Final
Omaha Lead Site
Final Feasibility Study

Omaha, Nebraska

April 2009

Prepared for:
USEPA Region VII

Prepared by:
Black & Veatch Special Projects Corp.

USEPA Contract No. EP-57-05-06
USEPA Work Assignment Number: Task Order No: 031
BVSPC Project No. 044746

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List of Acronyms

AES	Architect and Engineering Service
ARARs	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substances and Disease Registry
BHHRA	Baseline Human Health Risk Assessment
BVSPC	Black and Veatch Special Project Corporation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
COPC	Chemicals of Potential Concern
CTE	Central Tendency Exposure
DCHD	Douglas County Health Department
EBL	Elevated Blood Level
EPA	US Environmental Protection Agency
FS	Feasibility Study
HI	Hazard Index
HQ	Hazard Quotient
HEPA	High Efficiency Particulate Air
HEPAVAC	High Efficiency Particulate Air Vacuum Cleaner
HUD	U.S. Department of Housing and Urban Development
IC	Institutional Control
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectroscopy
IEUBK	Integrated Exposure Uptake Biokinetic Model
LBP	Lead Based Paint
LHCP	City of Omaha Lead Hazard Control Program
MCL	Maximum Contaminant Level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NCP	National Oil & Hazardous Substances Contingency Plan
NDEQ	Nebraska Department of Environmental Quality
NERL	National Exposure Research Laboratory
NPL	National Priorities List
OLS	Omaha Lead Site
OSWER	Office of Solid Waste and Emergency Response
O&M	Operation and Maintenance

ppm	parts per million
PRG	Preliminary Remediation Goal
PRPs	Potentially Responsible Parties
RME	Reasonable Maximum Exposure
RAO	Remedial Action Objectives
RAPMA	Remedial Action Plan Monitoring Act
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
TAG	Technical Assistance Group
TBC	To Be Considered
TCLP	Toxic Characteristic Leachate Procedure
TSCA	Toxic Substances and Control Act
USC	United States Code
UTL	Upper Tolerance Limit
XRF	X-Ray Fluorescence
µg/dl	micrograms per deciliter

1.0 Introduction

This Final Feasibility Study (FS) for residential soils remediation at the Omaha Lead Site (OLS), Omaha, Nebraska, (the Site) has been prepared under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). The purpose of this Final FS is to assist in the selection of a remedial action for cleanup of contaminated residential soils at the Site. This Final FS has been prepared by Black & Veatch Special Projects Corp. (BVSPC) for the U.S. Environmental Protection Agency (EPA) under the Region 7 Architect & Engineering Services (AES) Contract, Task Order 0031.

1.1 Purpose and Organization of the Report

The FS process is the procedure used to develop and evaluate remedial alternatives prior to selecting a remedial action. The FS report provides documentation for the CERCLA remedy selection process. The goals of this Final FS include the following:

- Providing a framework for evaluating and selecting technologies and remedial actions.
- Satisfying environmental review requirements for a remedial action.
- Complying with administrative record requirements for documentation of remedial action selection.

The purpose of the report is to present and evaluate the remedial alternatives that may be used to address the risks posed by the site. This Final FS, the final remedial investigation, and the risk assessment are significant documents in the Administrative Record which help form the basis from which a Proposed Plan will be developed. This Final FS does not propose a preferred remedial action. In the Proposed Plan, the EPA will indicate which type of cleanup action it prefers and seek public input on what types of cleanup actions should take place. Once the public has had an opportunity to review and comment on the Proposed Plan, a final record of decision (ROD) will be issued by the EPA which formally selects the final remedial action to be conducted at the OLS.

In addition to this introduction, this report is organized into the following sections:

- Section 2 - Potential Applicable or Relevant and Appropriate Requirements
- Section 3 - Identification and Screening of Technologies

- Section 4 - Identification and Screening of Applicable Technologies and Process Options
- Section 5 - Development of Alternatives
- Section 6 - Detailed Evaluation of Remedial Alternatives
- Section 7 - Comparative Analysis of Alternatives

1.2 Background Information

1.2.1 Site Location and Description

The site is comprised of numerous residences and residential-type properties which have been contaminated as a result of air emissions from lead smelting and refining industrial operations (Ref. 1). The ASARCO facility, which operated as a lead smelter/refinery from the 1870s to 1997, was located at 500 Douglas Street at the intersection of I-480 and Abbott Drive in the eastern portion of Omaha, Nebraska or more specifically, at 41° 15' 64" north latitude and 95° 55' 47" west longitude (Ref. 1). The ASARCO property was cleaned up under the State of Nebraska Remedial Action Plan Monitoring Act (RAPMA) program. The former Gould facility, located at 555 Farnam Street, operated as a secondary lead smelter and was acquired and cleaned up by Douglas County, and is now a County park. In addition, lead-based paint and leaded fuel emissions, which would be expected to be found in urban areas such as Omaha, may have contributed to the soil contamination to some extent. Land use within a 4-mile radius of the site area is residential, commercial, and industrial (Ref. 5).

The original boundaries of the OLS focus area were established at the time the Site was listed on the EPA National Priorities List (NPL). During the remedial investigation (RI) in 2004 (Ref. 21), the OLS focus area was expanded to include an area south of L Street to the Sarpy County Line (Harrison Street), an area north of Ames Avenue to Redick Avenue, and an area to the west of 45th Street. The focus area was expanded in 2008 to include an area north to Read Street and west to 56th Street. A map of the present final focus area is presented in Figure 1-1.

1.2.2 Operational History and Waste Characteristics

The ASARCO facility conducted lead refining operations from the early 1870s until 1997. The ASARCO facility was located on approximately 23 acres on the west bank of the Missouri River in downtown Omaha. The former lead refinery processed lead bullion containing recoverable amounts of metals, including gold, silver, antimony, and bismuth.

OLS Focus Area

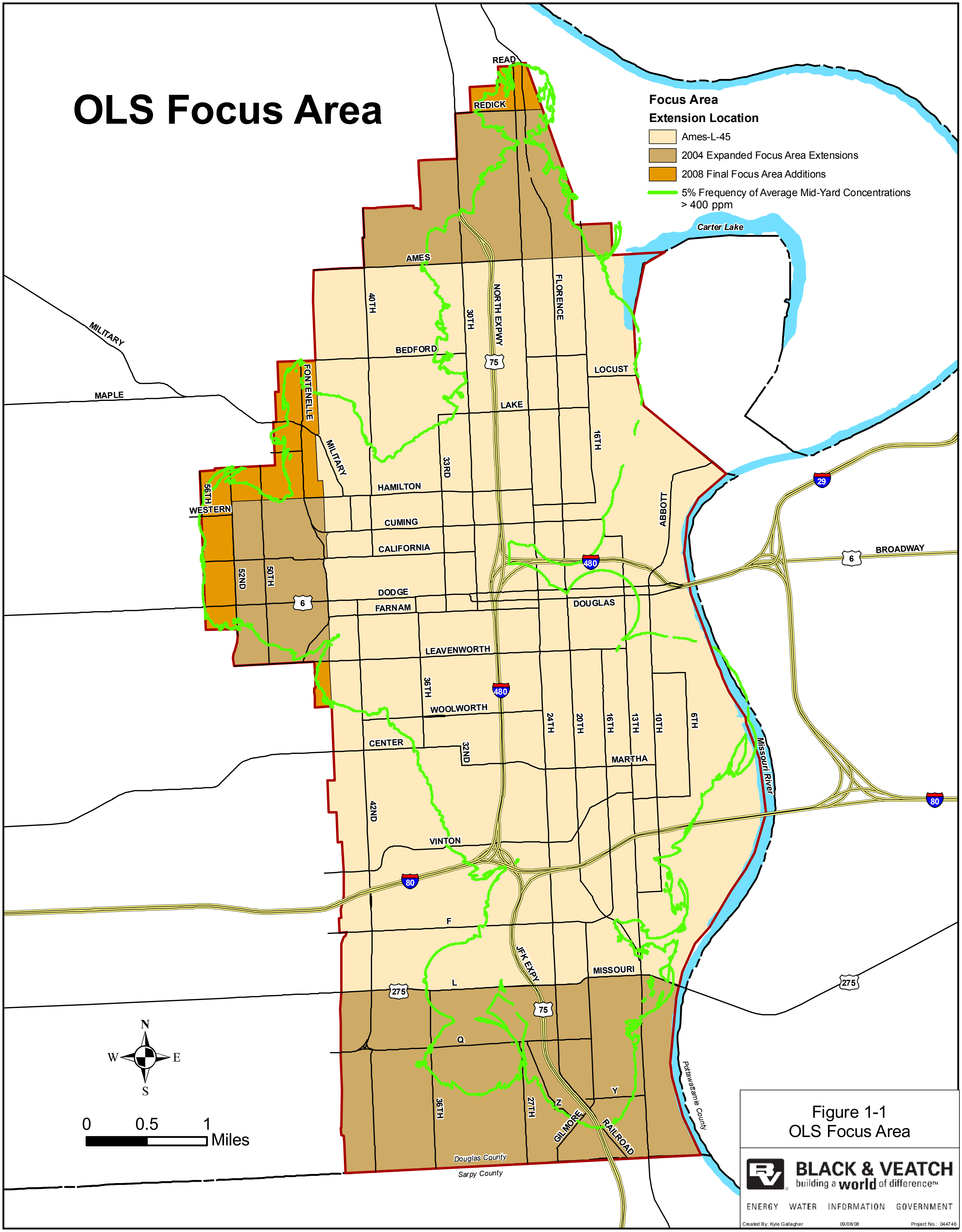

Figure 1-1
OLS Focus Area

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ENERGY WATER INFORMATION GOVERNMENT

Created By: Kyle Gallagher 09/08/08 Project No.: 044746

The refinery process used the traditional pyrometallurgical process, including the addition of metallic and non-metallic compounds to molten lead, and separation of the lead from the other metals and removing impurities. Refined lead and specialty metal by-products such as antimony-rich lead, bismuth, dore (silver-rich material), and antimony oxide were produced at the facility.

The fully refined lead was formed into 100-pound castings or 1-ton blocks. The metal was then shipped to industries requiring lead to produce various products. During the operational period, lead, cadmium, zinc, and arsenic were emitted into the atmosphere through smoke stacks. The pollutants were transported downwind in various directions and deposited on the ground surface due to the combined process of turbulent diffusion and gravitational settling.

A secondary lead smelter was operated at 555 Farnam Street in Omaha from the early 1950s until closing in 1982. Aaron Ferer & Sons, Co. constructed this facility to smelt lead batteries and other scrap lead. The facility was sold to a predecessor of Gould National Batteries in 1963 that operated the facility until closing. Several other businesses in the Omaha area used lead in their manufacturing process.

In 1998 the Omaha City Council solicited assistance from the EPA in addressing problems with lead contamination in the Omaha area. The EPA initiated the process to investigate the lead contamination in the area under the authority of CERCLA in 1999.

The EPA began sampling residential properties used for licensed child-care services in March 1999. Between March 1999 and February 2009, surface soil samples were collected from 37,076 residential properties. In 2004, BVSPC prepared a Remedial Investigation/Feasibility Study (RI/FS) Report to address the soil contamination at the site. Following preparation of the RI/FS, EPA issued an interim ROD on December 15, 2004. The selected remedy in the interim ROD required the excavation and removal of lead-contaminated soils, backfilling the excavated areas to original grade with clean topsoil, and restoring a grass lawn. Generally the properties that were designated for an interim response included:

- Any residential-type property where at least one non-foundation soil sample exceeded 800 parts per million (ppm) lead;
- Residences with any non-foundation sample exceeding 400 ppm lead where a child identified with an elevated blood lead level resides; and
- Child-care facilities and other high child-impact areas with any non-foundation sample exceeding 400 ppm lead.

When a remedial response action was initiated at a property meeting any of the above criteria, soil excavation and replacement were performed in all portions of the property where soils concentrations of 400 ppm or higher were detected, including drip zones. As of February 2009, the EPA has completed soil remediation at 4,611 properties at the OLS.

The interim remedy now underway also includes stabilization of deteriorating exterior lead based paint (LBP) in cases where the continued effectiveness of the remedy is threatened because remediated soils could become recontaminated by small paint particles mixing with soil. Currently, lead levels in exterior mid-yard samples must exceed the soil action levels specified in the interim ROD for the property to be potentially eligible for stabilization of deteriorating LBP. If the soil action levels are exceeded at a property, then structures on that property are potentially eligible for stabilization of deteriorating LBP based upon the results of a LBP assessment. The Interim ROD did not specify quantitative criteria for deteriorated LBP that would be used as an action level to determine eligibility for paint stabilization. Instead, EPA intended that the criteria to be used to determine eligibility for LBP stabilization would be developed during implementation of the interim remedial action. Until criteria are finalized, properties are being prioritized for LBP stabilization based upon the most severe deteriorating LBP problem detected during the screening and the presence of children under the age of seven. As of February 2009, LBP assessments had been performed on structures at 2,894 properties.

The EPA and the City of Omaha Lead Hazard Control Program (LHCP) are performing paint stabilization at homes where the remediated soils could become recontaminated by deteriorating LBP particles mixing with the soil. Lead-safe procedures are used to prepare the deteriorated surfaces, followed by priming and painting of all previously painted surfaces on eligible structures. Yard surfaces are vacuumed using high efficiency particulate air (HEPA) fitted equipment to remove visible paint chips following stabilization. The LBP stabilization program was initiated by the Omaha LHCP in 2007. EPA and LHCP continued LBP stabilization in 2008. As of February 2009, EPA contractors had completed LBP stabilization at 930 properties and Omaha LHCP contractors had completed stabilization at 257 properties.

1.2.3 Nature and Extent of Contamination

There are approximately 39,775 properties located in the final OLS focus area that are eligible for sampling. Between March 1999 and February 2009, surface soil samples were collected from 34,565 residential and residential-type properties within the OLS final focus area and 2,511 properties outside the final focus area and analyzed for lead. Jacobs Engineering conducted sampling between March 1999 and July 2000, and since then the sampling has been conducted by BVSPC. The properties sampled are relatively evenly distributed throughout the final focus area at the site with elevated lead concentrations in surface soil throughout the study area. At the time this Final FS Report was prepared, soil samples had not been collected from the western and northern areas which were added to the expanded focus area in 2008 to become the final focus area.

Of the 37,076 properties sampled in the investigation, 8,552 properties had at least one non-foundation sample with a total lead concentration between 400 ppm and 800 ppm and 4,144 properties had at least one non-foundation sample with a total lead concentration greater than or equal to 800 ppm, which is the lead concentration that triggers a response under the Interim ROD. A total of 4,611 properties have been remediated as of February 2009. Of the sampled properties, 8,085 properties [(8,552 + 4,144) – 4,611] with lead concentrations above 400 ppm remain to be remediated if a final action level of 400 ppm is selected by EPA in the Final ROD. Of the 5,210 properties that have not been sampled, it is estimated an additional 1,881 properties will need to be remediated if an action level of 400 ppm is selected by EPA based on the percentage of sampled properties that contained lead concentrations above 400 ppm.

Data from the 2004 RI Report indicated that the highest lead concentrations were expected to be along the direction of prevailing wind. The Final RI results appear to support this assertion because most of the homes with soil-lead concentrations exceeding 400 ppm are concentrated along the prevailing wind directions. An analysis of the Final RI results is presented in Section 5.0 of the Final RI report (Ref 31). An earlier investigation (Ref. 29) of subsurface soil-lead concentrations indicated that the lead has not generally migrated beyond the top 2-12 inches of soil. Conditions within the soil are not conducive to further migration.

1.2.4 Contaminant Fate and Transport

Early investigations at the OLS found evidence of high lead concentrations in surface soils along the corridors of the prevailing wind currents that pass through downtown Omaha. At the same time, two industrial properties on the east side of downtown Omaha were being investigated as possible sources of the contamination. The conclusions of these investigations demonstrated that the contamination was deposited from air currents transporting industrial emissions generated at the east edge of downtown, along the Missouri River and traveling outward. These potential sources have been closed and no other potential industrial sources of lead-contamination that could have widespread influence have been identified to date.

Investigations conducted at the site have studied potential migration of lead contamination from surface to subsurface soils. Investigations of soil chemistry and lead concentrations in subsurface soils at the site have indicated that the lead contamination at the site is concentrated in the top 12 inches of soil. Lead was detected in 511 surface samples where subsurface samples were collected at the same location. The number of samples in which lead was detected decreased at each downward interval. The average, maximum, and median lead concentrations also decreased as depth increased, indicating only minor migration downward from surface soils. These results led the EPA to discontinue depth sampling.

Additional migration of contaminants on the site may occur through wind, surface water erosion and human activity.

1.2.5 Baseline Risk Assessment

The BHHRA for the OLS was prepared by the Syracuse Research Corporation (Ref. 30). The purpose of the BHHRA is to characterize the risks to area residents, both now and in the future, from site-related contaminants present in environmental media, assuming that no steps are taken to remediate the environment or to reduce human contact with contaminated environmental media. The results of the final assessment are intended to help inform risk managers and the public about potential human risks attributable to site-related contaminants and to help determine where there is a need for action at the site.

The environmental medium of chief concern is surface soil that has been impacted by the wet or dry deposition of metal-containing airborne particulates released from historic lead smelting and refining operations. The human population of chief concern is residents in the area of the site, now or in the future, including both children and adults. Residents might be exposed to smelter-related contaminants in site soils by a number of different pathways, including ingestion, inhalation, and dermal contact with contaminated soil or dust, and ingestion of home-grown produce that may have taken up contaminants from the soil.

Chemicals of Potential Concern (COPCs) are chemicals which exist in the environment at concentration levels that might be of potential health concern to humans and which are or might be derived, at least in part, from site-related sources. The chief COPC at this site is lead. However, several other chemicals were identified that might also be of potential concern to humans, including the following: aluminum, antimony, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, thallium, vanadium, and zinc.

1.2.5.1 Risks from Exposure to Lead

The population of chief concern for lead exposure is young children (age 0-84 months). This is because young children tend to have higher intakes of lead than adults, tend to absorb more lead than adults, and are inherently more sensitive to lead than adults. If environmental exposures to lead in a residential area are acceptable for young children, exposures are usually also acceptable for older children and adults, including pregnant women.

In addition to these exposures to smelter-related releases of lead, children may also be exposed to lead from other sources as well. This includes lead from leaded paint, as well as lead in drinking water and food from grocery stores. Because risk from lead depends on exposure from all of these sources, these exposure pathways are also included in the risk evaluation for lead.

The EPA identified 10 µg/dL as the concentration level at which effects begin to occur that warrant avoidance. For convenience, the probability that an observed blood lead value will exceed 10 µg/dL is referred to as P10. The EPA has established a health-based goal there should be no more than a 5% chance that a child will have a blood lead value above 10 µg/dL. That is, if P10 is ≤ 5%, risks from lead are considered acceptable.

The EPA has developed a mathematical model for evaluating lead risks to residential children. This model is referred to as the Integrated Exposure Uptake Biokinetic Model (IEUBK) model. This model requires as input data on the levels of lead in all potentially contaminated environmental media (soil, dust, water, air, diet) at a specific location, and on the amount of these media taken in (by ingestion or inhalation) by a child living at that location. Given these inputs, the model calculates an estimate of the distribution of blood lead values that might occur in a population of children exposed to the specified conditions, including the value of P10.

The results of the lead risk evaluation include the following key points:

- Of the 28,478 properties evaluated, a total of 19,445 homes (68%) are predicted to have P10 values at or below the health-based goal of 5%, and 9,033 properties (32%) have values that exceed the goal.
- Of these 9,033 properties, 3,177 have P10 values between 5% and 10%, 3,051 properties have P10 values between 10% and 20%, and 2,805 properties have P10 values greater than 20%.
- The location of properties with P10 values greater than the health-based goal of 5% were widespread across the OLS final focus area and were frequently found within all zip codes, with the exception of 68117 (which only had 2 properties).

These results indicate that a number of homes or parcels within the final focus area have soil lead levels that are of potential health concern to children who may reside there, now or in the future.

1.2.5.2 Risks from Non-Lead Contaminants

Although lead was the primary contaminant released to the environment from the historic operation of the smelters in the OLS, other metal and metalloid contaminants may also have been released. Exposure of residents (adults and children) to non-lead chemicals of potential concern in site soils and dusts was evaluated on a property-by-property basis.

Exposure was calculated in accord with standard equations recommended by EPA. In brief, the amount of chemical ingested or absorbed per day from each medium was calculated from information on the concentration of the chemical in the medium and the amount of medium that is ingested or contacted. Because there are usually differences between individuals in the level of exposure due to differences in intake rates, body weights, exposure frequencies, and exposure durations, calculations were performed for individuals that are "average" or are otherwise near the central portion of the range, and on intakes that are near the upper end of the range (e.g., the 95th percentile). These two exposure estimates are referred to as Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME), respectively. Values of CTE and RME parameters for soil and dust were in accord with standard default values recommended by EPA for evaluation of residents.

The estimated non-cancer risks from most COPCs in surface soils for residential CTE and RME scenarios, including both children (age 0-6 years) and adults (age 7-30 years), are below a level of potential concern (Hazard Quotient (HQ) ≤ 1) for both child and adult residents. An exception is arsenic, which results in an HQ > 1 at about 11 percent of the properties. In addition, there are a small number of properties (< 1 percent of the total) where antimony, mercury and/or thallium yield HQ values above 1. Summation of non-cancer HQ values for chemicals that act on the same target tissue does not result in a substantial increase in non-cancer risk at most properties.

The only COPC at this site that is carcinogenic by the oral or dermal route is arsenic. As seen, estimated cancer risks to CTE residents are within EPA's target risk range (1E-06 to 1E-04) at all properties. Estimated risks to RME residents are also within EPA's target risk range at most properties, although risks exceed 1E-04 at 141 locations (5% of the properties with data). The excess individual lifetime cancer risks at these 141 properties range from 1E-04 to 1E-03.

2.0 Potential Applicable or Relevant and Appropriate Requirements

Pursuant to Section 121(d) of CERCLA, 42 United States Code (U.S.C.) § 9621(d), remedial actions shall attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment and control of further releases which, at a minimum, assures protection of human health and the environment. In addition, remedial actions shall, upon their completion, reach a level or standard of control for such hazardous substances, pollutants, or contaminants which at least attain legally applicable or relevant and appropriate federal standards, requirements, criteria, or limitations, or any promulgated standards, requirements, criteria, or limitations under a state environmental or facility siting law that is more stringent than any federal standard. These are termed as applicable or relevant and appropriate requirements (ARARs). In instances where the remedial actions do not achieve ARARs, the EPA must provide the basis for a waiver. An ARARs waiver is not contemplated for any of the alternatives evaluated in this Final FS.

Applicable requirements are those standards, requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. Relevant and appropriate requirements are those standards, requirements, criteria, or limitations promulgated under federal or state law that address problems or situations similar to those encountered at the CERCLA site, and therefore, are well suited for that site. Although not legally applicable, these requirements may nonetheless be relevant and appropriate for a particular CERCLA site.

The EPA Region 7 and the State of Nebraska determine which requirements are ARARs by considering the type of remedial actions contemplated, the hazardous substances present, the waste characteristics, the physical characteristics of the site, and other appropriate factors. Only the substantive portions of the requirements need to be followed for on-site actions; CERCLA procedural and administrative requirements require safeguards similar to those provided under other laws. Under Section 121(e) of CERCLA, 42 U.S.C. § 9621(e), and the National Oil and Hazardous Substances Contingency Plan (NCP), 40 Code of Federal Regulations (C.F.R.) § 300.400(e), federal state, and local permits are not required for the portions of CERCLA cleanups that are conducted entirely on-site, as long as the actions are selected and carried out in compliance with Section 121 of CERCLA.

There are three types of ARARs. The first type includes chemical-specific requirements. These ARARs set limits on concentrations of specific hazardous substances, pollutants, and contaminants in the environment. Examples of these types of ARARs are drinking water standards and ambient water quality criteria. Frequently, the chemical-specific ARARs constitute a basic level of protectiveness for certain hazardous substances. However, for some media, chemical-specific ARARs are not available.

A second type of ARAR includes location-specific requirements that set restrictions on certain types of activities such as those in wetlands, floodplains, and historic sites. Location specific ARARs generally apply to most alternatives under consideration because they are based on the location of the site.

The third type of ARAR includes action-specific requirements. These are technology-based restrictions that are triggered by the type of remedial action under consideration. Examples of action-specific ARARs are Resource Conservation and Recovery Act (RCRA) regulations for waste treatment, storage and disposal. Action-specific ARARs may vary depending on the remedial alternative under consideration. Potential federal and state action-specific ARARs are identified in Section 6 as each alternative is subjected to detailed analysis.

The potential federal and state chemical and location-specific ARARs for the Omaha Lead site Final FS, identified by the EPA, respectively, are presented in Tables 2-1 through 2-4 at the end of this section. These tables cite the requirements identified, state whether the requirements are applicable or relevant and appropriate, or to be considered and summarize the substantive standards to be met.

To be considered (TBC) criteria consist of advisories, criteria, or guidance that were developed by the EPA, other federal agencies, or states that may be useful in developing CERCLA remedies. TBCs do not meet the definition of ARARs, but may be necessary to determine what is protective and are useful when ARARs are not available.

2.1 Potential Chemical-Specific ARARs

The potential chemical-specific ARARs identified for this site relate to protection of human health from exposure to residential property soils because of the unacceptable risks associated with exposure of humans, particularly children under 7 years old, to contaminated soils. As discussed above, the principal contaminant is lead from smelter related operations.

Federal and Nebraska governments have not promulgated standards, requirements, criteria or limitations to control the level of hazardous substances, pollutants, or contaminants in the soil at residential properties. Therefore, the alternatives evaluated for this FS do not have chemical-specific ARARs for contaminated soils in residential properties. However, the risk assessment and other federal and state guidance are available to evaluate each alternative for its ability to achieve a basic level of protectiveness for hazardous substances in soil. These documents are listed in Table 2-1 under the category “To Be Considered”. Once contaminated soil has been removed from residential properties and disposed, Nebraska Department of Environmental Quality (NDEQ) Title 117 regulations, “Surface Water Quality Standards”, or similar requirements in the state where disposal occurs, would potentially establish effluent limits on the discharge of pollutants in storm water runoff from the soil disposal area.

The EPA regulations under the Toxic Substances and Control Act (TSCA) concerning lead hazards at residential properties are found in the Code of Federal Regulations (CFR) at 40 CFR Part 745. The regulations contain requirements preventing LBP poisoning in certain residential properties. The regulations define the maximum lead concentrations in dust samples from floors and window sills that present a dust-lead hazard. The regulation specifies that a dust-lead hazard is present in a residential dwelling when the weighted arithmetic mean lead loadings for all single surface or composite samples of floors and interior window sills are equal to or greater than 40 $\mu g/ft^2$ for floors and 250 $\mu g/ft^2$ for interior window sills, respectively.

The regulations also define when a soil lead hazard is present at a residential property. A soil lead hazard is present in a play area when the soil-lead concentration from a composite play area sample of bare soil is equal to or greater than 400 ppm or in the rest of the yard when the arithmetic mean lead concentration from a composite sample is equal to or greater than 1,200 ppm.

The regulations also impose requirements on the seller or lessor of target housing to disclose to the purchaser or lessee the presence of any known lead-based paint hazards, provide available records and reports, and attach specific disclosure and warning language to the sales or leasing contract.

Tables 2-1 and 2-2 identify the potential federal and state chemical-specific ARARs for the Omaha Lead Site.

2.2 Potential Location-Specific ARARs

Physical characteristics of the site may influence the type and location of remedial responses considered for this FS. Potential federal and state location-specific ARARs, presented in Tables 2-3 and 2-4, relate to historic preservation, fish and wildlife coordination procedures, wetlands protection, flood plain protection, and work in navigable waters. Additionally, NDEQ siting statues and location restriction regulations in Title 128 “Nebraska Hazardous Wastes Regulations” and Title 132 “Integrated Solid Waste Management Regulations” may be appropriate for consideration if siting a soil repository is included in a remedial alternative. The final determination of location-specific ARARs will depend upon detailed design and siting decisions made during remedial design.

2.3 Summary of ARARs

Contamination in the residential soils at the Omaha Lead Site poses a potential threat to human health. CERCLA requires that any remedial action selected shall attain a degree of cleanup that, at a minimum, assures protection of human health and the environment.

For this Final FS, the EPA and the NDEQ have determined that chemical specific ARARs are not available, but that the BHHRA and the EPA and state guidance are to be used for the evaluation and comparison of the remedial alternatives herein. Based on present knowledge, protection of human health can be assessed for remedial alternatives by considering the levels of protectiveness described in the BHHRA. Public health action-specific ARARs related to remedial actions are identified and considered once the alternatives have been developed in Section 6.

Table 2-1
Potential Federal Chemical-Specific ARARs

	Citations	Prerequisite	Requirement
A. Applicable Requirements	None		
B. Relevant and Appropriate	None		
1. Safe Drinking Water Act	National Primary Drinking Water Standards 40 C.F.R. Part 141 Subpart B and G	Establish maximum contaminant levels (MCLs), which are health based standards for public waters systems.	Required to meet MCLs.
2. Safe Drinking Water Act	National Secondary Drinking Water Standards 40 C.F.R. Part 143	Establish secondary maximum contaminant levels (SMCLs) which are non-enforceable guidelines for public water systems to protect the aesthetic quality of the water.	SMCLs may be relevant and appropriate if groundwater is used as a source of drinking water.
3. Safe Drinking Water Act	Maximum Contaminant Level Goals (MCLGs) 40 C.F.R. Part 141, Subpart F	Establishes non-enforceable drinking water quality goals.	The goals are set to levels that produce no known are anticipated adverse health effects. The MCLGs include an adequate margin of safety.
4. Clean Water Act	Water Quality Criteria 40 C.F.R. Part 131 Water Quality Standards	Establishes non-enforceable standards to protect aquatic life.	May be relevant and appropriate to surface water discharges, or may be a TBC.
5. Clean Air Act	National Primary and Secondary Ambient Air Quality Standards 40 C.F.R. Part 50	Establishes standards for ambient air quality to protect public health and welfare.	Requires air emissions to meet clean air standards.
6. National Pollutant Discharge Elimination System (NPDES)	40 CFR Parts 122, 125	Determines maximum concentrations for the discharge of pollutants from any point source into waters of the Untied States.	Requires non point discharge to meet NPDES permit standards.
B. To Be Considered			
1. EPA Revised Interim Soil-lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities	Office of Solid Waste and Emergency Response (OSWER) Directive 9355.4-12, August 1994 OSWER Directive 9200.4-27P, August 1988	Establishes screening levels for lead in soil for residential land use, describes development of site-specific preliminary remediation goals, and describes a plan for soil-lead cleanup at CERCLA sites.	This guidance recommends using the EPA Integrated Exposure Uptake Biokinetic Model (IEUBK) on a site-specific basis to assist in developing cleanup goals.
2. EPA Strategy for Reducing Lead Exposures	EPA, February 21, 1991	Presents a strategy to reduce lead exposure, particularly to young children.	The strategy was developed to reduce lead exposure to the greatest extent possible. Goals of the strategy are to 1) significantly reduce the incidence above 10 µg Pb/dL in children; and 2) reduce the amount of lead introduced into the environment.
3. Human Health Risk Assessment		Evaluates baseline health risk due to current site exposures and establish contaminant levels in environmental media at the site for the protection of public health because ARARs are not available for contaminants in soils.	The risk assessment approach using this data should be used in determining cleanup levels because ARARs are not available for contamination in soils.

Table 2-1, Continued
Potential Federal Chemical-Specific ARARs

	Citations	Prerequisite	Requirement
4. Superfund Lead-Contaminated Residential Sites Handbook	EPA OSWER 9285.7-30, August 2003.	Handbook developed by EPA to promote a nationally consistent decision making process for assessing and managing risks associated with lead contaminated residential sites across the country.	Use the available data to determine what has been done nationally to assess local risks.
5. Toxic Substances and Control Act (TSCA)	Lead-Based Paint Poisoning Prevention in Certain Residential Structures 40 CFR Part 745	Establishes EPA requirements for addressing lead-based paint poisoning prevention in certain residential structures.	Identifies and sets requirements for maximum amount of lead in dust samples collected from windows sills and floors. Impose requirements on the seller or lessor of target housing to disclose to the purchaser or lessee the presence of any known lead-based paint hazards, provide available records and reports, and attach specific disclosure and warning language to the sales or leasing contract.
6. Lead-Based Paint Poisoning Prevention Act; Residential Lead-Based Paint Hazard Reduction Act	Lead-Based Paint Poisoning Prevention in Certain Residential Structures 24 CFR Part 35	Establishes HUD requirements for addressing lead-based paint poisoning prevention in certain residential structures.	Identifies and sets requirements for maximum amount of lead in dust samples collected from windows sills, window troughs and floors. Establishes requirements for seller or lessor of target housing to disclose the presence of any known lead-based paint and/or lead-based paint hazards to purchaser or lessee and provide available records and reports. Sets requirements for amount of lead in paint.

Table 2-2
Potential State Chemical-Specific ARARs

	Citations	Prerequisite	Requirement
A. Applicable Requirements	None		
B. Relevant and Appropriate Requirements			
1. Nebraska Surface Water Quality Standards	Nebraska Department of Environmental Quality - Title 117	Regulates the discharge of constituents from any point source, including stormwater, to surface waters of the state. Provides for maintenance and protection of public health and aquatic life uses of surface water and groundwater.	Required for protection of wetlands, streams, lakes, and impounded waters from the runoff from toxic discharges.
2. Nebraska Safe Drinking Water Act	Nebraska Rev. Stat. 71-5301 et seq. and Title 179, Chapter 2	Establishes drinking water standards (MCLs), monitoring standards, and other treatment requirements.	Required to meet MCLs.
3. Nebraska Air Pollution Control Rules and Regulations	Nebraska Department of Environmental Quality - Title 129	Establishes Ambient Air Quality Standard and regulates emissions of contaminants into the air.	Required to meet ambient air quality standards.
C. To Be Considered			
1. Human Health Risk Assessment Report (HHRA)		Evaluates baseline health risk due to current site exposures and established contaminant levels in environmental media at the site for the protection of public health.	The risk assessment approach using this data should be used in determining cleanup levels because ARARs are not available for contaminants in soils.
2. Nebraska Voluntary Cleanup Program (VCP) Guidance	Nebraska Voluntary Cleanup Program Guidance, NDEQ, October 2008	Establishes cleanup levels or remediation goals for sites that are remediated under the Nebraska Voluntary Cleanup Program.	Table in Attachment 2-6 contains VCP Remediation Goal for lead in residential soil of 400 mg/kg based on direct contact exposure pathway.

Table 2-3
Potential Federal Location-Specific ARARs

	Citations	Prerequisite	Requirement
A. Applicable Requirements			
1. Historic project owned or controlled by a federal agency	National Historic Preservation Act: 16 U.S.C. 470, et.seq; 40 C.F.R. § 6.301; 36 C.F.R. Part 1.	Property within areas of the Site is included in or eligible for the National Register of Historic Places.	The remedial alternatives will be designed to minimize the effect on historic landmarks.
2. Site within an area where action may cause irreparable harm, loss, or destruction of artifacts.	Archeological and Historic Preservation Act; 16 U.S.C. 469, 40 C.F.R. 6.301.	Property within areas of the site contains historical and archaeological data.	The remedial alternative will be designed to minimize the effect on historical and archeological data.
3. Site located in area of critical habitat upon which endangered or threatened species depend.	Endangered Species Act of 1973, 16 U.S.C. 1531-1543; 50 C.F.R. Parts 17; 40 C.F.R. 6.302. Federal Migratory Bird Act; 16 U.S.C. 703-712.	Determination of the presence of endangered or threatened species.	The remedial alternatives will be designed to conserve endangered or threatened species and their habitat, including consultation with the Department of Interior if such areas are affected.
4. Site located within a floodplain soil.	Protection of Floodplains, Executive Order 11988; 40 C.F.R. Part 6.302, Appendix A.	Remedial action will take place within a 100-year floodplain.	The remedial action will be designed to avoid adversely impacting the floodplain in and around the soil repository to ensure that the action planning and budget reflects consideration of the flood hazards and floodplain management.
5. Wetlands located in and around the soil repository.	Protection of Wetlands; Executive Order 11990; 40 C.F.R. Part 6, Appendix A.	Remedial actions may affect wetlands.	The remedial action will be designed to avoid adversely impacting wetlands wherever possible including minimizing wetlands destruction and preserving wetland values.
6. Structures in waterways in and around the soil repository.	Rivers & Harbors Act, 33 C.F.R. Parts 320-330.	Placement of structures in waterways is restricted to pre-approval of the U.S. Army Corps of Engineers.	The remedial action will comply with these requirements.

Table 2-3 (Continued)
Potential Federal Location-Specific ARARs

	Citations	Prerequisite	Requirement
7. Water in and around the soil repository.	Clean Water Act, (Section 404 Permits) Dredge or Fill Substantive Requirements, 33 U.S.C. Parts 1251-1376; 40 C.F.R. Parts 230,231.	Capping, dike stabilization construction of berms and levees, and disposal of contaminated soil, waste material or dredged material are examples of activities that may involve a discharge of dredge or fill material. Four conditions must be satisfied before dredge and fill is an allowable alternative.	1. There must not be a practical alternative. 2. Discharge of dredged or fill material must not cause a violation of State water quality standards, violate applicable toxic effluent standards, jeopardize threatened or endangered species or injure a marine sanctuary. 3. No discharge shall be permitted that will cause or contribute to significant degradation of the water. 4. Appropriate steps to minimize adverse effects must be taken. Determine long- and short-term effects on physical, chemical, and biological components of the aquatic ecosystem.
8. Area containing fish and wildlife habitat in and around the soil repository.	Fish and Wildlife Conservation Act of 1980, 16 U.S.C. Part 2901 et seq.; 50 C.F.R. Part 83 and 16 U.S.C. Part 661, et seq. Federal Migratory Bird Act, 16 U.S.C. Part 703.	Activity affecting wildlife and non-game fish.	Remedial action will conserve and promote conservation of non-game fish and wildlife and their habitats.
B. Relevant and Appropriate Requirements			
1. 100-year floodplain	Location Standard for Hazardous Waste Facilities- RCRA; 42 U.S.C. 6901; 40 C.F.R. 264.18(b).	RCRA hazardous waste treatment and disposal.	Facility located in a 100-year floodplain must be designed, constructed, operated, and maintained to prevent washout during any 100-year/24 hour flood.
C. To Be Considered	None		

Table 2-4
Potential State Location-Specific ARARs

	Citations	Prerequisite	Requirement
A. Applicable Requirements			
1. Solid waste management regulations	Nebraska Department of Environmental Quality – Title 132 – Integrated Solid Waste Management Regulations	Requires permits for proper identifications and disposal of solid waste in municipal solid waste disposal areas.	Requires specified procedures for the location, design, operation, and ground water monitoring, closure, disposal, post closure, and financial assurance for solid waste disposal facilities. Requires specific procedures for special waste management.
2. Siting Procedures and Policies	Nebraska State Statutes 13-1701 to 13-1714	Policies and procedures are required in order to get approval for a solid waste disposal.	Requires approvals by local jurisdictions prior to the development of a site as a solid waste disposal area.
3. Flood-plain Management Act	Nebraska State Statues 13-1001 to 31-1031 and Title 258	Policies and procedures for construction or disposal in flood plains.	Governs certain activities occurring in flood plains
4. Nebraska Nongame and Endangered Species Act	Nebraska State Statues 37-801 to 37-811 and Title 163 Chapter 4, 012	Policies and procedures to ensure protection of Threatened and Endangered species Requires consultation with Nebraska Game and Parks Commission.	Requires actions which may affect threatened or endangered species and their critical habitat.
B. Relevant and Appropriate Requirements	None		
C. To Be Considered.			
1. Hazardous waste handling, transport and disposal regulations	Nebraska Department of Environmental Quality – TITLE 128 Nebraska Hazardous Waste Regulations	Requires operating permits for proper identifications, handling, transport, and disposal of hazardous materials.	Supplement the federal RCRA regulations and define state permitting requirements.
2. Siting Procedures and Policies	Nebraska State Statutes 81-1521.08 to 81-1521.23	Policies and procedures are required in order to get approval for a hazardous waste management facility.	Requires approvals by local jurisdictions prior to the development of a site as a hazardous waste management facility.

3.0 Remedial Action Objectives and Action Levels

In Section 1.0, the problem of residential soil contamination from lead refining/processing in Omaha was discussed. The purpose of this section is to develop goals for the remedial action and to present remedial technologies that can be applied to residential soils to meet the goals. Section 4.0 discusses the remedial alternatives that have been assembled using these technologies.

3.1 Remedial Action Objectives

This section defines the goals of the remedial action, and identifies the remedial action objectives (RAOs) for residential soils at the OLS. RAOs consist of quantitative goals for reducing human health and environmental risks and/or meeting established regulatory requirements at Superfund sites. Site characterization data, BHHRA results, ARARs, and other relevant site information are used to develop RAOs.

Based on current site data and evaluations of potential risk, lead was identified as being a contaminant of concern and the primary cause of human health risk at the site is through direct ingestion.

One RAO has been developed for residential soils in Omaha:

- Reduce the risk of exposure of young children to lead such that an individual child, or group of similarly exposed children, have no greater than a 5 percent chance of having a blood-lead concentration exceeding 10 micrograms per deciliter (ug/dL).

3.2 Development of Preliminary Remediation Goals and Action Level

3.2.1 Preliminary Remediation Goals for Protection of Children

The Syracuse Research Corporation prepared an October 16, 2008 memorandum that developed preliminary remediation goals (PRGs) for protection of children from lead in surface soils at the OLS. This memorandum is presented in Appendix C of this Final FS report. The PRG for lead in soil is based on the average mid-yard concentration of lead in a residential property that is associated with no more than a 5 percent chance that a child (age 0-84 months of age) living at the property will have a blood lead level that exceeds 10 µg/dL. The probability of having a blood lead level above 10 µg/dL is referred to as P10. The RAO for the final remedy at the OLS corresponds to this goal of less than a 5 percent probability for a child or group of similarly exposed children to have blood lead levels exceeding 10 µg/dL following completion of the remedial action.

The IEUBK model was used to determine the concentration of lead in soil that yields a P10 value which meets EPA's RAO for the OLS (P10 < 5 percent). PRGs were determined based on analysis of the fine-grained soil (< 250 μm) using a laboratory analytical method such as Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) as well as analysis of the bulk soil fraction (< 2 mm) using an X-Ray fluorescence (XRF) instrument. Each soil fraction in combination with a particular analytical method will yield a different PRG, as explained further in the OLS BHHRA (Ref. 30).

The PRG values which are derived from the IEUBK model are somewhat uncertain, due to uncertainty in the true values of the model and input parameters used in the IEUBK model calculation. Two important sources of uncertainty in the development of the PRG values involve uncertainty regarding the true relative bioavailability of soil lead and the relationship between lead in indoor dust and outdoor soil. Both of these factors serve as inputs to the IEUBK model. For the purpose of the PRG evaluation, a series of alternate PRG calculations was performed to evaluate the uncertainty that arises from variation in the relative bioavailability and the relationship between lead in interior dust and outdoor soil. These two factors were varied within a range of possible values, based on the varying results of site-specific investigations previously performed, in order to determine a plausible range of PRGs that would correspond to a P10 of less than 5 percent.

This plausible range of PRGs was calculated separately for analysis of the bulk fraction versus fine fraction of soil, and separately assuming the use of XRF versus ICP-AES analysis. Because the routine decision-making protocol guiding response action at individual properties at the OLS involves analysis of bulk soil samples using an XRF instrument, the PRG range calculated using this combination is of primary interest. Using XRF analysis of bulk soil, the plausible PRGs meeting the RAO for soil at the OLS range from 208 ppm to 366 ppm with a best estimate of 247 ppm. These PRGs are based on average mid-yard lead concentrations.

Since the maximum lead concentration in a single quadrant (not the average mid-yard concentration) is compared to an action level to determine if soil remediation will be conducted at a property, an additional calculation must be performed to determine the average mid-yard concentration that will result at each property following soil remediation. Under the current remedial action at the OLS[1], soil remediation involves removal of soil exceeding 400 ppm from all quadrants and the drip zone at individual properties. Since soils exceeding 400 ppm are removed during remediation, the average mid-yard concentration is greatly reduced at remediated properties. For the purpose of determining the resulting average mid-yard soil lead concentration, it can be assumed that some amount of background soil lead is present in the backfill soil that is used to replace excavated soils exceeding 400 ppm. For this calculation, the background concentration in

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[1] Remedial action under the current Interim Record of Decision is initiated at properties that are determined to be eligible if one or more mid-yard soil lead concentration exceeds the appropriate action level -- 800 ppm for typical properties and 400 ppm for EBL, child-care, and high-child impact properties.

clean soils used for backfill is assumed to be 20 ppm lead. To calculate the average mid-yard concentrations at remediated properties, it is assumed that all quadrants exceeding 400 ppm are excavated and replaced with soil having a lead concentration of 20 ppm.

The average mid-yard lead concentration that would remain following removal of soil in quadrants exceeding 400 ppm was calculated for the 33,331 individual properties that were sampled at the OLS through October 2008. The calculated average mid-yard lead concentration following remediation is then compared to the plausible range of PRGs that have been determined to meet the RAO. Of the 33,331 individual properties sampled at the OLS through October 2008, soil lead levels exceed 400 ppm in at least one mid-yard quadrant at 12,361 properties. Removal of quadrants exceeding 400 ppm at these properties would effectively reduce average mid-yard concentrations to much less than 366 ppm, which is the upper end of the range of plausible PRG values, since the presence of at least one quadrant that has been reduced to 20 ppm would significantly reduce the yard-wide average soil lead concentration. Of the remaining properties which are not eligible for soil remediation (i.e. individual mid-yard concentrations are all less than 400 ppm) average mid-yard lead concentrations are already less than 366 ppm at all but 21 properties. These 21 properties represent less than 0.07 percent of the 33,331 properties sampled at the OLS through October 2008. Based on these occurrences, it can be estimated that 4 additional properties of the 5,210 properties yet to be sampled at the OLS would have average mid-yard lead concentrations exceeding 366 ppm following remediation of eligible properties. This would increase the total number of properties with average mid-yard lead concentrations that do not fall within the plausible PRG range to only 25. Therefore, removing soils that exceed a 400 ppm action level based on individual quadrant mid-yard lead concentrations would reduce soil lead levels at virtually all OLS properties to meet the soil lead RAO.

In almost all cases, selection of a 400 ppm action level, as applied at the OLS, would reduce the residual risk following soil remediation to meet the RAO. During the remedy selection process, EPA may consider other measures to further reduce residual risk at the OLS. For example, EPA may consider additional response at the 25 individual properties that would remain with mid-yard concentrations that slightly exceed the plausible PRG range. In addition, EPA may include various types of institutional controls or other types of non-engineering measures to further control risks associated with lead exposure at all OLS properties. For the purpose of this Final FS, it is assumed that the RAO for soil lead would be met by removing or otherwise preventing exposure to soils exceeding 400 ppm based on measurements of individual quadrants. A 400 ppm soil lead action level for the OLS will be carried forward in this Final FS for development and comparison of remedial alternatives. EPA will select a final action level in the Final ROD following public review and comment on the preferred alternative presented in the Proposed Plan.

3.2.2 Preliminary Remediation Goals for Protection of Excavation Workers

Syracuse Research Corporation also prepared a March 16, 2009 memorandum that developed PRGs for protection of excavation workers from lead in subsurface soils at the OLS. This memorandum is presented in Appendix D of this Final FS report. The value of the PRG depends on the assumed frequency of exposure at the OLS, ranging from 1 day per week up to 5 days per week. The resulting PRG values represent the maximum acceptable average concentration of lead in subsurface soil that a worker may be exposed to in the OLS during a 13-week (91 day) work period. Based on available data on lead concentration values in soil as a function of depth, subsurface lead concentrations tend to be lower than surface concentrations, and all of the average values for lead in soil at various depths are substantially lower than all of the PRGs for an excavation worker, even if exposure is assumed to be very frequent (5 days/week). Based on this, it was concluded that risks to excavation workers in the OLS from exposure to lead in soil are not of significant health concern.

3.2.3 Number of Properties Requiring Remediation

The total number of residential properties that will require soil remediation under this Final FS is estimated at 9,966 properties. This number was determined from the previously sampled properties with lead soil concentrations greater than 400 ppm (12,696 properties) less the 4,611 properties containing lead concentrations properties greater than 400 ppm that have already been remediated. There are a total of 8,085 previously sampled properties with a lead concentration above 400 ppm that need to be remediated. Of the remaining 5,210 properties that have not been sampled, it is estimated that 1,881 will need to be remediated. This assumption is based on the percentage of previously sampled properties that have lead concentrations greater than 400 ppm.

4.0 Identification and Screening of Applicable Technologies and Process Options

General response actions have been identified to satisfy the RAO established for the site. The general response actions include no-action, institutional controls, excavation, disposal, capping, and chemical treatment. Remedial technologies and process options have been selected and screened for the general response actions. Remedial technologies include excavation and removal, capping, and chemical treatment. Process options for excavation and removal involve partial or complete excavation of a property. Capping would involve placing a protective barrier over the contaminated soil using soil, geosynthetics, or vegetation. Chemical treatment would involve immobilizing the lead by applying a stabilization agent to the soil. The screening evaluation was based on technical and administrative implementability, effectiveness, and relative cost. The screening process for the remedial technologies and process options is discussed in this section.

4.1 Institutional Controls

Institutional controls (IC) are non-engineered instruments, such as administrative and/or legal controls, that help to minimize the potential for human exposure to contamination and/or protect the integrity of a remedy. ICs work by limiting land or resource use and by providing information that helps modify or guide human behavior at a site. ICs are developed to reduce or prevent exposure to contamination in soil and dust and to protect the remedy where wastes are left in place. Therefore, ICs are included in this section along with engineered technologies. The following categories of IC mechanisms are discussed in this Final FS: Proprietary Controls, Government Controls, Enforcement and Permit Tools with IC Component, and Informational Devices.

4.1.1 Proprietary Controls

Proprietary controls are based on State law and use a variety of tools to prohibit activities that may compromise the effectiveness of the remedy or restrict activities or future uses of resources that may result in unacceptable risk to human health or the environment. They may also be used to provide site access for operation and maintenance activities. The most common examples of proprietary controls are easements and restrictive covenants that control certain uses of the property. This type of IC "runs with the land" and is binding on subsequent purchasers of the property. This type of IC is not presently being used to control activities at the OLS.

4.1.2 Government Controls

Government controls impose land or resource restrictions using the authority of an existing unit of government. Typical examples of government controls include zoning, building codes, and other ordinances. Zoning is an exercise of police power, which is defined as the authority of the government to exercise controls to protect the public's health, safety and welfare. Zoning ordinances typically consist of a map indicating the various land use zones in the community and set forth the regulations for the development of land. Zoning can serve as an effective IC when a large number of properties are affected by the remedy.

Local governments may also adopt building codes or other ordinances to protect the public. They may require property owners seeking a building permit for construction activities in a particular area to be notified of contamination and informed of any relevant management requirements for the contamination. Such measures could be used to prohibit certain types of construction (such as excavation) that would result in unacceptable exposures.

Other types of local ordinances could address requirements for property owners that rent properties to ensure that their properties do not pose an unacceptable health risk to their tenants. Local ordinances could also require lead hazards at properties to be mitigated or abated.

4.1.3 Enforcement and Permit Tools with IC Components

Enforcement and permit tools with IC components include orders, permits, and consent decrees. These instruments may be issued unilaterally or negotiated to compel a party to limit certain site activities as well as ensure the performance of affirmative obligations. Enforcement orders could potentially be used to enable EPA to obtain access to properties to sample the soil.

4.1.4 Informational Devices

Informational devices provide information or notification about whether a remedy is operating as designed or that residual or contained contamination may remain on site. Typical information devices include state and local registries, deed notices, advisories, and public health education activities.

Deed notices are filed in the local land records but, unlike proprietary controls, are not intended to convey an interest in real property. Consequently, such notices do not serve as enforceable restrictions on the future use of the property. However, a deed notice does provide notice to anyone reviewing the chain of title that the property either is, or was, contaminated and whether there may be other restrictions on the property.

The state or local governments could establish and maintain a registry that contains information concerning the properties at the site such as the status of soil sampling, soil remediation, LBP assessments, LBP stabilizations, or LBP certifications indicating that the property does not present a hazard.

4.2 Public Health Education

Public health education involves distribution of information about metal exposure to people in areas affected by metals in soils. Education can alert residents to the issues of exposure routes, sources of metals, people at risk, and preventative measures. Educating citizens living in residences with metals in soils can be used as a supplemental action to reduce exposure and decrease risk. Specific education activities that may prove effective at reducing exposures include:

- Providing community education through meetings and literature.
- Distributing fact sheets containing information on controlling lead exposure.
- Establishing public information centers that may distribute written information on controlling lead hazards or respond to questions from the public concerning lead hazards.
- Providing lead hazard information to the public through public media (television, radio, newspapers, internet).

Education, especially if it is the primary means of reaching remediation goals, must be an ongoing process. A limitation to public education is that educational programs require not only the cooperation of public health institutions, but public cooperation as well, to be successful. In addition, public concern and awareness may wane with time unless a continual mechanism of public education is in place. Additionally, education activities conducted over a long period of time can become expensive. Typically, the EPA prefers that health education is not a stand-alone remedy, but is used only as a supplemental activity in conjunction with an engineered action. Health education activities are useful to help address initial site risks as the remedy is implemented, and then could be phased out as cleanup of the contamination is completed.

4.3 Excavation

Excavation prevents human contact with soils through physical removal of soils for disposal. Residential soils can be either partially or totally removed. Soil excavation may be difficult and costly, particularly if properties are confined, inaccessible, steeply sloped, or contain trees, shrubs, walkways, and driveways.

4.3.1 Partial Removal

Partial removal of soils refers to excavation of portions of properties containing concentrations of lead above the action level and leaving behind soils with concentrations of lead below the action level. Portions of a property, but not the entire property, may contain soil with lead above the action level. Partial removal of soils may be appropriate for these properties. The limitation of partial excavation is the need for extensive testing to carefully delineate the soils to be removed. However, the cost for testing may be offset by the lower removal, transportation, and disposal costs for smaller quantities of soil. All excavated soils require appropriate disposal.

4.3.2 Complete Removal

Complete removal is the excavation of soil to a predetermined depth for entire residential properties. Complete excavation may not be appropriate because soils containing low concentrations of lead with little associated risk are removed, along with soils containing higher lead concentrations. In addition, complete removal may result in more unavoidable disturbance/disruption to property such as destruction of flower beds, gardens, and other sensitive areas of the home that could be avoided if soil testing indicates some areas of the property contain lead concentrations that are below a level of concern. Complete soil removal may be most appropriate where the majority of the properties contain soil contamination above the action level, and the extensive sampling associated with partial removal may be eliminated. The EPA has information for this site indicating that many of the residential properties with soil concentrations above the action level also have areas of their properties below the action level, and a complete removal of soils from properties may not be necessary. This technology is not considered further because of the much higher costs associated with complete removal.

4.4 Disposal

Disposal options must be considered with either partial or total excavation. The metals-contaminated soils removed from residential areas will require disposal in a secure facility. Several options exist for disposal of lead-contaminated soil from the Omaha site and are discussed in the following paragraphs.

4.4.1 New Repository

A soil repository could be constructed on an existing area within or near the Superfund site. The repository, which would be covered and/or revegetated, would allow for disposal of soils in a controlled environment, minimizing transport of lead. The primary limitation for this technology is land availability. Additionally, if the EPA constructed a discrete on-site repository for lead-contaminated soil disposal, the facility may require long-term operation and maintenance (O&M) by the State of Nebraska or through a permanent and enforceable agreement with the property owner.

4.4.2 *Sanitary Landfill*

Soils could also be disposed in off-site sanitary landfills as daily cover or as a special waste. The advantage of using existing landfills is the elimination of design and construction of a soil repository. The limitations of using an off-site disposal facility are possible regulatory constraints and cost. Costs for off-site disposal could be greater than on-site disposal due to the additional transportation expense and tipping fees at the landfill. Use as daily cover could reduce cost by lowering or eliminating tipping fees and reducing the tax burden. Another disadvantage to disposal in a sanitary landfill may be a limitation in the capacity of the landfill used for the soil disposal. Additionally, the soils require testing, prior to disposal, using the toxicity characteristic leaching procedure (TCLP). If soils fail the TCLP test for lead, pretreatment would be required prior to disposal. Because of the potentially large quantities of soil to be generated from excavation activities, pretreatment of soil prior to disposal may be difficult to implement, as well as cost prohibitive.

4.4.3 *Commercial Backfill*

The soil excavated from the residential properties in Omaha potentially could be used as beneficial fill in a commercial land use project, if it can be demonstrated that there would be no unacceptable risk to human health or the environment. While the lead-contaminated soil presents a hazard to humans, especially children, in residential settings, no significant risks would be created in a commercial or industrial setting if the soil is properly placed and appropriate ICs are placed on the disposal property.

4.5 Capping Technologies

Capping prevents direct human contact with waste. The technologies used for capping include:

- Soil
- Geosynthetics
- Vegetation

Capping technologies could be used separately or in combination, in individual properties or in a central soil repository, or in other land use projects, to prevent human contact with metals in soil. Each of the capping technologies is described in the following subsections.

4.5.1 Soil Capping

Soil caps are constructed using either simple topsoil covers or low permeability clay layers to prevent human contact and transport of soils off site. Simple topsoil caps could be used directly in residential properties to cover contaminated soil with a protective layer, preventing human contact with the covered contaminated soil. The advantage of topsoil capping is that contaminated soils remain in place, eliminating excavation, transport, and disposal problems. However, in-place capping would raise the property level 6 to 12 inches, which creates problems in correct contouring to existing driveways, walkways, and below grade window openings of homes. In large properties, capping could be used effectively in combination with excavation to achieve proper final grading of the property around existing structures.

Low permeable clay caps, although not applicable for residential properties, may be used as final cover for soil disposal areas. These types of soil covers are typically used for preventing infiltration of water into a contaminated soil disposal pile and to control future contaminant migration from the soil disposal area.

4.5.2 Geosynthetics

Geosynthetics can consist of geotextile fabrics and geomembrane barriers. Geotextile fabrics are woven from synthetic material and made to withstand both chemical degradation and biodegradation. The fabric is laid over untreated or undisturbed soils, effectively separating them from clean fill material. In residential soils, geotextiles can be used as either a physical or visual barrier to separate the clean soil cover from underlying contaminated soil. The advantage of these barriers is that a resident digging in a remediated property with contamination at depth would be notified of the contamination by the presence of the barrier.

Geomembrane barriers also have applicability as cover material over a soil disposal area to prevent surface water infiltration and control surface migration of contaminants. These types of covers, however, are much more costly than soil covers.

4.5.3 Vegetation

Vegetative covers such as sod can prevent human contact with soils by creating a physical barrier. Roots from cover plants hold the soil in place, preventing erosion and off-site transport by surface runoff or wind. Vegetative covers may be appropriate alone for soils with low concentrations of metals. Vegetative covers may also be used in conjunction with clay caps, clean fill (dust control), or geotextile fabrics. The advantage of a vegetative cover is that grass grows well in the Omaha area and, with proper maintenance, can be an effective barrier. The limitation of a vegetative cover is that routine maintenance (i.e., mowing, watering, and fertilizing) is necessary to maintain the cover. An additional disadvantage of a grass-only cover is that the protective layer is very thin, and without proper maintenance, the grass can die and contaminated soil can be readily re-exposed.

4.6 Stabilization

Stabilization refers to treatment of soils with chemical agents to either fix metals in place or form complexes that make metals less toxic. Two methods of stabilization appropriate for lead contamination are pozzolanic stabilization and phosphate addition. These technologies are both routinely used as treatment technologies in certain applications. Each stabilization method is described in the following subsections.

4.6.1 Pozzolanic Stabilization

Pozzolanic stabilization of residential soils is the addition of a solidifying agent such as Portland cement or fly ash with soils to form a monolith, similar to concrete. The pozzolan is added in place by introduction of a slurry mixture into the soil with auger mixing. The monolith created would reduce leachability and mobility of metals in soils by reducing soil particle surface area and inhibiting human contact by encapsulating soils. The advantage of pozzolanic stabilization is that treatment materials are inexpensive and readily available. The limitations with in-place pozzolanic stabilization include increased material volume, which would change the elevation of properties. Since paving properties is not generally acceptable to residents, this technology will not be further evaluated for application in residential properties.

4.6.2 Phosphate Stabilization

Phosphate stabilization is a chemical stabilization procedure in which phosphate salts are added to soils in either solid or liquid form and mixed with the soil. Phosphate ions combine with lead to form the less soluble lead phosphate complexes. Although the metals are not removed from the property, they become less bioavailable to humans since the lead that occurs in the soil as lead-phosphate is less likely to be absorbed by the body when ingested.

Phosphate can be added to the soil in the form of phosphoric acid, triple-super phosphate, or phosphate rock. For purposes of developing an alternative for this Final FS, phosphate stabilization would consist of adding phosphorus in the form of phosphoric acid along with potassium chloride

(KCl) to the residential soils. This combination is intended to react with lead in the soil to form the extremely insoluble chloropyromorphite, thus rendering the lead unavailable for leaching and less bioavailable to humans. Following application of the phosphoric acid, lime would be added to raise the soil pH to acceptable levels and the property would be sodded. An advantage of phosphate stabilization is that a limited amount of soil would have to be removed. Limitations of phosphate stabilization include: (1) The bench scale treatability study performed using soils from the OLS suggested only a 20% reduction in bioavailability of lead could be achieved (Ref. 22); (2) pilot scale studies performed at other sites have demonstrated that in the short-term, phosphate stabilization may reduce the bioavailability of lead by 30 to 50 percent (Ref. 23 and Ref. 24), thus limiting its applicability to properties with high lead concentrations; (3) its long-term effectiveness is inconclusive; (4) the application of phosphoric acid to residential soils to reduce the bioavailability of lead has not been implemented on a large scale at residential properties which could raise public concerns; and (5) a large amount of phosphoric acid would be transported and used in residential areas, which could result in increased short-term risks during implementation.

4.7 Actions to Address Other Non-Soil Sources of Lead

The EPA is aware that lead in the environment at the OLS originates from many sources. In addition to the identified soil exposure pathway, which the above listed technologies will address, other important sources of lead exposure are interior and exterior LBP, lead-contaminated interior dust that originates from LBP and contaminated soil, and to a much lesser extent, tap water. Generally, sources other than soil, exterior paint, interior dust, and tap water cannot be remediated by the EPA in the course of residential lead cleanups. CERCLA and the NCP limit Superfund authority to address interior lead-based paint. For example, CERCLA Section 104(a) (3) (B) limits the EPA's liability to respond to releases within residential structures as follows:

> "Limitations on Response. The President (EPA) shall not provide for removal or remedial action under this section in response to a release or threat of release…from products which are part of the structure of, and result in exposure within, residential buildings or business or community structures…"

The above cited section of CERCLA generally limits the EPA's authority to respond to lead-based paint inside a structure or house. In addition, hazardous substance, as used in the definition of a "facility", does not include consumer products such as paint that are in consumer use. However, the EPA has authority to address deteriorated LBP to prevent recontamination of soils that have been remediated.

The Office of Solid Waste and Emergency Response (OSWER) policy recommends against using money from the Superfund Trust Fund to address interior lead-based paint exposures, and recommends that actions to address or abate interior lead-based paint risks be addressed by others such as U.S. Department of Housing and Urban Development (HUD), local governments, health authorities, Potentially Responsible Parties (PRPs), private organizations, or individual homeowners. OSWER policy also recommends against using Superfund trust money to remove interior dust solely from lead-based paint or to replace lead plumbing within residential dwellings, and recommends that the regions seek partners to address these other lead exposure risks.

The EPA acknowledges the importance of addressing these other exposures in realizing an overall solution to the lead problems at residential Superfund sites. The EPA is committed to partnering with other organizations such as The Agency for Toxic Substances and Disease Registry (ATSDR), HUD, state environmental departments, state and local health departments and government agencies, private organizations, PRPs, and individual residents and to participate in a comprehensive lead risk reduction strategy that addresses lead risks comprehensively. The EPA can provide assessments of these other lead hazards to homeowners as part of its investigative activities and can provide funds to support health education efforts to reduce the risk of lead exposure in general. It should be noted that OSWER policy directs that the EPA should not increase the risk-based soil cleanup levels as a result of the action taken to address these other sources of exposure.

While acknowledging the importance of addressing lead exposures from all sources and developing a comprehensive approach, the EPA can only recommend, as part of a preferred or selected remedy, those actions that the EPA has the authority and policy direction to address. The EPA will make a determination regarding the need to remediate residential soils. At properties where a soil cleanup action is conducted, the EPA can also perform an assessment and provide recommendations to address other sources of lead exposures. In the absence of resources from other parties to address such lead hazards, at residences where remediation of soils is performed, the EPA remedy could also address:

- Controlling interior lead-contaminated dust through professional cleaning or providing high efficiency particulate air vacuum cleaners (HEPAVAC) to home owners when exterior soil contributes to interior dust contamination.
- Assessing the condition of, and stabilizing or otherwise controlling hazards at properties where flaking lead-based paint may threaten the future protectiveness of a soil cleanup by re-contaminating the clean soil placed in the excavated areas.
- Providing support to a health education program during cleanup actions.

4.8 Screening of Identified Technologies

This section screens the remedial technologies identified in Sections 4.1 through 4.6 for further consideration in developing remedial alternatives to satisfy the RAO.

4.8.1 No-Action

The "no-action" general response action is required as a baseline alternative against which the effectiveness of the other alternatives can be compared. Under this alternative, no remedial actions are taken at the site. Current risks posed from contaminants at the site remain unmitigated, uncontrolled, and unmanaged. Actions taken to reduce the potential for exposure (e.g. site fencing, deed restrictions, etc.) are not to be included as a component of the no-action alternative.

4.8.2 Institutional Controls

Proprietary Controls

Proprietary controls include easements and restrictive covenants that convey interests in real property. This type of IC "runs with the land" and is binding on subsequent purchasers of the property. Proprietary controls are difficult to implement because it is necessary for the restrictions to extend beyond the period of the remedial action and the EPA does not have a property interest at the site. This type of IC is not presently being used to control activities at the OLS and will not be carried forward for incorporation into a remedial alternative.

Governmental Controls

Government controls that impose land restrictions using the authority of an existing unit of government are applicable to the OLS. Typical examples of government controls include zoning, building codes, and other ordinances. Although zoning can serve as an effective IC when a large number of properties are affected by the remedy, a zoning ordinance that would restrict use of existing residential properties at the OLS may not be readily implementable and will not be carried forward for incorporation into a remedial alternative.

Local building codes or other ordinances to protect the public are a practical method to control lead hazards. The City of Omaha is presently considering an ordinance that makes it unlawful for any property owner to rent or allow the residential use by another person of a residential premise constructed prior to January 1, 1978, unless the property owner has provided the tenant a written certification by a state-certified lead paint risk assessor that (1) indicates the premises have been tested for lead paint and were found to not contain lead paint on any interior or exterior surface or (2) any lead dust found on the premises meets the standards of HUD regarding the presence of lead dust on window sills, window troughs, and floors, and that none of the lead paint on or within the premises is flaking, cracking, peeling, scaling, blistered, chipped, or loose.

A second ordinance under consideration by the City of Omaha would make it a nuisance to maintain or allow any open or exposed surface in any dwelling which is coated with, or consists of, or contains any lead-bearing substance if the surface is accessible or may become accessible to ingestion or inhalation by any person.

Enforcement and Permit Tools with IC Components

Enforcement and permit tools with IC components include orders, permits, and consent decrees. Enforcement orders could potentially be used to enable EPA to obtain access to properties to sample or remediate the soil. Although EPA may eventually use enforcement orders to obtain access to sample properties, enforcement orders will not be carried forward for incorporation into a remedial alternative.

Informational Devices

Informational devices provide information about the OLS to property owners. Informational devices will be carried forward for incorporation into the remedial alternatives. An information device that will be carried through for incorporation into the alternatives is establishment of a local registry that contains information concerning soil sampling, soil remediation, LBP assessments, LBP stabilizations, and LBP certifications indicating that the property does not present a hazard.

4.8.3 Public Health Education

Public health education includes providing community education through meetings and literature, distributing fact sheets containing information on controlling lead exposure; establishing public information centers that may distribute written information on controlling lead hazards or respond to questions from the public concerning lead hazards; and providing lead hazard information to the public through public media (television, radio, newspapers, internet). Public health education is an effective means of controlling exposure to lead and will be carried forward for incorporation into the remedial alternatives.

4.8.4 Excavation

Excavation of contaminated soil from residential properties is an accepted and highly utilized technology for addressing site risks. Excavation is easily implementable with readily available equipment. For purposes of this report the excavation process option includes backfilling excavated properties with clean soil. This technology will be carried forward for consideration in developing remedial alternatives to address the site risks.

4.8.5 Disposal

Disposal of contaminated soil excavated from residential properties is an accepted and highly utilized technology for addressing site risks. Disposal is easily implementable with readily available equipment. Several options have been identified for disposal of the excavated contaminated soil. For purposes of this report, the excavation process option includes transportation of the excavated soil to a sanitary landfill for use as landfill cover. The sanitary landfill where the excavated soil is presently used for daily cover is the Loess Hills Regional Landfill located in Malvern, Iowa. This technology will be carried forward for consideration in developing remedial alternatives to address the site risks.

4.8.6 Capping Technologies

Capping of large residential properties with clean topsoil to reduce exposures to contamination is less costly than excavation and disposal, yet still may be as protective in preventing exposure. Other types of capping, such as paving, are not practical for residential property soil contamination. Capping with topsoil will be retained for consideration in developing remedial alternatives to address the site risks.

Geomembrane barriers and low permeable clay caps have applicability for cover material over the soil disposal area to prevent surface water infiltration and control surface migration of contaminants. Geotextile fabrics can also be used as a physical barrier in residential properties to separate clean fill from contaminated soil at the bottom of excavations. These types of technologies will be retained for consideration during remedial alternative development, to address the soil disposal areas, and in some instances, in residential properties.

Vegetative covers are not considered protective when used alone in residential properties and will not be retained for consideration in developing remedial alternatives for residential properties. Vegetative covers are applicable for use in capping excavated soil at disposal areas and are retained for further consideration in those applications.

4.8.7 Stabilization

Pozzolonic stabilization is not an appropriate technology for residential soil in that it essentially turns the soil into a concrete slab. This technology will not be considered further.

The Omaha Lead Site Draft Treatability Study (Ref. 22) indicates minimal reduction (20%) in lead bioavailability using phosphate-based soil amendments as a stabilizing agent. Previous pilot scale studies have demonstrated that phosphate stabilization may reduce the bioavailability of lead by 30 to 50 percent in some soils (Ref. 23 and Ref. 24). However, the long-term effectiveness of phosphate stabilization to reduce the bioavailability of lead in soils has not been demonstrated. However, this technology will be retained for further consideration in a remedial alternative.

5.0 Development of Alternatives

This section documents the development of remedial alternatives for residential soils. Appropriate soil treatment and disposal technologies have been combined into three alternatives to address human exposure to residential soils at the OLS. To avoid considering all possible combinations of technologies, criteria are applied to limit the number of alternatives to only the most effective and implementable. The criteria for combining technologies into alternatives are:

- Alternatives must address the RAO.
- Alternatives must consist of unified groups of technologies.
- Alternatives must represent the full range of possible remedies from No Action to treatment and/or removal. Two alternatives that incorporate treatment and/or removal, along with the No Action alternative are developed in this section to address residential properties.

As the alternatives have been developed they were screened, as appropriate, based on cost, implementability, and effectiveness in accordance with the NCP requirements.

The following general technologies identified in Section 3 have been retained for consideration in developing the remedial alternatives. Other technologies were eliminated as either not technically practical or not cost effective for the OLS.

- Government Controls
- Informational Devices
- Public Health Education
- Excavation
- Disposal
- Capping
- Phosphate Stabilization

5.1 Preliminary Remedial Alternatives

The following alternatives are based on the applicable technologies identified in Section 4 and were developed to most efficiently meet the RAO and satisfy the ARARs. Also included for comparison is the No Action alternative. Additionally, the alternatives were developed to specifically address contamination resulting from industrial operations.

5.1.1 Alternative 1: No Action

The EPA is required by the NCP, 40 C.F.R. § 300.430(e)(6) to evaluate the No Action Alternative. The No Action Alternative may be appropriate at some sites where a removal action has already occurred that has reduced risks to human health and the environment. Although a remedial action is occurring at the Site, residual risks to human health remain as documented in the BHHRA. Under the No Action Alternative, the existing remedial action would cease. The concentrations of lead in residential property soils would remain at levels (i.e., lead concentrations greater than 400 ppm) that present a risk to human health, particularly for young children residing at the Site. The No Action Alternative is therefore not protective of human health.

5.1.2 Alternative 2: Excavation and Disposal

Under this alternative, residential property soils with at least one non-drip zone sample greater than 400 ppm lead will be excavated and disposed. Properties where only the drip zone soil exceeds 400 ppm lead would not be addressed under this action. Establishment and operation of a local lead hazard registry would be implemented to further control the residual risks associated with soil contamination below 400 ppm and other non-soil sources of lead. The existing soil sampling program would be continued to identify residential properties that require excavation. The EPA estimates that there are approximately 9,966 residential properties that contain soils with lead concentrations that exceed 400 ppm lead and have not been remediated. Excavated soil would be disposed at the existing sanitary landfill in Malvern, Iowa or at a new repository. The EPA is presently remediating the soil at approximately 1,000 properties per year and if the soil remediation continues at the existing pace, the remedial action would be completed in approximately 10 years. The time to implement this alternative could be shortened or lengthened by reducing or increasing the pace of soil remediation.

<u>Excavation</u>

This alternative includes the excavation and removal of soil, and backfilling the excavation with clean soil. Excavation of a property would be triggered when the highest mid-yard soil sample for the property contains greater than 400 ppm lead. Residential properties with at least one quadrant sample testing greater than 400 ppm for lead would have all quadrants exceeding 400 ppm and possibly the drip zones remediated. The drip zones would be remediated if the lead concentration is greater than 400 ppm.

Soil would be excavated using lightweight excavation equipment and hand tools in the portions of the property where the surface soil exceeds 400 ppm lead. Excavation would continue until reaching a residual lead concentration of less than 400 ppm in the initial one foot of excavation or less than 1,200 ppm at depths of greater than one foot. In garden areas, excavation would continue to a level of less than 400 ppm in the initial 2 feet of excavation or less than 1,200 ppm at depths greater than 2 feet. Fugitive dust would be controlled and monitored during soil excavation using dust suppression techniques.

Following excavation, clean fill and topsoil would be used to replace the soil removed, returning the property to its original elevation and grade. The EPA will not use soil from protected areas of Loess Hills as fill for the site.

Soil capping may be used as an acceptable alternative to, or in combination with, excavation to reduce cost in special cases such as large parks or schoolyards where placement of a cap would not create drainage problems. Capping in areas where surface soil-lead concentrations are greater than 400 ppm and less than 1,200 ppm would require a minimum of 12 inches of clean soil for the cap.

Vegetative Cover

After the topsoil has been replaced, the property would be sodded to restore the lawn. However, hydro-seeding or conventional seeding may be used in areas of properties with special considerations at the property owner's request.

Disposal

Three options are available to accommodate disposal of the excavated soils. The first option would be to haul the contaminated soil to an off-site sanitary landfill for use as daily cover and/or for disposal. Before the soil is hauled to the landfill, it is placed in a staging area and TCLP tests are conducted to ensure the soil is non-hazardous. To date, no soil samples from any staging area at the OLS have failed TCLP. This option is currently being used for an on-going remedial action at the site.

The second option would be to use the soil excavated from the residential properties as beneficial fill in the construction of a commercial or industrial facility. Lead-contaminated soils at the site are considered a risk to human health only in residential settings. Removed soils could be safely used in a commercial/industrial setting without creating a risk to human health. Constructed engineering features may also be necessary to protect the fill area. Long-term maintenance of any constructed engineering features would also be necessary.

Option three would consist of constructing a new repository on public or privately owned land. Public land would offer the advantage of control over future use of the property. Significant design and site preparation may be required for construction of the facility. This option is limited by the availability of land and willingness of landowners to maintain such a facility. This option would also be limited by the availability of land and willingness of landowners to maintain such a facility.

Exterior Lead-Based Paint

In order to prevent the re-contamination of the clean soil placed in properties after excavation, deteriorating exterior LBP may be stabilized on homes prior to or after the soil excavation in the properties. EPA has determined that there are no other parties with the capability or resources to address the recontamination threat posed by LBP.

Not all homes will require paint stabilization. Only those homes that are determined to have the potential for elevated soil lead levels to develop due to deteriorating LBP will be addressed. Paint would be stabilized using lead-safe work practices and all previously painted surfaces would be primed and repainted. The stabilization of exterior LBP will be conducted on a voluntary basis. Paint stabilization activities would only be offered at homes that are eligible for soil cleanup.

It is estimated that 14,577 sampled and unsampled properties will be eligible for paint assessments. The number of assessments performed to date is 2,894, leaving 11,683 additional properties that will eligible for paint assessments. Of the 2,894 completed assessments, 1,335 or 46 percent of the properties will be assumed to qualify for paint stabilization based on proposed eligibility criteria applied to completed LBP assessments at the 2,894 properties to date. There are an additional 133 properties that have been assessed and qualify for paint stabilization based on the proposed eligibility criteria, but have not been stabilized. It is estimated an additional 5,389 properties that have not been assessed will be eligible for paint stabilization based on proposed eligibility criteria applied to completed LBP assessments at the 2,894 properties to date.

Interior Lead Dust

At homes where soil cleanup actions are conducted, interior dust will be sampled to assess indoor lead exposure. Homes that exceed the EPA and HUD standards could undergo a one-time high-efficiency cleaning after the soil cleanup is completed at the property. Evidence suggests that lead based contamination dust can rapidly reaccumulate on household surfaces following dust removal (Ref. 28). Consequently, rather than providing a one time professional cleaning, HEPAVACs could be made available to the properties where soil cleanup is performed and lead concentrations in the dust exceed EPA/HUD criteria. Each homeowner at properties eligible for dust sampling would be provided information regarding household lead hazards and each homeowner receiving a HEPAVAC would be trained on the importance, use, and maintenance of the HEPAVAC.

For purposes of providing a cost estimate for this alternative it is assumed that a

HEPAVAC will be provided to homeowners whose homes exceed standards for interior dust. It is estimated that 14,577 properties are eligible for dust sampling (all properties eligible for soil remediation). It is assumed 50 percent of the 14,577 eligible properties will grant access to sample. Of the 7,289 properties that grant access, it is assumed for costing purposes that 20 percent (1,458 properties) will be eligible for interior dust response.

Governmental Controls

Local ordinances are being considered by the City of Omaha to address lead hazards in the OLS. If enacted, the proposed landlord certification ordinance would make it unlawful for any property owner to rent or allow the residential use by another person of a residential premise constructed prior to January 1, 1978, unless the property owner has provided the tenant with a written certification by a state-certified lead paint risk assessor that (1) indicates the premises have been tested for lead paint and were found to not contain lead paint on any interior or exterior surface or (2) any lead dust found on the premises meets the standards of HUD regarding the presence of lead dust on window sills, window troughs, and floors, and that none of the lead paint on or within the premises is flaking, cracking, peeling, scaling, blistered, chipped, or loose.

A second ordinance under consideration by the City of Omaha would make it a nuisance to maintain or allow any open or exposed surface in any dwelling which is coated with, or consists of, or contains any lead-bearing substance if the surface is accessible or may become accessible to ingestion or inhalation by any person.

Although these proposed ordinances could effectively reduce the potential for exposure to lead hazards at residential properties at the OLS, these measures will not be carried forward as elements of a remedial alternative. EPA supports the enactment of these ordinances and recognizes their potential benefit, but EPA does not have authority to ensure passage of the local ordinances and therefore can not assure their implementation.

Informational Devices

Information devices that could be implemented at the OLS site include operation of a local registry containing lead hazard information on properties in the OLS. The registry would be operated by the City of Omaha and would include information concerning the lead hazards at properties. Information maintained in the registry may include, but not be limited to, whether lead concentrations in the soil at a property exceed the action levels, and if so, whether the soil has been remediated; whether a LBP paint assessment has been performed and stabilization has been completed, if necessary; and any certifications that are made in accordance with the local proposed ordinances previously discussed.

Public Health Education

The present ongoing lead hazard education program in Omaha would be continued through completion of the remedial action in cooperation with ATSDR, NDEQ, and the Douglas County Health Department (DCHD). The existing 2 public information centers located at 3040 Lake Street and 4911 S. 25th Street in Omaha, Nebraska would continue to operate until the remedial action is completed. The public information centers would continue to distribute written information on controlling lead hazards and respond to questions from the public concerning EPA response activities.

Public health education activities providing community education through distribution of fact sheets containing information on controlling lead exposure would be continued. The EPA would continue providing lead hazard information to the public through public media (television, radio, newspapers, internet).

5.1.3 Alternative 3: Phosphate Stabilization; Excavation and Disposal

This alternative involves a combination of excavation and phosphate stabilization of residential soils and high child impact areas found to contain lead concentrations above 400 ppm. An estimated 9,966 properties have lead concentrations greater than 400 ppm. Because the bench-scale treatability study indicated that the bioavailability of lead would only be reduced by an average of 20 percent, it is assumed that a phosphate amendment could only be effective at reducing risks associated with lead concentrations in the soils by 20 percent. Consequently, phosphate stabilization would only be conducted on soils with lead concentrations above 400 ppm but less than 500 ppm. Residential properties with lead concentrations above 500 ppm lead would be excavated as described in Alternative 2.

The total number of residential properties with lead concentrations above 400 ppm and below the effective stabilization level of 500 ppm is estimated to be approximately 3,721 properties. There are an estimated 3,234 properties that have been sampled and have lead concentrations between 400 and 500 ppm. Of the remaining 5,210 properties that have not been sampled, 487 (9.3%) properties were estimated to have lead concentrations between 400 and 500 ppm based on completed soil sampling at the OLS. The remaining 6,245 properties would be remediated as described in Alternative 2.

In addition, this alternative includes all other activities described in Alternative 2, including public information and education, exterior lead-based paint stabilization, and interior dust response.

Phosphate Stabilization

Under this alternative, all residential properties and residential-type properties (i.e., child care facilities, parks, and playgrounds) with lead concentrations exceeding 400 ppm, but less than 500 ppm (the assumed concentration for costing purposes), would be treated with a phosphate amendment to reduce the bioavailability of metals in the soil, thereby controlling the health risk to children. The bench-scale treatability study performed on the OLS soils indicated that 1.5 phosphoric acid (PA) (weight, % P) would be the most effective amendment for reducing the bioavailability of lead in soils. Consequently, this alternative will assume the phosphate amendment that is used will be 1.5 PA. This alternative would involve stabilizing metals in the soil by adding phosphate into the soil to a depth of 6 to 10 inches. It is anticipated that the phosphate, in the form of phosphoric acid, would be roto-tilled into the soil, and allowed to stabilize for a few days. Then lime would be added to the soil to raise the pH, and the lawn would be re-established. Fencing would be installed and remain in place from the time of phosphoric acid application until the pH of property is return to a neutral pH. Stabilization of a property would be performed on properties when the highest measured non-drip zone sample for the property is greater than 400 ppm lead, but less than the effective stabilization level (assumed to be 500 ppm for cost purposes.)

A long-term monitoring program would be instituted to assess the effectiveness of phosphate stabilization. The program would include soil chemistry monitoring to assess the effects of natural weathering and the long-term stability of the lead-phosphate minerals formed during phosphate treatment. For costing purposes, 10 percent of the properties remediated using phosphate stabilization will be tested at 6 months, 2 years, and 5 years. The final decision to proceed with phosphate stabilization of properties will be made by the EPA after peer review and assessment of the bench scale treatability study and public comments on this Final FS Report.

Excavation

As with Alternative 2, this alternative includes the excavation and removal of soil, and backfilling the excavation with clean soil. Excavation of a property would be triggered when the highest mid-yard soil sample for the property contains greater than 500 ppm lead. Residential properties with at least one mid-yard quadrant sample testing greater than 500 ppm for lead would have all quadrants exceeding 400 ppm and possibly the drip zones remediated. The drip zones would be remediated if the lead concentration is greater than 400 ppm.

Soil would be excavated at properties with a high mid-yard soil lead concentration exceeding 500 ppm using lightweight excavation equipment and hand tools in the portions of the property where the surface soil exceeds 400 ppm lead. Excavation would continue until reaching a residual concentration of less than 400 ppm in the initial one foot of excavation or less than

1,200 ppm at depths of greater than one foot. In garden areas, excavation would continue to a level of less than 400 ppm in the initial 2 feet of excavation or less than 1,200 ppm at depths greater than 2 feet. Fugitive dust would be controlled and monitored during soil excavation using dust suppression techniques.

Following excavation, clean fill and topsoil would be used to replace soil removed, returning the property to its original elevation and grade. The EPA will not use soil from protected areas of Loess Hills as fill for the site.

Soil capping may be used as an acceptable alternative to, or in combination with, excavation to reduce cost in special cases such as large parks or schoolyards where placement of a cap would not create drainage problems. Capping in areas where surface soil-lead concentrations are greater than 400 ppm and less than 1,200 ppm would require a minimum of 12 inches of clean soil for the cap.

Vegetative Cover

After the topsoil has been replaced, the property would be sodded to restore the lawn. However, hydro-seeding or conventional seeding may be used in areas of properties with special considerations at the property owner's request.

Disposal

Three options are available to accommodate disposal of the excavated soils. The first option would be to haul the contaminated soil to an off-site sanitary landfill for use as daily cover and/or for disposal. Before the soil is hauled to the landfill, it is placed in a staging area and TCLP tests are conducted to ensure the soil is non-hazardous. To date no soil samples from any staging area at the OLS have failed TCLP. This option is currently being used for the on-going remedial action at the site.

The second option would be to use the soil excavated from the residential properties as beneficial fill in the construction of a commercial or industrial facility. Lead-contaminated soils at the site are considered a risk to human health only in residential settings. Removed soils could be safely used in a commercial/industrial setting without creating a risk to human health. Constructed engineering features may also be necessary to protect filled areas. Long-term maintenance of any constructed engineering features would also be necessary.

Option three would consist of constructing a new repository on public or privately owned land. Public land would offer the advantage of control over future use of the property. This alternative may have significant costs associated with design and site preparation would be required for construction of the facility. This option would also be limited by the availability of land and willingness of landowners to maintain such a facility.

Exterior Lead-Based Paint

In order to prevent the re-contamination of the clean soil placed in properties after excavation, deteriorating exterior LBP paint may be stabilized on homes prior to or after the soil excavation in the properties. EPA has determined that there are no other parties with the capability or resources to address the recontamination threat posed by LBP. The stabilization of exterior LBP would be conducted on a voluntary basis.

Not all homes will require paint stabilization. Only those homes that are determined to have the potential for elevated soil lead levels to develop due to deteriorating LBP will be addressed. Paint would be stabilized by using lead-safe work procedures and all previously painted surfaces would be primed and repainted. Exterior paint stabilization activities would only occur at homes that are eligible for soil cleanup.

It is estimated that 14,577 sampled and unsampled properties will eligible for paint assessments. The number of assessments performed to date is 2,894, leaving 11,683 properties that are eligible for paint assessments. Of the 2,894 completed assessments, 1,335 or 46 percent of the properties will be assumed to qualify for paint stabilization based on proposed eligibility criteria applied to completed LBP assessments at the 2,894 properties to date. There are an additional 133 properties that have been assessed and qualify for paint stabilization based on the proposed eligibility criteria, but have not been stabilized. It is estimated an additional 5,389 properties that have not been assessed will be eligible for paint stabilization based on proposed eligibility criteria applied to completed LBP assessments at the 2,894 properties to date.

Interior Lead Dust

At homes where soil cleanup actions are conducted, interior dust will be sampled to assess indoor lead exposure. Homes that exceed the EPA and HUD standards could undergo a one-time high-efficiency cleaning. The interior cleaning could be conducted on a voluntary basis for willing homeowners, after the soil cleanup is completed at the property. Evidence suggests that lead based contamination dust can rapidly reaccumulate on household surfaces following dust removal (Ref. 28). Consequently, rather than providing a one time professional cleaning, HEPAVACs could be made available to the properties where soil cleanup is performed and lead concentrations in the dust exceed allowable criteria. Each homeowner at properties eligible for dust sampling would be provided information on household lead hazards and each homeowner receiving a HEPAVAC would be trained on the importance, use, and maintenance of the HEPAVAC. For purposes of providing a cost estimate for this alternative it is assumed that a HEPAVAC will be provided to residents whose homes exceed EPA/HUD standards for interior dust.

It is estimated that 14,577 properties are eligible for dust sampling (all properties eligible for soil remediation), and that 50 percent of the 14,577 eligible properties will grant access to sample. Of the 7,289 properties that grant access, it is assumed for costing purposes that 20 percent (1,458 properties) will be eligible for interior dust response.

Governmental Controls

Two local ordinances are currently under consideration by the City of Omaha to address lead hazards in the OLS. One ordinance under consideration would make it unlawful for any property owner to rent or allow the residential use by another person of a residential premise constructed prior to January 1, 1978, unless the property owner has provided the tenant with a written certification by a state-certified lead paint risk assessor that (1) indicates the premises have been tested for lead paint and were found to not contain lead paint on any interior or exterior surface or (2) any lead dust found on the premises meets the standards of HUD regarding the presence of lead dust on window sills, window troughs, and floors, and that none of the lead paint on or within the premises is flaking, cracking, peeling, scaling, blistered, chipped, or loose.

The second ordinance under consideration by the City of Omaha would make it a nuisance to maintain or allow any open or exposed surface in any dwelling which is coated with, or consists of, or contains any lead-bearing substance if the surface is accessible or may become accessible to ingestion or inhalation by any person.

Although these proposed ordinances could effectively reduce the potential for exposure to lead hazards at residential properties at the OLS, these measures will not be carried forward as elements of a remedial alternative. EPA supports the enactment of these ordinances and recognizes their potential benefit, but EPA does not have authority to ensure passage of the local ordinances and therefore can not assure their implementation.

Informational Devices

Information devices that will be implemented at the OLS site include operation of a local registry containing lead hazard information on properties in the OLS. The registry would be operated by the City of Omaha and would include information concerning the lead hazards at properties. Information maintained in the registry may include, but not be limited to, whether lead concentrations in the soil at a property exceed the action levels, and if so, whether the soil has been remediated; whether a LBP paint assessment has been performed and stabilization has been completed, if necessary; and any certifications that are made in accordance with the local proposed ordinances previously discussed.

Public Health Education

The current lead hazard education program would be continued through completion of the remedial action in cooperation with the ATSDR, NDEQ, and the DCHD. The existing 2 public information centers located at 3040 Lake Street and 4911 S. 25th Street in Omaha, Nebraska would continue to operate until the remedial action is completed. The public information centers would continue to distribute written information on controlling lead hazards and respond to questions from the public concerning EPA response activities.

The public health education program that includes providing community education through distribution of fact sheets containing information on controlling lead exposure would be continued. The EPA would continue providing lead hazard information to the public through public media (television, radio, newspapers, internet).

6.0 Detailed Evaluation of Remedial Alternatives

The NCP, 40 C.F.R. Section 300 et. seq., requires the EPA to evaluate selected remedial alternatives against nine criteria. A selected or preferred alternative should best satisfy all nine criteria before it can be implemented. The first step is to ensure that the selected remedy satisfies the threshold criteria. The two threshold criteria are overall protection of public health and the environment and compliance with ARARs. In general, alternatives that do not satisfy these two criteria are rejected and not evaluated further. However, compliance with ARARs may be "waived" if site-specific circumstances warrant such a "waiver" as described in Section 300.430(f)(1)(ii)(C) of the NCP, 40 C.F.R. § 300.430(f)(1)(ii)(C). No ARAR waivers are contemplated for any of the alternatives evaluated in this FS.

The second step is to compare the selected remedy against a set of balancing criteria. The NCP establishes five balancing criteria, which include long-term effectiveness and permanence; reduction in toxicity, mobility, or volume achieved through treatment; implementability; short-term effectiveness; and cost. The third and final step is to evaluate the selected remedy on the basis of modifying criteria. The two modifying criteria are state and community acceptance. These final two criteria cannot be evaluated fully until the state and public have commented on the alternative and their comments have been analyzed.

6.1 Alternative Analysis Criteria

Each of the alternatives is subjected to nine evaluation criteria described in the NCP. The factors considered for each evaluation criterion and a brief description of each criterion follows:

6.1.1 Threshold Criteria

Overall Protection of Human Health and the Environment

This criterion provides a final check to assess whether each alternative meets the requirement that it is protective of human health and the environment. The overall assessment of protection is based on a composite of factors assessed under the evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

Compliance With ARARs

This criterion is used to decide how each alternative meets applicable or relevant and appropriate federal and state requirements, as defined in CERCLA Section 121. Compliance is judged with respect to:

- chemical-specific ARARs
- action-specific ARARs
- location-specific ARARs
- appropriate criteria, advisories and guidance

Potential chemical- and location-specific ARARs are identified in Tables 2-1 through 2-4. Potential federal and state action-specific ARARs relating to the remedial alternatives are identified in Tables 6-1 and 6-2.

6.1.2 Balancing Criteria

Long-Term Effectiveness

This criterion addresses the results of a remedial action in terms of the risk remaining at the site after the response objectives have been met. The primary focus of this evaluation is to determine the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes. The factors to be evaluated include:

- magnitude of risk remaining at the site after the remedial objectives are met,
- adequacy of controls, and
- reliability of controls (i.e., assessment of potential failure of the technical components).

Short-Term Effectiveness

This criterion addresses the effects of the alternative during the construction and operation phase until the remedial actions have been completed and the selected level of protection has been achieved. Each alternative is evaluated with respect to:

- protection of community during remedial actions,
- protection of workers during remedial actions,
- time until remedial response objectives are achieved, and
- environmental impacts.

Table 6-1
Potential Federal Action-Specific ARARs

	Citation	Prerequisite	Requirement
A. Applicable Requirements			
1. Disposal of Solid Waste in a Permanent Repository and closure of the Repository.	Subtitle D of RCRA, Section 1008, Section 4001, et seq., 42 U.S.C. §6941, et seq.	State or Regional Solid Waste Plans and implementing federal and state regulations to control disposal of solid waste. The yard soils disposed in the repository may not exhibit the toxicity characteristic and therefore, are not hazardous waste. However, these soils may be solid waste.	Contaminated residential soils will be consolidated from yards throughout the site into a single location. The disposal of this waste material should be in accordance with regulated solid waste management practices.
2. Disposal of Hazardous Waste in the Permanent Repository and Designation as a Corrective Action Management Unit (CAMU).	Subtitle C of RCRA, Section 3001 et seq., 42 U.S.C. §6921, et seq. and implementing regulations at 40 C.F.R. Subpart S, Corrective action for solid waste management units and temporary units, 40 C.F.R. §264.522	RCRA defines CAMUs to be used in connection with implementing remedial measures for corrective action under RCRA or at Superfund sites. Generally, a CAMU is used for consolidation or placement of remediation wastes within the contaminated areas at the facility. Placement of wastes in a CAMU does not constitute land disposal of hazardous waste and does not constitute creation of a unit subject to minimum technology requirements.	The RCRA requirements of Subtitle C are not applicable to the disposal of residential yard soils in the repository. Residential yard soils contaminated from smelter fall out are not excluded from regulation under the RCRA exclusion for extraction, beneficiation and mineral processing. Therefore, yard soils exhibiting a RCRA toxicity characteristic would be regulated under Subtitle C of RCRA. However, because of the CAMU regulation, these residential soils are remediation wastes and may be disposed without triggering RCRA disposal requirements. The remedial action will comply with the requirements of the CAMU rule.

Table 6-1, Continued
Potential Federal Action-Specific ARARs

	Citation	Prerequisite	Requirement
B. Relevant and Appropriate Requirements			
1. NPDES Storm Water Discharge for Permanent Repository.	40 C.F.R. Part 122, § 122.26	Establishes permitting process and discharge regulations for storm water	Required management of repository where waste materials come into contact with storm water. Also required during construction of the repository.
2. Transportation of excavated soils.	DOT Hazardous Material Transportation Regulations, 49 C.F.R. Parts 107, 171-177	Regulates transportation of hazardous wastes.	Relevant and appropriate for the excavation alternative which would transport wastes on-site.
C. To Be Considered	None		

Table 6-2
Potential State Action-Specific ARARs

	Citation	Prerequisite	Requirement
A. Applicable Requirements			
1. Fugitive dust control measures to be utilized during excavation activities	Nebraska Department of Environmental Quality – TITLE 129 Air Quality Regulations, Chapter 32	Requires operating and construction permits to provide that reasonable measures be used to prevent particulate emissions from leaving the premises. Also, sets ambient air quality standards for a number of air constituents.	Recommend that excavation of yard soils or tilling of yards in treatment alternative be handled in such a manner as to control fugitive emissions, such as use of a water spray during excavation, tilling or transportation. May be used in monitoring ambient air quality during implementation for lead and other particulates.
2. Solid waste management regulations	Nebraska Department of Environmental Quality – TITLE 132 – Integrated Solid Waste Management Regulations	Requires permits for proper identifications and disposal of solid waste in municipal solid waste disposal areas.	Requires specified procedures for the location, design, operation, and ground water monitoring, closure, post closure, and financial assurance for solid waste disposal facilities. Requires specific procedures for special waste management.
3. Siting Procedures and Policies	Nebraska State Statutes 13-1701 to 13-1714	Policies and procedures are required in order to get approval for a solid waste disposal area.	Requires approvals by local jurisdictions prior to the development of a site as a solid waste disposal area.
B. Relevant and Appropriate Requirements			
1. Nebraska Surface Water Quality Standards	Nebraska Department of Environmental Quality - TITLE 117	Regulates the discharge of constituents from any point source, including stormwater, to surface waters of the state. Provides for maintenance and protection of public health and aquatic life uses of surface water and groundwater.	Required for protection of wetlands, streams, lakes, and impounded waters from the runoff from toxic discharges.
2. Rules and Regulations pertaining to the issuance of permits under the National Pollutant Discharge Elimination System	Nebraska Department of Environmental Quality - TITLE 119	Defines and issues permits for the discharge of constituents from any point source, including storm water, to surface waters of the state. Establishes development of an approved action plan and discharge regulations for storm water	Required for protection of wetlands, streams, lakes, and impounded waters from the runoff from toxic discharges. Required of management of repository where waste materials come into contact with storm water. Also required during construction of the repository. Monitoring program shall be implemented to ensure compliance with discharge regulations.
C. To Be Considered			
1. Hazardous waste handling, transport and disposal regulations	Nebraska Department of Environmental Quality – TITLE 128 Nebraska Hazardous Waste Regulations	Requires operating permits for proper identifications, handling, transport, and disposal of hazardous materials.	Supplement the federal RCRA regulations and define state permitting requirements.

Table 6-2, Continued
Potential State Action-Specific ARARs

	Citation	Prerequisite	Requirement
2. Siting Procedures and Polices	Nebraska State Statues 81-1521.08 to 81-1521.23	Policies and procedures are required in order to get approval for a hazardous waste management facility	Requires approval by local jurisdictions prior to the development of a site as a hazardous waste management facility.

Reduction of Toxicity, Mobility, or Volume

This criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the contaminants. The factors to be evaluated include:

- treatment process and remedy,
- amount of hazardous material destroyed or treated,
- reduction in toxicity, mobility or volume of the contaminants,
- irreversibility of the treatment, and
- type and quantity of treatment residuals.

Implementability

This criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. Technical feasibility considers:

- the ability to construct technology,
- reliability of technology,
- ease of undertaking additional remedial actions if necessary,
- monitoring considerations,
- coordination with other agencies (e.g., state and local) to obtain permits or approvals for implementing remedial actions,
- availability of treatment, storage capacity, and disposal services,
- availability of necessary equipment and specialists, and
- availability of prospective technologies.

Cost

This criterion addresses the capital costs, annual operation and maintenance costs, and present worth analysis. Capital costs consist of direct (construction) and indirect (non-construction and overhead) costs. Direct costs include expenditures for the equipment, labor and material necessary to perform remedial actions. Indirect costs include expenditures for engineering, financial and other services that are not part of actual installation activities but are required to complete the installation of remedial alternatives. Annual operation and maintenance costs are post-construction costs necessary to ensure the continued effectiveness of a remedial action. A present worth analysis is used to evaluate expenditures that occur over different time periods by discounting all future costs to a common base year, usually the current year. This allows the cost of remedial action alternatives to be compared based on a single figure representing the amount of money that would be sufficient to cover all costs associated with the remedial action over its planned life. As suggested in the EPA's guidance, a discount rate of 7 percent will be applied. The cost estimates are expected to provide an accuracy of +50 percent to -30 percent.

6.1.3 Modifying Criteria

State Acceptance

This criterion evaluates the technical and administrative issues and concerns the state may have regarding each of the alternatives. The factors to be evaluated include those features of alternatives that the state supports, reservations of the state, and opposition of the state.

Community Acceptance

This criterion incorporates public concerns into the evaluation of the remedial alternatives. Typically, community acceptance cannot be determined during development of the FS. Evaluation of this criterion will be completed when the final FS and Proposed Plan have been released for review by the public. This criterion will then be addressed in the final ROD and the responsiveness summary.

6.2 Alternative Analysis

The following sub-sections present the individual analyses of the alternatives against the nine criteria.

6.2.1 Alternative 1: No Action

Overall Protection of Human Health and the Environment

This alternative does not provide protection for the environment or residents in Omaha because no actions are taken to mitigate the exposure to lead-contaminated soil.

Compliance With ARARs

The location-specific and action-specific ARARs are not applicable to this alternative. This alternative would not meet federal To Be Considered criteria. EPA (40 CFR Part 745) and HUD (24 CFR Part 35) regulations that include LBP hazard prevention standards would not be met. Lead concentrations in indoor dust would continue to exceed lead-hazard criteria in these regulations. As discussed in the BHHRA, an estimated 9,033 properties (32% of properties evaluated) would continue to have P10 values at or below the EPA health-based goal of 5%.

Long-Term Effectiveness

This alternative provides no effectiveness for the protection of health and environment over the long term. The public is still exposed to elevated levels of lead.

Short-Term Effectiveness

No risk is imposed on the remedial action workers during the short term. The public and environment are still exposed to the same levels of lead.

Reduction of Toxicity, Mobility, or Volume

There is no reduction in the toxicity, mobility, or volume of contamination under the No Action alternative.

Implementability

This alternative does not require implementation.

Cost

There would be no costs associated with the No Action alternative.

State Acceptance

It is assumed that this alternative would not be acceptable to the state.

Community Acceptance

The level of public awareness and involvement at the site indicates that this alternative would not be acceptable to the community.

6.2.2 Alternative 2: Excavation and Disposal

Overall Protection of Human Health and the Environment

Exposure to lead-contaminated soil is a significant health risk posed by the site. Residential soils have been identified as a primary contributor to risk associated with lead exposures at the OLS. In order to reduce exposure to lead and the associated risks, the excavation alternative replaces lead-contaminated residential soils with clean soils, thereby breaking the exposure pathway between lead-contaminated soils and children.

In order to prevent the re-contamination of the clean soil placed in properties after excavation, deteriorating exterior LBP may be stabilized on homes prior to or after the soil excavation in the properties. Only those homes that are determined to threaten the continued effectiveness of soil remediation due to deteriorating LBP will be addressed. Paint stabilization would follow lead safe work practices.

Household dust has also been identified as a lead exposure pathway. Residential soils are a contaminant source for house dust. Thus, remediating residential soils would reduce a contamination pathway to home interiors. Interior dust above the action level for wipe samples will be controlled in homes where soil is remediated. HEPAVACs and health education would be made available to residents at the properties that exceed the 400 ppm cleanup level when wipe sampling identifies interior dust levels that exceed EPA/HUD criteria.

Sanitary landfills, controlled fill areas, and soil repositories can be designed and engineered to protect human health and the environment, including controlling migration of contaminants into ground water and surface water. With appropriate precautions taken during staging and hauling of the soil, there will be no unacceptable impact associated with implementation of the excavation and soil replacement elements of this alternative.

This alternative would control the significant exposure pathways associated with contaminated residential soils. Once residential soils excavation, soil replacement, and revegetation is complete, the soils are properly disposed, the information registry is implemented, and the ongoing education program is continued, risks associated with lead-contaminated residential soils will be controlled. Therefore, the excavation and replacement of contaminated soils is protective of human health and the environment.

Compliance With ARARs & Potential Action-Specific ARARs

As discussed previously, there are no promulgated laws or standards for lead-contaminated soil. A preliminary site-specific action level of 400 ppm for lead in soils is being advanced in this Final FS to provide for the protection of human health at this site based on information from the BHHRA which constitutes a To Be Considered criterion. EPA and HUD regulations for interior dust levels are To Be Considered criteria and would be used to trigger interior dust response properties where interior dust sampling identifies dust lead levels that exceed the applicable criteria.

Alternative 2 would comply with the chemical- and location-specific ARARs and To Be Considered criteria identified in Section 2 and presented in Tables 2-1 through 2-4. Alternative 2 would comply with Executive Orders 11988 and 11990 because the soil repository used during the remedial action would not be located within a flood plain or wetland. Because there would not be any structures constructed in waterways or in areas of critical habitat to threatened or endangered species, Alternative 2 would comply with the Endangered Species Act and the Rivers and Harbors Act. Excavation of residential properties would be performed in a manner to minimize the effect on historic landmarks in the OLS and would comply with the National Historic Preservation Act.

The potential federal and state action-specific ARARs for the excavation alternative are identified in Tables 6-1 and 6-2. The excavation and disposal alternative would comply with action-specific ARARs. The principal action-specific ARARs for this alternative are the requirements for proper transport and disposal of the excavated soils. Soils will continue to be tested to determine whether they are a hazardous waste and, if determined to be hazardous, would be transported and disposed in an appropriate final management facility in accordance with U.S. Department of Transportation and EPA regulations in 49 CRF Parts 171-177 and 40 CFR Parts 263 and 264.

The remedial action would comply with requirements of the Clean Water Act. Storm water discharge permits requirements are not applicable to excavation of residential properties since excavation of residential properties would not disturb more than one acre. Landfills, controlled fills, or repositories where the excavated soil is disposed would comply with the discharge permit regulations in 40 CFR Part 122.

Fugitive dust control measures such as the application of water would be implemented at residential properties during the remedial action to comply with Title 129, Chapter 32 of the NDEQ regulations regarding dust control.

Long-Term Effectiveness

The residual risks (the risk remaining after implementation) would be significantly reduced under this alternative. Residential properties with the highest mid-yard lead concentrations greater than 400 ppm would have the soil removed until reaching a residual concentration of less than 400 ppm in the initial one foot of excavation or less than 1,200 ppm at depths of greater than one foot. In garden areas, excavation would continue to less than 400 ppm in the initial 2 feet of excavation or less than 1,200 ppm at depths greater than 2 feet. The removal of contaminated soil, replacement with clean backfill, and revegetation ensures that future potential for exposure will be significantly reduced.

Short-Term Effectiveness

This alternative is protective in the short term. Although lead-laden dust could be generated during excavation, dust suppression would be implemented for the protection of community and workers during the remedial action. The alternative would be lengthy to implement for all affected residences, requiring several years to complete. The average length of time to complete all elements of soil replacement and restoration at any one residence could be several weeks; however residential exposure to dust would be minimal since dust suppression would be implemented when disturbance of contaminated soil is occurring.

Contaminated soils would continue to be used as daily cover in a sanitary landfill, used as beneficial fill, or placed in a permanent repository. Disposal of the soil in a landfill or repository would have no negative environmental impacts provided storm water controls and other design and engineering controls are achieved and maintained.

Reduction of Toxicity, Mobility, or Volume

This alternative would significantly reduce the mobility of the contaminants of concern by consolidation of the contaminated soils in a landfill or other disposal area. Although the exposure pathway would be eliminated or minimized, the toxicity and volume of the material would not be reduced. Proper maintenance at the existing sanitary landfill or construction and long term maintenance of a controlled fill area or soil repository are important components of this alternative that ensure a significant reduction of mobility.

Implementability

This alternative is readily implementable. Excavation methods, backfilling, and revegetation are typical engineering activities. Experience gained during previous EPA response actions has shown that this action is readily implementable. The information and education components of this alternative are implementable, but require cooperation and action by the local government entities.

Cost

This alternative is expected to have approximate capital costs of $226.7 million, as shown on Table 6-3, based on the estimate of $13,000 per home for excavation, transport, backfilling, dust suppression and lawn restoration. The overall cost includes $129.6 million for excavation, transport, backfilling, dust suppression and lawn restoration.

Table 6-3
Alternative 2 - Cost Analysis for Excavation and Disposal
Present Worth Cost Estimate
Omaha Lead Site Final FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	Annual Cost
CAPITAL COSTS					
Mobilization (1)	1	Mob	$50,000	$50,000	
Obtain Soil and LBP Access/Soil Sampling (1)	5,210	Properties	$400	$2,084,000	
Material Movement (excavation, transport, backfill, dust suppression, and sodding) (2)	9,966	Properties	$13,000	$129,558,000	
Post Cleanup Reports (1)	9,966	Properties	$100	$996,600	
Paint Assessment	11,683	Properties	$210	$2,453,430	
Exterior Lead-based Paint Stabilization (2)	5,522	Properties	$4,000	$22,088,000	
Preparation of Health and Safety Plan	40	HR	$100	$4,000	
Preparation of QA/Sampling Plan	60	HR	$100	$6,000	
DIRECT CAPITAL COST SUBTOTAL				$157,240,030	
Bid Contingency (15%)				$23,586,000	
Scope Contingency (10%)				$15,724,000	
TOTAL DIRECT CAPITAL COST				$196,550,030	
Permitting and Legal (2%)				$3,931,000	
Construction Services (10%)				$19,655,000	
CONSTRUCTION COSTS TOTAL				$220,136,030	
Engineering Design (3%)				$6,604,100	
TOTAL CAPITAL COST				$226,740,000	
TOTAL ANNUAL CAPITAL COSTS[3]				$22,674,000	
ANNUAL COSTS					
Year 1					
Information Dissemination via Mass Media, Including Television	1	LS	$150,000		$150,000
Establish Information Registry	1	LS	$100,000		$100,000
Public Health Education	1	LS	$250,000		$250,000
Maintain 2 Public Information Centers	1	LS	$156,000		$156,000
Property Access/Indoor Dust Wipe Sampling	729	Properties	$100		$72,900
Interior Dust Response Outreach	729	Properties	$90		$65,610
Purchase HEPAVAC	146	Properties	$350		$51,100
HEPAVAC instructions	146	HR	$90		$13,140
Year 2-10					
Information Dissemination via Mass Media, Including Television	1	LS	$150,000		$150,000
Maintain Information Registry	1	LS	$100,000		$100,000
Public Health Education	1	LS	$250,000		$250,000
Maintain 2 Public Information Centers	1	LS	$156,000		$156,000
Property Access/Indoor Dust Wipe Sampling	729	Properties	$100		$72,900
Interior Dust Response Outreach	729	Properties	$90		$65,610
Purchase HEPAVAC	146	Properties	$350		$51,100
HEPAVAC instructions	146	HR	$90		$13,140
TOTAL PRESENT WORTH COST				$165,285,000	

7 percent discount rate used to calculate present worth.

HR - Hours

LS - Lump Sum

FT - Feet

EA - Each

1 - BVSPC 2004 (Ref. 25)

2 - Costs Provided by EPA based on historical costs at the OLS

3 - Total Annual Capital Costs each year for 10 years

Table 6-3 (Continued)

Alternative 2 - Cost Analysis for Excavation and Disposal
Present Worth Cost Estimate
Omaha Lead Site Final FS Report

Year	Annual Capital Costs	Annual Costs	Total Annual Costs	Intermittent Costs Include:
1	$22,674,000	$858,750	$23,532,800	
2	$22,674,000	$858,750	$23,532,800	
3	$22,674,000	$858,750	$23,532,800	
4	$22,674,000	$858,750	$23,532,800	
5	$22,674,000	$858,750	$23,532,800	
6	$22,674,000	$858,750	$23,532,800	
7	$22,674,000	$858,750	$23,532,800	
8	$22,674,000	$858,750	$23,532,800	
9	$22,674,000	$858,750	$23,532,800	
10	$22,674,000	$858,750	$23,532,800	
11		$0	$0	
12		$0	$0	
13		$0	$0	
14		$0	$0	
15		$0	$0	
16		$0	$0	
17		$0	$0	
18		$0	$0	
19		$0	$0	
20		$0	$0	
21		$0	$0	
22		$0	$0	
23		$0	$0	
24		$0	$0	
25		$0	$0	
26		$0	$0	
27		$0	$0	
28		$0	$0	
29		$0	$0	
30		$0	$0	
Total Annual Costs			$235,328,000	
Present Worth of Annual Costs			$165,285,000	

Annual costs for Alternative 2 are shown in Table 6-3. The annual costs during years one through 10 are estimated to be approximately $858,750. The present worth value of Alternative 2 for the next 10 years is estimated to be $165.3 million. The cost estimate is within an accuracy range of +50 percent to -30 percent.

State Acceptance

State acceptance of the proposed alternative will be evaluated during the public comment period.

Community Acceptance

Community acceptance will be evaluated after the public comment period closes for the Proposed Plan and this FS.

6.2.3 Alternative 3: Phosphate Stabilization; Excavation and Disposal

Overall Protection of Human Health and the Environment

Treatment of soils with lead concentrations between 400 ppm and 500 ppm would control the primary threat to human health and the environment. Excavation of soils exceeding 400 ppm at properties with high mid-yard soil-lead concentrations greater than 500 ppm would permanently remove contaminated soil, thereby breaking the exposure pathway between lead-contaminated soils and children. Under Alternative 3, excavation would remove the potential for exposure to the most highly contaminated soils, and phosphate treatment of moderately contaminated soils will convert the lead into a form that would be less bioavailable, reducing risk to humans.

Phosphate stabilization has not been used on a full-scale basis to remediate lead-contaminated soils in a residential setting. The long-term effectiveness of phosphate treatment has not been demonstrated, and future soil chemistry testing of treated soils would be required to assure continued protectiveness of this process. The phosphate treatability study indicated that the bioavailability of lead can be reduced in OLS soils by approximately 20 percent. Thus, only those properties with lead concentrations between 400 ppm and 500 ppm would be remediated using phosphate treatment. The final decision to proceed with phosphate stabilization of properties will be made by the EPA after assessing public comment on the Final FS and the Proposed Plan.

In order to prevent the re-contamination of clean soil placed in properties after excavation, deteriorating exterior LBP may be stabilized on homes prior to or after the soil excavation in the properties. LBP stabilization will only be offered at properties where deteriorating LBP threatens the continued effectiveness of soil remediation, and will be voluntary to homeowners. LBP stabilization involves removing loose and flaking LBP from affected surfaces using lead-safe work practices, and priming and repainting of all previously painted surfaces.

Household dust has also been identified as a lead exposure pathway. Residential soils are a contaminant source to house dust. Thus, remediating residential soils would reduce a contamination pathway to home interiors. Interior dust above the action level for wipe samples will be controlled in homes where soil is remediated by providing HEPAVACs, training, and health education about household lead hazards to residents.

Sanitary landfill, controlled fill areas, and soil repositories can be designed and engineered to protect human health and the environment, including controlling migration of contaminants into ground water and surface water. With appropriate precautions taken during staging and hauling of the soil, there will be no unacceptable impact associated with implementation of the excavation and soil replacement elements of this alternative.

This alternative would break the significant exposure pathways associated with contaminated residential soils. Once residential soils are treated with the phosphate amendment; or removed through excavation and properly disposed, risks associated with lead-contaminated residential soils will be controlled. The phosphate stabilization and excavation and disposal alternative is protective of human health and the environment if the phosphate treatment significantly reduces the bioavailability of lead on a long term basis.

Compliance With ARARs

As discussed previously, there are no promulgated laws or standards for lead-contaminated soil. However, a preliminary site-specific action level of 400 ppm for lead in soils is being advanced in this Final FS to provide for the protection of human health at this site based on information from the BHHRA, which constitutes a To Be Considered criterion. Alternative 3 would comply with To Be Considered criteria if the phosphate treatment is effective in reducing the bioavailability of lead such that residential properties would not have P10 values exceeding the EPA health-based goal of 5 percent. In addition, EPA and HUD criteria for interior dust levels would be used to trigger interior dust response at properties where soil is remediated.

Alternative 3 would not comply with the To Be Considered criteria if the phosphate treatment was not effective in reducing the bioavailability of lead over a long period of time. Under these circumstances, some residential properties would continue to have P10 values at or below the EPA health-based goal of 5 percent. In addition, the alternative might not meet federal To Be Considered criteria in EPA (40 CFR Part 745) and HUD (24 CFR Part 35) regulations that address LBP poisoning prevention standards for LBP. Since soil-lead concentrations in treated soils would remain above 400 ppm, there may be an increased opportunity for lead concentrations in indoor dust samples from floors and window sills to exceed EPA/HUD criteria.

Alternative 3 would comply with the chemical- and location-specific ARARs and To Be Considered criteria identified in Section 2 and presented in Tables 2-1 through 2-4 if phosphate treatment remains effective. Alternative 3 would comply with Executive Orders 11988 and 11990 because the sanitary landfill, controlled fill, or soil repository used during the remedial action would not be located within a flood plain or wetland. Because there would not be any structures constructed in waterways or in areas of critical habitat to threatened or endangered species, Alternative 3 would comply with the Endangered Species Act and the Rivers and Harbors Act. Treatment and excavation of soil at residential properties would be performed in a manner to minimize the effect on historic landmarks in the OLS and would comply with the National Historic Preservation Act.

The potential federal and state action-specific ARARs for Alternative 3 are identified in Tables 6-1 and 6-2. Alternative 3 would comply with action-specific ARARs. Transportation of chemicals required for soil treatment, including the phosphoric acid, would be accomplished to comply with the U.S. Department of Transportation regulations at 49 CFR, Parts 171-177. Soils would continue to be tested to determine whether they are a hazardous waste and, if determined to be hazardous, would be transported and disposed in a final management facility in accordance with U.S. Department of Transportation and EPA regulations in 49 CRF Parts 171-177 and 40 CFR Parts 263 and 264.

Alternative 3 will comply with requirements of the Clean Water Act. Storm water discharge permits requirements are not applicable to excavation of residential properties since excavation of residential properties will not disturb more than one acre. Landfills or repositories where the excavated soil is disposed will comply with the discharge permit regulations in 40 CFR Part 122.

Title 117, Chapter 4 of the NDEQ regulations protects all surface waters from human-induced pollution which causes nuisance aquatic life (e.g., algal blooms). The treatability study conducted for the OLS indicated that the leachable phosphorous from soil is low following treatment with the phosphate amendment. However, if the leachable phosphorous increases over time, the phosphorous could leach to surface waters and contribute to algal blooms.

Fugitive dust control measures such as the application of water will be implemented at residential properties during the remedial action to comply with Title 129, Chapter 32 of the NDEQ regulations regarding dust control.

Long-Term Effectiveness

The residual risks (the risk remaining after implementation) would be significantly reduced under the excavation portion of this alternative. Soils exceeding 400 ppm would be treated to reduce risks at properties with high mid-yard soil lead levels between 400 and 500 ppm. Soils exceeding 400 ppm would be excavated and removed at properties with high mid-yard concentrations exceeding 500 ppm. Effective treatment of soils from 400-500 ppm and permanent removal of excavated soils ensure that potential for future exposure will be significantly reduced.

Data generated from treatability studies indicate phosphate-treated soils may reduce the bioavailability of lead in the soils by 20 percent on a short term basis. Phosphate stabilization of soils has not been implemented at a residential site and the long-term effectiveness of phosphate stabilization of lead in soils has not been completely demonstrated at the OLS or at other sites. Long-term monitoring would be required to demonstrate the long-term effectiveness of this alternative.

Short-Term Effectiveness

The phosphate stabilization alternative may present significant risks to residents, workers, and the community in the short term. Depending on the application method, there would be a risk to workers from aerosol spray during application of the phosphoric acid. Workers would be required to wear protective clothing, including respiratory protection, during the application of the phosphoric acid. Workers may be exposed to phosphoric acid during transfer of acid from the storage tanks to the transport trucks. There would be short-term risk to the public from transporting large volumes of phosphoric acid through residential neighborhoods.

During the first 7 to 10 days after the addition of the phosphoric acid, the soil would have a low pH near the surface which could cause skin irritation or burns and pose a hazard to human health. Application of the phosphoric acid could also damage the exterior of the house, shrubs, or personal property if the acid were not carefully applied to control aerosol dispersion. The property would have to be fenced prior to the application of the phosphoric acid to keep people and pets off of the property during treatment of the property. The fence would have to remain in place until the lime is applied to raise the pH of the soil. Small animals and birds would still have access to the property and contact with the soil prior to the application of the lime could pose a risk to them.

The excavation and disposal portion of this alternative is protective in the short term. Although lead-laden dust could be generated during the excavation, dust suppression would be implemented for protection of community and workers during remedial action. The alternative would be lengthy to implement for all affected residences, requiring several years to complete. The length of time to complete all elements of soil replacement and restoration could be several weeks; however residential exposure to dust would be minimal since dust suppression would be implemented during disturbance of contaminated soils.

The contaminated soils would continue to be used as a cover in a sanitary landfill or placed in a controlled fill or permanent repository. Disposal of the soil in a landfill, controlled fill, or repository would have no negative environmental impacts provided storm water controls and other appropriate design and engineering controls are achieved and maintained.

Reduction of Toxicity, Mobility, or Volume

The treatment portion of this alternative would reduce the toxicity and mobility of the contamination for those properties with lead contamination between 400 and 500 ppm. The volume of the contaminated soils would not be reduced. However, the amount of soil requiring excavation and disposal would be approximately 37 percent less than Alternative 2.

The excavation portion of this alternative would significantly reduce the mobility of the contaminants of concern by consolidation of the contaminated soils in the landfill or other disposal area. Although the exposure pathway would be eliminated or minimized, the toxicity and volume of the material would not be reduced. Proper maintenance at the existing sanitary landfill or construction and long-term maintenance of a controlled fill or soil repository are important components of this alternative that ensure a significant reduction of mobility.

Implementability

This alternative would be implementable, although the phosphate treatment portion of the alternative would require careful planning. Phosphate application methods include the use of typical lawn or garden maintenance equipment. The application of the phosphoric acid treatment on residential properties has not been attempted on a large scale. This treatment alternative can cause skin irritation as well as damage to the respiratory system of workers if not handled properly. Phosphoric acid is viscous, making application difficult and it may crystallize in winter.

Assuming that approximately 916 gallons of phosphoric acid would be required to treat each property based on application rates from the bench scale treatability study, and assuming that 3,721 properties would require treatment, approximately 3.5 million gallons of acid would be required over the duration of the remedial action. Bulk storage facilities would be required and the phosphoric acid would have to be transported to the properties in vehicles. Additional risks to the public would include accidents involving the transport vehicles and chemical spills. If there is excess phosphoric acid, disposal of the excess acid will require the selection of a treatment and disposal facility or an agreement with the vendor to return the excess acid.

Excavation methods, backfilling, and revegetation are typical engineering activities. Phosphate treatment of residential soils has not been accomplished on a large scale in a residential area and may not be easily implemented. The information and education component of this alternative is implementable, but requires cooperation and action by the local government entities.

Cost

Table 6-4 presents the costs for Alternative 3. The excavation portion of this alternative is expected to have capital costs of $81.2 million, as shown on Table 6-4, based on the estimate of $13,000 per home for excavation, transport, dust suppression, backfilling and lawn restoration. The capital costs of phosphoric acid treatment and lawn restoration is $132.5 million.

The total capital cost for this alternative, including phosphate treatment and excavation, is estimated to be $347.6 million.

Annual costs for Alternative 3 are shown in Table 6-4. The annual costs for years one through 10 are estimated to be approximately $858,750. Annual costs for the long term monitoring program for the properties treated with the phosphate amendment are an additional $137,602 in years 2, 5, 10, 15, and 20. The present worth value of Alternative 3 is estimated to be $250.6 million. The cost estimate is within an accuracy range of +50 percent to -30 percent.

State Acceptance

State acceptance will be evaluated after the public comment period closes for the Proposed Plan and this FS.

Community Acceptance

Community acceptance will be completed after the public comment period closes for the Proposed Plan and this final FS.

Table 6-4
Alternative 3 - Cost Analysis for Phosphate Stabilization; Excavation and Disposal
Present Worth Cost Estimate
Omaha Lead Site Final FS Report

Cost Estimate Component	Quantity	Units	Unit Cost	Capital Cost	Annual Cost
CAPITAL COSTS					
Mobilization (1)	1		$50,000	$50,000	
Obtain Soil and LBP Access/Soil Sampling (1)	5,210	Properties	$400	$2,084,000	
Material Movement (excavation, transport, backfill, dust suppression and sodding)(3)	6,245	Properties	$13,000	$81,185,000	
Post Cleanup Reports (1)	6,245	Properties	$100	$624,500	
Phosphoric Acid Treatment and Sod (2)	3,721	Properties	$35,596	$132,452,716	
Paint Assessment	11,683	Properties	$210	$2,453,430	
Exterior Lead-based Paint Stabilization (1)	5,522	Properties	$4,000	$22,088,000	
Long-Term Monitoring Program for Phosphate Treated Properties (10% of total properties at 6 months)	372	Sampling Events	$344	$128,002	
Long-Term Monitoring Reports	1	Reports	$9,600	$9,600	
Preparation of Health and Safety Plan	40	HR	$100	$4,000	
Preparation of QA/Sampling Plan	60	HR	$100	$6,000	
DIRECT CAPITAL COST SUBTOTAL				$241,085,248	
Bid Contingency (15%)				$36,162,800	
Scope Contingency (10%)				$24,108,500	
TOTAL DIRECT CAPITAL COST				$301,356,548	
Permitting and Legal (2%)				$6,027,100	
Construction Services (10%)				$30,135,700	
CONSTRUCTION COSTS TOTAL				$337,519,348	
Engineering Design (3%)				$10,125,600	
TOTAL CAPITAL COST				$347,645,000	
TOTAL ANNUAL CAPITAL COSTS[4]				$34,764,500	
ANNUAL COSTS					
Year 1					
Information Dissemination via Mass Media, Including Television	1	LS	$150,000		$150,000
Establish Information Registry	1	LS	$100,000		$100,000
Public Health Education	1	LS	$250,000		$250,000
Maintain 2 Public Information Centers	1	LS	$156,000		$156,000
Property Access/Indoor Dust Wipe Sampling	729	Properties	$100		$72,900
Interior Dust Response Outreach	729	Properties	$90		$65,610
Purchase HEPAVAC	146	Properties	$350		$51,100
HEPAVAC instructions	146	HR	$90		$13,140
Year 2-10					
Information Dissemination via Mass Media, Including Television	1	LS	$150,000		$150,000
Maintain Information Registry	1	LS	$100,000		$100,000
Public Health Education	1	LS	$250,000		$250,000
Maintain 2 Public Information Centers	1	LS	$156,000		$156,000
Property Access/Indoor Dust Wipe Sampling	729	Properties	$100		$72,900
Interior Dust Response Outreach	729	Properties	$90		$65,610
Purchase HEPAVAC	146	Properties	$350		$51,100
HEPAVAC instructions	146	HR	$90		$13,140
Long-Term Monitoring Program for Phosphate Treated Properties (10% of total properties at 2, 5, 10, 15, and 20 years)	372	Sampling Events	$344		$128,002
Long-Term Monitoring Reports at Years 2, 5, 10, 15, and 20 years	1	Reports	$9,600		$9,600
TOTAL PRESENT WORTH COST				$250,577,000	

EA - Each

LS - Lump Sum

FT - Feet

HR - Hour

1 - BVSPC 2004 (Ref. 25)

2 - Appendix A

3 - Costs Provided by EPA based on historical costs at the OLS

4 - Total Annual Capital Costs each year for 10 years

Table 6-4 (Continued)
Alternative 3 - Cost Analysis for Phosphate Stabilization; Excavation and Disposal
Present Worth Cost Estimate
Omaha Lead Site FS Report

Year	Annual Capital Costs	Annual Costs	Intermittent Costs	Total Annual Costs	Intermittent Costs Include:
1	$34,764,500	$858,750	$0	$35,623,300	
2	$34,764,500	$996,352	$0	$35,760,900	Includes monitoring of phosphate treated properties
3	$34,764,500	$858,750	$0	$35,623,300	
4	$34,764,500	$858,750	$0	$35,623,300	
5	$34,764,500	$996,352	$0	$35,760,900	Includes monitoring of phosphate treated properties
6	$34,764,500	$858,750	$0	$35,623,300	
7	$34,764,500	$858,750	$0	$35,623,300	
8	$34,764,500	$858,750	$0	$35,623,300	
9	$34,764,500	$858,750	$0	$35,623,300	
10	$34,764,500	$996,352	$0	$35,760,900	Includes monitoring of phosphate treated properties
11			$0	$0	
12			$0	$0	
13			$0	$0	
14			$0	$0	
15		$137,602	$0	$137,600	Includes monitoring of phosphate treated properties
16			$0	$0	
17			$0	$0	
18			$0	$0	
19			$0	$0	
20		$137,602	$0	$137,600	Includes monitoring of phosphate treated properties
21			$0	$0	
22			$0	$0	
23			$0	$0	
24			$0	$0	
25			$0	$0	
26			$0	$0	
27			$0	$0	
28			$0	$0	
29			$0	$0	
30			$0	$0	
Total Annual Costs				$356,921,000	
Present Worth of Annual Costs				$250,577,000	

7.0 Comparative Analysis of Alternatives

A comparative analysis of alternatives using each of the nine evaluation criteria, as required by federal regulation, is presented in this section. The purpose of this analysis is to identify the advantages and disadvantages of each alternative relative to the other alternatives. A separate comparison of the alternatives is presented under the heading of each criterion.

7.1 Protection of Human Health and the Environment

Protection of human health and the environment is addressed to varying degrees by the three action alternatives. The No Action Alternative would have no effect on the site. Therefore, it does not address any of the identified risks to human health.

Alternative 2 – Excavation and Disposal, and Alternative 3 - Phosphate Stabilization; Excavation and Treatment, both provide protection of human health through reducing exposure to lead in contaminated soils. Alternative 3 provides protection through *in situ* treatment for soils with lead concentrations between 400 ppm and 500 ppm by immobilizing lead and reducing its bioavailability. This determination was supported by OLS Bench Scale Treatability Study. The final decision to proceed with phosphate stabilization of properties will be made by the EPA after assessing public comment on the Final FS Report.

Alternatives 2 and 3 provide protection through excavation and soil replacement by removing the contaminated soils from the exposure pathway and replacing the contaminated soil with clean soil. Excavation and soil replacement eliminates the risk of exposure through direct contact with lead-contaminated soil. Exposure to lead in interior house dust would be reduced by providing HEPAVACs, training, and health education to residents at eligible properties. Providing an information registry would provide further, ongoing risk reduction for Alternatives 2 and 3.

Alternative 2 provides permanence through complete removal and containment of contaminated soils at or above 400 ppm lead concentrations. Alternative 3 provides permanence through a combination of excavation and soil replacement and immobilization of lead in phosphate-treated contaminated soils. Permanence would be provided only if the phosphate stabilization remains effective on a long-term basis.

7.2 Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

Alternative 2 complies with identified federal and Nebraska ARARs and To Be Considered Criteria. Alternative 3 would comply with the To Be Considered criteria if the phosphate treatment were effective in reducing the bioavailability of lead, and would likely comply with identified federal and Nebraska ARARs. Alternative 3 would not comply with Title 117, Chapter 4 of the NDEQ regulations if leachable phosphorous increases over time and phosphorous leaches to surface waters and contributes to algal blooms.

The No Action Alternative does not comply with the To Be Considered criteria and has no ARARs with which to comply. The detailed evaluations of Alternatives 2 and 3 for achieving ARARs and To Be Considered criteria are discussed in Section 6. The identification of potential federal and state chemical- and location-specific ARARs is discussed in Section 2.

7.3 Long-Term Effectiveness

Alternative 3 reduces risks through a combination of treatment and excavation, while Alternative 2 achieves risk reduction through excavation only. Both Alternatives 2 and 3 reduce risks for homes with soil lead levels at or above 400 ppm by using effective engineering controls. Previous studies are inconclusive as to whether phosphate treatment results in long-term reduction in the bioavailability of lead in soils. Treatment of residential soils using a phosphate amendment has not been implemented during a full scale remediation project.

Alternatives 2 and 3 also utilize an information registry and public education to further control residual risks. The No Action alternative provides no effectiveness for the protection of public health and the environment over the long term.

7.4 Short-Term Effectiveness

Alternative 2 has short-term risks for the public, environment, and construction workers from excavation and transportation efforts. Disturbed contaminated soil could enter the ambient air during excavation and transportation. However, dust suppression would be implemented for the protection of the community and workers during the remedial action. The alternative would be lengthy to implement for all affected residences, requiring several years to complete. However, the length of time at any one residence during excavation would be minimal.

Alternative 3 has the same risks as Alternative 2 in addition to exposing workers, residents, and animals to phosphoric acid and lime. Depending on the method of applying the phosphoric acid, there would be a risk to workers and property from aerosol spray. Workers would be required to wear protective clothing, including respiratory protection, during the application of the phosphoric acid. Workers would also be exposed to phosphoric acid during transfer of phosphoric acid from bulk storage facilities to the transport trucks. In addition, there would be increased risks to residents from transporting bulk phosphoric acid through residential neighborhoods.

7.5 Reduction of Toxicity, Mobility or Volume

The No Action Alternative would not reduce toxicity, mobility or volume of site contaminants. Alternative 2 would significantly reduce contaminant mobility for residences with soils having lead concentrations greater than 400 ppm through soil excavation and replacement. Alternative 3 would reduce toxicity and mobility of contaminants through phosphate treatment of soils with lead concentrations between 400 ppm and 500 ppm lead, and through the removal and replacement of excavated soils. The volume of contaminants would not be reduced.

Mobility of excavated materials placed in a soil repository or landfill is greatly reduced due to the engineering features designed to contain the contaminated soils.

7.6 Implementability

Alternative 2 and the soil excavation and disposal portion of Alternative 3 are readily implementable from an engineering perspective. Excavation methods, backfilling, and revegetation are typical engineering controls. The experience of previous actions taken at the OLS by the EPA has shown that this alternative is readily implementable.

The phosphate treatment portion of Alternative 3 would be more difficult to implement. The application of the phosphoric acid treatment on residential properties has not been attempted on a large scale. This treatment alternative can cause skin irritation as well as damage to the respiratory system of workers if not handled properly. Phosphoric acid is viscous, making application difficult and it may crystallize in winter.

The phosphoric acid could damage the exterior of a home or personal property around the home if the acid is not carefully applied. The property would have to be fenced prior to the application of the phosphoric acid to restrict access to treated areas during treatment of the property. The fence would have to remain in place until the lime was applied. Small animals and birds would still have access to the property and contact with the soil prior to the application of the lime could pose a risk to them.

7.7 Cost

The present worth cost for Alternative 2 is estimated at $165.3 million. The present worth cost for Alternative 3 is estimated at $250.6 million. No costs are associated with Alternative 1, No Action. The costs of the alternatives are listed in Tables 6-3 and 6-4.

7.8 State Acceptance

State acceptance on the alternatives will be evaluated after the public comment period closes for the Proposed Plan and this Final FS.

7.9 Community Acceptance

Community acceptance of the alternatives will be evaluated after the public comment period closes for the Proposed Plan and this Final FS.

8.0 Bibliography

1. Fact Sheet and Explanatory Statement provided by the Nebraska Department of Environmental Quality for the Omaha Lead site.

2. CERCLIS Site Information, CERCLIS Hazardous Waste Sites [electronic bulletin board], April 20, 2000 [cited August 21, 2000]. Available from epa.gov/ superfund/sites/cursites /c3ne.htm; Internet.

3. U.S. Department of Commerce, Rainfall Frequency Atlas of the United States, Technical Paper Number 40, Washington, D.C.: GPO 1961.

4. Phase I Detailed Site Assessment for Groundwater at the ASARCO Omaha Plant, Omaha Nebraska. Prepared by Hydrometrics, Inc. for ASARCO Inc., March 1995.

5. Ken Brown, Director TSC, letter with attachment to Don Bahnke, Remedial Project Manager, U.S. EPA Region 7, September 20, 1999. Subject: Air Dispersion Modeling - ASARCO S.F. Site.

6. Don Bahnke, Remedial Project Manager, U.S. EPA Region 7, letter with attachment to Michael J. Sanderson, Director Superfund Division, August 2, 1999. Subject: Request for Removal Action, Twelve Month Exemption, and a Two Million Dollar Exemption at the Omaha Lead Site, Omaha, Nebraska and Council Bluffs, Iowa.

7. Ecological Risks Associated with Releases of ASARCO Omaha Refinery Groundwater into the Missouri River, Omaha, Nebraska. Prepared by Parametrix, Inc. for ASARCO Inc., November 29, 1995.

8. Soil and Groundwater Characterization for the ASARCO Omaha Plant, Omaha, Nebraska. Prepared by Hydrometrics Inc. for ASARCO, Inc., November 1995.

9. The Case of ASARCO, Incorporated, Consent Order of Stay, Before the Nebraska Department of Environmental Quality, January 13, 1997.

10. Joyce Tsuji, Director of Risk Assessment and Toxicology Services, letter with attachment to Dennis Heitmann, Nebraska Department of Environmental Quality, February 13, 1997. Subject: Risk Evaluation Report for the ASARCO Omaha Site.

11. Blood-lead Levels in Douglas County by Zip Codes, DCHD Facsimile Transmission, Kathy Leinenkugel Lead Program Coordinator, DCHD to Donald Bahnke, USEPA, February 2, 2001.

12. Douglas County Health Department, Douglas County Blood-lead Screening Results Exceed National Average, November 18, 1998.

13. Ken Brown, Director, TSC, letter with attachment to Don Bahnke, Remedial Project Manager, U.S. EPA Region 7, December 28, 1998. Subject: Contour Plots-ASARCO S.F. Site.

14. Background Summary Report, Omaha Lead Refining Site, Omaha, Douglas County, Nebraska. Prepared by Jacob Federal Operations for the Environmental Protection Agency, Region 7, January 27, 2000.

15. Don Bahnke, Federal Facilities/Special Emphasis Superfund Division U.S. EPA, Region 7, letter with attachment to Robert Little, Manager- Environmental Services ASARCO, Inc., April 5, 2000. Subject: Written consent for entry and access.

16. Trip Report, Omaha Lead Refining Site, Omaha, Douglas County, Nebraska, EPA Work Assignment No. 025-SISI-07ZY. Prepared by Jacobs Federal Operations for the United States Environmental Protection Agency, Region 7, May 31, 2000.

17. Gene Gunn, Chief Federal Facilities Superfund Division, letter with attachment to Michael Horn, July 10, 2000. Subject: Letter requesting the cooperation of Union Pacific Railroad Company to provide documents and information on the Omaha Lead Site.

18. Robert Litle, Owner of ASARCO, Inc., letter with attachment to Don Bahnke, Remedial Project Manager EPA Region 7, August 2, 2000. Subject: Omaha Lead Site.

19. Code of Federal Regulations Title 40: Protection of Environment, Chapter I, Subchapter J, Part 300 – National Oil and Hazardous Substances Pollution Contingency Plan. Available from epa.gov/docs/epacfr40/Chapt-I.info/subch-J.htm; Internet.

20. United States Environmental Protection Agency, Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final,

October 1988. Available from epa.gov/superfund/guidance/remedy/crifs/ overview.htm; Internet.

21. BVSPC, *Remedial Investigation, Residential Yard Soil, Omaha Lead Site, Omaha, Nebraska*, June 9, 2004.

22. Drexler, *Final Bench-Scale Treatability Study, Omaha Lead Site, Omaha, Nebraska*, February 2009.

23. D.E. Mosby, S. Casteel, J. Yang, and C.J. Gantzer. *Final Report Lead Bioavailability Study Phosphate Treatment of Lead-Contaminated Soils, Joplin, Missouri, Jasper County Superfund Site*. Prepared for Missouri Department of natural Resources Hazardous Waste Program, Jefferson City, MO and U.S. Environmental Protection Agency Region VII, Kansas City, KS, December 2006.

24. J. Yang, R.W. Blanchar, S. W. Casteel, and D.E. Mosby. *Effect of Phosphoric Acid Treatment on Lead Bioavailability in the Contaminated Soil in the Jasper County, Joplin, Missouri. Soil Treatments and Characterization*. Final Report Submitted to Missouri Department of natural Resources, July 2000.

25. BVSPC 2004, *Feasibility Study Residential Yard Soil, Omaha Lead Site, Omaha*, Nebraska, June 2004

26. BVSPC 2007, *Evaluation of Phosphate Treatment of Residential Properties; Omaha Lead Site, Omaha, Nebraska*, April 25, 2007.

27. EPA 2003, *Superfund Lead-Contaminated Residential Sites Handbook,* OSWER 9285.7-50, August 2003.

28. Charney, E., B. Kessler, M. Farfel, D. Jackson, *A Controlled Trial of the Effect of Dust Control Measures on Blood Levels*. New England Journal of Medicine 309 (18):1089-1093.

29. *Final Preliminary Assessment/Site Inspection Report, Omaha Lead Site, Omaha, Nebraska*. Prepared by Black & Veatch Special Projects, Corp., for the Environmental Protection Agency, Region 7, August 2001, Work Assignment No.048-SISI-07ZY.

30. *Baseline Human Health Risk Assessment for the Omaha Lead Site, Omaha, Nebraska*; Syracuse Research Corporation, February 2009.

31. *Final Remedial Investigation Report, Omaha Lead Site, Omaha, Nebraska;* Black & Veatch Special Projects Corp, April 2009.

Appendix A
Phosphate Treatment Cost Evaluation

Appendix A
Cost Evaluation

Phosphate Treatment of Residential Properties at the Omaha Lead Site, Omaha, Nebraska

Assumptions for Cost Evaluation
September, 2008

This evaluation presents the costs to implement a phosphate treatment remedial action at the Omaha Lead Site in Omaha, Nebraska. The evaluation contains the cost breakdown of the tasks and procedures required to implement the remedial action.

Following is an outline of the basic project assumptions; phosphate treatment procedures; miscellaneous cost impact issues, and other considerations that directly and indirectly affect the remediation process and impact the cost estimate:

A. Basic Project Assumptions:

1. Unit residential treatment area of 7,890 square feet (sf) [property area equivalent to 25% of nominal survey acreage of a typical property at 10,890 sf, minus 3,000 sf for improvements, landscaping, and other areas = 7,890 sf]

2. Contractors for project shall function as follows:
    a. Prime Contractor
    - Mobilization to property
    - Property assessment
    - Property area preparation (prior to treatment process)
    - Install protective barrier/erosion control
    - Roto-tilling #1 (to depth of about 15 cm)
    - Initial Application of Chemicals (Phosphoric Acid and Potassium Chloride)
    - Roto-tilling #2
    - Application of addt'l 5g Phosphate (P) Kg soil
    - Roto-tilling #3
    - Lime stabilization of soil / pH adjustment
    - Soil preparation for sod placement (see subcontractor below)
    - Re-install lawn features
    - Remove protective barrier/erosion control
    - Demobilization from property

    b. Subcontractor(s)
    - Lawn Service Subcontractor
        - Lay sod (following application of chemical agents by Prime Contractor, and soil preparation for sod placement)
        - Replacement of damaged plantings / shrubs, etc

3. 85% Phosphoric Acid (PA) is applied at rate of 10 U.S. gallons per 86.1113 sf. (37.8 Liters per 8 sq. meters); (note: per *Harcros Chemicals, Inc.*, PA is typically purchased by the pound at a weight of 13-14 lbs of raw acid/gallon; use 13.2 lbs/gal. PA is incorporated into the soil at approx. 6” depth during roto-tilling operations.

   Volume of PA required per property:
   7,890 sf /property x 10 gal / 86.1113 sf = 916.256 gal PA / property

   Weight of PA required per property:
   916.256 gal PA / property x 13.2 lbs / gal = 12,095 lbs / property

4. Potassium Chloride (KCl) (fertilizer grade) is applied at a rate of 335 lbs / 7,890 sf property (1.66 kilograms per 8 sq. meters). The KCl shall be applied in conjunction with the application of the Phosphoric Acid.

5. Lime is applied at a rate of 1837 lbs / 7,890 sf property (9.1 kilograms per 8 sq. meters). The Lime will be applied and incorporated in the soil by roto-tilling and grading for drainage, and compaction to 85% Proctor. Lime incorporation occurs after a period between 3 to 10 days following the application of the PA and KCl.

B. Listing of Chemical Treatment Procedures:

Step 1	Property Assessment (e.g., identify buried utility locations)
Step 2	Property preparation (prior to treatment process)
Step 3	Install protective barrier/ erosion controls around property
Step 4	Roto-tilling #1 of soil
Step 5	Apply Phosphoric Acid chemical
Step 6	Apply Potassium Chloride chemical
Step 7	Roto-tilling #2 of soil
Step 8	Apply Application of addt’l 5g Phosphate (P) Kg soil
Step 9	Roto-tilling #3 of soil
Step 10	Incorporate Lime into soil (incl Rototilling #4)
Step 11	Fine Grade / compaction of disturbed soil to prepare for sod placement
Step 12	Placement of Sod
Step 13	30 day watering period to establish sod (provide cost allowance to owner)
Step 14	Re-install lawn features
Step 15	Replacement of damaged plantings / shrubs, etc. (note: provide cost allowance)
Step 16	Remove protective barrier/erosion controls

C. Direct-Indirect cost impacts and considerations:

1. All properties are considered to be residential.

2. Costs of chemicals and sod placement are based on delivery to Omaha, NE.

3. The location of buried utilities issues (i.e., cable T.V., sprinkler systems, underground electrical) are a concern. An allowance for locating the utilities has been included in the estimate.

4. Costs associated with pet control issues are not addressed in this estimate.

5. HAZWOPER - OSHA Compliant Training costs are considered requirements for all personnel and included in the analysis.

6. Assumed Daily Log / Journaling tasks for remediation program inherent to all activities.

7. Cost evaluation does not provide for allowances where property conditions may exist in which owner has invested substantial resource into lawn care / maintenance, etc.

8. When soil is roto-tilled, it may bulk in volume approx. 15%, and require re-compaction prior to sod placement. (See Steps 5 through 10 of treatment procedures.)

10. Analysis assumes erosion control barrier will be required in addition to the protective barrier.

11. Analysis does not provide for Testing /Sampling following remediation procedures.

12. A cost allowance is made for areas of properties that may require some re-sodding at future date. For purpose of the cost evaluation, the basis is 10% of total residential properties requiring 5% sod re-placement.

13. No cost allowance is made for temporary displacement of individuals / pets / livestock, etc., during the remedial process.

14. Prime and Subs will need to mob / demob to each residential property. An allowance for mob / demob of equipment and personnel and documentation procedures is provided in the analysis.

15. Costs do not include oversight by agency personnel.

16. It is assumed contractor personnel shall be required to wear protective clothing during all chemical applications and presence on the property prior to sod placement. Respirators will be required during application of the phosphoric acid. (See item 5 above)

17. Analysis does not include costs associated with obtaining access to properties, characterization costs, or post-treatment evaluation costs.

18. Costs relating to damage of property features (i.e., sidewalks, drives, ornaments) are not included.

19. A cost allowance for watering the sod for 30 days is provided for in the estimate.

20. Costs associated with limitations and encumbrances to property access are not included.

21. Risks associated with the acidic and caustic nature of applied chemicals are not addressed. Risks may include ecological impacts and associated costs due to stormwater runoff which discharges into streams and air-borne particulates which become in contact with property features (i.e., housing, automobiles, and other property features.)

22. Risks, concerns, and issues which are associated with stormwater runoff discharged onto adjoining properties are not evaluated in this analysis.

23. A 10% contingency is added to the estimated phosphate treatment cost to allow for unforeseen conditions and circumstances relating to remedial operations.

24. Contractor delivery capability of chemicals in residential areas is an issue due to the limited size requirements of delivery vehicles and limited roadway features typically found in residential areas. Associated risks / costs impacts due to delivery of chemicals to a property are not included.

25. Availability and costs of the chemicals are affected by seasonal demands supplies on manufactures from agri-business, or other industries.

26. Due to the extensive gross chemical quantities required for a remediation program of residential properties, a controlled storage and staging facility of chemicals will be required for the OLS program. The facility would warehouse and allow for breakdown of delivered products into manageable and effective units. It would be required for the facility to adequately shelter the products from the elements and meet public safety needs. Sufficient personnel and equipment would be required to manage and maintain operations at the storage and staging facility. Although the specific requirements for the facility are not known, an allowance has been included in the analysis.

27. Davis-Bacon wage rates are used as basis of labor costs, from DB General decision NE20080001, dated 08/08/2008. Equipment costs are abstracted from 2007 MCACSES MII Region 5 Equipment database, then escalated to 2008 costs.

28. Costs are in current 2008 U.S. dollars (as of September 2008).

D. Following pricing information provided by:

1. Commodity chemical pricing:

Harcros Chemicals, Inc
Omaha, Nebraska
9000 F. Street
Omaha, NE 68127
Attn: Mr. Don Woolsey
Phone: (402) 331-4525

Note: Commodity chemical pricing from Harcros is intended only to reflect market conditions as of the date indicated below. The product supply and demand affect product price accordingly.

	Cost / Unit of Measure	**Cost / Unit of Measure**
Phosphoric Acid	**$0.24 / lb (Apr2007)** (Harcros Chemicals)	**$1.18 / lb (Sep2008)** (Harcros Chemicals)

(Product cost includes delivery to Omaha, NE, and is based on delivery by 45,000 gallon tanker truck. As stated per *Harcros Chemicals, Inc.*, PA is typically purchased based on a weight of 13 to 14 lbs of 75% tech grade acid / gallon; use **13.2** lbs/gallon to determine total pounds required per property. It is noted the cost / lb of has increase by over 400% since Apr2007)

	Cost / Unit of Measure	**Cost / Unit of Measure**
Potassium Chloride (Potash)	**$0.19 / lb (Apr2007)**	**$0.57 / lb (Sep2008)**
(Fertilizer Grade)	(Harcros Chemicals)	(Harcros Chemicals)

(Product cost includes delivery to Omaha, NE, and is based on 44,000 lb truck delivery of 50 lb bag dry product, on 2000 lb pallets)

	Cost / Unit of Measure	**Cost / Unit of Measure**
Lime	**$0.18 / lb (Apr2007)**	**$0.15 / lb (Sep2008)**
	(Harcros Chemicals)	(Home Depot)

(Product cost includes delivery of hydrated lime to Omaha, NE, and is based on 44,000 lb truck delivery of 50 lb bag dry product, on 2000 lb pallets).

Harcros Chemicals Inc *is a major distributor and producer of industrial chemicals. Privately held since a management buy-out in 2001, the Company began business in 1917 as Thompson-Hayward Chemicals, and in 1961 was purchased by North American Philips. In 1981, Harrisons and Crosfield plc purchased the bulk of the business from Philips, subsequently changing the name to Harcros Chemicals Inc.*

The core business of Harcros is the distribution of industrial chemicals, with twenty-eight branches in twenty states, including the cities of Omaha, NE., and Kansas City, KS.)

Updated ROM / budgetary cost information for chemicals provided by Harcros in September 2008 (from April 2007) is reflected above. Per D. Woolsey, substantial cost increases along with significant reductions in availability have occurred with all phosphors related products. 2008 estimated pricing for "Lime" was obtained from Home Depot, Inc.

2. Other Pricing: **Protective Barrier (Safety Fence)**
Home Depot, Inc.
$17.00 / 50-ft roll = approx. $0.35 per LF

Sod (Lawn Service)
Midwest Landscaping; Omaha, NE (402-339-5151) $0.20-$0.24 / SF
Interstate Grass Pad: Omaha, NE (402-331-6577) $0.27 / SF
Sod City: Omaha, NE (402-331-6577) $0.23 / SF

[Use avg……$0.25 / SF installed = $250.00 / MSF installed]

(note: sod providers noted above are currently supporting present remediation processes in Omaha, NE.)

BLACK & VEATCH

DATE: September 11, 2008

CLIENT: Environmental Protection Agency
PROJECT: Phosphate Treatment of Residential Properties at the Omaha Lead Site
LOCATION: Omaha, Nebraska

Prepared By:	**M. Ledbetter / G. Hicks**
Checked By:	**D. Sanders**

PROJECT NO. 044746.01.12

SHEET 1 OF 10

TOTAL SUMMARY OF ESTIMATED TREATMENT COSTS:

Item	Unit	Total Labor	Total Equip	Total Material	Subcontract	Total Contract
PROJECT COSTS (INCL (incl PT&I and Sales Tax , Prime Overhead, Profit)	**LS**	**$ 2,948**	**$ 4,852**	**$ 21,807**	**$ 2,433**	**$ 32,039**
SUBTOTALS		**$ 2,948**	**$ 4,852**	**$ 21,807**		**$ 32,039**
CONSTRUCTION BOND	**1%**	---	---	---	x	**$ 320**
ESTIMATED TREATMENT COST =						**$ 32,360**
TREATMENT CONTINGENCY @	**10%**	---		---		**$ 3,236**
Total estimated Phosphate Treatment costs for .25 acre Property =						**$ 35,596**

CLIENT:	**Environmental Protection Agency**
PROJECT:	**Phosphate Treatment of Residential Properties at the Omaha Lead Site**
LOCATION:	**Omaha, Nebraska**

Prepared By:	**M. Ledbetter / G. Hicks**
Checked By:	**D. Sanders**

PROJECT NO. 044746.01.12

COST ANALYSIS - PRIME CONTRACTOR SUMMARY

NOTES:

1. **COSTS ARE BASED ON 3,747 TOTAL NUMBER OF SAMPLE PROPERTIES REMEDIATED.**
2. **THIS SUMMARY REFLECTS ESTIMATED TOTAL TREATMENT COSTS IN 2008 DOLLARS.**
3. **COSTS ARE PRIMARILY DERIVED OR ABSTRACTED FROM MCACES MII UPB COST DATA, AND/OR PRICING INFORMATION PROVIDED BY VENDOR / SUPPLIERS.**
4. **TREATMENT COSTS HAVE BEEN ADJUSTED TO REFLECT "AREA COST FACTOR" IMPACTS BASED ON DAVIS-BACON HEAVY CONSTRUCTION WAGE RATES AS APPLIED TO THE OMAHA, NE , DOUGLAS COUNTYAREA. LABOR COSTS INCLUDE BASE RATES AND FRINGES.**
5. **ESTIMATE PRESUMES CONTRUCTION WILL BE WITH A SELF-PERFORMING PRIME CONTRACTOR AND ONE SUBCONTRACTOR.**
6. **ESTIMATE ASSUMES PRIME CONTRACTOR AND SUBCONTRACTOR WILL BE "LOCAL" TO OMAHA, NE, AND SHALL HAVE MINIMAL MOB & DEMOB COSTS.**
7. **THE TREATMENT CONTINGENCY PERCENTAGE ASSIGNED IS BASED ON LEVEL OF UNFORESEEN CONDITIONS IMPACTING REMEDIATION. THE CONTINGENCY ALLOWS FOR UNEXPECTED COSTS IN LABOR, MATERIAL, SITE CONDITION IMPACTS, ETC., WHICH MAY RESULT IN ADDITIONAL COSTS SPECIFIC TO ANY GIVEN PROPERTY. THE CONTINGENCY IS ADDED TO THE ESTIMATED TOTAL TREATMENT COST OF THE PROJECT.**

BLACK & VEATCH

DATE: September 11, 2008

CLIENT: **Environmental Protection Agency**
PROJECT: **Phosphate Treatment of Residential Properties at the Omaha Lead Site**
LOCATION: **Omaha, Nebraska**

PROJECT NO. 044746.01.12

BASIS FOR ESTIMATE
☐ CODE A (No Design Complete)
☐ CODE B (Preliminary Design)
☐ CODE C (Final Design)
☒ OTHER (Specifiy)

COST ANALYSIS - PRIME CONTRACTOR SUMMARY

ESTIMATORS: M. LEDBETTER / G. HICKS

SHEET 3 OF 10

PRIME CONTRACTOR SUMMARY	Quantity		Labor Cost		Equipment Cost		Material Cost		PRIME CONTRACTOR TOTAL COSTS	ACCUMLATIVE TOTAL COSTS
	No. Units	Unit Meas	Per Unit	Total Labor	Per Unit	Total Equip	Per Unit	Total Material		
TOTAL BARE COSTS (SEE PRIME / SUB WORKSHEETS)				$ 1,780.43		$ 3,486.54		$ 15,343.45		
Labor , Equipment & Materials Adjustments due to hazardous site conditions			10%	$ 178.04	10%	$ 348.65	5%	$ 767.17		
Total Bare Costs				$ 1,958.47		$ 3,835.19		$ 16,110.62		
Payroll Taxes and Insurance (PT&I) ; and Sales Tax (on material only)			19%	$ 372.11	0%	$ -	7%	$ 1,127.74		
SUBTOTAL				**$ 2,330.58**		**$ 3,835.19**		**$ 17,238.37**		
TOTAL DIRECT COST				**$ 2,330.58**		**$3,835.19**		**$ 17,238.37**		
OVERHEAD @			15%	$ 349.59	15%	$575.28	15%	$ 2,585.75		
SUBTOTAL				**$ 2,680.17**		**$ 4,410.47**		**$ 19,824.12**		
PROFIT			10%	$ 268.02	10%	$ 441.05	10%	$ 1,982.41		
SUBTOTAL				$ 2,948.19		$ 4,851.51		$ 21,806.53	$ 29,606.23	**$ 29,606.23**
TOTAL SUBCONTRACTOR COSTS									$ 2,211.89	
PRIME CONTRACTOR MARGIN ON SUBS								10%	$ 221.19	
									$ 2,433.08	**$ 2,433.08**
TOTAL PRIME CONTRACTOR										**$ 32,039.31**

Notes:

1. Costs shown on these pages of the anaysis are reflected as cost to the owner.

2. Costs do not include CONSTRUCTION BOND.

3. Costs within the Prime Contractor Summary do not include any CONTINGENCIES affiliated with the remedial program.

BLACK & VEATCH

DATE: September 11, 2008

CLIENT: Environmental Protection Agency
PROJECT: Phosphate Treatment of Residential Properties at the Omaha Lead Site
LOCATION: Omaha, Nebraska

PROJECT NO. 044746.01.12

COST ANALYSIS

BASIS FOR ESTIMATE

CODE A (No Design Complete)
CODE B (Preliminary Design)
CODE C (Final Design)
X OTHER (Specifiy)

ESTIMATORS: M. LEDBETTER / G. HICKS

SHEET 4 OF 10

PRIME CONTRACTOR WORK / TASK ITEM	Quantity		Labor Cost		Equipment Cost		Material Cost				UNIT
	No. Units	Unit Meas	Per Unit	Total Labor	Per Unit	Total Equip	Per Unit	Material Cost	Shipping	Total Material	TOTALS
GENERAL REQUIREMENTS											
Temp Facilties and Controls (mob / demob) ; incl logging/closeout procedures; (Prime - Contractor allowance) say $20.00 equip mob + $5.00 logging/closeout procedures = $25.00 per Property	1	LS	$ 25.00	$ 25.00	$ -	$ -	$ -	$ -	$ -	$ -	$ 25.00
Specialized Training (HAZWOPER - OSHA Compliant Training) Allow $500 for a one week (40 training session) which trains all personnel for duration of entire abatement Personnel requiring training are those involved in all preparation and treatment efforts prior to sod placement Training Costs are distributed over balance of 3,747 properties at the Omaha Lead Site project (Sept 2008). Est. 7 people trained ; $500 per wk training cost / 7 people = $71.43 cost per person ; assume $71.43 / 3,747 prop = approx. $0.02 course cost / per person / property; training costs paid for training: labor costs paid during training: 40 hrs x [assume 5 persons x $23.50 avg / hr+ 2 persons x $22.75 / hr] = $6520 div. by 3,747 = $1.74 thus $1.74 + $0.02 = $.1.76……use $1.76 / property = Avg. HAZWOPER - OSHA Compliant Training cost per Property	1	LS	$ 1.760	$ 1.76	$ -	$ -	$ -	$ -	$ -	$ -	$ 1.76
Controlled Chemical Storage and Staging Facility: Costs associated with a controlled storage and staging facility of chemicals should be incurred for the Omaha Lead Property abatement program. The facility would warehouse and allow for breakdown of delivered products into manageable and effective units. An Estimated amount of $3,000,000 is required for property / facility acquision; facility operations over estimated 7 year period; and de-commissioning of facility. Thus, $3,000,000 / 3,747 properties = $800.64 cost impact per property; say $800	1	LS	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 400.00	$ 400.00	$ -	$ 400.00	$ 800.00
PROPERTY ASSESSMENT											
Prior to remedial procedures and property preparation, evaluate specific needs to prep Property for treatment Incls photos of existing Property conditions prior to construction) (allow 1 hour avg time frame; 1 laborer = 1 Mhr); laborer may also be used in Property Area Prep below	1	Mhr	$ 25.25	$ 25.25	$ -	$ -	$ -	$ -	$ -	$ -	$ 25.25
PROPERTY AREA PREPARATION (prior to treatment process)											
Following initial assessment temporarily remove / store on-Property any lawn features which will impact an effective treatment process, and to provide protection of such features (allow 4 hours avg time frame; 2 laborers = 8 Mhr)	8	Mhr	$ 24.31	$ 194.48	$ -	$ -	$ -	$ -	$ -	$ -	$ 194.48
INSTALL PROTECTIVE BARRIER / EROSION CONTROL											
Install PROTECTIVE BARRIER around perimeter of .25 acre Property Property; allow 400 LF per Property (allow for 2 laborers to install approx. 200 LF per HR at $24.31 / hr = $0.243 / LF labor cost Material Costs: 400 LF x say 10 properties only x $5.00 LF of barrier with EC / [3,747x400] = $0.013 ; assume $0.02 / LF material / property	400	LF	$ 0.243	$ 97.20	$ -	$ -	$ 0.02	$ 8.00	$ -	$ 8.00	$ 105.20
ROTOTILLING #1											
Rototilling of property prior to application chemicals ; (Crew RT-1)	7.890	MSF	$ 0.50	$ 3.98	$ 0.54	$ 4.27					$ 8.25

COST ANALYSIS

SHEET 5 OF 10

PRIME CONTRACTOR WORK / TASK ITEM	Quantity		Labor Cost		Equipment Cost		Material Cost				UNIT
	No. Units	Unit Meas	Per Unit	Total Labor	Per Unit	Total Equip	Per Unit	Material Cost	Shipping	Total Material	TOTALS
APPLICATION OF CHEMICALS (Phosphoric Acid and Potassium Chloride)											
Spray application of Phosphoric Acid onto soil (1 complete Property = 7890 SF = 7.890 MSF); (Crew SPR-1)	12095	LBS	$ 0.0247	$ 298.80	$ 0.250	$ 3,023.75	$ 1.18	$ 14,272.10	$ -	$ 14,272.10	$ 17,594.65
Allow 916.256 gal / Property application rate; allow for (2) technicians ; 1 for application; 1 for monitoring tank truck											
assume 6 hrs total at application rate ; technicians hourly rate assumed at $24.90 / hr incl / fring.											
thus for 6 hr treatment process assume: (6 hrs x 2 techs x $24.90/hr)											
Use equipment cost approx. equivalent to labor cost, assume $0.025 / lb equip											
(Note: material costs per Harcros Chemicals, Inc., Omaha, NE)											
Application of Potassium Chloride [Potash] onto soil (1 complete Property = 7890 SF)	335	LBS	$ 0.148	$ 49.58	$ 0.025	$ 8.38	$ 0.57	$ 190.95	$ -	$ 190.95	$ 248.91
(includes both initial after rototilling #1 and secondary application afer rototilling #2)											
allow 335 LBS / Property application rate; allow for (1) technician ; Material costs per Harcros Chemicals, Inc.											
assume 2 hrs total at application rate of 167.5 CF per hour; technicians hourly rate assumed at $24.75 / hr											
thus for 2 hr treatment process assume: (2 hrs x 1 tech x $24.75 / hr) / 335 LBS = $0.148 / LB											
Safety wear / protective gear (i.e., TYVEK outwear, gloves, protective face masks)	3	SETS	$ -	$ -	$ -	$ -	$ 50.00	$ 150.00	$ -	$ 150.00	$ 150.00
(incl 1 pr coveralls $4.89; pr gloves @ $1.99; 1 ea respirator @ $25.00 ; protective eyeware @ $5.00 = 1 set											
Total cost of 1 set = $46.88.....assume $50.00 per person x 3 laborers = $150.00 / Property											
(pricing per Northern Safety Company)											
Decontamination Shower (ALLOW $700 / UNIT FOR 10 UNITS; pricing per *Northern Safety Company*)	1	Ea	$ 22.75	$ 22.75	$ -	$ -	$1.85	$ 1.85	$ -	$ 1.85	$ 24.60
($700 units X 10 ea div. 3,747 Properties = $1.87 per Property costs......assume $1.85; allow 1 Mhr at $15 for setup / Property; assume (1) technician required for I hr to set up unit											
ROTOTILLING #2											
(follows Phosphoric Acid and Potassium Chloride application- see above)											
Rototilling of property prior to application chemicals ; (Crew RT-1)	7.890	MSF	$ 0.50	$ 3.98	$ 0.54	$ 4.27					$ 8.25
ROTOTILLING #3 (follows 5g Phosphate (P) Kg soil application- see above)											
Rototilling of property prior to application chemicals ; (Crew RT-1)	7.890	MSF	$ 0.50	$ 3.98	$ 0.54	$ 4.27					$ 8.25
LIME STABILIZATION OF SOIL / PH ADJUSTMENT											
Application of LIme onto soil (1 complete Property Property = 7890 SF = 876.67 SY)	1837	LBS	$ 0.16	$ 293.92	$ 0.015	$ 27.56	$ 0.15	$ 275.55	$ -	$ 275.55	$ 597.03
Includes **Rototilling #4**, grade for drainage; and compaction to 85% Proctor;											
allow 1837 LBS / Property application ;											
allow 2.0954 LBS / SY application rate; allow for (1) technician											
assume application rate of 150 SY per hr per hour; 876.67 / 150 SY per hour = 5.84 hrs											
technicians hourly rate assumed at $24.75 / hr											
thus : (5.84 hrs x 2 techs x $24.75/hr) / 1837 LBS = $0.1574....assume $0.16 / LB labor											
Material costs per *Harcros Chemicals, Inc.*											
Costs of Safety wear / protective gear (i.e., Tryvek outwear, gloves, protective face masks) incl above incl above in "APPLICATION OF CHEMICALS"	x	x	x	x	x	x	x	x	x	x	x
Allowance for protection / relocation / repair of impacted buried / underground utilities :	1	LS	$ 99.00	$ 99.00	$ 25.00	$ 25.00	$ 45.00	$ 45.00	$ -	$ 45.00	$ 169.00
assume 4 Mhrs per Property x $24.75 for each Property = $99.00 labor											
assume $25 avg. equip. cost per each Property.											
assume $45 material cost avg per each Property.											
SOIL PREPARATION FOR SOD PLACEMENT											
(also see See Lawn Service Subcontractor)											
Costs of compaction of disturbed tilled soil included in "LIME SOIL STABILIZATION" above	x	x	x	x	x	x	x	x	x	x	x
Finish Grading / Fine grading of lawn / treatment area to prepare for sod placement (see Crew FG-1 costs)	7890	SF	$ 0.03	$ 266.32	$ 0.02	$ 189.03	$ -	$ -	$ -	$ -	$ 455.35

COST ANALYSIS

PRIME CONTRACTOR WORK / TASK ITEM	Quantity		Labor Cost		Equipment Cost		Material Cost				UNIT
	No. Units	Unit Meas	Per Unit	Total Labor	Per Unit	Total Equip	Per Unit	Material Cost	Shipping	Total Material	TOTALS
REINSTALL LAWN FEATURES Following initial assessment temporarily remove / store on-Property any lawn features which will impact an effective treatment process, and to provide protection of such features (allow 2 hours avg time frame with 2 laborers at $24.31 / hr per laborer = 4 Mhr)	4	Mhr	$ 24.31	$ 97.24	$ -	$ -	$ -	$ -	$ -	$ -	$ 97.24
REMOVE PROTECTIVE BARRIER Remove PROTECTIVE BARRIER around perimeter of .25 acre Property Property; allow 400 LF per Property (allow for 2 laborers to install approx. 200 LF per HR at $24.31 / hr = $0.243 / LF labor cost NO material costs incl	400	LF	$ 0.243	$ 97.20	$ -	$ -	$ -	$ -	$ -	$ -	$ 97.20
DEMOBILIZATION FROM PROPERTY **(See "Genral Requirements" above)**	x	x	x	x	x	x	x	x	x	x	x
				$ 1,780.43		**$ 3,486.54**				**$ 15,343.45**	**$20,610.42**

Notes:

1. Costs shown on page 4 and page 5 of the anaysis are reflected as "direct" costs to the Prime Contractor.

2. Costs shown on are developed for a single Property.

BLACK & VEATCH

DATE: September 11, 2008

CLIENT: **Environmental Protection Agency**
PROJECT: **Phosphate Treatment of Residential Properties at the Omaha Lead Site**
LOCATION: **Omaha, Nebraska**

PROJECT NO. 044746.01.12

BASIS FOR ESTIMATE

☐	CODE A (No Design Complete)
☐	CODE B (Preliminary Design)
☐	CODE C (Final Design)
☒	OTHER (Specifiy)

COST ANALYSIS

ESTIMATORS: **M. LEDBETTER / G. HICKS**

SHEET 7 OF 10

LAWN SERVICE SUBCONTRACTOR SUMMARY	Quantity		Labor Cost		Equipment Cost		Material Cost		SUBCONTRACTOR
	No. Units	Unit Meas	Per Unit	Total Labor	Per Unit	Total Equip	Per Unit	Total Material	TOTAL COSTS
TOTAL BARE COSTS (See SUBCONTRACTOR WORKSHEET)									
Direct costs for Lawn Service Subcontractor (see sheet 8 of 8)				$ 51.97		$ 0.30		$ 107.59	
Labor , Equipment & Materials Adjustments due to hazardous site conditions			10%	$ 5.20	10%	$ 0.03	5%	$ 5.38	
Total Bare Costs				$ 57.17		$ 0.33		$ 112.97	
Payroll Taxes and Insurance (PT&I) ; and Sales Tax (on material only)			19%	$ 10.86	0%	$ -	7%	$ 7.91	
SUBTOTAL "A" (Replacement of damaged plantings with watering only)				**$ 68.03**		**$ 0.33**		**$ 120.88**	
TOTAL DIRECT COST				**$ 68.03**		**$0.33**		**$ 120.88**	
OVERHEAD @			15%	$ 10.20	15%	$0.05	15%	$ 18.13	
SUBTOTAL				**$ 78.24**		**$ 0.37**		**$ 139.01**	
PROFIT			10%	$ 7.82	10%	$ 0.04	10%	$ 13.90	
SUBTOTAL "B" (with markup Subtotal "A" above)				$ 86.06		$ 0.41		$ 152.92	$ 239.39
SUBTOTAL "C" (Sod Placement assume incl markups)				$ 394.50		$59.18		$ 1,518.83	$ 1,972.50

TOTAL LAWN SERVICE SUBCONTRACTOR PER SITE = $ 2,211.89

BLACK & VEATCH

DATE: September 11, 2008

CLIENT: Environmental Protection Agency
PROJECT: Phosphate Treatment of Residential Properties at the Omaha Lead Site
LOCATION: Omaha, Nebraska

PROJECT NO. 044746.01.12

BASIS FOR ESTIMATE
CODE A (No Design Complete)
CODE B (Preliminary Design)
CODE C (Final Design)
X OTHER

COST ANALYSIS

ESTIMATORS: M. LEDBETTER / G. HICKS
SHEET 8 OF 10

LAWN SERVICE SUBCONTRACTOR TASK ITEM	Quantity		Labor Cost		Equipment Cost		Material Cost				UNIT
	No. Units	Unit Meas	Per Unit	Total Labor	Per Unit	Total Equip	Per Unit	Material Cost	Shipping	Total Material	TOTALS
LAWN SERVICE											
A. Lay Sod											
(see below for costs of laying sod)											
Allowance for cost of watering by owner to establish sod for a 1 month period (allow $50.00 / month)	1	LS					$ 50.00	$ 50.00	$ -	$ 50.00	$ 50.00
B. Replacement of damaged plantings / shrubs, etc.											
Allowance for replacement of damaged plantings / shrubs, etc.	1	LS	$ 50.00	$ 50.00	$ -	$ -	$ 50.00	$ 50.00	$ -	$ 50.00	$ 100.00
(Costs assumed average per each residential property)											
C. Allowance for Re-sod (followup to initial sod placement)											
Based on total project estimate of 3747 residential sites, assume 10% of Propertiess require 5% sod re-placment	0.03945	MSF	$ 50.00	$ 1.97	$ 7.50	$ 0.30	$ 192.50	$ 7.59	$ -	$ 7.59	$ 9.86
thus 7890 SF Treatment area per Yd x 3747 x 10% x 5% = 147,819 SF re-placement											
147819 SF / (7890 x 3747) SF proj total = .005 %											
.005 x 7890 / 1000 SF = .03945 MSF allowance per Properties site for sod re-placement											
				$ 51.97		**$ 0.30**				**$ 107.59**	**$ 159.86**

LAWN SERVICE SUBCONTRACTOR TASK ITEM	Quantity		Labor Cost		Equipment Cost		Material Cost				UNIT
	No. Units	Unit Meas	Per Unit	Total Labor	Per Unit	Total Equip	Per Unit	Material Cost	Shipping	Total Material	TOTALS
LAWN SERVICE											
D. Lay Sod (following the applications of chemical treatments to Properties)											
Lay new sod in lawn areas disturbed by treatment process (assume level ground, over 6 MSF)	7.890	MSF	$ 50.00	$ 394.50	$ 7.50	$ 59.18	$ 192.50	$ 1,518.83	$ -	$ 1,518.83	$ 1,972.50
(per current pricing data from Omaha area sod projects, use approx. $0.25 per SF as avg. price installed											
(note: pricing shown is considered a subcontracted price, assume markups included)											
SUBTOTAL "C" (Sod Placement ; assume incl markups)				**$ 394.50**		**$ 59.18**				**$ 1,518.83**	**$ 1,972.50**

Notes:
1. Costs shown above are reflected as "direct" costs to the Subcontractor.

2. Costs shown on are developed for a single Properties location.

3. Costs for laying sod are based on installed pricing data from current contractors in Omaha area involved in the present remedial program.

4. MSF = 1000 Square Feet

BLACK & VEATCH

DATE: September 11, 2008

Prepared I M. Ledbetter / G. Hicks

Checked E D. Sanders

CLIENT: Environmental Protection Agency
PROJECT: Phosphate Treatment of Residential Properties at the Omaha Lead Site
LOCATION: Omaha, Nebraska

PROJECT NO. 044746.01.12

SHEET 9 OF 10

CREW COSTS:

		Grp#	2008 Davis-Bacon			
			Base Hr Rate	Fringes	Harzardous	TOTAL
1	General Laborer		$16.76	$6.55	$1.00	$24.31
2	Supervisor	Est	$17.50	$6.75	$1.00	$25.25
3	Chemical Technician	Est	$17.20	$6.70	$1.00	$24.90
4	Power Equip Oper	1	$19.90	$7.45	$1.00	$28.35

Note: Base Rates based on DB Gen Decision NE20080001, dated 08 / 08 / 2008

Topsoil Removal Crew (Crew TS-1)

hr.	Item	LABOR 2008 Davis-Bacon Hr. Rate (incl Fringes)	EQUIP 2007 MII UPB Daily (btwn diff-severe)	2008 (esc. by 1.03) Daily	Esc. Rate / HR
1	Power Equip Oper	$28.35			
0.5	Labor (at $24.31 / hr)	$12.16			
1	Dozer, 80 hp		$300	$309.00	
		$40.51		$309.00	$38.63

Productivity: 200 CY per 8 hr day 25 CY per hr

Hourly cost per UOM: CY **$1.62** **$1.55**

Rototilling Crew (Crew RT-1)

hr.	Item	LABOR 2008 Davis-Bacon Hr. Rate (incl Fringes)	EQUIP 2007 MII UPB Daily (btwn diff-severe)	2008 (esc. by 1.03) Daily	Esc. Rate / HR
1	Power Equip Oper	$28.35			
1	Backhoe Ldr w/ attachment		$212	$243.80	
		$28.35		$243.80	$30.48

Productivity: 450 MSF per 8 hr day 56.25 MSF per hr

Hourly cost per UOM: MSF **$0.50** **$0.54**

CREW COSTS (con't):

Chem Spray Application Crew (Crew SPR-1)

hr.	Item	LABOR 2008 Davis-Bacon Hr. Rate (incl Fringes)	2007 MII UPB Daily (btwn diff-severe)	EQUIP 2008 (esc. by 1.03) Daily	Esc. Rate / HR
2	Chemical Technician	$49.80			
		$49.80		$0.00	$0.00

Allow 916.256 gal / Property application rate; allow for (2) technicians ; 1 for application; 1 for monitoring tank truck
assume 6 hrs total application rate (1 complete Property = 7890 SF = 7.890 MSF)
say 12095 lbs / property of Phosphoric Acid application (applied in 6 hr period)

12095 LBS per 6 hr period
Productivity: 16127 LBS per 8 hr period 2016 LBS per hr

Hourly cost per UOM: MSF **$0.0247** Say equals labor cost = **$0.250**

Finish Grading / Fine grading of lawn / treatment area to prepare for sod placement (Crew FG-1)

hr.	Item	LABOR 2008 Davis-Bacon Hr. Rate (incl Fringes)	2007 MII UPB Daily (abstracted)	EQUIP 2008 (esc. by 1.03) Daily	Esc. Rate / HR
1	Power Equip Oper	$28.35			
0.5	Labor (at $21.21 / hr)	$12.16			
1	Tractor w/ rake attachments		$200.00	$230.00	
		$40.51		$230.00	$28.75

Productivity: 9600 SF per 8 hr day 1200 SF per hr

Hourly cost per UOM: MSF **$0.034** **$0.024**

Appendix B
Bench Scale Treatability Study
Omaha Lead Site

Prepared for:
U.S. Environmental Protection Agency
Region 7
901 North 5th Street
Kansas City, Kansas 66101

Prepared for:
Black & Veatch Special Projects Corp.
6601 College Blvd.
Overland Park, Kansas 66211

Final
Bench-Scale Treatability Study

Omaha Lead Site
Omaha, Nebraska

February 2009

EPA Contract No.: EP-S7-05-06
EPA Task Order No.: 0101
BVSPC Project No.: 44759

Prepared by:
Dr. John Drexler
Laboratory for Environmental and Geological Studies
University of Colorado
Boulder, Colorado

Table of Contents

Appendices

Figures

Tables

Acronymns

ABA	Absolute Bioavailability
ASTM	American Society for Testing Materials
bgs	Below Ground Surface
BVSPC	Black & Veatch Special Projects Corp.
$Ca(OH)_2$	Calcium Hydroxide (Hydrated Lime)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (aka Superfund)
EMPA	Electron Microprobe Analysis
EPA	United States Environmental Protection Agency
IEUBK	Integrated Exposure Uptake Biokinetic
IVBA	*In Vitro* Bioaccessibility
LEGS	Laboratory for Environmental and Geological Studies
mg/kg	milligram per kilogram = ppm
NPL	National Priorities List
OLS	Omaha Lead Site
Pb	Lead
ppm	parts per million = mg/kg
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RA	Remedial Action
RBA	Relative Bioavailability
RBALP	Relative Bioavailability Leaching Procedure
RD	Remedial Design
RI/FS	Remedial Investigation/ Feasability Study
ROD	Record of Decision
SOP	Standard Operating Procedure
SPLP	Synthetic Precipitation Leaching Procedure
SU	Standard Units
TSP	Triple Super Phosphate

Glossary

ABA	Absolute Bioavailability – The amount of substance entering the blood via a particular biological pathway relative to the absolute amount that has been ingested.
AES	Architect-Engineer Services Contract between EPA Region 7 and Black & Veatch Special Projects Corp.
ASTM	American Society for Testing Materials – An organization that develops and publishes voluntary technical standards for a wide range of materials, products, systems, and services.
bgs	Below Ground Surface- An acronym that denotes a measurment or distance below the surface of the ground.
BVSPC	Black & Veatch Special Projects Corp. – The contractor under the EPA Architect-Engineer Services Contract who is serving as a consultant to EPA on the Omaha Lead Site.
$Ca(OH)_2$	Calcium Hydroxide (Hydrated Lime) – Lime is used to raise the pH of the soil following application of the phosphate amendment to the soil.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (aka Superfund) - The legislative authority that funds and carries out EPA solid waste emergency and long-term removal and remedial activities. These activities authorized by CERCLA include establishing the National Priorities List, investigating sites for inclusion on the list, determining their priority, and conducting and/or supervising cleanup and other remedial actions.
EMPA	Electron Microprobe Analysis – An analytical technique that is used to establish the composition of small areas on specimens by bombarding the specimen with a beam of accelerated electrons.
EPA	United States Environmental Protection Agency

FSP	Field Sampling Plan – The document that specifies the procedurres that will be followed during the field sampling activities, including the number of samples collected and the sampling methodology.
In-vitro	Testing or action outside an organism (e.g. inside a test tube or culture dish.)
In-vivo	Testing or action inside an organism.
LEGS	Laboratory for Environmental and Geological Studies – The organization within the University of Colorado that performed the bench scale study and performed the chemical and physical testing of the soil during the treatability study.
mg/kg	milligram per kilogram = parts per million – A unit measure of the concentration of a substance, i.e., milligrams of lead per kilogram of soil.
MSDS	Material Safety Data Sheet - A compilation of information required under the OSHA Communication Standard on the identity of hazardous chemicals, health, and physical hazards, exposure limits, and precautions.
NPL	National Priorities List - EPA's list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial action under Superfund. The Omaha Lead Site is on the NPL.
OLS	Omaha Lead Site – The Omaha NPL site. The OLS is comprised of individual residential properties that exceed the EPA action level for lead and are eligible for Superfund response.
Pb	Lead – The primary contaminant of concern at the Omaha Lead Site.
ppm	parts per million = mg/kg – Units commonly used to express contamination levels, as in establishing the maximum permissible amount of a contaminant in water, land, or air.

QA/QC	Quality Assurance - A system of procedures, checks, audits, and corrective actions to ensure that all EPA research design and performance, environmental monitoring and sampling, and other technical and reporting activities are of the highest achievable quality.
QAPP	Quality Assurance Project Plan – A plan prepared for the Omaha Lead Site that discusses the QA/QC procedures that will be implemented at the site.
RA	Remedial Action - The actual construction or implementation phase of a Superfund site cleanup that follows remedial design.
RBA	Relative Bioavailability - The ratio of the absorption of lead in soil to the absorption of a lead standard (lead acetate).
RBALP	Relative Bioavailability Leaching Procedure - A test that measures the fraction of a chemical solubilized from a soil sample under simulated gastrointestinal conditions. The in-vitro tests consist of an aqueous fluid, into which the contaminant is introduced. The solution than solubilizes the media under simulated gastric conditions. Once this procedure is complete, the solution is analyzed for lead and/or arsenic concentrations. The mass of the lead and/or arsenic found in the filtered extract is compared to the mass introduced into the test. The fraction liberated into the aqueous phase is defined as the bioavailable fraction of lead or arsenic in that media.
RD	Remedial Design - A phase of remedial action that follows the remedial investigation/feasibility study and includes development of engineering drawings and specifications for a site cleanup.
RI/FS	Remedial Investigation/ Feasability Study - An in-depth study designed to gather data needed to determine the nature and extent of contamination at a Superfund site; establish site cleanup criteria; identify preliminary alternatives for remedial action; and support technical and cost analyses of alternatives. The remedial investigation is usually done with the feasibility study. Together they are usually referred to as the "RI/FS".

ROD	Record of Decision - A public document that selects and explains which cleanup alternative(s) will be implemented at National Priorities List sites.
SOP	Standard Operating Procedure – A written document that details the method for an operation, analysis, or action with thoroughly prescribed techniques and steps and that is officially approved as the method for performing certain routine or repetitive tasks.
TSP	Triple Super Phosphate - A fertilizer produced by the action of concentrated phosphoric acid on ground phosphate rock. TSP was one of the chemical amendments used in the treatability study.

Executive Summary

The objective of this treatability study is to evaluate the influence of phosphate treatment on lead-contaminated Omaha Lead Site (OLS) soils. The information generated during this study will be used by EPA to evaluate and compare remedial alternatives in the final remedy selection process for the OLS. Studies conducted at other Superfund sites contaminated with similar forms of lead have concluded that the application of certain phosphate-based compounds (referred to as soil amendments) can result in the conversion of lead in soils to relatively insoluble minerals with reduced bioavailability. After treatment, lead remains present in the soil, but is transformed into a form that is less toxic.

It was estimated in the Final Remedial Investigation Report that approximately 8,552 OLS residential properties exhibit lead concentrations between 400 and 800 parts per million (ppm). If determined to be technically feasible, the amendment treatment of lead-contaminated soil at OLS residential properties exhibiting moderate lead levels (between 400 ppm and 800 ppm) could provide benefits over the excavation and replacement of soils at many OLS properties and provide protection of human health and the environment.

Prior to developing and implementing a field program, multiple amendment treatment scenarios were tested in the laboratory (bench scale) in an effort to limit the field program to the two or three most promising treatments. An extensive list of laboratory tests, including analytical chemistry and electron microprobe analyses, were performed on soil samples collected at various points in time during the study. The data from this group of laboratory tests, which are collectively referred to as "soil characterization testing," and "bench-scale testing" will allow EPA to evaluate potential chemical and physical changes in test soils in response to amendment addition.

An *In Vitro* test method, relative bioavailability leaching procedure (RBALP), was utilized to evaluate changes in soil lead bioaccessibility in response to amendment treatment. The RBALP is referred to as bioaccessibility testing to distinguish it from *in vivo* bioavailability studies which involve animal feeding studies. The RBALP is used because *in vivo* testing is more costly to perform than the RBALP test and requires a longer period of time to perform the testing. In addition to the RBALP, the synthetic precipitation leaching procedure (SPLP) (EPA Method 1312) was used to evaluate the potential leachability of lead, arsenic and phosphate and lead speciation was conducted on the untreated and treated soils.

EPA has gained experience at other Superfund sites with similar types of contamination, and has performed side-by-side comparison testing of *In Vitro* bioaccessibility and *in vivo* bioavailability test methods. RBALP performed at pH 1.5

correlates well with *in vivo* relative bioavailability (RBA) in untreated soils as evidenced by the close agreement of the two methods on the same soils in a previous swine study for the OLS. RBALP performed at pH 2.5 significantly underestimates the RBA when compared to *in vivo* results at the OLS. No test methods have been validated to measure bioaccessibility in phosphate treated soil. Although RBALP has not been validated for phosphate treated soils at pH 1.5 or pH 2.5, the procedure may provide an indication of the potential effectiveness in reducing the RBA of lead-contaminated soils.

Bioaccessibility testing results, together with the soil characterization data generated during this treatability study, are intended to provide the information required to evaluate the effectiveness of phosphate treatment on OLS soils. Although the information obtained from the treatability study will be useful to evaluate future remedial action alternatives at the OLS, the information from the study is not conclusive because of the following limitations of the study.

- It is difficult to perform *in-vivo* testing on soils with lead concentrations between 400 ppm and 800 ppm, which are the soils that are most likely to be treated with the phosphate amendment at the OLS.
- The i*n vitro* RBALP testing procedure used to estimate the relative bioaccessibility of lead in the soils has not been validated for use on phosphate amended soils.
- The bench scale treatability will only estimate the short term reduction in the RBA of lead in soils. There is no conclusive data indicating phosphate treatment results in long-term reduction in the RBA of lead in soils.

Duplicate matrices of soils were assembled containing controls and the phosphate amendments phosphoric acid (PA), phosphate rock (PR), and triple-super phosphate (TSP), both with and without amorphous iron. The matrices were run in triplicate using 2, 7, and 14 day reaction periods. The effectiveness of the amendments were evaluated based on the relative change *in vitro* bioaccessibility (IVBA) as measured using the RBALP i*n vitro* procedure, with extraction fluids at pH 1.5 and 2.5.

Virtually all of the phosphate amendments showed some reduction in IVBA however, the 14-day, 1.5% PA (1.5 PA) (with iron) was the most reductive. All of the amendments behaved equally as well on the three soil-types, producing an increased presence of some phosphate form.

The measured effectiveness of the amendment techniques varied between the pH 1.5 and pH 2.5 i*n vitro* results. The pH 1.5 data presented in Table 4-1, which has the strongest correlation with *in vivo* RBA, shows limited reduction in IVBA, ranging from 15 percent to 26 percent reduction for the three soil types tested. The RBALP at pH 2.5

showed more significant reduction in IVBA, ranging from 61 percent to 80 percent; however the RBALP at pH 2.5 did not show good correlation with *in vivo* results on the same test soils and has not been validated by *in vivo* studies.

One sample from each of the three soil types treated with 1.5 PA plus iron was speciated. The speciation indicated that the treatment procedure was forming a phosphate product. The speciation indicated the formation of a potentially more soluble primary or secondary orthophosphate rather than the more insoluble chloropyromorphite. These orthophosphates would be more bioaccessable than the lead phases in the untreated soils and support the limited decrease in IVBA observed in the treated soils. All of the phosphate amendments increased the solubility and potential release of phosphorus and arsenic.

1.0 Introduction

Black & Veatch Special Projects Corp. (BVSPC) has been tasked by EPA Region 7 to perform this treatability study for the Omaha Lead site (OLS) under Task Order 091 of EPA Contract No. EP-S7-05-06.

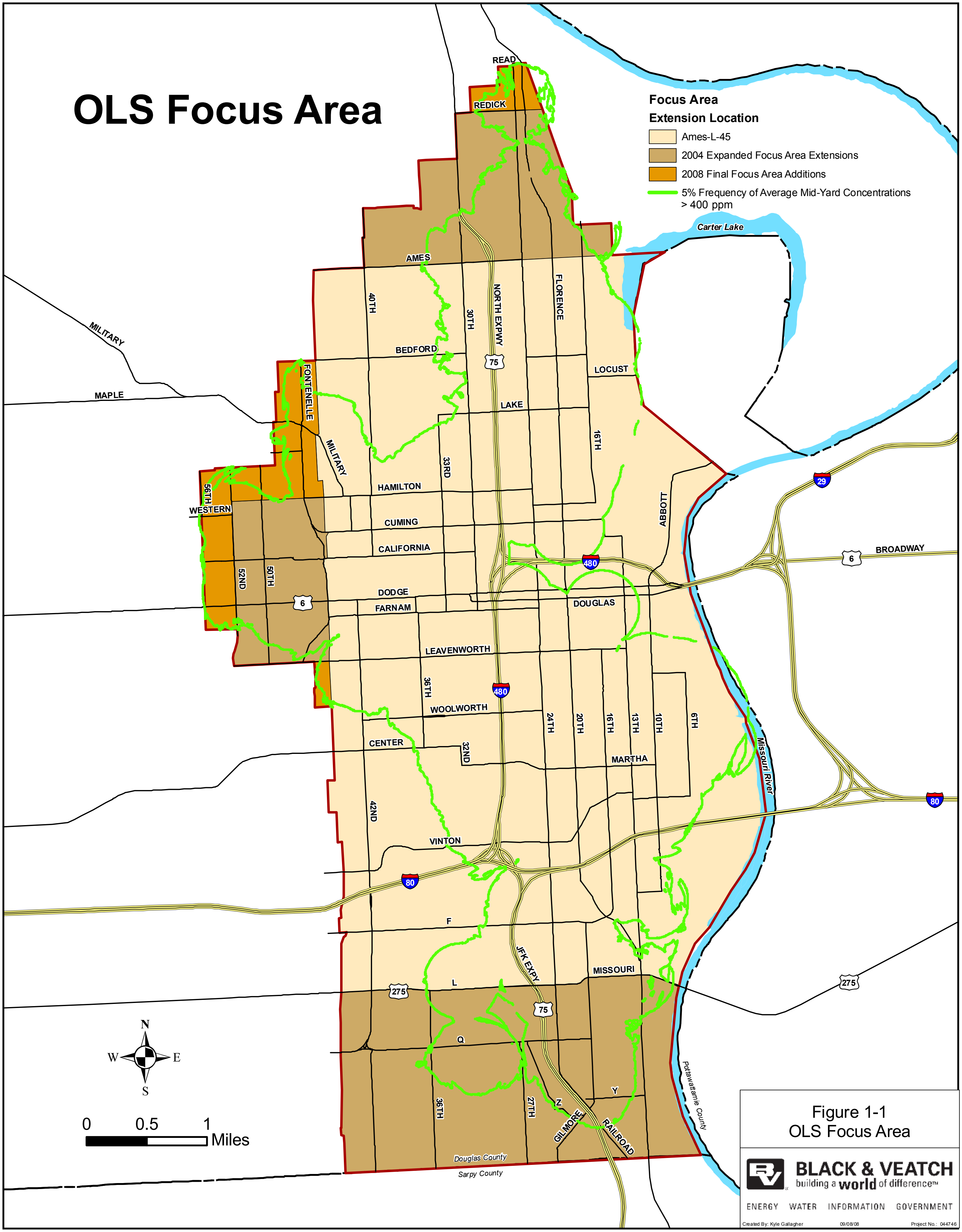
The OLS includes contaminated surface soils (generally between 0 to 6 inches below ground surface (bgs) present at residential properties, child-care facilities, and other residential-type properties in the city of Omaha, Nebraska, which were contaminated as a result of historic air emissions from lead smelting and refining operations. The OLS Focus Area encompasses approximately 27 square miles, centered on downtown Omaha, where two former lead processing facilities were located. The site includes only residential and residential-type properties and all non-residential properties are excluded from the OLS focus area, including commercial properties in the central business district.

The United States Environmental Protection Agency (EPA) began sampling residential yards and properties used for licensed child-care services in March 1999. The original boundaries of the OLS Focus Area were established at the time the Site was listed on the EPA National Priorities List (NPL). During the Remedial Investigation in 2004 (RI, Ref. 2), the OLS Focus Area was expanded to include an area south of L Street to the Sarpy County line (Harrison Street), an area north of Ames Avenue to Redick Avenue, and an area to the west of 45th Street. The focus area now extends north to Read Street and west to 56th Street (See Figure 1-1).

Between March 1999 and February 2009, surface soil samples were collected from over 37,000 residential properties. The December 2004 Interim Record of Decision (ROD, Ref. 1) identified response actions to be taken while the final ROD was developed, including excavation and replacement of contaminated soils at the most highly contaminated residential properties with surface soil lead concentrations exceeding 800 ppm. In addition, childcare facilities and properties where children with elevated blood lead levels reside are eligible for remediation if one or more mid-yard soil sample exceeds 400 mg/kg. If a property is eligible for remediation, all soils that test greater than 400 mg/kg are removed, including drip-zone soils.

This treatability study will evaluate the effectiveness of phosphate treatment on the bioaccessibility of lead-contaminated OLS soils. Studies conducted at other Superfund sites contaminated by lead smelting operations have concluded that the application of certain phosphate-based compounds can result in the conversion of lead in surface soils to relatively insoluble minerals with reduced bioavailability (Refs. 3, 4, and 5.

OLS Focus Area



Focus Area
Extension Location

- ▭ Ames-L-45
- ▨ 2004 Expanded Focus Area Extensions
- ■ 2008 Final Focus Area Additions
- ━ 5% Frequency of Average Mid-Yard Concentrations > 400 ppm

Figure 1-1
OLS Focus Area

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ENERGY WATER INFORMATION GOVERNMENT

Created By: Kyle Gallagher 09/08/08 Project No.: 044746

Earlier studies involving phosphate-based compounds in this area (Refs. 25 and 26) indicated very low solubilities for many lead-phosphates (Ksp !27 to !66), particularly chloropyromorphite [$Pb_5(PO_4)_3Cl$]. The transformation of soluble Pb mineralogical forms into chloropyromorthite continues to be the primary focus of many soil amendment studies. Sources of phosphorous used in the previous studies included phosphoric acid (PA) (H_3PO_4), triple-super phosphate (TSP), phosphate rock (PR) (a phosphorous-rich natural sediment), and/or hydroxyapatite (HA). Studies have combined one or more of these phosphorous sources with or without the addition of lime, iron, and/or manganese in an attempt to enhance amendment qualities. Most phosphate amendments are formulated to contain between 0.5 and 1.0 percent phosphorous by weight. The sources for phosphorous used in this study include PA, TSP, or PR.

PA, also called orthophosphoric acid, is an odorless, clear, viscous liquid, having a typical pH 1.5. It is a highly corrosive acid, which is incompatible with powdered metals, strong bases, and iron containing compounds. Due to its incompatibility with iron compounds, PA is often used to remove iron-oxide (rust) stains from stainless steel. PA is found commercially in detergents, cleaners, insecticides, fertilizers and cattle feed additives. In the bench scale treatability study, 85% PA (Mallinckrodt Chemicals 2796-45), which has a heavy metal contamination of less than 10 ppm, was used.

TSP ($Ca(H_2PO_4)_2$), also called monocalcium phosphate, is an off-white, granular solid. It is typically produced by reacting phosphate rock with sulfuric acid. This product was historically a very popular item used as a basic fertilizer, or mineral supplement in foods and feed; however, it has since been prohibited by most U.S. certifications. When combined with nitrate-based fertilizers it can create a highly volatile environment. Further, the phosphoric derivatives have a tendency to bind to iron, aluminum, calcium, magnesium, and sodium, essentially "tying-up" essential nutrients. Hi-Yield® *Triple Super Phosphate*, which has 45% available phosphate was used in the treatability study. Wet chemical analyses of this product indicated a lead concentration of 6 ppm.

PR, ($Ca_{10}F_2(PO_4)_5$), also called Kap rock, or fluoroapatite, is a tan, black, gray, or white solid with an "earthy" odor. PR is the only naturally occurring resource of phosphate. PR rock beds are formed near oceans and are often contaminated with other minerals such as magnesium, fluoride and silica. It is mainly used in the production of fertilizers, feed, and industrial products. Whitney Farms™ *Granulated Rock Phosphate*, which contains 3% available phosphoric acid, was used in the treatability study. Wet chemical analyses of this product indicated a lead concentration of 50 ppm.

The previous studies using PA, TSP, or PR have produced mixed results and, to date, phosphate amendments have not been used to treat soils at any large, lead contaminated sites. One study, (Ref. 30) using a phosphate amendment and a post treatment analyses period of five years was far less successful, with a reduction in IVBA (*in vitro*) of only 40%. In addition, (Ref. 30) showed a gradual increase in soil IVBA (3 to 65%) over the five year test period.

In addition, a number of potentially significant problems associated with phosphate amendments have been recognized, including both phyto- and earthworm toxicity (Refs. 27, 28, and 29). Both of these toxicities are primarily associated with very high applications of phosphorous and/or decreased soil pH. Additionally, treatment of soil with a phosphate amendment creates an additional risk of eutrophication of nearby waterways from surface water runoff.

Results from the soil characterization and bench-scale treatment studies described in this report may be used to design subsequent field studies for the treatability study. The scope and objectives of this portion of the treatability study correlate with the December 2004 Interim Record of Decision (ROD). The following paragraph is from the Interim ROD:

> *The treatability study consists of an initial bench scale test to determine the effect that the treatment technology has on the bioavailability of lead in site soils under laboratory conditions. If initial findings are positive, the second phase of the study involves actual field testing and additional bioavailability studies.*

1.1 Study Objectives

The overall objective of this treatability study is to provide data to help support a decision regarding the use of phosphate-based soil amendments at the OLS to treat lead-contaminated soils. As stated in the Interim ROD (EPA, 2004), "it is particularly important that the treatment process itself does not create a hazard to children or residents living at or near the affected properties. The end-products of the treatment process must also not pose an unacceptable short- or long-term risk to residents at or near treated properties. This treatability study must successfully demonstrate that unacceptable risks are not created at any time during the treatment process or thereafter." Specific objectives for this portion of the study include the following:

- In response to amendment treatment, evaluate changes over time (2-14 days) in chemical and physical characteristics of the treated soils, including lead speciation and mineralogy.
- Evaluate the influence of phosphate treatment on the bioaccessibility of lead contamination in mid-yard and drip zone OLS soils.

- Provide data that could be used to evaluate issues related to potential remediation costs and public acceptance of the remedy.

Although the information obtained from the treatability study will be useful to evaluate future remedial action alternatives at the OLS, the information from the study is not conclusive because of the following limitations of the study.

- It is more difficult to perform *in-vivo* testing on soils with lead concentrations between 400 ppm and 800 ppm, which are the soils that are most likely to be treated with the phosphate amendment at the OLS.
- The i*n vitro* testing procedure (Relative Bioavailability Leaching Procedure) used to estimate the relative bioavailability of lead in the soils has not been validated for use on phosphate amended soils.
- The bench scale treatability will only estimate the short term reduction in the relative bioavailability (RBA) of lead in soils. There is no conclusive data indicating phosphate treatment results in long-term reduction in the RBA of lead in soils.

1.2 Rationale for Types of Soil to be Tested

Three types of soils were subjected to amendment treatment in this study:

Test Soil	Soil Id.	Lab Id.	Average Lead Concentrations
A	93205	Soil A	Mid-yard soil between 400 & 800 ppm
B	93206	Soil B	Mid-yard soil greater than 1,000 ppm
C	93207	Soil C	Drip Zone soil greater than 1,000 ppm

The rationale for testing the 3 types of soil is as follows:

- Test Soil No. A has moderate lead concentrations between 400 and 800 ppm which is the potential treatment range discussed in the Interim ROD. For example, if an amendment treatment is found to be capable of lowering the bioavailability of lead by 50 percent, risks associated with elevated lead levels in soil may be reduced to acceptable levels. Bioaccessibility testing can be conducted on soils with lead concentrations below 1,000 ppm, but *in vivo* bioavailability testing is more suitable for soils with lead concentrations greater than 1,000 mg/kg.

- Test Soil No. B is a mid-yard soil with an average lead concentration exceeding 1,000 ppm. If the soil characterization and bioaccessibility testing results indicate that amendment treatment appears to be effective, EPA could elect to perform an *in vivo* bioavailability study in order to corroborate the bioaccessibility results and to strengthen the correlation between the i*n vitro* and *in vivo* results.
- Test Soil No. C is a drip zone soil with an average lead concentration greater than 1,000 ppm. By definition, the drip zone may be impacted by lead paint. EPA believes that it is of interest to evaluate the influence of phosphate treatment on drip zone soils because the information will be important when the remedial alternatives are evaluated in preparation for the Final ROD.

1.3 Preparation of Soil Used for Treatability Study

Soil used for the bench scale treatability study was prepared in accordance with the Treatability Study Work Plan (Ref. 20). Soil for the treatability study was collected from residential yards in OLS Focus Area. Candidate properties were identified based upon the lead concentrations in the yards. Soil screening at the properties involved collecting samples with a 2-inch diameter core barrel slide-hammer sampling device. Three soil types were prepared:

- Mid-yard soil with average lead levels between 400 and 800 parts per million (ppm);
- Mid-yard soil with average lead levels greater than 1,000 ppm; and
- Drip Zone soils with average lead concentrations greater than 1,000 ppm.

Soil was excavated from six of the candidate properties and transported to the OLS staging area and separated into three piles according to the lead concentration in the soil. The soil piles were thoroughly mixed and grab samples were collected from different locations in the piles of soil to confirm average lead levels in the soil. Soil from these piles was sent to the Laboratory for Environmental and Geological Studies (LEGS) at the University of Colorado for testing in the bench scale treatability study. Average lead concentrations in the bulk soils from the three soil piles were 568 ppm, 1,247 ppm, and 1,418 ppm, respectively (Ref. 20, Appendix C).

The LEGS was responsible for sample preparation as discussed in the Treatability Study Work Plan. Soils were air-dried in a controlled environment prior to sieving. Soils were then sieved with a #10 stainless steel sieve to provide bulk samples (particle size < 2 mm) for standard soil analyses and speciation testing. The bulk samples were sieved a second time using a #60 stainless steel sieve to provide fine samples (particle size < 250µ) for *in vitro* studies.

All non disposable equipment used for sample preparation was decontaminated before the tools and equipment were used or re-used. Stainless steel splitters or sieves were washed in RBS 35® detergent, triple rinsed in deionized (Type II) water, and air dried.

Following sample preparation, LEGS sent split samples to the EPA Region 7 laboratory for Quality assurance (QA) metals analyses.

2.0 Characterization Testing

2.1 Soil Characterization

The purpose of soil characterization testing is to assess amendment-soil interactions and quantify changes in physical and chemical characteristics of test soils over time. The tests performed on untreated soils will provide “control” information against which subsequent characterization testing results will be compared in order to understand changes in response to amendment addition.

Soil characterization testing and analyses was performed by the University of Colorado LEGS. Characterization testing included the following parameters: metals, soil pH, acidity, particle size distribution, soil classification, phosphorus, nitrogen, total organic carbon, cation exchange capacity, and lead mineral speciation using an electron microprobe. Speciation testing is intended to provide the following information: lead mineral phase, matrix association, particle size (longest dimension), frequency of occurrence, and relative metal mass using electron microprobe (EMPA) techniques. A principal objective of EMPA analyses is to evaluate changes in lead mineral speciation through the duration of the study.

2.1.1 Fundamental Chemical Characteristics

The chemical characteristics of the three test soils are provided in Table 2-1. Each parameter was run in duplicate (n=2) unless otherwise noted following the methods listed in Appendix A (Table 1A). All raw data and QA/QC are provided in accompanying electronic spreadsheets. A more extensive suite of metals was analyzed for each test soil on splits sent to EPA Region VII lab.

Table 2-1
Average Fundamental Chemical Characteristics of Test Soils

Soil ID	**Lab ID**	**Total Pb***	**pH**	**Acidity**	**Total P**	**Extractable P**	**SPLP P**	**CEC**	**TOC**	**N**
		mg/kg		**Meq/100g**	**mg/kg**	**mg/kg**	**mg/kg**	**cmol/kg**	**%**	**%**
93205	Soil A	752	7.2	65.4	1233	12.7	0.92	20.4	3.748	0.247
93206	Soil B	1100	7.4	70.2	1447	13.4	0.69	21.0	5.072	0.260
93207	Soil C	2230	7.7	80.1	1005	6.4	0.32	20.4	2.532	0.154

*Average lead concentration using analytical methods 3050 and 6010B. Concentrations vary from previously cited lead concentrations in bulk samples (BVSPC XRF results) because only a portion of the bulk sample was analyzed and different methods were used for analysis of soils.

2.1.2 Particle-Size, Texture, and Soil Classification

Soil texture refers to the relative proportion of sand, silt and clay size particles in a sample of soil. Clay size particles are the smallest being less than .002 mm in size. Silt is a medium size particle falling between .002 and .05 mm in size. The largest particle is sand with diameters between 0.05 for fine sand to 2.0 mm for very coarse sand. Soil scientists group soil textures into soil texture classes. A soil texture triangle is used to classify the texture class. Soil texture effects many other properties like structure, chemistry, and most notably, soil porosity, and permeability. Texture influences plant growth by its direct effect on soil aeration, water infiltration, and cation exchange capacity (CEC). Infiltration and permeability are rapid in sandy soils, very slow in clay soils, and intermediate in loam soils.

The three soils from the treatability study have been tested to determine their particle-size distribution, texture, and soil classification following the methods referenced in Appendix A (Table 1A). In addition, a number of related soil properties are provided. These results can be found in Table 2-2 and Figure 2-1. A single large (~125 g) sample was used for these analyses. All measurements and calculations can be found in electronic spreadsheets (Appendix E).

Table 2-2
Test Soil Particle-Size Analyses and Related Soil Properties

Parameter	Soil A (93205)	Soil B (93206)	Soil C (93207)
% Sand (.05-2.0mm)	47.7%	47.4%	23.5%
% Silt (.002-.05 mm)	51.7%	44.9%	72.6%
% Clay (<.002 mm)	0.6%	7.7%	3.9%
Classification	Silty Loam	Loam	Silty Loam
Wilting Point (cm^3 H_2O/cm^3 Soil)	0.074	0.087	0.090
Field Capacity (cm^3 H_2O/cm^3 Soil)	0.24	0.23	0.29
Available Water (in. H_2O/ ft. Soil)	2.0	1.73	2.45
Bulk Density (mg/m^3)	1.15	1.20	1.15
Porosity	56%	55%	56%

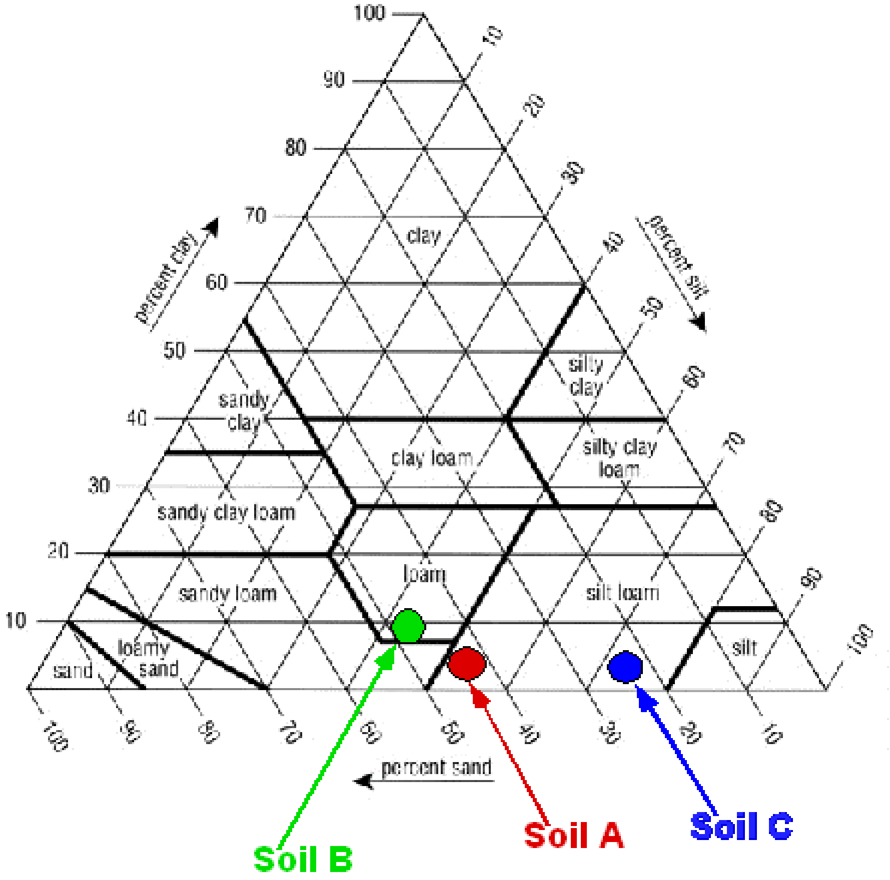
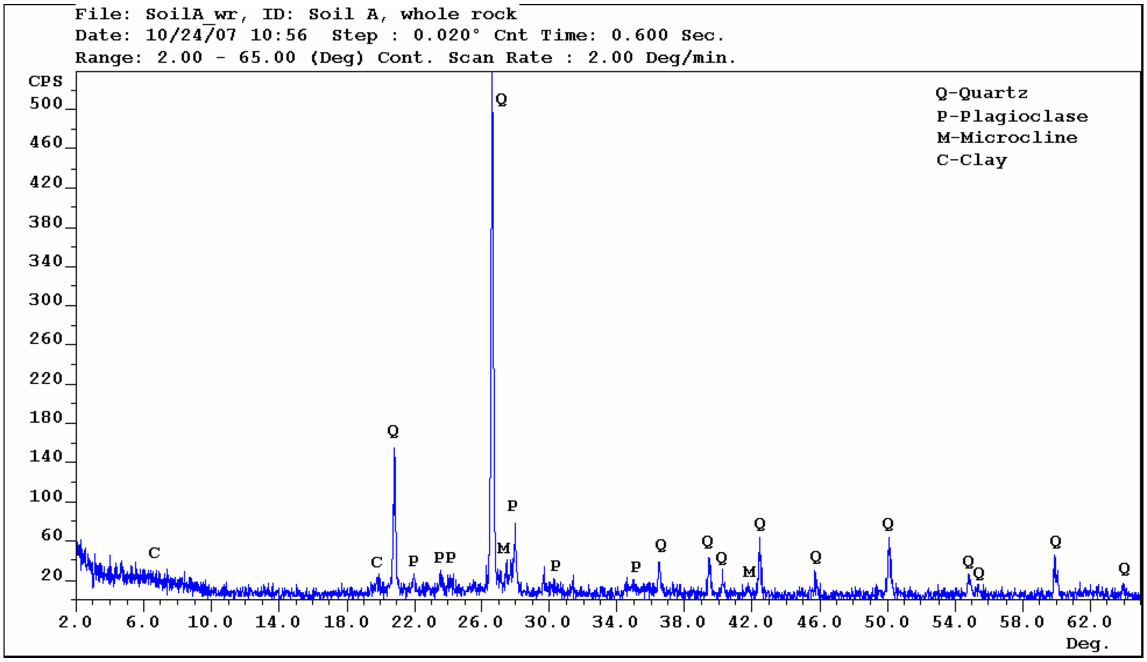


Figure 2-1 - Soil Textural Classes for the Three OLS Test Soils

2.1.3 *Mineralogy-X-ray Diffraction*

Clay mineral analyses were based on the standard method (Ref. 16). A detailed description of the methodology and results can be found in Appendix F. The bulk XRD analyses of all three soils are dominated (Figures 2-2 through 2-4) by quartz (SiO_2), plagioclase ($Na,CaAlSi_3O_8$), and microcline ($KAlSi_3O_8$). Soil B additionally contained a significant amount of hematite (Fe_2O_3). Further analyses of the soils clay fraction (Figures 2-5 and 2-6) indicate that all three soils are dominated by the presence of the minerals illite, kaolinite, and smectite.



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File: SoilA_wr, ID: Soil A, whole rock
Date: 10/24/07 10:56  Step : 0.020° Cnt Time: 0.600 Sec.
Range: 2.00 - 65.00 (Deg) Cont. Scan Rate : 2.00 Deg/min.
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Figure 2-2 - Whole-Rock XRD Spectra for OLS Test Soils A

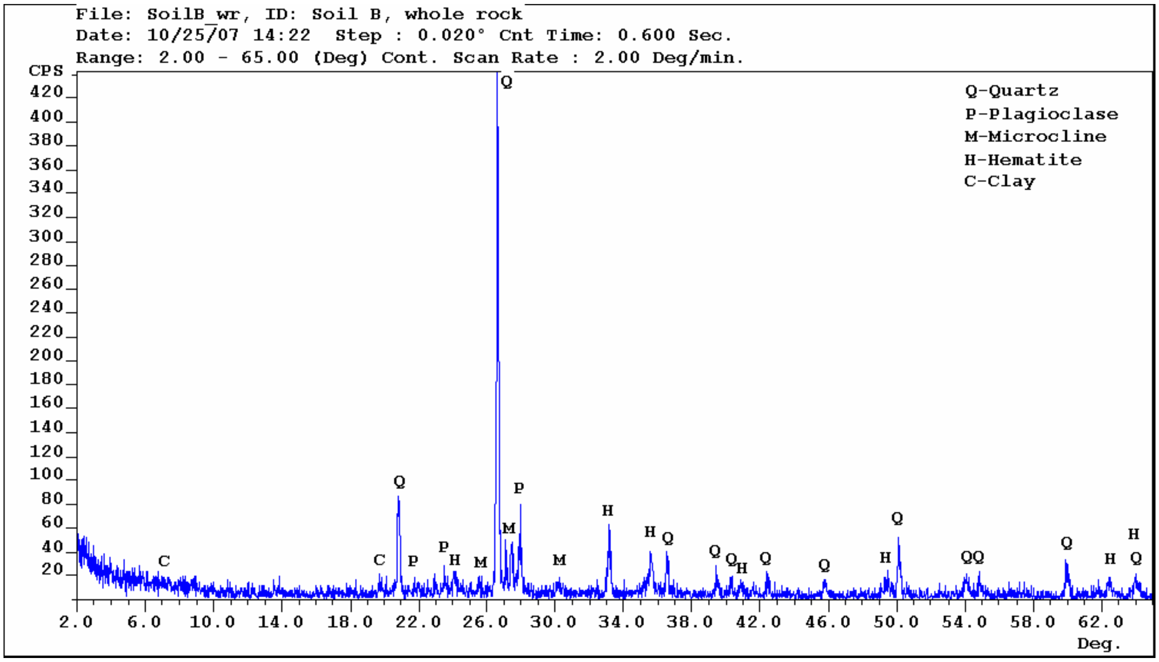


Figure 2-3 - Whole-Rock XRD Spectra for OLS Test Soils B

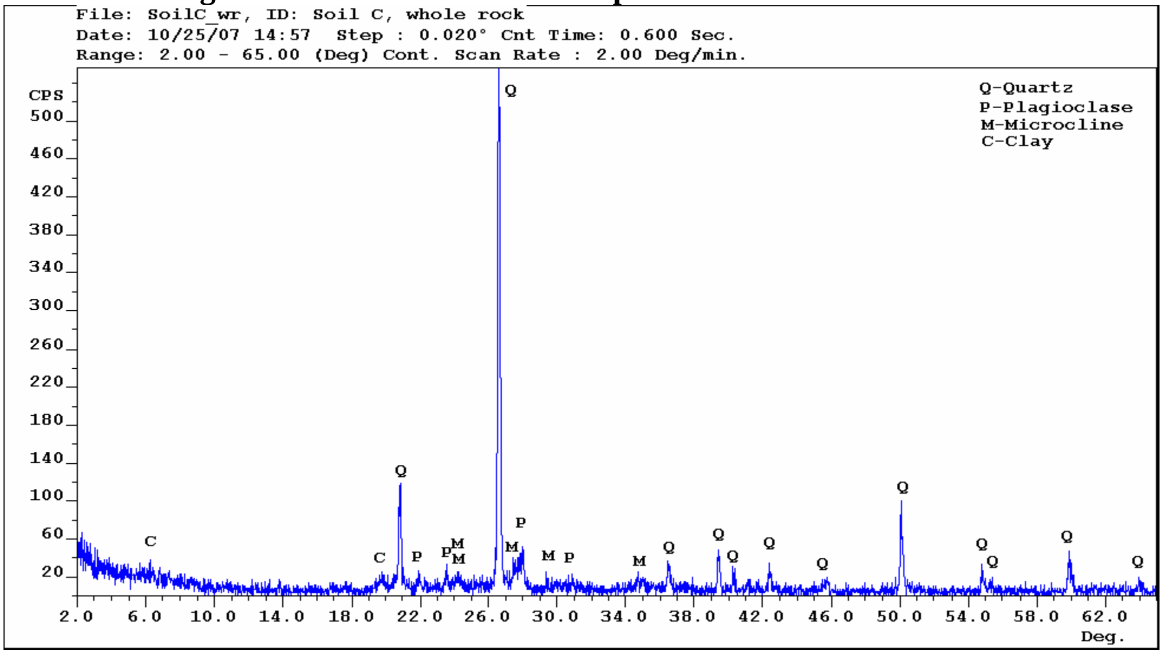


Figure 2-4 - Whole-Rock XRD Spectra for OLS Test Soils C

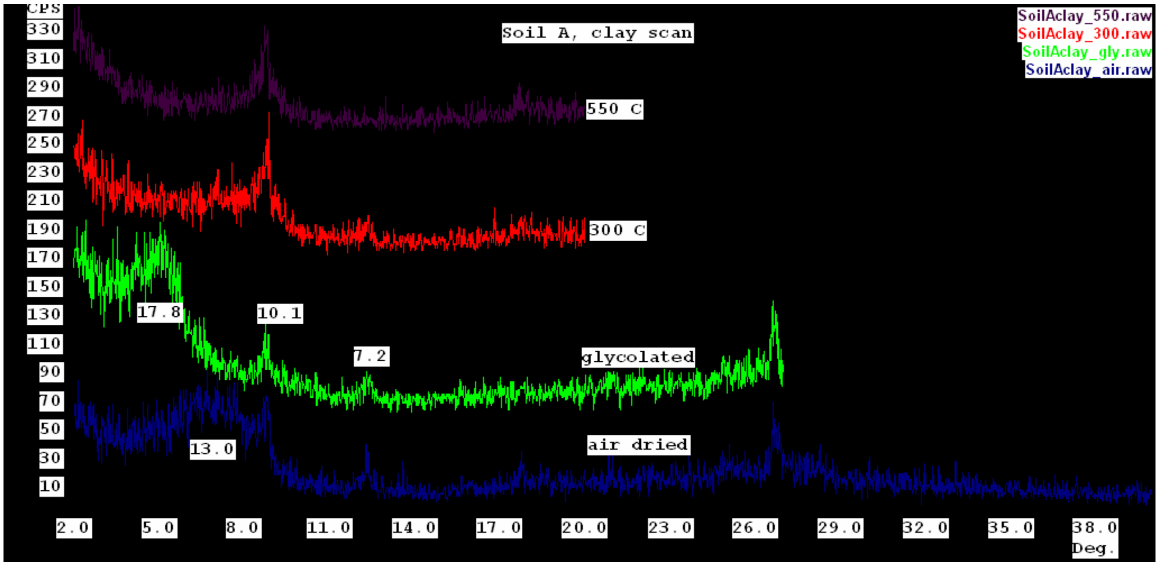


Figure 2-5 - Clay Fraction XRD Spectra for OLS Test Soils A

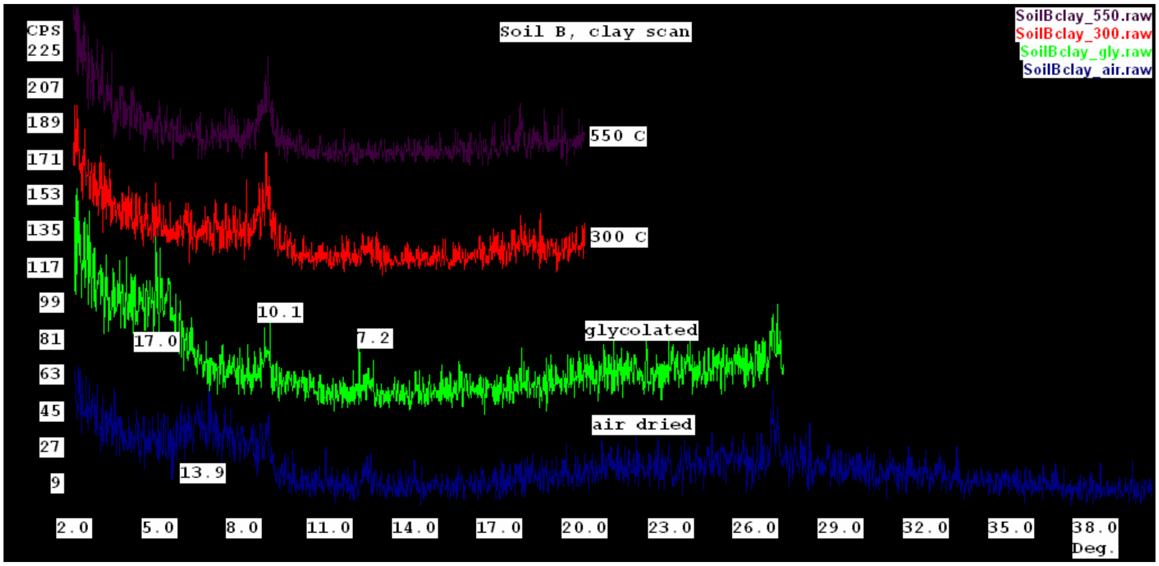


Figure 2-6. Clay Fraction XRD Spectra for OLS Test Soils B.

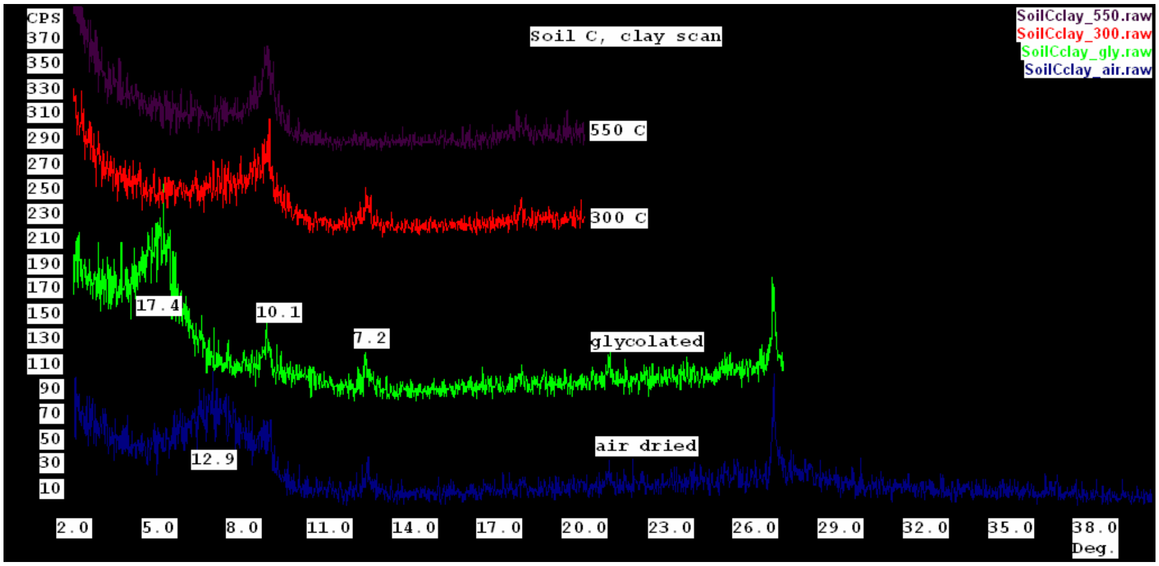


Figure 2-7 - Clay Fraction XRD Spectra for OLS Test Soils C

2.1.4 Speciation- EMPA

Lead speciation on the <2mm fraction for each of the OLS soils was conducted following the LEGS method (Appendix B) at the University of Colorado. A single split was taken for each soil. Data are summarized in Tables 2-3 to 2-5 and Figures 2-8 to 2-10, while a complete particle-by-particle data set is provided in an electronic spreadsheet contained in Appendix E.

In general, the dominant lead forms in the three test soils are: cerussite ($PbCO_3$), anglesite ($PbSO_4$), and a lead phosphate. Lead forms identified in the treatability study soils are generally consistent with those found in a previous apportionment study at the OLS; i.e., soils containing large relative masses of cerussite, anglesite, or lead phosphate were found in the apportionment study. These lead forms are consistent with results from the i*n vitro* bioassay work described later in this report.

Table 2-3

OLS Test Soil A Speciation Results.

Form	Particle Count Number	Size Mean	Std-Dev	Range low	Range high
total	103	14.65	30.12	1	250
MnOOH	39	16.18	16.19	3	85
FeOOH	25	10.52	10.36	1	50
FeSO4	10	7.2	8.28	3	28
Cerussite	1	6	ND	6	6
Brass	1	1	ND	1	1
Phosphate	20	13.1	33.94	1	150
Anglesite	2	126.5	174.66	3	250
PbMO	1	1	ND	1	1
Clay	3	5	4.36	2	10
Galena	1	5	ND	5	5

Form	(linear) freq	Bio freq	Rm Pb	Biorm Pb	Error-95%
%	%	%	%	%	
MnOOH	41.82	41.82	19.43	19.43	9.53
FeOOH	17.43	17.43	2.72	2.72	7.33
FeSO4	4.77	4.77	0.15	0.15	4.12
Cerussite	0.4	0.4	1.45	1.45	1.22
Brass	0.07	0.07	0	0	0.5
Phosphate	17.36	17.36	23.11	23.11	7.32
Anglesite	16.77	16.77	51.32	51.32	7.21
PbMO	0.07	0.07	0.16	0.16	0.5
Clay	0.99	0.99	0.12	0.12	1.92
Galena	0.33	0.33	1.53	1.53	1.11

Column headings: Frequency of occurrence weighed on the longest particle dimension = "**linear freq**", bioaccessable frequency is the frequency of occurrence population less any particle greater than 250 microns or enclosed in another particle = "**Bio freq**", relative lead mass based on frequency of occurrence = "**Rm Pb**", Bioaccessable lead mass is based on bioaccessable frequency of occurrence = "**Biorm Pb**", and counting error at the 95% confidence limit = "**Error-95%**". All factors are more fully defined in SOP, Appendix B.

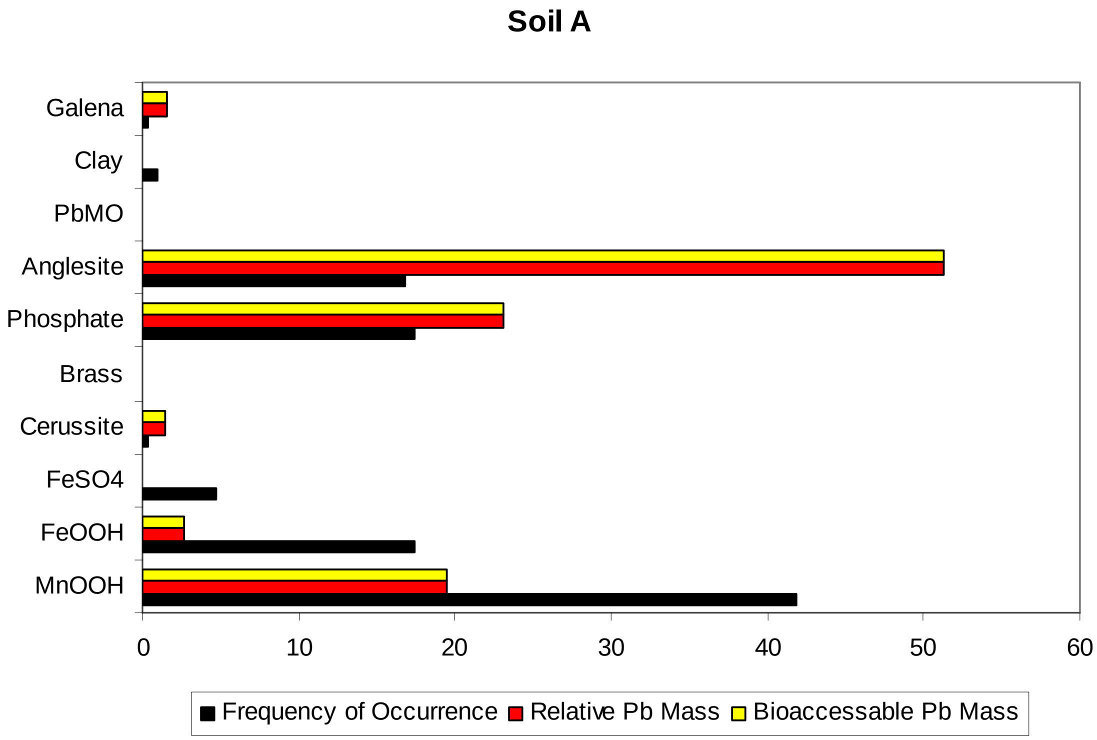


Figure 2-8 - OLS Test Soil A Speciation Results

Table 2-4

OLS Test Soil B Speciation Results.

Form	Particle Count Number	Size Mean	Std-Dev	Range low	Range high
total	135	13.12	62.09	1	690
Cerussite	63	4.71	25.03	1	200
FeOOH	24	19.29	19.53	4	75
Barite	2	5.5	3.54	3	8
Phosphate	21	7.29	9.2	1	43
PbTiO2	1	1	ND	1	1
PbSiO4	9	1.22	0.44	1	2
MnOOH	7	14.71	11.48	1	30
Anglesite	3	4	4.36	1	9
Galena	2	2	1.41	1	3
Brass	1	18	ND	18	18
Clay	1	8	ND	8	8
Paint	1	690	ND	690	690

Form	(linear) freq	Bio freq	Rm Pb	Biorm Pb	Error-95%
%	%	%	%	%	
Cerussite	16.77	27.41	66.29	72.08	6.3
FeOOH	26.14	42.87	4.45	4.85	7.41
Barite	0.62	1.02	0	0	1.33
Phosphate	8.64	14.17	13.8	15.06	4.74
PbTiO2	0.06	0.09	0.22	0.24	0.4
PbSiO4	0.62	1.02	0.7	0.77	1.33
MnOOH	5.82	9.54	2.96	3.23	3.95
Anglesite	0.68	1.11	2.25	2.46	1.38
Galena	0.23	0.37	1.13	1.24	0.8
Brass	1.02	1.67	0.01	0.01	1.69
Clay	0.45	0.74	0.06	0.07	1.13
Paint	38.96	0	8.12	0	8.23

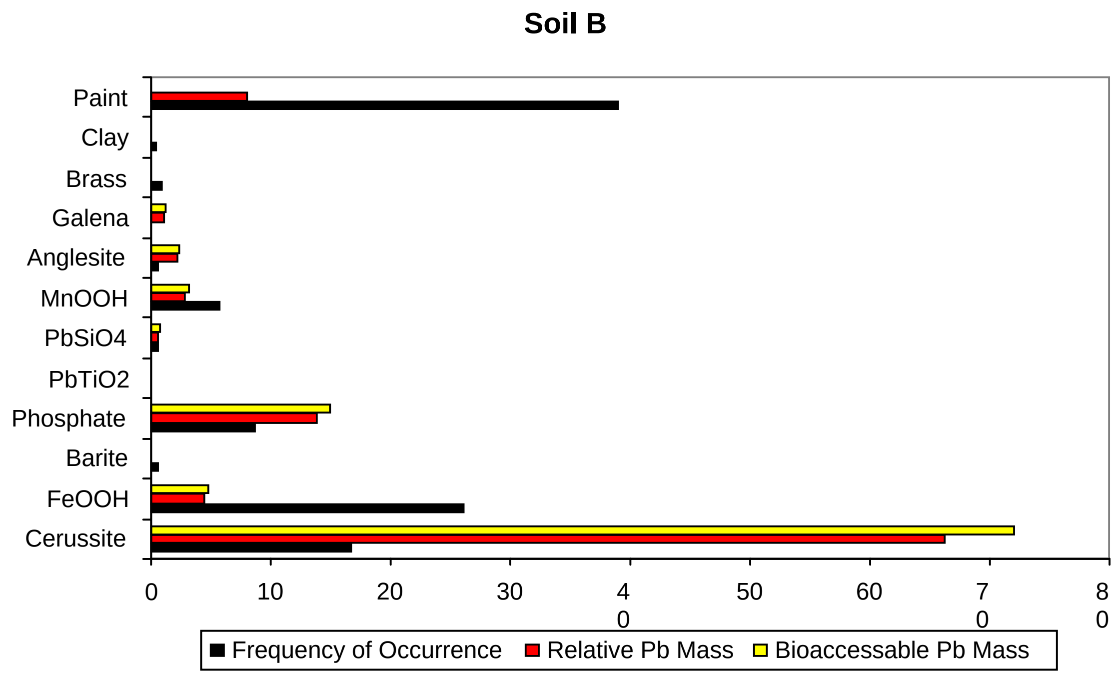


Figure 2-9 - OLS Test Soil B Speciation Results.

Table 2-5
OLS Test Soil C Speciation Results.

Form	Particle Count Number	Size Mean	Std-Dev	Range low	Range high
total	110	2.24	3.22	1	20
Cerussite	38	1.76	1.63	1	8
Phosphate	12	2.25	0.87	2	5
PbTiO2	25	1.04	0.2	1	2
Anglesite	2	8	0	8	8
MnOOH	3	18.33	2.08	16	20
PbMO	1	4	ND	4	4
PbSiO4	25	1.12	0.33	1	2
Clay	1	2	ND	2	2
Barite	1	10	ND	10	10
FeSO4	1	7	ND	7	7
FeOOH	1	4	ND	4	4

Form	(linear) freq	Bio freq	Rm Pb	Biorm Pb	Error-95%
%	%	%	%	%	
Cerussite	27.24	27.24	49.76	49.76	8.32
Phosphate	10.98	10.98	7.6	7.6	5.84
PbTiO2	10.57	10.57	19.23	19.23	5.75
Anglesite	6.5	6.5	10	10	4.61
MnOOH	22.36	22.36	5.26	5.26	7.79
PbMO	1.63	1.63	1.99	1.99	2.36
PbSiO4	11.38	11.38	5.94	5.94	5.94
Clay	0.81	0.81	0.05	0.05	1.68
Barite	4.07	4.07	0	0	3.69
FeSO4	2.85	2.85	0.05	0.05	3.11
FeOOH	1.63	1.63	0.13	0.13	2.36

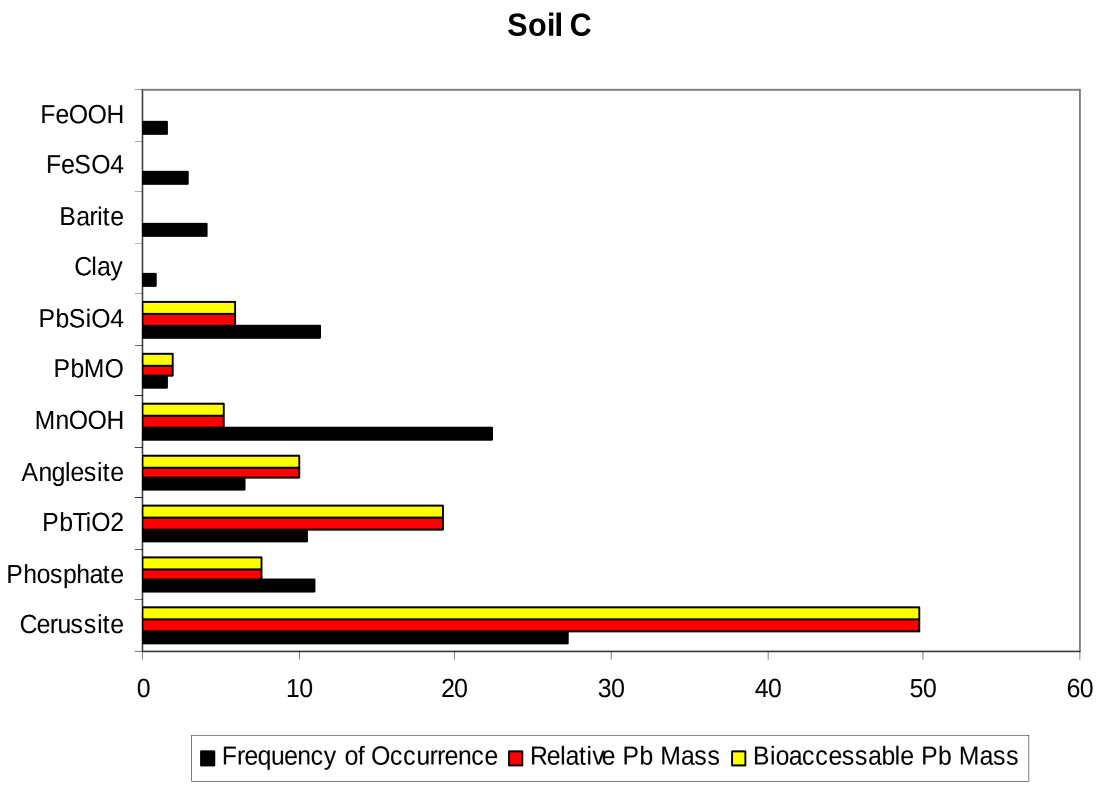


Figure 2-10 - OLS Test Soil C Speciation Results

2.2 Bioaccessibility Testing

An i*n vitro* procedure known as the "Relative Bioavailability Leaching Procedure" (RBALP) (Refs. 6 and 7) was utilized for this treatability study. The RBALP, which was developed by LEGS, has been used to estimate soil lead i*n vitro* bioaccessibility (IVBA) (Refs. 8, 9, 10, and 11). Bioaccessibility testing, which is an i*n vitro* test, was described in Section 2.2 of the Treatability Study Work Plan (Ref. 20).

A method of estimating bioavailability involves i*n vitro* testing which is, by definition, conducted "in laboratory glassware." The i*n vitro* method is referred to as *bioaccessibility* testing to distinguish it from *in vivo* bioavailability testing which involves animal feeding studies. The i*n vitro* method is significantly less resource intensive, can be performed more rapidly (weeks instead of months required for the *in-vivo* test method), does not require the sacrifice of animals, and the results have been shown to correlate well with the results of *in vivo* bioavailability studies (Ref. 10).

Unlike the *in vivo* procedure, which favors soils with at least 1,000 ppm lead, the RBALP can be applied to soils with lead concentrations in the target treatment range for this project (400 to 800 ppm). For detailed information on bioaccessibility testing objectives, methods and procedures, including a discussion of how the *in vivo* and i*n vitro* testing results are correlated mathematically, see Appendix C (RBALP Standard Operating Procedure).

Baseline bioaccessibility data for the OLS test soils are summarized in Tables 2-6 and 2-7. Data for both lead and arsenic are provided and represent an average of six replicate (n=6) analyses. Both the standard i*n vitro* pH of 1.5 was reported in addition to data for a pH of 2.5 in order to compare results with literature values from other amendment studies. Only one detailed field study has been conducted using phosphate amendments with supporting *in vitro* and *in vivo* data. Soils from Joplin, Missouri, comprised primarily of $PbCO_3$ and $PbSO_4$, (two fairly soluble forms of lead), have been studied over a time period of up to three years (Refs. 3, 4, and 5). A reduction in IVBA and RBA-rat, (based on *in vitro* and *in vivo* data, respectively) range from 2-70%. In this study, a better comparison between (RBA-rat) results was occasionally found when the *in vitro* (IVBA) procedure was run at pH 2.2.

Also, it is important to note that all *in vitro* data is based on a sieved (<250 μ) split of the sample, as this is the particle size that is considered bioaccessable by the EPA. Complete data package with raw data, calculations and QA/QC are provided in accompanying electronic spreadsheets in Appendix E.

Table 2-6

In Vitro Lead Bioaccessibility of OLS Test Soils

	<250µ Total Pb*	**IVBA-Pb pH 1.5**	**IVBA-Pb pH 2.5**
	mg/kg	%	%
Soil A	831 +/- 20	80 +/- 3	41 +/- 3
Soil B	1406 +/- 93	86 +/- 3	49 +/- 4
Soil C	2284 +/- 130	88 +/- 6	61 +/- 4

* Soil sample sieved at 60 mesh (250 µm)

Table 2-7

In Vitro Arsenic Bioaccessibility of OLS Test Soils

	<250µ Total As*	**IVBA-As pH 1.5**	**IVBA-As pH 2.5**
	mg/kg	%	%
Soil A	37 +/- 0.5	35 +/- 3	25 +/- 2
Soil B	43 +/- 0.8	37 +/- 4	24 +/- 2
Soil C	15 +/- 0.3	33 +/- 8	16 +/- 2

* Soil sample sieved at 60 mesh (250 µm)

3.0 Laboratory Bench Testing

Several forms of phosphate have been researched for the treatment of lead-contaminated soil including phosphate rock, triple super phosphate, and phosphoric acid. Previous studies have generally found that the bioavailability of lead is reduced by the application of phosphate amendments. Lead phosphate minerals are generally very stable with very low solubility and are expected to exhibit low bioavailability. Phosphoric acid has been evaluated in treatability studies and bench scale tests and has been shown to reduce lead bioavailability at other sites (Ref. 3, 4, and 5). Other types of amendments, including sulfate compounds and biosolids, have also yielded promising research results.

This treatability study will focus on documenting bioaccessibility changes in OLS soils resulting from phosphate amendments. One of the amendment schemes was similar to the treatment process developed for the Jasper County, Missouri, Superfund site, which utilized phosphoric acid. The treatment scheme used at Jasper County involved the following steps (Ref. 5):

- Phosphoric acid was incorporated into the soil, along with potassium chloride (KCl), in an effort to form lead phosphate minerals.
- Hydrated lime [$Ca(OH)_2$] was added several days after phosphoric acid amendment in order to raise soil pH and thereby promote sod rooting or grass seed growth.
- Soil samples were collected for testing at prescribed time intervals following the completion of amendment treatment.

For the OLS, laboratory bench testing followed the completion of pre-treatment soil characterization testing and was also conducted by the LEGS. The objective of this effort was to evaluate various amendment types and strategies and recommend treatment schemes and procedures for field-testing. Numerous treatment schemes were conducted on unsieved splits of soil provided to LEGS by BVSPC using three forms of phosphorus; phosphoric acid (PA), triple super phosphate (TSP), and phosphate rock (PR). The amendment concentrations ranged from 0.5 percent (for example, 0.5 PA) to 2.0 percent (for example, 2 TSP). Some scenarios included the addition of hydrous ferric oxide (HFO) in an effort to reduce arsenic mobilization under high phosphate conditions. All amendments had lime added at the end of their reactive interval to adjust the pH back to a near normal (7.5) pH value. In most instances it was not possible to adjust the pH to pre-treatment levels. The average post-treatment pH was ~ 8.7. It was determined that adding more lime for the bench-scale testing would dilute the samples to an unacceptable level, causing the lime to behave not as a pH buffer, but merely diluting the contaminated soils with a non-lead material. Amendments were run in duplicate (n=2) and sampled at 2, 7 and 14 days, Appendix A, (Table 2A). All analytical testing (SPLP, total P, extractable P, and RBALP) performed on the various treatment schemes are provided on accompanying electronic spreadsheets in Appendix E.

3.1 Total Phosphorus (P)

All of the amendment scenarios added considerable (1000X background) phosphorus to the OLS soils, 3,000-16,000 mg/kg P. As anticipated, the total phosphate remains generally constant, (Figures 3.1 to 3-3), throughout the 14 days testing interval. Phosphorus (P) is an essential element classified as a macronutrient for plants. Adequate P availability for plants stimulates early plant growth and hastens maturity. The soluble phosphate in the soil solution generally moves a short distance. Movement is slow but may be increased by rainfall or irrigation water flowing through the soil. As phosphate ions in solution migrate, most of the phosphate will react with other minerals within the soil. At the OLS, phosphate ions would likely react by adsorbing to soil particles or by combining with elements in the soil such as calcium (Ca), or magnesium (Mg), since soil pH is relatively high (pH >7.0), forming compounds that are solids. The adsorbed phosphate and the newly formed solids are relatively available to meet plant needs. The potential for migration of phosphorus to the water table can only be estimated once sorption isotherms for the OLS are determined; however, surface runoff of phosphorus is likely.

Although P is essential for plant growth, mismanagement of soil P can pose a threat to water quality. When lakes and rivers are polluted with P, excessive growth of algae often results. High levels of algae reduce water clarity and can lead to decreases in available dissolved oxygen (eutrophication) as the algae decays, conditions that can be very detrimental to fish populations.

The complete data set with QA/QC can be review in the accompanying electronic spreadsheet in Appendix E.

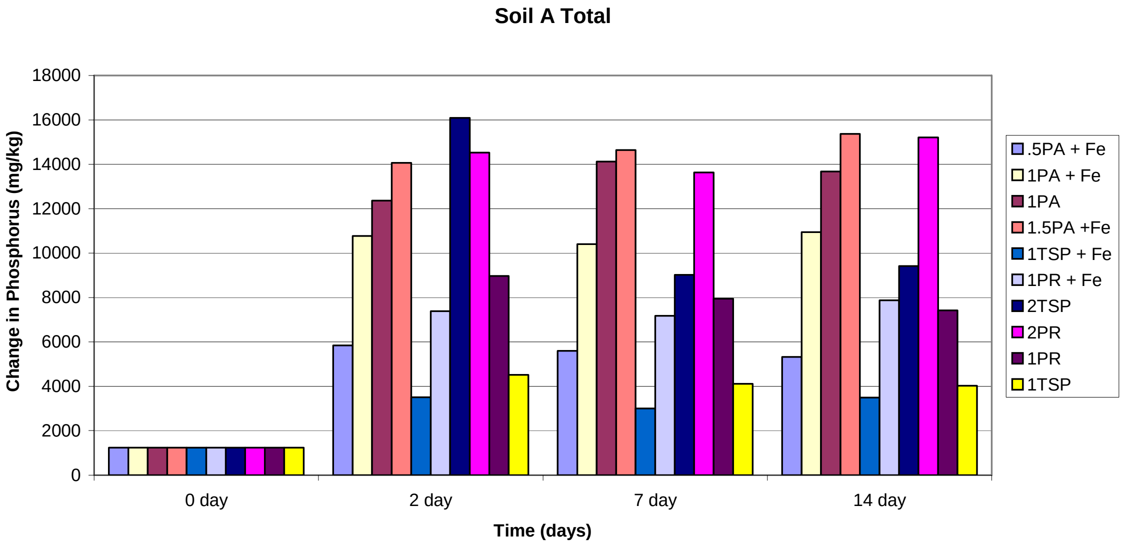


Figure 3-1 - Post-Treatment, Total Phosphorus from Soil A

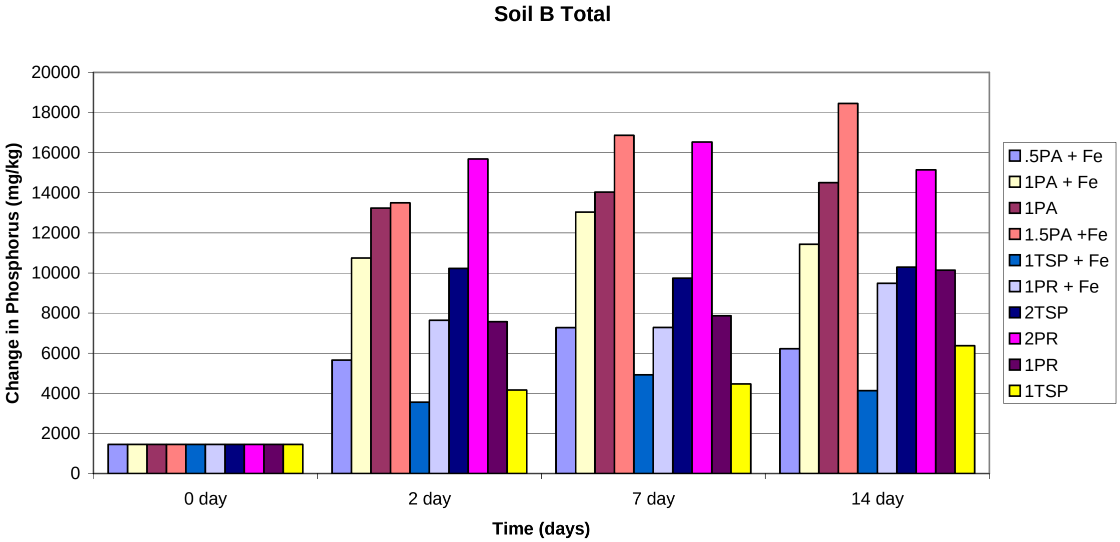


Figure 3-2 - Post-Treatment, Total Phosphorus from Soil B

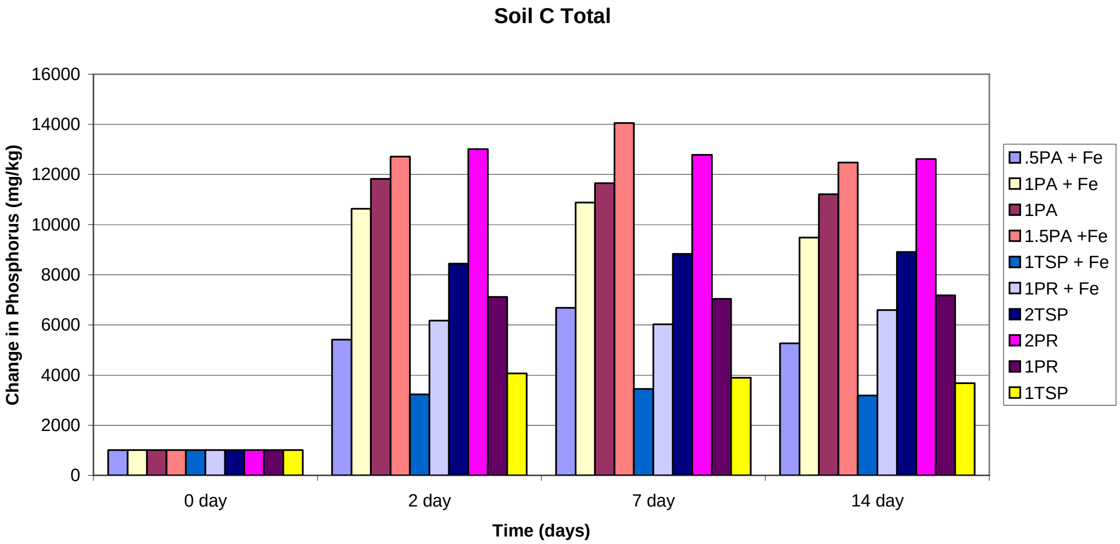


Figure 3-3 - Post-Treatment, Total Phosphorus from Soil C

3.2 Extractable P

Extractable phosphate concentrations are intended to provide an indication of the sustainability of the amendment procedure. Thus, over time, as more lead becomes soluble from normal weathering, there is an issue as to whether there is sufficient phosphorous left in the soil to promote lead phosphate formation. A considerable degree of variation can be seen between the various forms of phosphate amendments and extractable phosphorus. PR yields virtually no extractable phosphate, even after 14 days (Figures 3-4 to 3-6). The other forms, TSP and PA, have 100-800 mg/l extractable P, with PA having the highest final concentrations after 14 days. The complete data set with QA/QC can be reviewed in the accompanying electronic spreadsheet in Appendix E.

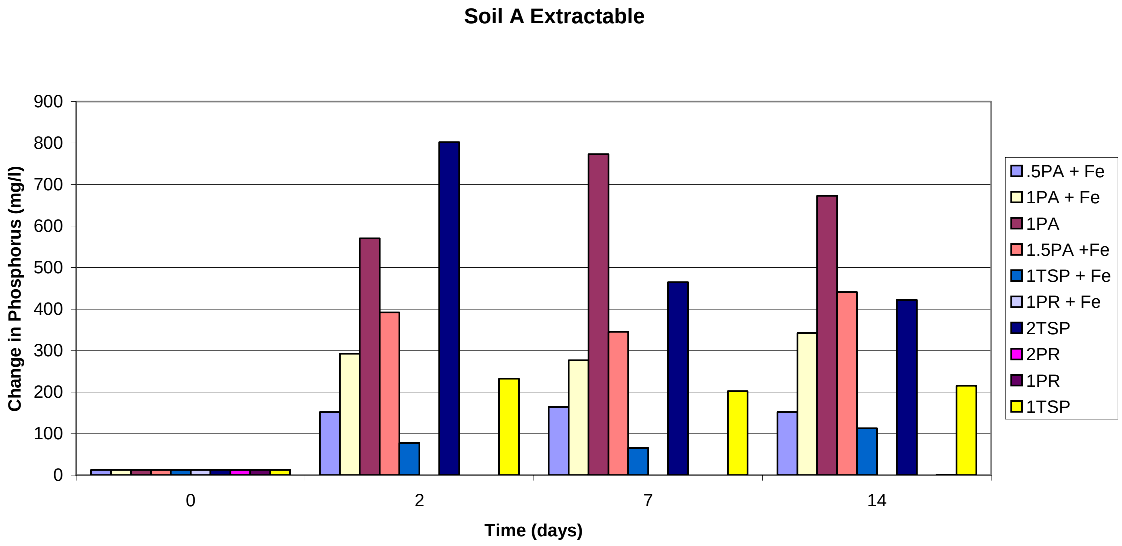


Figure 3-4 - Post-Treatment, Extractable Phosphorus from Soil A

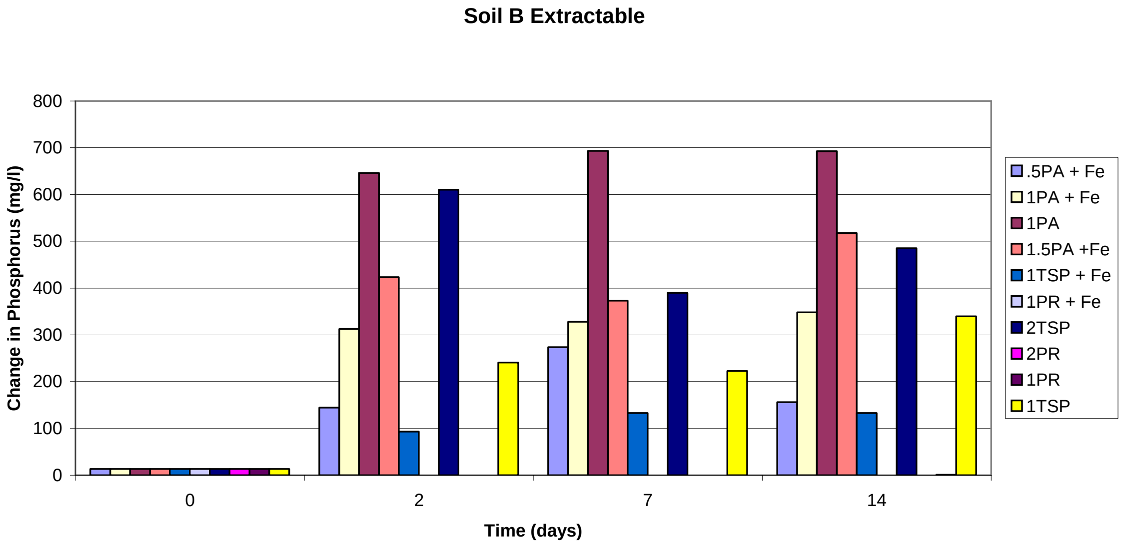


Figure 3-5 - Post-Treatment, Extractable Phosphorus from Soil B

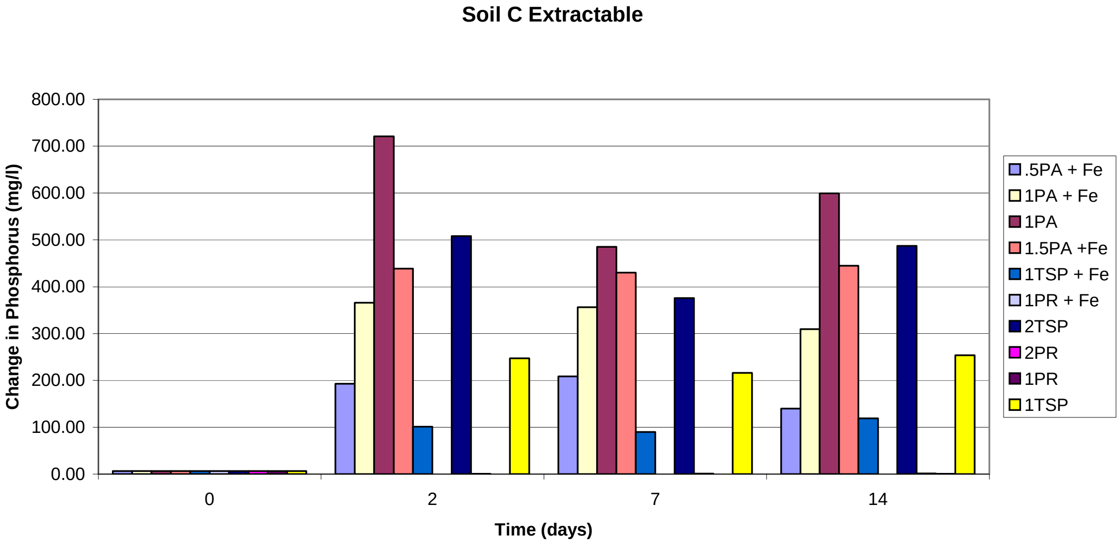


Figure 3-6 - Post-Treatment, Extractable Phosphorus from Soil C

3.3 SPLP- Leachable P

Leachable phosphorus, (the phosphorous that will most likely impact surface runoff and groundwater) as measure by SPLP, is generally low, 2-30 mg/l, above the control soils concentrations. In general, concentrations of phosphorus decrease with time. The samples amended with 2-TSP leached from 40-120 mg/l P and remained high throughout the 14 days. The complete data set with QA/QC can be reviewed in the accompanying electronic spreadsheet in Appendix E.

3.4 *In Vitro* Bioavailability

The *in vitro* bioavailability (IVBA) for lead, as measured using the RBALP, for each of the amended soils is presented in Figures 3-7 to 3-9. All of the samples show some reduction in bulk lead from the control (blue circle) samples. This change is primarily the result of dilution (from the low lead amendments) and a slight increase in particle size of the soils. The changes in IVBA are not significant and vary for each of the soils over time. In general, an average 20% reduction ($IVBA_{Initial} – IVBA_{Final} / IVBA_{Initial}$ *100) in bioaccessibility was achieved, with the highest reduction achieved using the amendment of 1.5PA + hydrous ferric oxide (HFO). None of the amendment scenarios consistently lowered the soil IVBA's below EPA's default level (this is the value for IVBA used in the Integrated Exposure Uptake Biokinetic (IEUBK) model when no site-specific bioavailability data is available) of 60%.

As discussed in the Treatability Work Plan (Ref.20), all samples were run with a second *in vitro* pH of 2.5 in order to be able to compare results with similar studies found in the literature. Running the RBALP at a pH of 2.5 (not a validated pH) indicates a much greater reduction in IVBA for all treated samples. As with the 1.5 pH samples, the 1.5PA + hydrous ferric oxide (HFO) amendment showed the greatest reduction, reducing IVBA to approximately 18% (11-24%) from the 50% average IVBA measured pre-treatment at pH 2.5. This represents nearly a 70% reduction in IVBA.

It is very important to note that there has been no validated *in vitro* method published for phosphate-amended soils at any pH values, including pH 1.5 and pH 2.5. Studies on amended soils have limited animal data (Ref. 5 and 21) and are highly variable, indicating both increases and decreases in RBA. Additionally, the 1.5 pH IVBA data from the RBALP agrees well with the OLS *in vivo* data (Ref. 22). Average RBA estimates obtained at pH 1.5 from RBALP are 76 and 71 percent for TM-1 and TM-2 (test materials from swine OLS study), whereas measured values *in vivo* are 96 and 83 percent, respectively. Because the increase in pH from 1.5 to 2.5 standard units (su) for the RBALP would lower estimated RBA, it is clear that the use of a 2.5 pH *in vitro* solution would significantly underestimate the RBA at the OLS.

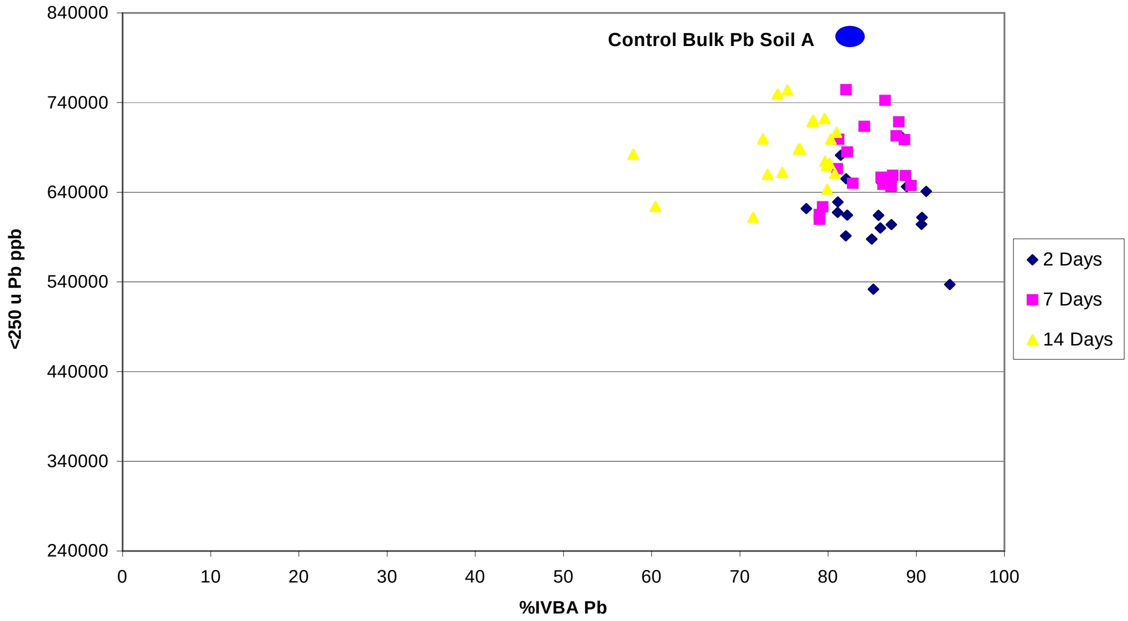


Figure 3-7 - Post-Treatment, IVBA for Lead in Soil A.

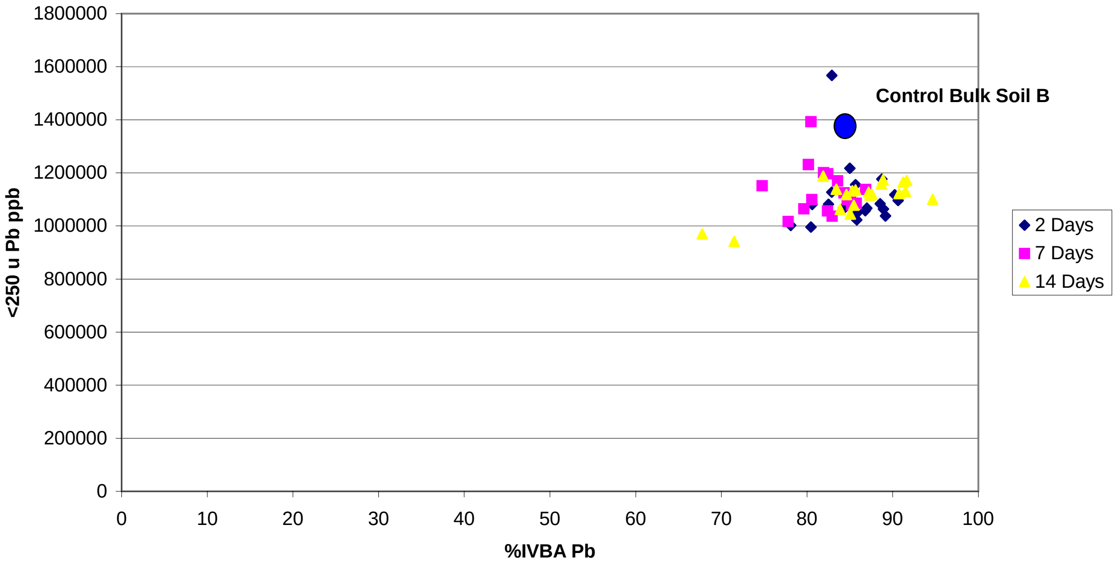


Figure 3-8 - Post-Treatment, IVBA for Lead in Soil B

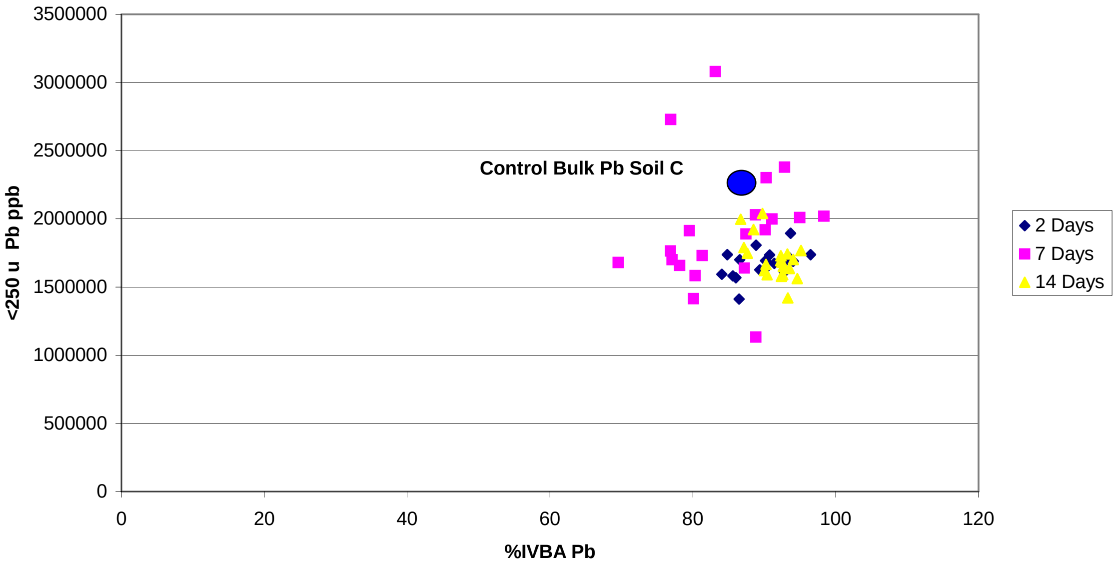


Figure 3-9 - Post-Treatment, IVBA for Lead in Soil C

3.5 Post Treatment Speciation

Post treatment speciation for lead is presented in Tables 3-1 to 3-3 and Figures 3-10 to 3-12. Only a single sample from the 1.5 PA + iron treatment (greatest reduction in IVBA) for each soil was speciated. It is apparent that the treatment procedure speciated is forming a phosphate product. The frequency of occurrence of lead phosphate forms increased in the treated soils to between 66 and 81% from the control soils that contained only 9-17 % lead phosphate. Based on the post-treatment speciation results it appears that the more soluble forms of lead including paint, cerussite, anglesite, and oxides of lead were preferentially dissolved and re-precipitated as a phosphate. Particle size of the lead-bearing forms also plays an apparent role. In all three soils the post treatment, mean particle-size of the lead-bearing forms increased from 14 to 36, 13 to 25, and 2 to 23 microns in soils A, B, and C, respectively. The small (more soluble) particles preferentially dissolved. It also appears that lead associated with iron and manganese oxides does not respond well to phosphate treatment.

Two general forms of phosphate compounds are observed. The first, (labeled as phosphate) generally contain significant quantities of lead (25-60 wt% PbO) but are hydrated, with 10-25 wt% water in their structure. These phosphates, although containing lead and chloride, are clearly not pyromorphite or chloropyromorphite. They are well hydrated, and contain more chlorine and phosphorus than the pyromorphites (Figures 3-13 and 3-14). Although thermodynamically pyromorphites are the stable phase (Ref. 23), they are seldom identified and their diagenetic formation may be kinetically prevented

(Ref. 24). Since the general premise of the phosphate treatment is the formation of the insoluble, Ksp= -84.4, chloropyromorphite, the formation of a potentially more soluble, primary or secondary orthophosphate (Ksp = -9.84, -11.43 respectively) is significant. These phosphates would not likely be less bioaccessable than many of the original lead phases (anglesite Ksp –7.7, and cerussite Ksp –12.8). These observations are in direct support of the limited decrease in IVBA observed in the treated soils.

The second phosphate compound, (Fe-hydrophosphate), is likely formed from the AFH (amorphous ferrihydroxide) added to the amended soils. These hydrated iron oxides have now sorbed phosphorus (1-20 wt% P_2O_5), chlorine (1-3 wt% Cl) and lead (0.08-2.1 wt% PbO). Since they are not chemically similar to either corkite ($PbFe_3PO_4SO_4$-OH_6) or drugmanite, ($Pb_2Fe\ (PO_4)_2$-OH_3) it is unlikely they represent a stable mineral form.

Table 3-1

Form	Number	Mean	Std-Dev	Range low	Range high
Total	96	35.76	36.72	1	155
Phosphate	21	9.62	23.73	1	110
MnOOH	2	102.5	45.96	70	135
Brass	1	2	ND	2	2
FeOOH	14	25.64	31.72	2	90
PbTiO2	2	2.5	0.71	2	3
Fe-HydroPhosphate	55	48.33	34.36	4	155
Lead Solder	1	2	ND	2	2

Form	(linear) freq	Bio freq	rm Pb	Biorm Pb	Error-95%
%	%	%	%	%	
Phosphate	5.88	5.88	47.87	47.87	4.71
MnOOH	5.97	5.97	16.53	16.53	4.74
Brass	0.06	0.06	0	0	0.48
FeOOH	10.46	10.46	9.65	9.65	6.12
PbTiO2	0.15	0.15	1.1	1.1	0.76
Fe-HydroPhosphate	77.42	77.42	24.68	24.68	8.36
Lead Solder	0.06	0.06	0.17	0.17	0.48

Post-Treatment Lead Speciation of Soil A.

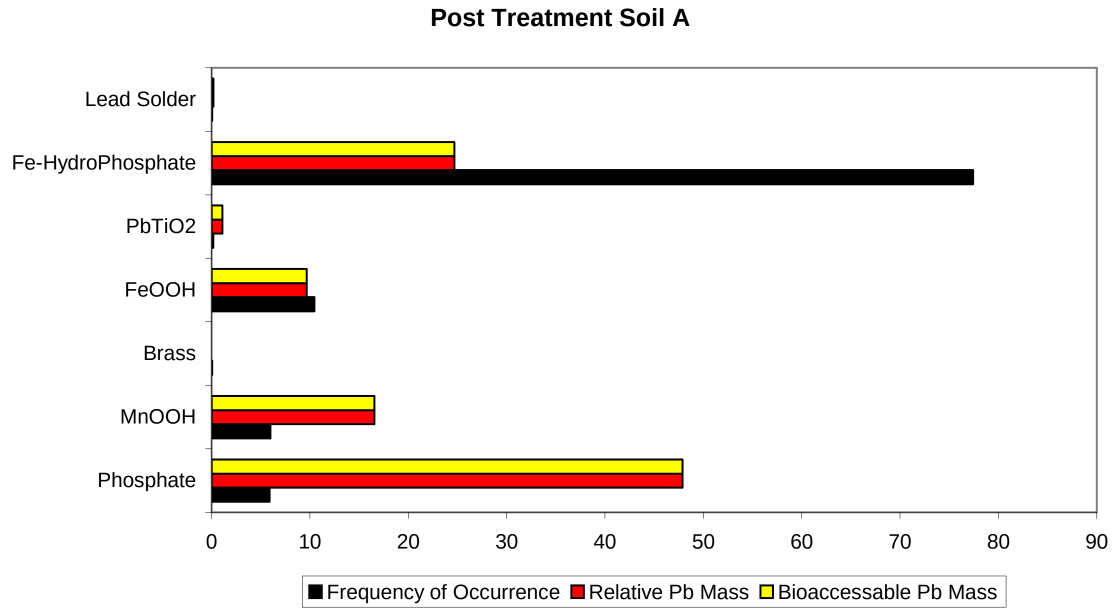


Figure 3-10 - Post-Treatment, Lead Speciation in Soil A

Table 3-2
Post-Treatment Lead Speciation of Soil B

Form	Number	Mean	Std-Dev	Range low	Range high
Total	103	25.4	27.88	1	150
Phosphate	32	5.75	6.4	1	30
FeOOH	15	14.53	11.27	3	45
Clay	1	80	ND	80	80
Brass	1	25	ND	25	25
MnOOH	2	20	1.41	19	21
Cerussite	1	2	ND	2	2
FeSO4	1	10	ND	10	10
Slag	1	70	ND	70	70
Fe-HydroPhosphate	49	40.55	30.64	7	150

Form	(linear) freq	Bio freq	rm Pb	Biorm Pb	Error-95%
%	%	%	%	%	
Phosphate	7.03	7.03	58.61	58.61	4.94
FeOOH	8.33	8.33	7.87	7.87	5.34
Clay	3.06	3.06	2.32	2.32	3.33
Brass	0.96	0.96	0	0	1.88
MnOOH	1.53	1.53	4.33	4.33	2.37
Cerussite	0.08	0.08	1.68	1.68	0.53
FeSO4	0.38	0.38	0.07	0.07	1.19
Slag	2.68	2.68	0.31	0.31	3.12
Fe-HydroPhosphate	75.96	75.96	24.79	24.79	8.25

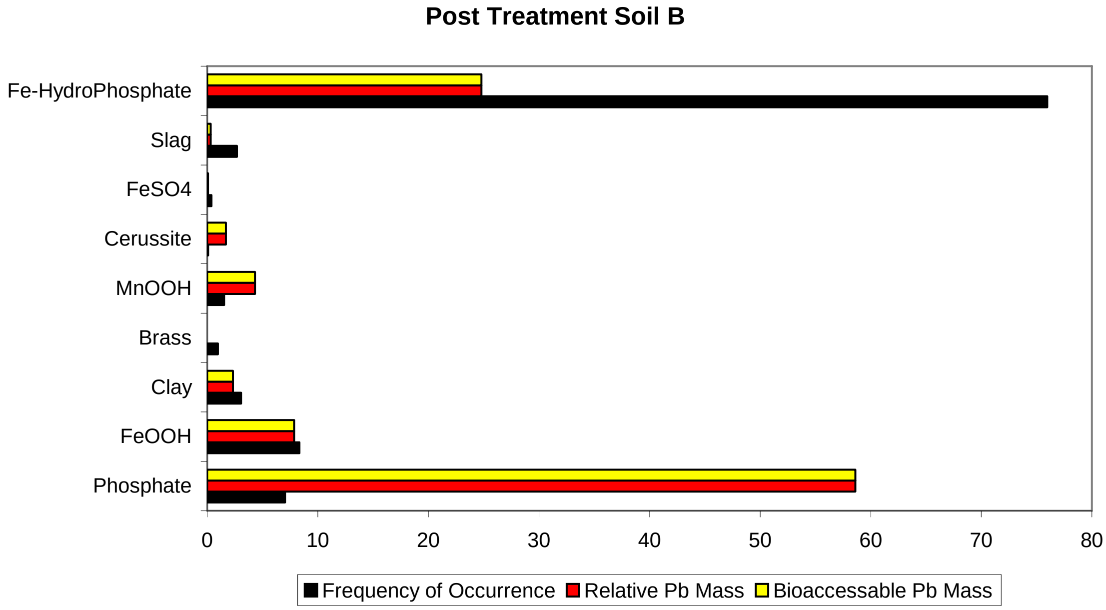


Figure 3-11 - Post-Treatment, Lead Speciation in Soil B

Table 3-3

Post-Treatment Lead Speciation of Soil C

Form	**Number**	**Mean**	**Std-Dev**	**Range low**	**Range high**
Total	277	23.01	36.62	1	252
Cerussite	52	7.9	8.72	1	48
MnOOH	15	41.2	26.78	2	90
Phosphate	117	15.97	37.22	1	252
SnMO	1	90	ND	90	90
FeOOH	21	39.43	35.44	7	135
Fe-HydroPhosphate	50	46.94	44.45	5	205
PbMO	1	15	ND	15	15
Barite	2	6	2.83	4	8
PbTiO2	14	1.07	0.27	1	2
Clay	1	55	ND	55	55
Galena	1	4	ND	4	4
Lead Solder	1	80	ND	80	80
Paint	1	30	ND	30	30

Form	**(linear) freq**	**Bio freq**	**rm Pb**	**Biorm Pb**	**Error-95%**
%	%	%	%	%	
Cerussite	6.45	6.71	31.39	33.86	2.89
MnOOH	9.7	10.1	6.08	6.56	3.48
Phosphate	29.31	26.4	54.04	50.42	5.36
SnMO	1.41	1.47	0.46	0.49	1.39
FeOOH	12.99	13.53	2.72	2.93	3.96
Fe-HydroPhosphate	36.83	38.34	2.66	2.87	5.68
PbMO	0.24	0.25	0.77	0.83	0.57
Barite	0.19	0.2	0	0	0.51
PbTiO2	0.24	0.25	0.4	0.43	0.57
Clay	0.86	0.9	0.14	0.16	1.09
Galena	0.06	0.07	0.39	0.42	0.29
Lead Solder	1.26	1.31	0.84	0.9	1.31
Paint	0.47	0.49	0.12	0.13	0.81

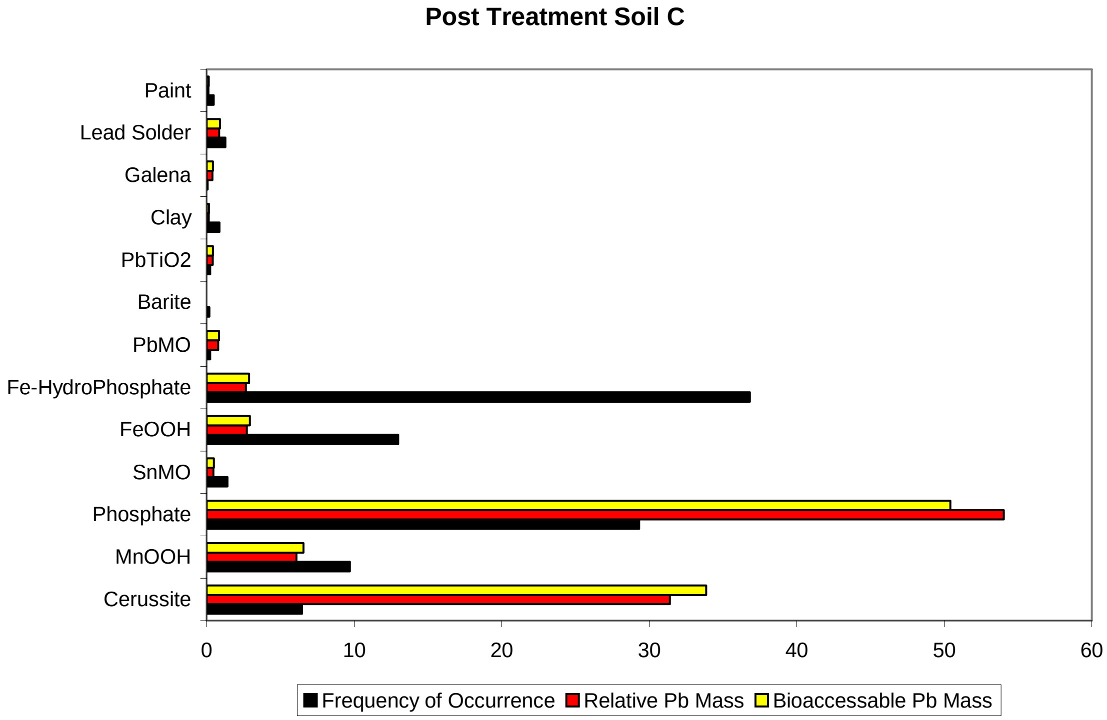
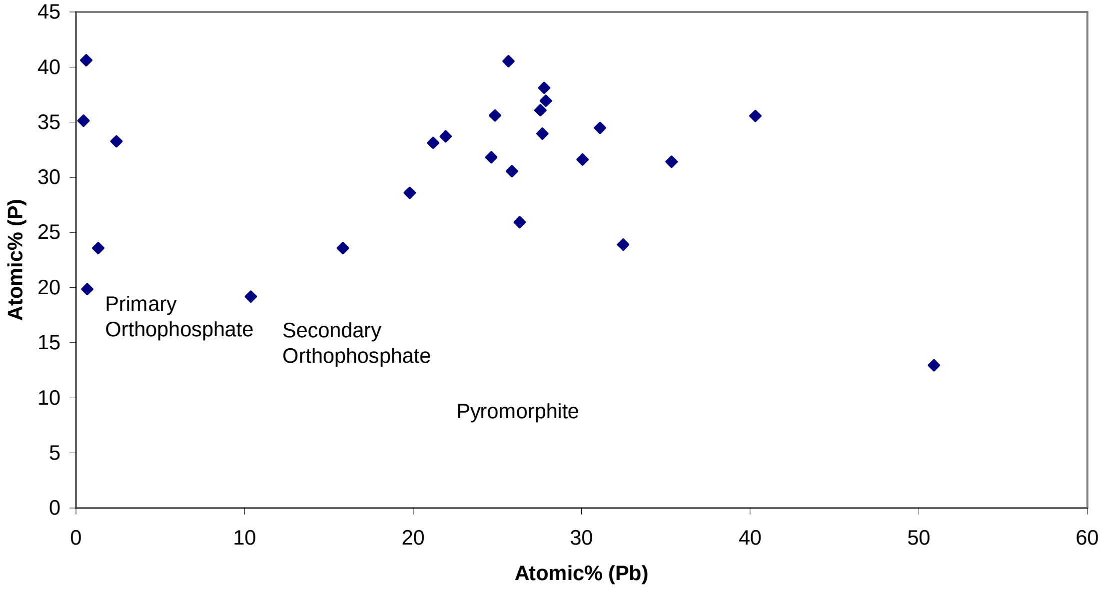
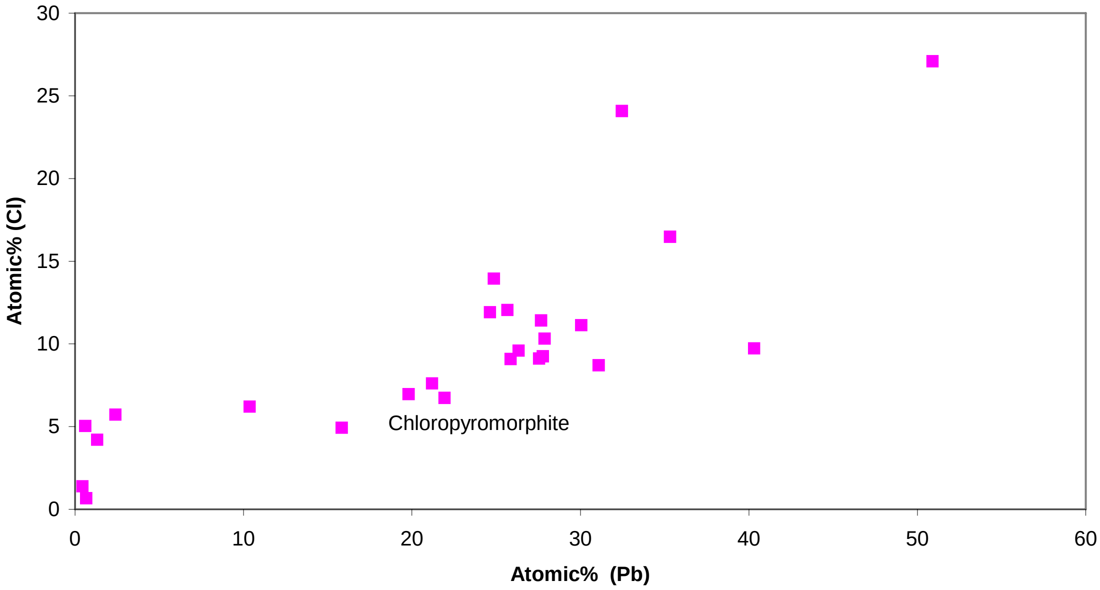


Figure 3-12 - Post-Treatment, Lead Speciation in Soil C

Figures 3-13 & 3-14 – EMPA analyses of Post-Treatment, phosphate compounds.





4.0 Conclusions

As outlined in the work plan, duplicate matrices of soils were assembled containing controls and the phosphate amendments PA, PR, and TSP, both with and without amorphous iron. The matrices were run in triplicate using 2, 7, and 14 day reaction periods. The effectiveness of the amendments were evaluated based on the relative change in IVBA as measured using the RBALP i*n vitro* procedure, with extraction fluids at pH 1.5 and 2.5.

In vivo testing favors soils with lead concentrations greater than 1,000 ppm. Validated test methods do not exist that can measure RBA in phosphate treated soil within the lead concentration range of interest at the OLS. Although RBALP has not been validated for phosphate treated soils at either pH 1.5 or pH 2.5, the procedure may provide an indication of the potential effectiveness in reducing the RBA of lead-contaminated soils.

RBALP at pH 1.5 correlates well with *in vivo* RBA in untreated soils as evidenced by the close agreement of the two methods on the same soils (TM-1 and TM-2) from the OLS. RBALP at pH 2.5 would significantly underestimate the RBA when compared to *in vivo* results at the OLS.

Virtually all of the phosphate amendments showed some reduction in IVBA however, the 14-day, 1.5 PA (with iron) was the most reductive. All of the amendments behaved equally as well on the three soil-types, producing an increased presence of some phosphate form. Two negative results of the phosphate amendments, which could result in localized environmental issues is their release of both phosphate and arsenic to the vadose zone.

The measured effectiveness of the amendment techniques clearly varies between the pH 1.5 and pH 2.5 i*n vitro* results. The pH 1.5 data presented in Table 4-1, which has the strongest correlation with *in vivo* RBA, shows limited reduction in IVBA, ranging from 15 percent to 26 percent reduction for the three soil types tested. The RBALP at pH 2.5 showed more significant reduction in IVBA, ranging from 61 percent to 80 percent; however the RBALP at pH 2.5 did not show good correlation with *in vivo* results on the same test soils and has not been validated by *in vivo* studies.

One sample from each of the three soil types treated with 1.5 PA plus iron was speciated. The speciation indicated that the treatment procedure was forming a phosphate product. The speciation indicated the formation of a potentially more soluble primary or secondary orthophosphate rather than the more insoluble chloropyromorphite. These orthophosphates would be more bioaccessable than the lead phases in the untreated soils and support the limited decrease in IVBA observed in the treated soils.

Finally, as pointed out previously, none of the amendment scenarios consistently lowered soil IVBA below EPA's default level of 60%, and therefore it is unlikely the data from the study would support altering EPA's cleanup decisions which are based on the IEUBK model. In addition, the long term effectiveness of the treatment scenarios has not been demonstrated at other sites and could not be assessed by this bench scale study.

Table 4-1
Summary of Best Performing Amendments

Soil	**Initial %IVBA PH (1.5/2.5)**	**Phosphate Amendment**					
				Post			
				IVBA	**IVBA**	**%Change***	**%Change**
			***In Vitro* pH**	**1.5**	**2.5**	**1.5**	**2.5**
A	80/41	1.5 PA + Iron		59%	14%	-26%	-66%
B	86/49	1.5 PA + Iron		69%	11%	-20%	-80%
C	88/61	1.5 PA + Iron		75%	24%	-15%	-61%

*Change in IVBA = Initial IVBA-Post treatment IVBA/ Initial IVBA*100

5.0 References

1. United States Environmental Protection Agency, *Interim Record of Decision, Omaha Lead Site, Operable Unit 01*. Prepared by USEPA, Region VII, December 15, 2004.

2. Black & Veatch Special Projects Corp. (BVSPC), Remedial Investigation, Residential Yard Soil, Omaha Lead Site, Omaha Nebraska, USEPA Work Assignment Number 070-RICO-07ZY. Prepared by BVSPC, Overland Park, Kansas, June 9, 2004.

3. Brown, Sally; Chaney, Rufus; Hallfrish, Judith; Ryan, James; and Berti, William, "In Situ Soil Treatments to Reduce Phyto- and Bioavailability of Lead, Zinc, and Cadmium", Journal of Environmental Quality, 33:522-531, 2004.

4. Hettiarachchi, G.M.; Pierzynski, G.M.; and Ransom, M.D., "In Situ Stabilization of Soil Lead Using Phosphorus", Journal of Environmental Quality, 30:1214-1221, 2001.

5. Mosby, David; Casteel, Stan; Yang, John; Gantzer, Clark; and Blanchar, Robert; Lead Bioavailability Study, Phosphate Treatment of Lead-Contaminated Soils, Joplin, Missouri, Jasper County Superfund Site, Prepared for USEPA, Region VII, Kansas City, Kansas, May 2002.

6. Medlin, E., and Drexler, J.W.; "Development of an *In Vitro* technique for the determination of bioavailability from metal-bearing solids", International Conference on the Biogeochemistry of Trace Elements, Paris, France, 1995.

7. Drexler, J.W.; "An *In Vitro* method that works! A simple, rapid, and accurate method for determination of lead bioavailability". EPA Workshop, Durham, NC., 1998.

8. Drexler, J.W., and W. Brattin; "An *In Vitro* Procedure for Estimation of Lead Relative Bioavailability with Validation", Environ. Health Persp. April, 2007.

9. Brattin, W., Weis, C., Casteel. S.W., Drexler, J.W., Henningsen, G.M., Estimation of Relative Bioavailability of Lead in Soil and Soil-Like Materials Using *In Vivo* and *In Vitro* Methods, USEPA Technical Document, OSWER 9285.7-77, Office of Solid Waste and Emergency Response, Washington, DC, 2004.

10. United States Environmental Protection Agency, Office of Solid Waste and Emergency Response, Draft Final Estimation of Relative Bioavailability of Lead in Soil and Soil-Like Materials Using *In Vivo* and *In Vitro* Methods. OSWER 9285.7-77, December 2004.

11. Drexler, J.W., Laboratory Report, Results and QA/QC for *In Vitro* Bioassay Results using the Relative Bioavailability Leaching Procedure (RBLP), Omaha Lead Site, 2004.

12. Klug, H.P., and Alexander, L.E., 1974, X-ray Diffraction Procedures, Wiley

13. Adatte, T., Stinnesbeck, W. & Keller, G. (1996). Lithostratigraphic and mineralogic correlations of near K/T boundary clastic sediments in northeastern Mexico: Implications for origin and nature of deposition. Geological Society of America Special Paper, 307, 211-226.

14. Ferrero, J. (1965). Dosage des principaux minéraux des roches par diffraction de Rayon X. Rapport C.F.P. (Bordeaux), inédit.

15. Ferrero, J. (1966). Nouvelle méthode empirique pour le dosage des minéraux par diffraction R.X. Rapport C.F.P. (Bordeaux), inédit.

16. Kübler, B. (1983). Dosage quantitatif des minéraux majeurs des roches sédimentaires par diffraction X. Cahier de l'Institut de Géologie de Neuchâtel, Série AX N°1.1 &1.2.

17. Kübler, B. (1987). Cristallinité de l'illite, méthodes normalisées de préparations, méthodes normalisées de mesures.- Cahiers Institut Géologie de Neuchâtel, Suisse, série ADX.

18. Moore, D.M., and Reynolds, R.C., 1997, X-Ray Diffraction and the Identification and Analysis of Clay Minerals, 2nd Edition.

19. Rolli, M. (1992). Dosage semi-quantitatif RX sur Scintag. Cahiers Institut Géologie de Neuchâtel, Suisse, série ADX, 49 pp.

20. BVSPC, 2007; Final Treatability Study Work Plan, Omaha Lead Site, Omaha,

Nebraska, June 2007.

21. Hettiarachchi, G.M., Pierzynski, G.M., Oehme, F.W., Sonmez, O, Ryan, J.A., Treatment of Contaminated Soil with Phosphorus and Manganese Oxide Reduces Lead Absorption by Sprague-Dawley Rats. J. Environ. Qual. 32, 1335-1345, 2003.

22. United States Environmental Protection Agency, *Interim IVBA Summary, Omaha Lead Site, Operable Unit 01*. Prepared by USEPA, Region VII, August 2008.

23. Nriagu, J.O., Lead orthophosphates—IV Formation and stability in the Environment. Geo. et Cosmo. Acta 38,887-898, 1974.

24. Sutherland, J.C., Kramer, J.R., and Krurtz, T.D., Mineral-water equilibrium, Great Lakes: silica and phosphorus. Publ. No. 15, Gt. Lakes Res. Div., Univ. of Michigan, 439-445, 1966.

25. Nriagu, J. O. (1973) Lead orthophosphates—II. Stability of chloropyromorphite at 25 C. Geochim. Cosmochim. Acta 38: 367-377.

26. Cotter-Howells, J.; Caporn, S. (1996) Remediation of contaminated land by formation of heavy metal phosphates. Appl. Geochem. 11: 335-342.

27. Ownby, D. R.; Galvan, K. A.; Lydy, M. J. (2005) Lead and zinc bioavailability to *Eisnia fetida* after phosphorus amendment to repository soils. Environ. Pollut. 136: 315-321.

28. Cao, X.; Ma, Q. Y.; Chen, M.; Singh, S. P.; Harris, W. G. (2002) Impacts of phosphate amendments on lead biogeochemistry at a contaminated site. Environ. Sci. Technol. 36: 5296-5304.

29. Russell, I. J.; Choquette, C.E.; Fang, S. L.; Dundulis, W.P.; Pao, A. A.; Pszenny, A. A. P. (1981) Forest Vegetation as a sink for atmospheric particulates; quantitative studies in rain and dry deposition. J. Geophys. Res. (Oceans & Atmos.) 86(C6); 5347-5363.

30. Barth,E.F., Succop, P.A., and Evans, M.L. (2004) Evaluation of Lead Availability in Amended Soils Monitored over a Long-Term Time Period. Environ. Monitoring and Assessment 30: 1-14.

Appendix A
Laboratory Testing Procedures

Appendix A

Proposed Testing Procedures.

Activity	**Parameter**	**Analysis**	**Method**	**Number of Analyses**						
				Initial	**30day**	**60 day**	**90 day**	**1yr**	**2 yr**	**3 yr**
PHASE 1	Soil Properties									
Characterization		Particle Size	ASTM D-2487/D422	4						
		pH	SW 846 9045C	4						
		Acidity	Thomas 1982	4						
		CEC	SW 846 9080/9081	4						
	Soil Chemistry	P total	Blanchard & Stearman 1984	4						
		P extractable	SW 846 9080/9081	4						
		N	Kjeldahl	4						
		TOC	EPA 9060	4						
		Metals*	EPA 3050,6020	4						
	Mineralogy	XRD		4						
		EMPA	Drexler, 00	4						
	Bioaccessability	RBALP	Drexler and Bratin,07	4						
Bench Testing	Soil Properties									
		pH	SW 846 9045C	88						
		P total	Blanchard & Stearman 1984	88						
	Soil Chemistry	P extractable	SW 846 9080/9081	88						
	Mineralogy	EMPA	Drexler, 00	4						
		RBALP	Drexler and Bratin,07	176						
	Bioaccessability	SPLP	EPA 1312	88						
	Column Leaching	Metals*	ASTM 4874	11						
Field Testing	Soil Properties	pH	SW 846 9045C		8	8	8	8	4	4
		Acidity	Thomas 1982		8	8	8	8	4	4
		CEC	SW 846 9080/9081		8	8	8	8	4	4
		Particle Size	ASTM D-2487/D422		8	8	8	8	4	4
		P extractable	SW 846 9080/9081		8	8	8	8	4	4
	Soil Chemistry	Metals*	EPA 3050,6020		8	8	8	8	4	4
		P total	Blanchard & Stearman 1984		8	8	8	8	4	4
		SPLP	EPA 1312							
		N	Kjeldahl		8	8	8	8	4	4
		TOC	EPA 9060				8	8	4	4
	Mineralogy	EMPA	Drexler, 00					8	4	4
	Bioaccessability	RBALP	Drexler and Bratin,07	8				8	4	4

* Metals = Pb, As, and P.

Appendix A

				Proposed Amendment rates based on 50.0g Soil							Day 2	Day 7	Day 14
Sample			**Lab ID**	**Phosphoric Acid**		**TSP**	**PR**	**KCl**	**Ca(OH)2**	**HFO**	**Soil Weight**	**Soil Weight**	**Soil Weight**
				wt% P	**ml Solution***	**g**	**g**	**mg**	**g****	**g**	**g**	**g**	**g**
CompA-1***	Control		A-1	0	0			0	0	0	49.892	49.899	49.702
CompA-2	Control		A-2	0	0			0	0	0	50.344	50.019	50.448
Compa-3	.5PA +Fe		A-3	1	0.6			26	1	4	50.154	49.906	49.785
CompA-4	.5PA +Fe		A-4	1	0.6			26	1	4	50.553	49.941	49.85
CompA-5	1PA +Fe	Soil A	A-5	2	12			50	2	4	49.72	49.737	50.537
CompA-6	1PA +Fe		A-6	2	12			50	2	4	50.477	49.778	50.296
CompA-7	1PA		A-7	2	12			50	2	0	49.876	50.572	49.72
CompA-8	1PA		A-8	2	12			50	2	0	49.873	50.009	49.951
CompA-9	15PA +Fe		A-9	3	16			76	3	4	50.284	49.81	49.704
CompA-10	15PA +Fe		A-10	3	16			76	3	4	50.278	50.037	50.311
CompA-11	1TSP		A-11			1		50	2	0	49.783	50.328	50.381
CompA-12	1TSP		A-12			1		50	2	0	50.176	50.29	50.329
CompA-13	1PR		A-13				2	50	2	0	50.194	50.264	49.81
CompA-14	1PR		A-14				2	50	2	0	49.554	49.807	50.239
CompA-15	1TSP +Fe		A-15			1		50	2	4	50.138	49.991	49.553
CompA-16	1TSP +Fe		A-16			1		50	2	4	50.11	50.403	50.479
CompA-17	1PR +Fe		A-17				2	50	2	4	49.76	50.243	50.09
CompA-18	1PR +Fe		A-18				2	50	2	4	49.98	50.041	50.021
CompA-19	2TSP		A-19			2		50	2	0	49.595	49.933	50.255
CompA-20	2TSP		A-20			2		50	2	0	49.824	49.859	50.635
CompA-21	2PR		A-21				4	50	2	0	50.298	49.984	49.764
CompA-22	2PR		A-22				4	50	2	0	50.288	49.871	50.601
CompB-1***	Control		B-1	0	0			0	0	0	50.489	50.162	49.974
CompB-2	Control		B-2	0	0			0	0	0	49.582	50.195	50.327
CompB-3	.5PA +Fe		B-3	1	0.6			26	1	4	49.695	50.36	50.163
CompB-4	.5PA +Fe		B-4	1	0.6			26	1	4	49.983	49.614	49.943
CompB-5	1PA +Fe	Soil B	B-5	2	12			50	2	4	49.946	49.836	50.017
CompB-6	1PA +Fe		B-6	2	12			50	2	4	50.968	49.938	50.311
CompB-7	1PA		B-7	2	12			50	2	0	50.579	49.554	49.921
CompB-8	1PA		B-8	2	12			50	2	0	5136	50.099	50.239
CompB-9	15PA +Fe		B-9	3	16			76	3	4	50.859	50.206	49.686
CompB-10	15PA +Fe		B-10	3	16			76	3	4	50.491	50.079	50.136
CompB-11	1TSP		B-11			1		50	2	0	50	50.31	50.185
CompB-12	1TSP		B-12			1		50	2	0	49.87	49.83	50.006
CompB-13	1PR		B-13				2	50	2	0	49.558	49.928	50.177
CompB-14	1PR		B-14				2	50	2	0	50.346	49.934	49.709
CompB-15	1TSP +Fe		B-15			1		50	2	4	49.661	50.329	49.698
CompB-16	1TSP +Fe		B-16			1		50	2	4	49.594	49.657	49.739
CompB-17	1PR +Fe		B-17				2	50	2	4	49.812	50.097	50.31
CompB-18	1PR +Fe		B-18				2	50	2	4	49.547	50.09	49.979
CompB-19	2TSP		B-19			2		50	2	0	49.554	49.931	50.153
CompB-20	2TSP		B-20			2		50	2	0	50.124	50.017	50.157
CompB-21	2PR		B-21				4	50	2	0	49.859	50.147	50.482
CompB-22	2PR		B-22				4	50	2	0	49.733	49.82	50.197
CompC-1***	Control		C-1	0	0			0	0	0	51381	50.135	50.351
CompC-2	Control		C-2	0	0			0	0	0	50.274	50.326	50.169
CompC-3	.5PA +Fe		C-3	1	0.6			26	1	4	50.987	49.955	50.464
CompC-4	.5PA +Fe		C-4	1	0.6			26	1	4	49.398	50.208	50.16
CompC-5	1PA +Fe	Soil C	C-5	2	12			50	2	4	49.906	49.998	50.165
CompC-6	1PA +Fe		C-6	2	12			50	2	4	49.931	50.558	50.324
CompC-7	1PA		C-7	2	12			50	2	0	51893	50.129	50.565
CompC-8	1PA		C-8	2	12			50	2	0	49.926	49.934	50.565
CompC-9	15PA +Fe		C-9	3	16			76	3	4	49.836	49.858	50.484
CompC-10	15PA +Fe		C-10	3	16			76	3	4	50.327	49.966	50.321
CompC-11	1TSP		C-11			1		50	2	0	51285	50.227	50.273
CompC-12	1TSP		C-12			1		50	2	0	51189	49.905	50.268
CompC-13	1PR		C-13				2	50	2	0	51294	50.365	50.282
CompC-14	1PR		C-14				2	50	2	0	50.444	49.726	50.281
CompC-15	1TSP +Fe		C-15			1		50	2	4	50.23	50.468	50.515
CompC-16	1TSP +Fe		C-16			1		50	2	4	50.978	50.588	50.19
CompC-17	1PR +Fe		C-17				2	50	2	4	52.009	50.402	50.331
CompC-18	1PR +Fe		C-18				2	50	2	4	50.395	50.475	50.092
CompC-19	2TSP		C-19			2		50	2	0	50.713	50.057	50.29
CompC-20	2TSP		C-20			2		50	2	0	50.692	50.438	50.28
CompC-21	2PR		C-21				4	50	2	0	50.19	50.057	50.43
CompC-22	2PR		C-22				4	50	2	0	50.752	50.423	50.203
	* Based on 85% phosphoric acid solution.										2-day		
	** Lime is added after 14 day period of equilibration with soil and other amendments.										7-day		
	*** Odd samples have phosphate amendment added in two, half increments separated by 7 days.										14-day		

			2 day liming					
Sample			**Lab ID**	**Initial Ca(OH)2**	**pH**	**30 min Ca(OH)2**	**pH**	**24 hr Ca(OH)2**
				g**	**30 min**	**g****	**24hr**	**g****
CompA-1***	Control		A2-1	0	7.24			
CompA-2	Control		A2-2	0	7.57			
Compa-3	.5PA +Fe		A2-3	1	5.49	2	7.74	2
CompA-4	.5PA +Fe		A2-4	1	5.42	2	9.4	2
CompA-5	1PA +Fe	Soil A	A2-5	2	4.35	2	7.36	2
CompA-6	1PA +Fe		A2-6	2	4.87	2	6.8	2
CompA-7	1PA		A2-7	2	4.42	2	7.6	2
CompA-8	1PA		A2-8	2	4.49	2	6.42	2
CompA-9	15PA +Fe		A2-9	3	4.36	2	6	2
CompA-10	15PA +Fe		A2-10	3	4.31	2	6.61	2
CompA-11	1TSP		A2-11	2	7.49		8.4	
CompA-12	1TSP		A2-12	2	7.56		8.33	
CompA-13	1PR		A2-13	2	10.49		9.88	
CompA-14	1PR		A2-14	2	11.55		10.53	
CompA-15	1TSP +Fe		A2-15	2	9.16		8.29	
CompA-16	1TSP +Fe		A2-16	2	8.91		7.86	
CompA-17	1PR +Fe		A2-17	2	10.2		8.88	
CompA-18	1PR +Fe		A2-18	2	10.82		8.62	
CompA-19	2TSP		A2-19	2	7.21		7.03	
CompA-20	2TSP		A2-20	2	6.65		7.09	
CompA-21	2PR		A2-21	2	11.18		10.34	
CompA-22	2PR		A2-22	2	10.19		9.36	
CompB-1***	Control		B2-1	0				
CompB-2	Control		B2-2	0				
CompB-3	.5PA +Fe		B2-3	1	6.05	2	9.48	2
CompB-4	.5PA +Fe		B2-4	1	5.88	2	8.9	2
CompB-5	1PA +Fe	Soil B	B2-5	2	4.97	2	5.22	2
CompB-6	1PA +Fe		B2-6	2	5.43	2	7.4	2
CompB-7	1PA		B2-7	2	6.13	2	6.59	2
CompB-8	1PA		B2-8	2	6.34	2	6.66	2
CompB-9	15PA +Fe		B2-9	3	6.79	2	5.26	2
CompB-10	15PA +Fe		B2-10	3	5.33	2	5.76	2
CompB-11	1TSP		B2-11	2	7.56		8.57	
CompB-12	1TSP		B2-12	2	7.39		8.35	
CompB-13	1PR		B2-13	2	10.15		10.26	
CompB-14	1PR		B2-14	2	10.48		10.21	
CompB-15	1TSP +Fe		B2-15	2	8.84		8.41	
CompB-16	1TSP +Fe		B2-16	2	8.53		7.62	
CompB-17	1PR +Fe		B2-17	2	9.78		9.23	
CompB-18	1PR +Fe		B2-18	2	9.22		8.99	
CompB-19	2TSP		B2-19	2	8.22		7.98	
CompB-20	2TSP		B2-20	2	8.12		8.05	
CompB-21	2PR		B2-21	2	8.67		10.43	
CompB-22	2PR		B2-22	2	7.63		9.5	
CompC-1***	Control		C2-1	0				
CompC-2	Control		C2-2	0				
CompC-3	.5PA +Fe		C2-3	1	5.5	2	8.2	2
CompC-4	.5PA +Fe		C2-4	1	7.18	2	7.01	2
CompC-5	1PA +Fe	Soil C	C2-5	2	5.5	2	6.54	2
CompC-6	1PA +Fe		C2-6	2	5.14	2	7.04	2
CompC-7	1PA		C2-7	2	5.3	2	5.877	2
CompC-8	1PA		C2-8	2	5.03	2	7.04	2
CompC-9	15PA +Fe		C2-9	3	5.4	2	5.68	2
CompC-10	15PA +Fe		C2-10	3	4.85	2	7.78	2
CompC-11	1TSP		C2-11	2	7.14		8.32	
CompC-12	1TSP		C2-12	2	6.25		8.35	
CompC-13	1PR		C2-13	2	10.11		10.42	
CompC-14	1PR		C2-14	2	10.88		10.46	
CompC-15	1TSP +Fe		C2-15	2	9		8.43	
CompC-16	1TSP +Fe		C2-16	2	8.84		8.08	
CompC-17	1PR +Fe		C2-17	2	9.75		9.28	
CompC-18	1PR +Fe		C2-18	2	9.22		8.62	
CompC-19	2TSP		C2-19	2	7.47		7.36	
CompC-20	2TSP		C2-20	2	7.58		7.73	
CompC-21	2PR		C2-21	2	10.1		10.3	
CompC-22	2PR		C2-22	2	9.32		9.65	

7 Day Liming

Sample			Lab ID	Initial Ca(OH)2	pH	30 min Ca(OH)2	pH
				g**	30 min	g**	24hrs
CompA-1***	Control		A7-1	0			
CompA-2	Control		A7-2	0			
Compa-3	.5PA +Fe		A7-3	5	10.447		9.13
CompA-4	.5PA +Fe		A7-4	5	10.04		8.48
CompA-5	1PA +Fe	Soil A	A7-5	5	8.738		6.94
CompA-6	1PA +Fe		A7-6	5	8.107	+2	6.28
CompA-7	1PA		A7-7	5	5.4		7.43
CompA-8	1PA		A7-8	5	5.829		7.282
CompA-9	1.5PA +Fe		A7-9	5	5.39	+2	6.17
CompA-10	1.5PA +Fe		A7-10	5	6.024	+2	6.058
CompA-11	1TSP		A7-11	2	7.18		8.156
CompA-12	1TSP		A7-12	2	7.098		8.422
CompA-13	1PR		A7-13	1	9.84		8.89
CompA-14	1PR		A7-14	1	9.24		9.07
CompA-15	1TSP +Fe		A7-15	2	9.31		8.25
CompA-16	1TSP +Fe		A7-16	2	9.27		8.33
CompA-17	1PR +Fe		A7-17	1	9.027		7.97
CompA-18	1PR +Fe		A7-18	1	8.87		8.3
CompA-19	2TSP		A7-19	2	6.97		7.97
CompA-20	2TSP		A7-20	2	7.024		7.775
CompA-21	2PR		A7-21	1	9.81		8.96
CompA-22	2PR		A7-22	1	9.27		8.81
CompB-1***	Control		B7-1	0			
CompB-2	Control		B7-2	0			
CompB-3	.5PA +Fe		B7-3	5	10.57		10.56
CompB-4	.5PA +Fe		B7-4	5	10.88		10.613
CompB-5	1PA +Fe	Soil B	B7-5	5	8.46		7.5
CompB-6	1PA +Fe		B7-6	5	10.1		8.17
CompB-7	1PA		B7-7	5	5.42		7.83
CompB-8	1PA		B7-8	5	5.7		8.17
CompB-9	1.5PA +Fe		B7-9	5	6.97		7.05
CompB-10	1.5PA +Fe		B7-10	5	11.54	ut 20 grams lime (ope	11.027
CompB-11	1TSP		B7-11	2	10.69		9.87
CompB-12	1TSP		B7-12	2	9.907		9.446
CompB-13	1PR		B7-13	1	10.99		10.19
CompB-14	1PR		B7-14	1	10.77		9.61
CompB-15	1TSP +Fe		B7-15	2	10.62		10.36
CompB-16	1TSP +Fe		B7-16	2	11.17		10.2
CompB-17	1PR +Fe		B7-17	1	10.47		9.8
CompB-18	1PR +Fe		B7-18	1	10.8		9.76
CompB-19	2TSP		B7-19	2	9.06		8.56
CompB-20	2TSP		B7-20	2	9.211		8.57
CompB-21	2PR		B7-21	1	10.63		9.53
CompB-22	2PR		B7-22	1	11.04		10.4
CompC-1***	Control		C7-1	0			
CompC-2	Control		C7-2	0			
CompC-3	.5PA +Fe		C7-3	5	1207		11.17
CompC-4	.5PA +Fe		C7-4	5	12.13		11.16
CompC-5	1PA +Fe	Soil C	C7-5	5	11.61		9.27
CompC-6	1PA +Fe		C7-6	5	11.64		10.2
CompC-7	1PA		C7-7	5	6.88		8.98
CompC-8	1PA		C7-8	5	6.21		8.535
CompC-9	1.5PA +Fe		C7-9	5	10.75		8..92
CompC-10	1.5PA +Fe		C7-10	5	10.72		9.606
CompC-11	1TSP		C7-11	2	9.86		9.74
CompC-12	1TSP		C7-12	2	10.188		9.739
CompC-13	1PR		C7-13	1	10.87		10.13
CompC-14	1PR		C7-14	1	10.76		10.77
CompC-15	1TSP +Fe		C7-15	2	11.24		10.34
CompC-16	1TSP +Fe		C7-16	2	11.01		10.12
CompC-17	1PR +Fe		C7-17	1	10.851		10.48
CompC-18	1PR +Fe		C7-18	1	11.02		10.126
CompC-19	2TSP		C7-19	2	8.58		8.74
CompC-20	2TSP		C7-20	2	8.4		8.428
CompC-21	2PR		C7-21	1	10.248		9.861
CompC-22	2PR		C7-22	1	10.6		10.32

14 day liming

Sample			Lab ID	Initial Ca(OH)2 g**	pH 30 min		pH 24hrs
CompA-1***	Control		A14-1	0			
CompA-2	Control		A14-2	0			
Compa-3	.5PA +Fe		A14-3	5	10.1		9.2
CompA-4	.5PA +Fe		A14-4	5	9.5		9.5
CompA-5	1PA +Fe	Soil A	A14-5	5	7.7		9.1
CompA-6	1PA +Fe		A14-6	5	6.9		9.8
CompA-7	1PA		A14-7	5	6.8		9.4
CompA-8	1PA		A14-8	5	7.5		7.9
CompA-9	15PA +Fe		A14-9	5	6.9		6.5
CompA-10	15PA +Fe		A14-10	5	7.9		7
CompA-11	1TSP		A14-11	2	9.8		9
CompA-12	1TSP		A14-12	2	10.6		9.9
CompA-13	1PR		A14-13	1	9.5		9.7
CompA-14	1PR		A14-14	1	10.1		9
CompA-15	1TSP +Fe		A14-15	2	9.2		8.2
CompA-16	1TSP +Fe		A14-16	2	9.4		8.6
CompA-17	1PR +Fe		A14-17	1	9.7		8.8
CompA-18	1PR +Fe		A14-18	1	8.5		9.2
CompA-19	2TSP		A14-19	2	8		7.8
CompA-20	2TSP		A14-20	2	8.9		7.7
CompA-21	2PR		A14-21	1	9.6		9.3
CompA-22	2PR		A14-22	1	9.5		9.1
CompB-1***	Control		B14-1	0			
CompB-2	Control		B14-2	0			
CompB-3	.5PA +Fe		B14-3	5	11.6		9.8
CompB-4	.5PA +Fe		B14-4	5	11.2		9.7
CompB-5	1PA +Fe	Soil B	B14-5	5	10.5		8.6
CompB-6	1PA +Fe		B14-6	5	9.5		7.7
CompB-7	1PA		B14-7	5	9.5		8.2
CompB-8	1PA		B14-8	5	8.3		7.9
CompB-9	15PA +Fe		B14-9	5	7.7		7.9
CompB-10	15PA +Fe		B14-10	5	7.4		8.6
CompB-11	1TSP		B14-11	2	9.9		9.6
CompB-12	1TSP		B14-12	2	9.8		9.9
CompB-13	1PR		B14-13	1	10.8		10.2
CompB-14	1PR		B14-14	1	11		8.3
CompB-15	1TSP +Fe		B14-15	2	9.3		8.5
CompB-16	1TSP +Fe		B14-16	2	9.7		9
CompB-17	1PR +Fe		B14-17	1	9.6		7.7
CompB-18	1PR +Fe		B14-18	1	9.5		7.6
CompB-19	2TSP		B14-19	2	8		8.4
CompB-20	2TSP		B14-20	2	8.9		8.7
CompB-21	2PR		B14-21	1	8.8		9.6
CompB-22	2PR		B14-22	1	10		9.7
CompC-1***	Control		C14-1	0			
CompC-2	Control		C14-2	0			
CompC-3	.5PA +Fe		C14-3	5	10.9		10.8
CompC-4	.5PA +Fe		C14-4	5	11.5		10.8
CompC-5	1PA +Fe	Soil C	C14-5	5	10.5		9.5
CompC-6	1PA +Fe		C14-6	5	9.9		9.2
CompC-7	1PA		C14-7	5	9.1		11.1
CompC-8	1PA		C14-8	5	9.3		9.2
CompC-9	15PA +Fe		C14-9	5	8.2		8.4
CompC-10	15PA +Fe		C14-10	5	8.5		8.2
CompC-11	1TSP		C14-11	2	9.6		9.6
CompC-12	1TSP		C14-12	2	9.5		9.7
CompC-13	1PR		C14-13	1	10.4		9.8
CompC-14	1PR		C14-14	1	10.2		9.6
CompC-15	1TSP +Fe		C14-15	2	10.3		9.4
CompC-16	1TSP +Fe		C14-16	2	9.4		8.9
CompC-17	1PR +Fe		C14-17	1	9.3		8.9
CompC-18	1PR +Fe		C14-18	1	9.4		8.8
CompC-19	2TSP		C14-19	2	9.4		8.2
CompC-20	2TSP		C14-20	2	8		8.1
CompC-21	2PR		C14-21	1	9.1		9.4
CompC-22	2PR		C14-22	1	10.6		9.5

Appendix B

Metal Speciation Standard Operating Procedure

Appendix B

UNIVERSITY of COLORADO
Laboratory for Geological and Environmental Studies (LEGS)

October 11, 2007 (Rev. #2)

Title: METAL SPECIATION SOP

SYNOPSIS: A standardized method for speciating metals in solid samples is described. Equipment operating conditions, sample preparation and handling, and statistical equations for data analysis and presentation are included.

1.0 OBJECTIVES

The objectives of this Standard Operating Procedure (SOP) are to specify the proper methodologies and protocols to be used during metal speciation of various solid samples including; tailings, slags, sediments, dross, bag house dusts, wipes, paint, soils, and dusts for metals. The metal speciation data generated from this SOP may be used to assess the solid samples as each phase relates to risk. Parameters to be characterized during the speciation analyses include particle size, associations, stoichiometry, frequency of occurrence of metal-bearing forms and relative mass of metal-bearing forms. This electron microprobe analyses (EMPA) technique, instrument operation protocols and sample preparation to be used during implementation of the Metals Speciation SOP are discussed in the following sections.

2.0 BACKGROUND

To date, numerous metal-bearing forms have been identified from various environments within western mining districts (Emmons et al., 1927; Drexler, 1991 per. comm.; Drexler, 1992; Davis et al., 1993; Ruby et al., 1994; CDM, 1994; WESTON, 1995), and industrial or agricultural (Drexler , 1999 per. comm.) settings, Table 2-1. This listing does not preclude the identification of other metal-bearing forms, but only serves as an initial point of reference. Many of these forms are minerals with varying metal concentrations (e.g., lead phosphate, iron-lead oxide, and slag). Since limited thermodynamic information is available for many of these phases and equilibrium conditions are rarely found in soil environments, the identity of the mineral class (e.g., lead phosphate) will be sufficient and exact stoichiometry is not necessary.

It may be important to know the particle-size distribution of metal-bearing forms in order to assess potential risk. It is believed that particles less than 250 microns (µm) are most available for human ingestion and/or inhalation (Bornschein, et al., 1987). For this study, the largest dimension of any one metal-bearing form will be measured and the frequency of occurrence weighted by that dimension. Although not routinely performed, particle area can be determined, it has been shown (CDM, 1994) that data collected on particle area produces similar results. These measurements add a considerable amount of time to the procedure, introduce new sources of potential error and limit the total number of particles or samples that can be observed in a study.

Mineral association may have profound effects on the ability for solubilization. For example, if a lead-bearing form in one sample is predominantly found within quartz grains while in another sample it is free in the sample matrix, the two samples are likely to pose significantly different risk levels to human health. Therefore, associations of concern include the following:

1) free or liberated
2) inclusions within a second phase
3) cementing

3.0 SAMPLE SELECTION

Samples should be selected and handled according to the procedure described in the Project Plan.

4.0 SCHEDULE

A schedule for completion of projects performed under this Metals Speciation SOP will be provided in writing or verbally to the contractor along with monthly reporting requirements if large projects are performed. These schedules are based on an aggressive analytical program designed to ensure that the metals speciation analyses are completed in a timely period. Monthly reports are expected to reflect schedule status.

5.0 INSTRUMENTATION

Speciation analyses will be conducted at the Laboratory for Environmental and Geological Studies (LEGS) at the University of Colorado, Boulder or other comparable facilities. Primary equipment used for this work will include:

Electron Microprobe (JEOL 8600) equipped with four wavelength spectrometers, energy dispersive spectrometer (EDS), BEI detector and Geller Microanalytical data processing system. An LEDC spectrometer crystal for carbon and LDE-1 crystal for oxygen analyses are essential.

6.0 PRECISION AND ACCURACY

The precision of the EMPA speciation and polarized light microscopy (PLM) will be evaluated based on sample duplicates analyzed at a frequency of 10%. The precision of the data generated by the manual PLM particle count and by the "EMPA point count" will be evaluated by preparing a graph that compares the original result with the duplicate result. The accuracy of the analyses will be estimated based on a number of methods, depending on the source of the data. Data generated by the "EMPA point count" or will be evaluated statistically based on the methods of Mosimann (1965) at the 95% confidence level on the frequency data following Equation 1.

$$E_{0.95} = 2P(100-P)/N \qquad \text{(Eq. 1)}$$

Where: $E_{0.95}$ = Probable error at the 95% confidence level

P = Percentage of N of an individual metal-bearing phase based on percent length frequency

N = Total number of metal-bearing grains counted

In general, site-specific concentrations for these variable, metal-bearing forms will be determined by performing “peak counts” on the appropriate wavelength spectrometer. Average concentrations will then be used for further calculations. Data on specific gravity will be collected from referenced databases or estimated based on similar compounds.

7.0 PERSONNEL RESPONSIBILITY

The analysts will carefully read this SOP prior to any sample examination.

It is the responsibility of the laboratory supervisor and designates to ensure that these procedures are followed, to examine quality assurance (QA) samples and replicate standards, and to check EDS and WDS calibrations. The laboratory supervisor will collect results, ensure they are in proper format, and deliver them to the contractor.

Monthly reports summarizing all progress, with a list of samples speciated to date with data analyses sheets (DAS), will be submitted each month.

It is also the responsibility of the laboratory supervisor to notify the contractor representative of any problems encountered in the sample analysis process.

8.0 SAMPLE PREPARATION

Grain mounts (1.5 inches in diameter) of each sample will be prepared using air-cured epoxy. This grain mounting technique is appropriate for most speciation projects, however polished thin-sections, paint chips, dust wipes, or filters may be prepared in a similar manner. The grain mounting is performed as follows:

1) Log the samples for which polished mounts will be prepared.

2) Inspect all disposable plastic cups, making sure each is clean and dry.

3) Label each “mold” with its corresponding sample number.

4) All samples will be split to produce a homogeneous 1-4 gram sample.

5) Mix epoxy resin and hardener according to manufacturer’s directions.

6) Pour 1 gram of sample into mold. Double check to make sure sample numbers on mold and the original sample container match. Pour epoxy into mold to just cover sample grains.

7) Use a new wood stirring stick with each sample, carefully blend epoxy and grains so as to coat all grains with epoxy.

8) Set molds to cure at ROOM TEMPAERATURE in a clean restricted area. Add labels with sample numbers and cover with more epoxy resin. Leave to cure completely at room temperature.

9) One at a time remove each sample from its mold and grind flat the back side of the mount.

10) Use 600 grit wet abrasive paper stretched across a grinding wheel to remove the bottom layer and expose as many mineral grains as possible. Follow with 1000 grit paper.

11) Polish with 15 um oil-based diamond paste on a polishing paper fixed to a lap. Use of paper instead of cloth minimizes relief.

12) Next use 6um diamond polish on a similar lap.

13) Finally polish the sample with 1um oil-based diamond paste on polishing paper, followed by 0.05 um alumina in water suspension. The quality should be checked after each step. Typical polishing times are 30 minutes for 15 um, 20 minutes for 6 um, 15 minutes for 1 um, and 10 minutes for 0.05 um.

NOTE: use low speed on the polishing laps to avoid “plucking” of sample grains.

14) Samples should be completely cleaned in an ultrasonic cleaner with isopropyl alcohol or similar solvent to remove oil and fingerprints.

15) To ensure that no particles of any metal are being cross-contaminated during sample preparation procedures, a blank (epoxy only) mold will be made every 20th sample (5% of samples) following all of the above procedures. This mold will then be speciated along with the other samples.

16) Each sample must be carbon coated. Once coated, the samples should be stored in a clean, dry environment with the carbon surface protected from scratches or handling.

9.0 GEOCHEMICAL SPECIATION USING ELECTRON MICROPROBE

All investigative samples will also be characterized using EMPA analysis to determine the chemical speciation, particle size distribution and frequency for several target metals.

10.1 Concentration Prescreening

All samples will be initially examined using the electron microprobe to determine if the number of particles are too great to obtain a representative count. The particle counting will be considered representative if the entire sample (puck) has been traversed about the same time in which the counting criteria are achieved.

If this examination reveals that one metal is abundant (> 1% of total metals concentration), clean quartz sand (SiO_2) will be mixed with the sample material. The sand should be certified to be free of target analytes. The quartz sand should be added to an aliquot of the investigative sample, then mixed by turning the sample for a minimum of one hour, or until the sample is fully homogenized. The initial mass of the investigative sample aliquot, and the mass of the quartz addition will be recorded.

10.2 Point Counting

Counts are made by traversing each sample from left-to-right and top-to-bottom as illustrated in Figure 10-2. The amount of vertical movement for each traverse would depend on magnification and CRT (cathode-ray tube) size. This movement should be minimized so that NO portion of the sample is missed when the end of a traverse is reached. Two magnification settings generally are used. One ranging from 40-100X and a second from 300-600X. The last setting will allow one to find the smallest identifiable (1-2 micron) phases.

The portion of the sample examined in the second pass, under the higher magnification, will depend on the time available, the number of metal-bearing particles, and the complexity of metal mineralogy. A maximum of 8 hours will be spent on each analysis.

10.3 Data Reduction

Analysts will record data as they are acquired from each sample using the LEGS software, (Figure 10-3A) which places all data in a spreadsheet file format. Columns have been established for numbering the metal-bearing phase particles, their identity, size of longest dimension in microns, along with their association (L = liberated, C= cementing, I = included) (Figure 10-3B). The analyst may also summarize his/her observations in the formatted data summary files.

The frequency of occurrence and relative metal mass of each metal-bearing form as it is distributed in each sample will be depicted graphically as a frequency bar-graph. The particle size distribution of metal-bearing forms will be depicted in a histogram. Size-histograms of each metal-bearing form can be constructed from data in the file.

Data from EMPA will be summarized using two methods. The first method is the determination of FREQUENCY OF OCCURRENCE. This is calculated by summing the longest dimension of all the metal-bearing phases observed and then dividing each phase by the total.

Equation 2 will serve as an example of the calculation.

$$F_M \text{ in phase-1} = \frac{\Sigma\,(\text{PLD})_{\text{phase 1}}}{\Sigma\,(\text{PLD})_{\text{phase-1}} + \Sigma(\text{PLD})_{\text{phase-2}} + \Sigma\,(\text{PLD})_{\text{phase-n}}} \qquad \text{(Eq. 2)}$$

Where:
F_M = Frequency of occurrence of metal in a single phase.
PLD = An individual particle's longest dimension
$\%F_M$ in phase-1 = F_M in phase-1 * 100

These data thus illustrate which metal-bearing phase(s) are the most commonly observed in the sample or relative volume percent.

The second calculation used in this report is the determination of RELATIVE METAL MASS. These data are calculated by substituting the PLD term in the equation above with the value of M_M. This term is calculated as defined below.

$$M_M = FM * SG * ppm_M \qquad \text{(Eq. 3)}$$

Where:
M_M = Mass of metal in a phase
SG = Specific Gravity of a phase
ppm_M = Concentration in ppm of metal in a phase

The advantage in reviewing the RELATIVE METAL MASS determination is that it gives one information as to which metal-bearing phase(s) in a sample are likely to control the total bulk concentration for a metal of interest. For example, PHASE-1 may comprise 98% relative volume of the sample; however, it has a low specific gravity and contains only 1,000 parts per million (ppm) arsenic. PHASE-2 comprised 2% of the sample, has a high specific gravity, and contains 850,000 ppm of arsenic. In this example it is PHASE-2 that is the dominant source of arsenic to the sample.
1The third calculation is to determine the BIOACCESSABLE MASS lead (Bio_{Pb}). For this calculation the same procedure as outlined above is used however, the original particle-count data set has been screened to use **only** liberated and cemented particles less than 250 microns in size (BIOACCESSABLE FREQUENCY) . The reasoning behind these calculations are: 1) A particle greater than 250 microns is not bioaccessable. It will not adhere to clothes or hands. 2) A particle of lead that is enclosed within another mineral is considered far less bioaccessable, as one would need to dissolve the outer mineral or free the enclosed lead particle to make it available. 3) Finally, these data are considered likely to better reflect results observed from *invitro* or *invivo* studies.

The accuracy of an analysis will be estimated from a statistical evaluation of point counting data based on the method of Mosimann (1965) these data will be tabulated in Table 3 as $E^{95\%}$.

10.4 Analytical Procedure

A brief visual examination of each sample will be made, prior to EMPA examination. This examination may help the operator by noting the occurrence of slag and/or organic matter. Standard operating conditions for quantitative and qualitative analyses of most metal-bearing forms are given in Table 8-1. However, it is the responsibility of the operator to select the appropriate analytical line (crystal/KeV range) to eliminate peak overlaps and ensure proper identification/quantification of each analyte. Quality control will be maintained by analyzing duplicates at regular intervals (Section 8.5).
The backscattered electron threshold will be adjusted so that all particles in a sample are seen. This procedure will minimize the possibility that low metal-bearing minerals may be overlooked during the scanning of the polished grain mount. The scanning will be done manually in a manner similar to that depicted in Figure 8-2. Typically, the magnification used for scanning all samples except for airborne samples will be 40-100X and 300-600X. The last setting will allow the smallest identifiable (1-2 um) phases to be found. Once a candidate particle is identified, then the backscatter image will be optimized to discriminate any different phases that may be making up the particle or defining its association. Identification of the metal-bearing phases will be done using both EDS and WDS on an EMPA, with spectrometers typically peaked at sulfur, oxygen, carbon and the metal(s) of concern (M). The size of each metal-bearing phase will be determined by measuring in microns the longest dimension.

As stated previously, a maximum of 8 hours will be spent in scanning and analyzing each mount. For most speciation projects the goal is to count between 100-200 particles. In the event that these goals are achieved in less than 8 hours, particle counting may continue or the analyst may move to another sample in order to increase the sample population.

Quantitative Analyses

Quantitative EMPA analyses are required to establish the average metal content of the metal-bearing minerals, which have variable metal contents as: Iron-(M) sulfate, Iron-(M) oxide, Manganese-(M) oxide, organic, and slag. These determinations are important, especially in the case of slag, which is expected to have considerable variation in their dissolved metal content.

EMPA quantitative results will be analyzed statistically to establish mean values. They may also be depicted as histograms to show the range of metal concentrations measured as well as the presence of one or more populations in terms of metal content. In the later case, non-parametric statistics may have to be used or the median value has to be established.

Associations

The association of the metal-bearing forms will be established from the backscattered electron images. Particular attention will be paid in establishing whether the grains are totally enclosed, encapsulated or liberated. The rinds of metal-bearing grains will be identified. Representative photomicrographs of backscatter electron images establishing the association of the principal metal-bearing forms will be obtained for illustration purposes.

2Compound Identification

As outlined in the EMPA SOP, an electron microprobe with combined EDS (energy dispersive spectrometer) and multiple WDS (wavelength dispersive spectrometers) are used to identify all metal-bearing phases of interest. A 1-2 gram split of dryed sample is placed in a 2.5 cm plastic mold and impregnated with epoxy. Once the sample is hardened it is polished and carbon coated for EMPA. The EMPA is operated at 15 kV accelerating voltage, with a 20 NanoAmp current and a 1 micron focused beam. Elements of interest are standardized using certified mineral or pure metal standards and counting times are chosen to provide 3-sigma detection limits of between 100-200 ppm. Elemental concentrations are corrected using ZAF factors and concentration errors are generally less than 5% relative. For a more detail explanation of the EMPA method of analyses see Birks, 1971, or Heinrich, 1981.

Although the electron microprobe is capable of determining stoichiometries of virtually any compound composed of elements Be thru U, such a task requires a great deal of standardization and analytical time to complete. It has been determined that for the purposes these data are utilized in either risk assessments or site characterizations the term “speciation” would have a more general definition. The primary justification for this factor is that it has been shown the time required for more precise phase identification greatly impacted on the total identified-particle population. The significance to the data interpretation is highly dependent on the total number of metal-bearing phases counted. Not only would the time impact the statistical significance of sample interpretation, but it would limit the total number of samples one could study, thus the representativeness of the data to the site.

A number of phases for both lead and arsenic are considered stoichiometric. These include the following:

Galena (PbS)
Lead Oxide (PbO)
Native Lead (Pb)
Cerussite ($PbCO_3$)

Anglesite ($PbSO_4$)
Crocoite ($PbCrO_4$)
Alamosite ($PbSiO_3$)
Lead Arsenate (PbAsO)
Arsenolite (As_2O_3)
Realgar (AsS)
Orpiment (As_2S_3)
Arsenopyrite (AsFeS)

The author is aware that these are not all strictly stoichiometric phases. As an example, "lead oxide" would include; litharge (PbO), massicot (PbO), minium (Pb_3O_4, plattnerite (PbO_2), and scrutinyite (αPbO_2). In addition, phases such as lead hydroxide, lead isobuyrate, lead lactate, lead laurate, lead malate, lead oxalate and even lead nitrate would be grouped in this category. The phase "lead arsenate" would include; schultenite ($PbHAsO_4$), paulmooreite ($Pb_2As_2O_5$) as well as all the meta/ortho arsenate/arsenite phases. With very careful EMPA analyses most of these phases could be isolated; however, as the data is currently used this effort is not taken unless the client request further work.

The remaining phases that are commonly identified are far more generic. The concentration of the metal(s) of interest in these phases are thus variable and require site-specific estimates of there concentration values. These are obtained for each project by randomly collecting EMPA quantitative analyses (for lead or arsenic) for these phases and calculating average values. For these phases the first criteria used in identification is to determine if the phase is either; an oxide, carbonate, sulfide, sulfate, or phosphate. Secondly, with the exception of the "phosphates", the major cation associated with the phase is further identified. Therefore, phases such as Fe-sulfate, FeOOH, MnOOH, PbMO, AsMO, or $PbMSO_4$ are identified. Some of these phases could represent a stoichiometric mineral forms such as allactite $Mn_7(AsO_4)_2(OH)_8$, plumbojarosite $PbFe_6(SO_4)_4(OH)_{12}$, plumboferrite $PbFe_4O_7$, carminite $PbFe_2[OHAsO_4]_2$, nelenite $(Mn,Fe)_{16}Si_{12}As_3O_{36}(OH)_{17}$, or quenselite $PbMnO_2(OH)$; however, it is the authors belief that most of these phases are metastable and/or amorphous and have some quantity of arsenic and/or lead sorbed to their surface.

The "phosphate" group is even more generic in that the only common dominant ion is PO_4. There are many crystalline forms of phosphate that contain lead such as; pyromorphite $Pb_5[Cl(PO_4)_3]$, plumbogummite $PbAl_3(PO_4)_2(OH)_5$-H_2O, orpheite $PbAl_3[(OH)_6(PO_4,SO_4)_2]$, drugmanite $Pb_2(Fe,Al)(PO_4)2OH$-H_2O, and corkite $PbFe_3[(OH)_6\ SO_4\ PO_4]$. Although arsenic and phosphorus are considered competitive, a number of arsenic-bearing phosphates have been identified; walentaite $(Ca,Mn,Fe)Fe_3(AsO_4,PO_4)_4$-$7H_2O$, morelandite $(Ba,Ca,Pb)_5\ Cl[AsO_4,PO_4]_3$, and turneaureite $Ca_5(Cl)[(AsO_4, PO_4)_3]$. As with previous phases, careful EMPA analyses could isolated the complete stoichiometry; however, as the data is currently used this effort is not taken unless the client request further work.

Since the chemistry and/or sorption capacity of these categories are quite variable one should be careful in ascribing RBA (relative bioaccessability) to these metal forms. In particular, if sorption is the primary factor controlling the presence of arsenic or lead, factors such as temperature, redox, and pH can influence the metal stability significantly. However, if particle size and morphology (liberated-included) are similar, it appears, primarily from in vitro studies, that iron oxides and sulfates tend to be less bioaccessable than manganese oxides and phosphates.

10.5 Instrument Calibration and Standardization

The WDS will have spectrometers calibrated for the metal of concern, carbon, oxygen and sulfur on the appropriate crystals using mineral standards. The EDS will have multi-channel analyzer (MCA) calibrated for known peak energy centroids. Calibration will be performed so as to have both low (1.0-3.0 KeV) and high (6.0-9.0 KeV) energy peaks fall within 0.05 KeV of its known centroid.

The magnification marker on the instrument will be checked once a week. This will be performed by following manufacturer instructions or by measurement of commercially available grids or leucite spheres. Size measurements must be within 4 microns of certified values.

Initial calibration verification standards (ICVs) must be analyzed at the beginning of each analytical batch or once every 48 hours, whichever is more frequent. A set of mineral or glass standards will be run quantitatively for the metal of concern, sulfur, oxygen and carbon. If elemental quantities of the ICVs do not fall within +/- 5% of certified values for each element, the instrument must be recalibrated prior to analysis of investigative samples.

The metal-bearing forms in these samples will be identified using a combination of EDS, WDS and BEI. Once a particle is isolated with the backscatter detector, a 5-second EDS spectra is collected and peaks identified. The count rates for the metal(s) of concern, sulfur, carbon and oxygen can be either visually observed on the wavelength spectrometers or K-ratios calculated.

10.6 Documentation

Photomicrographs must be taken for each sample, at a rate of 5% (1 photograph per 20 particles counted), for a maximum of 10 per sample and submitted with the results . Particles selected for photography must be recorded on the EMPA graph.
A 128x128 (minimum) binary image in ".tif" format may be stored. Recorded on each photomicrograph and negative will be a scale bar, magnification, sample identification , date and phase identification. Abbreviations for the identified phases can be used. Examples are listed in Table 10-2. A final list must be submitted with the laboratory report.

10.0 PERSONAL HEALTH AND SAFETY

Each individual operating the electron microprobe instruments will have read the “Radiation Safety Handbook” prepared by the University and follow all State guidelines for operation of X-ray equipment.

Latex gloves and particulate masks will be worn during preparation of sample cups. All material that comes in contact with the samples or used to clean work surface areas will be placed in poly-bags for disposal.

11.0 FINAL REPORT

A final laboratory report will be provided to the Contractor. The report will include all EMPA data including summary tables and figures. Individual sample data will be provided on disk.

Speciation results will include: 1) a series of tables summarizing frequency of occurrence for each metal phase identified along with a confidence limit; (Figure 11.0A) 2) summary histograms of metal phases identified for each waste type; (Figure 11.0B) 3) a summary histogram of particle size distribution in each waste type; (Figure 11.0C) and 4) a summary of metal phase associations (Figure 11.0D) . Representative photomicrographs or .tif images will also be included in the final report (Figure 11.0E).

12.0 REFERENCES

Birks, L.S., 1971, Electron Probe Microanalysis, 2nd Ed., New York: Wiley-Interscience

Bornschein, R.L., P.A. Succop, K.M. Kraft, and C.S. Clark. 1987. Exterior surface lead dust, interior lead house dust and childhood lead exposure in an urban environment. In D.D. HEMPAhil, Ed., Trace Substances in Environmental Health XX Proceedings of the University of Missouri's 20th Annual Conference. June 1986, pp 322-332. University of Missouri, Columbia, MO.

CDM (Camp Dresser and McKee). 1994. Metal Speciation Data Report, Leadville, CO. CERCLA Site. September, 1994.

Davis, A., J.W. Drexler, M.V. Ruby, and A. Nicholson. 1993. The micromineralogy of mine wastes in relation to lead bioavailability, Butte, Montana. *Environ. Sci. Technol*. (In Press).

Drexler, J.W. 1992. Speciation Report on the Smuggler Mine, Aspen CO., Prepared for EPA.

Emmons, S.F., J.D. Irving, and G.F. Loughlin. 1927. Geology and Ore Deposits of the Leadville Mining District, Colorado. USGS Professional Paper 148.

Heinrich, K.F.J., 1981, Electron Beam X-ray Microanalysis. New York. Van Nostrand.

Mosimann, J.E. 1965. Statistical methods for the Pollen Analyst. In: B. Kummel and D. Raup (EDS.). *Handbook of Paleontological Techniques.* Freeman and Co., San Francisco, pp. 636-673.

Ruby, M.V., A. Davis, J.H. KEMPAton, J.W. Drexler, and P.D. Bergstrom. 1992. Lead bioavailability: Dissolution kinetics under simulated gastric conditions. *Environ. Sci. Technol.* 26(6): pp 1242-1248.

WESTON (Roy F. Weston, Inc.). 1995. Metal Speciation Interpretive Report, Leadville, CO. CERCLA Site. March, 1995.

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Table 2-1
Common Metal-Bearing Forms Found Within Mining, Smelting, Agricultural, Industrial and Residential Media

OXIDES

- Lead Oxide
- Manganese (metal) oxide
- Iron (metal) oxide
- Lead molybdenum oxide
- Arsenic (metal) Oxide
- Lead (metal) Oxides
- Cadmium Oxide
- Copper Oxides
- Zinc Oxide
- Lead Arsenate
- Arsenic Trioxide
- Calcium (metal) oxide

SILICATES

- Slag
- Lead silicate
- Arsenic silicate
- Zinc silicate
- Clays

SULFATES

- Iron (metal) sulfate
- Lead sulfate
- Lead barite
- Zinc Sulfate
- Arsenic sulfate
- Copper sulfate

CARBONATES

- Lead Carbonate
- Zinc Carbonate

PHOSPHATES

- (metal) phosphates

SULFIDES

- Lead sulfide
- Sulfur-containing salts
- Iron-arsenic sulfide
- Zinc sulfide
- Copper sulfides
- Copper-iron sulfide
- Cadmium Sulfide

OTHER

- Native: Lead, Copper, Cadmium, Mercury, Indium, Thallium, Selenium
- Lead/Arsenic/Cadmium/Mercury Chlorides
- Paint
- Solder
- Organic lead
- Lead vanadate
- Minor telluride, and bismuth-lead phases

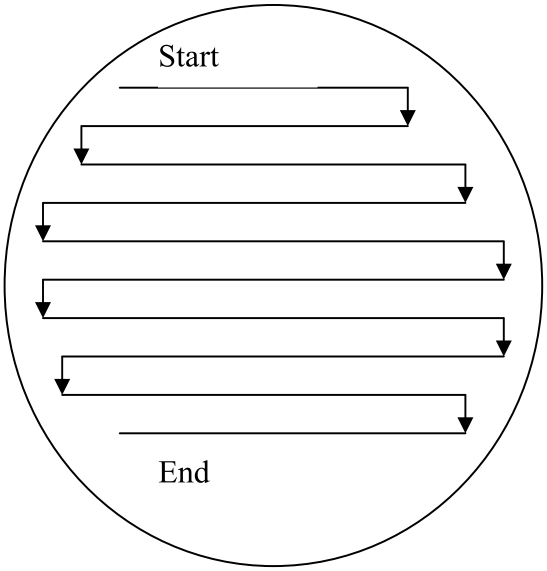
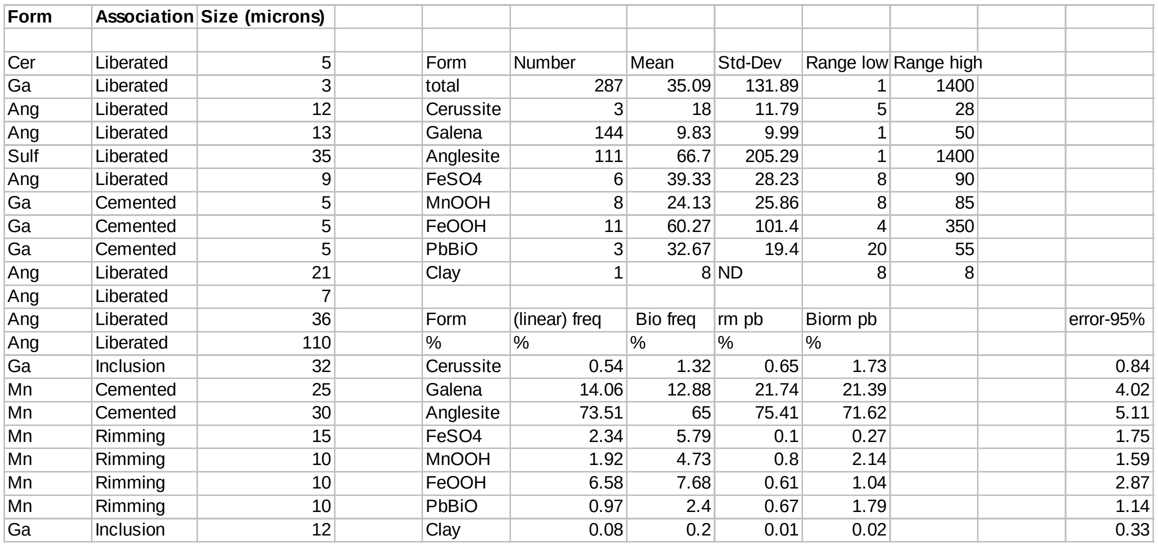
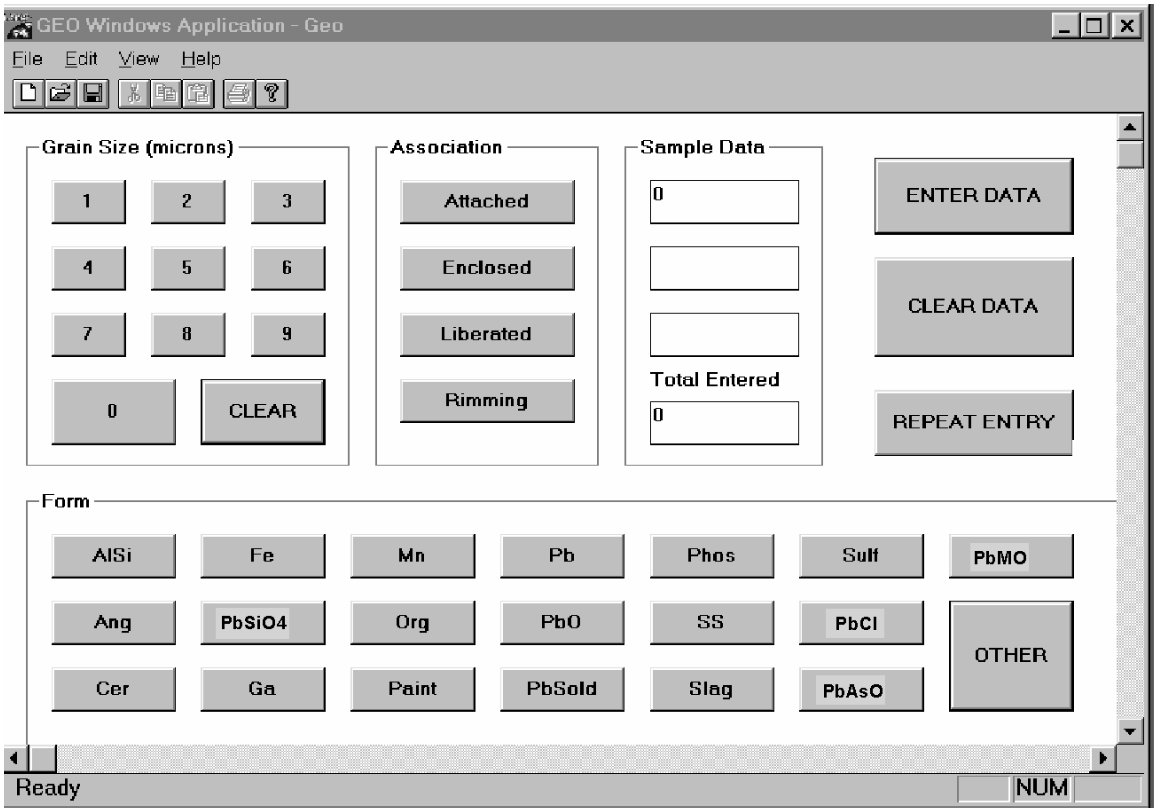


Figure 10-2



Form	Association	Size (microns)									
Cer	Liberated	5		Form	Number	Mean	Std-Dev	Range low	Range high		
Ga	Liberated	3		total	287	35.09	131.89	1	1400		
Ang	Liberated	12		Cerussite	3	18	11.79	5	28		
Ang	Liberated	13		Galena	144	9.83	9.99	1	50		
Sulf	Liberated	35		Anglesite	111	66.7	205.29	1	1400		
Ang	Liberated	9		FeSO4	6	39.33	28.23	8	90		
Ga	Cemented	5		MnOOH	8	24.13	25.86	8	85		
Ga	Cemented	5		FeOOH	11	60.27	101.4	4	350		
Ga	Cemented	5		PbBiO	3	32.67	19.4	20	55		
Ang	Liberated	21		Clay	1	8	ND	8	8		
Ang	Liberated	7									
Ang	Liberated	36		Form	(linear) freq	Bio freq	rm pb	Biorm pb			error-95%
Ang	Liberated	110		%	%	%	%	%			
Ga	Inclusion	32		Cerussite	0.54	1.32	0.65	1.73			0.84
Mn	Cemented	25		Galena	14.06	12.88	21.74	21.39			4.02
Mn	Cemented	30		Anglesite	73.51	65	75.41	71.62			5.11
Mn	Rimming	15		FeSO4	2.34	5.79	0.1	0.27			1.75
Mn	Rimming	10		MnOOH	1.92	4.73	0.8	2.14			1.59
Mn	Rimming	10		FeOOH	6.58	7.68	0.61	1.04			2.87
Mn	Rimming	10		PbBiO	0.97	2.4	0.67	1.79			1.14
Ga	Inclusion	12		Clay	0.08	0.2	0.01	0.02			0.33

Figure 10-3B



Sample Data: 0

Total Entered: 0

Figure 10-3A

Table 10-1
EMPA Standard Operating Conditions

	WDS	EDS
Accelerating Voltage	15 KV	15-20 KV
Beam Size	1-2 microns	1-2 microns
Cup Current	10-30 NanoAmps	10-30 NanoAmps
Ev/Channel	NA	10 or 20
Stage Tilt	NA	Fixed
Working Distance	NA	Fixed
MCA time Constant	NA	7.5-12 microseconds
X-ray lines	S K-alpha PET O K-alpha LDE1 C K-alpha LDEC Zn K-alpha PET As L-alpha TAP Cu K-alpha LIF Cd L-alpha PET Pb M-alpha PET Pb L-alpha LIF In L-alpha PET Tl L-alpha LIF Hg L-alpha LIF Se L-alpha LIF Sb L-alpha PET	S K-alpha 2.31 KeV O K-alpha 0.52 KeV C K-alpha 0.28 KeV Pb M-alpha 2.34 KeV Pb L-alpha 10.5 KeV Zn K-alpha 8.63 KeV Cu K-alpha 8.04 KeV As K-alpha 10.5 KeV As L-alpha 1.28 KeV Cd L-alpha 3.13 KeV In L-alpha 3.28 KeV Tl M-alpha 2.27 KeV Tl L-alpha 10.26 KeV Hg L-alpha 9.98 KeV Hg M-alpha 2.19 KeV Se L-alpha 1.37 KeV Sb L-alpha 3.60 KeV

Table 10-2
Suggested Abbreviation for Photomicrographs

Metal-bearing Phase	Abbreviation
In	In
Tl	Tl
Hg	Hg
Se	Se
Sb	Sb
Lead Sulfide	Ga
Lead Sulfate	Ang
Lead Carbonate	Cer
Mn-(M) Oxide	Mn(M)
Fe-(M) Oxide	Fe(M)
(M)Phosphate	(M)Phos
Fe-(M) Sulfate	Fe(M)Sul
Metal Oxide	(M)O
Pb-Mo Oxide	Wulf
Slag	Slag
Metallic Phase	(M)
Metal Silicate	(M)Si
Solder	Sold
Paint	Pnt
Metal-bearing Organic	(M)(Org)
(M) barite	(M)Bar
Pb arsenate	PbAsO
Pb vanadate	PbVan
As-Sb Oxide	AsSbO
Chalcopyrite	Cp
Sphalerite	Sph
Arsenopyrite	Apy

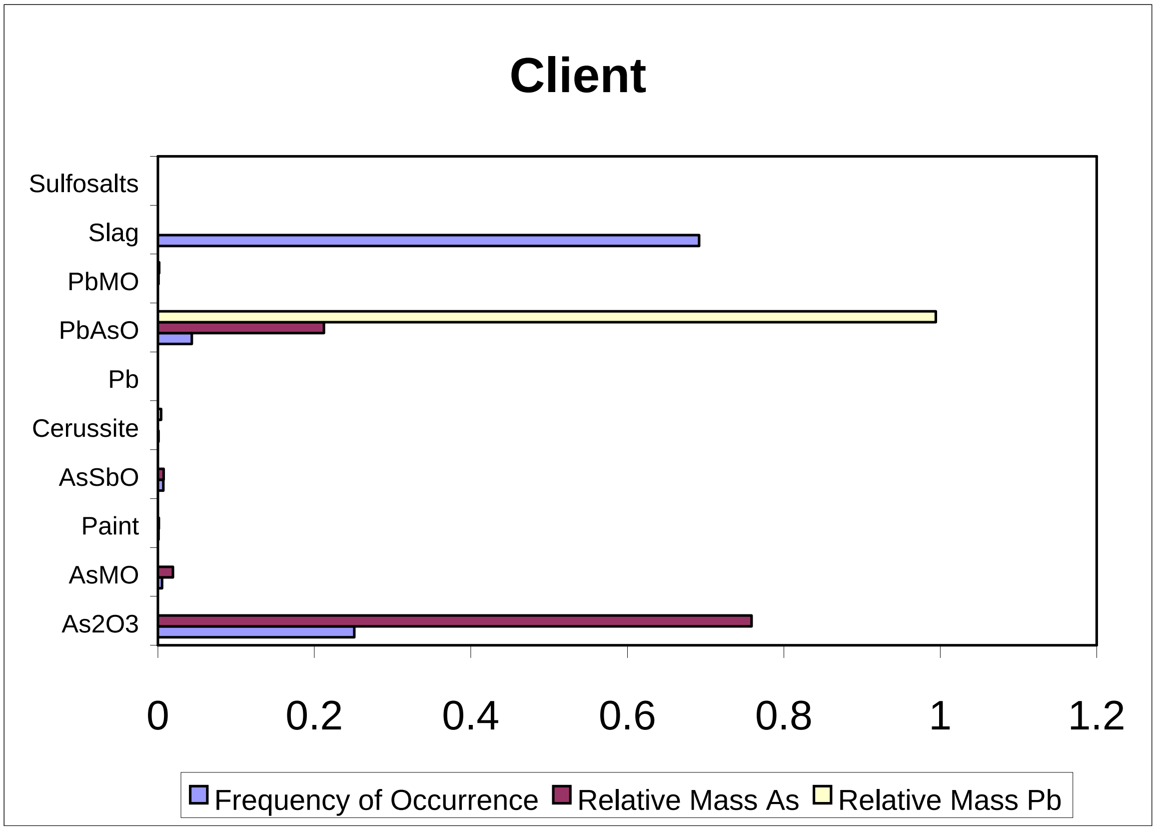

Client
Sulfosalts
Slag
PbMO
PbAsO
Pb
Cerussite
AsSbO
Paint
AsMO
As2O3
0
0.2
0.4
0.6
0.8
1
1.2
Frequency of Occurrence
Relative Mass As
Relative Mass Pb

Figure 11-0B

Table 1
Metal Speciation Frequency of Occurrence and Error Summary.

	Sample 1	+/-	Sample 2	+/-	Sample 3	+/-
Brass	4%	1-21				
Cerussite	8%	2-26	23%	17-30	9%	4-15
Fe-Pb Oxide	41%	23-61	64%	57-71	54%	42-61
PbMO*	5%	2-22	1%	Tr-4	Tr	
Pb Phosphate	33%	16-53	7%	4-12	24%	17-33
Fe-Pb Sulfate	10%	2-28			9%	4-16
CuAlSO4			1%	Tr-4	2%	Tr-6
Galena			3%	1-6		
Pb Vanadate			Tr		Tr	
Clays					Tr	
Particles Counted		22		173		104

* M represents the occurrence of small quantities of Sb and Sn.

Figure 11-10A

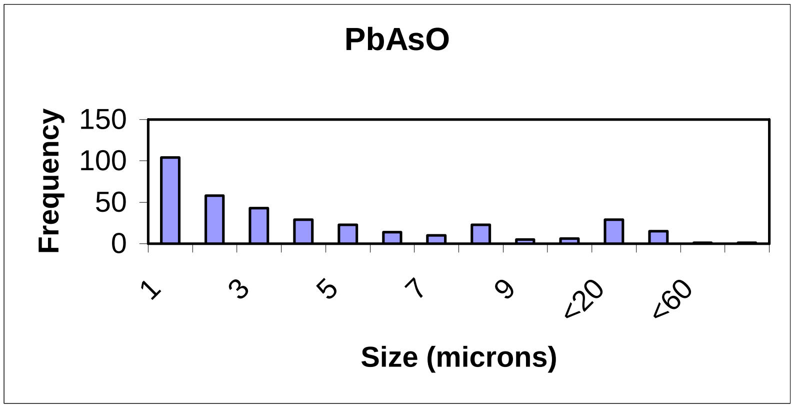


Figure 11-0C

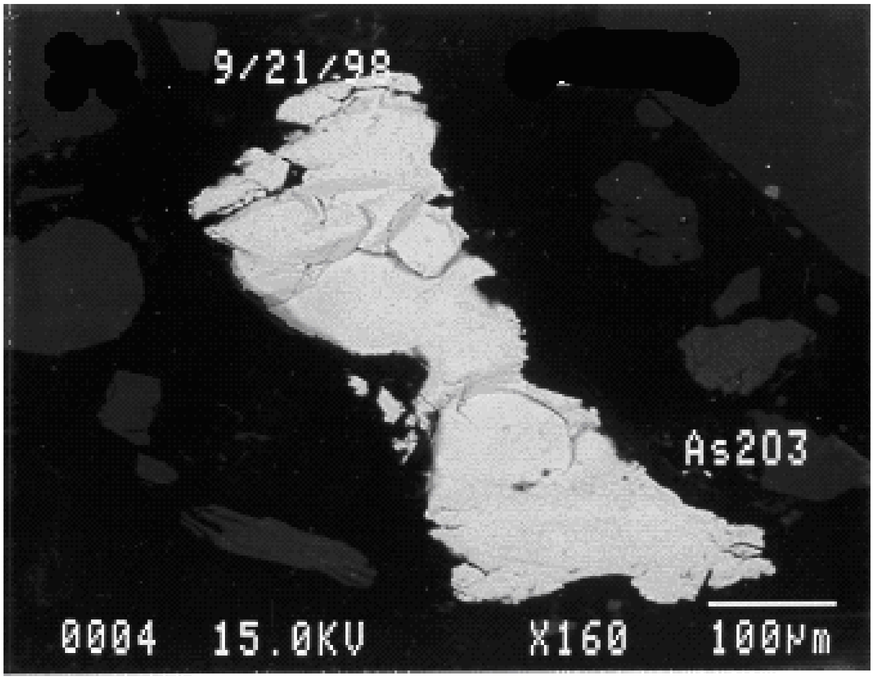


Figure 11-0E

Appendix C

Relative Bioavailability Leaching Procedure

Relative Bioavailability Leaching Procedure (RBLP)

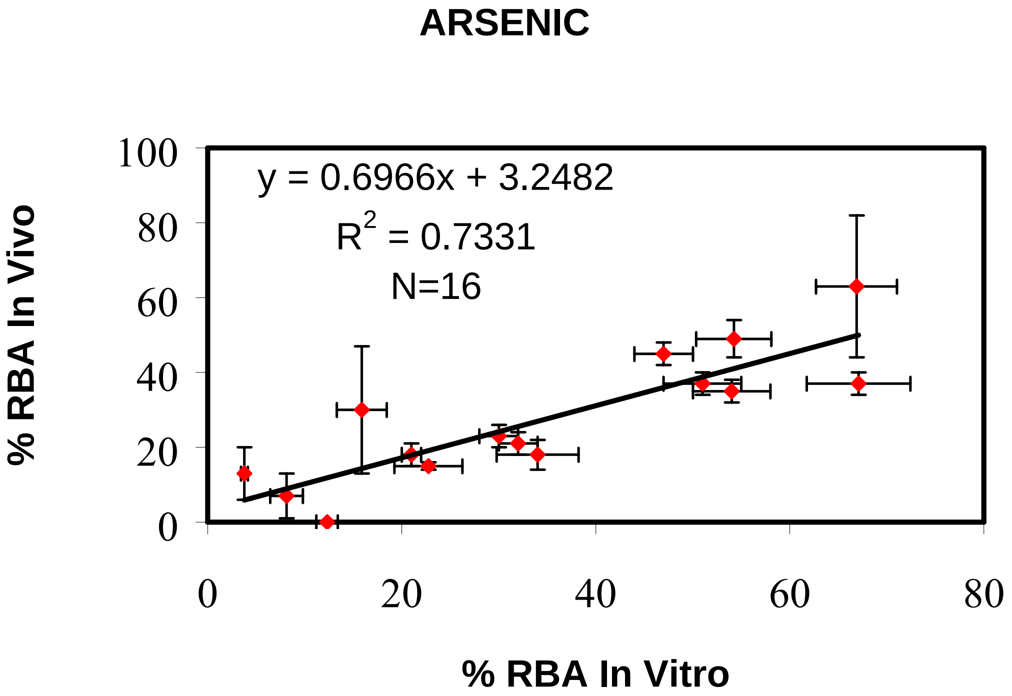
Standard Operating Procedure

1.0 Purpose

An increasingly important property of contaminated media found at environmental sites is the bioavailabilty of individual contaminants. Bioavailability is the fraction of a contaminant that is absorbed by an organism via a specific exposure route. Many animal studies have been conducted to experimentally determine oral bioavailability of individual metals, particularly lead and arsenic. During the period 1989-97, a juvenile swine model developed by USEPA Region VIII was used to predict the relative bioavailability of lead and arsenic in approximately 20 substrates (Weis and LaVelle 1991; Weis et al. 1994). The bioavailability determined was relative to that of a soluble salt (i.e. lead acetate trihydrate or sodium arsenate). The tested media had a wide range of mineralogy, and produced a range of lead and arsenic bioavailabilty values. In addition to the swine studies, other animal models (e.g. rats and monkeys) have been used for measuring the bioavailabilty of lead and arsenic from soils.

Several researchers have developed in vitro tests to measure the fraction of a chemical solubilized from a soil sample under simulated gastrointestinal conditions. The in vitro tests consist of an aqueous fluid, into which the contaminant is introduced. The solution than solubilizes the media under simulated gastric conditions. Once this procedure is complete, the solution is analyzed for lead and/or arsenic concentrations. The mass of the lead and/or arsenic found in the filtered extract is compared to the mass introduced into the test. The fraction liberated into the aqueous phase is defined as the bioavailable fraction of lead or arsenic in that media. To date, for lead-bearing materials tested in the USEPA swine studies, this in vitro assay has correlated well ($R^2 = 0.93$, $p = .0001$) with relative bioavailability. Arsenic has yet to be fully validated but shows a promising correlation with in vivo results.

It has been postulated that a simplified in vitro method could be used to determine bioavailability of lead and arsenic. The method described in this SOP represents a simplified in vitro method, which is currently being subjected to a formal validation.



2.0 Scope

This procedure has been developed to test contaminated media in animal studies, to determine the correlation between in vitro and in vivo. Only samples from which mineralogy has been fully characterized by EMPA techniques and for which bioavailability results from acceptable animal studies are available have been used for this study. A total of 20 substrates have been tested in validating the relative bioavailability leaching procedure (RBLP).

3.0 Relevant Literature

Background on the development and validation of in vitro test systems for estimating lead and arsenic bioaccessibility can be found in; Ruby et al. (1993, 1996); Medlin (1972); Medlin and Drexler, 1997; Drexler, 1998; and Drexler et al., 2003.

Background information for the USEPA swine studies may be found in (Weis and LaVelle, 1991; Weis et al. 1994; and Casteel et al., 1997) and in the USEPA Region VIII Center in Denver, Colorado.

4.0 Sample Preparation

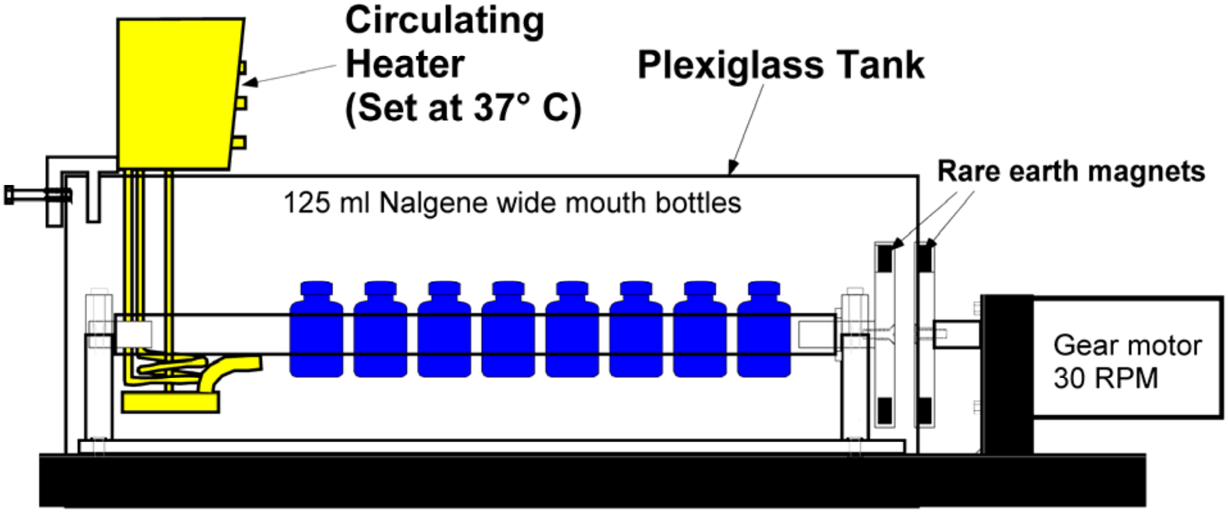
All media are prepared for the in vitro assay by first drying (<40 °C) all samples and then sieving to < 250 m. The <250 micron size fraction was used because this is the particle size is representative of that which adheres to children's hands. Samples were thoroughly mixed prior to use to ensure homogenization. Samples are archived after the study completion and retained for further analysis for a period of six months unless otherwise requested. Prior to obtaining a subsample for testing in this procedure, each sample must be homogenized in its sample container by end-over-end mixing.

5.0 Apparatus and Materials

5.1 Equipment

The main piece of equipment required for this procedure is the extraction device illustrated in Figure 1. The device can be purchased from the Department of Geological Sciences, University of Colorado. For further information contact Dr. John W. Drexler, at (303) 492-5251 or drexlerj@spot.colorado.edu. The device holds ten 125 ml, wide-mouth high-density polyethylene (HDPE) bottles. These are rotated within a Plexiglas tank by a TCLP extractor motor with a modified flywheel. The water bath must be filled such that the extraction bottles remained immersed. Temperature in the water bath is maintained at 37 +/- 2 °C using an immersion circulator heater (Fisher Scientific Model 730).

The 125-ml HDPE bottles must have an airtight screw-cap seal (Fisher Scientific #02-893-5C), and care must be taken to ensure that the bottles do not leak during the extraction procedure.



Patent Pending University of
Colorado, Boulder.

5.2 Standards and Reagents

The leaching procedure for this method uses an aqueous extraction fluid at a pH value of 1.5. The pH 1.5 fluid is prepared as follows:

Prepare 2 L of aqueous extraction fluid using ASTM Type II demonized (DI) water. The buffer is made up in the following manner. To 1.9 L of DI water, add 60.06 g glycine (free base, reagent grade), and bring the solution volume to 2 L (0.4M glycine). Place the mixture in the water bath at 37 °C until the extraction fluid reaches 37 °C. Standardize the pH meter (one should use both a 2.0 and a 4.0 pH buffer for standardization) using temperature compensation at 37 °C or buffers maintained at 37 °C in the water bath. Add trace metal grade, concentrated hydrochloric acid (12.1N) until the solution pH reaches a value of 1.50 +/_ 0.05 (approximately 60 mL).

All reagents must be free of lead and arsenic, and the final fluid must be tested to confirm that lead and arsenic concentrations are less than one-fourth the project required detection limits (PRDLs) of 100 and 20 µg/L, respectively (e.g., less than 25 µg/L lead and 5µg/L arsenic in the final fluid.

Cleanliness of all materials used to prepare and/or store the extraction fluid and buffer is essential. All glassware and equipment used to prepare standards and reagents must be properly cleaned, acid washed, and finally, triple-rinsed with demonized water prior to use.

6.0 Leaching Procedure

Measure 100 +/- 0.5 mL of the extraction fluid, using a graduated cylinder, and transfer to a 125 mL wide-mouth HPDE bottle. Add 1.00 +/- 0.5 g of test substrate (<250 m) to the bottle, ensuring that static electricity does not cause soil particles to adhere to the lip or outside threads of the bottle. If necessary, use an antistatic brush to eliminate static electricity prior to adding the media. Record the mass of substrate added to the bottle. Hand-tighten each bottle top and shake/invert to ensure that no leakage occurs, and that no media is caked on the bottom of the bottle.

Place the bottle into the modified TCLP extractor, making sure each bottle is secure and the lid(s) are tightly fastened. Fill the extractor with 125 mL bottles containing test materials or QA samples.

The temperature of the water bath must be 37 +/- 2 °C.

Turn on the extractor and rotate end-over-end at 30 +/- 2 rpm for 1 hour. Record the start time of rotation.

When extraction (rotation) is complete, immediately stop the extractor rotation and remove the bottles. Wipe them dry and place upright on the bench top.

Draw extract directly from the reaction vessel into a disposable 20 cc syringe with a Luer-Lok attachment. Attach a 0.45 µm cellulose acetate disk filter (25 mm diameter) to the syringe, and filter the extract into a clean 15 mL polypropylene centrifuge tube (labeled with sample ID) or other appropriate sample vial for analysis.

Record the time that the extract is filtered (i.e. extraction is stopped). If the total time elapsed is greater than 1 hour 30 minutes, the test must be repeated.

Measure the pH of the remaining fluid in the extraction bottle. If the fluid pH is not within +/_ 0.5 pH units of the starting pH, the test must be discarded and the sample reanalyzed as follows:

If the pH has changed more than 0.5 units, the test will be re-run in an identical fashion. If the second test also results in a decrease in pH of greater than 0.5 s.u. this will be recorded, and the extract filtered for analysis. If the pH has increased by 0.5 s.u. or more, the test must be repeated, but the extractor must be stopped at specific intervals and the pH manually adjusted down to pH of 1.5 with dropwise addition of HCl (adjustments at 5, 10, 15, and 30 minutes into the extraction, and upon final removal from the water bath { 60 min}). Samples with rising pH values might better be run following the method of Medlin, 1997.

Store filtered samples in a refrigerator at 4 °C until the are analyzed. Analysis for lead and arsenic concentrations must occur within 1 week of extraction for each sample.

Extracts are to be analyzed for lead and arsenic, as specified in SOP #2, following EPA methods 6010B, 6020, or 7061A.

6.1 Quality Control/Quality Assurance

Quality Assurance for the extraction procedure will consist of the following quality control samples.

Reagent Blank-extraction fluid analyzed once per batch.

Bottle Blank-extraction fluid only run through the complete procedure at a frequency of 1 in 20 samples.

Duplicate sample-duplicate sample extractions to be performed on 1 in 10 samples.

Matrix Spike-a subsample of each material used will be spiked at concentrations of 10 mg/L lead and 1 mg/L arsenic and run through the extraction procedure (frequency of 1 in 10 samples).

National Institute of Standards and Testing (NIST) Standard Reference Material (SRM) 2711 will be used as a control soil. The SRM will be analyzed at a frequency of 1 in 25 samples.

Control limits and corrective actions are listed in Table 1.

	Analysis Frequency	**Control Limits**
Reagent Blank	once per batch	< 25 Φg/L lead
Bottle blank	5%	<50 Φg/L lead
Blank spike*	5%	85-115% recovery
Matrix spike*	10%	75-125% recovery
Duplicate sample	10%	+/- 20% RPD**
Control soil***	5%	+/- 10% RPD

* Spikes contained 10 mg/L lead. ** RPD= relative percent difference. *** The National Institute of Standards and Technology (NIST) Standard Reference Material (SRM)

7.0 Chain-of-Custody Procedures

All media once received by the Laboratory must be maintained under standard chain-of-custody.

8.0 Data Handling and Verification

All sample and fluid preparation calculations and operations must be recorded on data sheets, Figure 3. Finally all key data will be entered into the attached EXCEL spreadsheet for final delivery and calculation of Bioavailability.

9.0 References

Casteel, S.W., R.P. Cowart, C.P. Weis, G.M. Henningsen, E.Hoffman and J.W. Drexler, 1997. Bioavailability of lead in soil from the Smuggler Mountain site of Aspen Colorado. Fund. Appl. Toxicol. 36: 177-187.

Drexler, J.W., 1998. An in vitro method that works! A simple, rapid and accurate method for determination of lead bioavailability. EPA Workshop, Durham, NC..

Drexler, J.W., Weis, C,P., W. Brattin, 2003. Lead Bioavailability: A Validated in vitro method. Fund. Appl. Toxicol. (In Press).

Medlin, E., and Drexler, J.W., 1995. Development of an in vitro technique for the determination of bioavalability from metal-bearing solids., International Conference on the Biogeochemistry of Trace Elements, Paris, France.

Medlin, E.A., 1997, An In Vitro method for estimating the relative bioavailability of lead in humans. Masters thesis. Department of Geological Sciences, University of Colorado, Boulder.

Ruby, M.W., 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 bioaccessability of ingested mine-waste lead. Environ. Sci. Technol. 27(13): 2870-2877.

Ruby, M.W., A. Davis, R. Schoof, S. Eberle. And C.M. Sellstone. 1996 Estimation of lead and arsenic bioavailbilty using a physiologically based extraction test. Environ. Sci. Technol. 30(2): 422-430.

Weis, C.P., and J.M. LaVelle. 1991. Characteristics to consider when choosing an animal model for the study of lead bioavailability. In: Proceedings of the International Symposium on the Bioavailability and Dietary Uptake of Lead. Sci. Technol. Let. 3:113-119.

Weis, C.P., R.H., Poppenga, B.J. Thacker, and G.M. Henningsen, 1994. Design of parmacokinetic and bioavailability studies of lead in an immature swine model. In: Lead in paint, soil, and dust: health risks, exposure studies, control measures, measurement methods, and quality assurance, ASTM STP 1226, M.E. Beard and S.A. Iske (Eds.). American Society for Testing and Materials, Philadelphia, PA, 19103-1187.

Appendix D

Mineralogy by X-Ray diffraction

Appendix D

Mineralogy by X-Ray Diffraction

X-ray diffraction (XRD) has long been regarded as a definitive tool for identifying minerals in geological materials, especially those containing significant proportions of clay minerals (Ref. 18). XRD analysis of clay-bearing substances may be based on the evaluation of a bulk sample of the whole material mounted in randomly oriented powder form. Analyses of clay-fractions themselves, however, may use oriented aggregate samples of the clay fraction subjected to XRD after saturation with ethylene glycol to isolate expandable clay minerals and after heating to collapse any expandable lattice structures. The samples were prepared following standard procedures (Refs. 16 and 13). Splits of the bulk sample were used for characterization of the whole rock mineralogy. Approximately 5 g of each soil sample was ground with a "shatter-box" crusher to obtain a homogenous powder with particle sizes <40µm.

Clay mineral analyses were based on the standard method (Ref. 16). A split of the powdered soil was mixed with de-ionized water (pH 7-8) and agitated. The carbonate fraction was removed with the addition of HCl (0.5 N) at < 80°C temperature for 30 minutes or more until all the carbonate was dissolved. Ultrasonic desegregation is accomplished during 3 minute intervals. The insoluble residue was washed and centrifuged (5-6 times) until a neutral suspension was obtained (pH 7-8). Separation of the clay-size fractions were obtained by the timed settling method based on Stokes law. The selected fraction was then dispersed onto glass slides and air-dried at room temperature. XRD analysis of oriented clay samples were made after air-drying at room temperature, treating with ethylene-glycol, and heat treated steps.

All samples were analyzed on a Scintag PAD V X-ray diffractometer. Scannned from 3° to 65°2θ at the following parameters: radiation = CuKα; scan rate = 2°/min; step size = 0.02; voltage = 40 kV; current = 30 mA; and slits = 0.2 mm. To correct for misalignments of the goniometer a diffractogram of quartz (100) reflection at 4.26 Å was obtained. The methods described by Refs. 12,14,15,16, and 19 were used. The bulk XRD analyses of all three soils are dominated (Figures 2.2-2.4) by quartz (SiO_2), plagioclase ($Na,CaAlSi_3O_8$), and microcline ($KAlSi_3O_8$). Soil B (93206) additionally contained a significant amount of hematite (Fe_2O_3). The further analyses of their clay fraction (Figures 2.5-2.6) require greater interpretation, however, it appears all three soils are dominated by the presence of the minerals illite, kaolinite, and smectite as described below.

Illite

Illite is distinguished by the peak series; 10Å, 5Å, and 3.33Å. It is unaffected by glycolation and heat treatment to (550°C). It is perhaps the easiest to identify. The only possible misidentification is with palygorsite at 10.4Å and hydrated halloysite at 10Å but these minerals lack the characteristic illite peaks at 5Å, and 3.33Å.

Kaolinite

Kaolinite is a large class of clay minerals that range from the very ordered (narrow and intense diffraction peaks) to the very disordered (weak and broad diffraction peaks). The characteristic lines of kaolinite are 7.1Å and 3.57Å. These are possibly confused with chlorite (14Å, 7Å and 3.53Å), but the loss of the 7Å peak at 550°C rules out chlorite. Kaolinite survives heat treatment to 350°C, but not to 550°C. Kaolinite is unaffected by glycolation.

Smectite

Smectite is a diverse group. Members of the smectite group include the dioctahedral minerals montmorillonite, beidellite, and nontronite, and the trioctahedral minerals hectorite (Li-rich), saponite (Mg-rich), and sauconite (Zn-rich). In air-dried samples it has a peak in the range 12Å to 15Å which on glycolation it expands uniformly to 17.2Å (the peak usually sharpens and increases in intensity with glycolation - also an often observed 002 peak occurs at 8.5Å– there is no 002 peak in the air-dried oriented samples). Confirmation was obtained by heating to 300°C - the first diffraction peak collapses to an illite-like 10Å peak.

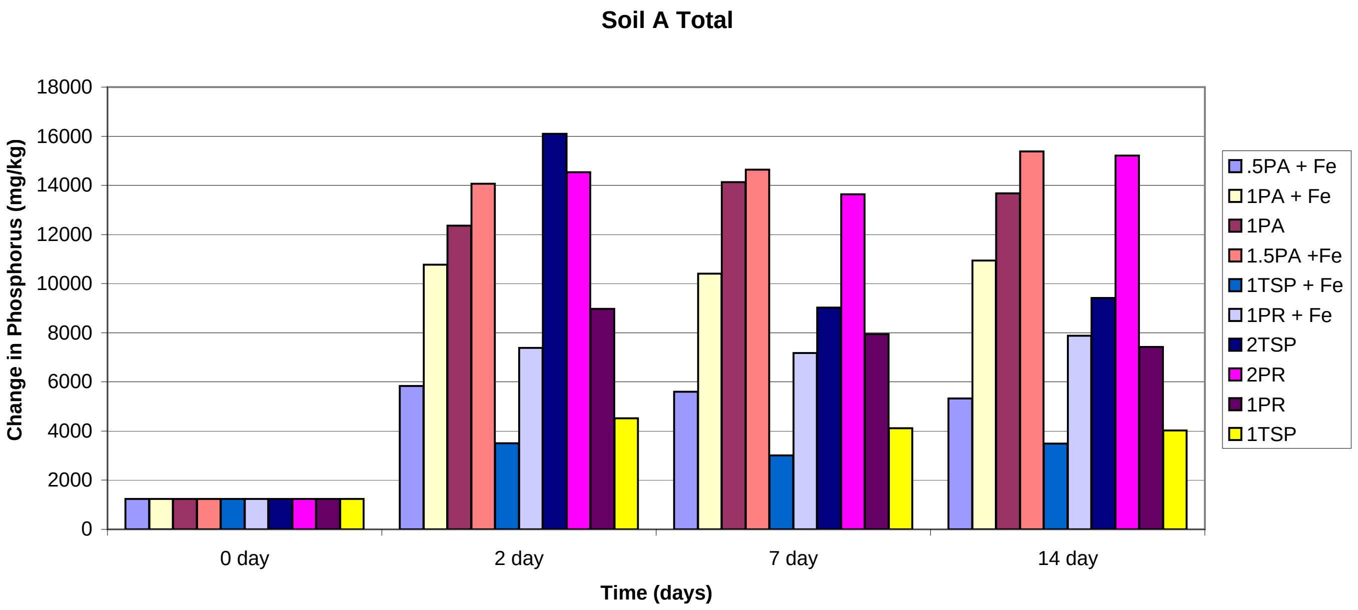
Appendix E
Electronic Data

	P ppm	Change in P	Average Change
MDL=0.06			
A3-2	7439.998395	6206.998	5839.123961
A4-2	6704.249527	5471.25	
A5-2	11745.9904	10512.99	10771.39548
A6-2	12262.80057	11029.8	
A7-2	13884.78438	12651.78	12364.43662
A8-2	13310.08886	12077.09	
A9-2	14717.25254	13484.25	14066.04311
A10-2	15880.83368	14647.83	
A11-2	5386.092255	4153.092	4518.229044
A12-2	6116.365833	4883.366	
A13-2	9822.195909	8589.196	8970.676568
A14-2	10585.15723	9352.157	
A15-2	4658.174606	3425.175	3505.719991
A16-2	4819.265376	3586.265	
A17-2	8683.240335	7450.24	7381.976075
A18-2	8546.711815	7313.712	
A19-2	18018.4179	16785.42	16093.51617
A20-2	16634.61444	15401.61	
A21-2	16053.43519	14820.44	14532.76997
A22-2	15478.10475	14245.1	
A3-7	6352.821312	5119.821	5602.513595
A4-7	7318.205879	6085.206	
A5-7	11853.64943	10620.65	10406.36567
A6-7	11425.08191	10192.08	
A7-7	15326.81037	14093.81	14127.90249
A8-7	15394.9946	14161.99	
A9-7	16346.72501	15113.73	14639.17975
A10-7	15397.63448	14164.63	
A11-7	5403.713051	4170.713	4114.718127
A12-7	5291.723202	4058.723	
A13-7	8923.229814	7690.23	7948.448252
A14-7	9439.66669	8206.667	
A15-7	4084.340902	2851.341	3002.666644
A16-7	4386.992386	3153.992	
A17-7	9289.428919	8056.429	7175.598337
A18-7	7527.767755	6294.768	
A19-7	10369.91935	9136.919	9025.182441
A20-7	10146.44553	8913.446	
A21-7	14264.71159	13031.71	13640.65124
A22-7	15482.59089	14249.59	
A3-14	7079.93768	5846.938	5320.767122
A4-14	6027.596565	4794.597	
A5-14	12254.87941	11021.88	10941.79402
A6-14	12094.70863	10861.71	
A7-14	15569.83278	14336.83	13679.5558
A8-14	14255.27881	13022.28	
A9-14	16746.76305	15513.76	15375.58031
A10-14	16470.39758	15237.4	
A11-14	5483.189753	4250.19	4028.468409
A12-14	5039.747064	3806.747	
A13-14	8547.239795	7314.24	7421.948982
A14-14	8762.658168	7529.658	
A15-14	4887.656276	3654.656	3494.206939
A16-14	4566.757602	3333.758	
A17-14	8573.750508	7340.751	7874.035875
A18-14	9640.321243	8407.321	
A19-14	11054.54154	9821.542	9413.840887
A20-14	10239.14023	9006.14	
A21-14	16787.96102	15554.96	15210.32014
A22-14	16098.67926	14865.68	

Control	
A1-2	1232.919
A1-7	1301.493
A1-14	1263.107
A2-2	1225.912
A2-7	1172.385
A2-14	1202.563
Average	**1233.063**
StDev	**45.27388**
B1-2	1418.918
B1-7	1413.406
B1-14	1520.994
B2-2	1429.489
B2-7	1414.314
B2-14	1484.186
Average	**1446.884**
StDev	**45.05537**
C1-2	1133.173
C1-7	962.7538
C1-14	974.23
C2-2	975.9716
C2-7	999.0791
C2-14	988.1236
Average	**1005.555**
StDev	**63.75016**

Total Phosphorous

		A				B				C			
		0	2	7	14	0	2	7	14	0	2	7	14
Series 1	.5PA + Fe	**1233**	5839.124	5602.51	5320.77	**1446.00**	5648.62	7269.76	6227.51	**1005.00**	5414.93	6684.25	5268.79
Series 3	1PA + Fe	**1233**	10771.4	10406.37	10941.79	**1446.00**	10743.71	13038.61	11431.57	**1005.00**	10629.93	10888.28	9488.18
Series 5	1PA	**1233**	12364.44	14127.90	13679.56	**1446.00**	13239.54	14033.33	14507.47	**1005.00**	11824.35	11656.81	11217.90
Series 7	1.5PA +Fe	**1233**	14066.04	14639.18	15375.58	**1446.00**	13500.40	16870.95	18452.86	**1005.00**	12709.61	14051.39	12480.44
Series 9	1TSP	**1233**	4518.229	4114.72	4028.47	**1446.00**	4161.36	4469.25	6373.83	**1005.00**	4067.53	3897.82	3679.68
Series 11	1PR	**1233**	8970.677	7948.45	7421.95	**1446.00**	7568.49	7866.38	10141.77	**1005.00**	7114.02	7034.83	7185.09
Series 13	1TSP + Fe	**1233**	3505.72	3002.67	3494.21	**1446.00**	3555.33	4920.24	4131.60	**1005.00**	3223.69	3443.39	3186.78
Series 15	1PR + Fe	**1233**	7381.976	7175.60	7874.04	**1446.00**	7645.44	7284.47	9490.64	**1005.00**	6171.85	6019.53	6587.46
Series 17	2TSP	**1233**	16093.52	9025.18	9413.84	**1446.00**	10230.68	9736.38	10286.49	**1005.00**	8443.15	8832.82	8909.46
Series 19	2PR	**1233**	14532.77	13640.65	15210.32	**1446.00**	15678.75	16523.72	15135.23	**1005.00**	13008.19	12782.18	12617.06
		0 day	2 day	7 day	14 day		2 day	7 day	14 day		2 day	7 day	14 day



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B6-2	12195.52385	10749.52	
B7-2	14601.21227	13155.21	13239.53534
B8-2	14769.85841	13323.86	
B9-2	14839.01817	13393.02	13500.40153
B10-2	15053.78488	13607.78	
B11-2	5697.515418	4251.515	4161.362966
B12-2	5517.210514	4071.211	
B13-2	8793.77584	7347.776	7568.490801
B14-2	9235.205762	7789.206	
B15-2	4678.400354	3232.4	3555.331452
B16-2	5324.262549	3878.263	
B17-2	8131.532496	6685.532	7645.439615
B18-2	10051.34673	8605.347	
B19-2	11792.36621	10346.37	10230.68289
B20-2	11560.99958	10115	
B21-2	17928.59982	16482.6	15678.75014
B22-2	16320.90046	14874.9	
B3-7	9451.925303	8005.925	7269.761847
B4-7	7979.598392	6533.598	
B5-7	14979.0874	13533.09	13038.61496
B6-7	13990.14253	12544.14	
B7-7	16025.79834	14579.8	14033.32512
B8-7	14932.85189	13486.85	
B9-7	19248.95009	17802.95	16870.9493
B10-7	17384.94851	15938.95	
B11-7	5754.608637	4308.609	4469.247148
B12-7	6075.885659	4629.886	
B13-7	9120.980757	7674.981	7866.379157
B14-7	9503.777558	8057.778	
B15-7	7064.520299	5618.52	4920.244652
B16-7	5667.969005	4221.969	
B17-7	8516.510891	7070.511	7284.469256
B18-7	8944.427621	7498.428	
B19-7	11065.40854	9619.409	9736.379815
B20-7	11299.35109	9853.351	
B21-7	16725.03601	15279.04	16523.72192
B22-7	19214.40782	17768.41	
B3-14	7832.097231	6386.097	6227.512277
B4-14	7514.927324	6068.927	
B5-14	12860.11122	11414.11	11431.56517
B6-14	12895.01913	11449.02	
B7-14	15743.49333	14297.49	14507.46737
B8-14	16163.44142	14717.44	
B9-14	18548.99249	17102.99	18452.86384
B10-14	21248.73519	19802.74	
B11-14	6433.604439	4987.604	6373.834092
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B13-14	13817.82606	12371.83	10141.76843
B14-14	9357.710803	7911.711	
B15-14	5615.999367	4169.999	4131.600046
B16-14	5539.200725	4093.201	
B17-14	9646.283384	8200.283	9490.642604
B18-14	12227.00182	10781	
B19-14	12091.8459	10645.85	10286.48953
B20-14	11373.13315	9927.133	
B21-14	16356.83897	14910.84	15135.23112
B22-14	16805.62327	15359.62	
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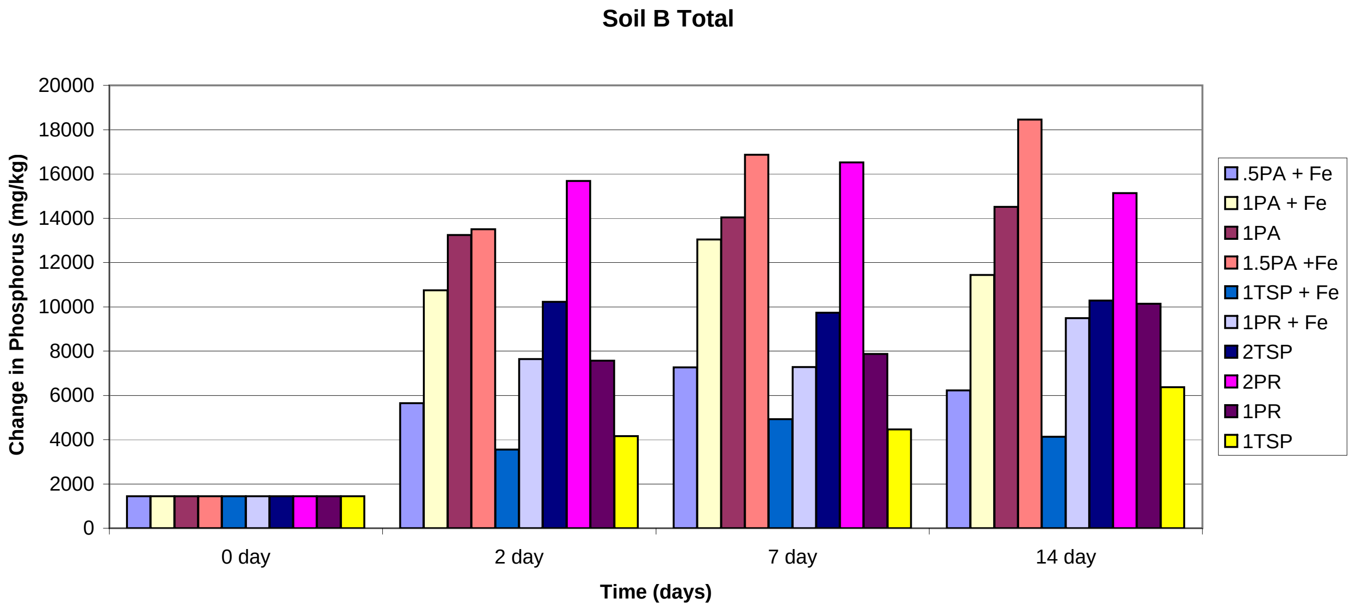
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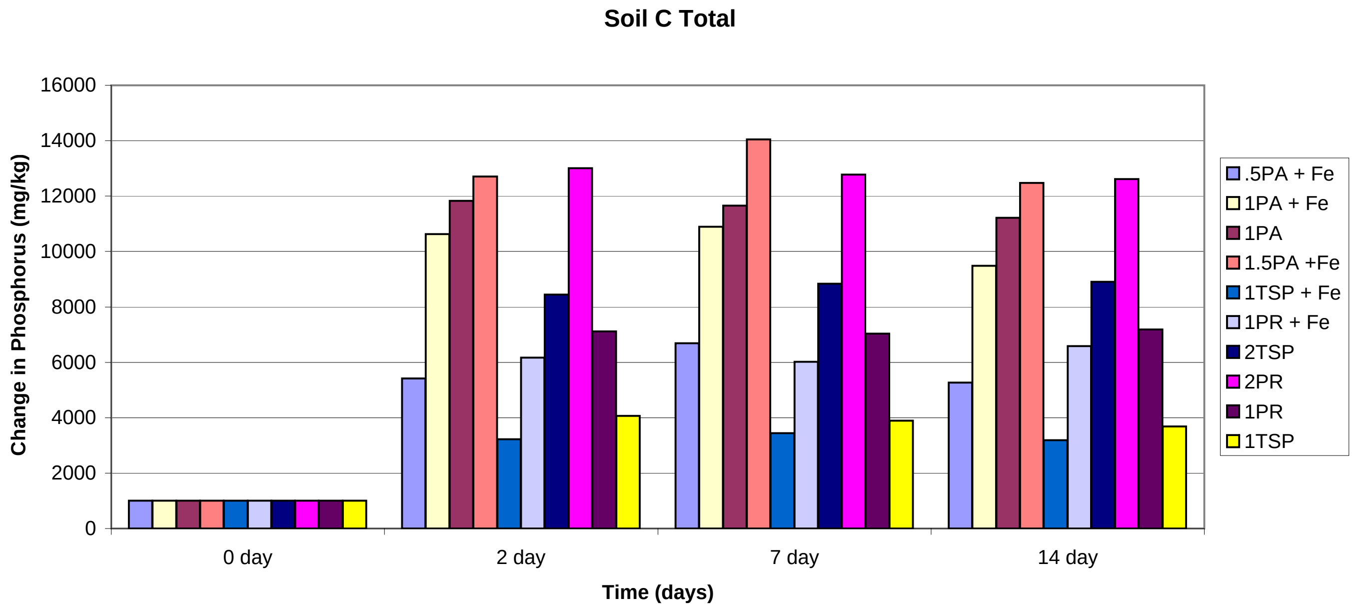
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C7-2	13266.59601	12261.6	11824.34922
C8-2	12392.10244	11387.1	
C9-2	13605.64686	12600.65	12709.60515
C10-2	13823.56343	12818.56	
C11-2	5077.474134	4072.474	4067.530693
C12-2	5067.587252	4062.587	
C13-2	8311.715213	7306.715	7114.0156
C14-2	7926.315986	6921.316	
C15-2	4299.581235	3294.581	3223.692522
C16-2	4157.803809	3152.804	
C17-2	6866.250206	5861.25	6171.854263
C18-2	7487.45832	6482.458	
C19-2	9912.374081	8907.374	8443.15327
C20-2	8983.932459	7978.932	
C21-2	13680.16338	12675.16	13008.18611
C22-2	14346.20884	13341.21	

C3-7	7665.761768	6660.762	6684.247933
C4-7	7712.734097	6707.734	
C5-7	12367.33243	11362.33	10888.27907
C6-7	11419.2257	10414.23	
C7-7	12672.18732	11667.19	11656.80965
C8-7	12651.43198	11646.43	
C9-7	15170.2323	14165.23	14051.38908
C10-7	14942.54586	13937.55	
C11-7	4788.507582	3783.508	3897.82117
C12-7	5017.134758	4012.135	
C13-7	6981.130203	5976.13	7034.834787
C14-7	9098.539371	8093.539	
C15-7	4251.213928	3246.214	3443.385048
C16-7	4645.556168	3640.556	
C17-7	6699.908735	5694.909	6019.528251
C18-7	7349.147767	6344.148	
C19-7	10272.38972	9267.39	8832.818808
C20-7	9403.247897	8398.248	
C21-7	13421.53461	12416.53	12782.18219
C22-7	14152.82978	13147.83	

C3-14	6297.837106	5292.837	5268.794145
C4-14	6249.751184	5244.751	
C5-14	10572.70475	9567.705	9488.182349
C6-14	10413.65994	9408.66	
C7-14	11839.07819	10834.08	11217.89809
C8-14	12606.71798	11601.72	
C9-14	13673.87469	12668.87	12480.44041
C10-14	13297.00614	12292.01	
C11-14	4778.529562	3773.53	3679.677936
C12-14	4590.826309	3585.826	
C13-14	7922.222887	6917.223	7185.086121
C14-14	8457.949355	7452.949	
C15-14	4138.475739	3133.476	3186.778449
C16-14	4245.08116	3240.081	
C17-14	7453.97506	6448.975	6587.459265
C18-14	7730.943471	6725.943	
C19-14	10278.73352	9273.734	8909.455663
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C22-14	14009.67309	13004.67	

QA/QC

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SC 5PPM	5.031
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STAND 20PPM	20.499
STAND 20PPM	19.629
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STAND-20PPM	20.257
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BLANK	0.031
BLANK	-0.002

	P ppm	Exchangable P	Change in P	Average Change
MDL	0.062			
A3-2	175.860		163.160	151.685
A4-2	152.910		140.210	
A5-2	323.010		310.310	292.61
A6-2	287.610		274.910	
A7-2	606.41		593.710	570.485
A8-2	559.960		547.260	
A9-2	398.470		385.770	392.22
A10-2	411.37		398.670	
A11-2	217.52		204.820	232.265
A12-2	272.41		259.710	
A13-2	9.96		-2.740	-2.475
A14-2	10.49		-2.210	
A15-2	86.72		74.020	77.47
A16-2	93.62		80.920	
A17-2	1		-11.700	-11.555
A18-2	1.29		-11.410	
A19-2	822.61		809.910	802.215
A20-2	807.22		794.520	
A21-2	10.24		-2.460	-2.1
A22-2	10.96		-1.740	
A3-7	168.52		155.820	163.925
A4-7	184.73		172.030	
A5-7	316.67		303.970	276.795
A6-7	262.32		249.620	
A7-7	730.8		718.100	773.1
A8-7	840.8		828.100	
A9-7	379.33		366.630	345.205
A10-7	336.48		323.780	
A11-7	211.86		199.160	202.445
A12-7	218.43		205.730	
A13-7	10.75		-1.950	-1.48
A14-7	11.69		-1.010	
A15-7	75.92		63.220	65.485
A16-7	80.45		67.750	
A17-7	1		-11.700	-11.7
A18-7	1		-11.700	
A19-7	471.97		459.270	464.705
A20-7	482.84		470.140	
A21-7	9.66		-3.040	-2.17
A22-7	11.4		-1.300	
A3-14	179.48		166.780	152.095
A4-14	150.11		137.410	
A5-14	389.12		376.420	342.42
A6-14	321.12		308.420	
A7-14	683.45		670.750	673.045
A8-14	688.04		675.340	
A9-14	472.3		459.600	440.815
A10-14	434.73		422.030	
A11-14	238.26		225.560	215.36
A12-14	217.86		205.160	
A13-14	15.55		2.850	1.2
A14-14	12.25		-0.450	
A15-14	128.01		115.310	112.95
A16-14	123.29		110.590	
A17-14	3.72		-8.980	-9.47
A18-14	2.74		-9.960	
A19-14	433.84		421.140	421.79
A20-14	435.14		422.440	
A21-14	12.48		-0.220	-0.895
A22-14	11.13		-1.570	
B3-2	163.24		149.840	144.52
B4-2	152.6		139.200	
B5-2	331.35		317.950	312.69
B6-2	320.83		307.430	
B7-2	639.95		626.550	646.275
B8-2	679.4		666.000	
B9-2	464.43		451.030	423.475
B10-2	409.32		395.920	
B11-2	263.97		250.570	240.98
B12-2	244.79		231.390	
B13-2	11.06		-2.340	-2.275
B14-2	11.19		-2.210	
B15-2	92.47		79.070	92.945

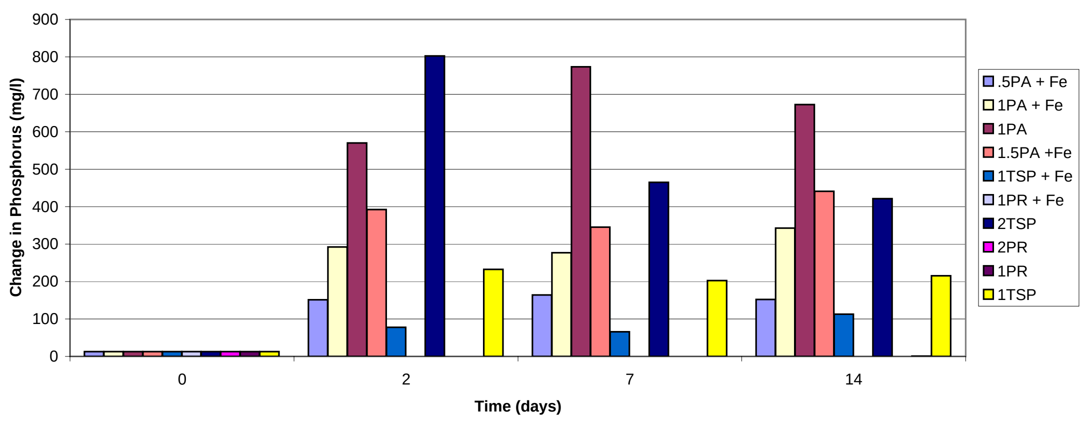
Control

A1-2	12.36
A2-2	11.570
A1-7	11.91
A2-7	13.8
A-1-14	13.1
A-2-14	13.41
Average	**12.69167**
Stdev	**0.882075**
B1-2	13.13
B2-2	12.5
B1-7	13.21
B2-7	13.02
B1-14	13.88
B2-14	14.55
Average	**13.38167**
Stdev	**0.723088**
C1-2	6.52
C2-2	6.66
C1-7	6.34
C2-7	4.64
C1-14	6.92
C2-14	7.19
Average	**6.378333**
Stdev	**0.902761**

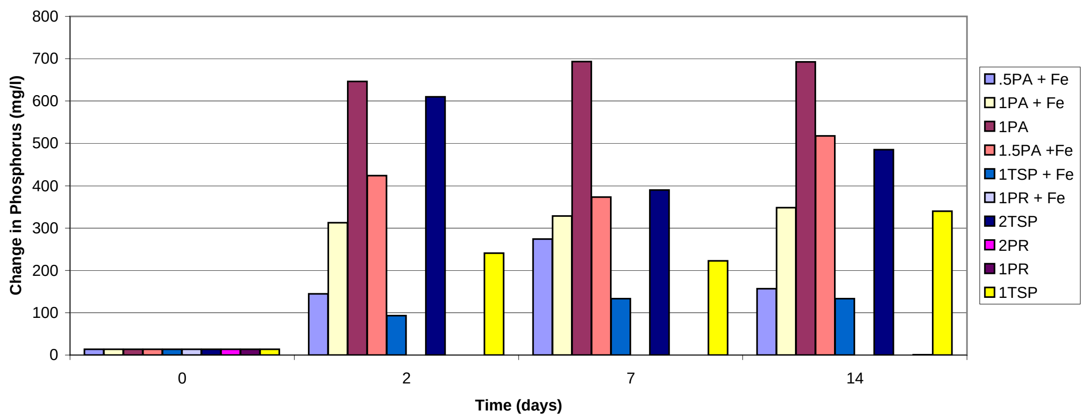
Phosphorous

		A				B				C			
		0	2	7	14	0	2	7	14	0	2	7	14
Series 1	.5PA + Fe	**12.69167**	151.685	163.93	152.10	**13.38167**	144.52	273.75	156.32	**6.38**	192.98	208.58	139.86
Series 3	1PA + Fe	**12.69167**	292.61	276.80	342.42	**13.38167**	312.69	328.15	347.85	**6.38**	365.76	356.19	309.29
Series 5	1PA	**12.69167**	570.485	773.10	673.05	**13.38167**	646.28	693.44	692.67	**6.38**	721.10	485.25	599.30
Series 7	1.5PA +Fe	**12.69167**	392.22	345.21	440.82	**13.38167**	423.48	372.89	517.88	**6.38**	438.83	430.11	444.69
Series 9	1TSP	**12.69167**	232.265	202.45	215.36	**13.38167**	240.98	222.82	339.62	**6.38**	247.20	216.00	253.78
Series 11	1PR	**12.69167**	-2.475	-1.48	1.20	**13.38167**	-2.28	-2.29	0.86	**6.38**	-0.04	-0.18	0.54
Series 13	1TSP + Fe	**12.69167**	77.47	65.49	112.95	**13.38167**	92.95	132.85	133.10	**6.38**	101.35	89.84	118.92
Series 15	1PR + Fe	**12.69167**	-11.555	-11.70	-9.47	**13.38167**	-11.60	-13.00	-10.81	**6.38**	-5.32	-5.40	-5.07
Series 17	2TSP	**12.69167**	802.215	464.71	421.79	**13.38167**	610.15	389.60	485.09	**6.38**	508.07	375.92	487.13
Series 19	2PR	**12.69167**	-2.1	-2.17	-0.89	**13.38167**	-1.03	-1.69	-0.32	**6.38**	0.67	0.71	1.23
		0 day	2 day	7 day	14 day		2 day	7 day	14 day		2 day	7 day	14 day

Soil A Extractable



Soil B Extractable

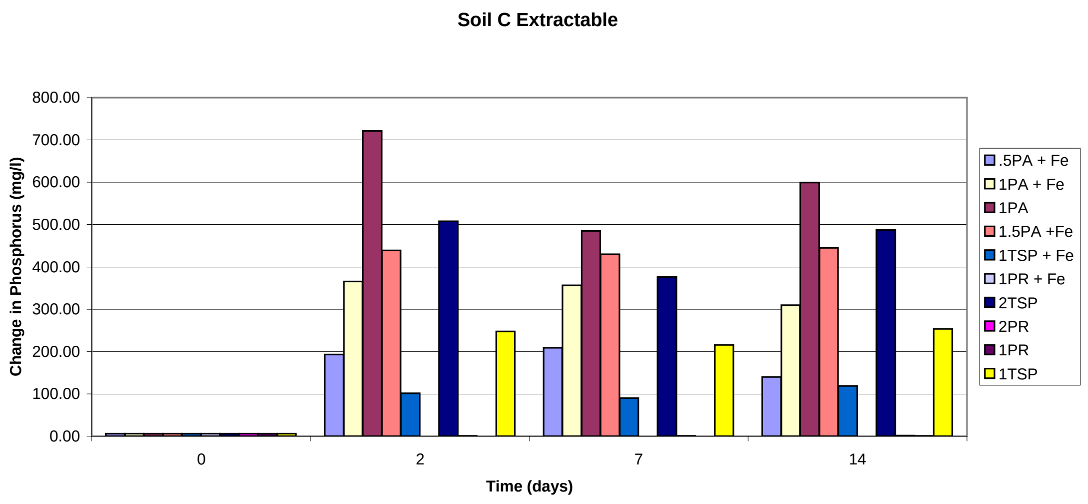


B16-2	120.22	106.820	
B17-2	1.99	-11.410	-11.6
B18-2	1.61	-11.790	
B19-2	676.07	662.670	610.15
B20-2	571.03	557.630	
B21-2	13.05	-0.350	-1.03
B22-2	11.69	-1.710	

B3-7	318.75	305.350	273.75
B4-7	255.55	242.150	
B5-7	339.22	325.820	328.15
B6-7	343.88	330.480	
B7-7	812.01	798.610	693.44
B8-7	601.67	588.270	
B9-7	486.84	473.440	372.89
B10-7	285.74	272.340	
B11-7	227.55	214.150	222.815
B12-7	244.88	231.480	
B13-7	11.03	-2.370	-2.29
B14-7	11.19	-2.210	
B15-7	161.76	148.360	132.85
B16-7	130.74	117.340	
B17-7	0.38	-13.020	-13
B18-7	0.42	-12.980	
B19-7	413.22	399.820	389.6
B20-7	392.78	379.380	
B21-7	11.73	-1.670	-1.69
B22-7	11.69	-1.710	

B3-14	153.96	140.560	156.315
B4-14	185.47	172.070	
B5-14	340.17	326.770	347.85
B6-14	382.33	368.930	
B7-14	702.01	688.610	692.665
B8-14	710.12	696.720	
B9-14	557.79	544.390	517.875
B10-14	504.76	491.360	
B11-14	300.17	286.770	339.62
B12-14	405.87	392.470	
B13-14	13.5	0.100	0.86
B14-14	15.02	1.620	
B15-14	164.16	150.760	133.095
B16-14	128.83	115.430	
B17-14	3.48	-9.920	-10.81
B18-14	1.7	-11.700	
B19-14	495.02	481.620	485.085
B20-14	501.95	488.550	
B21-14	12.65	-0.750	-0.32
B22-14	13.51	0.110	

C3-2	188.83	182.430	192.975
C4-2	209.92	203.520	
C5-2	393.45	387.050	365.755
C6-2	350.86	344.460	
C7-2	802.2	795.800	721.095
C8-2	652.79	646.390	
C9-2	395.69	389.290	438.83
C10-2	494.77	488.370	
C11-2	250.13	243.730	247.2
C12-2	257.07	250.670	
C13-2	6.53	0.130	-0.04
C14-2	6.19	-0.210	
C15-2	110.91	104.510	101.345
C16-2	104.58	98.180	
C17-2	1.01	-5.390	-5.315
C18-2	1.16	-5.240	
C19-2	515.52	509.120	508.065
C20-2	513.41	507.010	
C21-2	6.92	0.520	0.665
C22-2	7.21	0.810	



C3-7	215.35	208.950	208.58
C4-7	214.61	208.210	
C5-7	384.39	377.990	356.185
C6-7	340.78	334.380	
C7-7	489.4	483.000	485.245
C8-7	493.89	487.490	
C9-7	465.24	458.840	430.105
C10-7	407.77	401.370	
C11-7	226.04	219.640	215.995
C12-7	218.75	212.350	
C13-7	5.71	-0.690	-0.18
C14-7	6.73	0.330	
C15-7	82.63	76.230	89.84
C16-7	109.85	103.450	
C17-7	1	-5.400	-5.4
C18-7	1	-5.400	
C19-7	396.27	389.870	375.915
C20-7	368.36	361.960	
C21-7	7.04	0.640	0.705
C22-7	7.17	0.770	

C3-14	150.47	144.070	139.86
C4-14	142.05	135.650	
C5-14	331.84	325.440	309.29
C6-14	299.54	293.140	
C7-14	543.65	537.250	599.3
C8-14	667.75	661.350	
C9-14	456.92	450.520	444.69
C10-14	445.26	438.860	
C11-14	247.45	241.050	253.775
C12-14	272.9	266.500	
C13-14	7.65	1.250	0.54
C14-14	6.23	-0.170	
C15-14	129.19	122.790	118.915
C16-14	121.44	115.040	
C17-14	1.42	-4.980	-5.07
C18-14	1.24	-5.160	
C19-14	510.67	504.270	487.125
C20-14	476.38	469.980	
C21-14	7.63	1.230	1.225
C22-14	7.62	1.220	

MDL	Pb ppb 0.073	Change in Pb	Average Change
A3-2	0.09	-5.75	-5.638025
A4-2	0.31	-5.53	
A5-2	0.22	-5.62	-5.72068
A6-2	0.02	-5.82	
A7-2	0.41	-5.43	-5.5359
A8-2	0.20	-5.64	
A9-2	0.20	-5.64	-5.65895
A10-2	0.17	-5.67	
A11-2	2.19	-3.65	-3.63205
A12-2	2.23	-3.61	
A13-2	17.80	11.96	4.197415
A14-2	2.27	-3.57	
A15-2	1.40	-4.44	-4.6705
A16-2	0.93	-4.91	
A17-2	4.37	-1.47	-1.4768
A18-2	4.36	-1.48	
A19-2	9.17	3.33	4.4693
A20-2	11.44	5.60	
A21-2	30.97	25.13	25.4172
A22-2	31.54	25.70	
A3-7	0.22	-5.62	-5.6668
A4-7	0.12	-5.72	
A5-7	0.13	-5.71	-5.77585
A6-7	0.00	-5.84	
A7-7	1.01	-4.83	-4.384
A8-7	1.90	-3.94	
A9-7	0.00	-5.84	-5.84
A10-7	0.00	-5.84	
A11-7	1.36	-4.48	-4.5841
A12-7	1.15	-4.69	
A13-7	16.96	11.12	9.6968
A14-7	14.11	8.27	
A15-7	0.54	-5.30	-4.82565
A16-7	1.49	-4.35	
A17-7	3.02	-2.82	-2.9601
A18-7	2.74	-3.10	
A19-7	5.41	-0.43	-0.77535
A20-7	4.72	-1.12	
A21-7	37.34	31.50	31.6904
A22-7	37.72	31.88	
A3-14	2.67	-3.17	-4.23656979
A4-14	0.53	-5.31	
A5-14	0.21	-5.63	-5.73480652
A6-14	0.00	-5.84	
A7-14	0.15	-5.69	-5.76488737
A8-14	0.00	-5.84	
A9-14	0.00	-5.84	-5.84
A10-14	0.00	-5.84	
A11-14	1.72	-4.12	-4.60690139
A12-14	0.74	-5.10	
A13-14	13.61	7.77	8.715021811
A14-14	15.50	9.66	
A15-14	0.36	-5.48	-5.47011261
A16-14	0.38	-5.46	
A17-14	4.18	-1.66	-1.45917889
A18-14	4.58	-1.26	
A19-14	6.59	0.75	-0.95963878
A20-14	3.17	-2.67	
A21-14	31.59	25.75	30.17552557
A22-14	40.44	34.60	
B3-2	0.59	-9.52	-9.37505
B4-2	0.88	-9.23	
B5-2	0.00	-10.11	-10.11
B6-2	0.00	-10.11	
B7-2	0.53	-9.58	-8.7054
B8-2	2.28	-7.83	
B9-2	0.00	-10.11	-10.11
B10-2	0.00	-10.11	
B11-2	4.21	-5.90	-6.09425
B12-2	3.82	-6.29	
B13-2	43.69	33.58	34.02935

Pb Concentrations

Controls

	ppb
Soil A	
A1-2	6.66
A2-2	7.23
A1-7	3.88
A2-7	4.66
A1-14	6.00
A2-14	6.26
D1	6.04
D2	6.03
Average	**5.843516**
Soil B	
B1-2	11.37
B2-2	11.61
B1-7	9.43
B2-7	7.64
B1-14	8.57
B2-14	8.82
D9	10.24
D10	13.20
Average	**10.11053**
Soil C	
C1-2	17.91
C2-2	16.09
C1-7	13.89
C2-7	15.34
C1-14	18.15
C2-14	16.24
D17	43.55
D18	24.58
Average	**20.719**

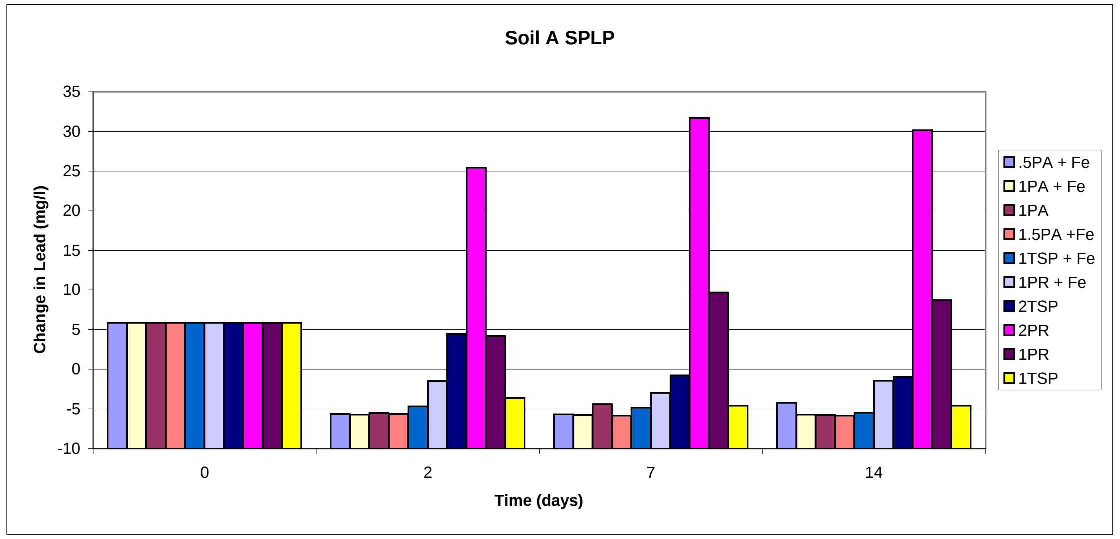
TSP leaches a lot of P

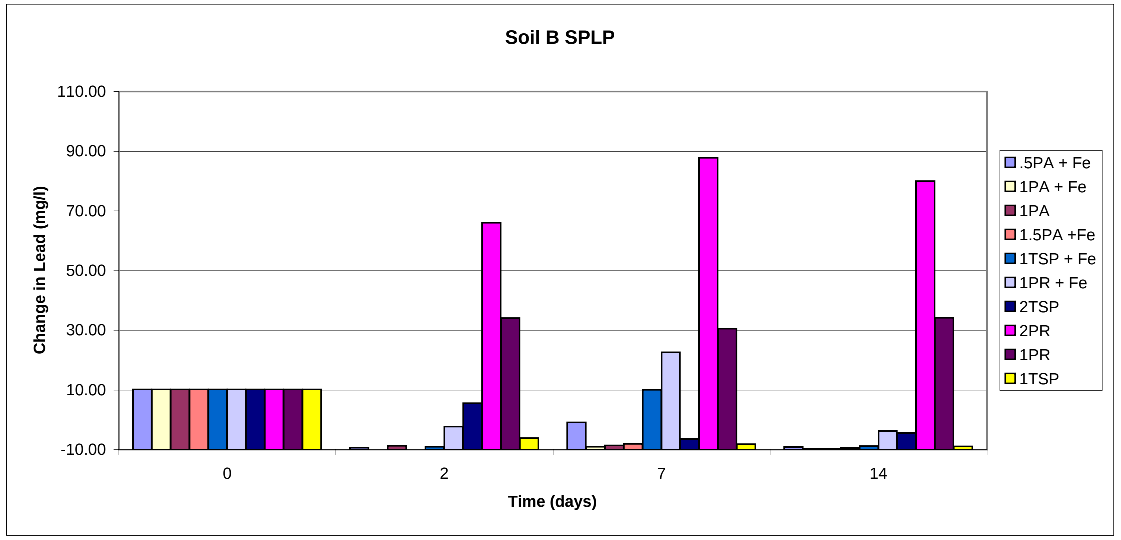
PR leaches Pb
P without Fe leaches As

	Zn ppb	**As ppb**	**Cd ppb**	**Pb ppb**
A1-2	28.41	58.16	0.36	6.66
A2-2	29.23	56.55	0.32	7.23
A1-7	19.52	33.33	0.69	3.88
A2-7	18.46	57.75	0.37	4.66
A1-14	16.10	65.92	0.16	6.00
A2-14	18.93	58.52	0.16	6.26
D-1	19.83	53.79	0.19	6.04
D-2	19.55	55.93	0.16	6.03
Average	**21.25**	**54.99**	**0.30**	**5.84**
B1-2	25.50	42.51	0.26	11.37
B2-2	25.23	41.65	0.24	11.61
B1-7	26.10	44.53	0.91	9.43
B2-7	23.33	41.48	0.30	7.64
B1-14	22.19	40.90	0.25	8.57
B2-14	24.26	39.23	0.26	8.82
D-9	26.03	43.14	0.19	10.24
D-10	27.84	44.19	0.20	13.20
Average	**25.06**	**42.20**	**0.33**	**10.11**
C1-2	14.14	7.25	0.12	17.91
C2-2	12.87	6.51	0.12	16.09
C1-7	12.02	7.29	0.63	13.89

Lead

		A				B				C			
		0	2	7	14	0	2	7	14	0	2	7	14
Series 1	.5PA + Fe	**5.843516**	-5.638025	-5.67	-4.24	**10.11**	-9.38	-0.87	-9.10	**20.72**	-18.12	-12.65	-20.04
Series 3	1PA + Fe	**5.843516**	-5.72068	-5.78	-5.73	**10.11**	-10.11	-9.08	-9.74	**20.72**	-20.72	26.93	-20.65
Series 5	1PA	**5.843516**	-5.5359	-4.38	-5.76	**10.11**	-8.71	-8.62	-9.80	**20.72**	-20.63	-20.72	-20.72
Series 7	1.5PA +Fe	**5.843516**	-5.65895	-5.84	-5.84	**10.11**	-10.11	-8.08	-9.46	**20.72**	-20.72	-20.41	-20.68
Series 9	1TSP	**5.843516**	-3.63205	-4.58	-4.61	**10.11**	-6.09	-8.20	-8.90	**20.72**	-19.29	-19.66	-19.38
Series 11	1PR	**5.843516**	4.197415	9.70	8.72	**10.11**	34.03	30.56	34.23	**20.72**	83.81	77.93	36.23
Series 13	1TSP + Fe	**5.843516**	-4.6705	-4.83	-5.47	**10.11**	-9.05	10.02	-8.82	**20.72**	-1.48	205.87	-20.10
Series 15	1PR + Fe	**5.843516**	-1.4768	-2.96	-1.46	**10.11**	-2.32	22.61	-3.79	**20.72**	-7.17	1056.61	-8.99
Series 17	2TSP	**5.843516**	4.4693	-0.78	-0.96	**10.11**	5.53	-6.44	-4.42	**20.72**	-12.13	-10.95	-16.43
Series 19	2PR	**5.843516**	25.4172	31.69	30.18	**10.11**	66.04	87.77	79.95	**20.72**	149.98	248.43	89.60
		0 day	2 day	7 day	14 day		2 day	7 day	14 day		2 day	7 day	14 day





B14-2	44.59	34.48	
B15-2	1.16	-8.95	-9.04755
B16-2	0.96	-9.15	
B17-2	8.10	-2.01	-2.3222
B18-2	7.48	-2.63	
B19-2	9.69	-0.42	5.5318
B20-2	21.59	11.48	
B21-2	74.35	64.24	66.0403
B22-2	77.95	67.84	

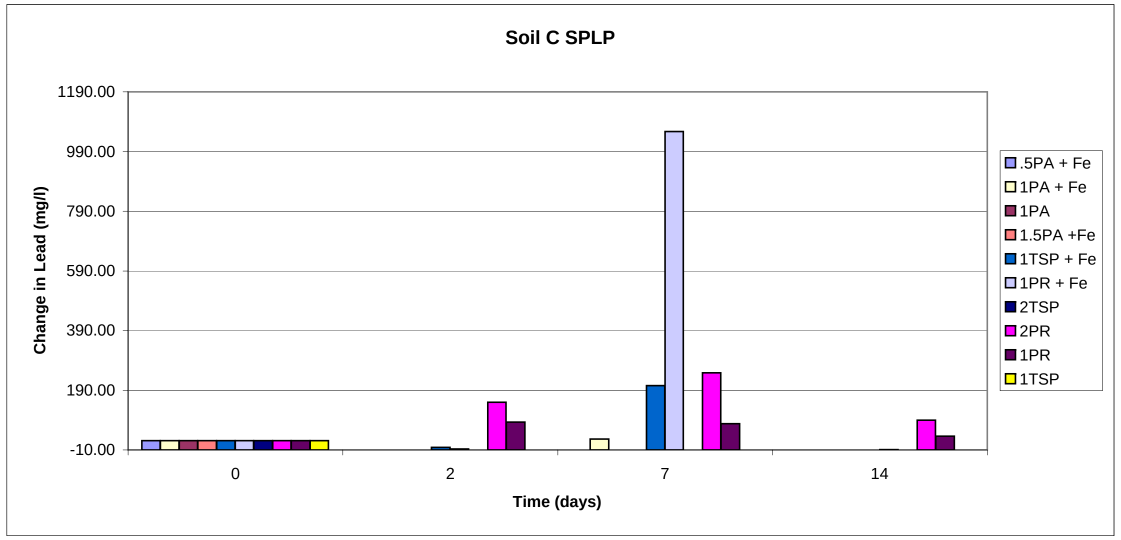
B3-7	10.95	0.84	-0.87005
B4-7	7.53	-2.58	
B5-7	1.12	-8.99	-9.079
B6-7	0.94	-9.17	
B7-7	1.95	-8.16	-8.62325
B8-7	1.03	-9.08	
B9-7	0.82	-9.29	-8.0825
B10-7	3.23	-6.88	
B11-7	2.04	-8.07	-8.19875
B12-7	1.78	-8.33	
B13-7	33.61	23.50	30.5575
B14-7	47.73	37.62	
B15-7	17.01	6.90	10.0155
B16-7	23.24	13.13	
B17-7	32.76	22.65	22.6069
B18-7	32.67	22.56	
B19-7	4.11	-6.00	-6.4352
B20-7	3.24	-6.87	
B21-7	83.55	73.44	87.7659
B22-7	112.20	102.09	

B3-14	0.79	-9.32	-9.10004534
B4-14	1.23	-8.88	
B5-14	0.00	-10.11	-9.73893672
B6-14	0.74	-9.37	
B7-14	0.00	-10.11	-9.80332622
B8-14	0.61	-9.50	
B9-14	0.33	-9.78	-9.46201584
B10-14	0.97	-9.14	
B11-14	1.39	-8.72	-8.90043118
B12-14	1.03	-9.08	
B13-14	55.31	45.20	34.23274191
B14-14	33.38	23.27	
B15-14	2.14	-7.97	-8.82147319
B16-14	0.44	-9.67	
B17-14	6.61	-3.50	-3.79329062
B18-14	6.02	-4.09	
B19-14	7.01	-3.10	-4.42227095
B20-14	4.37	-5.74	
B21-14	104.74	94.63	79.95416809
B22-14	75.39	65.28	

C3-2	0.00	-20.72	-18.120691
C4-2	5.20	-15.52	
C5-2	0.00	-20.72	-20.72
C6-2	0.00	-20.72	
C7-2	0.17	-20.55	-20.634617
C8-2	0.00	-20.72	
C9-2	0.00	-20.72	-20.72
C10-2	0.00	-20.72	
C11-2	1.67	-19.05	-19.294406
C12-2	1.18	-19.54	
C13-2	117.65	96.93	83.80978
C14-2	91.41	70.69	
C15-2	1.01	-19.71	-1.475301
C16-2	37.48	16.76	
C17-2	14.34	-6.38	-7.16765
C18-2	12.76	-7.96	
C19-2	9.68	-11.04	-12.13245
C20-2	7.49	-13.23	
C21-2	171.47	150.75	149.97575
C22-2	169.92	149.20	

C3-7	3.45	-17.27	-12.64785
C4-7	12.70	-8.02	
C5-7	94.82	74.10	26.9333
C6-7	0.49	-20.23	
C7-7	0.00	-20.72	-20.72
C8-7	0.00	-20.72	
C9-7	0.34	-20.38	-20.40725

C2-7	12.83	7.60	0.18	15.34
C1-14	11.09	6.85	0.14	18.15
C2-14	12.43	6.98	0.15	16.24
D-17		6.42	0.19	43.55
D-18	14.06	6.05	0.15	24.58
Average	**12.78**	**6.87**	**0.21**	**20.72**
	141.26			



C10-7	0.29	-20.43	
C11-7	1.40	-19.32	-19.6564
C12-7	0.72	-20.00	
C13-7	68.90	48.18	77.9306
C14-7	128.41	107.69	
C15-7	29.33	8.61	205.8726
C16-7	423.86	403.14	
C17-7	1164.01	1143.29	1056.60755
C18-7	990.65	969.93	
C19-7	12.13	-8.59	-10.9525
C20-7	7.41	-13.31	
C21-7	254.11	233.39	248.42595
C22-7	284.18	263.46	

C3-14	0.73	-19.99	-20.0409125
C4-14	0.62	-20.10	
C5-14	0.00	-20.72	-20.6523275
C6-14	0.14	-20.58	
C7-14	0.00	-20.72	-20.72
C8-14	0.00	-20.72	
C9-14	0.00	-20.72	-20.6758955
C10-14	0.09	-20.63	
C11-14	1.35	-19.37	-19.3839696
C12-14	1.32	-19.40	
C13-14	66.35	45.63	36.23203512
C14-14	47.56	26.84	
C15-14	0.78	-19.94	-20.0971487
C16-14	0.46	-20.26	
C17-14	12.13	-8.59	-8.98610003
C18-14	11.34	-9.38	
C19-14	3.71	-17.01	-16.4303768
C20-14	4.87	-15.85	
C21-14	90.75	70.03	89.59660953
C22-14	129.88	109.16	

MDL	As ppb 0.073	Change in As	Average Change
A3-2	2.90	-52.10	-38.20507
A4-2	30.69	-24.31	
A5-2	32.63	-22.37	-37.497635
A6-2	2.38	-52.62	
A7-2	176.21	121.21	118.23675
A8-2	170.27	115.27	
A9-2	44.08	-10.92	-10.9545
A10-2	44.01	-10.99	
A11-2	166.76	111.76	126.65775
A12-2	196.55	141.55	
A13-2	48.75	-6.26	-28.4667
A14-2	4.32	-50.68	
A15-2	20.01	-34.99	-35.5422
A16-2	18.91	-36.09	
A17-2	1.58	-53.42	-52.86865
A18-2	2.68	-52.32	
A19-2	321.11	266.11	259.41785
A20-2	307.73	252.73	
A21-2	48.64	-6.36	-8.38905
A22-2	44.59	-10.41	
A3-7	18.75	-36.25	-37.3183
A4-7	16.62	-38.38	
A5-7	13.42	-41.58	-43.75655
A6-7	9.06	-45.94	
A7-7	177.31	122.31	127.6763
A8-7	188.04	133.04	
A9-7	14.54	-40.46	-42.25995
A10-7	10.94	-44.06	
A11-7	185.17	130.17	133.1005
A12-7	191.03	136.03	
A13-7	61.67	6.67	4.2425
A14-7	56.81	1.81	
A15-7	17.04	-37.96	-39.82725
A16-7	13.31	-41.69	
A17-7	1.53	-53.47	-53.6241
A18-7	1.23	-53.77	
A19-7	253.62	198.62	197.06295
A20-7	250.50	195.50	
A21-7	47.69	-7.31	-8.65815
A22-7	44.99	-10.01	
A3-14	14.10	-40.90	-40.0526543
A4-14	15.79	-39.21	
A5-14	33.13	-21.87	-23.837564
A6-14	29.19	-25.81	
A7-14	185.58	130.58	136.4563566
A8-14	197.33	142.33	
A9-14	45.56	-9.44	-9.78899386
A10-14	44.86	-10.14	
A11-14	174.00	119.00	92.93629456
A12-14	121.88	66.88	
A13-14	67.67	12.67	11.33629784
A14-14	65.00	10.00	
A15-14	13.14	-41.86	-42.6761558
A16-14	11.51	-43.49	
A17-14	2.89	-52.11	-51.7537771
A18-14	3.60	-51.40	
A19-14	298.43	243.43	232.2329355
A20-14	276.03	221.03	
A21-14	54.90	-0.10	-5.59694005
A22-14	43.91	-11.09	
B3-2	19.93	-22.07	-20.146
B4-2	23.78	-18.22	
B5-2	23.49	-18.51	-17.7479
B6-2	25.02	-16.98	
B7-2	165.48	123.48	133.3472
B8-2	185.22	143.22	
B9-2	37.40	-4.60	-10.0236
B10-2	26.55	-15.45	
B11-2	177.25	135.25	133.6462
B12-2	174.04	132.04	
B13-2	47.16	5.16	5.1944

As Concentrations

Controls

	ppb
Soil A	
A1-2	58.16
A2-2	56.55
A1-7	33.33
A2-7	57.75
A1-14	65.92
A2-14	58.52
D1	53.79
D2	55.93
Average	**54.99292**
Soil B	
B1-2	42.51
B2-2	41.65
B1-7	44.53
B2-7	41.48
B1-14	40.90
B2-14	39.23
D9	43.14
D10	44.19
Average	**42.20394**
Soil C	
C1-2	7.25
C2-2	6.51
C1-7	7.29
C2-7	7.60
C1-14	6.85
C2-14	6.98
D17	6.42
D18	6.05
Average	**6.868433**

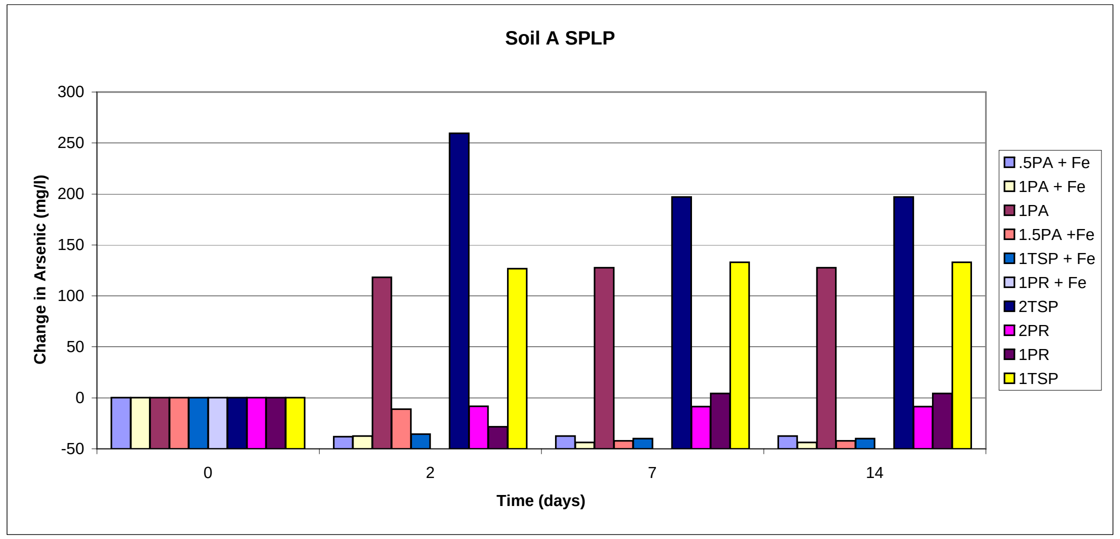
TSP leaches a lot of P

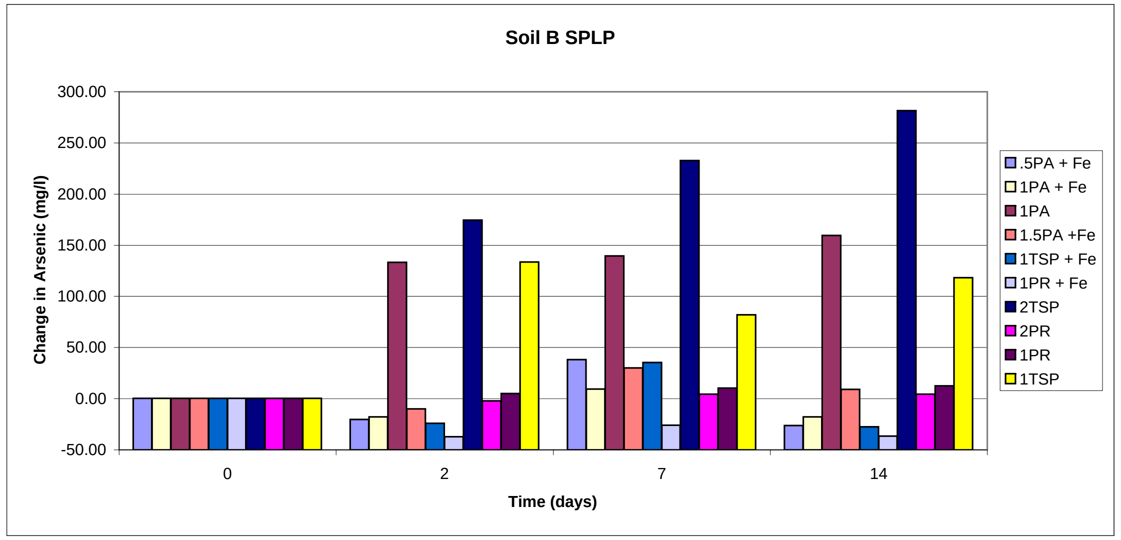
PR leaches Pb
P without Fe leaches As

	Zn ppb	**As ppb**	**Cd ppb**	**Pb ppb**
A1-2	28.41	58.16	0.36	6.66
A2-2	29.23	56.55	0.32	7.23
A1-7	19.52	33.33	0.69	3.88
A2-7	18.46	57.75	0.37	4.66
A1-14	16.10	65.92	0.16	6.00
A2-14	18.93	58.52	0.16	6.26
D-1	19.83	53.79	0.19	6.04
D-2	19.55	55.93	0.16	6.03
Average	**21.25**	**54.99**	**0.30**	**5.84**
B1-2	25.50	42.51	0.26	11.37
B2-2	25.23	41.65	0.24	11.61
B1-7	26.10	44.53	0.91	9.43
B2-7	23.33	41.48	0.30	7.64
B1-14	22.19	40.90	0.25	8.57
B2-14	24.26	39.23	0.26	8.82
D-9	26.03	43.14	0.19	10.24
D-10	27.84	44.19	0.20	13.20
Average	**25.06**	**42.20**	**0.33**	**10.11**
C1-2	14.14	7.25	0.12	17.91
C2-2	12.87	6.51	0.12	16.09
C1-7	12.02	7.29	0.63	13.89

Arsenic

		A				B				C		
		0	2	7	14	0	2	7	14	0	2	7
Series 1	.5PA + Fe	**0.301482**	-38.20507	-37.32	-37.32	**0.33**	-20.15	38.13	-26.15	**0.21**	-2.04	16.71
Series 3	1PA + Fe	**0.301482**	-37.497635	-43.76	-43.76	**0.33**	-17.75	9.53	-17.72	**0.21**	0.18	16.61
Series 5	1PA	**0.301482**	118.23675	127.68	127.68	**0.33**	133.35	139.68	159.57	**0.21**	38.45	31.73
Series 7	1.5PA +Fe	**0.301482**	-10.9545	-42.26	-42.26	**0.33**	-10.02	29.97	9.14	**0.21**	1.37	19.49
Series 9	1TSP	**0.301482**	126.65775	133.10	133.10	**0.33**	133.65	82.08	118.29	**0.21**	35.74	28.88
Series 11	1PR	**0.301482**	-28.4667	4.24	4.24	**0.33**	5.19	10.29	12.62	**0.21**	1.99	4.18
Series 13	1TSP + Fe	**0.301482**	-35.5422	-39.83	-39.83	**0.33**	-24.15	35.38	-27.44	**0.21**	-1.55	23.53
Series 15	1PR + Fe	**0.301482**	-52.86865	-53.62	-53.62	**0.33**	-37.05	-25.86	-36.49	**0.21**	-6.90	9.45
Series 17	2TSP	**0.301482**	259.41785	197.06	197.06	**0.33**	174.63	232.60	281.39	**0.21**	43.35	51.03
Series 19	2PR	**0.301482**	-8.38905	-8.66	-8.66	**0.33**	-2.02	4.45	4.48	**0.21**	1.69	1.78
		0 day	2 day	7 day	14 day		2 day	7 day	14 day		2 day	7 day





B14-2	47.23	5.23	
B15-2	17.05	-24.95	-24.15405
B16-2	18.64	-23.36	
B17-2	5.48	-36.52	-37.05285
B18-2	4.41	-37.59	
B19-2	220.51	178.51	174.6254
B20-2	212.74	170.74	
B21-2	41.07	-0.93	-2.0216
B22-2	38.89	-3.11	

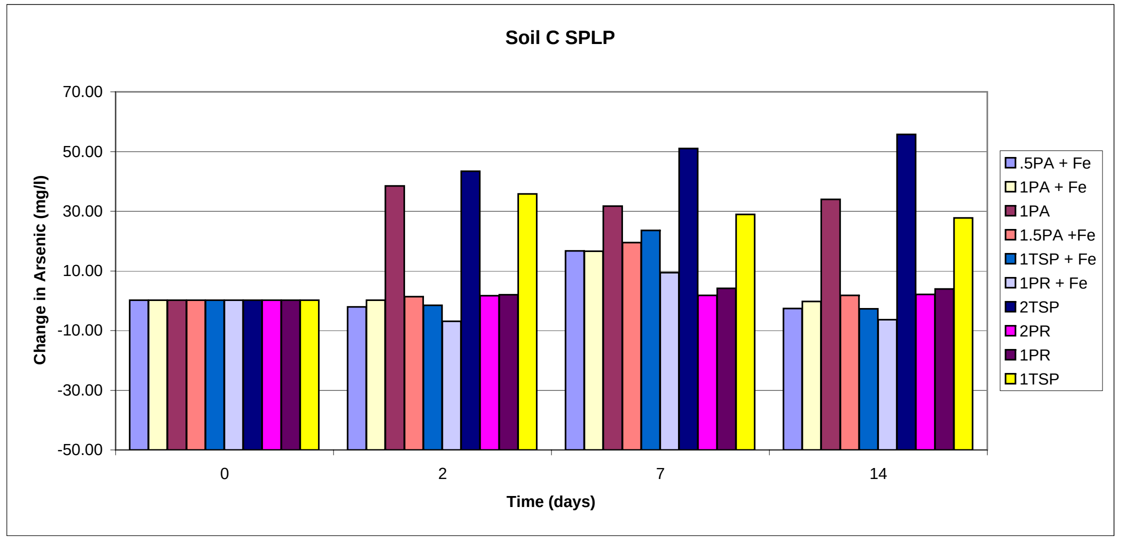
B3-7	81.98	39.98	38.12515
B4-7	78.27	36.27	
B5-7	51.81	9.81	9.53215
B6-7	51.26	9.26	
B7-7	193.97	151.97	139.68205
B8-7	169.39	127.39	
B9-7	73.95	31.95	29.9664
B10-7	69.98	27.98	
B11-7	105.94	63.94	82.07875
B12-7	142.22	100.22	
B13-7	54.26	12.26	10.2948
B14-7	50.33	8.33	
B15-7	76.62	34.62	35.38155
B16-7	78.15	36.15	
B17-7	17.22	-24.78	-25.86225
B18-7	15.06	-26.94	
B19-7	269.40	227.40	232.5999
B20-7	279.80	237.80	
B21-7	46.33	4.33	4.4496
B22-7	46.57	4.57	

B3-14	15.08	-26.92	-26.1497182
B4-14	16.62	-25.38	
B5-14	21.78	-20.22	-17.7225898
B6-14	26.78	-15.22	
B7-14	179.38	137.38	159.5669459
B8-14	223.75	181.75	
B9-14	61.38	19.38	9.13858619
B10-14	40.90	-1.10	
B11-14	161.02	119.02	118.2892487
B12-14	159.56	117.56	
B13-14	52.47	10.47	12.61759653
B14-14	56.77	14.77	
B15-14	16.84	-25.16	-27.4356743
B16-14	12.28	-29.72	
B17-14	6.12	-35.88	-36.4902164
B18-14	4.90	-37.10	
B19-14	336.71	294.71	281.3946014
B20-14	310.08	268.08	
B21-14	48.27	6.27	4.483235161
B22-14	44.70	2.70	

C3-2	4.05	-2.85	-2.0410898
C4-2	5.67	-1.23	
C5-2	7.13	0.23	0.1835712
C6-2	7.04	0.14	
C7-2	47.25	40.35	38.4471744
C8-2	43.44	36.54	
C9-2	7.80	0.90	1.3684416
C10-2	8.74	1.84	
C11-2	40.87	33.97	35.7435584
C12-2	44.42	37.52	
C13-2	9.36	2.46	1.9879104
C14-2	8.42	1.52	
C15-2	5.34	-1.56	-1.5461452
C16-2	5.37	-1.53	
C17-2	0.00	-6.90	-6.9
C18-2	0.00	-6.90	
C19-2	53.38	46.48	43.35455
C20-2	47.13	40.23	
C21-2	8.87	1.97	1.69225
C22-2	8.31	1.41	

C3-7	20.42	13.52	16.7067
C4-7	26.80	19.90	
C5-7	23.58	16.68	16.6113
C6-7	23.44	16.54	
C7-7	35.55	28.65	31.73305
C8-7	41.71	34.81	
C9-7	30.08	23.18	19.4915

C2-7	12.83	7.60	0.18	15.34
C1-14	11.09	6.85	0.14	18.15
C2-14	12.43	6.98	0.15	16.24
D-17		6.42	0.19	43.55
D-18	14.06	6.05	0.15	24.58
Average	**12.78**	**6.87**	**0.21**	**20.72**
	141.26			



C10-7	22.70	15.80	
C11-7	39.58	32.68	28.8822
C12-7	31.99	25.09	
C13-7	10.89	3.99	4.1766
C14-7	11.27	4.37	
C15-7	27.53	20.63	23.5275
C16-7	33.33	26.43	
C17-7	15.33	8.43	9.44615
C18-7	17.36	10.46	
C19-7	57.47	50.57	51.03455
C20-7	58.40	51.50	
C21-7	8.28	1.38	1.7758
C22-7	9.07	2.17	

C3-14	4.02	-2.88	-2.57684192
C4-14	4.63	-2.27	
C5-14	5.23	-1.67	-0.19718147
C6-14	8.18	1.28	
C7-14	40.24	33.34	33.93622787
C8-14	41.43	34.53	
C9-14	7.85	0.95	1.800762449
C10-14	9.55	2.65	
C11-14	34.19	27.29	27.71721365
C12-14	35.04	28.14	
C13-14	11.46	4.56	3.902684587
C14-14	10.15	3.25	
C15-14	4.09	-2.81	-2.66877487
C16-14	4.37	-2.53	
C17-14	0.00	-6.90	-6.32192737
C18-14	1.16	-5.74	
C19-14	70.07	63.17	55.76947272
C20-14	55.27	48.37	
C21-14	8.03	1.13	2.156717484
C22-14	10.09	3.19	

MDL	P ppm 0.073	Change in P	Average Change
A3-2	4.498	3.56575	2.89175
A4-2	3.15	2.21775	
A5-2	8.333	7.40075	6.58775
A6-2	6.707	5.77475	
A7-2	25.653	24.72075	23.16875
A8-2	22.549	21.61675	
A9-2	15.08	14.14775	13.46825
A10-2	13.721	12.78875	
A11-2	28.809	27.87675	36.36225
A12-2	45.78	44.84775	
A13-2	0.624	-0.30825	-0.25925
A14-2	0.722	-0.21025	
A15-2	8.562	7.62975	8.28775
A16-2	9.878	8.94575	
A17-2	0.225	-0.70725	-0.72925
A18-2	0.181	-0.75125	
A19-2	240.21	239.27775	237.04225
A20-2	235.739	234.80675	
A21-2	0.864	-0.06825	-0.12325
A22-2	0.754	-0.17825	
A3-7	2.285	1.35275	1.64475
A4-7	2.869	1.93675	
A5-7	3.052	2.11975	1.12875
A6-7	1.07	0.13775	
A7-7	38.323	37.39075	38.83475
A8-7	41.211	40.27875	
A9-7	2.109	1.17675	0.86475
A10-7	1.485	0.55275	
A11-7	22.834	21.90175	24.76825
A12-7	28.567	27.63475	
A13-7	0.761	-0.17125	-0.14725
A14-7	0.809	-0.12325	
A15-7	5.464	4.53175	5.50475
A16-7	7.41	6.47775	
A17-7	0.12	-0.81225	-0.81675
A18-7	0.111	-0.82125	
A19-7	113.963	113.03075	105.12275
A20-7	98.147	97.21475	
A21-7	0.762	-0.17025	-0.19525
A22-7	0.712	-0.22025	
A3-14	1.508	0.57575	0.63775
A4-14	1.632	0.69975	
A5-14	10.348	9.41575	6.69575
A6-14	4.908	3.97575	
A7-14	19.103	18.17075	18.48375
A8-14	19.729	18.79675	
A9-14	16.233	15.30075	15.34075
A10-14	16.313	15.38075	
A11-14	11.817	10.88475	6.66475
A12-14	3.377	2.44475	
A13-14	0.771	-0.16125	-0.18825
A14-14	0.717	-0.21525	
A15-14	3.578	2.64575	2.23575
A16-14	2.758	1.82575	
A17-14	0.21	-0.72225	-0.73025
A18-14	0.194	-0.73825	
A19-14	59.574	58.64175	54.82125
A20-14	51.933	51.00075	
A21-14	0.736	-0.19625	-0.28225
A22-14	0.564	-0.36825	
B3-2	2.455	1.74575	1.86775
B4-2	2.699	1.98975	
B5-2	8.396	7.68675	7.51275
B6-2	8.048	7.33875	
B7-2	26.194	25.48475	25.10725
B8-2	25.439	24.72975	
B9-2	20.375	19.66575	15.72725
B10-2	12.498	11.78875	
B11-2	31.159	30.44975	30.99675
B12-2	32.253	31.54375	
B13-2	0.719	0.00975	0.01275

P Concentrations

Controls

	ppm
Soil A	
A1-14	1.036
A2-14	0.915
A1-2	1.02
A2-2	0.986
A1-7	0.649
A2-7	0.906
Average	**0.918667**
Stdev	**0.142452**
Soil B	
B1-14	0.688
B2-14	0.652
B1-2	0.711
B2-2	0.68
B1-7	0.73
B2-7	0.668
Average	**0.688167**
Stdev	**0.02847**
Soil C	
C1-14	0.283
C2-14	0.295
C1-2	0.298
C2-2	0.309
C1-7	0.359
C2-7	0.37
Average	**0.319**
Stdev	**0.03637**

TSP leaches a lot of P

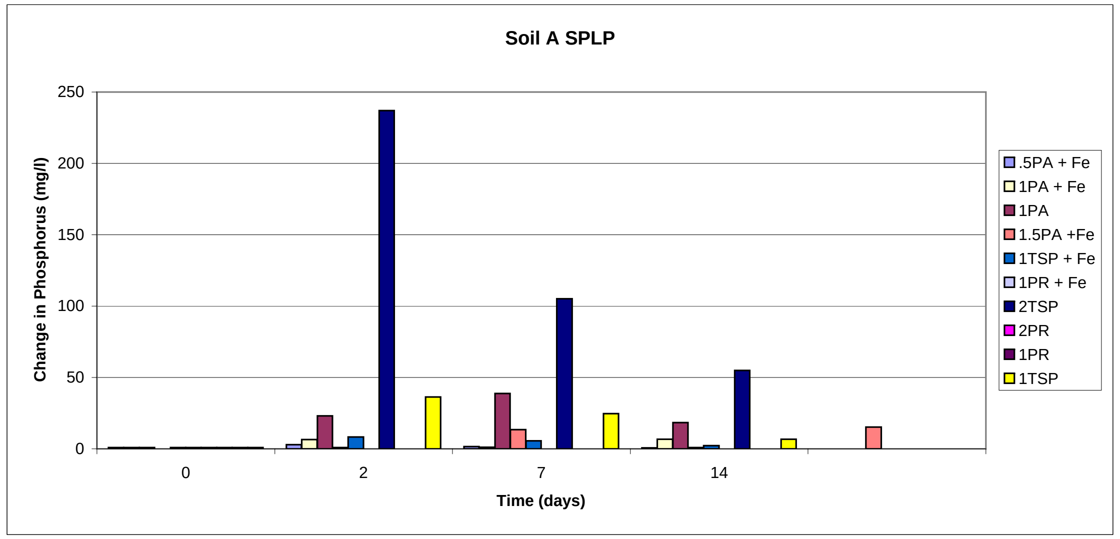
PR leaches Pb

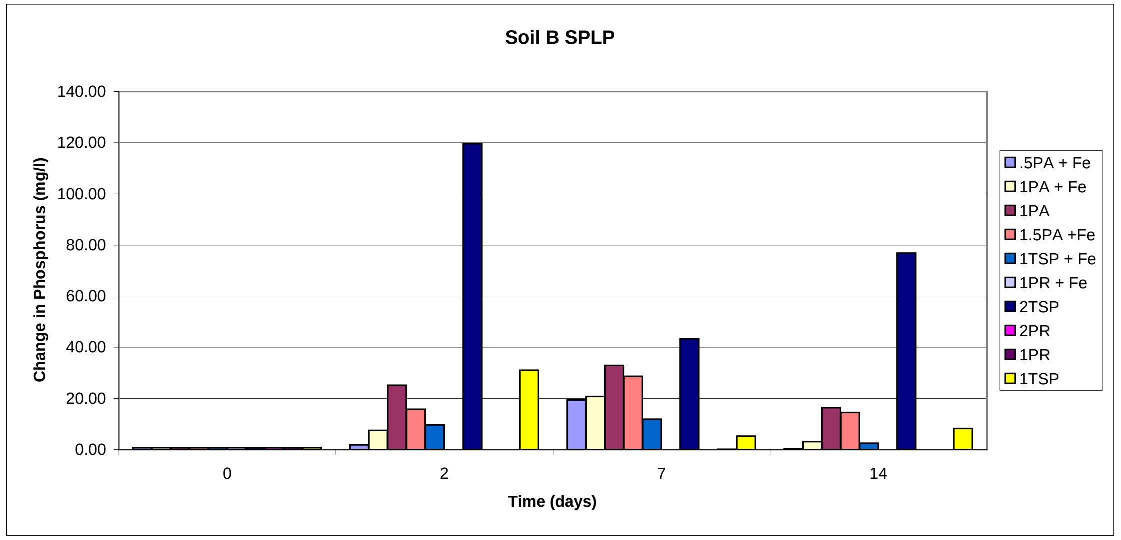
P without Fe leaches As

	Zn ppb	**As ppb**	**Cd ppb**	**Pb ppb**
A1-2	28.41	58.16	0.36	6.66
A2-2	29.23	56.55	0.32	7.23
A1-7	19.52	33.33	0.69	3.88
A2-7	18.46	57.75	0.37	4.66
A1-14	16.10	65.92	0.16	6.00
A2-14	18.93	58.52	0.16	6.26
D-1	19.83	53.79	0.19	6.04
D-2	19.55	55.93	0.16	6.03
Average	**21.25**	**54.99**	**0.30**	**5.84**
B1-2	25.50	42.51	0.26	11.37
B2-2	25.23	41.65	0.24	11.61
B1-7	26.10	44.53	0.91	9.43
B2-7	23.33	41.48	0.30	7.64
B1-14	22.19	40.90	0.25	8.57
B2-14	24.26	39.23	0.26	8.82
D-9	26.03	43.14	0.19	10.24
D-10	27.84	44.19	0.20	13.20
Average	**25.06**	**42.20**	**0.33**	**10.11**
C1-2	14.14	7.25	0.12	17.91
C2-2	12.87	6.51	0.12	16.09
C1-7	12.02	7.29	0.63	13.89

Phosphorous

		A				B				C			
		0	2	7	14	0	2	7	14	0	2	7	14
Series 1	.5PA + Fe	**0.93225**	2.89175	1.64	0.64	**0.71**	1.87	19.35	0.43	**0.32**	2.16	7.42	0.54
Series 3	1PA + Fe	**0.93225**	6.58775	1.13	6.70	**0.71**	7.51	20.82	3.19	**0.32**	6.02	20.80	2.71
Series 5	1PA	**0.93225**	23.16875	38.83	18.48	**0.71**	25.11	32.91	16.39	**0.32**	28.45	9.39	11.20
Series 7	1.5PA +Fe	**0.93225**	13.46825	0.86	15.34	**0.71**	15.73	28.70	14.47	**0.32**	9.57	30.09	4.80
Series 9	1TSP	**0.93225**	36.36225	24.77	6.66	**0.71**	31.00	5.22	8.28	**0.32**	37.78	9.19	6.84
Series 11	1PR	**0.93225**	-0.25925	-0.15	-0.19	**0.71**	0.01	0.07	-0.06	**0.32**	0.06	0.11	0.03
Series 13	1TSP + Fe	**0.93225**	8.28775	5.50	2.24	**0.71**	9.65	11.84	2.48	**0.32**	7.19	13.34	1.47
Series 15	1PR + Fe	**0.93225**	-0.72925	-0.82	-0.73	**0.71**	-0.50	-0.03	-0.53	**0.32**	-0.21	1.91	-0.22
Series 17	2TSP	**0.93225**	237.04225	105.12	54.82	**0.71**	119.62	43.30	76.81	**0.32**	106.15	25.64	70.64
Series 19	2PR	**0.93225**	-0.12325	-0.20	-0.28	**0.71**	0.00	0.01	-0.08	**0.32**	0.12	0.07	0.01
		0 day	2 day	7 day	14 day		2 day	7 day	14 day		2 day	7 day	14 day





B14-2	0.725	0.01575	
B15-2	8.322	7.61275	9.64675
B16-2	12.39	11.68075	
B17-2	0.197	-0.51225	-0.49825
B18-2	0.225	-0.48425	
B19-2	118.67	117.96075	119.61625
B20-2	121.981	121.27175	
B21-2	0.732	0.02275	-0.00075
B22-2	0.685	-0.02425	

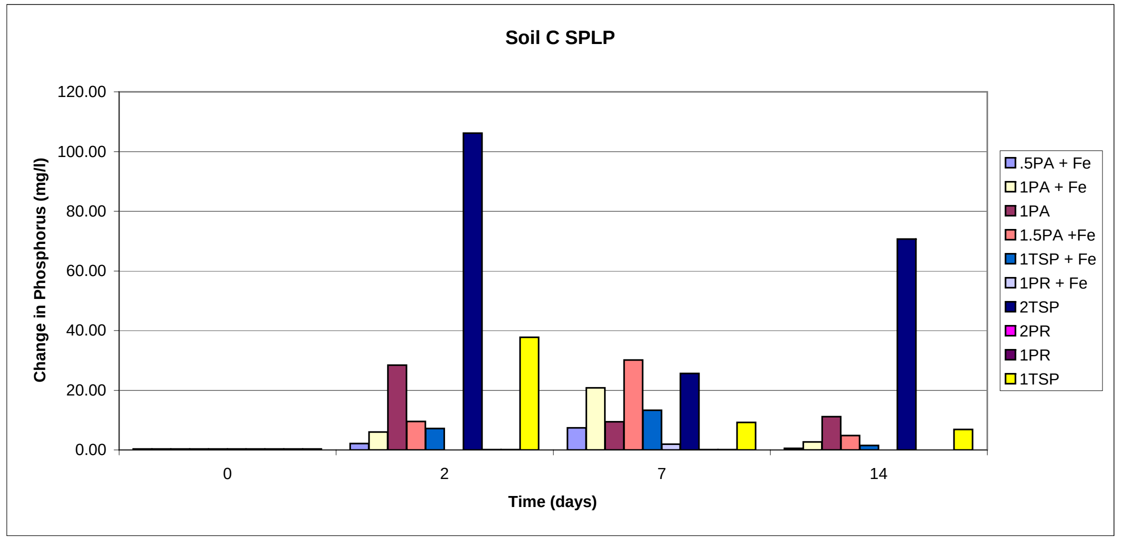
B3-7	23.816	23.10675	19.35125
B4-7	16.305	15.59575	
B5-7	24.184	23.47475	20.82325
B6-7	18.881	18.17175	
B7-7	37.428	36.71875	32.91425
B8-7	29.819	29.10975	
B9-7	45.264	44.55475	28.69925
B10-7	13.553	12.84375	
B11-7	3.516	2.80675	5.21725
B12-7	8.337	7.62775	
B13-7	0.817	0.10775	0.06525
B14-7	0.732	0.02275	
B15-7	13.258	12.54875	11.84225
B16-7	11.845	11.13575	
B17-7	0.694	-0.01525	-0.02625
B18-7	0.672	-0.03725	
B19-7	46.641	45.93175	43.29525
B20-7	41.368	40.65875	
B21-7	0.707	-0.00225	0.01175
B22-7	0.735	0.02575	

B3-14	0.962	0.25275	0.42525
B4-14	1.307	0.59775	
B5-14	2.989	2.27975	3.18775
B6-14	4.805	4.09575	
B7-14	13.077	12.36775	16.39225
B8-14	21.126	20.41675	
B9-14	19.151	18.44175	14.46625
B10-14	11.2	10.49075	
B11-14	8.904	8.19475	8.28075
B12-14	9.076	8.36675	
B13-14	0.661	-0.04825	-0.06025
B14-14	0.637	-0.07225	
B15-14	4.094	3.38475	2.48225
B16-14	2.289	1.57975	
B17-14	0.161	-0.54825	-0.53175
B18-14	0.194	-0.51525	
B19-14	89.257	88.54775	76.80625
B20-14	65.774	65.06475	
B21-14	0.629	-0.08025	-0.07625
B22-14	0.637	-0.07225	

C3-2	2.275	1.95575	2.15525
C4-2	2.674	2.35475	
C5-2	6.868	6.54875	6.01825
C6-2	5.807	5.48775	
C7-2	28.356	28.03675	28.44875
C8-2	29.18	28.86075	
C9-2	7.973	7.65375	9.56575
C10-2	11.797	11.47775	
C11-2	38.237	37.91775	37.77525
C12-2	37.952	37.63275	
C13-2	0.402	0.08275	0.06425
C14-2	0.365	0.04575	
C15-2	6.668	6.34875	7.18675
C16-2	8.344	8.02475	
C17-2	0.102	-0.21725	-0.21425
C18-2	0.108	-0.21125	
C19-2	119.842	119.52275	106.15275
C20-2	93.102	92.78275	
C21-2	0.445	0.12575	0.12075
C22-2	0.435	0.11575	

C3-7	6.252	5.93275	7.42275
C4-7	9.232	8.91275	
C5-7	23.203	22.88375	20.79975
C6-7	19.035	18.71575	
C7-7	7.579	7.25975	9.39425
C8-7	11.848	11.52875	
C9-7	35.21	34.89075	30.09025

C2-7	12.83	7.60	0.18	15.34
C1-14	11.09	6.85	0.14	18.15
C2-14	12.43	6.98	0.15	16.24
D-17		6.42	0.19	43.55
D-18	14.06	6.05	0.15	24.58
Average	**12.78**	**6.87**	**0.21**	**20.72**
	141.26			



C10-7	25.609	25.28975	
C11-7	10.883	10.56375	9.18975
C12-7	8.135	7.81575	
C13-7	0.415	0.09575	0.11325
C14-7	0.45	0.13075	
C15-7	12.767	12.44775	13.34475
C16-7	14.561	14.24175	
C17-7	2.266	1.94675	1.90675
C18-7	2.186	1.86675	
C19-7	25.994	25.67475	25.63825
C20-7	25.921	25.60175	
C21-7	0.401	0.08175	0.07325
C22-7	0.384	0.06475	

C3-14	0.862	0.54275	0.53825
C4-14	0.853	0.53375	
C5-14	2.464	2.14475	2.70775
C6-14	3.59	3.27075	
C7-14	10.711	10.39175	11.20225
C8-14	12.332	12.01275	
C9-14	5.029	4.70975	4.80075
C10-14	5.211	4.89175	
C11-14	7.417	7.09775	6.84275
C12-14	6.907	6.58775	
C13-14	0.373	0.05375	0.03075
C14-14	0.327	0.00775	
C15-14	1.258	0.93875	1.46975
C16-14	2.32	2.00075	
C17-14	0.085	-0.23425	-0.22075
C18-14	0.112	-0.20725	
C19-14	57.335	57.01575	70.63575
C20-14	84.575	84.25575	
C21-14	0.306	-0.01325	0.00775
C22-14	0.348	0.02875	

In Vitro-Pb pH1.5

	%IVBA	Change in IVBA	Average Change
A-3-2 1.5	81.4	1.9	3.7
A-4-2 1.5	85.1	5.6	
A-5-2 1.5	77.5	-2.0	1.7
A-6-2 1.5	85.0	5.4	
A-7-2 1.5	90.6	11.1	11.1
A-8-2 1.5	90.6	11.1	
A-9-2 1.5	82.2	2.7	2.1
A-10-2 1.5	81.1	1.5	
A-11-2 1.5	88.4	8.8	7.7
A-12-2 1.5	86.1	6.6	
A-13-2 1.5	93.8	14.3	10.8
A-14-2 1.5	86.8	7.3	
A-15-2 1.5	85.7	6.2	3.9
A-16-2 1.5	81.1	1.6	
A-17-2 1.5	82.0	2.5	2.5
A-18-2 1.5	82.0	2.5	
A-19-2 1.5	88.9	9.4	10.5
A-20-2 1.5	91.1	11.6	
A-21-2 1.5	85.9	6.4	7
A-22-2 1.5	87.2	7.6	
A3-7 1.5	88.8	9.2	5.9
A4-7 1.5	82.2	2.6	
A5-7 1.5	82.8	3.3	1.6
A6-7 1.5	79.4	-0.1	
A7-7 1.5	86.0	6.5	7
A8-7 1.5	87.2	7.6	
A9-7 1.5	79.0	-0.5	-0.5
A10-7 1.5	79.0	-0.5	
A11-7 1.5	87.7	8.2	8.3
A12-7 1.5	88.0	8.5	
A13-7 1.5	88.7	9.1	5.8
A14-7 1.5	82.0	2.5	
A15-7 1.5	84.1	4.6	4.6
A16-7 1.5			
A17-7 1.5	87.3	7.8	4.6
A18-7 1.5	81.0	1.5	
A19-7 1.5	81.2	1.7	4.3
A20-7 1.5	86.5	6.9	
A21-7 1.5	89.4	9.9	8.3
A22-7 1.5	86.2	6.7	
A3-14 1.5	80.2	0.6	-2
A4-14 1.5	74.8	-4.7	
A5-14 1.5	73.1	-6.4	-7.2
A6-14 1.5	71.5	-8.0	
A7-14 1.5	72.6	-6.9	-3.3
A8-14 1.5	79.8	0.3	
A9-14 1.5	60.4	-19.1	-20.3
A10-14 1.5	57.9	-21.6	
A11-14 1.5	74.3	-5.3	-3.2
A12-14 1.5	78.3	-1.2	
A13-14 1.5	79.6	0.1	0.75
A14-14 1.5	80.9	1.4	
A15-14 1.5	76.7	-2.9	-1.4
A16-14 1.5	79.6	0.1	
A17-14 1.5	76.8	-2.7	-0.75
A18-14 1.5	80.8	1.2	
A19-14 1.5	80.3	0.8	-1.6
A20-14 1.5	75.4	-4.1	
A21-14 1.5	79.9	0.4	-0.45
A22-14 1.5	78.2	-1.3	

93205 400-800ppm Pb

Controls

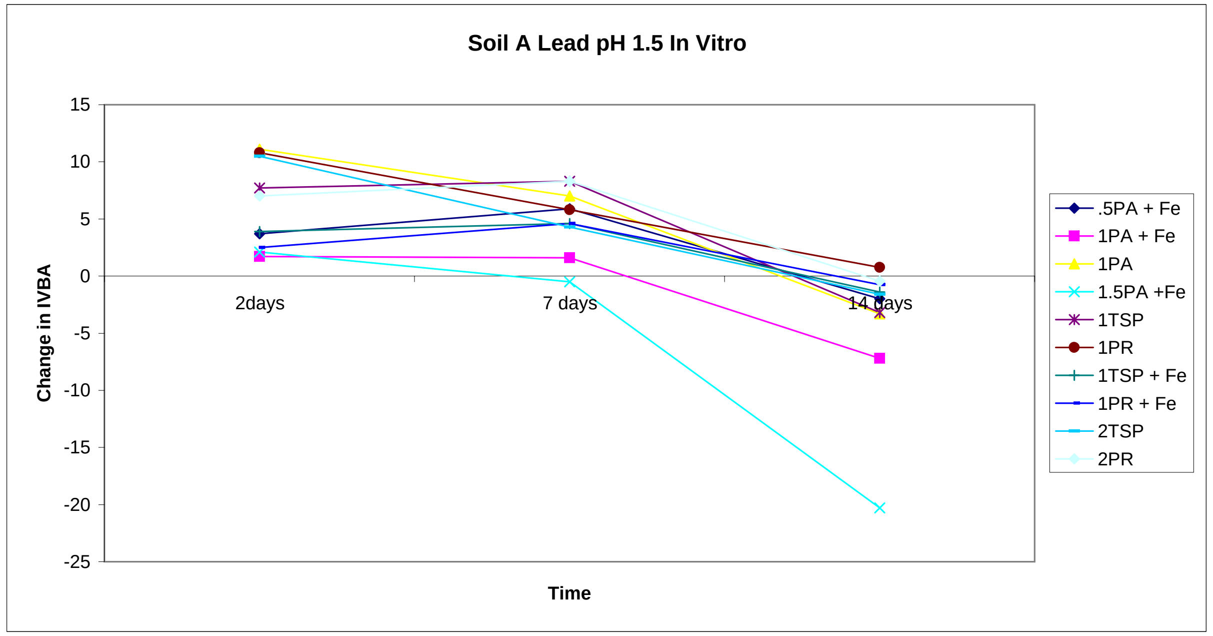
In Vitro-Pb pH1.5

A-1-2 1.5	83.5
A-2-2 1.5	80.6
A1-7 1.5	82.6
A2-7 1.5	77.8
A1-14 1.5	76.8
A2-14 1.5	76.9
D-1 1.5	79.4
D-2 1.5	78.7
Average	**79.5**
Standard Dev.	**2.530773**

In Vitro-Pb pH 2.5

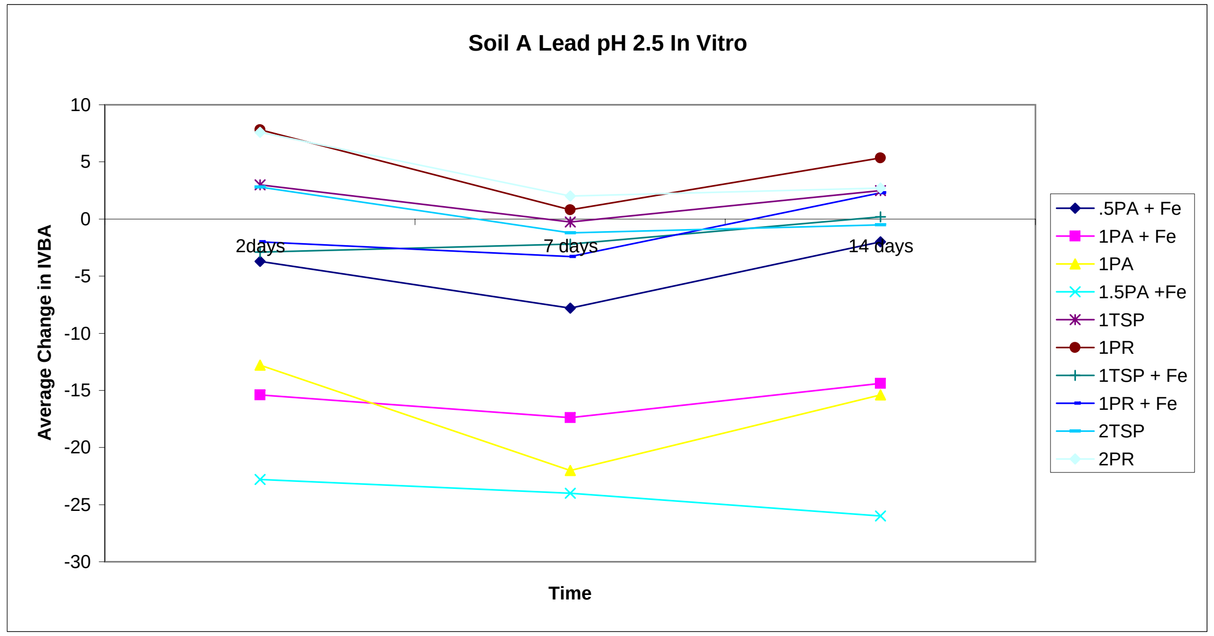
A1-2 2.5	42.0
A2-2 2.5	42.9
A1-7 2.5	37.6
A2-7 2.5	36.9
A1-14 2.5	43
A2-14 2.5	41
D-1	40.3
D-2	40.3
Average	**40.5**
Standard Dev.	**2.246352**

	pH 1.5			**pH 2.5**		
.5PA + Fe	3.7	5.9	-2	-3.7	-7.8	-2
1PA + Fe	1.7	1.6	-7.2	-15.4	-17.4	-14.4
1PA	11.1	7	-3.3	-12.8	-22	-15.4
1.5PA +Fe	2.1	-0.5	-20.3	-22.8	-24	-26
1TSP	7.7	8.3	-3.2	3	-0.25	2.5
1PR	10.8	5.8	0.75	7.8	0.8	5.35
1TSP + Fe	3.9	4.6	-1.4	-2.9	-2.2	0.2
1PR + Fe	2.5	4.6	-0.75	-2	-3.3	2.3
2TSP	10.5	4.3	-1.6	2.8	-1.2	-0.5
2PR	7	8.3	-0.45	7.6	2	2.7
	2days	7 days	14 days			



In Vitro-Pb pH 2.5

A3-2 2.5	36.9	-3.5	-3.7
A4-2 2.5	36.5	-3.9	
A5-2 2.5	25.8	-14.6	-15.4
A6-2 2.5	24.4	-16.1	
A7-2 2.5	28.4	-12.1	-12.8
A8-2 2.5	27.1	-13.4	
A9-2 2.5	18.0	-22.4	-22.8
A10-2 2.5	17.2	-23.3	
A11-2 2.5	42.7	2.3	3
A12-2 2.5	44.2	3.7	
A13-2 2.5	48.8	8.3	7.8
A14-2 2.5	47.8	7.3	
A15-2 2.5	38.2	-2.2	-2.9
A16-2 2.5	37.0	-3.5	
A17-2 2.5	38.0	-2.5	-2
A18-2 2.5	39.1	-1.4	
A-19-2 2.5	36.3	-4.1	2.8
A-20-2 2.5	38.9	-1.5	
A-21-2 2.5	46.9	6.4	7.6
A-22-2 2.5	49.3	8.8	



A3-7 2.5	34.8	-5.6	-7.8
A4-7 2.5	30.4	-10.1	
A5-7 2.5	22.1	-18.4	-17.4
A6-7 2.5	24.0	-16.5	
A7-7 2.5	19.6	-20.9	-22
A8-7 2.5	17.3	-23.1	
A9-7 2.5	15.2	-25.3	-24
A10-7 2.5	17.5	-23.0	
A11-7 2.5	40.4	-0.1	-0.25
A12-7 2.5	40.0	-0.4	
A13-7 2.5	43.1	2.7	0.8
A14-7 2.5	39.4	-1.1	
A15-7 2.5	37.1	-3.4	-2.2
A16-7 2.5	37.8	-2.7	
A17-7 2.5	37.3	-3.1	-3.3
A18-7 2.5	36.8	-3.7	
A19-7 2.5	38.8	-1.7	-1.2
A20-7 2.5	39.9	-0.6	
A21-7 2.5	45.1	4.7	2
A22-7 2.5	43.6	3.1	

A3-14 2.5	37	-3.1	-2
A4-14 2.5	39	-1.0	
A5-14 2.5	25	-15.0	-14.4
A6-14 2.5	27	-13.8	
A7-14 2.5	22	-18.0	-15.4
A8-14 2.5	28	-12.9	
A9-14 2.5	14	-26.9	-26
A10-14 2.5	15	-25.1	
A11-14 2.5	42	1.6	2.5
A12-14 2.5	44	3.4	
A13-14 2.5	46	5.4	5.35
A14-14 2.5	46	5.3	
A15-14 2.5	40	-0.6	0.2
A16-14 2.5	41	1.0	
A17-14 2.5	43	2.5	2.3
A18-14 2.5	43	2.1	
A19-14 2.5	41	0.3	-0.5
A20-14 2.5	39	-1.3	
A21-14 2.5	45	4.5	2.7
A22-14 2.5	41	0.9	

In Vitro-Pb pH 1.5	%IVBA	Change in IVBA	Average Change
B-3-2 1.5	82.5	-3.2	-2.3
B-4-2 1.5	84.2	-1.5	
B-5-2 1.5	85.8	0.1	-2.5
B-6-2 1.5	80.6	-5.1	
B-7-2 1.5	88.5	2.8	0.65
B-8-2 1.5	84.2	-1.5	
B-9-2 1.5	78.1	-7.6	-6.4
B-10-2 1.5	80.5	-5.2	
B-11-2 1.5	85.0	-0.7	1.1
B-12-2 1.5	88.7	3.0	
B-13-2 1.5	85.7	0.0	2.5
B-14-2 1.5	90.6	4.9	
B-15-2 1.5	87.0	1.3	-0.75
B-16-2 1.5	82.9	-2.8	
B-17-2 1.5	86.8	1.1	0.6
B-18-2 1.5	85.8	0.1	
B-19-2 1.5	90.2	4.5	0.85
B-20-2 1.5	82.9	-2.8	
B-21-2 1.5	89.2	3.4	3.3
B-22-2 1.5	88.9	3.2	
B3-7 1.5	83.6	-2.1	-1.1
B4-7 1.5	85.7	0.0	
B5-7 1.5	80.6	-5.1	-4.2
B6-7 1.5	82.4	-3.3	
B7-7 1.5	84.7	-1.0	-2.1
B8-7 1.5	82.4	-3.3	
B9-7 1.5	82.9	-2.8	-5.3
B10-7 1.5	77.8	-7.9	
B11-7 1.5	80.5	-5.3	-2.1
B12-7 1.5	86.9	1.1	
B13-7 1.5	85.1	-0.6	-0.55
B14-7 1.5	85.2	-0.5	
B15-7 1.5	84.3	-1.4	-3.5
B16-7 1.5	80.2	-5.5	
B17-7 1.5	81.9	-3.8	-7.3
B18-7 1.5	74.8	-10.9	
B19-7 1.5	79.6	-6.1	-5.5
B20-7 1.5	80.8	-4.9	
B21-7 1.5	79.4	-6.3	-4.9
B22-7 1.5	82.1	-3.6	
B3-14 1.5	83.4	-2.3	-3.1
B4-14 1.5	81.9	-3.8	
B5-14 1.5	85.1	-0.7	-1.25
B6-14 1.5	83.9	-1.8	
B7-14 1.5	94.7	9.0	5.3
B8-14 1.5	87.3	1.6	
B9-14 1.5	71.5	-14.2	-16
B10-14 1.5	67.8	-17.9	
B11-14 1.5	91.2	5.5	5.2
B12-14 1.5	90.7	5.0	
B13-14 1.5	91.5	5.8	4.4
B14-14 1.5	88.7	3.0	
B15-14 1.5	87.6	1.9	0.4
B16-14 1.5	84.6	-1.1	
B17-14 1.5	85.3	-0.4	-0.3
B18-14 1.5	85.5	-0.2	
B19-14 1.5	88.9	3.2	4.5
B20-14 1.5	91.6	5.9	

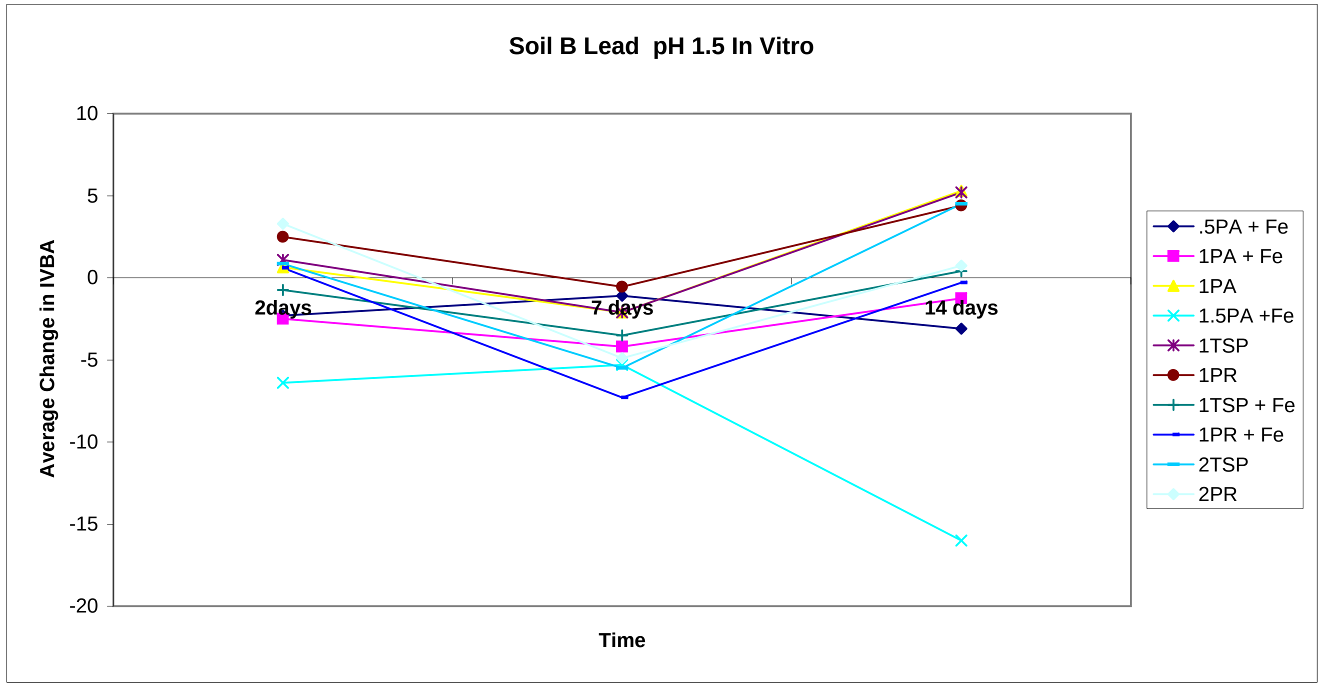
93206 >1000 PPM Pb

Controls

In Vitro-Pb pH1.5	
B-1-2 1.5	82.2
B-2-2 1.5	90.6
B1-7 1.5	87.7
B2-7 1.5	84.8
B1-14 1.5	86.1
B2-14 1.5	83.3
D-9 1.5	74.7
D-10 1.5	96.3
Average	**85.7**
Standard Dev.	**6.318617**

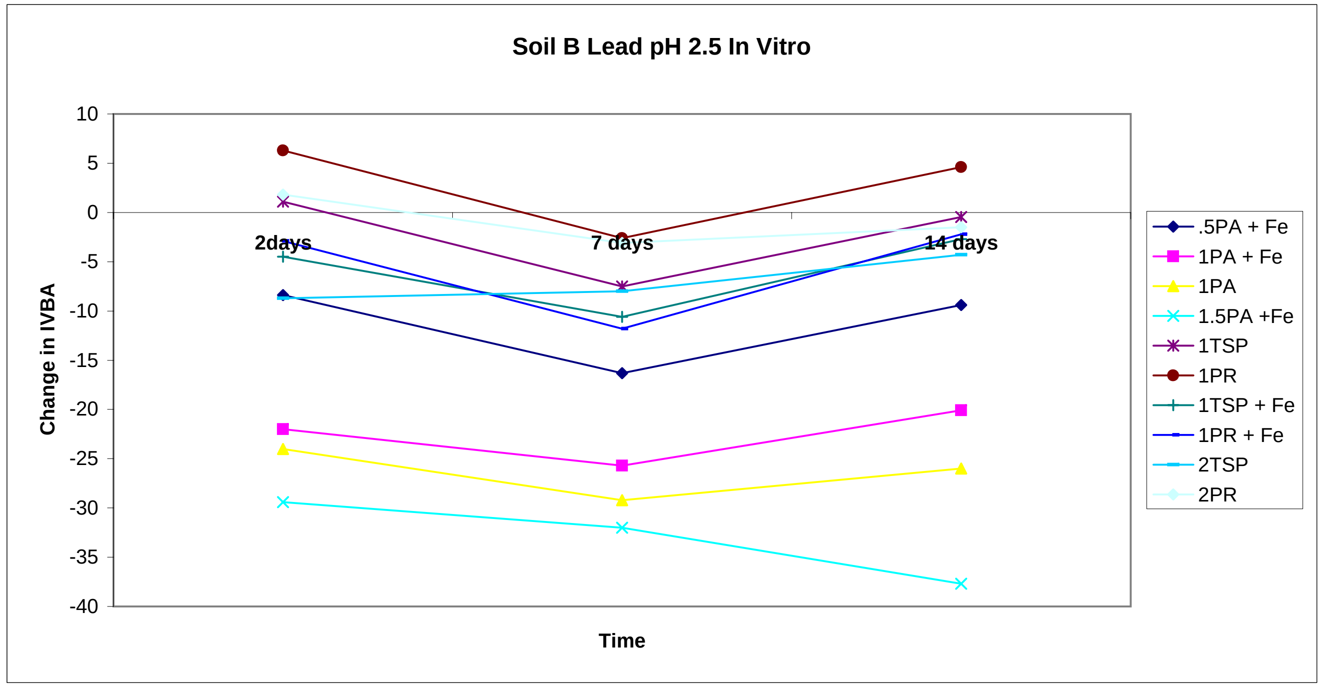
In Vitro-Pb pH 2.5	
B-1-2 2.5	50.7
B-2-2 2.5	53.3
B1-7 2.5	44.2
B2-7 2.5	44.2
B1-14 2.5	49.7
B2-14 2.5	50.3
D-9 2.5	46.9
D-10 2.5	55.8
Average	**49.4**
Standard Dev.	**4.11063**

	pH 1.5			pH 2.5		
.5PA + Fe	-2.3	-1.1	-3.1	-8.4	-16.3	-9.4
1PA + Fe	-2.5	-4.2	-1.25	-22	-25.7	-20.1
1PA	0.65	-2.1	5.3	-24	-29.2	-26
1.5PA +Fe	-6.4	-5.3	-16	-29.4	-32	-37.7
1TSP	1.1	-2.1	5.2	1.1	-7.5	-0.45
1PR	2.5	-0.55	4.4	6.3	-2.6	4.6
1TSP + Fe	-0.75	-3.5	0.4	-4.5	-10.6	-2.7
1PR + Fe	0.6	-7.3	-0.3	-2.9	-11.8	-2.2
2TSP	0.85	-5.5	4.5	-8.7	-8	-4.3
2PR	3.3	-4.9	0.75	1.8	-3.1	-1.5
	2days	7 days	14 days			



B21-14 1.5	87.2	1.5	0.75
B22-14 1.5	85.7	0.0	

In Vitro-Pb pH 2.5



B-3-2 2.5	38.9	-10.5	-8.4
B-4-2 2.5	43.0	-6.3	
B-5-2 2.5	28.5	-20.9	-22
B-6-2 2.5	26.2	-23.2	
B-7-2 2.5	25.2	-24.2	-24
B-8-2 2.5	25.3	-24.1	
B-9-2 2.5	19.5	-29.9	-29.4
B-10-2 2.5	20.4	-29.0	
B-11-2 2.5	49.1	-0.3	1.1
B-12-2 2.5	51.8	2.4	
B-13-2 2.5	53.8	4.4	6.3
B-14-2 2.5	57.7	8.3	
B-15-2 2.5	46.7	-2.7	-4.5
B-16-2 2.5	43.1	-6.3	
B-17-2 2.5	47.1	-2.2	-2.9
B-18-2 2.5	45.8	-3.6	
B-19-2 2.5	42.2	-7.1	-8.7
B-20-2 2.5	39.1	-10.3	
B-21-2 2.5	50.6	1.2	1.8
B-22-2 2.5	51.9	2.5	

B3-7 2.5	30.3	-19.1	-16.3
B4-7 2.5	35.7	-13.6	
B5-7 2.5	22.0	-27.4	-25.7
B6-7 2.5	25.3	-24.1	
B7-7 2.5	19.3	-30.1	-29.2
B8-7 2.5	21.1	-28.3	
B9-7 2.5	13.4	-36.0	-32
B10-7 2.5	21.4	-28.0	
B11-7 2.5	40.7	-8.7	-7.5
B12-7 2.5	43.1	-6.3	
B13-7 2.5	45.6	-3.8	-2.6
B14-7 2.5	48.0	-1.4	
B15-7 2.5	37.3	-12.1	-10.6
B16-7 2.5	40.1	-9.2	
B17-7 2.5	37.3	-12.1	-11.8
B18-7 2.5	37.8	-11.6	
B19-7 2.5	41.5	-7.9	-8
B20-7 2.5	41.2	-8.2	
B21-7 2.5	47.0	-2.3	-3.1
B22-7 2.5	45.4	-3.9	

B3-14 2.5	40.2	-9.2	-9.4
B4-14 2.5	39.7	-9.7	
B5-15 2.5	29.7	-19.7	-20.1
B6-14 2.5	28.9	-20.5	
B7-14 2.5	24.1	-25.3	-26
B8-14 2.5	22.6	-26.8	
B9-14 2.5	13.5	-35.9	-37.7
B10-14 2.5	10.0	-39.4	
B11-14 2.5	50.2	0.8	-0.45
B12-14 2.5	47.7	-1.7	
B13-14 2.5	53.9	4.5	4.6
B14-14 2.5	54.1	4.7	
B15-14 2.5	47.4	-1.9	-2.7
B16-14 2.5	45.8	-3.6	

B17-14 2.5	47.6	-1.8	-2.2
B18-14 2.5	46.8	-2.5	
B19-14 2.5	44.8	-4.6	-4.3
B20-14 2.5	45.4	-4.0	
B21-14-2.5	49.1	-0.3	-1.5
B22-14 2.5	46.7	-2.7	

In Vitro-Pb pH1.5

	%IVBA	Change in IVBA	Average Change
C-3-2 1.5	92.7	3.9	2.2
C-4-2 1.5	89.4	0.5	
C-5-2 1.5	86.0	-2.8	-3
C-6-2 1.5	85.6	-3.2	
C-7-2 1.5	92.8	4.0	2.6
C-8-2 1.5	90.2	1.3	
C-9-2 1.5	84.1	-4.8	-3.6
C-10-2 1.5	86.5	-2.4	
C-11-2 1.5	96.5	7.6	3.8
C-12-2 1.5	88.9	0.0	
C-13-2 1.5	93.7	4.9	3.4
C-14-2 1.5	90.8	1.9	
C15-2 1.5	84.8	-4.0	-3.15
C-16-2 1.5	86.6	-2.3	
C17-2 1.5	90.0	1.1	1.8
C-18-2 1.5	91.4	2.6	
C19-2 1.5	92.8	4.0	4.3
C-20-2 1.5	93.5	4.7	
C21-2 1.5	94.0	5.2	5.2
C-22-2 1.5	94.1	5.2	
C3-7 1.5	80.3	-8.5	-8.9
C4-7 1.5	79.5	-9.3	
C5-7 1.5	88.8	0.0	-5.3
C6-7 1.5	78.2	-10.7	
C7-7 1.5	77.1	-11.7	-11.8
C8-7 1.5	76.9	-12.0	
C9-7 1.5	69.6	-19.3	-14
C10-7 1.5	80.1	-8.7	
C11-7 1.5	81.3	-7.5	-4.6
C12-7 1.5	87.2	-1.6	
C13-7 1.5	98.4	9.5	6.7
C14-7 1.5	92.8	4.0	
C15-7 1.5	88.7	-0.1	0.6
C16-7 1.5	90.1	1.3	
C17-7 1.5	83.2	-5.7	-8.8
C18-7 1.5	76.9	-11.9	
C19-7 1.5	91.1	2.3	0.45
C20-7 1.5	87.4	-1.4	
C21-7 1.5	90.3	1.4	3.8
C22-7 1.5	95.0	6.1	
C3-14 1.5	93.2	4.4	4.1
C4-14 1.5	92.7	3.8	
C5-14 1.5	92.6	3.8	4.1
C6-14 1.5	93.3	4.4	
C7-14 1.5	92.3	3.5	3.6
C8-14 1.5	92.5	3.7	
C9-14 1.5	90.2	1.4	1.5
C10-14 1.5	90.4	1.6	
C11-14 1.5	95.1	6.3	3.6
C12-14 1.5	89.8	0.9	
C13-14 1.5	86.7	-2.1	1.6
C14-14 1.5	94.1	5.2	
C15-14 1.5	90.0	1.2	0.45
C16-14 1.5	88.5	-0.3	
C17-14 1.5	87.6	-1.2	2.3
C18-14 1.5	94.6	5.8	
C19-14 1.5	92.3	3.5	0.9
C20-14 1.5	87.2	-1.7	
C21-14 1.5	92.4	3.6	4.2
C22-14 1.5	93.5	4.7	

93207 DRIPLINE

Controls

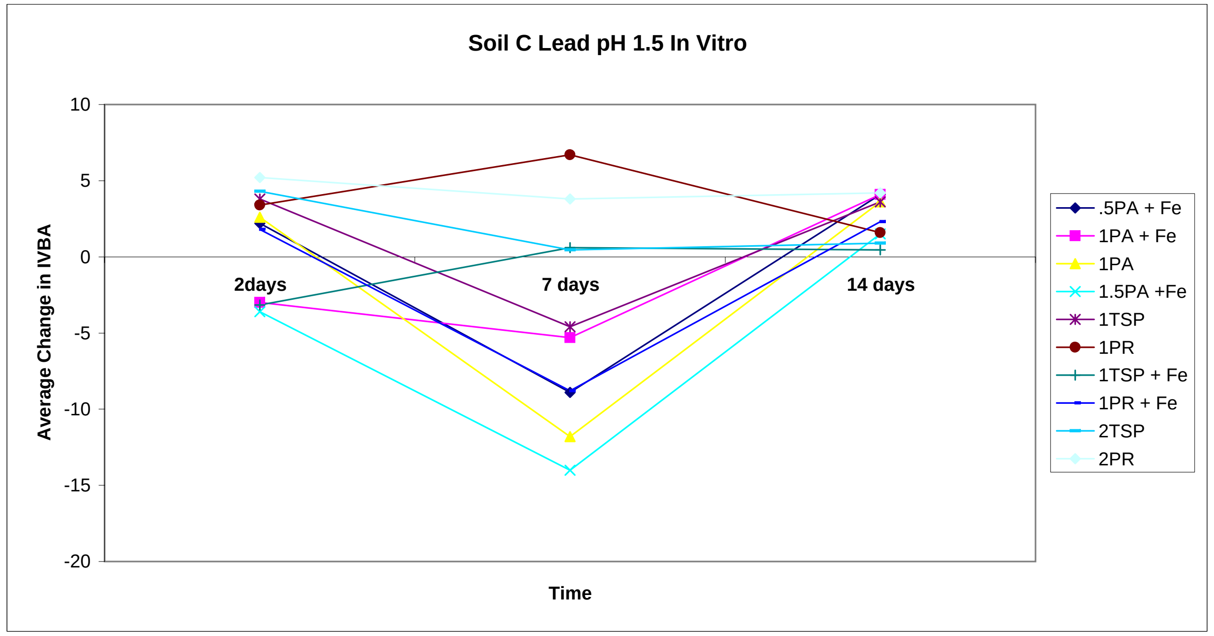
In Vitro-Pb pH1.5

C-1-2 1.5	88.7
C-2-2 1.5	90.4
C1-7 1.5	79.9
C2-7 1.5	81.8
C1-14 1.5	94.0
C2-14 1.5	95.0
D-17 1.5	89.1
D-18 1.5	91.9
Average	**88.8**
Standard Dev.	**5.4281**

In Vitro-Pb pH 2.5

C1-2 2.5	58.7
C2-2 2.5	60.0
C1-7 2.5	56.6
C2-7 2.5	57.7
C1-14 2.5	66.7
C2-14 2.5	62.9
D-17 2.5	57.9
D-18 2.5	63.5
Average	**60.5**
Standard Dev.	**3.508048**

	pH 1.5			**pH 2.5**		
.5PA + Fe	2.2	-8.9	4.1	-16	-18.8	-7.7
1PA + Fe	-3	-5.3	4.1	-31.6	-27.2	-18.7
1PA	2.6	-11.8	3.6	-26.4	-29.8	-20.7
1.5PA +Fe	-3.6	-14	1.5	-36	-33	-31.3
1TSP	3.8	-4.6	3.6	-4	-5.7	-1.1
1PR	3.4	6.7	1.6	2.5	2.8	4.6
1TSP + Fe	-3.15	0.6	0.45	-9.2	-10.4	-4.4
1PR + Fe	1.8	-8.8	2.3	-2.2	-9.4	-3.9
2TSP	4.3	0.45	0.9	-11	-15.5	-14.8
2PR	5.2	3.8	4.2	0.3	-1	-0.4
	2days	7 days	14 days			

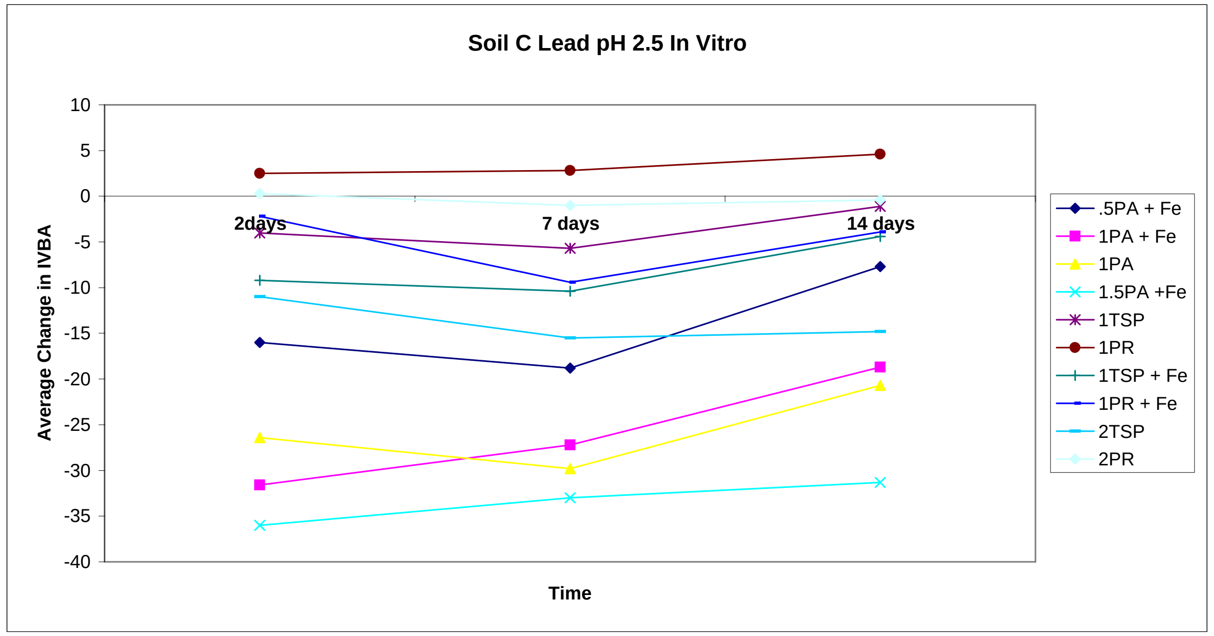


In Vitro-Pb pH2.5

C3-2 2.5	44.6	-15.9	-16
C4-2 2.5	44.4	-16.1	
C5-2 2.5	27.5	-33.0	-31.6
C6-2 2.5	30.3	-30.2	
C7-2 2.5	33.2	-27.3	-26.4
C8-2 2.5	35.1	-25.4	
C9-2 2.5	24.6	-35.9	-36
C10-2 2.5	24.4	-36.1	
C11-2 2.5	58.6	-1.9	-4
C12-2 2.5	54.5	-6.0	
C13-2 2.5	62.6	2.1	2.5
C14-2 2.5	63.3	2.8	
C15-2 2.5	52.5	-8.0	-9.2
C16-2 2.5	50.1	-10.4	
C17-2 2.5	58.8	-1.7	-2.2
C18-2 2.5	57.9	-2.6	
C19-2 2.5	49.5	-11.0	-11
C20-2 2.5	49.4	-11.1	
C21-2 2.5	60.1	-0.4	0.3
C22-2 2.5	61.5	1.0	

C3-7 2.5	42.0	-18.5	-18.8
C4-7 2.5	41.3	-19.2	
C5-7 2.5	33.2	-27.3	-27.2
C6-7 2.5	33.5	-27.0	
C7-7 2.5	31.0	-29.5	-29.8
C8-7 2.5	30.4	-30.1	
C9-7 2.5	25.4	-35.1	-33
C10-7 2.5	29.6	-30.9	
C11-7 2.5	54.8	-5.7	-5.7
C12-7 2.5	54.8	-5.7	
C13-7 2.5	65.1	4.6	2.8
C14-7 2.5	61.5	1.0	
C15-7 2.5	52.6	-7.9	-10.4
C16-7 2.5	47.6	-12.9	
C17-7 2.5	54.0	-6.5	-9.4
C18-7 2.5	48.3	-12.2	
C19-7 2.5	41.5	-19.0	-15.5
C20-7 2.5	48.6	-11.9	
C21-7 2.5	58.8	-1.7	-1
C22-7 2.5	60.2	-0.3	

C3-14 2.5	52.5	-8.0	-7.7
C4-14 2.5	53.1	-7.4	
C5-14 2.5	42.1	-18.4	-18.7
C6-14 2.5	41.6	-18.9	
C7-14 2.5	39.4	-21.1	-20.7
C8-14 2.5	40.2	-20.3	
	28.1	-32.4	-31.3
C10-14 2.5	30.2	-30.3	
C11-14 2.5	60.4	-0.1	-1.1
C12-14 2.5	58.4	-2.1	
C13-14 2.5	67.2	6.7	4.6
C14-14 2.5	63.0	2.5	
C15-14 2.5	57.1	-3.4	-4.4
C16-14 2.5	55.1	-5.4	
C17-14 2.5	55.1	-5.4	-3.9
C18-14 2.5	58.1	-2.4	
C19-14 2.5	46.4	-14.1	-14.8
C20-14 2.5	45.0	-15.5	
C21-14 2.5	61.1	0.6	-0.4
C22-14 2.5	59.1	-1.4	



EPA Treatability	**SLIP Weight g**
C1-14	3.01577
C2-14	2.98856
C3-14	3.05678
C4-14	3.04297
C5-14	3.01133
C6-14	3.02897
C7-14	3.04651
C8-14	3.01664
blank	
blank-spk	
C9-14	2.98185
C10-14	3.04541
C11-14	2.99749
C12-14	3.02553
C13-14	2.93872
C14-14	2.98046
C15-14	3.03046
C16-14	3.00308
C17-14	3.04722
C18-14	2.9874
C19-14	3.041
C20-14	3.02527
C21-14	3.0023
C22-14	3.08371
blank	
B1-14-SPK	
B1-14	3.00942
B2-14	3.02608
B3-14	3.06777
B4-14	3.07012
B5-14	3.02635
B6-14	3.00702
B7-14	3.03832
B8-14	3.00751
B9-14	3.0705
B10-14	3.04674
B11-14	3.03746
B11-14-SPK	
blank	
B12-14	2.93661
B13-14	2.97482
B14-14	3.08998
B15-14	2.97975
B16-14	2.93596
B17-14	2.92812
B18-14	2.94624
B19-14	3.14309
B20-14	2.99659

EPA Treatability	**SLIP Weight g**
B21-14	2.99651
B22-14	3.01592
Blank	
A1-14	3.03551
A2-14	3.04561
A3-14	3.02515
A4-14	3.06913
A5-14	2.98259
A6-14	2.99486
A7-14	2.93192
A8-14	2.94584
A9-14	2.98538
A10-14	3.00874
BLANK	
A10-14-SPK	
A11-14	3.08209
A12-14	2.99797
A13-14	2.92858
A14-14	3.03507
A15-14	3.00825
A16-14	3.05932
A17-14	2.96728
A18-14	2.97178
A19-14	3.07439
A20-14	3.01505
A21-14	3.08169
A22-14	2.99005
BLANK	
BLANK-SPK	
A1-7	2.99057
A2-7	2.97962
A3-7	2.98793
A4-7	2.96624
A5-7	3.02566
A6-7	2.95351
A7-7	2.99065
A8-7	2.99665
A9-7	2.9609
A10-7	3.02913
A10-7-SPK	
BLANK	
A11-7	2.97091
A12-7	3.00411
A13-7	3.01274
A14-7	3.04122
A15-7	2.99404
A16-7	2.97656
A17-7	3.03602
A18-7	3.04733

EPA Treatability	SLIP Weight g
A19-7	3.05565
A20-7	3.01418
A21-7	3.01267
A22-7	3.01033
BLANK	
BLANK-SPK	
B1-7	3.12861
B2-7	3.01936
B3-7	2.97349
B4-7	2.98607
B5-7	3.01736
B6-7	2.97332
B7-7	3.00017
B8-7	3.02748
B9-7	3.06166
B10-7	3.02019
B10-7-SPK	
BLANK	
B11-7	3.04957
B12-7	3.04211
B13-7	2.92252
B14-7	3.07833
B15-7	3.0462
B16-7	2.99797
B17-7	3.04541
B18-7	2.99546
B19-7	3.01385
B20-7	3.01617
B21-7	3.01452
B22-7	3.01336
BLANK	
BLANK-SPK	
C1-7	3.00744
C2-7	3.00068
C3-7	2.95978
C4-7	2.98323
C5-7	2.97709
C6-7	3.00008
C7-7	3.05846
C8-7	3.0175
C9-7	3.05028
C10-7	3.02484
BLANK	
BLANK-SPK	
C11-7	3.03975
C12-7	3.01075
C13-7	3.00409
C14-7	3.03782
C15-7	2.96595

EPA Treatability	**SLIP Weight g**
C16-7	2.99863
C17-7	3.00964
C18-7	3.00364
C19-7	3.02725
C20-7	3.05541
C21-7	2.98178
C22-7	3.00082
C22-7-SPK	
BLANK	
D-1	3.08543
D-2	2.98302
D-3	2.99965
D-4	2.98849
D-5	2.99971
D-6	3.02166
D-7	2.99455
D-8	3.00934
D-9	3.03444
D-10	3.02303
BLANK	
BLANK-SPK	
D-11	3.00303
D-12	3.04847
D-13	3.00597
D-14	3.01831
D-15	2.98646
D-16	3.01367
D-17	3.00163
D-18	3.0165
D-19	2.98902
D-20	3.03471
D-20-SPK	
BLANK	
D-21	3.00342
D-22	2.99035
D-23	2.99648
D-24	3.0768
C1-2	3.08992
C2-2	3.01445
C3-2	2.98734
C4-2	3.03344
C5-2	3.03028
C6-2	3.01207
BLANK	
BLANK-SPK	
C7-2	2.997
C8-2	3.00665
C9-2	3.03904
C10-2	3.03412

EPA Treatability	**SLIP Weight g**
C11-2	2.98365
C12-2	3.06347
C13-2	3.07967
C14-2	3.03716
C15-2	3.06814
C-15-2-SPK	
C16-2	3.02345
BLANK	
C17-2	3.04784
C18-2	3.03255
C19-2	3.01667
C20-2	3.0381
C21-2	3.0184
C22-2	2.9814
B1-2	2.99443
B2-2	3.02321
B3-2	3.01254
B4-2	3.03166
B5-2	3.01726
B6-2	2.9881
B7-2	3.05718
B8-2	3.0374
B9-2	3.04539
B10-2	2.97086
BLANK	
BLANK-SPK	
B11-2	3.04305
B12-2	3.0109
B13-2	2.9891
B14-2	3.08576
B15-2	3.00822
B16-2	3.02334
B17-2	3.04636
B18-2	3.05837
B19-2	3.00047
B20-2	3.02577
B21-2	3.01952
B22-2	3.01674
B22-2-SPK	
BLANK	
A1-2	3.05893
A2-2	3.05298
A3-2	3.01737
A4-2	3.02973
A5-2	3.02682
A6-2	3.00512
A7-2	3.04433
A8-2	2.99848
A9-2	3.0217

EPA Treatability	SLIP Weight g
A10-2	2.99491
BLANK	
BLANK-SPK	
A11-2	3.02993
A12-2	2.99687
A13-2	3.01643
A14-2	3.04355
A15-2	2.99633
A16-2	3.02947
A17-2	2.99036
A18-2	2.99569
A19-2	2.9951
A20-2	2.99491
A21-2	3.01556
A22-2	3.05801
BLANK	
A22-2-SPK	
BLANK-SPK	

	Pb IVBA	
pH	1.5	2.5
Soil A	84	42
	81	43
	83	38
	78	37
	77	43
	77	41
Average	80.0	40.7
StDev	3.098387	2.581989
	831 mg/kg +/- 20	
	82	51
	91	53
Soil B	88	44
	85	44
	86	50
	83	50
Average	85.8	48.7
StDev	3.311596	3.777124
	1406 mg/kg +/- 93	
	89	59
	90	60
Soil C	80	57
	82	58
	94	67
	95	63
Average	88.3	60.7
StDev	6.15359	3.723797
	2284 mg/kg +/- 130	

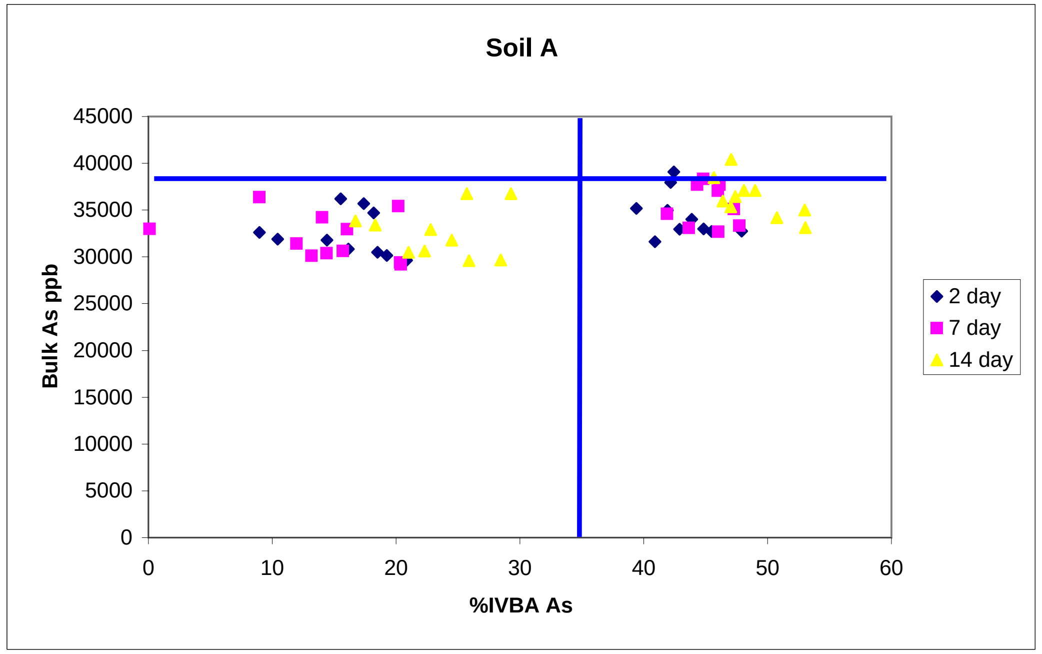
	As IVBA	
pH	1.5	2.5
Soil A	33	27
	33	26
	33	23
	34	23
	40	27
	39	24
	35.3	25.0
	3.265986	1.897367
	37 mg/kg +/- 0.5	
Soil B	34	25
	34	26
	39	22
	36	22
	41	25
	43	26
	37.8	24.3
	3.763863	1.861899
	43 mg/kg +/- 0.8	
Soil C	22	15
	22	14
	38	19
	35	16
	39	18
	40	18
	32.7	16.7
	8.430105	1.966384
	15 mg/kg +/- 0.3	

TABLE 2 . Preliminary Summary Of In Vitro Bioassay Results

As IVBA generally increases 10% w/ phosphate ---no change with Solucorp

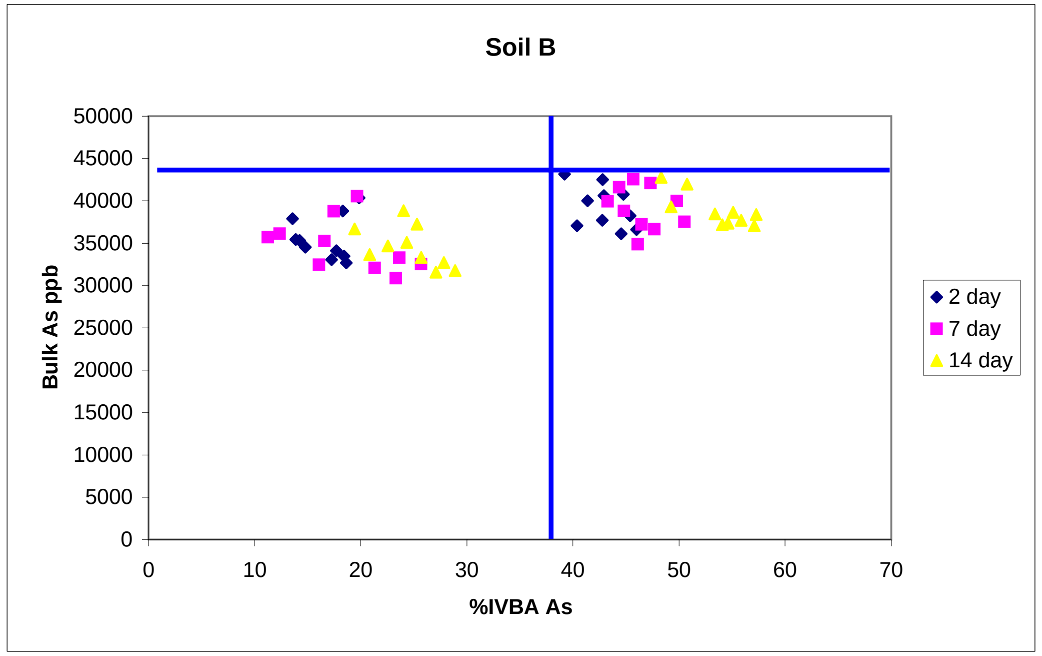
Sample	ID	As in <250u bulk soil µg/kg	mass soil (g)	calc As #1	ICP As (µg/l)	solution amt (l)	% Relative As Bioavailability
A-1-2 1.5		36964	1.0008	36.99	120	0.1	33
A-2-2 1.5		37051	1.00044	37.07	121	0.1	33
A-3-2 1.5		31785	1.00028	31.79	46	0.1	14
A-4-2 1.5		34690	1.00039	34.70	63	0.1	18
A-5-2 1.5		30480	1.00098	30.51	56	0.1	19
A-6-2 1.5		30824	1.00056	30.84	50	0.1	16
A-7-2 1.5		32725	1.0007	32.75	149	0.1	45
A-8-2 1.5		32764	1.00026	32.77	157	0.1	48
A-9-2 1.5		30159	1.00041	30.17	58	0.1	19
A-10-2 1.5		29645	1.00111	29.68	62	0.1	21
A-11-2 1.5		35193	1.00058	35.21	139	0.1	39
A-12-2 1.5		32984	1.00093	33.01	148	0.1	45
A-13-2 1.5		34032	1.00137	34.08	150	0.1	44
A-14-2 1.5		34973	1.00095	35.01	147	0.1	42
A-15-2 1.5		31903	1.00046	31.92	33	0.1	10
A-16-2 1.5		32629	1.00104	32.66	29	0.1	9
A-17-2 1.5		35688	1.00048	35.71	62	0.1	17
A-18-2 1.5		36214	1.00021	36.22	56	0.1	16
A-19-2 1.5		32962	1.00072	32.99	141	0.1	43
A-20-2 1.5		31624	1.00015	31.63	129	0.1	41
A-21-2 1.5		39070	1.00027	39.08	166	0.1	42
A-22-2 1.5		37956	1.00073	37.98	160	0.1	42
A1-7 1.5		36861	1.01195	37.30	124	0.1	33
A2-7 1.5		37956	1.00367	38.10	128	0.1	34
A3-7 1.5		30121	1.00685	30.33	40	0.1	13
A4-7 1.5		31408	0.99967	31.40	38	0.1	12
A5-7 1.5		30385	1.02156	31.04	45	0.1	14
A6-7 1.5		30629	1.02473	31.39	49	0.1	16
A7-7 1.5		32680	0.98472	32.18	148	0.1	46
A8-7 1.5		33096	1.00873	33.38	146	0.1	44
A9-7 1.5		29186	1.00031	29.20	60	0.1	20
A10-7 1.5		29380	1.00916	29.65	60	0.1	20
A11-7 1.5		35107	1.02114	35.85	170	0.1	47
A12-7 1.5		33329	1.01487	33.82	161	0.1	48
A13-7 1.5		37056	1.01979	37.79	174	0.1	46
A14-7 1.5		38319	1.01045	38.72	174	0.1	45
A15-7 1.5		34237	1.01394	34.71	49	0.1	14
A16-7 1.5		32992	1.01478	33.48	0	0.1	0
A17-7 1.5		36379	1.02301	37.22	33	0.1	9
A18-7 1.5		35403	1.0035	35.53	72	0.1	20
A19-7 1.5		32968	0.99547	32.82	53	0.1	16

Control	**Soil A**	**Soil B**	**Soil C**
	36963.69905	42744	14962
	37050.91192	42000	14551
	36861	41570	14968
	37956	42860	15091
	36476	43234	14102
	36571	43870	14398
Average	**36980**	**42713**	**14679**
stdev	**528**	**830**	**366**

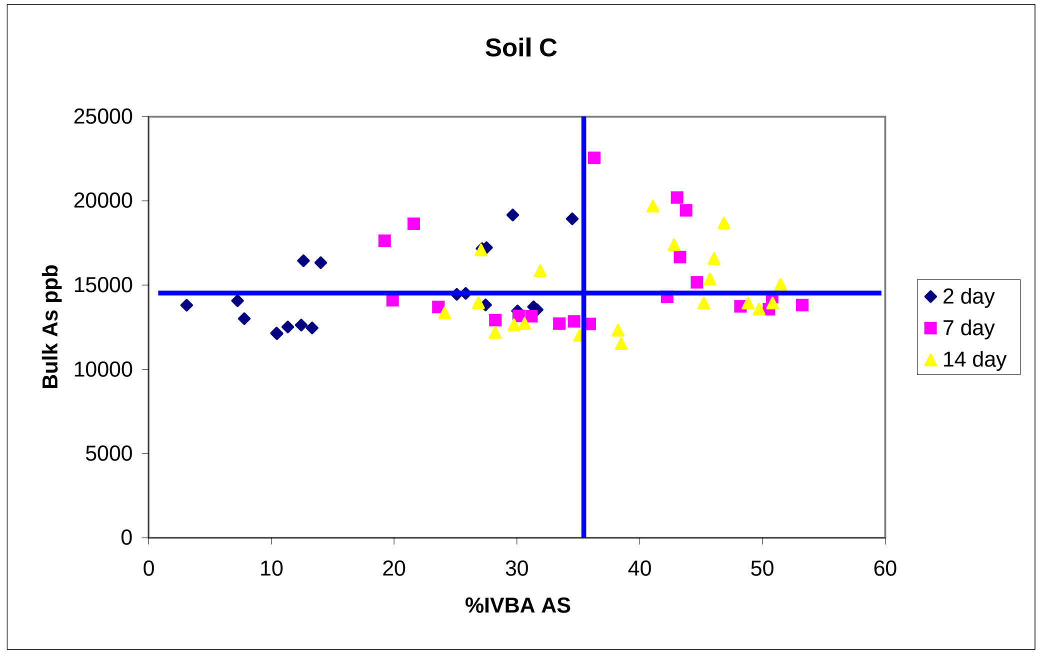


A20-7 1.5	34608	1.0217	35.36	148	0.1	42
A21-7 1.5	37696	1.00871	38.02	175	0.1	46
A22-7 1.5	37714	1.01221	38.17	169	0.1	44

A1-14 1.5	36476	1.02006	37.21	147	0.1	40
A2-14 1.5	36571	1.01951	37.28	145	0.1	39
A3-14 1.5	30622	1.02389	31.35	70	0.1	22
A4-14 1.5	30495	0.99949	30.48	64	0.1	21
A5-14 1.5	31792	1.00800	32.05	78	0.1	24
A6-14 1.5	29588	1.02223	30.25	78	0.1	26
A7-14 1.5	34169	1.00226	34.25	174	0.1	51
A8-14 1.5	33130	1.02185	33.85	180	0.1	53
A9-14 1.5	29664	0.99555	29.53	84	0.1	28
A10-14 1.5	32907	1.00151	32.96	75	0.1	23
A11-14 1.5	35961	1.00967	36.31	168	0.1	46
A12-14 1.5	36453	1.02391	37.32	177	0.1	47
A13-14 1.5	37095	1.01109	37.51	184	0.1	49
A14-14 1.5	37089	0.99744	36.99	178	0.1	48
A15-14 1.5	33850	1.02161	34.58	58	0.1	17
A16-14 1.5	33385	1.01654	33.94	62	0.1	18
A17-14 1.5	36767	1.01034	37.15	96	0.1	26
A18-14 1.5	36753	1.00930	37.10	109	0.1	29
A19-14 1.5	35013	0.99377	34.80	184	0.1	53
A20-14 1.5	35354	1.02636	36.29	171	0.1	47
A21-14 1.5	38466	1.02824	39.55	181	0.1	46
A22-14 1.5	40410	1.02256	41.32	194	0.1	47



B-1-2 1.5	42744	1.00157	42.81	148	0.1	34
B-2-2 1.5	42000	1.00082	42.03	143	0.1	34
B-3-2 1.5	35342	1.00128	35.39	50	0.1	14
B-4-2 1.5	34538	1.00054	34.56	51	0.1	15
B-5-2 1.5	33463	1.02483	34.29	63	0.1	18
B-6-2 1.5	34131	1.00879	34.43	61	0.1	18
B-7-2 1.5	36614	1.00898	36.94	170	0.1	46
B-8-2 1.5	36116	1.01777	36.76	164	0.1	45
B-9-2 1.5	32684	1.00740	32.93	61	0.1	19
B-10-2 1.5	33072	1.00087	33.10	57	0.1	17
B-11-2 1.5	40021	1.00965	40.41	167	0.1	41
B-12-2 1.5	37726	1.00695	37.99	162	0.1	43
B-13-2 1.5	40607	1.00669	40.88	175	0.1	43
B-14-2 1.5	40765	1.01098	41.21	184	0.1	45
B-15-2 1.5	35457	1.02827	36.46	51	0.1	14
B-16-2 1.5	37912	1.02665	38.92	53	0.1	14
B-17-2 1.5	38800	1.01727	39.47	72	0.1	18
B-18-2 1.5	40344	1.00788	40.66	81	0.1	20
B-19-2 1.5	38234	1.01275	38.72	176	0.1	45
B-20-2 1.5	37075	1.01397	37.59	152	0.1	40
B-21-2 1.5	43171	1.01160	43.67	171	0.1	39
B-22-2 1.5	42521	1.00379	42.68	183	0.1	43



B1-7 1.5	41570	1.00697	41.86	163	0.1	39
B2-7 1.5	42860	1.01990	43.71	158	0.1	36
B3-7 1.5	33282	1.00400	33.42	79	0.1	24
B4-7 1.5	32516	1.01051	32.86	84	0.1	26
B5-7 1.5	35252	1.00692	35.50	59	0.1	17
B6-7 1.5	32465	1.02285	33.21	53	0.1	16
B7-7 1.5	34867	1.01840	35.51	164	0.1	46

B8-7 1.5	36640	1.00969	37.00	176	0.1	48
B9-7 1.5	32088	1.01627	32.61	70	0.1	21
B10-7 1.5	30875	0.99483	30.71	72	0.1	23
B11-7 1.5	38818	0.99694	38.70	173	0.1	45
B12-7 1.5	37225	1.00000	37.22	173	0.1	46
B13-7 1.5	41615	1.01111	42.08	187	0.1	44
B14-7 1.5	39928	1.01311	40.45	175	0.1	43
B15-7 1.5	36123	1.00030	36.13	45	0.1	12
B16-7 1.5	35698	0.99206	35.41	40	0.1	11
B17-7 1.5	38777	1.00888	39.12	68	0.1	17
B18-7 1.5	40530	1.01495	41.14	81	0.1	20
B19-7 1.5	39993	1.01901	40.75	203	0.1	50
B20-7 1.5	37520	1.01198	37.97	192	0.1	51
B21-7 1.5	42561	1.00643	42.83	196	0.1	46
B22-7 1.5	42079	1.00682	42.37	201	0.1	47

B1-14 1.5	43234	1.01482	43.87	179	0.1	41
B2-14 1.5	43870	1.01687	44.61	192	0.1	43
B3-14 1.5	35104	1.00365	35.23	86	0.1	24
B4-14 1.5	34682	1.00195	34.75	78	0.1	23
B5-14 1.5	32719	1.01729	33.29	93	0.1	28
B6-14 1.5	33330	1.01794	33.93	87	0.1	26
B7-14 1.5	38370	1.01314	38.87	223	0.1	57
B8-14 1.5	37374	1.00289	37.48	205	0.1	55
B9-14 1.5	31768	1.00905	32.06	93	0.1	29
B10-14 1.5	31580	1.02882	32.49	88	0.1	27
B11-14 1.5	38449	1.00466	38.63	206	0.1	53
B12-14 1.5	37715	1.00954	38.07	213	0.1	56
B13-14 1.5	38640	1.00409	38.80	214	0.1	55
B14-14 1.5	39281	1.02546	40.28	198	0.1	49
B15-14 1.5	33644	1.00592	33.84	71	0.1	21
B16-14 1.5	36675	0.9975	36.58	71	0.1	19
B17-14 1.5	38845	1.01239	39.33	94	0.1	24
B18-14 1.5	37269	1.02849	38.33	97	0.1	25
B19-14 1.5	37194	1.01619	37.80	204	0.1	54
B20-14 1.5	37075	1.00994	37.44	214	0.1	57
B21-14 1.5	41973	1.00732	42.28	215	0.1	51
B22-14 1.5	42779	1.03438	44.25	214	0.1	48

C-1-2 1.5	14962	1.01940	15.25	33	0.1	22
C-2-2 1.5	14551	0.99509	14.48	32	0.1	22
C-3-2 1.5	12627	1.00867	12.74	16	0.1	12
C-4-2 1.5	13015	1.01274	13.18	10	0.1	8
C-5-2 1.5	12519	1.00999	12.64	14	0.1	11
C-6-2 1.5	12458	1.01251	12.61	17	0.1	13
C-7-2 1.5	13722	1.00474	13.79	43	0.1	31
C-8-2 1.5	13475	1.04266	14.05	42	0.1	30
C-9-2 1.5	12167	1.01257	12.32	13	0.1	10
C-10-2 1.5	12129	1.00045	12.13	13	0.1	10
C-11-2 1.5	13832	1.00284	13.87	38	0.1	27
C-12-2 1.5	14513	1.03229	14.98	39	0.1	26
C-13-2 1.5	17234	1.01159	17.43	48	0.1	28
C-14-2 1.5	17166	1.01513	17.43	47	0.1	27
C15-2 1.5	13817	1.02624	14.18	4	0.1	3
C-16-2 1.5	14069	1.00222	14.10	10	0.1	7
C17-2 1.5	16461	0.99887	16.44	21	0.1	13
C-18-2 1.5	16342	1.01065	16.52	23	0.1	14
C19-2 1.5	14452	1.03255	14.92	37	0.1	25
C-20-2 1.5	13550	1.01731	13.78	44	0.1	32
C21-2 1.5	18940	1.03489	19.60	68	0.1	35
C-22-2 1.5	19163	1.00355	19.23	57	0.1	30

C1-7 1.5	14968	1.02015	15.27	58	0.1	38
C2-7 1.5	15091	0.99581	15.03	53	0.1	35
C3-7 1.5	12844	1.01443	13.03	45	0.1	35
C4-7 1.5	12709	1.00685	12.80	43	0.1	33
C5-7 1.5	13141	0.99714	13.10	41	0.1	31
C6-7 1.5	12926	1.00586	13.00	37	0.1	28
C7-7 1.5	13732	1.01120	13.89	67	0.1	48
C8-7 1.5	13573	0.99641	13.52	68	0.1	51
C9-7 1.5	12695	1.02239	12.98	47	0.1	36
C10-7 1.5	13173	0.99954	13.17	40	0.1	30
C11-7 1.5	15150	1.01679	15.40	69	0.1	45
C12-7 1.5	14314	1.03645	14.84	63	0.1	42
C13-7 1.5	16658	1.00701	16.78	73	0.1	43
C14-7 1.5	19441	1.01855	19.80	87	0.1	44
C15-7 1.5	13695	1.01425	13.89	33	0.1	24
C16-7 1.5	14102	1.00658	14.19	28	0.1	20
C17-7 1.5	17630	1.01524	17.90	34	0.1	19
C18-7 1.5	18641	1.01286	18.88	41	0.1	22
C19-7 1.5	13811	1.02005	14.09	75	0.1	53
C20-7 1.5	14294	1.01343	14.49	74	0.1	51
C21-7 1.5	22559	1.01541	22.91	83	0.1	36
C22-7 1.5	20189	1.02043	20.60	89	0.1	43
C1-14 1.5	14102	1.00901	14.23	56	0.1	39
C2-14 1.5	14398	1.00960	14.54	58	0.1	40
C3-14 1.5	12733	1.01282	12.90	39	0.1	31
C4-14 1.5	12645	1.00968	12.77	38	0.1	30
C5-14 1.5	12199	1.00980	12.32	35	0.1	28
C6-14 1.5	12026	1.02624	12.34	43	0.1	35
C7-14 1.5	13940	1.01290	14.12	72	0.1	51
C8-14 1.5	13589	1.00170	13.61	68	0.1	50
C9-14 1.5	12334	1.01042	12.46	48	0.1	38
C10-14 1.5	11535	1.02472	11.82	45	0.1	38
C11-14 1.5	13935	1.00590	14.02	68	0.1	49
C12-14 1.5	13936	1.01772	14.18	64	0.1	45
C13-14 1.5	17402	1.01368	17.64	75	0.1	43
C14-14 1.5	16578	1.00843	16.72	77	0.1	46
C15-14 1.5	13348	1.02248	13.65	33	0.1	24
C16-14 1.5	13972	1.01363	14.16	38	0.1	27
C17-14 1.5	17095	1.01271	17.31	47	0.1	27
C18-14 1.5	15861	1.01168	16.05	51	0.1	32
C19-14 1.5	15045	1.02435	15.41	79	0.1	51
C20-14 1.5	15370	1.00170	15.40	70	0.1	46
C21-14 1.5	18685	1.00485	18.78	88	0.1	47
C22-14 1.5	19694	1.00617	19.82	81	0.1	41

QA/QC

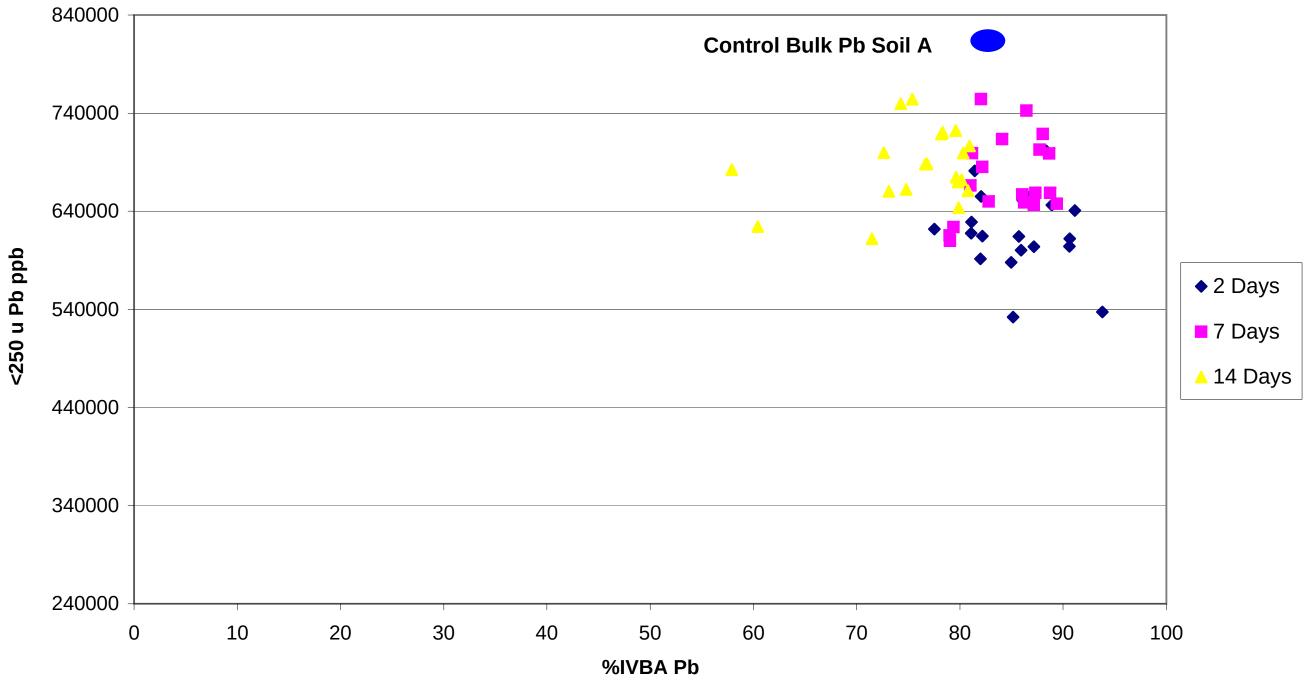
blank				1	0.1	
blank-spk (2500 ppb)				2627	0.1	
Nist-2711-E	105000	1.0268	107.81	575	0.1	53
blank				0	0.1	
blank-spk (2500 ppb)				2479	0.1	

Blank				-0.05842	0.1		
blank-spk (2500 ppb)				2540.541	0.1		
blank				0	0.1		
blank-spk (2500 ppb)				2454	0.1		
Nist2711-C	105000	1.02615	107.75	604	0.1	56	average IVBA vlaue for NIST 2711=59
blank				0	0.1		
blank-spk (2500 ppb)				2382	0.1		
Nist2711-B	105000	1.03082	108.24	560	0.1	52	
blank				-0.01005	0.1		
blank-spk (2500 ppb)				2439.721	0.1		
Nist2711-A	105000	1.01566	106.64	544.1155	0.1	51	
blank				0.006423	0.1		
blank-spk (2500 ppb)				2405.322	0.1		
Nist2711-D	105000	1.01633	106.71	566	0.1	53	
blank				0	0.1		
blank-spk (2500 ppb)				2437	0.1		
Nist2710-E	626000	1.02091	639.09	3266	0.1	51	average IVBA value for NIST 2710 =55
blank				0	0.1		
blank-spk (2500 ppb)				2502	0.1		
nist2710-D	626000	1.02203	639.79	3689.488	0.1	58	
blank				-0.15678	0.1		
blank-spk (2500 ppb)				2463.724	0.1		
nist-2710-C	626000	1.00193	627.21	3605.394	0.1	57	
Blank				-0.07225	0.1		
blank-spk (2500 ppb)				2404.512	0.1		
Nist-2710-B	626000	1.0255	641.96	3569.82	0.1	56	
NIST-2710-A	626000	1.00278	627.74	3624.683	0.1	58	
Blank				-0.06013	0.1		
blank-spk (2500 ppb)				2373.31	0.1		
Blank				-0.07259	0.1		
blank-spk (2500 ppb)				2369.278	0.1		
Blank				-0.13046	0.1		
blank-spk (2500 ppb)				2430.357	0.1		

TABLE 2 . Preliminary Summary Of In Vitro Bioassay Results

Sample	ID	Pb in <250u bulk soil µg/kg	mass soil (g)		calc Pb #1	ICP Pb (µg/l)	solution amt (l)	% Relative Pb Bioavailability	
A-1-2 1.5		805137	1.0008	805.78		6731	0.1	84	
A-2-2 1.5		808650	1.00044	809.01		6521	0.1	81	
A-3-2 1.5		681294	1.00028	681.48		5549	0.1	81	**81**
A-4-2 1.5		532026	1.00039	532.23		4532	0.1	85	
A-5-2 1.5		621795	1.00098	622.40		4826	0.1	78	
A-6-2 1.5		587869	1.00056	588.20		4998	0.1	85	
A-7-2 1.5		611942	1.0007	612.37		5551	0.1	91	
A-8-2 1.5		604253	1.00026	604.41		5476	0.1	91	
A-9-2 1.5		614677	1.00041	614.93		5054	0.1	82	
A-10-2 1.5		617640	1.00111	618.33		5013	0.1	81	
A-11-2 1.5		701391	1.00058	701.80		6202	0.1	88	
A-12-2 1.5		650821	1.00093	651.43		5609	0.1	86	
A-13-2 1.5		537240	1.00137	537.98		5047	0.1	94	
A-14-2 1.5		654949	1.00095	655.57		5690	0.1	87	
A-15-2 1.5		614403	1.00046	614.69		5268	0.1	86	
A-16-2 1.5		629066	1.00104	629.72		5108	0.1	81	
A-17-2 1.5		591390	1.00048	591.67		4852	0.1	82	
A-18-2 1.5		655213	1.00021	655.35		5377	0.1	82	
A-19-2 1.5		646260	1.00072	646.73		5750	0.1	89	
A-20-2 1.5		640882	1.00015	640.98		5842	0.1	91	
A-21-2 1.5		600208	1.00027	600.37		5160	0.1	86	
A-22-2 1.5		603908	1.00073	604.35		5269	0.1	87	
B-1-2 1.5		1377381	1.00157	1379.54		11343	0.1	82	
B-2-2 1.5		1311224	1.00082	1312.30		11892	0.1	91	
B-3-2 1.5		1082182	1.00128	1083.57		8939	0.1	82	
B-4-2 1.5		1062169	1.00054	1062.74		8948	0.1	84	
B-5-2 1.5		1046255	1.02483	1072.23		9197	0.1	86	
B-6-2 1.5		1080661	1.00879	1090.16		8786	0.1	81	
B-7-2 1.5		1083535	1.00898	1093.27		9680	0.1	89	
B-8-2 1.5		1067811	1.01777	1086.79		9153	0.1	84	
B-9-2 1.5		1002386	1.0074	1009.80		7886	0.1	78	
B-10-2 1.5		995630	1.00087	996.50		8018	0.1	80	
B-11-2 1.5		1217070	1.00965	1228.81		10444	0.1	85	
B-12-2 1.5		1176734	1.00695	1184.91		10515	0.1	89	

	Soil A	Soil B	Soil C
Control Bulk Pb	ppb		
	805137.5	1377381	2220312
	808649.9	1311224	2157539
	827954	1427932	2330276
	844000	1448251	2365095
	827083	1436138	2169086
	828561	1439339	2194213
	865589	1557081	2295361
	847586	1250712	2546670
Average	831820	1406007	2284819
StDev	20121	93371	130468

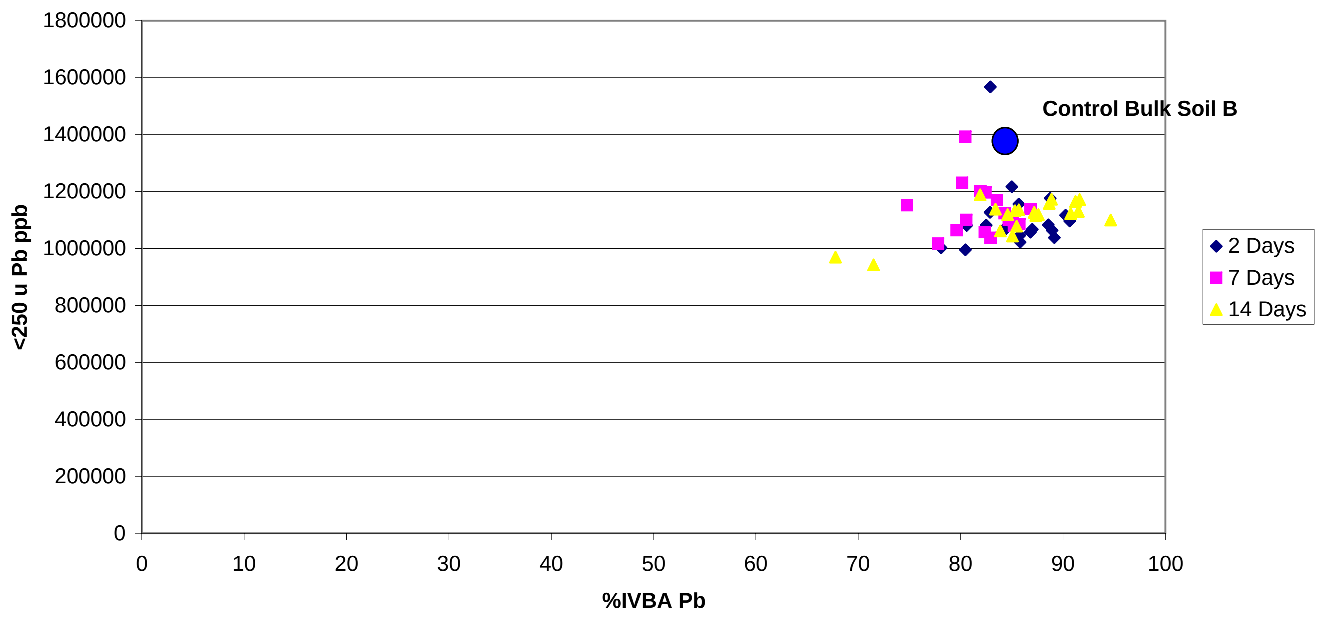


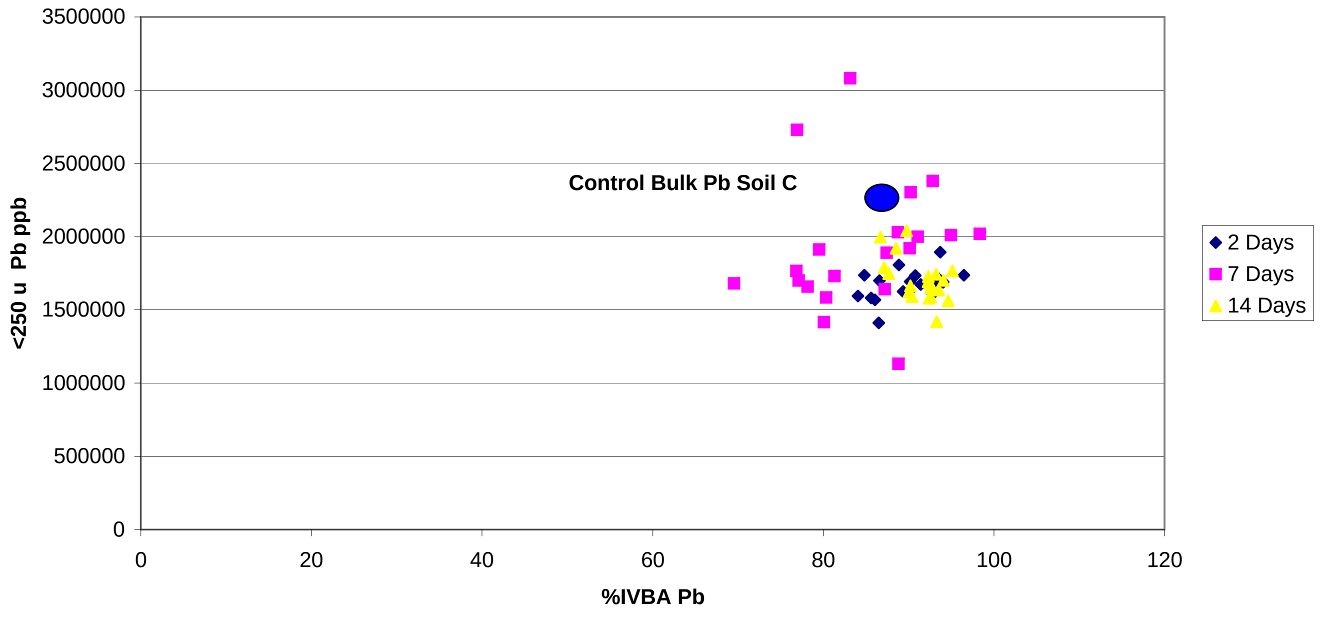
B-13-2 1.5	1155706	1.00669	1163.44	9967	0.1	86
B-14-2 1.5	1096131	1.01098	1108.17	10045	0.1	91
B-15-2 1.5	1067154	1.02827	1097.32	9545	0.1	87
B-16-2 1.5	1127347	1.02665	1157.39	9593	0.1	83
B-17-2 1.5	1057823	1.01727	1076.09	9340	0.1	87
B-18-2 1.5	1022882	1.00788	1030.94	8847	0.1	86
B-19-2 1.5	1117094	1.01275	1131.34	10210	0.1	90
B-20-2 1.5	1567277	1.01397	1589.17	13175	0.1	83
B-21-2 1.5	1037699	1.0116	1049.74	9358	0.1	89
B-22-2 1.5	1064065	1.00379	1068.10	9498	0.1	89

C-1-2 1.5	2220312	1.0194	2263.39	20068	0.1	89
C-2-2 1.5	2157539	0.99509	2146.95	19410	0.1	90
C-3-2 1.5	1618747	1.00867	1632.78	15136	0.1	93
C-4-2 1.5	1625407	1.01274	1646.11	14709	0.1	89
C-5-2 1.5	1568554	1.00999	1584.22	13630	0.1	86
C-6-2 1.5	1582247	1.01251	1602.04	13713	0.1	86
C-7-2 1.5	1609242	1.00474	1616.87	15009	0.1	93
C-8-2 1.5	1693382	1.04266	1765.62	15923	0.1	90
C-9-2 1.5	1594532	1.01257	1614.58	13571	0.1	84
C-10-2 1.5	1412139	1.00045	1412.77	12218	0.1	86
C-11-2 1.5	1736799	1.00284	1741.73	16805	0.1	96
C-12-2 1.5	1806966	1.03229	1865.31	16576	0.1	89
C-13-2 1.5	1893764	1.01159	1915.71	17949	0.1	94
C-14-2 1.5	1735079	1.01513	1761.33	15988	0.1	91

C15-2 1.5	1737645	1.02624	1783.24	15125	0.1	85
C-16-2 1.5	1700083	1.00222	1703.86	14749	0.1	87
C17-2 1.5	1623469	0.99887	1621.63	14593	0.1	90
C-18-2 1.5	1673180	1.01065	1691.00	15458	0.1	91
C19-2 1.5	1681157	1.03255	1735.88	16108	0.1	93
C-20-2 1.5	1713476	1.01731	1743.14	16300	0.1	94
C21-2 1.5	1689139	1.03489	1748.07	16437	0.1	94
C-22-2 1.5	1690294	1.00355	1696.29	15955	0.1	94
A1-7 1.5	827954	1.01195	837.85	6919	0.1	83
A2-7 1.5	844000	1.00367	847.10	6588	0.1	78
A3-7 1.5	658684	1.00685	663.20	5886	0.1	89
A4-7 1.5	685079	0.99967	684.85	5628	0.1	82
A5-7 1.5	649964	1.02156	663.98	5498	0.1	83
A6-7 1.5	623924	1.02473	639.35	5076	0.1	79
A7-7 1.5	656944	0.98472	646.91	5566	0.1	86
A8-7 1.5	646450	1.00873	652.09	5684	0.1	87
A9-7 1.5	609855	1.00031	610.04	4821	0.1	79
A10-7 1.5	615261	1.00916	620.90	4906	0.1	79
A11-7 1.5	702865	1.02114	717.72	6296	0.1	88
A12-7 1.5	718707	1.01487	729.39	6421	0.1	88
A137-7 1.5	698685	1.01979	712.51	6318	0.1	89
A14-7 1.5	754238	1.01045	762.12	6252	0.1	82
A15-7 1.5	713505	1.01394	723.45	6084	0.1	84

A17-7 1.5	658857	1.02301	674.02	5886	0.1	87
A18-7 1.5	666174	1.0035	668.51	5417	0.1	81
A19-7 1.5	699173	0.99547	696.01	5651	0.1	81
A20-7 1.5	742458	1.0217	758.57	6559	0.1	86
A21-7 1.5	647617	1.00871	653.26	5840	0.1	89
A22-7 1.5	648775	1.01221	656.70	5662	0.1	86





B1-7 1.5	1427932	1.00697	1437.88	12610	0.1	88
B2-7 1.5	1448251	1.0199	1477.07	12519	0.1	85
B3-7 1.5	1169929	1.004	1174.61	9816	0.1	84
B4-7 1.5	1085163	1.01051	1096.57	9402	0.1	86
B5-7 1.5	1099567	1.00692	1107.18	8920	0.1	81
B6-7 1.5	1056847	1.02285	1081.00	8905	0.1	82
B7-7 1.5	1099673	1.0184	1119.91	9486	0.1	85
B8-7 1.5	1196311	1.00969	1207.90	9957	0.1	82
B9-7 1.5	1036598	1.01627	1053.46	8735	0.1	83
B10-7 1.5	1016903	0.99483	1011.65	7872	0.1	78

B11-7 1.5	1299449	0.99694	1295.47	10422	0.1	80
B12-7 1.5	1139335	1.00000	1139.34	9896	0.1	87
B13-7 1.5	1176003	1.01111	1189.07	10117	0.1	85
B14-7 1.5	1392479	1.01311	1410.73	12023	0.1	85
B15-7 1.5	1137812	1.0003	1138.15	9596	0.1	84
B16-7 1.5	1108866	0.99206	1100.06	8818	0.1	80
B17-7 1.5	1078790	1.00888	1088.37	8917	0.1	82
B18-7 1.5	1124049	1.01495	1140.85	8531	0.1	75
B19-7 1.5	1230887	1.01901	1254.29	9986	0.1	80
B20-7 1.5	1200982	1.01198	1215.37	9816	0.1	81
B21-7 1.5	1151611	1.00643	1159.02	9203	0.1	79
B22-7 1.5	1064332	1.00682	1071.59	8801	0.1	82
C1-7 1.5	2330276	1.02015	2377.23	18998	0.1	80
C2-7 1.5	2365095	0.99581	2355.19	19257	0.1	82
C3-7 1.5	1584236	1.01443	1607.10	12910	0.1	80
C4-7 1.5	1912556	1.00685	1925.66	15315	0.1	80
C5-7 1.5	1132165	0.99714	1128.93	10027	0.1	89

C6-7 1.5	1658073	1.00586	1667.79	13035	0.1	78
C7-7 1.5	1700748	1.0112	1719.80	13262	0.1	77
C8-7 1.5	1764689	0.99641	1758.35	13516	0.1	77
C9-7 1.5	1680722	1.02239	1718.35	11953	0.1	70
C10-7 1.5	1415041	0.99954	1414.39	11329	0.1	80
C11-7 1.5	1729932	1.01679	1758.98	14307	0.1	81
C12-7 1.5	1639902	1.03645	1699.68	14824	0.1	87
C13-7 1.5	2019028	1.00701	2033.18	20000	0.1	98
C14-7 1.5	2378515	1.01855	2422.64	22492	0.1	93
C15-7 1.5	2028967	1.01425	2057.88	18263	0.1	89
C16-7 1.5	1919677	1.00658	1932.31	17419	0.1	90
C17-7 1.5	3080028	1.01524	3126.97	26006	0.1	83
C18-7 1.5	2729021	1.01286	2764.12	21262	0.1	77
C19-7 1.5	1998361	1.02005	2038.43	18568	0.1	91
C20-7 1.5	1889105	1.01343	1914.48	16738	0.1	87
C21-7 1.5	2301750	1.01541	2337.22	21097	0.1	90
C22-7 1.5	2009449	1.02043	2050.50	19473	0.1	95
C1-14 1.5	2169086	1.00901	2188.63	20569	0.1	94
C2-14 1.5	2194213	1.0096	2215.28	21051	0.1	95
C3-14 1.5	1742609	1.01282	1764.95	16454	0.1	93
C4-14 1.5	1652061	1.00968	1668.05	15457	0.1	93
C5-14 1.5	1590131	1.0098	1605.71	14868	0.1	93
C6-14 1.5	1420552	1.02624	1457.83	13599	0.1	93
C7-14 1.5	1692734	1.0129	1714.57	15824	0.1	92

C8-14 1.5	1681235	1.0017	1684.09	15576	0.1	92
C9-14 1.5	1665741	1.01042	1683.10	15187	0.1	90
C10-14 1.5	1591136	1.02472	1630.47	14739	0.1	90
C11-14 1.5	1768201	1.0059	1778.63	16920	0.1	95
C12-14 1.5	2039655	1.01772	2075.80	18631	0.1	90
C13-14 1.5	1997255	1.01368	2024.58	17551	0.1	87
C14-14 1.5	1701493	1.00843	1715.84	16144	0.1	94
C15-14 1.5	1621237	1.02248	1657.68	14923	0.1	90
C16-14 1.5	1921166	1.01363	1947.35	17237	0.1	89
C17-14 1.5	1746869	1.01271	1769.07	15505	0.1	88
C18-14 1.5	1562146	1.01168	1580.39	14954	0.1	95
C19-14 1.5	1728690	1.02435	1770.78	16348	0.1	92
C20-14 1.5	1790238	1.0017	1793.28	15630	0.1	87
C21-14 1.5	1579062	1.00485	1586.72	14661	0.1	92
C22-14 1.5	1635866	1.00617	1645.96	15391	0.1	94
B1-14 1.5	1436138	1.01482	1457.42	12542	0.1	86
B2-14 1.5	1439339	1.01687	1463.62	12189	0.1	83
B3-14 1.5	1138105	1.00365	1142.26	9528	0.1	83
B4-14 1.5	1188256	1.00195	1190.57	9750	0.1	82
B5-14 1.5	1044157	1.01729	1062.21	9035	0.1	85
B6-14 1.5	1062344	1.01794	1081.40	9069	0.1	84
B7-14 1.5	1099800	1.01314	1114.25	10548	0.1	95
B8-14 1.5	1115837	1.00289	1119.06	9774	0.1	87
B9-14 1.5	942462	1.00905	950.99	6798	0.1	71
B10-14 1.5	970125	1.02882	998.08	6763	0.1	68
B11-14 1.5	1165078	1.00466	1170.51	10678	0.1	91
B12-14 1.5	1122074	1.00954	1132.78	10279	0.1	91
B13-14 1.5	1130880	1.00409	1135.51	10390	0.1	91
B14-14 1.5	1158275	1.02546	1187.76	10531	0.1	89
B15-14 1.5	1119399	1.00592	1126.03	9862	0.1	88
B16-14 1.5	1118696	0.9975	1115.90	9440	0.1	85
B17-14 1.5	1132633	1.01239	1146.67	9781	0.1	85
B18-14 1.5	1078621	1.02849	1109.35	9481	0.1	85
B19-14 1.5	1173586	1.01619	1192.59	10597	0.1	89
B20-14 1.5	1171676	1.00994	1183.32	10843	0.1	92
B21-14 1.5	1126662	1.00732	1134.91	9896	0.1	87
B22-14 1.5	1135944	1.03438	1175.00	10066	0.1	86
A1-14 1.5	827083	1.02006	843.67	6476	0.1	77
A2-14 1.5	828561	1.01951	844.73	6497	0.1	77
A3-14 1.5	672190	1.02389	688.25	5517	0.1	80
A4-14 1.5	662275	0.99949	661.94	4951	0.1	75
A5-14 1.5	660231	1.008	665.51	4867	0.1	73
A6-14 1.5	612198	1.02223	625.81	4474	0.1	71
A7-14 1.5	699693	1.00226	701.27	5093	0.1	73
A8-14 1.5	669668	1.02185	684.30	5463	0.1	80
A9-14 1.5	624309	0.99555	621.53	3756	0.1	60
A10-14 1.5	682428	1.00151	683.46	3957	0.1	58
A11-14 1.5	749581	1.00967	756.83	5622	0.1	74
A12-14 1.5	720232	1.02391	737.45	5777	0.1	78
A13-14 1.5	722377	1.01109	730.39	5815	0.1	80
A14-14 1.5	706748	0.99744	704.94	5706	0.1	81
A15-14 1.5	688054	1.02161	702.92	5389	0.1	77
A16-14 1.5	674617	1.01654	685.78	5462	0.1	80
A17-14 1.5	688336	1.01034	695.45	5342	0.1	77
A18-14 1.5	661108	1.0093	667.26	5390	0.1	81
A19-14 1.5	699407	0.99377	695.05	5583	0.1	80
A20-14 1.5	754132	1.02636	774.01	5835	0.1	75
A21-14 1.5	643645	1.02824	661.82	5288	0.1	80

A22-14 1.5	718730	1.02256	734.94	5747	0.1	78	
blank				0	0.1		
blank-spk (2500 ppb)				2571	0.1		
Nist-2711-E	1162000	1.0268	1193.14	9797	0.1	82	
blank				0	0.1		
blank-spk (2500 ppb)				2416	0.1		
Nist2710-E	5532000	1.02091	5647.67	46181	0.1	82	
Blank				-0.20815	0.1		
blank-spk (2500 ppb)				2450.219	0.1		
Blank				-0.33483	0.1		
blank-spk (2500 ppb)				2392.72	0.1		
A16-7 1.5	686585	1.01478	696.73	-2.36156	0.1		
blank				0	0.1		
blank-spk (2500 ppb)				2426	0.1		
blank				-0.0069	0.1		average IVBA values for NIST 2711 =84
blank-spk (2500 ppb)				2346.681	0.1		
Nist2711-A	1162000	1.01566	1180.20	9726.621	0.1	82	
Blank				-0.30102	0.1		
blank-spk (2500 ppb)				2370.786	0.1		
blank				0	0.1		
blank-spk (2500 ppb)				2443	0.1		
Nist2711-D	1162000	1.01633	1180.98	9829	0.1	83	
blank				0	0.1		
blank-spk (2500 ppb)				2418	0.1		
Nist2711-C	1162000	1.02615	1192.39	10099	0.1	85	
blank				0	0.1		
blank-spk (2500 ppb)				2346	0.1		
Nist2711-B	1162000	1.03082	1197.81	9601	0.1	80	
blank				-0.03037	0.1		average IVBA values for NIST 2710 = 75
blank-spk (2500 ppb)				2368.692	0.1		
nist2710-D	5532000	1.02203	5653.87	42220.26	0.1	75	
blank				-0.03244	0.1		
blank-spk (2500 ppb)				2414.094	0.1		
nist-2710-C	5532000	1.00193	5542.68	41403.8	0.1	75	
Blank				-0.36673	0.1		
blank-spk (2500 ppb)				2413.644	0.1		
Nist-2710-B	5532000	1.0255	5673.07	40687.22	0.1	72	
NIST-2710-A	5532000	1.00278	5547.38	40225.56	0.1	73	
Blank				-0.32308	0.1		
blank-spk (2500 ppb)				2352.26	0.1		

	Soil A	Soil B	Soil C
Amended	681293.8	1082182	1618747
	532026.5	1062169	1625407
	621795.4	1046255	1568554
	587868.7	1080661	1582247
	611941.5	1083535	1609242
	604252.9	1067811	1693382
	614676.7	1002386	1594532
	617640.1	995630	1412139
	701391.3	1217070	1736799
	650820.7	1176734	1806966
	537239.9	1155706	1893764
	654948.7	1096131	1735079
	614402.6	1067154	1737645
	629066.3	1127347	1700083
	591390	1057823	1623469
	655213.5	1022882	1673180
	646259.9	1117094	1681157
	640881.8	1567277	1713476
	600207.9	1037699	1689139
	603908.3	1064065	1690294
	658684	1169929	1584236
	685079	1085163	1912556
	649964	1099567	1132165
	623924	1056847	1658073
	656944	1099673	1700748
	646450	1196311	1764689
	609855	1036598	1680722
	615261	1016903	1415041
	702865	1299449	1729932
	718707	1139335	1639902
	698685	1176003	2019028
	754238	1392479	2378515
	713505	1137812	2028967
	658857	1108866	1919677
	666174	1078790	3080028
	699173	1124049	2729021
	742458	1230887	1998361
	647617	1200982	1889105
	648775	1151611	2301750
	672190	1064332	2009449
	662275	1138105	1742609

	660231	1188256	1652061
	612198	1044157	1590131
	699693	1062344	1420552
	669668	1099800	1692734
	624309	1115837	1681235
	682428	942462	1665741
	749581	970125	1591136
	720232	1165078	1768201
	722377	1122074	2039655
	706748	1130880	1997255
	688054	1158275	1701493
	674617	1119399	1621237
	688336	1118696	1921166
	661108	1132633	1746869
	699407	1078621	1562146
	754132	1173586	1728690
	643645	1171676	1790238
	718730	1126662	1579062
		1135944	1635866
Average	659397	1119523	1770330
StDev	48803	95795	295592
%Difference from Control	20.73%	20.38%	22.52%

TABLE 2 . Preliminary Summary Of In Vitro Bioassay Results

Sample	ID	As in <250u bulk soil μg/kg	mass soil (g)	calc As #1	ICP As (μg/l)	solution amt (l)	% Relative As Bioavailability
A1-2 2.5		36964	1.00261	37.06	99	0.1	27
A2-2 2.5		37051	1.01143	37.47	96	0.1	26
A3-2 2.5		31785	1.00697	32.01	41	0.1	13
A4-2 2.5		34690	1.00531	34.87	50	0.1	14
A5-2 2.5		30480	1.01436	30.92	43	0.1	14
A6-2 2.5		30824	1.01914	31.41	39	0.1	12
A7-2 2.5		32725	1.00358	32.84	128	0.1	39
A8-2 2.5		32764	1.02226	33.49	142	0.1	43
A9-2 2.5		30159	1.02134	30.80	47	0.1	15
A10-2 2.5		29645	1.00691	29.85	46	0.1	15
Blank					0		
Blank-spk (2500 ppb)					2446		
A11-2 2.5		35193	1.00798	35.47	112	0.1	32
A12-2 2.5		32984	1.00277	33.08	119	0.1	36
A13-2 2.5		34032	1.02274	34.81	118	0.1	34
A14-2 2.5		34973	1.00438	35.13	102	0.1	29
A15-2 2.5		31903	1.01092	32.25	25	0.1	8
A16-2 2.5		32629	1.00027	32.64	29	0.1	9
A17-2 2.5		35688	1.01574	36.25	33	0.1	9
A18-2 2.5		36214	1.02124	36.98	32	0.1	9
A-19-2 2.5		32962	1.00376	33.09	118	0.1	36
A-20-2 2.5		31624	1.00669	31.84	114	0.1	36
Blank					0		
Blank-spk (2500 ppb)					2479		
A-21-2 2.5		39070	1.00625	39.31	124	0.1	31
A-22-2 2.5		37956	0.99986	37.95	125	0.1	33
B-1-2 2.5		42744	1.02734	43.91	112	0.1	25
B-2-2 2.5		42000	1.01229	42.52	112	0.1	26
B-3-2 2.5		35342	1.01167	35.75	36	0.1	10
B-4-2 2.5		34538	1.01162	34.94	34	0.1	10
B-5-2 2.5		33463	1.00419	33.60	38	0.1	11
B-6-2 2.5		34131	1.04282	35.59	43	0.1	12
B-7-2 2.5		36614	1.01164	37.04	127	0.1	34
B-8-2 2.5		36116	1.01433	36.63	127	0.1	35
B-9-2 2.5		32684	1.00073	32.71	40	0.1	12
B-10-2 2.5		33072	1.01823	33.68	39	0.1	11
B-11-2 2.5		40021	1.01617	40.67	122	0.1	30
B-12-2 2.5		37726	1.00145	37.78	123	0.1	33
Blank					0		
Blank-spk (2500 ppb)					2507		
B-13-2 2.5		40607	1.01026	41.02	135	0.1	33
B-14-2 2.5		40765	0.99633	40.62	126	0.1	31
B-15-2 2.5		35457	1.01067	35.83	33	0.1	9
B-16-2 2.5		37912	1.01375	38.43	36	0.1	9

B-17-2 2.5	38800	1.01457	39.37	36	0.1	9
B-18-2 2.5	40344	1.00814	40.67	35	0.1	9
B-19-2 2.5	38234	1.01069	38.64	108	0.1	28
B-20-2 2.5	37075	1.01084	37.48	109	0.1	29
B-21-2 2.5	43171	1.00891	43.56	122	0.1	28
B-22-2 2.5	42521	1.01446	43.14	125	0.1	29
Blank				0		
Blank-spk (2500 ppb)				2491		
C1-2 2.5	14962	1.01991	15.26	22	0.1	15
C2-2 2.5	14551	1.0099	14.70	20	0.1	14
C3-2 2.5	12627	0.99335	12.54	0	0.1	0
C4-2 2.5	13015	1.02134	13.29	3	0.1	2
C5-2 2.5	12519	1.02697	12.86	1	0.1	0
C6-2 2.5	12458	1.02033	12.71	3	0.1	3
C7-2 2.5	13722	1.01778	13.97	25	0.1	18
C8-2 2.5	13475	1.01738	13.71	25	0.1	18
C9-2 2.5	12167	1.0245	12.46	7	0.1	6
C10-2 2.5	12129	0.98456	11.94	6	0.1	5
Blank				0		
Blank-spk (2500 ppb)				2446		
C11-2 2.5	13832	1.014	14.03	30	0.1	21
C12-2 2.5	14513	1.01252	14.70	30	0.1	20
C13-2 2.5	17234	1.00698	17.35	28	0.1	16
C14-2 2.5	17166	0.99933	17.15	28	0.1	16
C15-2 2.5	13817	1.01003	13.96	4	0.1	3
C16-2 2.5	14069	1.01541	14.29	2	0.1	1
C17-2 2.5	16461	1.02764	16.92	7	0.1	4
C18-2 2.5	16342	1.02436	16.74	5	0.1	3
C19-2 2.5	14452	1.02365	14.79	29	0.1	19
C20-2 2.5	13550	1.02686	13.91	28	0.1	20
C21-2 2.5	18940	1.02329	19.38	32	0.1	16
C22-2 2.5	19163	1.00876	19.33	34	0.1	18
Blank				0		
Blank-spk (2500 ppb)				2523		
Blank				0		
Blank-spk (2500 ppb)				2517		
Blank				0		
Blank-spk (2500 ppb)				2317		
A1-7 2.5	36861	1.01122	37.28	84	0.1	23
A2-7 2.5	37956	1.00614	38.19	90	0.1	23
A3-7 2.5	30121	1.0154	30.58	30	0.1	10
A4-7 2.5	31408	1.0043	31.54	28	0.1	9
A5-7 2.5	30385	1.00287	30.47	32	0.1	10
A6-7 2.5	30629	1.02663	31.45	33	0.1	11
A7-7 2.5	32680	1.00666	32.90	112	0.1	34
A8-7 2.5	33096	1.01203	33.49	116	0.1	35
A9-7 2.5	29186	1.00882	29.44	40	0.1	13
A10-7 2.5	29380	1.01022	29.68	36	0.1	12
A11-7 2.5	35107	1.01419	35.61	103	0.1	29
A12-7 2.5	33329	1.01167	33.72	105	0.1	31
A13-7 2.5	37056	1.02031	37.81	116	0.1	31
A14-7 2.5	38319	1.01358	38.84	108	0.1	28
A15-7 2.5	34237	1.01641	34.80	20	0.1	6
A16-7 2.5	32992	0.99871	32.95	15	0.1	5
A17-7 2.5	36379	1.00909	36.71	35	0.1	10
A18-7 2.5	35403	1.01088	35.79	21	0.1	6
A19-7 2.5	32968	1.01687	33.52	104	0.1	31
A20-7 2.5	34608	1.00376	34.74	102	0.1	29
A21-7 2.5	37696	1.01044	38.09	112	0.1	29
A22-7 2.5	37714	1.00093	37.75	109	0.1	29
blank				0		
Blank-spk (2500 ppb)				2298		
B1-7 2.5	41570	1.00238	41.67	92	0.1	22
B2-7 2.5	42860	0.98795	42.34	93	0.1	22
B3-7 2.5	33282	1.01095	33.65	45	0.1	13
B4-7 2.5	32516	1.02084	33.19	43	0.1	13
B5-7 2.5	35252	1.00057	35.27	28	0.1	8
B6-7 2.5	32465	0.99931	32.44	26	0.1	8

B7-7 2.5	34867	0.99401	34.66	115	0.1	33
B8-7 2.5	36640	1.00477	36.81	112	0.1	31
B9-7 2.5	32088	0.99805	32.03	38	0.1	12
B10-7 2.5	30875	1.02573	31.67	49	0.1	16
blank				0		
Blank-spk (2500 ppb)				2278		
B11-7 2.5	38818	1.01728	39.49	106	0.1	27
B12-7 2.5	37225	1.0181	37.90	110	0.1	29
B13-7 2.5	41615	1.00774	41.94	100	0.1	24
B14-7 2.5	39928	1.01652	40.59	121	0.1	30
B15-7 2.5	36123	1.01348	36.61	29	0.1	8
B16-7 2.5	35698	0.99608	35.56	27	0.1	8
B17-7 2.5	38777	1.02249	39.65	29	0.1	7
B18-7 2.5	40530	1.00674	40.80	27	0.1	7
B19-7 2.5	39993	0.99828	39.92	147	0.1	37
B20-7 2.5	37520	1.01676	38.15	148	0.1	39
B21-7 2.5	42561	1.00743	42.88	143	0.1	33
B22-7 2.5	42079	1.02639	43.19	147	0.1	34
C1-7 2.5	14968	1.02206	15.30	30	0.1	19
C2-7 2.5	15091	1.02737	15.50	25	0.1	16
C3-7 2.5	12844	1.01688	13.06	16	0.1	12
C4-7 2.5	12709	1.01095	12.85	16	0.1	12
blank				-0.009		
Blank-spk (2500 ppb)				2658		
C5-7 2.5	13141	1.02358	13.45	11	0.1	8
C6-7 2.5	12926	0.99736	12.89	10	0.1	8
C7-7 2.5	13732	1.03088	14.16	33	0.1	23
C8-7 2.5	13573	1.03531	14.05	38	0.1	27
C9-7 2.5	12695	1.0152	12.89	11	0.1	9
C10-7 2.5	13173	0.99659	13.13	11	0.1	8
C11-7 2.5	15150	1.0001	15.15	31	0.1	21
C12-7 2.5	14314	1.01051	14.46	26	0.1	18
C13-7 2.5	16658	1.02583	17.09	37	0.1	21
C14-7 2.5	19441	1.01108	19.66	39	0.1	20
blank				0.081		
Blank-spk (2500 ppb)				2527		
C15-7 2.5	13695	1.00999	13.83	7	0.1	5
C16-7 2.5	14102	1.0151	14.31	4	0.1	3
C17-7 2.5	17630	1.01551	17.90	3	0.1	2
C18-7 2.5	18641	1.02369	19.08	4	0.1	2
C19-7 2.5	13811	1.01164	13.97	27	0.1	19
C20-7 2.5	14294	1.0007	14.30	36	0.1	25
C21-7 2.5	22559	1.01168	22.82	36	0.1	16
C22-7 2.5	20189	1.01702	20.53	36	0.1	18
C1-14 2.5	14102	1.03359	14.58	26	0.1	18
C2-14 2.5	14398	1.02164	14.71	26	0.1	18
BLANK				-0.075		
Blank-spk (2500 ppb)				2489		
C3-14 2.5	12733	0.98953	12.60	14	0.1	11
C4-14 2.5	12645	1.02045	12.90	10	0.1	8
C5-14 2.5	12199	0.99142	12.09	10	0.1	8
C6-14 2.5	12026	1.02455	12.32	10	0.1	8
C7-14 2.5	13940	1.01257	14.12	35	0.1	24
C8-14 2.5	13589	1.00931	13.72	39	0.1	28
C9-14 2.5	12334	1.02183	12.60	16	0.1	13
C10-14 2.5	11535	1.00022	11.54	14	0.1	12
C11-14 2.5	13935	1.0097	14.07	32	0.1	23
C12-14 2.5	13936	1.01039	14.08	35	0.1	25
C13-14 2.5	17402	1.02416	17.82	32	0.1	18
C14-14 2.5	16578	1.00033	16.58	30	0.1	18
C15-14 2.5	13348	0.99398	13.27	6	0.1	4
C16-14 2.5	13972	1.02127	14.27	7	0.1	5
blank				-0.061		
Blank-spk (2500 ppb)				2446		
C17-14 2.5	17095	1.01703	17.39	9	0.1	5
C18-14 2.5	15861	1.01095	16.03	9	0.1	6
C19-14 2.5	15045	1.01426	15.26	35	0.1	23
C20-14 2.5	15370	1.03026	15.84	30	0.1	19

C21-14 2.5	18685	1.0102	18.88	33	0.1	17
C22-14 2.5	19694	1.00137	19.72	38	0.1	19
B1-14 2.5	43234	1.00467	43.44	108	0.1	25
B2-14 2.5	43870	1.02777	45.09	115	0.1	26
B3-14 2.5	35104	1.0161	35.67	41	0.1	11
B4-14 2.5	34682	1.01896	35.34	42	0.1	12
blank				-0.013		
Blank-spk (2500 ppb)				2621		
B5-15 2.5	32719	1.01325	33.15	46	0.1	14
B6-14 2.5	33330	1.01056	33.68	43	0.1	13
B7-14 2.5	38370	0.9929	38.10	145	0.1	38
B8-14 2.5	37374	0.98996	37.00	145	0.1	39
B9-14 2.5	31768	0.99431	31.59	50	0.1	16
B10-14 2.5	31580	0.99165	31.32	46	0.1	15
B11-14 2.5	38449	1.01285	38.94	133	0.1	34
B12-14 2.5	37715	1.01935	38.44	146	0.1	38
B13-14 2.5	38640	0.99962	38.63	127	0.1	33
B14-14 2.5	39281	1.01461	39.86	130	0.1	33
BLANK				-0.083		
Blank-spk (2500 ppb)				2600		
B15-14 2.5	33644	1.00465	33.80	30	0.1	9
B16-14 2.5	36675	0.99995	36.67	31	0.1	8
B17-14 2.5	38845	0.99897	38.81	41	0.1	11
B18-14 2.5	37269	1.01854	37.96	35	0.1	9
B19-14 2.5	37194	1.00389	37.34	139	0.1	37
B20-14 2.5	37075	1.01117	37.49	145	0.1	39
B21-14-2.5	41973	1.00605	42.23	131	0.1	31
B22-14 2.5	42779	1.02318	43.77	125	0.1	28
BLANK				-0.014		
Blank-spk (2500 ppb)				2604		
A1-14 2.5	36476	1.01622	37.07	102	0.1	27
A2-14 2.5	36571	1.03159	37.73	92	0.1	24
A3-14 2.5	30622	1.01873	31.20	36	0.1	11
A4-14 2.5	30495	0.98984	30.18	35	0.1	12
A5-14 2.5	31792	1.00899	32.08	37	0.1	12
A6-14 2.5	29588	0.99912	29.56	48	0.1	16
A7-14 2.5	34169	1.01343	34.63	134	0.1	39
A8-14 2.5	33130	1.00573	33.32	122	0.1	37
A9-14 2.5	29664	1.04499	31.00	45	0.1	15
A10-14 2.5	32907	1.00801	33.17	41	0.1	12
A11-14 2.5	35961	1.00485	36.14	112	0.1	31
A12-14 2.5	36453	1.01772	37.10	123	0.1	33
A13-14 2.5	37095	0.99729	36.99	122	0.1	33
A14-14 2.5	37089	1.014	37.61	124	0.1	33
A15-14 2.5	33850	1.01009	34.19	27	0.1	8
A16-14 2.5	33385	1.00055	33.40	24	0.1	7
A17-14 2.5	36767	1.00242	36.86	43	0.1	12
A18-14 2.5	36753	1.01796	37.41	47	0.1	13
A19-14 2.5	35013	1.01805	35.65	129	0.1	36
A20-14 2.5	35354	1.00641	35.58	124	0.1	35
A21-14 2.5	38466	1.01327	38.98	123	0.1	32
A22-14 2.5	40410	1.01352	40.96	116.46	0.1	28
BLANK				0.068		
Blank-spk (2500 ppb)				2636.235		

TABLE 2 . Preliminary Summary Of In Vitro Bioassay Results

Sample	ID	Pb in <250u bulk soil μg/kg	mass soil (g)	calc Pb #1	ICP Pb (μg/l)	solution amt (l)	% Relative Pb Bioavailability
A1-2 2.5		805137	1.00261	807.24	3389	0.1	42
A2-2 2.5		808650	1.01143	817.89	3507	0.1	43
A3-2 2.5		681294	1.00697	686.04	2534	0.1	37
A4-2 2.5		532026	1.00531	534.85	1954	0.1	37
A5-2 2.5		621795	1.01436	630.72	1630	0.1	26
A6-2 2.5		587869	1.01914	599.12	1463	0.1	24
A7-2 2.5		611942	1.00358	614.13	1745	0.1	28
A8-2 2.5		604253	1.02226	617.70	1674	0.1	27
A9-2 2.5		614677	1.02134	627.79	1132	0.1	18
A10-2 2.5		617640	1.00691	621.91	1068	0.1	17
Blank					0		
Blank Spike (2500 ppb)					2470		
A11-2 2.5		701391	1.00798	706.99	3022	0.1	43
A12-2 2.5		650821	1.00277	652.62	2883	0.1	44
A13-2 2.5		537240	1.02274	549.46	2682	0.1	49
A14-2 2.5		654949	1.00438	657.82	3142	0.1	48
A15-2 2.5		614403	1.01092	621.11	2375	0.1	38
A16-2 2.5		629066	1.00027	629.24	2328	0.1	37
A17-2 2.5		591390	1.01574	600.70	2281	0.1	38
A18-2 2.5		655213	1.02124	669.13	2615	0.1	39
A-19-2 2.5		646260	1.00376	648.69	2357	0.1	36
A-20-2 2.5		640882	1.00669	645.17	2512	0.1	39
Blank					0		
Blank Spike (2500 ppb)					2496		
A-21-2 2.5		600208	1.00625	603.96	2832	0.1	47
A-22-2 2.5		603908	0.99986	603.82	2977	0.1	49
B-1-2 2.5		1377381	1.02734	1415.04	7169	0.1	51
B-2-2 2.5		1311224	1.01229	1327.34	7075	0.1	53
B-3-2 2.5		1082182	1.01167	1094.81	4254	0.1	39
B-4-2 2.5		1062169	1.01162	1074.51	4625	0.1	43
B-5-2 2.5		1046255	1.00419	1050.64	2991	0.1	28
B-6-2 2.5		1080661	1.04282	1126.93	2955	0.1	26
B-7-2 2.5		1083535	1.01164	1096.15	2757	0.1	25
B-8-2 2.5		1067811	1.01433	1083.11	2737	0.1	25
B-9-2 2.5		1002386	1.00073	1003.12	1953	0.1	19
B-10-2 2.5		995630	1.01823	1013.78	2067	0.1	20
B-11-2 2.5		1217070	1.01617	1236.75	6075	0.1	49
B-12-2 2.5		1176734	1.00145	1178.44	6105	0.1	52
Blank					0		
Blank-spk (2500 ppb)					2612		

B-13-2 2.5	1155706	1.01026	1167.56	6285	0.1	54
B-14-2 2.5	1096131	0.99633	1092.11	6303	0.1	58
B-15-2 2.5	1067154	1.01067	1078.54	5039	0.1	47
B-16-2 2.5	1127347	1.01375	1142.85	4922	0.1	43
B-17-2 2.5	1057823	1.01457	1073.24	5060	0.1	47
B-18-2 2.5	1022882	1.00814	1031.21	4724	0.1	46
B-19-2 2.5	1117094	1.01069	1129.04	4769	0.1	42
B-20-2 2.5	1567277	1.01084	1584.27	6195	0.1	39
B-21-2 2.5	1037699	1.00891	1046.94	5300	0.1	51
B-22-2 2.5	1064065	1.01446	1079.45	5599	0.1	52
Blank				0		
Blank-spk (2500 ppb)				2583		
C1-2 2.5	2220312	1.01991	2264.52	13292	0.1	59
C2-2 2.5	2157539	1.0099	2178.90	13083	0.1	60
C3-2 2.5	1618747	0.99335	1607.98	7178	0.1	45
C4-2 2.5	1625407	1.02134	1660.09	7377	0.1	44
C5-2 2.5	1568554	1.02697	1610.86	4437	0.1	28
C6-2 2.5	1582247	1.02033	1614.41	4884	0.1	30
C7-2 2.5	1609242	1.01778	1637.85	5444	0.1	33
C8-2 2.5	1693382	1.01738	1722.81	6040	0.1	35
C9-2 2.5	1594532	1.0245	1633.60	4026	0.1	25
C10-2 2.5	1412139	0.98456	1390.34	3388	0.1	24
Blank				0		
Blank-spk (2500 ppb)				2521		
C11-2 2.5	1736799	1.014	1761.11	10314	0.1	59
C12-2 2.5	1806966	1.01252	1829.59	9979	0.1	55
C13-2 2.5	1893764	1.00698	1906.98	11947	0.1	63
C14-2 2.5	1735079	0.99933	1733.92	10975	0.1	63
C15-2 2.5	1737645	1.01003	1755.07	9209	0.1	52
C16-2 2.5	1700083	1.01541	1726.28	8642	0.1	50
C17-2 2.5	1623469	1.02764	1668.34	9804	0.1	59
C18-2 2.5	1673180	1.02436	1713.94	9927	0.1	58
C19-2 2.5	1681157	1.02365	1720.92	8526	0.1	50
C20-2 2.5	1713476	1.02686	1759.50	8699	0.1	49
C21-2 2.5	1689139	1.02329	1728.48	10385	0.1	60
C22-2 2.5	1690294	1.00876	1705.10	10482	0.1	61
Blank				0		
Blank-spk (2500 ppb)				2613		
Blank				0		
Blank-spk (2500 ppb)				2582		
Blank				0		
Blank-spk (2500 ppb)				2370		
A1-7 2.5	827954	1.01122	837.24	3149	0.1	38
A2-7 2.5	844000	1.00614	849.18	3133	0.1	37
A3-7 2.5	658684	1.0154	668.83	2330	0.1	35
A4-7 2.5	685079	1.0043	688.03	2089	0.1	30
A5-7 2.5	649964	1.00287	651.83	1438	0.1	22
A6-7 2.5	623924	1.02663	640.54	1534	0.1	24
A7-7 2.5	656944	1.00666	661.32	1294	0.1	20
A8-7 2.5	646450	1.01203	654.23	1134	0.1	17
A9-7 2.5	609855	1.00882	615.23	936	0.1	15
A10-7 2.5	615261	1.01022	621.55	1088	0.1	18
A11-7 2.5	702865	1.01419	712.84	2880	0.1	40
A12-7 2.5	718707	1.01167	727.09	2912	0.1	40
A13-7 2.5	698685	1.02031	712.87	3075	0.1	43
A14-7 2.5	754238	1.01358	764.48	3008	0.1	39
A15-7 2.5	713505	1.01641	725.21	2690	0.1	37
A16-7 2.5	686585	0.99871	685.70	2591	0.1	38
A17-7 2.5	658857	1.00909	664.85	2483	0.1	37
A18-7 2.5	666174	1.01088	673.42	2475	0.1	37
A19-7 2.5	699173	1.01687	710.97	2755	0.1	39
A20-7 2.5	742458	1.00376	745.25	2971	0.1	40
A21-7 2.5	647617	1.01044	654.38	2954	0.1	45
A22-7 2.5	648775	1.00093	649.38	2830	0.1	44

blank				0		
Blank-spk (2500 ppb)				2354		
B1-7 2.5	1427932	1.00238	1431.33	6326	0.1	44
B2-7 2.5	1448251	0.98795	1430.80	6328	0.1	44
B3-7 2.5	1169929	1.01095	1182.74	3587	0.1	30
B4-7 2.5	1085163	1.02084	1107.78	3960	0.1	36
B5-7 2.5	1099567	1.00057	1100.19	2417	0.1	22
B6-7 2.5	1056847	0.99931	1056.12	2671	0.1	25
B7-7 2.5	1099673	0.99401	1093.09	2111	0.1	19
B8-7 2.5	1196311	1.00477	1202.02	2536	0.1	21
B9-7 2.5	1036598	0.99805	1034.58	1384	0.1	13
B10-7 2.5	1016903	1.02573	1043.07	2227	0.1	21
blank				0		
Blank-spk (2500 ppb)				2352		
B11-7 2.5	1299449	1.01728	1321.90	5375	0.1	41
B12-7 2.5	1139335	1.0181	1159.96	5003	0.1	43
B13-7 2.5	1176003	1.00774	1185.11	5406	0.1	46
B14-7 2.5	1392479	1.01652	1415.48	6792	0.1	48
B15-7 2.5	1137812	1.01348	1153.15	4300	0.1	37
B16-7 2.5	1108866	0.99608	1104.52	4434	0.1	40
B17-7 2.5	1078790	1.02249	1103.05	4111	0.1	37
B18-7 2.5	1124049	1.00674	1131.62	4277	0.1	38
B19-7 2.5	1230887	0.99828	1228.77	5094	0.1	41
B20-7 2.5	1200982	1.01676	1221.11	5025	0.1	41
B21-7 2.5	1151611	1.00743	1160.17	5458	0.1	47
B22-7 2.5	1064332	1.02639	1092.42	4964	0.1	45
C1-7 2.5	2330276	1.02206	2381.68	13481	0.1	57
C2-7 2.5	2365095	1.02737	2429.83	14012	0.1	58
C3-7 2.5	1584236	1.01688	1610.98	6765	0.1	42
C4-7 2.5	1912556	1.01095	1933.50	7981	0.1	41
blank				0.009		
Blank-spk (2500 ppb)				2580		
C5-7 2.5	1132165	1.02358	1158.86	3843	0.1	33
C6-7 2.5	1658073	0.99736	1653.70	5535	0.1	33
C7-7 2.5	1700748	1.03088	1753.27	5434	0.1	31
C8-7 2.5	1764689	1.03531	1827.00	5559	0.1	30
C9-7 2.5	1680722	1.0152	1706.27	4340	0.1	25
C10-7 2.5	1415041	0.99659	1410.22	4177	0.1	30
C11-7 2.5	1729932	1.0001	1730.11	9474	0.1	55
C12-7 2.5	1639902	1.01051	1657.14	9086	0.1	55
C13-7 2.5	2019028	1.02583	2071.18	13493	0.1	65
C14-7 2.5	2378515	1.01108	2404.87	14794	0.1	62
blank				0.017		
Blank-spk (2500 ppb)				2534		
C15-7 2.5	2028967	1.00999	2049.24	10774	0.1	53
C16-7 2.5	1919677	1.0151	1948.66	9284	0.1	48
C17-7 2.5	3080028	1.01551	3127.80	16896	0.1	54
C18-7 2.5	2729021	1.02369	2793.67	13497	0.1	48
C19-7 2.5	1998361	1.01164	2021.62	8391	0.1	42
C20-7 2.5	1889105	1.0007	1890.43	9194	0.1	49
C21-7 2.5	2301750	1.01168	2328.63	13693	0.1	59
C22-7 2.5	2009449	1.01702	2043.65	12310	0.1	60
C1-14 2.5	2169086	1.03359	2241.95	14950	0.1	67
C2-14 2.5	2194213	1.02164	2241.70	14100	0.1	63
BLANK				0.053		
Blank-spk (2500 ppb)				2495		
C3-14 2.5	1742609	0.98953	1724.36	9049	0.1	52
C4-14 2.5	1652061	1.02045	1685.85	8949	0.1	53
C5-14 2.5	1590131	0.99142	1576.49	6643	0.1	42
C6-14 2.5	1420552	1.02455	1455.43	6056	0.1	42
C7-14 2.5	1692734	1.01257	1714.01	6750	0.1	39
C8-14 2.5	1681235	1.00931	1696.89	6820	0.1	40
C9-14 2.5	1665741	1.02183	1702.10	4778	0.1	28
C10-14 2.5	1591136	1.00022	1591.49	4812	0.1	30

C11-14 2.5	1768201	1.0097	1785.35	10792	0.1	60
C12-14 2.5	2039655	1.01039	2060.85	12027	0.1	58
C13-14 2.5	1997255	1.02416	2045.51	13755	0.1	67
C14-14 2.5	1701493	1.00033	1702.05	10719	0.1	63
C15-14 2.5	1621237	0.99398	1611.48	9200	0.1	57
C16-14 2.5	1921166	1.02127	1962.03	10804	0.1	55
blank				0.228		
Blank-spk (2500 ppb)				2497		
C17-14 2.5	1746869	1.01703	1776.62	9796	0.1	55
C18-14 2.5	1562146	1.01095	1579.25	9169	0.1	58
C19-14 2.5	1728690	1.01426	1753.34	8138	0.1	46
C20-14 2.5	1790238	1.03026	1844.41	8292	0.1	45
C21-14 2.5	1579062	1.0102	1595.17	9742	0.1	61
C22-14 2.5	1635866	1.00137	1638.11	9682	0.1	59
B1-14 2.5	1436138	1.00467	1442.84	7172	0.1	50
B2-14 2.5	1439339	1.02777	1479.31	7447	0.1	50
B3-14 2.5	1138105	1.0161	1156.43	4645	0.1	40
B4-14 2.5	1188256	1.01896	1210.79	4806	0.1	40
blank				0.168		
Blank-spk (2500 ppb)				2608		
B5-15 2.5	1044157	1.01325	1057.99	3139	0.1	30
B6-14 2.5	1062344	1.01056	1073.56	3103	0.1	29
B7-14 2.5	1099800	0.9929	1091.99	2635	0.1	24
B8-14 2.5	1115837	0.98996	1104.63	2495	0.1	23
B9-14 2.5	942462	0.99431	937.10	1266	0.1	14
B10-14 2.5	970125	0.99165	962.02	965	0.1	10
B11-14 2.5	1165078	1.01285	1180.05	5920	0.1	50
B12-14 2.5	1122074	1.01935	1143.79	5457	0.1	48
B13-14 2.5	1130880	0.99962	1130.45	6089	0.1	54
B14-14 2.5	1158275	1.01461	1175.20	6361	0.1	54
BLANK				0.053	0.1	
Blank-spk (2500 ppb)				2620	0.1	
B15-14 2.5	1119399	1.00465	1124.60	5335	0.1	47
B16-14 2.5	1118696	0.99995	1118.64	5125	0.1	46
B17-14 2.5	1132633	0.99897	1131.47	5386	0.1	48
B18-14 2.5	1078621	1.01854	1098.62	5145	0.1	47
B19-14 2.5	1173586	1.00389	1178.15	5274	0.1	45
B20-14 2.5	1171676	1.01117	1184.76	5377	0.1	45
B21-14-2.5	1126662	1.00605	1133.48	5569	0.1	49
B22-14 2.5	1135944	1.02318	1162.27	5423	0.1	47
BLANK				0.118		
Blank-spk (2500 ppb)				2628		
A1-14 2.5	827083	1.01622	840.50	3609	0.1	43
A2-14 2.5	828561	1.03159	854.73	3494	0.1	41
A3-14 2.5	672190	1.01873	684.78	2562	0.1	37
A4-14 2.5	662275	0.98984	655.55	2589	0.1	39
A5-14 2.5	660231	1.00899	666.17	1696	0.1	25
A6-14 2.5	612198	0.99912	611.66	1634	0.1	27
A7-14 2.5	699693	1.01343	709.09	1594	0.1	22
A8-14 2.5	669668	1.00573	673.51	1855	0.1	28
A9-14 2.5	624309	1.04499	652.40	884	0.1	14
A10-14 2.5	682428	1.00801	687.89	1058	0.1	15
A11-14 2.5	749581	1.00485	753.22	3168	0.1	42
A12-14 2.5	720232	1.01772	732.99	3215	0.1	44
A13-14 2.5	722377	0.99729	720.42	3304	0.1	46
A14-14 2.5	706748	1.014	716.64	3279	0.1	46
A15-14 2.5	688054	1.01009	695.00	2771	0.1	40
A16-14 2.5	674617	1.00055	674.99	2801	0.1	41
A17-14 2.5	688336	1.00242	690.00	2963	0.1	43
A18-14 2.5	661108	1.01796	672.98	2865	0.1	43
A19-14 2.5	699407	1.01805	712.03	2901	0.1	41
A20-14 2.5	754132	1.00641	758.97	2972	0.1	39
A21-14 2.5	643645	1.01327	652.19	2937	0.1	45
A22-14 2.5	718730	1.01352	728.45	3017.371	0.1	41

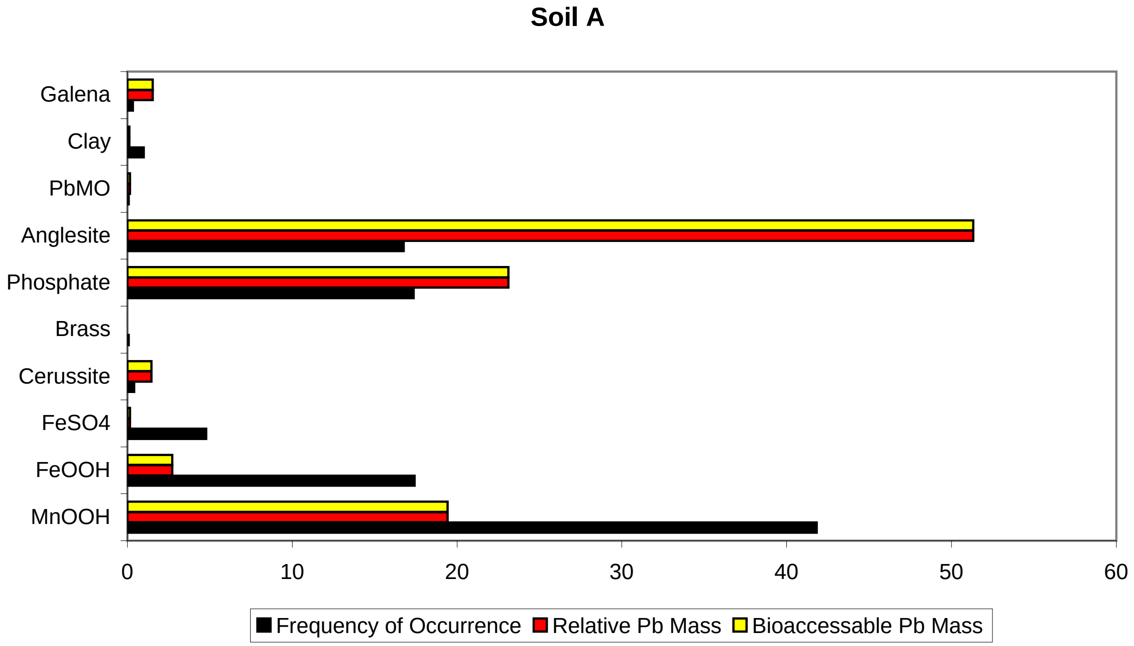
BLANK	-0.015
Blank-spk (2500 ppb)	2250.793

Form	Association	Size (microns)
Mn	Cemented	17
Mn	Liberated	4
Fe	Cemented	11
Mn	Cemented	8
Mn	Cemented	7
Mn	Cemented	3
Mn	Cemented	3
Mn	Cemented	3
Mn	Cemented	3
Mn	Cemented	3
Mn	Cemented	7
Sulf	Liberated	15
Fe	Liberated	4
Fe	Cemented	7
Cer	Liberated	6
Fe	Cemented	13
brass	Liberated	1
Fe	Cemented	9
Fe	Rimming	5
Sulf	Liberated	8
Phos	Cemented	3
Fe	Cemented	6
Mn	Cemented	18
Mn	Rimming	14
Mn	Cemented	11
Mn	Cemented	14
Mn	Cemented	27
Mn	Cemented	26
Mn	Cemented	44

Form	Particle Count Number	Size Mean	Std-Dev	Range low	Range high
total	103	14.65	30.12	1	250
MnOOH	39	16.18	16.19	3	85
FeOOH	25	10.52	10.36	1	50
FeSO4	10	7.2	8.28	3	28
Cerussite	1	6	ND	6	6
Brass	1	1	ND	1	1
Phosphate	20	13.1	33.94	1	150
Anglesite	2	126.5	174.66	3	250
PbMO	1	1	ND	1	1
Clay	3	5	4.36	2	10
Galena	1	5	ND	5	5

Form	(linear) freq	Bio freq	Rm Pb	Biorm Pb	Error-95%
%	%	%	%	%	
MnOOH	41.82	41.82	19.43	19.43	9.53
FeOOH	17.43	17.43	2.72	2.72	7.33
FeSO4	4.77	4.77	0.15	0.15	4.12
Cerussite	0.4	0.4	1.45	1.45	1.22
Brass	0.07	0.07	0	0	0.5
Phosphate	17.36	17.36	23.11	23.11	7.32
Anglesite	16.77	16.77	51.32	51.32	7.21
PbMO	0.07	0.07	0.16	0.16	0.5
Clay	0.99	0.99	0.12	0.12	1.92
Galena	0.33	0.33	1.53	1.53	1.11

Sulf	Rimming	28
Mn	Cemented	13
Fe	Liberated	50
Mn	Cemented	3
Mn	Cemented	28
Ang	Liberated	3
Mn	Liberated	16
Mn	Liberated	8
Fe	Cemented	4
Fe	Cemented	10
Mn	Liberated	22
Phos	Liberated	9
Fe	Cemented	9
Fe	Cemented	27
Mn	Rimming	8
Fe	Liberated	8
Mn	Cemented	16
Mn	Cemented	12
Phos	Cemented	40
Fe	Cemented	9
Fe	Liberated	10
Fe	Liberated	8
Phos	Cemented	3
Phos	Cemented	4
Mn	Cemented	8
Mn	Rimming	13
Mn	Rimming	7
Mn	Rimming	3
PbMO	Cemented	1
Ang	Cemented	250
Phos	Cemented	150
Mn	Rimming	50
Fe	Rimming	4
Fe	Liberated	3
Fe	Cemented	1
Fe	Cemented	1
Fe	Liberated	4
Phos	Cemented	8
Mn	Cemented	13
Mn	Cemented	42
Fe	Liberated	21
Sulf	Liberated	3
Sulf	Liberated	3
Sulf	Liberated	3



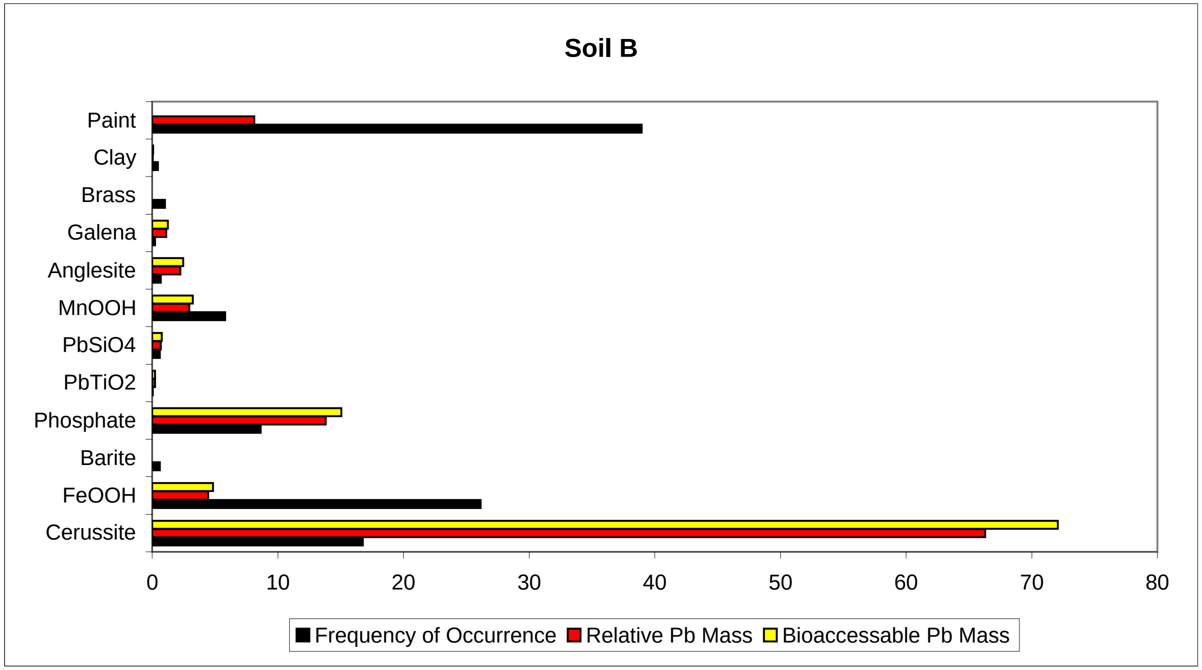
Sulf	Liberated	3
Sulf	Liberated	3
Sulf	Liberated	3
Sulf	Liberated	3
Mn	Cemented	85
AlSi	Liberated	2
AlSi	Liberated	10
AlSi	Liberated	3
Fe	Liberated	9
Phos	Liberated	2
Mn	Cemented	16
Mn	Cemented	10
Fe	Cemented	22
Phos	Cemented	1
Phos	Cemented	1
Phos	Cemented	1
Phos	Cemented	1
Phos	Cemented	1
Phos	Cemented	1
Phos	Cemented	1
Phos	Cemented	1
Phos	Cemented	1
Phos	Cemented	1
Phos	Cemented	1
Mn	Cemented	10
Ga	Liberated	5
Phos	Liberated	32
Fe	Liberated	8
Mn	Liberated	8
Mn	Cemented	28

Form	Association	Size (microns)
Cer	Liberated	1
Fe	Liberated	11
Cer	Cemented	1
bar	Cemented	3
Cer	Cemented	1
Phos	Liberated	3
Cer	Liberated	2
Cer	Cemented	1
Fe	Cemented	32
Fe	Cemented	6
Cer	Liberated	1
Fe	Cemented	13
Fe	Rimming	10
Fe	Cemented	14
Cer	Liberated	1
pbtio2	Liberated	1
Cer	Cemented	1
PbSiO4	Liberated	1
Cer	Liberated	1
Cer	Liberated	4
Cer	Liberated	3
Cer	Liberated	1
Mn	Liberated	6
Phos	Liberated	3
Fe	Rimming	5
Mn	Cemented	30
Fe	Cemented	65
Cer	Cemented	3
Cer	Liberated	1
Cer	Liberated	1
Cer	Liberated	1
Fe	Liberated	4

Form	Particle Count Number	Size Mean	Std-Dev	Range low	Range high
total	135	13.12	62.09	1	690
Cerussite	63	4.71	25.03	1	200
FeOOH	24	19.29	19.53	4	75
Barite	2	5.5	3.54	3	8
Phosphate	21	7.29	9.2	1	43
PbTiO2	1	1	ND	1	1
PbSiO4	9	1.22	0.44	1	2
MnOOH	7	14.71	11.48	1	30
Anglesite	3	4	4.36	1	9
Galena	2	2	1.41	1	3
Brass	1	18	ND	18	18
Clay	1	8	ND	8	8
Paint	1	690	ND	690	690

Form	(linear) freq	Bio freq	Rm Pb	Biorm Pb	Error-95%
%	%	%	%	%	
Cerussite	16.77	27.41	66.29	72.08	6.3
FeOOH	26.14	42.87	4.45	4.85	7.41
Barite	0.62	1.02	0	0	1.33
Phosphate	8.64	14.17	13.8	15.06	4.74
PbTiO2	0.06	0.09	0.22	0.24	0.4
PbSiO4	0.62	1.02	0.7	0.77	1.33
MnOOH	5.82	9.54	2.96	3.23	3.95
Anglesite	0.68	1.11	2.25	2.46	1.38
Galena	0.23	0.37	1.13	1.24	0.8
Brass	1.02	1.67	0.01	0.01	1.69
Clay	0.45	0.74	0.06	0.07	1.13
Paint	38.96	0	8.12	0	8.23

Cer	Cemented	1
Cer	Liberated	3
Cer	Liberated	1
Cer	Liberated	1
PbSiO4	Liberated	1
Cer	Cemented	1
Phos	Cemented	5
Phos	Liberated	2
Mn	Cemented	18
Cer	Liberated	1
Phos	Cemented	11
Cer	Rimming	1
Phos	Cemented	4
Phos	Cemented	7
Phos	Liberated	43
Fe	Cemented	16
Phos	Cemented	2
Ang	Rimming	1
Phos	Liberated	19
Cer	Liberated	1
Cer	Liberated	1
Cer	Liberated	1
bar	Rimming	8
Phos	Liberated	6
PbSiO4	Liberated	1
PbSiO4	Liberated	1
Mn	Cemented	1
Fe	Cemented	12
Cer	Inclusion	1
Fe	Cemented	16
Phos	Liberated	1
Phos	Liberated	6
Ga	Liberated	3
Cer	Liberated	3
Phos	Liberated	5
Cer	Cemented	2
Cer	Cemented	1
Fe	Rimming	16
Ang	Liberated	2
Cer	Liberated	1
Fe	Cemented	7
Fe	Liberated	5
Fe	Liberated	4
Cer	Liberated	1
Cer	Rimming	1



Phos	Liberated	4
Cer	Liberated	9
Cer	Liberated	5
Cer	Liberated	2
Mn	Liberated	29
Cer	Liberated	1
Cer	Liberated	2
brass	Liberated	18
AlSi	Cemented	8
Cer	Liberated	1
PbSiO4	Rimming	1
PbSiO4	Liberated	1
Fe	Liberated	23
Cer	Liberated	1
Cer	Cemented	200
Cer	Liberated	1
Cer	Liberated	4
Cer	Liberated	1
Mn	Cemented	13
Cer	Liberated	2
Phos	Liberated	5
PbSiO4	Liberated	1
Cer	Liberated	2
Fe	Liberated	75
Mn	Cemented	6
Phos	Cemented	13
Phos	Liberated	5
Ga	Liberated	1
Cer	Liberated	3
Fe	Liberated	35
Cer	Liberated	1
Cer	Liberated	2
Cer	Cemented	1
Fe	Cemented	4
Fe	Cemented	4
Phos	Liberated	4
Phos	Liberated	3
Cer	Liberated	1
Cer	Liberated	1
PbSiO4	Liberated	2
Fe	Cemented	42
Cer	Liberated	1
Cer	Liberated	1
Cer	Liberated	1
Cer	Liberated	1

Cer	Liberated	1
Cer	Liberated	1
Cer	Liberated	1
Cer	Liberated	1
Cer	Liberated	1
Cer	Liberated	1
Fe	Liberated	40
Phos	Liberated	2
Ang	Rimming	9
Fe	Liberated	4
PbSiO4	Liberated	2
Cer	Liberated	1
Paint	Liberated	690

Form	Association	Size (microns)
Cer	Liberated	1
Phos	Cemented	2
Phos	Cemented	2
Phos	Cemented	2
Phos	Cemented	2
Phos	Cemented	2
Phos	Cemented	2
Phos	Cemented	2
Phos	Cemented	2
Phos	Cemented	2
Phos	Cemented	2
Phos	Cemented	2
pbtio2	Liberated	2
Ang	Liberated	8
Ang	Liberated	8
Mn	Liberated	19
Mn	Rimming	20
PbMO	Liberated	4
Cer	Liberated	5
Cer	Cemented	1
Cer	Cemented	1
pbtio2	Liberated	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	3
PbSiO4	Liberated	2
PbSiO4	Liberated	2
PbSiO4	Liberated	1
Cer	Cemented	1
PbSiO4	Liberated	2

Form	Particle Count Number	Size Mean	Std-Dev	Range low	Range high
total	110	2.24	3.22	1	20
Cerussite	38	1.76	1.63	1	8
Phosphate	12	2.25	0.87	2	5
PbTiO2	25	1.04	0.2	1	2
Anglesite	2	8	0	8	8
MnOOH	3	18.33	2.08	16	20
PbMO	1	4	ND	4	4
PbSiO4	25	1.12	0.33	1	2
Clay	1	2	ND	2	2
Barite	1	10	ND	10	10
FeSO4	1	7	ND	7	7
FeOOH	1	4	ND	4	4

Form	(linear) freq	Bio freq	Rm Pb	Biorm Pb	Error-95%
%	%	%	%	%	
Cerussite	27.24	27.24	49.76	49.76	8.32
Phosphate	10.98	10.98	7.6	7.6	5.84
PbTiO2	10.57	10.57	19.23	19.23	5.75
Anglesite	6.5	6.5	10	10	4.61
MnOOH	22.36	22.36	5.26	5.26	7.79
PbMO	1.63	1.63	1.99	1.99	2.36
PbSiO4	11.38	11.38	5.94	5.94	5.94
Clay	0.81	0.81	0.05	0.05	1.68
Barite	4.07	4.07	0	0	3.69
FeSO4	2.85	2.85	0.05	0.05	3.11
FeOOH	1.63	1.63	0.13	0.13	2.36

Cer	Liberated	5
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Liberated	4
Cer	Liberated	2
AlSi	Liberated	2
bar	Cemented	10
Sulf	Liberated	7
Phos	Cemented	5
Mn	Cemented	16
Fe	Cemented	4
Cer	Cemented	2
Cer	Liberated	5
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
Cer	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
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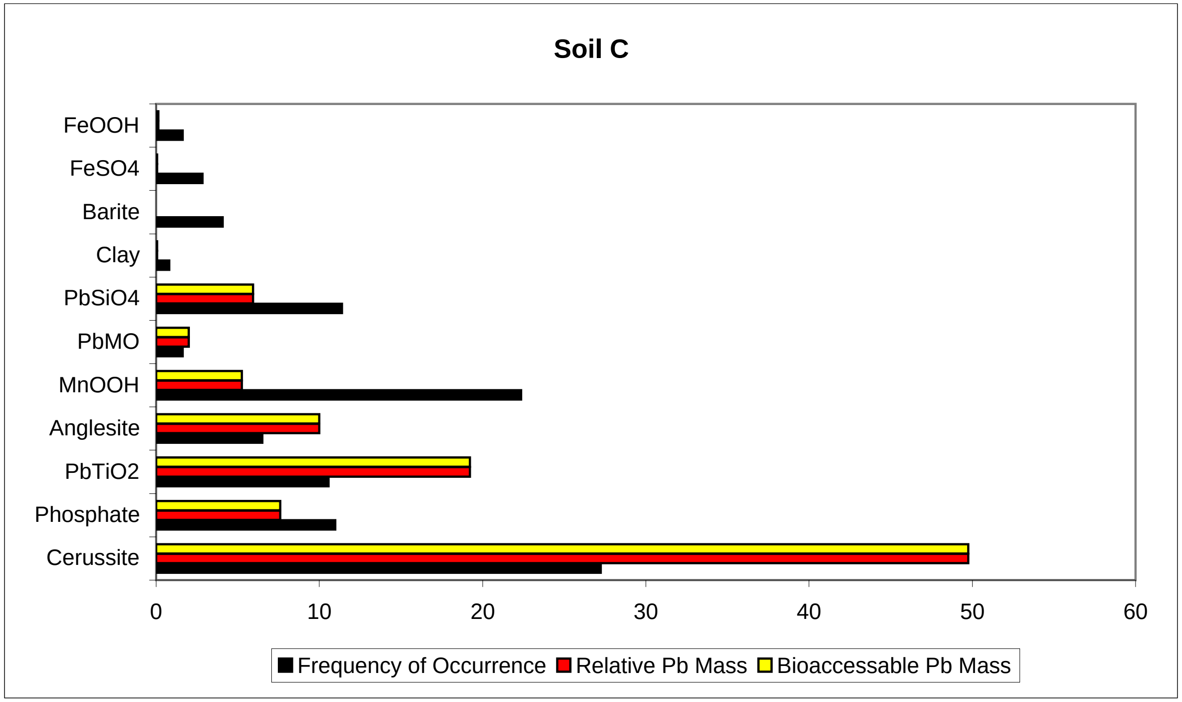
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1



pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
pbtio2	Cemented	1
Cer	Cemented	8
Cer	Cemented	4
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1
PbSiO4	Cemented	1

Appendix C

Preliminary Remediation Goals for Protection of Children from Lead in Soil at the Omaha Lead Site

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MEMORANDUM

To: Bob Feild, USEPA Region 7 RPM
Michael Beringer, USEPA Region 7 Toxicologist
From: Bill Brattin, Jennifer Walter
Date: October 16, 2008
Subject: Preliminary Remediation Goals for Protection of Children from Lead in Surface Soil at the Omaha Lead Site

---

1.0 INTRODUCTION

This memorandum presents preliminary remediation goals (PRGs) for protection of residents from lead in surface soil at the Omaha Lead Site (OLS).

The PRG for lead in soil is the average concentration of lead in a residential yard that is associated with no more than a 5% chance that a child (age 0-84 months of age) living at the property will have a blood lead level that exceeds 10 µg/dL (USEPA 1998).

2.0 METHOD FOR CALCULATING THE PRG FOR LEAD

Mathematical Model

The standard model developed by the USEPA to assess the risks of lead exposure in residential children is referred to as the Integrated Exposure Uptake Biokinetic (IEUBK) model (USEPA 1994). This model requires input data on the levels of lead in various environmental media at a specific location, and on the amount of these media contacted by a child living at that location. All of these inputs to the IEUBK model are central tendency point estimates (i.e., arithmetic means or medians). These point estimates are used to calculate an estimate of the central tendency (the geometric mean, GM) of the distribution of blood lead values that might occur in a population of children exposed to lead under the specified conditions. Assuming the distribution is lognormal, and given (as input) an estimate of the variability between different children (this is specified by the geometric standard deviation or GSD), the model calculates the expected distribution of blood lead values, and estimates the probability that any random child might have a blood lead value over 10 µg/dL. For convenience, the probability of having a blood lead level above 10 µg/dL is referred to as P10.

The PRG is computed by finding the concentration of lead in soil that yields a P10 value equal to EPA's health-based goal (P10 ≤ 5%). This may be done in a number of different ways. For this site, the soil PRG was calculated by running a batch file that calculated the value of P10 for a range of different soil levels, and finding the soil level that yielded a P10 value of 5%.

Input Parameters

The IEUBK model input parameters used in the PRG model runs are the same values used in the baseline human health risk assessment (USEPA 2008a). These values are presented in Table 1. Most of the values are the national defaults recommended for use by USEPA (USEPA 1994). Some of the values (i.e., the relative bioavailability of lead, the relationship between lead in dust and soil, and the concentration of lead in air and water) are based on site-specific data, as described in the risk assessment (USEPA 2008a).

3.0 RESULTS

Based on the approaches and inputs specified above, the resulting PRG for protection of current and future residential children at the OLS from lead in soil is 298 mg/kg.

This PRG corresponds to the acceptable concentration of lead in the "fine" particle fraction (< 250 µm) of soil. This is because it is believed that the fine fraction of soil is most likely to adhere to the hands of children. This PRG is appropriate for comparison to lead measured in fine-grained soil (< 250 µm) using an accurate analytical method such as Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES).

However, most data on the concentration of lead in residential yards at the OLS are based on measurements of the bulk soil fraction (< 2 mm) using X-ray fluorescence (XRF). This complicates the use of the PRG of 298 mg/kg in two ways:

- First, as is often observed at mining, milling and smelting sites, the concentration of lead in soil at this site is slightly higher (about 4%) in the fine-grained soil fraction than in the bulk fraction (USEPA 2008a). This is because metal-rich particles derived from mining, milling and smelting operations tend to be smaller than most soil particles. Because children are assumed to ingest mainly particles from the fine fraction, application of the PRG to the bulk fraction could be under-protective.
- Second, measurements of lead in soil using XRF are sometimes not the same as measurements by ICP. This is because XRF measurements are subject to a wide variety of interferences (e.g., water content, particle size, presence of other metals, etc.). Thus, to the extent that XRF yields a biased estimate of the true concentration, use of XRF data for comparison to the PRG might cause an error in either direction. At this site, XRF tends to underestimate the concentration of lead in soil by an average of about 16%.

Because of the observable differences in lead concentrations associated with the soil particle size and the potential for differences between the XRF and ICP analytical techniques utilized at this site, and because the PRG will usually be applied to measurements of bulk soil analyzed using XRF, the risk-based PRG of 298 mg/kg was converted to a Bulk-XRF equivalent concentration using the linear relationships derived in the risk assessment (USEPA 2008a):

$$Bulk(XRF) = \frac{Fine(ICP)}{1.16 \cdot 1.04}$$

Based on this equation, the risk-based PRG for lead in the fine fraction of soil using ICP-AES of 298 mg/kg corresponds to a PRG of 247 mg/kg in the bulk soil fraction analyzed using XRF.

4.0 UNCERTAINTY ANALYSIS

The PRG values derived above for lead are somewhat uncertain, due to uncertainty in the true values of the input parameters used in the IEUBK model calculations. This uncertainty includes all of the inputs listed in Table 1. Of these parameters, the uncertainty in the soil and dust ingestion rates and in the true geometric standard deviation (GSD) are usually the most important. In addition to these user-adjustable parameters, there are also a large number of other pharmacokinetic variables that are used in the model but are not subject to revision by the model user.

For the purposes of this evaluation, a series of alternative PRG calculations were performed to evaluate the uncertainty in the PRG that arises from two of the site-specific model inputs used at this site: 1) relative bioavailability (RBA), and 2) the relationship between lead in indoor dust to that in residential yard soil. All other input values (e.g., concentration of lead in the diet, GSD, etc.) were maintained at the values shown in Table 1.

Alternate Relative Bioavailability Estimates

For RBA, four alternative values were evaluated. These values included the IEUBK model default RBA for lead (0.6), as well as a low estimate (0.7), best estimate (0.8) and high estimate (0.9) based on site-specific data. These alternative RBA values and their bases are presented in Table 2 (Panel A, upper section).

Alternate Estimates of the Relationship Between Lead in Soil and Indoor Dust

The concentration of lead in indoor dust input parameter (Cdust) is estimated from the concentration of lead in outdoor soil (Csoil) using an equation that is derived from site-specific data. The general equation is as follows:

$$\text{Cdust} = \text{D0} + M_{sd} \cdot \text{Csoil}$$

where:

D0 = Concentration of lead in dust (mg/kg) that is not attributable to outdoor soil
Cdust = concentration of lead in indoor dust (mg/kg)
Csoil = outdoor soil lead concentration (mg/kg)
M_{sd} = mass fraction of soil in dust (mg Pb/kg in dust per mg Pb/kg in soil)

Appendix F of the risk assessment (USEPA 2008a) describes a number of different statistical methods that were evaluated for quantifying this relationship from site-specific data. In order to provide a range of possible alternative estimates of the relationship, the results of three alternative statistical methods were used. These methods included the approach that is considered to be "best" for estimating the model parameters (D0 and M_{sd}), one method that is judged to have a tendency to overestimate the value of M_{sd}, and another method that is thought to likely underestimate the value of M_{sd}. The resulting equations are shown in Table 2 (Panel A, lower section). In addition, the equation recommended as the default by USEPA (1994) was also used. In this approach, the value of D0 is determined by the contribution of air to dust (Cdust = 100 µg/g in dust per µg/m^3 in air · 0.036 µg/m^3 = 3.6 µg/g).

Results

Using the alternate values/approaches for deriving estimates of RBA and the concentration of lead in indoor dust, a total of 16 alternative PRG estimates were calculated. The results are shown in Table 2 (Panel B) and summary statistics of the PRG estimates are shown in Table 2 (Panel C). Best estimates are indicated by grey shading.

The results in Panel B clearly show that relative bioavailability has a significant impact on the PRG values, while the 3 methods for estimating indoor dust lead concentrations have a relatively minor impact on the PRG estimates. As seen in Panel C, the PRG for lead in the fine fraction of soil measured using ICP-AES ranges from 251 to 442 mg/kg. If lead is measured in bulk soil using XRF, the PRGs range from 208 to 366 mg/kg.

Note that all of the PRG values calculated above are conditional on the assumed human exposure parameters and the toxicokinetic assumptions in the IEUBK model. If any of the assumptions for these exposure parameters, or changes to the IEUBK model occur in the future, then the PRG calculations may need to be revisited.

5.0 REFERENCES

CDC. 1997. National Health and Nutrition Examination Survey, III 1988-1994. CD-ROM Series 11, No. 1. July.

Food and Drug Administration (FDA). 2006. Total Diet Study. U. S. Food and Drug Administration Center for Food Safety and Applied Nutrition Office of Plant and Dairy Foods and Beverages. August.

USEPA. 1994. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. Publication Number 9285.7-15-1. EPA/540/R-93/081.

USEPA. 1998. Clarification to the 1994 Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities. OSWER Directive 9200.4-27. EPA/540-F98/030. August.

USEPA. 2008a. Draft-Final Baseline Human Health Risk Assessment for the Omaha Lead Site. U.S. Environmental Protection Agency, Region 7. Kansas City, KS. October.

USEPA. 2008b. Air Quality System Database (AQS). http://www.epa.gov/air/data/index.html . (Accessed July 2008).

USEPA. 2008c. Frequent Questions from Risk Assessors on the IEUBK model. Using newer lead in food data from the Food and Drug Administration (FDA) total diet study. http://www.epa.gov/superfund/health/contaminants/lead/ieubkfaq.htm#fda. Accessed September 2008.

Table 1. IEUBK Model Inputs

A. Age-Independent Model Inputs:

PARAMETER	VALUE	BASIS
Soil concentration (mg/kg)	Property-specific	Yard-wide average concentration[1] (excluding drip zone samples)
Indoor dust concentration (mg/kg)	Property-specific	Calculated using site-specific M_{sd} equation: $C_{dust} = 42 + 0.74 \cdot C_{soil}$
Air concentration (µg/m^3)	0.036	Average concentration in air at the Site (2000 – 2002) (USEPA 2008b)
Indoor air concentration (ug/m^3)	30% of outdoors	USEPA (1994a) default
Drinking water concentration (µg/L)	1.36	Average concentration in tap water at the Site. Assumes water consumed is 50% first draw and 50% post flush
Absorption Fractions: Air Diet Water Soil Dust	 32% 50% 50% 40% 40%	 USEPA (1994a) default USEPA (1994a) default USEPA (1994a) default Site-specific value Site-specific value
Fraction soil	45%	USEPA (1994a) default
GSD	1.6	USEPA (1994a) default

[1] Fine fraction, ICP-equivalent concentration of lead in soil: Fine(ICP) = Coarse(XRF) · 1.16 · 1.04

B. Age-Dependent Model Inputs:

	AIR		DIET	WATER	SOIL
Age (years)	Time Outdoors (hrs)	Ventilation Rate (m^3/day)	Dietary Intake [2] (µg/day)	Intake (L/day)	Intake (mg/day)
0-1	1.0	2.0	2.26	0.20	85
1-2	2.0	3.0	1.96	0.50	135
2-3	3.0	5.0	2.13	0.52	135
3-4	4.0	5.0	2.04	0.53	135
4-5	4.0	5.0	1.95	0.55	100
5-6	4.0	7.0	2.05	0.58	90
6-7	4.0	7.0	2.22	0.59	85

2] Revised USEPA (2008a) recommended dietary intake parameters, based on updated dietary lead estimates from the Food and Drug Administration's Total Diet Study (FDA 2006) and food consumption data from NHANES III (CDC 1997) .

Table 2. Uncertainty Analysis of PRG Estimate

A. VARIABLE INPUT VALUES

Parameter	Method	Value	Notes
Relative Bioavailability (RBA)	Default	0.6	USEPA recommended default value.
	Lower Bound	0.7	Mean RBA estimated from in vitro bioavailability (IVBA) data
	Best Estimate	0.8	RBA value used in the risk assessment, derived based on a weight-of-evidence evaluation of the *in vivo* and in vitro RBA estimates.
	Upper Bound	0.9	Average of *in vivo* RBA point estimates
Equation for Estimating the Concentration of Lead in Dust (Cdust)	Default	Cdust = 0.7*Csoil + 3.6	USEPA recommended default value for Msd (0.7). Site-specific intercept value, calculated by: intercept = Cair * USEPA default conversion factor for the concentration of lead in indoor dust from outdoor air.
	Lower Bound	Cdust = 0.36*Csoil + 154	Cdust equation based on the 3-Group Approach (Method 5 in Appendix F), a method for estimating Cdust that is biased low.
	Best Estimate	Cdust = 0.74*Csoil + 42	Cdust equation used in the risk assessment, based on the evaluation presented in Appendix F.
	Upper Bound	Cdust = 0.85*Csoil + 0	Cdust equation based on the One-Group (Zero Intercept) Approach (Method 6 in Appendix F). This method for estimating Cdust is biased high.

B. PRG RESULTS (concentration of lead in the fine fraction, analyzed by ICP)

		Equation for Estimating Cdust			
		Default	Lower Bound	Best Estimate	Upper Bound
RBA	Default	442	442	406	404
	Lower Bound	378	360	344	346
	Best Estimate	331	299	298	304
	Upper Bound	294	251	262	270

C. SUMMARY STATISTICS OF PRG ESTIMATES

		PRG (mg/kg)			
		Average	Minimum	Maximum	Best Estimate
ICP	Fine	**339**	**251**	**442**	**298**
	Bulk	326	241	425	287
XRF	Fine	293	216	381	257
	Bulk	281	208	366	247

Appendix D

Preliminary Remediation Goals for Protection of Excavation Workers from Lead in Sub-Surface Soil at the Omaha Lead Site

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MEMORANDUM

To: Bob Feild, USEPA Region 7 RPM
Michael Beringer, USEPA Region 7 Toxicologist
From: Bill Brattin, Jennifer Walter
Date: March 16, 2009
Subject: Preliminary Remediation Goals for Protection of Excavation Workers from Lead in Sub-Surface Soil at the Omaha Lead Site

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1.0 INTRODUCTION

In 2009, USEPA released a Human Health Risk Assessment for the Omaha Lead Site (OLS) that evaluated risks from lead in soil to children residing at homes within the final focus area (USEPA 2009a). The risk assessment noted that if the level of lead in soil is safe for exposure of children, it is also safe for exposure of adults. A potential exception to this principle comes when surface soils are cleaned up to levels that protect children, but the level of lead in subsurface levels may remain somewhat elevated. Although a child is not likely to be exposed to lead in subsurface soil, some categories of workers (e.g., excavation workers) may be exposed to contaminated sub-surface soil as part of their normal work activities.

The purpose of this document is to calculate a series of Preliminary Remediation Goals (PRGs) for lead in sub-surface soil that could be of potential concern to an excavation worker, depending on the frequency that the workers is engaged in excavation activities within the site. The resulting PRG values are then used to evaluate whether levels of lead observed in subsurface soil at the OLS are likely to be of potential concern to this population of workers.

2.0 BASIC EQUATIONS

USEPA has developed a standard approach for assessing risks associated with non-residential exposure to lead from soil (USEPA 2003). This approach uses the Adult Lead Methodology (ALM) to predict blood lead levels as a result of site-related soil exposure. The sub-populations of chief concern are pregnant women and women of child-bearing age, because the blood lead level of a fetus is nearly equal to the blood lead level of the mother. USEPA has established a health-based goal to ensure that there is no more than a 5% chance that the fetus of an exposed woman would have a blood lead level above 10 µg/dL.

The ALM predicts the blood lead level in an adult by summing the "baseline" blood lead level (PbB_0) (that which would occur in the absence of any site-related exposures) with the increment in blood lead that is expected as a result of exposure to lead in site soil. The latter is estimated by multiplying the average daily absorbed dose of lead from soil by a "biokinetic slope factor" (BKSF). Thus, the basic equation for exposure to lead in soil is:

$$PbB_{adult,central} = PbB_{0adult} + BKSF \cdot PbS \cdot IRs \cdot AFs \cdot (EFs/AT)$$

where:

$PbB_{adult,central}$ = Central tendency (geometric mean) blood lead concentration (µg /dL) in women of child-bearing age) that are exposed to soil at the site

PbB_0 = "Background" geometric mean blood lead concentration (µg /dL) in women of child-bearing age in the absence of exposure at the site

BKSF = Biokinetic slope factor (µg /dL blood lead increase per ug/day lead absorbed)

PbS = Soil lead concentration (µg/g)

IRs = Intake rate of soil (g/day)

AFs = Absolute gastrointestinal absorption fraction for lead in soil (dimensionless). The value of AFs is given by:

$$AFs = AF(food) \cdot RBA(soil)$$

EFs = Exposure frequency for contact with site soils (days/year)

AT = Averaging time (days)

Once the geometric mean blood lead value is calculated, the full distribution of likely blood lead values in the population of exposed women can then be estimated by assuming the distribution is lognormal with a specified inter-individual geometric standard deviation (GSD_i) for the population of concern. The 95th percentile of the distribution is given by the following equation:

$$PbB_{adult,95th} = PbB_{adult,central} \cdot GSD_i^{1.645}$$

Given the $PbB_{adult,95th}$ value, the concentration in the blood of the fetus is calculated as:

$$PbB_{fetus,95th} = PbB_{adult,95th} \cdot Ratio_{fetal/maternal}$$

The ratio of blood lead concentration in the fetus to that in the mother is generally around 0.9 (USEPA 2003). Consequently, the 95th percentile blood lead level in the mother that corresponds to a 95th percentile value of 10 µg/dL in the fetus is:

$$PbB_{adult,95th} = 10\ \mu g/dL\ /\ 0.9 = 11.1\ \mu g/dL$$

Combining and rearranging the equations above yields the following equation for calculating the concentration of lead in soil that is of potential concern to the fetus of an adult woman worker:

$$PRG = \frac{\left(\dfrac{11.1}{GSD_i^{1.645}}\right) - PbB_0}{BKSF \cdot IR \cdot AF \cdot (EF / AT)}$$

3.0 PARAMETER INPUT VALUES

Parameter input values selected for use are listed in Table 1. Most of the values are defaults recommended by USEPA (2003) for use in the ALM. Non-default values are discussed below.

IR

The soil ingestion rate for an excavation worker is assumed to be 0.1 g/day. USEPA (2009b) considers this value to be a reasonable default ingestion rate that has been commonly used as a central tendency estimate for contact-intensive adult scenarios (such as agricultural workers or construction workers).

AF

The absorption fraction of lead from soil is calculated using the site-specific RBA for soil of 0.8 as follows:

$$AF = 0.2 \cdot 0.8 = 0.16$$

This RBA value is the same as was used in the risk calculations for children, and is based on both *in vivo* and *in vitro* measurements (USEPA 2009a).

EF and AT

USEPA guidance indicates that the minimum exposure duration appropriate for modeling intermittent exposures is about 3 months, with a minimum exposure frequency of 1 day per week (USEPA 2003). The exposure duration must be sufficiently long to allow blood lead concentrations to approach quasi-steady state. Based on this, a value of 91 days (13 weeks) was assumed for AT.

There are no data available on the frequency that an excavation worker may be exposed at an individual property within the OLS. In the absence of data, a series of alternative values of EF were assumed, ranging from 1 day per week (13 days out of 91 days) up to 5 days per week (65 days out of 91 days).

PbB_0 and GSD_i

Blood lead summary statistics for PbB_0 and GSD_i are available from a series of National Health and Nutritional Evaluation Surveys (NHANES) performed by the National Center for Health Statistics of the Centers for Disease Control. Data collected during the years 1988-1994 (Phase 1 and 2 of NHANES III) for adult females (ages 17-45) in the Midwest Region of the United States indicate a baseline blood lead value (PbB_0) of 1.5 µg/dL, and a GSD_i of 2.18 (USEPA 2002). However, analysis of more recent NHANES data for the years 1999 to 2004 indicates that both PbB_0 and GSD_i are now somewhat lower, with a PbB_0 of 1.0 µg/dL and a GSD_i of 1.8 (SRC 2009). Although these values have not yet been incorporated into official USEPA guidance, they reflect the best available science and are used here for the purposes of evaluating potential risks to construction workers.

4.0 Preliminary Remediation Goals (PRGs)

Based on these inputs, the Preliminary Remediation Goals (PRGs) associated with differing assumed exposure frequencies are as shown below:

Assumed Exposure Frequency (days/week)	PRG* (ppm)
1	3500
2	1800
3	1200
4	880
5	710

* Values are shown to two significant figures

These PRG values represent the maximum acceptable average concentration of lead in subsurface soil that a worker may be exposed to in the OLS during a 13-week (91 day) work period. Note that it is not reasonable to assume that a worker will be exposed to subsurface soil at a single property for 13 weeks. Consequently, comparison of the PRGs to concentration values observed at individual properties is not appropriate. Rather, it is likely that a worker will be exposed at a number of different properties within this time span, and PRGs must be interpreted by comparison to the average concentration across all of the properties contacted.

5.0 EVALUATION OF SITE DATA

Data on the concentration of lead in subsurface soil collected during the Remedial Investigation (Black and Veatch 2001) at the OLS are summarized below:

Statistic	Soil Depth Interval			
	0-2”	0-8”	8-16”	16-24”
Count	550	548	548	549
Average	280	223	175	128

As shown, average lead concentrations tend to decrease as a function of increasing depth, which is consistent with the concept that most of the lead originates from surficial sources. Importantly, all of the average values for lead in soil at various depths are substantially lower than all of the PRGs for an excavation worker, even if exposure is assumed to be very frequent (5 days/week). Based on this, it is concluded that risks to excavtion workers in the OLS from exposure to lead in soil are not of significant health concern.

6.0 REFERENCES

Black and Veatch. 2001. Final Preliminary Assessment/Site Inspection Report, Omaha Lead Site, Omaha Nebraska. Prepared by Black and Veatch Special Projects Corp., August, 2001.

SRC. 2009. Blood Lead Summary Statistics Based on NHANES Data From 1999-2004.

USEPA. 2002. Blood Lead Concentrations of U.S. Adult Females: Summary Statistics from Phases 1 and 2 of the National Health and Nutrition Evaluation Survey (NHANES III). U.S. Environmental Protection Agency, Technical Review Workgroup for Lead. EPA 9285.7-52. March.

USEPA. 2003. Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposure to Lead in Soil. Office of Solid Waste and Emergency Response. EPA-540-R-03-001. January.

USEPA. 2009a. Baseline Human Health Risk Assessment. Omaha Lead Site. Remedial Investigation Report, Volume III, Appendix M. Prepared for, and with oversight by U.S. Environmental Protection Agency Region 7, by Syracuse Research Corporation. February 2009a.

USEPA. 2009b. Frequent Questions from Risk Assessors on the Adult Lead Methodology. Appropriate Soil Ingestion Rate (IR) for a Construction Scenario. Available online at: http://www.epa.gov/superfund/health/contaminants/lead/almfaq.htm, last updated August 18, 2008.

TABLE 1
ALM INPUT PARAMETERS

Parameter	Value	Units	Basis
PbB_0	1.0	µg/dL	Average blood lead concentration for adult females (ages 17-45) in the Midwest Region, based on the most recent NHANES data collected during 1999 – 2004 (SRC 2009).
BKSF	0.4	µg/dL per µg/day absorbed	USEPA (2003) default
GSD_i	1.8		GSD for adult females (ages 17-45) in the Midwest Region, based on the most recent NHANES data collected during 1999 – 2004 (SRC 2009)
$Ratio_{fetal/maternal}$	0.9	--	USEPA (2003) default
AF_{food}	0.2	--	USEPA (2003) default
IR_s	0.1	g/day	Default for contact intensive worker (USEPA 2009b)
RBA_{soil}	0.8	--	Site-specific measurements (see USEPA 2009a)
EF	1-5	days/week	Assumed
AT	91	days/year	Assumes 13 weeks (7 days/week x 13 weeks).