( )

8.3 EMERGENCY TELEPHONE NUMBERS

Police Department	911
Rescue Service	911
Primary Hospital	(716) 464-2130
Alternate Hospital	(716) 275-2100
Fire Department	911
Off-site Emergency Services	911
Poison Control Center	(800) 962-1253
National Response Center	(800) 424-8802
NYSDEC Spill Reporting Hotline	(800) 457-7362
Project Manager: Geoff Knight	(716) 424-4700
Construction Manager: Rick Day	(207) 828-3441
Program Manager: Lisa Spahr	(207) 828-3553
ABB Environmental HSM: C.E. Sundquist	(800) 848-2697 x3309
ABB Kent-Taylor: Bob Halton	(716) 273-6201
Site Security (Ogden Security - Earl Barney)	(716) 546-3849

8.4 ROUTES TO EMERGENCY MEDICAL FACILITIES

The primary source of medical assistance for the site is:

St. Mary's Hospital, 89 Gennesee Street. See Figure 8-1.

DIRECTIONS TO ST. MARY'S:

Left on West Avenue from Hague Street.
Follow West Avenue to Intersection of West Avenue and Chili/West Main Street.
Hospital is located on the south side of this intersection.

The alternate source of medical assistance for the site is:

Strong Memorial Hospital, Elmwood Avenue. See Figure 8-2.

DIRECTIONS TO STRONG MEMORIAL:

Right on West Avenue from Hague Street.
Follow West Ave. 8 blocks to Thurston Road, turn left.
Follow Thurston to Chili Avenue, turn right.
Follow Chili to the 390 South.
390 South Approximately 3 miles to the 15 North (South Avenue/Mt. Hope Avenue)
Approximately 1/4 mile to Crittenden Road, turn right.
Hospital 1/10 mile on right side.

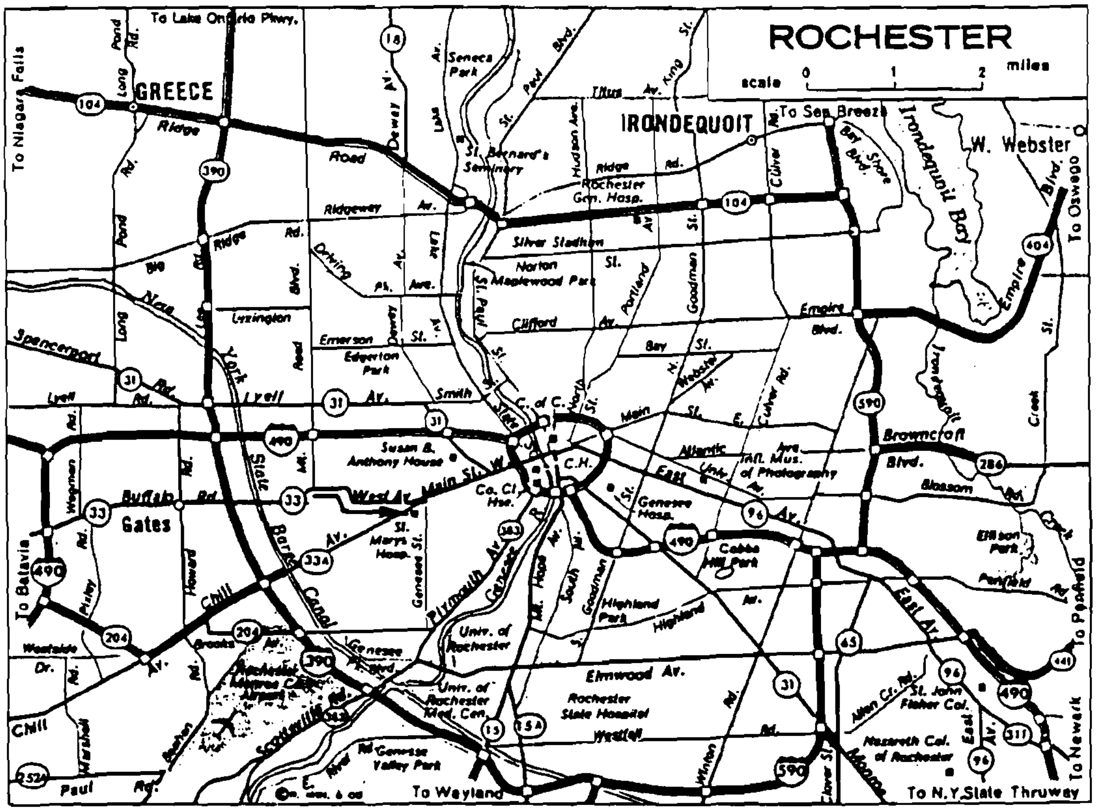

FIGURE 8-1
PRIMARY
HOSPITAL ROUTE MAP
AMES STREET FACILITY
ROCHESTER, NEW YORK

ABB Environmental Services, Inc.

7198-00

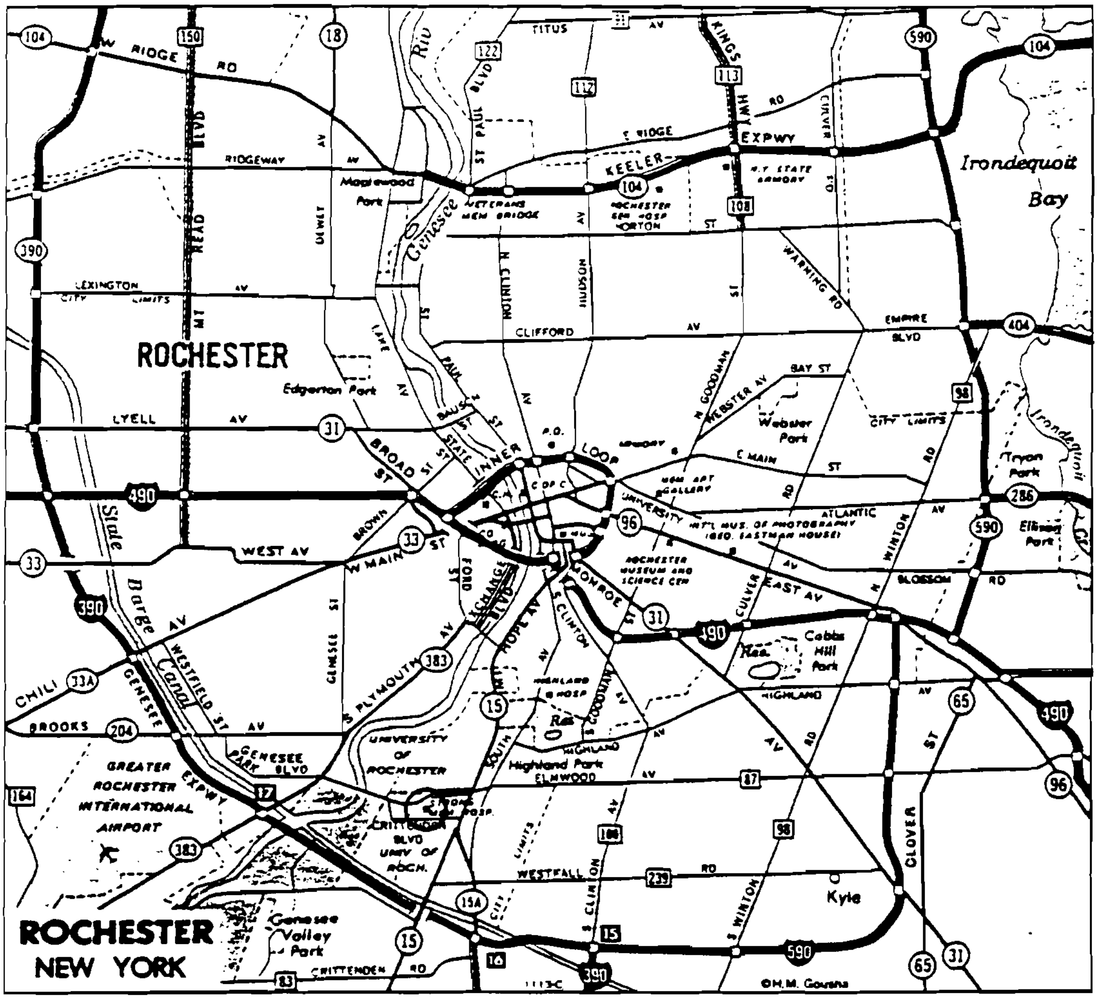

FIGURE 8-2
SECONDARY
HOSPITAL ROUTE MAP
AMES STREET FACILITY
ROCHESTER, NEW YORK

8.5 HASP APPROVALS

By their signatures, the undersigned certify that this HASP will be used for the protection of the health and safety of all persons entering this site.

Health and Safety Officer	Date
Project Manager	Date
Health and Safety Manager/Supervisor	Date

ATTACHMENT A

VISITOR LOG AND SAFETY INFORMATION

VISITOR LOG AND SIGNATURE FORM
AMES STREET SITE

NOTICE: The purpose of this form is to ensure that visitors to the Ames Street property are aware that construction and other activities are taking place and as a result, health and safety hazards potentially exist at the site. The primary methods used to inform visitors of potential hazards are: 1) each visitor must review the *Safety Information and Procedures for Visitors to the Ames Street Site* and, 2) a Combustion Engineering representative or contractor familiar with the site and potential hazards will deliver a short safety briefing prior to your entering the site. To ensure this is done for your visit, please complete this form and return it to your escort.

General Information

Name: ________________________________

Affiliation: ________________________________

Date(s) of visit: ________________________________

Purpose of visit: ________________________________

Site area(s) to be visited: ________________________________
Planned activities: ________________________________

Escort's name:

Additional Hazard Information

Nature/locations of active operations:

Summary of other potential hazards not discussed in *Safety Information and Procedures:*

"I have read and understand the Safety Information and Procedures for Visitors to the Ames Street Site, and have been briefed by a Combustion Engineering representative on potential health and safety hazards. During my visit I agree to abide by the Safety Procedures and will follow direction provided by my escort".

Signature: Date:

SAFETY INFORMATION AND PROCEDURES FOR VISITORS TO THE AMES STREET SITE

(Page 1 of 2)

Welcome to the Ames Street Site. You must be aware that this site may contain potential health and safety hazards related to general site conditions, construction activities, or chemicals. The information and procedures provided herein are designed to ensure your visit to the site is a safe one.

Potential Health and Safety Hazards:

1. This is a closed facility, and most ground floor windows and doors have been permanently boarded up. Entrance and exit to the buildings is possible only at those locations shown on the attached site plan.

2. Utilities have been shut off throughout most of the buildings; many areas or rooms are either dimly lit, or completely dark. Electricity, water and phones are generally available only at the field trailer area shown on the attached site plan.

3. The combination of dim or absent lighting and the potential presence of equipment, demolition or other debris, snow, ice, or water, may lead to a significant "slip, trip and fall" hazard in some areas. These areas may or may not be marked with caution tape or other devices.

4. Hazardous materials such as asbestos, mercury, petroleum solvents and other chemicals may be present. These areas may or may not be marked with caution tape or other devices.

5. Ongoing activities such as building demolition or environmental sampling may present hazards due to motorized equipment, noise, chemical use, or other factors. Active work areas may or may not be marked with caution tape or other devices.

Safety Procedures

The following must be observed by all visitors to the Ames Street site.

1. Personal protective equipment is required when entering or touring the site for any reason:

   - hard hat
   - suitable footwear (no open-toed shoes, no sneakers or tennis shoes; steel-toed shoes are preferred)

   Based on your specific activity while at the site, other safety equipment may be required.

2. Before entering the site, you must be briefed by a Combustion Engineering representative or contractor on the hazards specific to the areas you will visit or your planned activities. The briefing will include a description of hazards in the areas you will visit; review of Material Safety Data Sheets (MSDSs) for chemicals of concern; a discussion of current activities occurring on the site; and instructions on how to avoid potential health and safety hazards. **It is critical that you pay close attention to the information and instructions provided during this briefing**. The individual providing the briefing will be happy to respond to any questions or concerns you may have.

SAFETY INFORMATION AND PROCEDURES FOR VISITORS TO THE AMES STREET SITE

(Page 2 of 2)

Safety Procedures (cont'd)

3. Each visitor or group will be provided with an escort who is familiar with the site and potential hazards. **Visitors must remain within the escort's sight and follow his/her instructions at all times, unless specifically authorized otherwise.** Do not enter any room or area of the site or otherwise move about on your own unless authorized to do so.

4. Do not approach or interfere with site operations or the persons engaged in them (including talking) **for any reason**, unless specifically authorized to do so by your escort. Doing so may pose a hazard to you, or them.

5. In the event you encounter what appears to be an abnormal or dangerous situation, report it immediately to your escort or other Combustion Engineering representative or contractor. Do not attempt to take corrective action on your own.

6. Do not operate or attempt to operate any equipment or machinery of any type.

7. Do not handle or attempt to handle chemicals or potentially hazardous materials of any type, or handle building materials or other substances from areas which your escort indicates may contain hazardous materials.

8. Smoking, eating and drinking are permitted only in the vicinity of the field trailers.

9. Small children or pets are not allowed on the site.

ATTACHMENT B

TASK ANALYSIS AND PROTECTIVE MEASURES

TASK ANALYSIS

ABB ENVIRONMENTAL SERVICES, INC.
AMES STREET SITE

NOTE: *Review Ames Street Facility HASP before completing this form.*

GENERAL TASK INFORMATION

Task Title:____PAN number:__________

FOL (name):____________________HSO (name):____________________

Form prepared by:____Date:__________

HSS Approval:____Date:__________

PM Approval:____Date:__________

Planned activity(s):

Overall Task Category (from HASP):____

Other concurrent site activities/tasks:

Activity/task:____Task Category:____

Activity/task:____Task Category:____

Activity/task:____Task Category:____

Will these activities/tasks impact this task? (describe):

UTHORIZED PERSONNEL:

____________________________ ____________________________

____________________________ ____________________________

____________________________ ____________________________

* Current First-aid Certification + Current CPR Certification

of General Information. For each of this task's activities, complete a separate "Activity Analysis" form.

ACTIVITY ANALYSIS
(Page 1)

tivity:____

iown or suspected chemical/material hazards (list):________________________________

____

iemical/material location(s) (circle): Surface soil Subsurface soil Groundwater Building Materials

Other (list):____

imary exposure route(s) (circle): Dermal Inhalation Ingestion Puncture

fety hazard(s) (circle): Height Equipment Cold Stress Noise Eye Overhead Confined Spaces Heat Stress Machinery Burns Lifting Slips/Falls

ier (list):____

erall Hazard Estimation: Serious Moderate Low None Unknown

GINEERING CONTROLS SELECTED (specify):

Level of Personal Protection:___

:artridge Respirator
:artridge Type:____
Iard Hat
afety Boots/Shoes
iemical Resistant Boots
sposable Boot Covers

Face Shield
Safety Glasses
Ear Protection

Gloves
- inner
- outer

Coveralls
Tyveks
- regular
- coated

ACTIVITY ANALYSIS
(Page 2)

Monitoring Equipment (circle):

Combustible Gas/Oxygen Meter   Explosimeter   PID   FID

Jerome Mercury Vapor Analyzer

ther (list):________   Draeger Tubes (specify type):________

ergency Equipment (circle):   First Aid Kit   Fire Extinguisher   Eye Wash

(list):________

nant levels for modifying protective equipment: Refer to HASP Section 3.1

nation:

and/or equipment leaving contaminated sites are subject to decontamination. Under no (except emergency evacuation) will personnel be allowed to leave the site prior to decontamination. nation procedures to be used at the site are as follows:

ste is to be placed into plastic bags and then into D.O.T. drums located:

edures not covered above:

FIELD TEAM REVIEW

reviewed the health and safety information in the HASP and task analyses. I
nd the information and will comply with their requirements.

Name:__________________ Date:__________________

lame:__________________ Date:__________________

e:__________________ Date:__________________

__________________ Date:__________________

__________________ Date:__________________

__________________ Date:__________________

FINAL

SITE INVESTIGATION WORK PLAN
PHASE I

APPENDICES H, I AND J

AMES STREET SITE
ROCHESTER, NEW YORK

Prepared by:

ABB Environmental Services, Inc.
Rochester, New York

February 1996

ABB Environmental Services, Inc.

ASEA BROWN BOVERI

APPENDIX H

BACKGROUND INFORMATION FOR INDUSTRIAL SOIL INGESTION SCREENING CONCENTRATION

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Region III
841 Chestnut Street
Philadelphia, Pennsylvania 19107

October 20, 1995

SUBJECT: Risk-Based Concentration Table, July - December 1995

FROM: Roy L. Smith, Ph.D.
Office of RCRA
Technical & Program Support Branch (3HW70)

TO: RBC Table mailing list

Attached is the EPA Region III risk-based concentration (RBC) table, which we distribute semi-annually to all interested parties.

IMPORTANT MESSAGE

EPA Region III has established a homepage on the World Wide Web which you can find at http://earth1.epa.gov:80/ or http://www.epa.gov/. Our homepage will soon include the RBC table in downloadable form. We strongly encourage all RBC table users having Internet access to obtain the table electronically rather than on paper. In this way, users can obtain the most current issue immediately in a form that can be used directly as input for risk assessment calculations. This distribution method will also save large amounts of paper and cost substantially less.

For those lacking Internet access, it's once again time to re-register to receive a paper copy of the RBC table. We need to hear from you periodically to ensure that you still have an interest and that we have your correct address. Please fax your registration request to Vanessa Sizer at 215-597-9890, including your name, address, and phone number. Please don't phone to re-register; we need hard copy to document your continued interest. If we don't hear from you by March 30, 1996, we'll assume you no longer need a paper copy. Thanks for your cooperation.

CONTENTS, USES, AND LIMITATIONS OF THE RBC TABLE

The table contains reference doses and carcinogenic potency slopes (obtained from IRIS through September 1, 1995, HEAST through May 1995, the EPA-NCEA Superfund Health Risk Technical Support Center, and other EPA sources) for nearly 600 chemicals. These toxicity constants have been combined with "standard" exposure scenarios to calculate RBCs--chemical concentrations corresponding to fixed levels of risk (*i.e.*, a hazard quotient of 1, or lifetime cancer risk of 10^{-6}, whichever occurs at a lower concentration) in water, air, fish tissue, and soil.

The RBC table also includes soil screening levels (SSLs) for protection of groundwater

ANSWERS TO FREQUENTLY ASKED QUESTIONS

To help you better understand the RBC table, here are answers to our most often-asked questions:

1. How can the age-adjusted inhalation factor (11.66) be less than either the inhalation rate for a child (12) or for an adult (20)?

Age-adjusted factors are not intake rates, but rather partial calculations which have different units than intake rates do. The fact that these partial calculations have values similar to intake rates is really coincidental, an artifact of the similar magnitude of years of exposure and time-averaged body weight.

2. Why does arsenic appear in the RBC table separately as a carcinogen and a non-carcinogen, while other contaminants do not?

Arsenic is double-entered to ensure that the risk assessor realizes that non-carcinogenic concerns are significant for arsenic. Otherwise, one might be tempted to accept a 1e-4 risk (37 ppm in residential soil), when the oral reference dose would be exceeded at 23 ppm.

Also, EPA has a little-known risk management policy for arsenic (dating from 1988) that suggests that arsenic-related cancer risks of up to 1e-3 can be accepted because the cancers are squamous cell carcinomas with a low mortality rate. Thus, noncarcinogenic RBCs represent an important limitation on acceptable arsenic concentrations.

3. Many contaminants have no inhaled reference dose or carcinogenic potency slope in IRIS, yet these numbers appear in the RBC table with IRIS given as the source. Where did the numbers come from?

Most inhaled reference doses and potency slopes in the RBC table are converted from reference concentrations and unit risk values which do appear in IRIS. These conversions assume 70-kg persons inhaling 20 m^3/d. For example, the inhalation unit risk for arsenic (4.3e-3 risk per $\mu g/m^3$) is divided by 20 m^3/d and multiplied by 70 kg times 1000 μg/mg, yielding a CPSi of 15.1 risk per mg/kg/d.

4. Why does the RBC table base soil RBCs for cadmium and manganese on reference doses that apply only to drinking water?

The RBC table's use of the drinking water RfDs for cadmium and manganese reflects (1) the limited space available in the already-crowded table, and (2) the intended use of the table as a screening tool rather than a source of cleanup levels (thereby making false positives acceptable). For a formal risk assessment, Region III would use the food RfDs for soil ingestion.

At this time, only two substances (as far as we know) have distinct oral RfDs for water and food--cadmium and manganese. Adding the two food RfDs to the table would require an entire column, which would be about 99.9% blank. The table has become so crowded that it would be difficult to accommodate another column. Also, we given this problem a relatively low reference dose or potency slope for inorganic lead, so it wasn't possible to calculate risk-based concentrations. EPA considers lead a special case because:

(1) Lead is ubiquitous in all media, so human exposure comes from multiple sources. Comparing single-medium exposures with a reference dose would be misleading.

(2) If EPA did develop a reference dose for lead by the same methods other reference doses, we would probably find that most people already exceed it. Since EPA already knows this and is moving aggressively to lower lead releases nationally, such findings at individual sites would be irrelevant and unduly alarming.

(3) EPA decided to take a new approach to separate important lead exposures from trivial ones. EPA developed a computer model (the IEUBK model) which predicts children's blood lead concentrations using lead levels in various media as inputs. The idea is to evaluate a child's entire environment, and reduce lead exposures in the most cost-effective way.

On the practical side, there are several EPA policies which effectively substitute for RBCs. The EPA Office of Solid Waste has released a detailed directive on risk assessment and cleanup of residential soil lead. The directive recommends that soil lead levels less than 400 ppm be considered safe for residential use. Above that level, the document suggests collecting certain types of data and modeling children's blood lead with the IEUBK model. For the purposes of the RBC table, the de facto residential soil number would be 400 mg/kg. For water, we suggest 15 ppb (from the national EPA Action Level), and for air, the National Ambient Air Quality Standard.

9. Where did the potency slopes for carcinogenic PAHs come from?

The source of the potency slopes for PAHs is "Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons", Final Draft, EPA Environmental Criteria and Assessment Office, Cincinnati, OH. It's available from NTIS as document number ECAO-CIN-842 (March, 1993). The slopes are expressed in terms of order-of-magnitude equivalence factors relating the compounds to benzo[a]pyrene; we have converted these TEQs to potency slopes to fit the format of the table.

10. May I please have a copy of the January 1991 RBC table?

We're sorry, but no. The RBC table doesn't represent regulation or guidance, so past issues should have no legal importance. Each time we update the table we destroy all obsolete copies, electronic and paper. We do this to ensure that only one set of RBCs, that based on current information, exists at any time.

11. I've noticed that some soil RBCs are 1 million parts per million. Since some of these substances are liquids, that's obviously ridiculous. What is that basis for these calculations?

A soil RBC of 1 million parts per million means that no amount of the contaminant in soil will cause a receptor to exceed the oral reference dose by incidental ingestion of soil. In

It has been NCEA's policy to deny requests for documentation of interim toxicity constants. Although Region 3 has sometimes provided this documentation on request, for the above-stated reasons we have no assurance that the documentation, or even the interim numbers, are current. We've decided to discontinue distributing information that may be misleading. If one of the "E"-coded contaminants is a major risk contributor at your site, we strongly suggest that you work with EPA to develop an up-to-date reference dose or slope factor.

CHANGES IN THIS ISSUE OF THE RBC TABLE

New or revised EPA toxicity constants are now marked with "**" before the contaminant name. This is to help users quickly pick out substances with new RBCs. Formerly these contaminants were printed in underlined boldface type that copied badly. A new basis code, "M" for MCL, has been added to the upper right corner of each page. This code denotes soil screening levels for groundwater protection that are based on EPA Maximum Contaminant Levels.

If you want to raise issues or get answers to questions about the RBC table, please call the Technical Support Help Line at 215-597-1116. The line has a voice mail system to take your calls if we're not available. We'll return your call as soon as we can. Please limit calls to RBC issues; if you have a question about applying RBCs to a site, please call the EPA Regional office handling the project. Thanks for your help and cooperation, and we hope the RBC table continues to be a useful resource.

Attachment

Exposure variables	**Value**	**Symbol**
Occupational:		
Exposure frequency (d/y):	250	EFo
Exposure duration (y):	25	EDo
Fraction of contaminated soil ingested (unitless)	0.5	FC

*: Contaminant-specific toxicological constants. The priority among sources of toxicological constants was as follows: (1) IRIS, (2) HEAST, (3) HEAST alternative method, (4) EPA-NCEA Superfund Health Risk Technical Support Center, (5) withdrawn from IRIS or HEAST, and (6) other EPA documents. Each source was used only if numbers from higher-priority sources were unavailable. The EPA Superfund Health Risk Technical Support Center, part of the EPA National Center for Environmental Assessment in Cincinnati, develops provisional RfDs and CPSs on request for contaminants not in IRIS or HEAST. These provisional values are labeled "E = EPA-NCEA provisional" in the table. It is possible they may be obsolete. If one of the "E" constants is important to a Superfund risk assessment, consider requesting, through a Regional risk assessor, a new provisional value.

Age-adjusted factors

Because contact rates with tap water, ambient air, and residential soil are different for children and adults, carcinogenic risks during the first 30 years of life were calculated using age-adjusted factors. These factors approximated the integrated exposure from birth until age 30 by combining contact rates, body weights, and exposure durations for two age groups - small children and adults. The age-adjusted factor for soil was obtained from RAGS IB; the others were developed by analogy.

Air inhalation

$$IFAadj \; \frac{m^3 \cdot y}{kg \cdot d} = \frac{EDc \cdot IRAc}{BWc} + \frac{(EDtot - EDc) \cdot IRAa}{BWa}$$

Tap water ingestion

$$IFWadj \; \frac{L \cdot y}{kg \cdot d} = \frac{EDc \cdot IRWc}{BWc} + \frac{(EDtot - EDc) \cdot IRWa}{BWa}$$

Soil ingestion

$$IFSadj \; \frac{mg \cdot y}{kg \cdot d} = \frac{EDc \cdot IRSc}{BWc} + \frac{(EDtot - EDc) \cdot IRSa}{BWa}$$

Residential water

Volatilization terms were calculated only for compounds with a mark in the "VOC" column. Compounds having a Henry's Law constant greater than 10^{-5} were considered volatile. The list may be incomplete, but is unlikely to include false positives. The equations and the volatilization factor (K, above) were obtained from RAGS IB. Oral potency slopes and reference doses were used for both oral and inhaled exposures for volatile compounds lacking inhalation values. Inhaled potency slopes were substituted for unavailable oral potency slopes only for volatile compounds; inhaled RfDs were substituted for unavailable

Commercial/industrial soil ingestion

RBCs were based on adult occupational exposure, including an assumption that only 50% of total soil ingestion is work-related.

Carcinogens

$$RBC\ \frac{mg}{kg} = \frac{TR \cdot BWa \cdot ATc}{EFo \cdot EDo \cdot \dfrac{IRSa}{10^6\ \frac{mg}{kg}} \cdot FC \cdot CPSo}$$

Non-carcinogens

$$RBC\ \frac{mg}{kg} = \frac{THQ \cdot RfDo \cdot BWa \cdot ATn}{EFo \cdot EDo \cdot \dfrac{IRSa}{10^6\ \frac{mg}{kg}} \cdot FC}$$

Residential soil ingestion

RBCs for carcinogens were based on combined childhood and adult exposure; RBCs for non-carcinogens were based on childhood exposure only.

Carcinogens

$$RBC\ \frac{mg}{kg} = \frac{TR \cdot ATc}{EFr \cdot \dfrac{IFSadj}{10^6\ \frac{mg}{kg}} \cdot CPSo}$$

Non-carcinogens

$$RBC\ \frac{mg}{kg} = \frac{THQ \cdot RfDo \cdot BWc \cdot ATn}{EFr \cdot EDc \cdot \dfrac{IRSc}{10^6\ \frac{mg}{kg}}}$$

Development of Soil Screening Levels

General

In December 1994 the EPA Office of Solid Waste and Emergency Response proposed Soil Screening Guidance (Document 9355.4-1, PB95-963530, EPA540/R-94/101, available through NTIS at 703-487-4650). This draft document provides (1) a framework in which soil screening levels are to be used, (2) a detailed methodology for calculating soil screening levels, and (3) soil screening levels for 107 substances.

Consistent with this new guidance, the risk-based concentration table now includes two columns of generic soil screening levels (SSLs). OSWER's 107 proposed soil screening levels have been added verbatim. In addition, the proposed SSL methodology has been used to calculate soil screening levels for more substances, which are also included in the consulting that document. The "unofficial" SSLs were developed under the following conditions:

Soil Screening Levels for Inhalation

Inhaled reference doses and potency slopes were used if available. If inhalation values were not available, oral RfDs and potency slopes were substituted. SSLs were calculated only for substances for which aqueous solubility, Koc, Henry's Law constant, and diffusivity in air were available. SSLs were calculated only for substances for which a volatilization factor could be calculated. This was done because OSWER's large proposed particulate emission factor rendered it pointless to estimate SSLs for particulate emissions alone. The final calculated SSL shown in the RBC table is the smaller of the risk-based SSL and the soil saturation concentration. All calculated SSLs were rounded to 2 significant figures.

The OSWER risk algorithms for inhalation were revised in order to be consistent with the rest of the RBC table. Only calculated SSLs were affected by this; SSLs proposed by OSWER are presented verbatim. Calculated SSLs for inhalation of carcinogens were based on an integrated lifetime exposure rather than adult exposure. SSLs for inhalation of noncarcinogens were based on adult exposure for 350 days per year rather than 365 days per year. The following algorithms were used to calculate inhalation SSLs:

Carcinogens

$$SSL\ \frac{mg}{kg} = \frac{TR \cdot ATc}{EFr \cdot IFAadj \cdot \left(\frac{1}{VF} + \frac{1}{PEF}\right) \cdot CPSi}$$

Non-carcinogens

$$SSL\ \frac{mg}{kg} = \frac{THQ \cdot BWa \cdot ATn \cdot RfDi}{EFr \cdot EDtot \cdot IRAa \cdot \left(\frac{1}{VF} + \frac{1}{PEF}\right)}$$

Soil Screening Levels for Groundwater Use

All algorithms were as proposed by OSWER. MCLs were used as target groundwater concentrations if available. If MCLs were unavailable the risk-based concentration in the "tap water" column of the RBC table was used as the target groundwater concentration. All SSLs for groundwater are based on a dilution-attenuation factor (DAF) of 10. Since these SSLs scale linearly with DAF, the SSLs for DAF=1 would be ten times lower. They were omitted to conserve space. All groundwater SSLs were rounded to 2 significant figures and capped at unity.

Sources: I=IRIS H=HEAST A=HEAST alternate W=Withdrawn from IRIS or HEAST
E=EPA-NCEA Regional Support provisional value O=Other EPA documents.

Basis: C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

Contaminant	CAS	RfDo mg/kg/d	RfDi mg/kg/d	CPSo kg·d/mg	CPSi kg·d/mg	VOC	Risk-Based Concentrations: Tap Water µg/L	Risk-Based Concentrations: Ambient Air µg/m3	Risk-Based Concentrations: Fish mg/kg	Risk-Based Concentrations: Soil Ingestion: Industrial mg/kg	Risk-Based Concentrations: Soil Ingestion: Residential mg/kg	Soil Screening Levels-Transfers from Soil to: Air mg/kg	Soil Screening Levels-Transfers from Soil to: Groundwater mg/kg
Arsine	7784421		1.43E-05 I				0.52 N	0.052 N					
Assure	76578148	9.00E-03 I					330 N	33 N	12 N	18000 N	700 N		
Asulam	3337711	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Atrazine	1912249	3.50E-02 I		2.22E-01 H			0.3 C	0.028 C	0.014 C	26 C	2.9 C		
Avermectin B1	65195553	4.00E-04 I					15 N	1.5 N	0.54 N	820 N	31 N		
Azobenzene	103333			1.10E-01 I	1.08E-01 I		0.61 C	0.058 C	0.029 C	52 C	5.8 C		
Barium and compounds	7440393	7.00E-02 I	1.43E-04 A				2600 N	0.52 N	95 N	140000 N	5500 N	350000 E	32 E
Baygon	114261	4.00E-03 I					150 N	15 N	5.4 N	8200 N	310 N		
Bayleton	43121433	3.00E-02 I					1100 N	110 N	41 N	61000 N	2300 N		
Baythroid	68359375	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Benefin	1861401	3.00E-01 I					11000 N	1100 N	410 N	610000 N	23000 N		
Benomyl	17804352	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Bentazon	25057890	2.50E-03 I					91 N	9.1 N	3.4 N	5100 N	200 N		
Benzaldehyde	100527	1.00E-01 I				☒	610 N	370 N	140 N	200000 N	7800 N		
Benzene	71432		1.71E-03 E	2.90E-02 I	2.90E-02 I	☒	0.36 C	0.22 C	0.11 C	200 C	22 C	0.5 E	0.02 E
Benzenethiol	108985	1.00E-05 H					0.37 N	0.037 N	0.014 N	20 N	0.78 N		
Benzidine	92875	3.00E-03 I		2.30E+02 I	2.35E+02 I		0.00029 C	0.00003 C	0.00001 C	0.025 C	0.0028 C	1.3 C	1.100E-06 C
Benzoic acid	65850	4.00E+00 I					150000 N	15000 N	5400 N	1E+06 N	310000 N	320 S	280 E
Benzotrichloride	98077			1.30E+01 I			0.0052 C	0.00048 C	0.00024 C	0.44 C	0.049 C	0.012 C	0.000073 C
Benzyl alcohol	100516	3.00E-01 H					11000 N	1100 N	410 N	610000 N	23000 N		
Benzyl chloride	100447			1.70E-01 I		☒	0.062 C	0.037 C	0.019 C	34 C	3.8 C	0.5 C	0.0003
Beryllium and compounds	7440417	5.00E-03 I		4.30E+00 I	8.40E+00 I		0.016 C	0.00075 C	0.00073 C	1.3 C	0.15 C	690 E	180 E
Bidrin	141662	1.00E-04 I					3.7 N	0.37 N	0.14 N	200 N	7.8 N		
Biphenthrin (Talstar)	82657043	1.50E-02 I					550 N	55 N	20 N	31000 N	1200 N		
1,1-Biphenyl	92524	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N	9000 S	110 N
Bis(2-chloroethyl)ether	111444			1.10E+00 I	1.16E+00 I	☒	0.0092 C	0.0054 C	0.0029 C	5.2 C	0.58 C	0.3 E	0.0003 E
Bis(2-chloroisopropyl)ether	39638329	4.00E-02 I		7.00E-02 H	3.50E-02 H	☒	0.26 C	0.18 C	0.045 C	82 C	9.1 C		
Bis(chloromethyl)ether	542881			2.20E+02 I	2.17E+02 I	☒	0.00005 C	0.00003 C	0.00001 C	0.026 C	0.0029 C	0.00004 C	1.000E-07 C
Bis(2-chloro-1-methylethyl)ether				7.00E-02 W	7.00E-02 W		0.96 C	0.089 C	0.045 C	82 C	9.1 C		
Bis(2-ethylhexyl)phthalate (DEHP)	117817	2.00E-02 I		1.40E-02 I			4.8 C	0.45 C	0.23 C	410 C	46 C	210 E	11 E
Bisphenol A	80057	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Boron (and borates)	7440428	9.00E-02 I	5.71E-03 H				3300 N	21 N	120 N	180000 N	7000 N		
Boron trifluoride	7637072		2.00E-04 H				7.3 N	0.73 N					
Bromodichloromethane	75274	2.00E-02 I		6.20E-02 I		☒	0.17 C	0.1 C	0.051 C	92 C	10 C	1800 E	0.3 E
Bromoethene	593602				1.10E-01 H	☒	0.096 C	0.057 C					
Bromoform (tribromomethane)	75252	2.00E-02 I		7.90E-03 I	3.85E-03 I	☒	2.4 C	1.6 C	0.4 C	720 C	81 C	46 E	0.5 E
Bromomethane	74839	1.40E-03 I	1.43E-03 I			☒	8.7 N	5.2 N	1.9 N	2900 N	110 N	2 E	0.1 E
4-Bromophenyl phenyl ether	101553	5.80E-02 O					2100 N	210 N	78 N	120000 N	4500 N		
Bromophos	2104963	5.00E-03 H					180 N	18 N	6.8 N	10000 N	390 N		

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Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level
S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations			Soil Ingestion		Soil Screening Levels-Transfers from Soil to:	
Contaminant	CAS	RfDo mg/kg/d	RfDi mg/kg/d	CPSo kg·d/mg	CPSi kg·d/mg	VOC	Tap Water µg/L	Ambient Air µg/m3	Fish mg/kg	Industrial mg/kg	Residential mg/kg	Air mg/kg	Groundwater mg/kg
Chlorodifluoromethane	75456		1.43e+01 I			☒	87000 N	52000 N					
Chloroethane	75003	4.00E-01 E	2.86E+00 I			☒	8600 N	10000 N	540 N	820000 N	31000 N	2600 S	33 N
2-Chloroethyl vinyl ether	110758	2.50E-02 O				☒	150 N	91 N	34 N	51000 N	2000 N		
Chloroform	67663	1.00E-02 I		6.10E-03 I	8.05E-02 I	☒	0.15 C	0.078 C	0.52 C	940 C	100 C	0.2 E	0.
Chloromethane	74873			1.30E-02 H	6.30E-03 H	☒	1.4 C	0.99 C	0.24 C	440 C	49 C	0.063 C	0.0066 C
4-Chloro-2,2-methylaniline hydrochloride	3165933			4.60E-01 H			0.15 C	0.014 C	0.0069 C	12 C	1.4 C		
4-Chloro-2-methylaniline	95692			5.80E-01 H			0.12 C	0.011 C	0.0054 C	9.9 C	1.1 C		
beta-Chloronaphthalene	91587	8.00E-02 I					2900 N	290 N	110 N	160000 N	6300 N	2.8 S	140 N
o-Chloronitrobenzene	88733			2.50E-02 H		☒	0.42 C	0.25 C	0.13 C	230 C	26 C		
p-Chloronitrobenzene	100005			1.80E-02 H		☒	0.59 C	0.35 C	0.18 C	320 C	35 C		
2-Chlorophenol	95578	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N	53000 E	2 E
2-Chloropropane	75296		2.86E-02 H			☒	170 N	100 N				22 N	0.64 N
Chlorothalonil	1897456	1.50E-02 I		1.10E-02 H			6.1 C	0.57 C	0.29 C	520 C	58 C		
o-Chlorotoluene	95498	2.00E-02 I				☒	120 N	73 N	27 N	41000 N	1600 N	1200 N	5.6 N
Chlorpropham	101213	2.00E-01 I					7300 N	730 N	270 N	410000 N	16000 N		
Chlorpyrifos	2921882	3.00E-03 I					110 N	11 N	4.1 N	6100 N	230 N		
Chlorpyrifos-methyl	5598130	1.00E-02 H					370 N	37 N	14 N	20000 N	780 N		
Chlorsulfuron	64902723	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Chlorthiophos	60238564	8.00E-04 H					29 N	2.9 N	1.1 N	1600 N	63 N		
Chromium III and compounds	16065831	1.00E+00 I	5.71E-07 W				37000 N	0.0021 N	1400 N	1E+06 N	78000 N		
Chromium VI and compounds	18540299	5.00E-03 I			4.20E+01 I		180 N	0.00015 C	6.8 N	10000 N	390 N	140 E	1
Coal tar	8001589				2.20E+00 W			0.0028 C					
Cobalt	7440484	6.00E-02 E					2200 N	220 N	81 N	120000 N	4700 N		
Coke Oven Emissions	8007452				2.17E+00 I			0.0029 C					
**Copper and compounds	7440508	4.00E-02 E					1500 N	150 N	54 N	82000 N	3100 N		
Crotonaldehyde	123739	1.00E-02 W		1.90E+00 H	1.90E+00 W		0.035 C	0.0033 C	0.0017 C	3 C	0.34 C		
Cumene	98828	4.00E-02 I	2.57E-03 H				1500 N	9.4 N	54 N	82000 N	3100 N	81 N	65 N
Cyanides:													
Barium cyanide	542621	1.00E-01 W					3700 N	370 N	140 N	200000 N	7800 N		
Calcium cyanide	592018	4.00E-02 I					1500 N	150 N	54 N	82000 N	3100 N		
Copper cyanide	544923	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Cyanazine	21725462	2.00E-03 H		8.40E-01 H			0.08 C	0.0075 C	0.0038 C	6.8 C	0.76 C		
Cyanogen	460195	4.00E-02 I					1500 N	150 N	54 N	82000 N	3100 N		
Cyanogen bromide	506683	9.00E-02 I					3300 N	330 N	120 N	180000 N	7000 N		
Cyanogen chloride	506774	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Free cyanide	57125	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Hydrogen cyanide	74908	2.00E-02 I	8.57E-04 I				730 N	3.1 N	27 N	41000 N	1600 N		
Potassium cyanide	151508	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Potassium silver cyanide	506616	2.00E-01 I					7300 N	730 N	270 N	410000 N	16000 N		

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Basis : C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
						V O C	Tap Water	Ambient Air	Fish	Soil Ingestion			
		RfDo	RfDi	CPSo	CPSi					Industrial	Residential	Air	Groundwater
Contaminant	CAS	mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg		µg/L	µg/m3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
4-(2,4-Dichlorophenoxy)butyric Acid	94826	8.00E-03 I					290 N	29 N	11 N	16000 N	630 N		
1,2-Dichloropropane	78875		1.14E-03 I	6.80E-02 H		☒	0.16 C	0.092 C	0.046 C	84 C	9.4 C	11 E	0.02 E
2,3-Dichloropropanol	616239	3.00E-03 I					110 N	11 N	4.1 N	6100 N	230 N		
1,3-Dichloropropene	542756	3.00E-04 I	5.71E-03 I	1.75E-01 H	1.30E-01 H	☒	0.077 C	0.048 C	0.018 C	33 C	3.7 C	0.1 E	0.001
Dichlorvos	62737	5.00e-04 I	1.43E-04 I	2.90E-01 I			0.23 C	0.022 C	0.011 C	20 C	2.2 C	3.5 C	0.00072 C
Dicofol	115322			4.40E-01 W			0.15 C	0.014 C	0.0072 C	13 C	1.5 C		
Dicyclopentadiene	77736	3.00E-02 H	5.71E-05 A			☒	0.42 N	0.21 N	41 N	61000 N	2300 N		
Dieldrin	60571	5.00E-05 I		1.60E+01 I	1.61E+01 I		0.0042 C	0.00039 C	0.0002 C	0.36 C	0.04 C	2 E	0.001 E
Diesel emissions			1.43E-03 I				52 N	5.2 N					
Diethyl phthalate	84662	8.00E-01 I					29000 N	2900 N	1100 N	1E+06 N	63000 N	520 E	110 E
Diethylene glycol, monobutyl ether	112345		5.71E-03 H				210 N	21 N					
Diethylene glycol, monoethyl ether	111900	2.00E+00 H					73000 N	7300 N	2700 N	1E+06 N	160000 N		
Diethylformamide	617845	1.10E-02 H					400 N	40 N	15 N	22000 N	860 N		
Di(2-ethylhexyl)adipate	103231	6.00E-01 I		1.20E-03 I			56 C	5.2 C	2.6 C	4800 C	530 C		
Diethylstilbestrol	56531			4.70E+03 H			0.00001 C	1E-06 C	7E-07 C	0.0012 C	0.00014 C		
Difenzoquat (Avenge)	43222486	8.00E-02 I					2900 N	290 N	110 N	160000 N	6300 N		
Diflubenzuron	35367385	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
1,1-Difluoroethane	75376		1.14E+01 I			☒	69000 N	42000 N					
Diisopropyl methylphosphonate (DIMP)	1445756	8.00E-02 I					2900 N	290 N	110 N	160000 N	6300 N		
Dimethipin	55290647	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Dimethoate	60515	2.00E-04 I					7.3 N	0.73 N	0.27 N	410 N	16 N		
3,3'-Dimethoxybenzidine	119904			1.40E-02 H			4.8 C	0.45 C	0.23 C	410 C	46 C		
Dimethylamine	124403		5.71E-06 W				0.21 N	0.021 N					
2,4-Dimethylaniline hydrochloride	21436964			5.80E-01 H			0.12 C	0.011 C	0.0054 C	9.9 C	1.1 C		
2,4-Dimethylaniline	95681			7.50E-01 H			0.09 C	0.0083 C	0.0042 C	7.6 C	0.85 C		
N-N-Dimethylaniline	121697	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		
3,3'-Dimethylbenzidine	119937			9.20E+00 H			0.0073 C	0.00068 C	0.00034 C	0.62 C	0.069 C	29 C	0.00039 C
N,N-Dimethylformamide	68122	1.00E-01 H	8.57E-03 I				3700 N	31 N	140 N	200000 N	7800 N		
1,1-Dimethylhydrazine	57147			2.60E+00 W	3.50E+00 W		0.026 C	0.0018 C	0.0012 C	2.2 C	0.25 C		
1,2-Dimethylhydrazine	540738			3.70E+01 W	3.70E+01 W		0.0018 C	0.00017 C	0.00009 C	0.15 C	0.017 C		
2,4-Dimethylphenol	105679	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N	5400 S	3 E
2,6-Dimethylphenol	576261	6.00E-04 I					22 N	2.2 N	0.81 N	1200 N	47 N		
3,4-Dimethylphenol	95658	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
Dimethyl phthalate	131113	1.00E+01 H					370000 N	37000 N	14000 N	1E+06 N	780000 N	1600 E	1200 E
Dimethyl terephthalate	120616	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
1,2-Dinitrobenzene	528290	4.00E-04 H					15 N	1.5 N	0.54 N	820 N	31 N		
1,3-Dinitrobenzene	99650	1.00E-04 I					3.7 N	0.37 N	0.14 N	200 N	7.8 N		
1,4-Dinitrobenzene	100254	4.00E-04 H					15 N	1.5 N	0.54 N	820 N	31 N		
4,6-Dinitro-o-cyclohexyl phenol	131895	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		

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S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
										Soil Ingestion			
Contaminant	CAS	RfDo	RfDi	CPSo	CPSi	VOC	Tap Water	Ambient Air	Fish	Industrial	Residential	Air	Groundwater
		mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg		µg/L	µg/m3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Ethyl p-nitrophenyl phenylphosphorothioate	2104645	1.00E-05 I					0.37 N	0.037 N	0.014 N	20 N	0.78 N		
Ethylnitrosourea	759739			1.40E+02 W			0.00048 C	0.00005 C	0.00002 C	0.041 C	0.0046 C		
Ethylphthalyl ethyl glycolate	84720	3.00E+00 I					110000 N	11000 N	4100 N	1E+06 N	230000 N		
Express	10120	8.00E-03 I					290 N	29 N	11 N	16000 N	630 N		
Fenamiphos	22224926	2.50E-04 I					9.1 N	0.91 N	0.34 N	510 N	20 N		
Fluometuron	2164172	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
Fluoride	7782414	6.00E-02 I					2200 N	220 N	81 N	120000 N	4700 N		
Fluoridone	59756604	8.00E-02 I					2900 N	290 N	110 N	160000 N	6300 N		
Flurprimidol	56425913	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
Flutolanil	66332965	6.00E-02 I					2200 N	220 N	81 N	120000 N	4700 N		
Fluvalinate	69409945	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
Folpet	133073	1.00E-01 I		3.50E-03 I			19 C	1.8 C	0.9 C	1600 C	180 C		
Fomesafen	72178020			1.90E-01 I			0.35 C	0.033 C	0.017 C	30 C	3.4 C		
Fonofos	944229	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		
Formaldehyde	50000	2.00E-01 I			4.55E-02 I		7300 N	0.14 C	270 N	410000 N	16000 N		
Formic Acid	64186	2.00E+00 H					73000 N	7300 N	2700 N	1E+06 N	160000 N		
Fosetyl-al	39148248	3.00E+00 I					110000 N	11000 N	4100 N	1E+06 N	230000 N		
Furan	110009	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
Furazolidone	67458			3.80E+00 H			0.018 C	0.0016 C	0.00083 C	1.5 C	0.17 C		
Furfural	98011	3.00E-03 I	1.43E-02 A				110 N	52 N	4.1 N	6100 N	230 N		
Furium	531828			5.00E+01 H			0.0013 C	0.00013 C	0.00006 C	0.11 C	0.013 C		
Furmecyclox	60568050			3.00E-02 I			2.2 C	0.21 C	0.11 C	190 C	21 C		
Glufosinate-ammonium	77182822	4.00E-04 I					15 N	1.5 N	0.54 N	820 N	31 N		
Glycidaldehyde	765344	4.00E-04 I	2.86E-04 H				15 N	1 N	0.54 N	820 N	31 N		
Glyphosate	1071836	1.00E-01 I					3700 N	370 N	140 N	200000 N	7800 N		
Haloxyfop-methyl	69806402	5.00E-05 I					1.8 N	0.18 N	0.068 N	100 N	3.9 N		
Harmony	79277273	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
HCH (alpha)	319846			6.30E+00 I	6.30E+00 I		0.011 C	0.00099 C	0.0005 C	0.91 C	0.1 C	0.9 E	0.0004 E
HCH (beta)	319857			1.80E+00 I	1.80E+00 I		0.037 C	0.0035 C	0.0018 C	3.2 C	0.35 C	16 E	0.002 E
HCH (gamma) Lindane	58899	3.00E-04 I		1.30E+00 H			0.052 C	0.0048 C	0.0024 C	4.4 C	0.49 C	4.2 C	0.006 E
HCH-technical	608731			1.80E+00 I	1.79E+00 I		0.037 C	0.0035 C	0.0018 C	3.2 C	0.35 C		
Heptachlor	76448	5.00E-04 I		4.50E+00 I	4.55E+00 I	☒	0.0023 C	0.0014 C	0.0007 C	1.3 C	0.14 C	0.3 E	0.06 E
Heptachlor epoxide	1024573	1.30E-05 I		9.10E+00 I	9.10E+00 I	☒	0.0012 C	0.00069 C	0.00035 C	0.63 C	0.07 C	1 E	0.03 E
Hexabromobenzene	87821	2.00E-03 I				☒	12 N	7.3 N	2.7 N	4100 N	160 N		
Hexachlorobenzene	118741	8.00E-04 I		1.60E+00 I	1.61E+00 I	☒	0.0066 C	0.0039 C	0.002 C	3.6 C	0.4 C	1 E	0.8 E
Hexachlorobutadiene	87683	2.00E-04 H		7.80E-02 I	7.70E-02 I	☒	0.14 C	0.081 C	0.04 C	73 C	8.2 C	1 E	0.1 E
Hexachlorocyclopentadiene	77474	7.00E-03 I	2.00E-05 H			☒	0.15 N	0.073 N	9.5 N	14000 N	550 N	2 E	10 E
Hexachlorodibenzo-p-dioxin mixture	19408743			6.20E+03 I	4.55E+03 I		0.00001 C	1E-06 C	5E-07 C	0.0009 C	0.0001 C		
Hexachloroethane	67721	1.00E-03 I		1.40E-02 I	1.40E-02 I	☒	0.75 C	0.45 C	0.23 C	410 C	46 C	49 E	0.2 E

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S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
										Soil Ingestion			
Contaminant	CAS	RfDo mg/kg/d	RfDi mg/kg/d	CPSo kg·d/mg	CPSi kg·d/mg	VOC	Tap Water µg/L	Ambient Air µg/m3	Fish mg/kg	Industrial mg/kg	Residential mg/kg	Air mg/kg	Groundwater mg/kg
Methamidophos	10265926	5.00E-05 I					1.8 N	0.18 N	0.068 N	100 N	3.9 N		
Methanol	67561	5.00E-01 I					18000 N	1800 N	680 N	1E+06 N	39000 N		
Methidathion	950378	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
Methomyl	16752775	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Methoxychlor	72435	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N	41 S	62 E
2-Methoxyethanol acetate	110496	2.00E-03 A					73 N	7.3 N	2.7 N	4100 N	160 N		
2-Methoxyethanol	109864	1.00E-03 H	5.71E-03 I				37 N	21 N	1.4 N	2000 N	78 N		
2-Methoxy-5-nitroaniline	99592			4.60E-02 H			1.5 C	0.14 C	0.069 C	120 C	14 C		
Methyl acetate	79209	1.00E+00 H					37000 N	3700 N	1400 N	1E+06 N	78000 N		
Methyl acrylate	96333	3.00E-02 A					1100 N	110 N	41 N	61000 N	2300 N		
2-Methylaniline hydrochloride	636215			1.80E-01 H			0.37 C	0.035 C	0.018 C	32 C	3.5 C		
2-Methylaniline	95534			2.40E-01 H			0.28 C	0.026 C	0.013 C	24 C	2.7 C		
Methyl chlorocarbonate	79221	1.00E+00 W					37000 N	3700 N	1400 N	1E+06 N	78000 N		
4-(2-Methyl-4-chlorophenoxy) butyric acid	94815	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
2-Methyl-4-chlorophenoxyacetic acid	94746	5.00E-04 I					18 N	1.8 N	0.68 N	1000 N	39 N		
2-(2-Methyl-14-chlorophenoxy)propionic acid	93652	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
Methylcyclohexane	108872		8.57E-01 H				31000 N	3100 N				60 S	1500 N
Methylene bromide	74953	1.00E-02 A				☒	61 N	37 N	14 N	20000 N	780 N		
Methylene chloride	75092	6.00E-02 I	8.57E-01 H	7.50E-03 I	1.64E-03 I	☒	4.1 C	3.8 C	0.42 C	760 C	85 C	7 E	0.01 E
4,4'-Methylene bis(2-chloroaniline)	101144	7.00E-04 H		1.30E-01 H	1.30E-01 H		0.52 C	0.048 C	0.024 C	44 C	4.9 C		
4,4'-Methylenebisbenzeneamine	101779			2.50E-01 W			0.27 C	0.025 C	0.013 C	23 C	2.6 C		
4,4'-Methylene bis(N,N'-dimethyl)aniline	101611			4.60E-02 I			1.5 C	0.14 C	0.069 C	120 C	14 C		
4,4'-Methylenediphenyl isocyanate	101688		5.71E-06 I			☒	0.035 N	0.021 N					
Methyl ethyl ketone	78933	6.00E-01 I	2.86E-01 I			☒	1900 N	1000 N	810 N	1E+06 N	47000 N		
Methyl hydrazine	60344			1.10E+00 W			0.061 C	0.0057 C	0.0029 C	5.2 C	0.58 C		
Methyl isobutyl ketone	108101	8.00E-02 H	2.29E-02 A				2900 N	84 N	110 N	160000 N	6300 N		
Methyl methacrylate	80626	8.00E-02 H					2900 N	290 N	110 N	160000 N	6300 N		
2-Methyl-5-nitroaniline	99558			3.30E-02 H			2 C	0.19 C	0.096 C	170 C	19 C		
Methyl parathion	298000	2.50E-04 I					9.1 N	0.91 N	0.34 N	510 N	20 N	28 S	0.041 N
2-Methylphenol (o-cresol)	95487	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N	12000 S	6 E
3-Methylphenol (m-cresol)	103394	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
4-Methylphenol (p-cresol)	106445	5.00E-03 H					180 N	18 N	6.8 N	10000 N	390 N		
Methyl styrene (mixture)	25013154	6.00E-03 A	1.14E-02 A			☒	60 N	42 N	8.1 N	12000 N	470 N	100 N	1 N
Methyl styrene (alpha)	98839	7.00E-02 A				☒	430 N	260 N	95 N	140000 N	5500 N	8.8 S	7.5 N
Methyl tertbutyl ether (MTBE)	1634044	5.00E-03 E	8.57E-01 I			☒	180 N	3100 N	6.8 N	10000 N	390 N		
Metolaclor (Dual)	51218452	1.50E-01 H					5500 N	550 N	200 N	310000 N	12000 N		
Metribuzin	21087649	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Mirex	2385855	2.00E-04 I		1.80E+00 W			0.037 C	0.0035 C	0.0018 C	3.2 C	0.35 C		
Molinate	2212671	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		

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Basis: C=carcinogenic effects N=noncarcinogenic effects E=EPA draft Soil Screening Level S=soil saturation concentration M=EPA MCL.

							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
						V	Tap	Ambient		Soil Ingestion			
		RfDo	RfDi	CPSo	CPSi	O	Water	Air	Fish	Industrial	Residential	Air	Groundwater
Contaminant	CAS	mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg	C	µg/L	µg/m3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Oxadiazon	19666309	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Oxamyl	23135220	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Oxyfluorfen	42874033	3.00E-03 I					110 N	11 N	4.1 N	6100 N	230 N		
Paclobutrazol	76738620	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
Paraquat	1910425	4.50E-03 I					160 N	16 N	6.1 N	9200 N	350 N		
Parathion	56382	6.00E-03 H					220 N	22 N	8.1 N	12000 N	470 N	110 S	3.9 N
Pebulate	1114712	5.00E-02 H					1800 N	180 N	68 N	100000 N	3900 N		
Pendimethalin	40487421	4.00E-02 I					1500 N	150 N	54 N	82000 N	3100 N		
Pentabromo-6-chloro cyclohexane	87843			2.30E-02 H			2.9 C	0.27 C	0.14 C	250 C	28 C		
Pentabromodiphenyl ether	32534819	2.00E-03 I					73 N	7.3 N	2.7 N	4100 N	160 N		
Pentachlorobenzene	608935	8.00E-04 I				☒	4.9 N	2.9 N	1.1 N	1600 N	63 N	570 N	48 N
Pentachloronitrobenzene	82688	3.00E-03 I		2.60E-01 H		☒	0.041 C	0.024 C	0.012 C	22 C	2.5 C		
Pentachlorophenol	87865	3.00E-02 I		1.20E-01 I			0.56 C	0.052 C	0.026 C	48 C	5.3 C	7.9 C	0.2 E
Permethrin	52645531	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		
Phenmedipham	13684634	2.50E-01 I					9100 N	910 N	340 N	510000 N	20000 N		
Phenol	108952	6.00E-01 I					22000 N	2200 N	810 N	1E+06 N	47000 N	21000 S	49 E
m-Phenylenediamine	108452	6.00E-03 I					220 N	22 N	8.1 N	12000 N	470 N		
p-Phenylenediamine	106503	1.90E-01 H					6900 N	690 N	260 N	390000 N	15000 N		
Phenylmercuric acetate	62384	8.00E-05 I					2.9 N	0.29 N	0.11 N	160 N	6.3 N		
2-Phenylphenol	90437			1.94E-03 H			35 C	3.2 C	1.6 C	3000 C	330 C		
Phorate	298022	2.00E-04 H					7.3 N	0.73 N	0.27 N	410 N	16 N		
Phosmet	732116	2.00E-02 I					730 N	73 N	27 N	41000 N	1600 N		
**Phosphine	7803512	3.00E-04 I	8.57E-05 H				11 N	0.31 N	0.41 N	610 N	23 N		
**Phosphoric acid	7664382	I	2.86E-03				100 N	10 N					
Phosphorus (white)	7723140	2.00E-05 I					0.73 N	0.073 N	0.027 N	41 N	1.6 N		
p-Phthalic acid	100210	1.00E+00 H					37000 N	3700 N	1400 N	1E+06 N	78000 N		
Phthalic anhydride	85449	2.00E+00 I	3.43E-02 H				73000 N	130 N	2700 N	1E+06 N	160000 N		
Picloram	1918021	7.00E-02 I					2600 N	260 N	95 N	140000 N	5500 N		
Pirimiphos-methyl	29232937	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
Polybrominated biphenyls		7.00E-06 H		8.90E+00 H			0.0076 C	0.0007 C	0.00035 C	0.64 C	0.072 C		
Polychlorinated biphenyls (PCBs)	1336363			7.70E+00 I			0.0087 C	0.00081 C	0.00041 C	0.74 C	0.083 C		
Aroclor 1016	12674112	7.00E-05 I					2.6 N	0.26 N	0.095 N	140 N	5.5 N		
Aroclor 1254	11097691	2.00E-05 I					0.73 N	0.073 N	0.027 N	41 N	1.6 N		
Polychlorinated terphenyls (PCTs)				4.50E+00 E			0.015 C	0.0014 C	0.0007 C	1.3 C	0.14 C		
Polynuclear aromatic hydrocarbons												110000 S	
Acenaphthene	83329	6.00E-02 I					2200 N	220 N	81 N	120000 N	4700 N	120 S	200 E
Anthracene	120127	3.00E-01 I					11000 N	1100 N	410 N	610000 N	23000 N	6.8 S	4300 E
Benz[a]anthracene	56553			7.30E-01 E	6.10E-01 E		0.092 C	0.01 C	0.0043 C	7.8 C	0.88 C	27 S	0.7 E
Benzo[b]fluoranthene	205992			7.30E-01 E	6.10E-01 E		0.092 C	0.01 C	0.0043 C	7.8 C	0.88 C	23 S	4 E

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S=soil saturation concentration M=EPA MCL.

Contaminant	CAS	RfDo	RfDi	CPSo	CPSi	VOC	Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
							Tap Water	Ambient Air	Fish	Soil Ingestion Industrial	Soil Ingestion Residential	Air	Groundwater
		mg/kg/d	mg/kg/d	kg·d/mg	kg·d/mg		µg/L	µg/m3	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Silver and compounds	7440224	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		
Simazine	122349	5.00E-03 I		1.20E-01 H			0.56 C	0.052 C	0.026 C	48 C	5.3 C		
Sodium azide	26628228	4.00E-03 I					150 N	15 N	5.4 N	8200 N	310 N		
Sodium diethyldithiocarbamate	148185	3.00E-02 I		2.70E-01 H			0.25 C	0.023 C	0.012 C	21 C	2.4 C		
Sodium fluoroacetate	62748	2.00E-05 I					0.73 N	0.073 N	0.027 N	41 N	1.6 N		
Sodium metavanadate	13718268	1.00E-03 H					37 N	3.7 N	1.4 N	2000 N	78 N		
Strontium, stable	7440246	6.00E-01 I					22000 N	2200 N	810 N	1E+06 N	47000 N		
Strychnine	57249	3.00E-04 I					11 N	1.1 N	0.41 N	610 N	23 N		
Styrene	100425	2.00E-01 I	2.86E-01 I			☒	1600 N	1000 N	270 N	410000 N	16000 N	1400 E	2 E
Systhane	88671890	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
2,3,7,8-TCDD (dioxin)	1746016			1.56E+05 H	1.16E+05 H		4E-07 C	5E-08 C	C	4E-05 C	4E-06 C		
Tebuthiuron	34014181	7.00E-02 I					2600 N	260 N	95 N	140000 N	5500 N		
Temephos	3383968	2.00E-02 H					730 N	73 N	27 N	41000 N	1600 N		
Terbacil	5902512	1.30E-02 I					470 N	47 N	18 N	27000 N	1000 N		
Terbufos	13071799	2.50E-05 H					0.91 N	0.091 N	0.034 N	51 N	2 N		
Terbutryn	886500	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
1,2,4,5-Tetrachlorobenzene	95943	3.00E-04 I				☒	1.8 N	1.1 N	0.41 N	610 N	23 N	91 N	0.69 N
1,1,1,2-Tetrachloroethane	630206	3.00E-02 I		2.60E-02 I	2.59E-02 I	☒	0.41 C	0.24 C	0.12 C	220 C	25 C		
1,1,2,2-Tetrachloroethane	79345			2.00E-01 I	2.03E-01 I	☒	0.052 C	0.031 C	0.016 C	29 C	3.2 C	0.4 E	0.001 E
Tetrachloroethylene (PCE)	127184	1.00E-02 I		5.20E-02 E	2.03E-03 E	☒	1.1 C	3.1 C	0.061 C	110 C	12 C	11 E	0.04 E
2,3,4,6-Tetrachlorophenol	58902	3.00E-02 I					1100 N	110 N	41 N	61000 N	2300 N		
p,a,a,a-Tetrachlorotoluene	5216251			2.00E+01 H		☒	0.00053 C	0.00031 C	0.00016 C	0.29 C	0.032 C		
Tetrachlorovinphos	961115	3.00E-02 I		2.40E-02 H			2.8 C	0.26 C	0.13 C	240 C	27 C		
Tetraethyldithiopyrophosphate	3689245	5.00E-04 I					18 N	1.8 N	0.68 N	1000 N	39 N		
Tetraethyl lead	78002	1.00E-07 I					0.0037 N	0.00037 N	0.00014 N	0.2 N	0.0078 N	0.00068 N	0.000034 N
**1,1,1,2-Tetrafluoroethane	811972	I	2.29E+01			☒	140000 N	84000 N					
Thallic oxide	1314325	7.00E-05 W					2.6 N	0.26 N	0.095 N	140 N	5.5 N		
Thallium													0.4 E
Thallium acetate	563688	9.00E-05 I					3.3 N	0.33 N	0.12 N	180 N	7 N		
Thallium carbonate	6533739	8.00E-05 I					2.9 N	0.29 N	0.11 N	160 N	6.3 N		
Thallium chloride	7791120	8.00E-05 I					2.9 N	0.29 N	0.11 N	160 N	6.3 N		
Thallium nitrate	10102451	9.00E-05 I					3.3 N	0.33 N	0.12 N	180 N	7 N		
Thallium selenite	12039520	9.00E-05 W					3.3 N	0.33 N	0.12 N	180 N	7 N		
Thallium sulfate	7446186	8.00E-05 I					2.9 N	0.29 N	0.11 N	160 N	6.3 N		
Thiobencarb	28249776	1.00E-02 I					370 N	37 N	14 N	20000 N	780 N		
2-(Thiocyanomethylthio)-benzothiazole	21564170	3.00E-02 H					1100 N	110 N	41 N	61000 N	2300 N		
Thiofanox	39196184	3.00E-04 H					11 N	1.1 N	0.41 N	610 N	23 N		
Thiophanate-methyl	23564058	8.00E-02 I					2900 N	290 N	110 N	160000 N	6300 N		
Thiram	137268	5.00E-03 I					180 N	18 N	6.8 N	10000 N	390 N		

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							Risk-Based Concentrations					Soil Screening Levels-Transfers from Soil to:	
										Soil Ingestion			
Contaminant	CAS	RfDo mg/kg/d	RfDi mg/kg/d	CPSo kg·d/mg	CPSI kg·d/mg	VOC	Tap Water µg/L	Ambient Air µg/m3	Fish mg/kg	Industrial mg/kg	Residential mg/kg	Air mg/kg	Groundwater mg/kg
Vanadium sulfate	36907423	2.00E-02 H					730 N	73 N	27 N	41000 N	1600 N		
Vernam	1929777	1.00E-03 I					37 N	3.7 N	1.4 N	2000 N	78 N		
Vinclozolin	50471448	2.50E-02 I					910 N	91 N	34 N	51000 N	2000 N		
Vinyl acetate	108054	1.00E+00 H	5.71E-02 I				37000 N	210 N	1400 N	1E+06 N	78000 N	370 E	8
Vinyl bromide	593602		8.57E-04 I			☒	5.2 N	3.1 N				2 N	0.018 N
Vinyl chloride	75014			1.90E+00 H	3.00E-01 H	☒	0.019 C	0.021 C	0.0017 C	3 C	0.34 C	0.002 E	0.01 E
Warfarin	81812	3.00E-04 I					11 N	1.1 N	0.41 N	610 N	23 N	0.046 N	1800 N
m-Xylene	108323	2.00E+00 H	2.00E-01 W			☒	1400 N	730 N	2700 N	1E+06 N	160000 N	950 S	240 M
o-Xylene	9.55E+04	2.00E+00 H	2.00E-01 W			☒	1400 N	730 N	2700 N	1E+06 N	160000 N	730 S	1.50E+02 M
p-Xylene	1.06E+05		8.57E-02 W			☒	520 N	310 N				1000 S	2.20E+02 M
Xylene (mixed)	1.33E+06	2.00E+00 I				☒	12000 N	7300 N	2700 N	1E+06 N	160000 N	320 E	7.40E+01 E
Zinc	7.44E+06	3.00E-01 I					11000 N	1100 N	410 N	610000 N	23000 N		4.20E+04 E
Zinc phosphide	1.31E+06	3.00E-04 I					11 N	1.1 N	0.41 N	610 N	23 N		
Zineb	1.21E+07	5.00E-02 I					1800 N	180 N	68 N	100000 N	3900 N		

APPENDIX I

DERIVATION OF CONSTRUCTION WORKER SOIL INGESTION SCREENING CONCENTRATION

DERIVATION OF CONSTRUCTION WORKER SOIL INGESTION SCREENING CONCENTRATION

The construction worker soil ingestion screening concentration has been derived using the same basic approach as the industrial soil screening value, except that a construction worker soil ingestion rate has been utilized and a one year exposure duration was assumed for construction activities related to site redevelopment. A target hazard quotient of 1 is the basis of the screening concentration. Since a one year exposure is considered a subchronic exposure scenario, a subchronic Reference Dose (RfD) for mercury has been employed. However, the conservative screening value is based on the subchronic RfD for methyl mercury (0.0001 mg/kg/day), the mercury species with the lowest RfD. The USEPA has adopted the chronic RfD as the subchronic RfD as well. The calculation of the soil ingestion screening concentration for the construction worker is shown in Table B-1.

The construction worker soil ingestion rate (118 mg soil per day) has been calculated based on a series of assumptions previously made by the USEPA. The soil ingestion rate represents a recalculation of work previously conducted by Hawley, with an updated skin soil adherence rate. The soil ingestion rate has been calculated as follows. Hawley has assumed that an adult working outdoors ingests twice daily a quantity of soil corresponding to one-half the covering of the inside surface of the fingers and thumbs of both hands. According to USEPA (1992), the inside surface of the fingers and thumbs of both hands is 14% of the surface area of the hands or 118 cm^2 and the upper bound estimate of soil adherence rate is 1.0 mg/cm^2. Based on this information, the daily soil intake rate is: 2×0.5 (118 cm^2) x 1.0 mg soil/cm2 = 118 mg soil / day.

Hawley, J.K., 1985. Assessment of Health Risk from Exposure to Contaminated Soil, Risk Analysis, Vol.
5, No. 4, pp.289-302.

USEPA, 1992. Dermal Exposure Assessment: Principles and Applications, Interim Report, EPA/600/8-91/011B, January

TABLE B-1 - DERIVATION OF CONSTRUCTION WORKER SOIL INGESTION SCREENING CONCENTRATION

CONSTRUCTION WORKER SCENARIO	UN ITS	VALUE	
SOIL INGESTION RATE	MG/DAY	118	
FREQUENCY OF EXPOSURE	DAYS/WK	5	
DURATION OF EXPOSURE	WEEKS	50	
FRACTION OF SOIL INGESTION AT SITE	NA	0.5	
BODYWEIGHT	KG	70	
RELATIVE ABSORPTION FACTOR	NA	1	
UNITS CONVERSION FACTOR (CF1)	KG/MG	1.00E-06	
UNITS CONVERSION FACTOR (CF2)	DAY/WK	7.00E+00	
ORAL RfD	MG/KG/DAY	1.00E-04	METHYL MERCURY
TARGET HAZARD INDEX	NA	1.00E+00	
TARGET CONCENTRATION (SOIL INGESTION)	MG/KG	166	

TARGET SOIL CONC (INGESTION ONLY) = TARGET HI X RfD X BW X DURATION X CF2 / (SOIL INGESTION RATE X FREQUENCY X DURATION X RELATIVE ABSORPTION FACTOR X FRACTION FROM SITE X CF1)

APPENDIX J

MERCURY SPECIATION AND BIOAVAILABILITY TESTING BACKGROUND INFORMATION AND TECHNIQUES

TECHNICAL BACKGROUND AND RATIONALE

MERCURY SPECIATION

Mercury can occur in soils as elemental mercury in liquid or vapor form, organic mercury compounds, mercuric chloride, or one of several different mineral species, including mercuric oxides, carbonates, and sulfides. In general, organic mercury, mercuric chloride, and elemental mercury in the vapor phase are very soluble and bioavailable, mercuric oxides and carbonates are less soluble, and liquid elemental mercury and mercuric sulfides are insoluble and non-bioavailable. Furthermore, mercury speciation may vary with depth in soils. The chemical form of mercury controls its mobility in the soil, its bioavailability when ingested, and its response to specific remedial actions. Therefore, an understanding of mercury speciation in soils at the Ames Street site will be critical for determining the bioavailability of mercury, evaluating risk, and selecting appropriate remedial actions.

The importance of mercury speciation can be illustrated with two examples. If a soil contains only organic mercury compounds, which generally are highly soluble, the mercury is likely to be highly bioavailable. In addition, a relatively simple technology—such as soil washing—may be a viable means of remediating the soil. In contrast, if all the mercury is present as insoluble mercuric sulfide, the bioavailability will be low and will result in a less stringent site-specific cleanup standard for soil across the site. However, due to the same physical properties, mercuric sulfide may be more difficult to remove from the soils, and a more aggressive remedial technology may be required to meet the cleanup standard.

Mercury speciation in soils can be evaluated using three general methods:

- Sequential extractions
- Electron microprobe analysis
- Heavy mineral separations.

Recently, several investigators have focused on developing sequential extraction procedures to quantitatively evaluate the speciation of mercury in soils (Revis et al. 1989; Miller 1993; Sakamoto et al. 1992). Application of the procedures of each investigator to the same samples from Oak Ridge, Tennessee showed mercury occurring predominantly as elemental mercury and mercuric sulfide minerals (Barnett et al. 1994). However, the relative proportions of the two species did not agree among procedures, indicating that the extractions were either not fully effective in removing specific mercury compounds or not fully specific in extracting individual mercury species. This problem is common to sequential extraction methods (Belzile et al. 1989). All the extraction techniques gave similar levels of organic mercury in soils. However, the method of Miller (1993), developed by the EPA, generally found much less elemental mercury and mercuric sulfide than the other two extraction procedures. The method of Sakamoto et al. (1992) tended to have poor recovery for elemental mercury. The method of Revis et al. (1993) showed higher recoveries of mercuric sulfide and elemental mercury, but it does not include a procedure for mercuric oxides and carbonates (acid-soluble mercury). Given the drawbacks of all the methods, a procedure combining the most effective aspects of each is likely to produce the most reliable results.

Electron microprobe analysis is a mineralogical technique that provides direct visual evidence of the mercury phases present in soil. The microprobe is used to determine the distribution of the specific mercury-bearing phases in the soil and can be used to qualitatively, rather than quantitatively, confirm the visible amounts of these phases. Microprobe analysis is particularly useful for documenting the morphology and composition of the metal-bearing grains and photographing these relations. This information can then be used to assess the bioavailability of the metal in the soil (Davis et al. 1993). The microprobe technique, however, is not without limitations. It is difficult to quantitatively determine the entire mass of mercury in the soil, because some phases may be distributed throughout the soil at low concentrations that are difficult to quantify. Also, it may be difficult to detect mercury-bearing phases in soils with very low levels of mercury. Finally, in preparing the samples for microprobe analysis, some of the organic and elemental mercury may be lost due to volatilization, potentially skewing the results.

Heavy mineral separation of mercury-bearing phases from soil is an additional mineralogical technique to provide information on the distribution of mercury species in the soil. This technique involves grinding a soil sample and mixing in a high-density liquid such as methylene iodide (specific gravity 3.325). In this liquid, silicate minerals and organic materials will float, and heavy mercury-bearing phases will settle out, along with other heavy minerals. This heavy mineral concentrate can then be analyzed visually, by microprobe, and by x-ray diffraction to detect mercury-bearing phases. The results of heavy mineral separations provide visual confirmation of the mercury speciation results. More importantly, mineral separations provide conclusive evidence of the presence or absence of significant concentrations of all mercury phases in site soils.

The interpretation of mercury speciation data will focus on determining the internal consistency and applicability of the sequential extraction results. Total mercury concentrations will be compared to the sum of the individual mercury species determined in each soil. Also, duplicate analyses will be compared. Speciation results from soils spiked with known quantities of mercury species will be evaluated to determine the portion of mercury re-extracted by the speciation procedures. Once the sequential extraction data are analyzed, these results will be compared to microprobe and heavy mineral separation data, to evaluate whether the different speciation techniques provide consistent results. If the results are different, the discrepancies will be evaluated in light of the known limitations of the analytical methods, to develop a realistic assessment of the distribution of mercury species in soils from the Ames Street site.

MERCURY BIOAVAILABILITY

In humans, an orally administered dose of a compound is seldom completely absorbed, and differences in the extent of absorption of orally administered compounds exist among different exposure media. For most compounds, the toxicity values derived by the U.S. Environmental Protection Agency (EPA) are not adjusted to absorbed dose (i.e., the dose response evaluation is based on the administered dose). This procedure can lead to errors in assessing the risks of exposure to a particular chemical in a medium other than the one used in the toxicity or epidemiology studies on which the toxicity values are based. For example, the EPA's oral toxicity value, or reference dose (RfD), for inorganic mercury was derived from studies in which mercuric chloride dissolved in water was administered to laboratory animals. Because it is likely that most of the mercury at the Ames Street site is present in forms that are less soluble than mercuric chloride, absorption of mercury from ingested site soils will be reduced compared to mercuric chloride. If these differences in mercury bioavailability are not accounted for, risks associated with ingestion of mercury in site soils will be overestimated. The adjustment factor to correct for differences in absorption from different exposure media is termed the bioavailability adjustment factor (BAF). This fractional value is used to adjust the dose or intake so that it is expressed in the same terms as the doses used to generate the toxicity values.

Substantial evidence exists that mercury solubility and bioavailability vary with mercury species. Studies in rodents suggest that 10 to 20 percent of mercuric chloride is absorbed from single oral doses. Several studies comparing tissue levels in rodents after single or repeated doses of mercuric chloride and mercuric sulfide have concluded that mercuric sulfide is very poorly absorbed. In 1993, the EPA reviewed available studies on the toxicity and bioavailability of mercuric sulfide in response to a petition for a provisional mercuric sulfide reference dose for an Oak Ridge, Tennessee, site. At that time, the EPA concluded that insufficient information was available to derive a separate RfD for mercuric sulfide, but they did note that comparison of relative tissue levels of mercury in animal studies suggested that mercuric sulfide was 30 to 80 times less bioavailable than mercuric chloride. Thus, a relative BAF of 1/30 to 1/80 (0.03–0.01) may be appropriate when applying toxicity values for mercuric chloride to mercuric sulfide. Little or no information is available on the oral absorption of other mercury compounds or elemental mercury relative to mercuric chloride; however, other mercury species are likely to be more bioavailable than mercuric sulfide. The bioavailability of mercury species in soil may be further reduced due to interactions with soil constituents. Thus, site-specific BAFs will vary, depending on the mix of mercury species present at the site and the composition of other soil constituents. Because a variety of mercury species may be present in soils at the Ames Street site, site-specific mercury BAF(s) will be determined based on a study of site soil samples.

For the purpose of this study, bioaccessible mercury is defined as the fraction of mercury that is soluble in the gastrointestinal (GI) tract and is available for absorption, while bioavailability is defined as the fraction of mercury that is absorbed into the bloodstream. Because mercury in soil must be solubilized in order to become bioavailable, mercury bioaccessibility is a precursor to, and provides an upper-bound estimate of, mercury bioavailability.

The PTI *in vitro* test has been utilized to assay the bioavailability of lead and arsenic in soils, and has been validated in several animal models (Ruby et al. 1993, 1995; Appendix A, Attachment D). For this study, the standard PTI *in vitro* test has been modified to provide a test system appropriate for mercury bioaccessibility evaluation (see Methodology section, below).

In vitro assays similar to the PTI test have been employed at several other sites to estimate site-specific bioavailability of mercury in soil. At the Almaden Quick Silver County Park in Los Gatos, California, the form of mercury present in site soils, which resulted from mining and ore processing (predominantly mercuric sulfide), was experimentally measured to be from 0.03 to 9.4 percent as soluble as mercuric chloride, in a simulated gastrointestinal environment (CDM 1992). The Los Gatos site samples were tested using a leaching procedure designed to emulate the human gastrointestinal system. Two-hundred milligrams (mg) of sample (sieved to <2 mm) was added to 480 milliliters (mL) of a pH-2.5 solution of dilute hydrochloric acid (HCl) in 500-mL bottles, and the bottles were agitated for 4 hours to simulate conditions in the human stomach. The human intestine was emulated by adjusting the pH of the solution to 6.5 using sodium hydroxide, and agitating for an additional 4 hours. At the end of the simulated stomach and intestinal phases, aliquots of the solutions were filtered (0.45 μm) and analyzed for their mercury content. Based on the results of this *in vitro* assay, the Santa Clara County Parks and Recreation Department and California state regulatory authorities agreed to use a BAF of 0.3 for the Los Gatos site.

An *in vitro* procedure nearly identical to the one above was used to evaluate the solubility of mercury in soil samples collected at Oak Ridge National Laboratory in Tennessee (Barnett and Turner 1995). The experimental procedure was altered in that the soil samples were pulverized after sieving, and only the <180-μm size fraction was subjected to the leaching procedure. For 19 of the 20 samples, the mercury in soils was determined to be from 0.3

to 14.2 percent soluble (average of 3.2 percent). One sample, the only sample with detectable mercury vapor in the sample headspace, contained 45.9 percent soluble mercury by this *in vitro* method. Mercuric chloride was determined to be 100 percent soluble in the *in vitro* test system. Based on these analyses, the EPA accepted a site-specific BAF of 0.1 for mercury in soils (DOE 1995).

METHODOLOGY

OVERVIEW

Mercury speciation analysis will be conducted on selected soil samples to determine the forms of mercury present. The speciation data will indicate the predicted solubility of mercury in the soil samples and will provide a mechanistic explanation for the estimated bioavailability of mercury from the Ames Street site soils. An *in vitro* test that replicates human gastrointestinal tract chemistry and function will be performed on selected samples following speciation to determine the fraction of mercury in soil samples that is soluble and available for absorption in the gastrointestinal tract (i.e., the fraction that is bioaccessible). Because the bioaccessible fraction of mercury provides an upper-bound estimate on the bioavailability of ingested mercury, the *in vitro* test data for the Ames Street site soil samples can be used to develop conservative site-specific BAF(s). The resulting BAF(s) can then be used to adjust the soil mercury intake estimates and to develop revised site-specific soil remediation goals.

MERCURY SPECIATION ANALYSIS

As described above, both sequential extractions and mineralogical techniques for determining the speciation of mercury in soils are not without limitations. In order to address these limitations, PTI will conduct a coupled study of mercury speciation that combines sequential extractions and mineralogical techniques. The use of more than one method will allow for data cross-checking and validation, which will increase the reliability of study results. Also, the combined approach will allow for better quantification of mercury species distribution, especially organic and elemental mercury in soils, and the mineralogical photographs will provide visual evidence of mercury distribution.

Total mercury concentrations will be measured in all of the soil samples. Speciation analysis will then be conducted on selected samples with total mercury concentration >10 mg/kg. Prior to speciation analysis, mercury in the headspace of the sample bottles will be determined in the laboratory at room temperature using a Jerome mercury vapor analyzer, Model 431X. Speciation analysis will be performed on dry samples. Because of the volatile nature of mercury, the samples will be air dried at room temperature, instead of oven dried. The speciation analysis will first be performed using a sequential extraction procedure, whereby samples are extracted with chloroform to analyze for organic mercury, and then treated with 0.1 M H_2SO_4 to extract mercuric oxide and carbonate minerals. The remaining sample will be analyzed for total mercury (i.e., elemental mercury + mercuric sulfide) and then heated to extract elemental mercury. Mercuric sulfide will be the concentration of total mercury left after heating. Elemental mercury will be determined by subtracting the mercuric sulfide concentration from the total mercury concentration prior to heating. In addition to the sequential extractions, speciation will be determined by microprobe and heavy mineral separations. These results will provide corroborative visual evidence of various mercury phases in site soils. Quality assurance and quality control (QA/QC) procedures will be implemented, including collection and analysis of sample duplicates, spiked soils, and sample blanks. The results of the various mercury speciation studies will be used to identify samples for further *in vitro* studies to assess mercury bioavailability.

IN VITRO BIOAVAILABILITY TESTING

The *in vitro* procedure is described in detail in the SAP (Appendix A). Extracts from the *in vitro* procedure will be submitted to Columbia Analytical Services (Kelso, Washington) for mercury analysis. Analytical methods and laboratory quality assurance measures are described below. The *in vitro* test results for selected Ames Street site samples will be used to develop a site-specific BAF for mercury, based on the average fraction of mercury solubilized from the soils, corrected for recovery of mercuric chloride in the assay. Multiple BAFs may be developed for different areas of the site or different mercury forms in soil, based on the speciation data, if the testing results support this approach to data interpretation.

QA/QC procedures will be implemented by spiking two stomach solution samples. Instead of adding a soil sample to the reaction vessel, a known amount of an aqueous solution of reagent-grade mercuric chloride ($HgCl_2$) will be added as a spike. The QA/QC procedure will then follow the *in vitro* test method as described in the SAP (Appendix A). The samples will be spiked with a low concentration of $HgCl_2$, relative to total soil mercury concentrations. The duplicate spike solutions will be evaluated to determine recovery of mercuric chloride in the *in vitro* test.

MERCURY SPECIATION ANALYSIS

SAMPLE PREPARATION

Based on the total mercury results, samples will be selected from locations at the Ames Street site for speciation analysis. The samples selected must contain enough mercury (i.e., > 10 mg/kg) to perform the speciation analyses and to quantify the spatial distribution of mercury in Ames Street site soil. Speciation will be performed to determine organic mercury, mercury oxide, elemental mercury, and mercuric sulfide. Personnel at the PTI laboratory in Boulder, Colorado will perform the sequential extractions.

MERCURY VAPOR ANALYSIS

To measure the headspace mercury in the 16-oz soil sampling bottles, attach the Jerome Model 431X mercury vapor analyzer to the septum. If the Jerome Model 431X mercury vapor analyzer reads the upper detection limit of 1 mg/m^3, then a Jerome Dilution Module can be used. This device will dilute the headspace mercury so that a percentage of mercury vapor can be detected. After reading the headspace mercury, the samples will be air dried.

SPECIATION EXTRACTION METHODS

The methods of Revis et al. (1989) and Sakamoto et al. (1992) will be followed for the extraction of mercury species from the Ames Street site soils. Modifications have been made to both procedures in order to combine the two methods.

The PTI laboratory will be set up to perform extractions of mercury species. All procedures will be performed under a vapor hood. Sample extracts for each mercury species will be sent to Columbia Analytical Services (CAS) for mercury analyses.

Organic Mercury and Acid-Soluble Mercury

Sakamoto et al. (1992) developed a method for differential determination of organic mercury and acid-soluble mercury, which includes mercury(I) oxide, mercury(II) oxide, mercury carbonates, and mercuric chloride, based on the successive extraction of these mercury compounds with chloroform and sulfuric acid. The mercury in each extract is determined by cold vapor atomic adsorption spectroscopy (CVAAS).

The method for extracting organic mercury from soils is as follows:

- Place 20 mL of chloroform and 1–5 g of sediment sample in a 50-mL glass centrifuge tube
- Stopper the tube and shake in a shaker for 2 minutes
- Centrifuge at 3000 rpm for 2 minutes
- Transfer the chloroform phase into a separatory funnel
- Repeat the extraction with another 20 mL of chloroform
- Add 3 mL of 0.01 M sodium thiosulfate solution to the combined chloroform extract in the separatory funnel and shake for 2 minutes
- Send the aqueous solution to CAS to determine the mercury concentration by CVAAS.

The method for extracting acid-soluble mercury from soils is as follows:

- After completion of the organic mercury extraction, leave the 50-mL glass centrifuge tube unstoppered to evaporate the residual chloroform to dryness
- Add 10 mL of 0.1 M sulfuric acid to the residue
- Stopper the centrifuge tube and shake it in the shaker for 2 minutes
- Centrifuge it at 3000 rpm for 2 minutes
- Send the supernatant to CAS to determine the mercury concentration by CVAAS

- Air dry and save the residue in the centrifuge tube for the elemental mercury extraction.

Elemental Mercury (Hg^0) and Mercuric Sulfide

To separate and determine elemental mercury (Hg^0) and mercuric sulfide (HgS), use the residue remaining after extracting organic mercury and mercury oxide, and follow the method of Revis et al. (1989):

- Send a residue split to CAS to determine ΣHg (i.e., Hg^0 + HgS) using CVAAS
- Thinly spread a 5-g sample of homogenized residue on a stainless steel tray
- Place the tray in a continuously aerated oven at 150 °C for 5 days
- Digest the sample with aqua regia acid
- Send the sample to CAS to determine ΣHg by CVAAS
- The amount of HgS in the sample is the amount of ΣHg after roasting.
- The amount of Hg^0 in the sample is the difference between the ΣHg prior to roasting and the amount of HgS after roasting.

MICROPROBE ANALYSIS

Polished sample "pucks" will be prepared at the Laboratory for Geological Studies, University of Colorado, Boulder, for electron microprobe analysis by embedding 4 grams of sample in epoxy within a sample mold, setting the mold to cure at room temperature, and grinding a flat surface on the sample side to expose as much sample as possible. Successive polishing steps will employ a 600-grit wet/dry abrasive paper stretched across a glass plate, 15-µm and 6-µm diamond on a cloth pad fixed to a steel lap, and finally 0.1-µm diamond on a felt pad fixed to a steel lap. All polishing steps will use kerosene to avoid dissolution of water-soluble Hg phases, and all polishing will be performed at low speeds to avoid plucking of the sample grains. Finally, sample pucks will be cleaned in an ultrasonic cleaner with isopropyl alcohol, air dried, and placed in a carbon coater, where a thin layer of carbon will be sputtered onto the surface of each puck.

Electron microprobe analysis (EMPA) will also be conducted at the Laboratory for Geological Studies, University of Colorado, Boulder, on a JEOL 8600 electron microprobe operating at 15 kV with a 20-nA specimen current and a 1-µm beam, according to the methods described in Attachment C, as adapted for mercury speciation. Quantitative mineralogic data will be collected using wavelength dispersive spectrometers and mineral standards, and corrected using Phi Rho Z parameters. The Hg-bearing particles will be identified using a combination of energy dispersive detection (EDS), wavelength dispersive detection (WDS), and backscatter electron image detection (BEI). Initially, spectra are generated for each grain that allow identification of all elements with an atomic mass greater than or equal to that of carbon. Subsequently, the elemental proportions are quantified using standards, and the mineral proportions are identified based on the equivalent weight of the oxide. Therefore, the identifications provide quantitative stoichiometric ratios from which the mineral identity can be calculated. The relations between Hg-bearing phases will be established from BEI images and WDS/EDS analyses as necessary. Representative BEI photomicrographs of identified phases and their associations will be produced, with scale bar, magnification, sample identification, and phase identification recorded on each photomicrograph.

Individual Hg-bearing particles will be analyzed (representing one point count each) until a minimum of 100 particles has been evaluated, or 5 hr of machine time has been spent on the analysis. Point counts will be made by traversing each sample from left to right and top to bottom in a grid pattern, with each vertical displacement moving only to the adjacent field of view. Magnification settings of 40 to 100× and 300 to 600× will be used; the latter magnification allows analysis of the smallest identifiable (1–2 µm) phases. The grain size of each Hg carrier will be determined by measuring the dimension of the long axis. Percent compositions of Hg phases in each sample will be determined by summing the total area of all Hg grains and dividing the area for each phase by the total area.

HEAVY MINERAL SEPARATIONS

Heavy minerals will be identified in the PTI laboratory in Boulder, Colorado by shaking 5 g of ground and sieved soil in 100 mL of methylene iodide (specific gravity 3.325) in a separatory funnel. The samples will be allowed to settle until the liquid clears. The heavy fraction will be dispensed into a beaker and triple washed with acetone. The heavy fraction will be collected, then examined and photographed under a binocular microscope. This heavy fraction will also be analyzed by powder x-ray diffraction at the Laboratory for Geological Studies, University of Colorado, Boulder. Finally, the heavy mineral fraction will be analyzed by electron microprobe in a fashion similar to the bulk soil samples. Results of this visual observation of mercury species in soils will be tabulated and used to assist in evaluating the sequential extraction mercury speciation.

ANALYTICAL PROCEDURES

Sample extracts will be shipped on ice under strict chain of custody, in accordance with SOP-5, to CAS and the PTI laboratory in Boulder, Colorado. Soil samples for total mercury analysis will be analyzed by CVAAS (Method 7471A, U.S. EPA 1991), which includes acid digestion. Sample results will be reported on a dry-weight basis. Aqueous-phase extracts will be analyzed for mercury by a similar CVAAS methodology (Method 7470A, U.S. EPA 1991). Samples also will be analyzed for total sulfides, total carbonates, and TOC.

IN VITRO BIOAVAILABILITY TESTING

SAMPLE PREPARATION

Selected soil samples will undergo the *in vitro* procedure to estimate relative mercury bioavailability. The samples will be prepared in PTI's Boulder, Colorado laboratory by air drying and sieving to <250 µm. The <250-µm size fraction has been selected for this study because this particle size has been observed to adhere to children's hands, and is the fraction of soil most likely to be ingested (Duggan and Inskip 1985).

A split of each sieved sample (<250 µm) also will be submitted for determination of total mercury and sulfur, and total organic carbon (TOC), by the analytical method described below.

IN VITRO TEST METHOD

The *in vitro* test is designed to determine the fraction of mercury that is solubilized and available for absorption in the gastrointestinal tract. Development of the test, and the rationale for selection of representative parameters, are described in detail in the literature included in Attachment D. The *in vitro* method was designed to replicate gastrointestinal-tract parameters for a human child, including stomach and small intestinal pH and chemistry, soil-to-solution ratio, stomach mixing, and stomach emptying rate. The method is implemented in two phases, simulating the passage of ingested soil from the acidic environment of the stomach to the near-neutral conditions of the small intestine.

Because of the concern for potential loss of volatile mercury from the reaction vessel, the *in vitro* test methodology used to estimate the bioavailability of arsenic and lead has been altered for mercury bioavailability testing. The reaction will be carried out in a sealed container, to minimize potential loss of volatile mercury. Argon gas will be introduced into the reaction vessel at the beginning of the *in vitro* assay to purge it of atmospheric oxygen, to simulate the anoxic conditions present in the gastrointestinal tract. A gold trap will be placed on the inflowing argon gas to remove mercury from the inflowing gas.

The *in vitro* test will be conducted according to the following method (all chemicals from Sigma Chemical Company, unless otherwise noted):

- Prepare the stomach solution by adding the following compounds to 1 L of deionized water (stirred continually on a stir plate):

  1.25 g pepsin (50 mg, activity of 800–2,500 units/mg)
  0.50 g citrate (Fisher Chemical Co.)
  0.50 g malate (Aldrich Chemical Co.)
  420 µL lactic acid (synthetic syrup 85 percent w/w)
  500 µL acetic acid (97 percent w/w; Fisher Chemical Co.).

- Adjust the pH of the stomach solution to 2.5 by adding a measured volume of concentrated HCl.

- Add 150 mL of stomach solution to the 200-mL acrylic reaction vessel (see Attachment D).

- Sparge the stomach solution with argon for 5 minutes to remove oxygen.

- Measure the Eh of the stomach solution.

- Sparge the stomach solution with argon for an additional 2 minutes.

- Add 1.5 g of soil and seal the reaction vessel.

- Submerge the reaction vessel approximately half-way into a temperature-controlled water bath heated to maintain a constant 37 °C in the reaction vessel (Attachment D)

- Allow the soil/stomach solution to stand (no agitation) for 10 minutes.

- Stir the mixture with a plastic propeller stir rod mounted in a rheostat-controlled motor (Arrow Engineering Model 1750 motor on a rheostat setting of 2, resulting in approximately 150 rpm for the stir rod).

- Check the pH at 5-minute intervals, and readjust to pH 2.5 with HCl if necessary.

- Collect 5-mL samples at 30 and 60 minutes, using a stainless-steel hypodermic syringe to pierce the sampling septum. Centrifuge the 5-mL samples at approximately 2500 xg for 25 minutes and decant the supernatant for analysis.

- At 1 hour, titrate the solution to pH 7.0 by adding a 5-in length of dialysis tubing containing approximately 1 g of $NaHCO_3$ to each reaction vessel. The dialysis tubing is added without exposing the reaction vessel to atmospheric oxygen.

- Allow the pH of the reaction vessel solution to increase slowly to 7.0 ±0.2 before removing the dialysis bag.

- Dissolve 260 mg of bile salts and 75 mg of pancreatin in 10 mL of deionized water and inject the fluid into the reaction vessel through the septum.

- Using a stainless-steel hypodermic syringe, obtain 5 mL of intestinal-phase sample through the septum at 1.0 and 3.0 hours after the reaction fluid reaches equilibrium at pH 7. Centrifuge each sample at approximately 2500 xg for 25 minutes and decant the supernatant for analysis.

- Measure and record the concentration of mercury vapor in the headspace of the reaction flask by connecting a mercury vapor analyzer (Jerome Model 431X) to the reaction vessel, and opening the sealed sampling septum to allow air flow through the reaction vessel.

- After the final sample is collected, measure and record the pH and Eh of the flask contents.

- Measure and record the final volume of the flask contents in a graduated cylinder.

- Analyze each of the two stomach-phase and the two small-intestinal-phase samples for mercury concentration, by the analytical method described below.

IN VITRO TEST SYSTEM EVALUATION

Prior to analyzing samples for the purpose of developing a site-specific bioavailability adjustment factor (BAF), site soil samples will be evaluated using the *in vitro* test to determine the potential for loss of mercury during the test (e.g., from volatilization, or mercury adhering to the test cell walls). In a mass balance experiment, two site soil samples will be tested in triplicate in the assay. The absolute quantity of mercury recovered in the fluid, solid, and vapor phases from the reaction vessel after the assay is completed (analytical procedures described below) will be compared to the quantity of mercury determined to be present in the soil sample before the *in vitro* assay (estimated from analysis of a split of the soil sample), to evaluate recovery of mercury from the test system.

ANALYTICAL PROCEDURES

All *in vitro* test samples will be shipped to CAS under strict chain of custody. Soil samples for total mercury analysis will be analyzed by CVAAS (Method 7471A, U.S. EPA 1991), which includes acid digestion. Sample results will be reported on a dry-weight basis. *In vitro* extracts will be analyzed for mercury by a similar CVAAS methodology (Method 7470A, U.S. EPA 1991).

QUALITY CONTROL PROCEDURES

MERCURY SPECIATION ANALYSIS

Quality Assurance and Quality Control (QA/QC) samples will be collected in accordance with SOP-6 to provide checks on sample collection and handling procedures, and analytical accuracy and precision. Field quality control will include field duplicates, external contamination blanks (ECBs), cross-contamination blanks (CCBs), and standard reference materials (SRMs). Laboratory quality control will include blank, spike, and duplicate samples. PTI laboratory control samples will be prepared as specified below.

IN VITRO TESTING

In vitro test quality control samples will include two soils that will be run through the procedure in triplicate. In addition, two *in vitro* tests with a soluble mercury spike will be performed to evaluate matrix spike recovery. Finally, a blank stomach solution spiked with a known amount of soluble mercury will be submitted as a blind laboratory control sample.

LABORATORY QUALITY CONTROL

The specific quality control procedures to be performed for the analyses of mercury and other metals are cited in U.S. EPA (1991). The laboratory quality control samples will include a preparation blank, laboratory control sample, laboratory duplicate, and matrix spike sample for each batch of 20 samples or each digestion group, whichever is more frequent.

For every 20 or fewer samples of a similar matrix analyzed by a particular method, the laboratory will submit a complete data package containing the following data and supporting information:

- A cover letter discussing the analytical procedures used and the problems encountered during sample analysis (if any).

- Sample log listing the identifying sample numbers and corresponding laboratory numbers (if applicable) for all samples included in the data package.

- Chain-of-custody forms for all samples included in the data package.

- Analyte concentrations with reporting units identified.

- The original raw laboratory data, bench sheets, and instrument printouts for all samples, including all laboratory quality control samples and blanks.

- Final dilution volumes, sample sizes, wet-to-dry ratios, and any other information—including formulas—required to derive the final reported sample concentration from the raw laboratory data.

- Final analytical results, with appropriate concentration units, for all *in vitro* and quality control *in vitro* samples, as well as laboratory quality control samples when required (i.e., laboratory method blanks, laboratory control samples [LCSs], and matrix spike samples).

- Instrument detection limits for each analyte in each package.

- A summary form indicating which method blanks are associated with each batch of samples for every analysis.

- Summarized recovery and/or relative percent difference (RPD) results for all laboratory quality assurance and quality control (QA/QC) checks, including all laboratory spike samples, calibration check samples, laboratory duplicate samples, method blanks, and LCSs for each analysis.

- Appropriate laboratory data qualification codes and their definitions.

- Summary forms for all initial and continuing instrument calibrations performed that apply to the project samples in each data package. These summaries must include the exact concentrations for the calibration standards and the acceptable linear calibration ranges for each instrument used. Some measure of the linearity of the initial calibration curve also must be determined and reported, as specified in the method.

REFERENCES

Barnett, M.O., and R.R. Turner. 1995. Bioavailability of mercury in East Fork Poplar Creek soils. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN. Y-12 ER Report.

Barnett, M.O., L.A. Harris, R.R. Turner, T.J. Henson, R.E. Melton, and R.J. Stevenson. 1994. Characterization of mercury species in contaminated floodplain soils. Water Air Soil Pollut.

Belzile, N., P. Lecomte, and A. Tessler. 1989. Testing readsorption of trace elements during partial chemical extractions of bottom sediments. Environ. Sci. Technol. 23:1015–1020.

CDM. 1992. Final report. Risk assessment, Almaden Quicksilver County Park, Volume II - Appendices. Appendix E. Camp Dresser & McKee, Inc., Denver, CO, May 29, 1992.

Davis, A., J.W. Drexler, M.V. Ruby, and A. Nicholson. 1993. Micromineralogy of mine wastes in relation to lead bioavailability, Butte, Montana. Environ. Sci. Technol. 27(7):1415- 1425.

DOE. 1995. Record of Decision for Lower East Fork Poplar Creek. U.S. Department of Energy, Office of Environmental Restoration and Waste Management. Prepared by Jacobs ER Team, Oak Ridge, TN. DOE/OR/02-1370&D1. May.

Miller, E.L. 1993. Speciation of mercury in soil. EPA Contract 68-CO-0049. U.S. Environmental Protection Agency, Quality Assurance and Methods Development Division, Environmental Monitoring Systems Laboratory, Office of Research and Development, Lockheed Environmental Sciences and Technology Company, Las Vegas, NV.

Revis, N.W., T.R. Osborne, D. Sedgley, and A. King. 1989. Quantitative method for determining the concentration of mercury(II) in soils and sediments. Analyst 114:823–825.

Ruby, M.V., A. Davis, T.E. Link, R. Schoof, R.L. Chaney, G.B. Freeman, and P. Bergstrom. 1993. Development of an *in vitro* screening test to evaluate the *in vivo* bioaccessibility of ingested mine-waste lead. Environ. Sci. Technol. 27(13):2870–2877.

Ruby, M.V., A. Davis, T.E. Link, R. Schoof, S. Eberle. 1995. Development of a physiologically based test to estimate lead bioavailability. The Toxicologist 15(1):135.

Sakamoto, H.T., T. Tomiyasu, and N. Yonehara. 1992. Differential determination of organic mercury, mercury(II) oxide and mercury(II) sulfide in sediments by cold vapor atomic adsorption spectrometry. Anal. Sci. 8:35–39.

U.S. EPA. 1991. Test methods for evaluating solid waste. Physical/chemical methods. SW-846. Third ed. U.S. Environmental Protection Agency, Washington, DC.