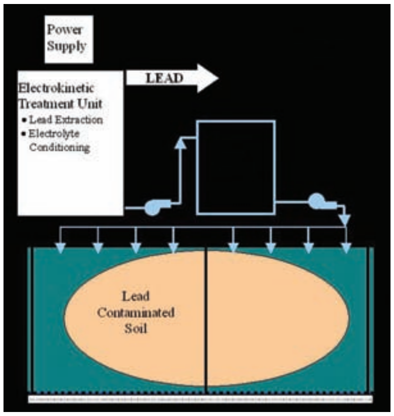
United States
Environmental Protection
Agency

Electrochemical Design Associates
(formerly Geokinetics International, Inc.)
Lead Recovery Technology Evaluation

Building 394 Battery Shop Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility Honolulu, Hawaii

Innovative Technology Evaluation Report



SITE
SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

EPA/540/R-04/506
September 2003

FINAL

INNOVATIVE TECHNOLOGY EVALUATION REPORT

ELECTROCHEMICAL DESIGN ASSOCIATES
(FORMERLY GEOKINETICS INTERNATIONAL, INC.)
LEAD RECOVERY TECHNOLOGY EVALUATION

at the

BUILDING 394 BATTERY SHOP
PEARL HARBOR NAVAL SHIPYARD AND INTERMEDIATE MAINTENANCE FACILITY
HONOLULU, HAWAII

Prepared for:

U.S. Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
Cincinnati, Ohio

Prepared by:

Tetra Tech EM Inc.
1230 Columbia Street, Suite 1000
San Diego, California 92101

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CONTENTS

FIGURES

TABLES

NOTICE

The information in this document has been funded by the U.S. Environmental Protection Agency's (EPA) under Contract No. 68-C-00-181 to Tetra Tech EM Inc. It has been subjected to the Agency's peer and administrative reviews and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute an endorsement of recommendation for use.

FOREWORD

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and groundwater; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

ABSTRACT

This report presents performance and economic data from U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) Program evaluation of Electrochemical Design Associates (EDA), formerly known as Geokinetics International Inc., Lead Recovery Technology Evaluation. The demonstration evaluated the technology's ability to remove lead contamination from soil.

The EDA technology was operated by injecting electrolyte solution into the treatment tank, allowing the electrolyte solution to migrate vertically and horizontally through the soil. The ethylene diamine tetraacetic acid in the electrolyte solution acted as a chelating agent, forming a soluble $Pb\text{-}EDTA^{2-}$ complex. The $Pb\text{-}EDTA^{2-}$ complex within the electrolyte was removed from the bottom of the treatment tank through extraction pipes. From here, the electrolyte solution flowed into the header tank and fed directly into the proprietary electrolyte solution management system (ESMS). The ESMS consisted of proprietary electrochemical lead recovery cells. Once it had passed through the ESMS, the electrolyte solution was delivered to a holding tank where it was stored and the pH was adjusted. From here, the electrolyte solution was re-delivered to the treatment tank and the process was repeated. The entire system is a batch closed-loop process, which is initiated and controlled by a single automated process control system (GII 1998b).

This demonstration tested the ability of the EDA technology to remove lead from in two phases. Phase I was conducted at Building 394 Battery Shop from August 8 to September 28, 2001 and Phase II was conducted from April 1 to July 22, 2002.

Primary demonstration objectives evaluated whether the EDA technology reduced lead concentrations in soil to below the clean-up goal of 2,000 milligrams per kilogram (mg/kg). The EDA technology reduced lead concentrations in soil; however, not below the 2,000 mg/kg clean-up goal for all batches.

Potential sites for applying this technology include Superfund and other hazardous waste sites where soils are contaminated with lead. Economic data indicate that remediation costs of using this technology are affected by site-specific factors, such as the availability to electrical and water lines. The operating cost for implementing the EDA technology is estimated to be $11,980 per ton for a 5-ton pilot study, and $546 per ton for a 500-ton full-scale study. Capital costs are not available at this time.

ACKNOWLEDGMENTS

This report was prepared for the U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) program by Tetra Tech EM Inc. (Tetra Tech) under the direction and coordination of Mr. Thomas Holdsworth at the National Risk Management Research Laboratory (NRMRL) in Cincinnati, Ohio.

The lead recovery technology evaluation was a cooperative effort that involved the following personnel from EPA NRMRL SITE Program in cooperation with the Pacific Division Naval Facilities Engineering Command (PACNAVFACENGCOM), and Electrochemical Design Associates (EDA), formerly known as Geokinetics International Inc.:

Annette Gatchett	EPA NRMRL Assistant Director of Technology
Thomas Holdsworth	EPA NRMRL Work Assignment Manager
Ann Vega	EPA NRMRL Quality Assurance Coordinator
Clint Zenigami	PACNAVFACENGCOM Remedial Project Manager
Randal Kido	Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility
Richard Sturm	AMEC Project Manager
Lewis Mitani	EPA Region IX Project Manager
Mike Miyasaka	State of Hawaii Department of Health Project Manager
Stephen Clarke	Electrochemical Design Associates Project Manager
Carl Rhodes	Tetra Tech EM Inc. SITE Program Manager
Greg Swanson	Tetra Tech EM Inc. SITE QA Manager
Linda Hunter	Tetra Tech EM Inc. Project Quality Control Coordinator
Roger Argus	Tetra Tech EM Inc. Project Manager
Barry Hicks	Tetra Tech EM Inc. Project Field Manager
Donna Rydberg	Severn Trent Laboratory Project Manager

ACRONYMS AND ABBREVIATIONS

ARAR	Applicable or relevant and appropriate requirement
CAA	Clean Air Act
CAMU	Corrective action management unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
EDA	Electrochemical Design Associates
EDTA	Ethylene diamine tetraacetic acid
EE/CA	Engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
ESMS	Electrolyte solution management system
ETU	Electrochemical treatment unit
ITER	Innovative technology evaluation report
kg	Kilogram
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
MS/MSD	Matrix spike/matrix spike duplicate
NRMRL	National Risk Management Research Laboratory
OSWER	Office of Solid Waste and Emergency Response
ORD	Office of Research and Development
PACNAVFACENGCOM	Pacific Division Naval Facilities Engineering Command
PPE	Personal protective equipment
QA	Quality assurance
QA/QC	Quality assurance/quality control
QC	Quality control
RCRA	Resource Conservation and Recovery Act
RI	Remedial investigation
RSE	Removal site evaluation
SARA	Superfund Amendments and Preauthorization Act of 1986
SI	Site inspection
SITE	Superfund Innovative Technology Evaluation

TCLP	Toxic Characteristics Leaching Procedures
Tetra Tech	Tetra Tech EM Inc.

EXECUTIVE SUMMARY

The Electrochemical Design Associates (EDA), formerly known as Geokinetics International Inc., lead recovery technology was evaluated as a remediation technology to remove lead from the soil. The evaluation was accomplished through a partnership between the U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE), and Pacific Division Naval Facilities Engineering Command (PACNAVFACENGCOM). The demonstration was conducted at Building 394 Battery Shop, Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility, Honolulu, Hawaii.

The purpose of this Innovative Technology Evaluation Report (ITER) is to present information that will assist SITE decision-makers in evaluating the lead recovery technology as a potential remediation alternative for application at sites with lead contamination in soil.

The executive summary briefly describes the lead recovery technology, provides an overview of the SITE evaluation of the technology, summarizes the SITE evaluation results, and discusses the Superfund feasibility evaluation criteria for the lead recovery technology.

The Lead Recovery Technology

The basic process for electrokinetic treatment of soil ex-situ is similar to in-situ treatment, except that the ex-situ soil contact with the process fluids is within a water-tight soil containment vessel , eliminating problems with loss of fluids and potential mobilization of lead to beyond the treatment area.

Drainage at the bottom of the soil containment vessel is provided through a gravel pack, which contains a manifold of slotted well screen to improve flow to the collection pump. One or two layers of filter fabric (drainfield cloth or equivalent) and a screen separate the soil and gravel pack to reduce the movement of soil particles into the electrochemical treatment unit (ETU).

An ethylene diamine tetraacetic acid (EDTA) solution is infiltrated through the soil. Lead within the soil bonds with the EDTA during infiltration, forming a $Pb\text{-}EDTA^{2-}$ complex. The solution is recovered at the bottom of the tank, and transferred to the ETU where lead is removed from the EDTA solution by electroplating. The EDTA solution is then reconditioned in the electrolyte solution management system

(ESMS) as necessary (pH adjustment, EDTA concentration adjustment) and recirculated through the soil. Plated lead is scraped from the electrodes and containerized. Treated soil is stored under cover and tested for disposal purposes.

Overview of the Lead Recovery Technology SITE Demonstration

The EDA lead recovery technology demonstration was conducted in two phases using lead-contaminated soil from the former battery acid pit adjacent to Building 394. The first phase was conducted from August 8, 2001 to September 28, 2001, and the second phase was conducted from April 1, 2002 to July 22, 2002.

The SITE evaluation for the lead recovery technology was designed with three primary and three secondary objectives to provide potential users of the technology with the information necessary to assess the applicability of the lead recovery technology for other contaminated sites.

The primary objectives (P) of the technology demonstration were as follows:

P1 Determine if the EDA Technology is able to reduce soil lead concentrations in the treatment tank to less than the regulatory threshold limit of 2,000 mg/kg.

P2 Determine the removal efficiency of the EDA technology for lead within the treatment tank.

P3 Determine whether the post-treatment soil meets the Resource Conservation and Recovery Act (RCRA) landban standards for Toxic Characteristics Leaching Procedure (TCLP) for lead concentration.

The secondary objectives (S) of the technology demonstration were as follows:

S1 Evaluate the mass of lead recovered by the electrolyte solution management system (ESMS) and estimate the recovery efficiency of the ESMS.

S2 Document specific EDA system operation and maintenance parameters.

S3 Estimate capital and operating costs for constructing a full-scale EDA system.

Key findings of the EDA technology are listed below:

- Approximately six percent of the total post-treatment soil samples met the regulatory threshold lead concentration of 2,000 milligrams per kilogram or less (1 of 18 post treatment samples).
- The average lead removal efficiency was 59 percent for all three bins. Due to variations in the treatment process for Bin 4, which included changing the concentration of the EDTA solution and extensively flushing the soil with water, the removal efficiency was 81 percent.
- TCLP lead concentrations did not meet the RCRA landban standard of the 5.0 milligrams per liter for samples collected from Bin 1 and Bin 2 due to adsorption of the $Pb\text{-}EDTA^{2-}$ complex to soil particles during infiltration. Extensive flushing of water in Bin 4 effectively removed sorbed solution, which resulted in a reduction in TCLP lead concentrations and attainment of the RCRA landban standard.

Technology Evaluation Summary

Table ES-1 briefly discusses the Superfund feasibility evaluation criteria for the lead recovery technology to assist Superfund decision-makers considering the technology for remediation of lead-contaminated soils at hazardous waste sites.

Table ES-1
Evaluation Criteria for EDA Lead Recovery Technology

Overall Protection of Human Health and the Environment	Compliance with Federal ARARs	Long-Term Effectiveness and Performance	Short-Term Effectiveness	Reduction of Toxicity, Mobility, or Volume Through Treatment
Provides both short- and long-term protection by removing lead in soil.	Requires compliance with Toxic Substances Control Act (TSCA) regulations for treatment, management, and disposal of lead-contaminated waste. Prior to cleaning a site, the contaminated material must be sampled to determine waste management requirements. May require compliance with hazardous waste storage requirements, depending on the contaminant extracted.	Effectively removes lead with high level of treatment efficiency. Does not destroy or degrade the physical properties of the affected media. (Note: This lead recovery Technology FEATS evaluation did not directly evaluate the "long-term" effectiveness of this technology; however destruction of contaminants is considered to be a "long-term" treatment.)	Presents minimal short-term risks to workers and nearby community, including noise and exposure to airborne contaminants. Pretreatment of material (i.e. grinding) can enhance treatment success.	Reduces toxicity and mobility of contaminated soil by extracting lead from the soil. Minimal waste is generated during the contaminant destruction process.

Table ES-1 (Continued)
Evaluation Criteria for EDA Lead Recovery Technology

Implementability	Cost	Community Acceptance	State Acceptance
Technology is a mobile system that can be transported anywhere. Can be applied to any amount of material. There is no maximum or minimum volume. System is not labor intensive and requires minimal physical effort. The equipment cannot be left to run unattended.	Based on information from GII, and observations made during the SITE evaluation, the estimated cost is \$45,063 per ton for treating 5 tons of soil; and \$28,252 per ton for treating 25 tons of soil. These costs include personnel, equipment and supplies, chemicals, and technical support. Actual cost is site-specific and depends on the media to be treated, severity of contamination, contaminant, and amount of material to be treated.	Minimal short-term risks and long-term permanence make this technology favorable to the public. Implementation of the technology creates low levels of noise and creates no traffic problems.	If remediation is conducted as part of a Resource Conservation and Recovery Act (RCRA) corrective action, state regulatory agencies may require permits to be obtained before implementing the system. These may include a permit to operate the treatment technology. However, the effectiveness of the technology make it favorable for state acceptance. (Note: For the sites in Hawaii where the FEATS demonstration soil was collected, EPA and DOH required a lead cleanup goal of 2,000 mg/kg.)

1.0 INTRODUCTION

This section describes the U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) Program and reports the purpose and organization of the innovative technology evaluation report (ITER), the demonstration background, and the ability of the Electrochemical Design Associates (EDA), formerly known as Geokinetics International Inc., lead recovery technology to remove lead contamination from soil. For additional information about the SITE Program, the EDA lead recovery technology, and the evaluation site, refer to key contacts listed at the end of this section.

1.1 PROJECT BACKGROUND

The primary purpose of the SITE Program is to advance the development and demonstration, and thereby establish the commercial availability, of innovative treatment technologies applicable to Superfund and other hazardous waste sites. The SITE Program was established by the EPA Office of Solid Waste and Emergency Response (OSWER) and Office of Research and Development (ORD) in response to the Superfund Amendments and Preauthorization Act of 1986 (SARA), which recognizes the need for an alternative or innovative treatment technology research and demonstration program. The SITE Program is administered by ORD's National Risk Management Research Laboratory (NRMRL) in Cincinnati, Ohio. The overall goal of the SITE Program is to carry out a program of research, evaluation, testing, development, and demonstration of alternative or innovative treatment technologies that can be used in response actions to achieve more permanent protection of human health and welfare and the environment.

The SITE Program consists of four component programs: (1) the Demonstration Program, (2) the Emerging Technology Program, (3) the Monitoring and Measurement Technologies Program, and (4) the Technology Transfer Program. This ITER was prepared under the SITE Demonstration Program. The objective of the Demonstration Program is to provide reliable performance and cost data on innovative technologies so that potential users can assess a given technology's suitability for specific site cleanups. To produce useful and reliable data, demonstrations are conducted at hazardous waste sites or under conditions that closely simulate actual waste site conditions. Innovative technologies chosen for a SITE demonstration must be pilot- or full-scale applications and must offer some advantage over existing technologies.

Implementation of the SITE Program is a significant, ongoing effort involving ORD, OSWER, various EPA regions, and private business concerns, including technology developers and parties responsible for site remediation. Cooperative agreements between EPA and the innovative technology developer establish responsibilities for conducting the demonstrations and evaluating the technology. The developer is typically responsible for demonstrating the technology at the selected site and is expected to pay any costs for the transport, operation, and removal of related equipment. EPA is typically responsible for evaluating the performance of the technology during the demonstration. This responsibility includes project planning, site preparation, technical assistance support, sampling and analysis, quality assurance and quality control (QA/QC), report preparation, information dissemination, and transport and disposal of treated waste materials.

In 1990, an expanded Site Inspection (SI) at the site was conducted. Based on the results of the SI, a remedial investigation was conducted including: a geophysical survey; collection of soil and groundwater samples; analysis of samples for chemical and geotechnical parameters; assessment of hydraulic aquifer characteristics; and performance of a land survey. Following the remedial investigation, and based on the analytical findings, a removal site evaluation (RSE) was conducted for the site. In July 1997, Tetra Tech conducted soil sampling at the site in support of the proposed lead remediation technology evaluation (Tetra Tech 1997a). In April 1999, Tetra Tech conducted pre-treatment sampling at Building 394 site in accordance with the previously planned lead remediation technology evaluation (Tetra Tech 1999a).

1.2 TECHNOLOGY DESCRIPTION

The Electrochemical Design Associates Lead Recovery Technology is a soil remediation process that mobilizes lead in soil by introducing ethylene diamine tetraacetic acid (EDTA), a lead chelating agent, into the soil mass. EDA conducted Phase I and Phase II treatability studies on site soil to determine an appropriate chelating agent. EDTA, a weak acid, was identified by EDA as a successful chelating agent due to its ability to absorb lead from the highly buffered soil present at the site. EDTA is a non-hazardous and environmentally safe organic acid which naturally biodegrades (GII 1998b).

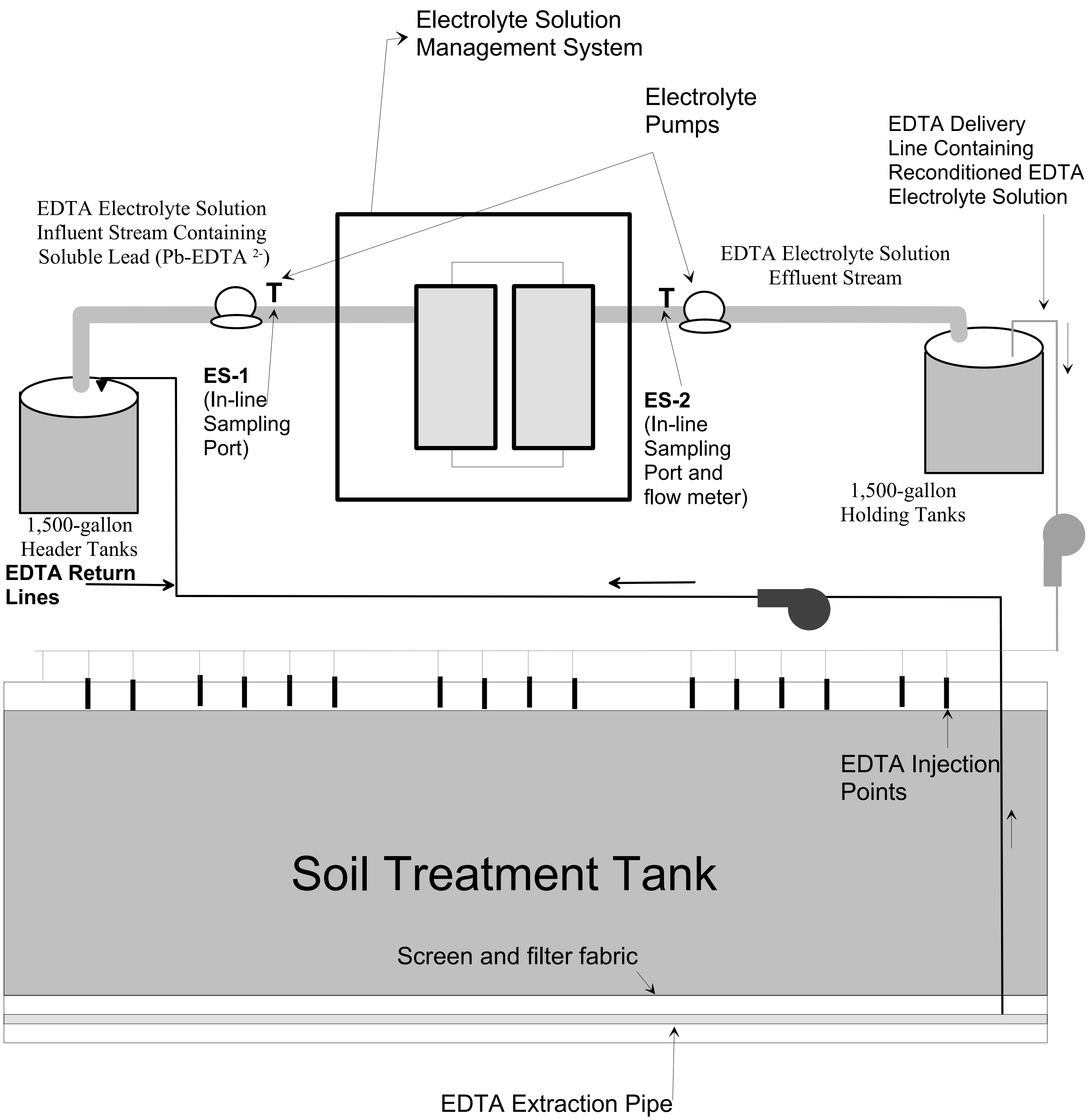
EDA found that by saturating the soil column in the laboratory with an electrolyte solution containing EDTA (0.3 molar concentration) at a pH of 5 to 6, lead was mobilized in ionic form (in solution) by the formation of a Pb-$EDTA^{2-}$ complex. To mobilize and remove lead from the site soil by the EDA ex-situ process, EDA used a 4-cubic-yard batch treatment process (Dimensions: 4 feet by 4 feet by 6 feet). Treatment involved flushing the soil with the EDTA electrolyte solution. The electrolyte solution was introduced into the treatment tank containing the volume of soil to be treated through a manifold of microjets distributed across the top of the tank. The solution, then, migrated through the soil column while the EDTA extracted lead from the soil; thus forming the Pb-$EDTA^{2-}$ complex. The electrolyte solution (containing Pb-$EDTA^{2-}$ complex) was then allowed to drain the bottom of the tank. Once the electrolyte solution was removed from the tank, it was then delivered to a holding tank prior to being cycled through a proprietary electrochemical processing unit. Here lead was electroplated out of solution and recovered as metallic lead. Afterward, the electrolyte solution was delivered to a holding tank where it was regenerated (pH adjusted) before being reintroduced to the soil undergoing treatment. Lead removed from the electrolyte solution was accumulated and transported off site for recycling. The entire system is a batch, closed-loop process. During operation, frequent sampling and analysis was used to monitor the concentration of lead in the electrolyte solution extracted from the soil.

Site-Specific Configuration

The system designed by EDA for this evaluation consisted of the following:

- Two 1,500-gallon primary electrolyte solution holding tanks
- An electrolyte solution management system
- One 1,500-gallon header tank
- A process control system

Figure 1-1 shows the general configuration of the proposed ex-situ treatment process.



ELECTROCHEMICAL DESIGN ASSOCIATES, INC.
TECHNOLOGY EVALUATION

FIGURE 1-1
SYSTEM SCHEMATIC

1.3 KEY CONTACTS

Additional information regarding the SITE Program and the evaluation can be obtained from the EPA SITE Task Order:

Mr. Thomas Holdsworth
U.S. Environmental Protection Agency
Office of Research and Development
26 W. Martin Luther King Drive
Cincinnati, Ohio 45268
Telephone: (513)-569-7675 and (513) 569-7635
FAX: (513)-569-7676 and (513) 569-7585
E-mail: holdsworth.thomas@epa.gov

Additional information on the EDA Lead Recovery technology or the evaluation can be obtained from the technology developer:

Stephen Clarke
Electrochemical Design Associates
829 Heinz Street
Berkeley, CA 94710
Telephone: (510) 704-2940
FAX: (510) 848-1581
E-mail: steve.clarke@e-d-a.com

Additional information on the demonstration area or the evaluation can be obtained from Pacific Division Naval Facilities Engineering Command (PACNAVFACENGCOM):

Clint Zenigami
Pacific Division
Naval Facilities Engineering Command
Environmental Restoration Branch

258 Makalapa Drive, Suite 100
Code ENV1821
Pearl Harbor, Hawaii 96860-7300
Telephone: (808) 472 - 1433
FAX: (808) 421 - 3800
Email: zenigamict@efdpac.navfac.navy.mil

Information on the SITE Program is also available through the following on-line information clearinghouse: The Vendor Information System for Innovative Treatment Technologies (Hotline: (800) 245-4505) database contains information on 154 technologies offered by 97 developers. Technical reports may be obtained by contacting U.S. EPA/NCEPI, P.O. Box 42419, Cincinnati, Ohio 45242-2419, or by calling (800) 490-9198.

2.0 TECHNOLOGY APPLICATIONS ANALYSIS

This section of the report describes the general applicability of EDA's lead recovery technology to contaminated sites. The analysis is based primarily on this SITE demonstration, which evaluated the treatment of lead contaminated soil. Conclusions are based exclusively on these data since only limited information is available on other applications of the technology. Vendor claims regarding the applicability of the lead recovery system are included in the appendix.

2.1 FEASIBILITY STUDY EVALUATION CRITERIA

2.1.1 Overall Protection of Human Health and the Environment

The system was setup and maintained by EDA. Soil treated was characterized by AMEC based on the RI and engineering evaluation and cost analysis (EE/CA) for the subject site (Ogden 1995, 1996); and Tetra Tech during pre-treatment sampling for the proposed in-situ technology evaluation.

Personal protective equipment (PPE) was worn to protect field personnel from known or suspected physical hazards and from potential airborne contamination. The levels of personal protection used during excavation and sampling were selected based on known or anticipated physical hazards, concentration of contaminants that may be encountered on site, and their chemical properties, toxicity, exposure routes, and contaminant matrices.

Field personnel wore Level D clothing when initially entering the site. Chemical-resistant clothing was worn when Level C protection was warranted. Chemical-resistant clothing protected the skin from contact with skin-destructive and absorbable chemicals, and helped to prevent contaminants from leaving the site when removed before leaving the treatment area. Lead concentrations in dust were monitored to establish when respirator protection was necessary.

2.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

This section describes the performance of the EDA lead recovery technology in removing lead during the evaluation and compliance with applicable or relevant and appropriate requirements (ARARs) identified for the technology demonstration. Potential federal ARARs for the technology are presented in Table 2-1. These regulations include the Comprehensive Environmental Response, Compensation and Liability act (CERCLA); Resource Conservation and Recovery Act (RCRA); the Clean Air Act (CAA); and Occupational Safety and Health Administration (OSHA) requirements.

Table 2-1 Summary of Applicable Regulations

Act or Authority	Applicability	Application to EDA Lead Recovery System	Citation
CERCLA	Superfund sites	This program authorizes and regulates the cleanup of environmental contamination. It applies to all CERCLA site cleanups and requires that other environmental laws be considered as appropriate to protect human health and the environment.	40 CFR, Part 300
RCRA	Superfund and RCRA sites	RCRA defines and regulates the treatment, storage, and disposal of hazardous wastes. RCRA also regulates corrective action at generator and treatment, storage and disposal facilities.	40 CFR, Parts 260 through 270
CAA	Air emissions from stationary and mobile sources	If VOC emissions occur or hazardous air pollutants are of concern, these standards may be applicable to ensure that air pollution is not associated with the use of this technology. State air program requirements should also be considered.	40 CFR, Parts 50 and 70
OSHA Requirements	All remedial actions	OSHA regulates on-site construction activities and the health and safety of workers at hazardous waste sites installation and operation of the system at Superfund or RCRA sites must meet OSHA requirements.	29 CFR, Parts 1900 through 1926

This discusses federal environmental regulations that could be pertinent to operation of the EDA technology, including transport, treatment, storage, and disposal of wastes and treatment residuals during a response action pursuant to the CERCLA of 1980 as amended by the SARA. CERCLA provides for federal funding to respond to releases or potential releases of any hazardous substance into the environment, as well as to releases of pollutants or contaminants that may present an imminent or significant danger to public health and welfare or to the environment.

EPA has prepared the National Oil and Hazardous Substances Pollution Contingency Plan (NOHSPCP) for hazardous substance response. The NOHSPCP is codified at Title 40 CFR Part 300, and delineates the methods and criteria used to determine the appropriate extent of removal and cleanup for hazardous substances, pollutants or contaminants as defined by CERCLA.

SARA includes a strong statutory preference for innovative technologies that provide long-term protection and directs EPA to:

- Use remedial alternatives that permanently and significantly reduce the volume, toxicity, or mobility of hazardous substances, pollutants, or contaminants
- Select remedial actions that protect human health and the environment, are cost-effective, and involve permanent solutions and alternative treatment or resource recovery technologies to the maximum extent possible
- Avoid off-site transport and disposal of untreated hazardous substances or contaminated materials when practicable treatment technologies exist [Section 121(b)].

In general, two types of response actions are possible under CERCLA: removal activities, and remedial actions. The EDA lead recovery technology is likely to be part of a CERCLA remedial action. Remedial actions are governed by the SARA amendments to CERCLA. As stated above, these amendments promote remedies that permanently reduce the volume, toxicity, and mobility of hazardous substances, pollutants, or contaminants. The lead recovery technology is a toxicity reduction technology, as it reduces lead in solid media.

On-site CERCLA remedial actions must comply with federal and more stringent state ARARs. CERCLA provides no ARARs itself; instead, CERCLA requires that remedial actions comply with the substantive requirements of other environmental statutes. ARARs are determined on a site-by-site basis considering the types of chemicals present (chemical-specific), actions taken and waste streams generated (action-specific), and location of the site in relation to sensitive environments (location-specific). Location-specific ARARs depend on site-specific conditions and are not addressed in this report. This discussion addresses potential chemical- and action-specific ARARs. The waste streams generated relate to the material to be treated, the material after treatment, and PPE. The lead recovery technology is an ex-situ treatment technology and the generation and disposal of lead remediation waste is regulated by the Toxic

Substances Control Act and its implementing regulations at 40 CFR Part 761. If other contaminants are also present at a site, the site wastes should be characterized to determine whether they meet the definition of hazardous wastes under RCRA. If so, RCRA requirements for the management of hazardous wastes will also be ARARs for this technology. Specific ARARs that may be applicable to the lead recovery technology are identified in Table 2-2.

Resource Conservation and Recovery Act

RCRA, an amendment to the Solid Waste Disposal Act, is the primary federal legislation governing hazardous waste activities. RCRA was enacted in 1976 to address safe disposal of the enormous volume of municipal and industrial solid waste generated annually. Subtitle C of RCRA contains requirements for generation, transport, treatment, storage, and disposal of hazardous waste, most of which are also relevant and appropriate to CERCLA activities where hazardous wastes are managed. The Hazardous and Solid Waste Amendments of 1984 greatly expanded the scope and requirements of RCRA. RCRA regulations define hazardous wastes and regulate their transport, treatment, storage, and disposal.

These regulations are applicable to the lead recovery technology only if RCRA-defined hazardous wastes are generated during the CERCLA action. The regulations that are likely to be listed as ARARs include the requirement to characterize waste for a hazardous waste generator (40 CFR P262.11); the requirement to determine if the hazardous waste is restricted from land disposal (40 CFR 268.7(a)); and either 40 CFR 262.34(a) for storage of waste on site up to 90 days prior to off-site shipment, or 40 CFR 264.553 for storage of waste in a temporary unit for up to 1 year prior to disposal. However, the requirements for treatment and disposal units are not ARARs unless these activities (such as land disposal or storage of waste) will be conducted on site. Potential hazardous wastes generated by using lead recovery technology include the extracted contaminants in the soil to be treated, the residual process chemicals, and used PPE. If these wastes are determined to be hazardous according to RCRA (either because of a characteristic or a listing carried by the waste), all substantive RCRA requirements regarding management and disposal of hazardous waste must be addressed by the remedial managers. Criteria for identifying characteristic hazardous wastes are included in 40 CFR Part 261 Subpart C. Listed wastes from specific and nonspecific industrial sources, off-specification products, spill cleanups, and other industrial sources are itemized in 40 CFR Part 261 Subpart D. The technology could be used on sites where lead, cadmium, chromium or other metals are present and could, depending on

Table 2-2
Potential Federal ARARs for the Lead Recovery Technology

Process Activity	ARAR	Description	Basis	Response
Waste treatment	40 CFR Part 761.3 and 761.61 or state equivalent	Standards that apply to treatment and disposal of Pb remediation wastes	Generally applies to materials contaminated from Pb releases more than 48 hours old	Three options provided for Pb remediation waste disposal; includes cleanup levels and performance
On-site/off-site disposal	40 CFR Part 761.61(b) or state equivalent	Technology-specific performance standards for disposal of Pb remediation waste	Pb remediation wastes may be disposed by meeting technology-specific performance standards for chemical landfills, incinerators, etc.	Permitted landfills, incinerators or other technologies may be used for disposal of Pb remediation waste
On-site/off-site disposal (continued)	SARA Section 121(d)(3)	Requirements for the off-site disposal of wastes from a Superfund site. This statutory requirement is not an ARAR and cannot be waived.	If the waste is being generated from a response action authorized under CERCLA, there may be additional disposal requirements.	Wastes must be disposed of at a permitted and compliant waste disposal facility.
Transportation for off-site disposal	4 CFR Part 172 or state equivalent	DOT requirements for packaging and labeling hazardous materials prior to transport	The treated waste must be managed as a hazardous material under DOT regulations	Packaging and labeling requirements for hazardous materials are not ARARs and may not be waived.

Notes:

ARAR	Applicable or Relevant and Appropriate Requirements
CERCLA	Comprehensive Environmental Response, Comensation, and Liability Act
CFR	Code of Federal Regulations
DOT	Department of Transportation
Pb	Lead
SARA	Superfund Amendments and Reauthorization Act

concentrations, be characteristic hazardous wastes. Contaminated PPE is subject to land disposal restriction only if it contains more than 5 percent contamination per square inch.

Listed hazardous wastes (40 CFR Part 261 Subpart D) remain listed wastes regardless of the treatment they may undergo and regardless of the final contamination levels in the resulting effluent streams and residues. This regulation implies that, even after remediation, treated wastes are still classified as hazardous if the pre-treatment material was a listed waste. Under the contained-in policy, listed wastes contained in other materials that are managed as waste require that those materials be managed as listed wastes. For generation of any hazardous waste, the site responsible party must obtain an EPA identification number. Other applicable RCRA requirements may include a Uniform Hazardous Waste Manifest (if the waste is transported), restrictions on placing the waste in land disposal units, time limits on accumulating waste, and permits for storing the waste.

RCRA corrective action regulations regarding corrective action management units (CAMU) and temporary units may be ARARs for CERCLA action involving RCRA hazardous waste. The CAMU rule allows for disposal of remediation wastes without triggering landfill disposal requirements and minimum technology requirements. The temporary units rule allows treatment or tanks without triggering RCRA tank regulations.

Other Non-ARAR Requirements

Several requirements must be addressed by remedial managers although they are not ARARs. These requirements cannot be waived. CERCLA remedial actions and RCRA corrective actions must be performed in accordance with the OSHA requirements detailed in 29 CFR Parts 1900 through 1926, especially 29 CFR Part 1910.120, which provides for the health and safety of workers at hazardous waste sites. On-site construction activities at Superfund or RCRA corrective action sites must be conducted in accordance with 29 CFR Part 1926, which describes safety and health regulations for construction sites. State OSHA requirements, which may be significantly stricter than federal standards, must also be met. All technicians operating the lead recovery system are required to have completed an OSHA training course and must be familiar with all OSHA requirements relevant to hazardous waste sites. Noise levels are not expected to be high. The levels of noise anticipated are not expected to adversely affect the community.

Department of Transportation Regulations

Off-site shipment of hazardous materials is subject to Department of Transportation (DOT) requirements for packaging and placarding. The treated soil from the lead recovery technology would likely be a hazardous material subject to DOT regulations regulations in 49 CFR Parts 172 and 173. These requirements cannot be waived, and as such, are not ARARs.

CERCLA Off-Site Rule

The CERCLA Off-Site Rule requires that wastes taken from a CERCLA site for off-site disposal must be transported to permitted waste disposal facilities. These facilities must be properly permitted and must not have any violations that adversely affect human health or the environment. Each EPA region has a coordinator for assistance in identifying disposal facilities in the region that are in compliance with their appropriate permits and that are approved to receive waste from CERCLA sites.

Clean Air Act

The CAA as amended in 1990 regulates stationary and mobile sources of air emissions. CAA regulations are generally implemented through combined federal, state, and local programs. The CAA requires that treatment, storage, and disposal facilities comply with primary and secondary ambient air quality standards. Air emissions from the EDA lead recovery system may result from dust during the excavation process. State air quality standards may require additional measures to prevent fugitive emissions.

Occupational Safety and Health Administration Requirements

OSHA regulations in 29 CFR, Parts 1900 through 1926, are designed to protect worker health and safety. Both Superfund and RCRA corrective actions must meet OSHA requirements, particularly Part 1910.129, "Hazardous Waste Operations and Emergency Response." Part 1926, "Safety and Health Regulations for Construction," applies to any on-site construction activities. For example, electric utility hookups for the EDA lead recovery system must comply with Part 1926, Subpart K, "Electrical." Product chemicals used with the EDA lead recovery system must be managed in accordance with OSHA requirements (for example, Part 1926, Subpart D, "Occupational Health and Environmental Controls, " and Subpart H, "Materials Handling, Storage, and Disposal"). More stringent state or local requirements must also be met, if applicable. In addition, health and safety plans for site remediation should address chemicals of concern and include monitoring practices to ensure that worker health and safety are maintained.

2.1.3 Long-Term Effectiveness and Permanence

This criterion refers to the ability of a remedy to maintain reliable protection of human health and the environment over time. Electrokinetics is a treatment technology for metals in the soil. Electrokinetics transforms the physical state of contaminated soil to clean soil with a solid-metal product.

2.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

This criterion refers to the anticipated performance of the treatment technology potentially employed in a Superfund remediation. With electrokinetics, the contamination of the soil is reduced by permanently removing the metals from the soil. If high-density soil treatment blocks are desired, the runs of electrolyte solution would increase. When the EDA system is run the way that was originally planned for the SITE demonstration (that is, in situ), there would be no waste product planned for disposal as it would be completely remediated.

Results of lead tests indicated that the EDA process reduced the lead in the soil. However, this did not reach below the regulatory limit defined for a characteristic waste as defined by RCRA.

2.1.5 Short-Term Effectiveness

This criterion addresses the period of time needed to achieve lasting protection of human health and the environment as well as any adverse impacts that may be posed during the construction and implementation period before cleanup goals are achieved.

2.1.6 Ability to Implement

This criterion considers the technical and administrative feasibility of a remedy, including the availability of materials and services needed to implement a particular option. EDA operates other pilot programs, but does not operate on the open market yet. Therefore, only the primary and secondary objectives need to be evaluated for this criterion.

2.1.7 Cost

This criterion addresses estimated capital, operation and maintenance costs as well as net present worth costs. Costs for treatment by the EDA technology will depend on site-specific factors such as the volume of material to be treated, physical properties of the material, contaminant types and concentrations, and site location. Section 3 of this report provides a detailed discussion of costs for the application of this technology.

2.1.8 State Acceptance

Because few applications of the EDA Electrokinetic system have been attempted beyond the bench- or pilot scale, limited information is available to assess state acceptance of the system. Although some contaminants may be released during electrode and ancillary equipment installation, the potential for emissions during drilling is substantially lower than during excavation. State acceptance of the technology may involve consideration of performance data from applications such as the SITE demonstration and results from on-site, pilot-scale studies using the actual wastes to be treated during later, full-scale remediation.

2.1.9 Community Acceptance

Because few applications of the EDA system have been attempted beyond the bench- or pilot scale, limited information is available to assess state acceptance of the system. Although some contaminants may be released during electrode and ancillary equipment installation, the potential for emissions during drilling is substantially lower than during excavation.

EDA claims one distinguishing feature of the lead recovery process is that no portion of the original molecule is discharged to the atmosphere or to water. Further, EDA claims that the process is reductive in nature and therefore not capable of forming dioxins or furans, which can be found in oxidizing technologies. This result is especially beneficial because communities are becoming increasingly aware of waste facilities and concerned over contaminant releases to the atmosphere and surrounding water.

Due the operational parameters of the lead recovery system, there are almost no potential hazards to the community from implementation of the EDA technology. No loud or heavy equipment is associated with the technology, and no substantial quantities of waste are generated apart from the treated soil. When proper operational and safety procedures are followed, hazards to personnel are minimized and the potential for a chemical spill to the environment that might endanger the community is minimal.

2.2 TECHNOLOGY APPLICABILITY

The EDA process was tested for the remediation of lead in the soil at the SITE demonstration. However, EDTA removes metals in a specific order within the plating process providing the potential capability to remove other metals.

2.3 KEY FEATURES OF THE TREATMENT TECHNOLOGY

The most common remediation method for soil contaminated with metals is excavation and permanent landfill disposal. The byproducts of the EDA lead recovery technology can be recyclable amounts of lead and other metals such as iron and copper that may present in treated soil. A major advantage of this technology is that contaminants can be reused rather than transferred to a landfill.

2.4 MATERIALS HANDLING REQUIREMENTS

It was imperative that sample logging and tracking procedures are in place and followed. Defined procedures ensured that all core samples were properly labeled following retrieval from the sampler, tracked through the homogenization area and homogenized correctly, and that appropriate sample volumes of homogenized samples were collected and properly labeled before shipping to the analytical laboratory.

Prior to collecting the core samples from each grid-cell, the sampling personnel recorded the grid-cell number being sampled, the sampler's name, and the date and time. This information was logged on a field sampling form. A field sampling form was completed for each grid-cell sample. As each 2-foot core sample was retrieved, the sampling personnel recorded the time and the core samples were labeled with their grid-cell number, depth interval, samplers initial, and date and time. This information was written on the acetate sleeve with a permanent marker.

In addition, a site plan is required to provide for personnel protection and special handling measures. Wastes need to be appropriately stored until sampling results indicate their acceptability for disposal or release to a treatment facility.

2.5 SITE SUPPORT REQUIREMENTS

Site-specific factors can impact the application of the lead recovery system. These factors should therefore be considered before the system is selected for remediation of a specific site. Site-specific factors addressed in this section include site access, area, and preparation requirements; climate requirements; utility and supply requirements; support system requirements; and personnel requirements.

Site Access, Area, and Preparation Requirements: The site must be prepared for the mobilization, O&M, and demobilization of the equipment. Access roads are necessary for equipment transport. The site must be accessible to equipment necessary to install electrodes and ancillary equipment, such as Geoprobe® and drill rigs. The air space in the equipment installation area must be clear of obstacles (such as overhead wires).

In addition to the treatment area and corresponding exclusion zone, enough space should be available to accommodate the control trailer, hazardous waste storage area, water tanks, and supply storage. This additional area is estimated to require 8,800 square feet.

Climate Requirements: Climate does not determine the effectiveness or the applicability in this demonstration. The only time the climate may effect the demonstration is when the soil needs to be dried after the treatment.

Utility and Supply Requirements: The electrochemical treatment unit (ETU) system demonstrated at Pearl Harbor Naval Shipyard was powered by a 20 kV DC power supply unit providing 200 amps at 100V DC.

Maintenance Requirements: Maintenance of a full-scale lead recovery system is estimated to require 15 hours weekly, 3 hours / 5 days per week. This estimate is based on the assumption that the design of parts of the system that caused frequent shutdowns during the SITE demonstration, such as bladders and float switches, would be modified to eliminate the problems.

2.6 LIMITATIONS OF THE TECHNOLOGY

Prior to implementing electrokinetic remediation at a specific site, field and laboratory screening tests should be conducted to determine if the site is amenable to this technology. Field conductivity surveys are necessary to determine the soil's electrical conductivity. Also, buried metallic objects and utility lines could short circuit the current path, thereby influencing the voltage gradient and affecting the contaminant extraction rate. Electromagnetic surveys should be conducted to determine the presence of buried metallic objects.

In addition, if volatile organic carbons (VOC) are present in soil undergoing electrokinetic treatment, the VOCs may be stripped from the soil to significantly increase the soil vapor VOC concentrations that would result in significant VOC migration from the treatment area, if soil temperature exceeds 50^0C. Special measure therefore need to be taken to contain and control VOC emissions.

3.0 ECONOMIC ANALYSIS

This economic analysis presents the costs for using the lead recovery technology to remove lead from the soil collected at Building 394 Battery Shop, Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility in Honolulu, Hawaii. Costs are organized under 12 categories applicable to typical cleanup activities at Superfund and RCRA sites (Evans 1990).

3.1 INTRODUCTION

The primary purpose of this economic analysis is to provide a cost estimate for using EDA's Lead Recovery Technology to commercially remediate lead-contaminated soil. This analysis is based on the assumptions and costs provided by EDA, and on the results and experiences gained from the SITE evaluation that was conducted at Building 394 Battery Shop, Pearl harbor Naval Shipyard and Intermediate Maintenance Facility, Honolulu, Hawaii. The SITE demonstration included the treatment of three 500-gallon bins of lead-contaminated soil. The average pre-treatment lead soil concentration ranged from 13,800 milligrams per kilogram (mg/kg) to 153,000 mg/kg. Results of the SITE demonstration are presented in Section 4.0 of this report.

Economic calculations were compiled for: (1) 5 tons of soil with lead contamination similar to the SITE evaluation using the EDA lead recovery technology, and (2) 500 tons of soil with lead contamination similar to the SITE evaluation using the EDA lead recovery technology. Many factors affect the cost of treatment. These include, but are not limited to; treatment mass, initial soil contaminate concentration, final required target soil contaminate concentration, treatment soil type and characteristics, system design and operating parameters, and type of contaminants.

3.2 CONCLUSIONS

This analysis presents cost estimates for treating contaminated soil with the EDA lead recovery technology. Table 3-1 lists a detailed breakdown of each cost category for each of the cases. Costs that are assumed to be the technology-independent obligation of the responsible party or site owner have been omitted from this cost estimate and are indicated by a line (---) in Tables 3-1 and 3-2. Categories with no costs associated with this technology are indicated by a zero (0) in Tables 3-1 and 3-2. Figures 3-1, and Figure 3-2 show graphic presentations of the costs for pilot-study and the full-scale project respectively.

The estimated treatment costs are $11,980 per ton, and $546 per ton for the 5-ton case and the 500-ton case, respectively. The cost of labor required is directly proportional to the treatment time per ton of soil. Therefore, the estimated treatment cost would be lower if the percent lead reduction per EDA run is increased, and the treatment time per batch is decreased. Also, the treatment time decreases for lower initial lead concentrations and therefore treatment costs could decrease. For the 5-ton case and the 25-ton case, the treatment time per cycle is based on 7, 24-hour days.

3.3 ISSUES AND ASSUMPTIONS

This section lists the major assumptions, site-specific factors, equipment and operating parameters, and financial calculations used in this economic analysis of the EDA lead recovery technology.
The cost estimates presented in this analysis are representative of charges typically assessed to the client by the vendor, but do not include profit. In general, assumptions are based on information provided by the vendor and observations made during this and other SITE evaluation projects.

Many actual or potential costs that exist were not included as part of this estimate. They were omitted because site-specific engineering designs that are beyond the scope of this SITE project would be required. Also, certain functions were assumed to be the obligation of the responsible party or site owner and were not included in the estimates. These costs are site-specific; thus, calculations are left to the decision-maker so that relevant information may be obtained for specific cases. Whenever possible, applicable information is provided on these topics so that a decision-maker can independently perform the calculations required to acquire relevant economic data.

Table 3-1 Estimated Costs for Treatment Using the EDA Lead Recovery Technology

Treatment Unit	Pilot Study	Full-Scale Study
Treatment Volume per Batch (tons)	**5**	**25**
Number of Batches	**1**	**20**
Site and Facility Preparation Costs		
Site selection and preparation	---	---
Soil collection, transportation, and stockpiling	---	---
Legal Searches	---	---
Access rights and roads	---	---
Preparations for support facilities	---	---
Auxiliary buildings	---	---
Technology setup costs (labor, assembly, testing)	$4,100	$8,000
Transportation of EDA system	$1,500	$3,000
Total Site and Facility Preparation Costs	**$5,600**	**$11,000**
Permitting and Regulatory Costs		
Permits	---	---
System monitoring requirements	---	---
Development of monitoring and protocols	---	---
Total Permitting and Regulatory Costs	---	---
Equipment Costs		
Power Supply (DC)	$2,000	$2,000
Control computer and data acquisition	$1,200	$1,200
Sensors and signal conditioners	$400	$400
Tanks (other than ETU Cells)	$1,000	$1,000

Treatment Unit	Pilot Study	Full-Scale Study
Treatment Volume per Batch (tons)	**5**	**25**
Number of Batches	**1**	**20**
Tanks (other than ETU Cells)	$1,000	$1,000
Cells (5)	$5,000	$5,000
Pumps (all)	$2,000	$2,000
Plumbing and hardware	$700	$700
Safety Equipment	$1,000	$1,000
Transformer (480V to 120V)	$1,000	$1,000
Total Equipment Costs	**$14,300**	**$14,300**
Startup and Fixed Costs		
Working capital	---	---
Insurance and taxes	---	---
Initiation of monitoring programs	---	---
Contingency	---	---
Total Startup and Fixed Costs	---	---
Labor Costs		
Operator (Field Technician)	$10,000	$161,300
Chemist/supervisor	$4,000	$32,200
Total Labor Costs	**$14,000**	**$193,500**
Supplies and Consumables Costs		
Health and Safety	$200	$2,100
Chemicals	$0	$0

Treatment Unit	Pilot Study	Full-Scale Study
Treatment Volume per Batch (tons) **Number of Batches**	**5** **1**	**25** **20**
Spare Parts	$300	$2,400
Total Supplies and Consumables Costs	**$500**	**$4,500**
Utilities Costs		
Electricity	$300	$2,400
Water	$0	$0
Total Utilities Cost	**$300**	**$2,400**
Effluent Treatment and Disposal Costs		
On-site facility costs	---	---
Off-site facility costs	---	---
-recovered metal	$0	$0
-solution disposal	$15,000	$15,000
Total Effluent Treatment and Disposal Costs	**$15,000**	**$15,000**
Residuals and Waste Shipping, Handling and Transport Costs		
Preparation	---	---
PPE, drops cloths, and small equipment	---	---
Shipping & Handling	$100	$1,600
Total Residuals and Waste Shipping, Handling and Transport Costs	**$200**	**$1,600**

Treatment Unit	Pilot Study	Full-Scale Study
Treatment Volume per Batch (tons) **Number of Batches**	**5** **1**	**25** **20**
Analytical Costs		
Operations (laboratory)	$2,000	$14,500
Environmental monitoring (regulatory)	---	---
Total Analytical Costs	**$2,000**	**$14,500**
Facility Modification, Repair, and Replacement Costs		
Design adjustments	---	---
Routine maintenance (material and labor)[a]	$0[a]	$0[a]
Total Facility Modification, Repair, and Replacement Costs	**$0**	**$0**
Site Restoration Costs		
Equipment demobilization	$6,000	$12,000
Transportation	$2,000	$4,000
Total Site Restoration Costs	**$8,000**	**$16,000**
TOTAL OPERATING COSTS	**$59,900**	**$272,800**
COST PER TON	**$11,980**	**$546**

a Maintenance labor is included in the operating labor.

Table 3-2 Estimated Cost Percentages for Treatment Using the EDA Lead Recovery Technology

Treatment Unit **Total Treatment Volume (tons)** **Number of Batches**	**Pilot Study** **5** **1**	**%**	**Full-Scale Study** **25** **20**	**%**
Site Facility Preparation Costs	$5,600	9.3	$11,000	4.0
Permitting and Regulatory Costs	---	---	---	---
Equipment Costs	$14,300	23.9	$14,300	5.2
Startup and Fixed Costs	---	---	---	---
Labor Costs	$14,000	23.4	$193,500	70.9
Supplies and Consumable Costs	$500	0.8	$4,500	1.6
Utilities Costs	$300	0.5	$2,400	0.9
Effluent Treatment and Disposal Costs	$15,000	25	$15,000	5.5
Residuals Shipping, Handling and Transport Costs	$200	0.3	$1,600	0.6
Analytical Costs	$2,000	3.3	$14,500	5.3
Facility Modifications, Repair, and Replacement Costs	$0	0.0	$0	0.0
Site Restoration Costs	$8,000	13.4	$16,000	5.9
Total Costs	**$59,900**		**$272,800**	

a Maintenance labor is included under operating costs

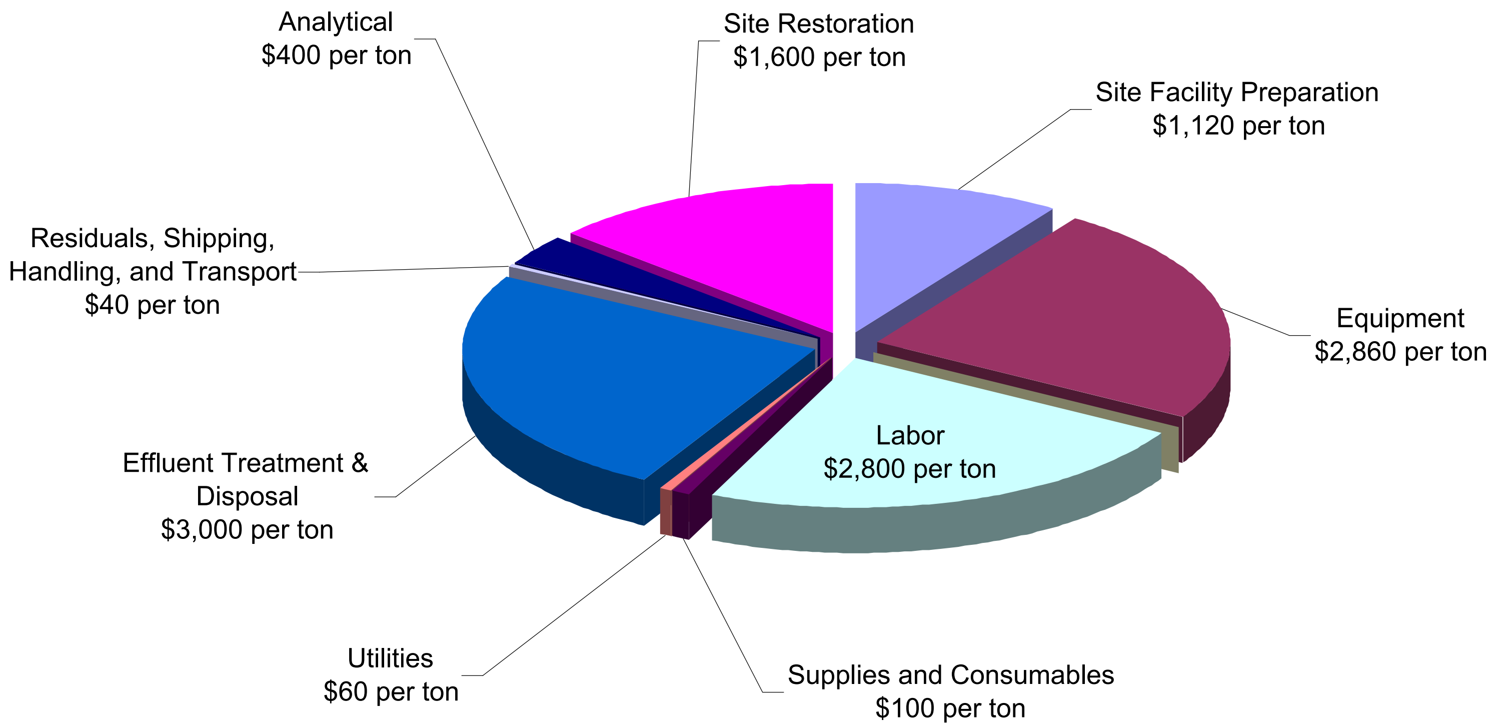


Figure 3-1 Estimated Treatment Costs for 5 Tons of Soil Using EDA Lead Removal Technology

* Permitting & Regulatory Costs were not included in the economic analysis.
**Facility Modifications, Repair, & Replacement Costs were included under Labor Costs and Equipment Costs.

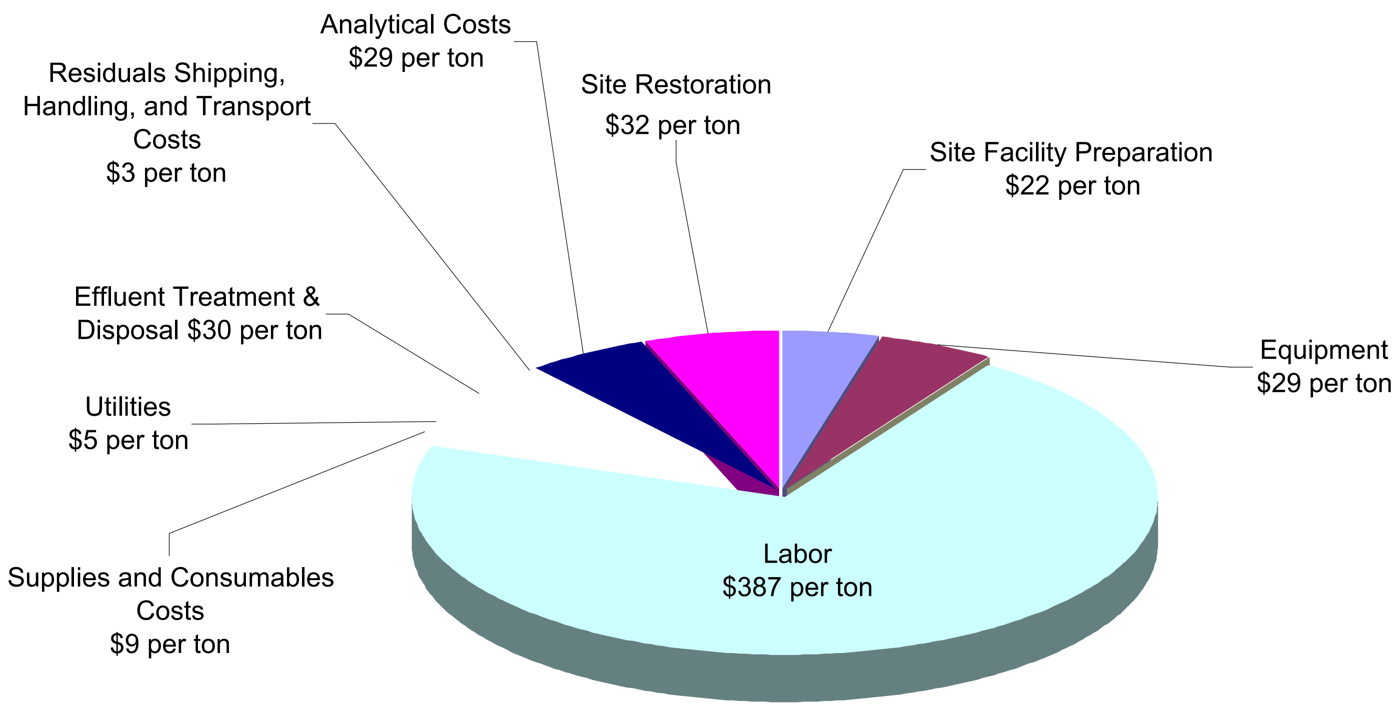


Figure 3-2 Estimated Treatment Cost for 500 Tons of Soil Using the EDA Lead Removal Technology

* Permitting & Regulatory Costs were not included in the economic analysis.

**Facility Modifications, Repair, & Replacement Costs were included under Labor Costs and Equipment Costs.

3.4 BASIS FOR ECONOMIC ANALYSIS

In order to compare the cost-effectiveness of technologies in the SITE Program, EPA breaks down costs into 12 categories (Evans 1990):

- Site and facility preparation costs
- Permitting and regulatory costs
- Equipment costs
- Start-up and fixed costs
- Labor costs
- Supplies and consumable Costs
- Utilities costs
- Effluent treatment and disposal costs
- Residuals and waste shipping, handling, and transport costs
- Analytical costs
- Facility modification, repair, and replacement costs
- Site restoration costs

These 12 cost categories reflect typical clean-up activities encountered at Superfund sites. The clean-up activities are defined below, and form the basis for the detailed estimated costs presented in Tables 3-1 and 3-2.

3.4.1 Site and Facility Preparation Cost

Site preparation costs include administrative, treatment area preparation, treatability study, and system design costs. For the purposes of these cost calculations, "site" refers to the location where the EDA technology is treating lead-contaminated soil. It is assumed that preliminary site preparation and soil excavation will be performed by the responsible party. The amount of preliminary site preparation required will depend on the site. Site preparation tasks include site design and layout, surveying,, legal research, obtaining access rights, preparations for support and decontamination facilities, utility connections, fixed auxiliary buildings, and excavation and stockpiling the soil. Since these costs are site-specific, they are not included as part of the site preparation costs in this cost estimate.

Only technology-specific site preparation costs are included. These are limited to transportation and setup of the EDA system. For this cost estimate, it is assumed that the site is 1,000 miles away and that treatment will be outdoors. Transportation to the site for the ETU unit used in the pilot-study case includes one trailer and a mileage rate of $1.50 per mile for a total of $1,500. The full-scale study assumes two trailers.

Technology-specific site preparation labor costs are required for setting up the equipment when it arrives on site and are based on estimates by EDA and observations during the SITE evaluation. Labor to setup the equipment and perform shakedown testing was $4,100 for the pilot study and $8,000 for the full-scale study.

3.4.2 Permitting and Regulatory Costs

Permitting and regulatory costs are generally the obligation of the responsible party (or site owner), not that of the vendor. These costs may include actual permit costs, system monitoring requirements, the development of monitoring and analytical protocols, and health and safety monitoring. No permitting and regulatory costs are included in Table 3.1. Permitting and regulatory costs can vary greatly because they are generally specific to the site and particular waste. Permitting costs are not included in this analysis.

3.4.3 Equipment Costs

Equipment costs for the pilot and full-scale studies incorporates recent data from the evaluation completed in Hawaii. Equipment costs for both studies are assumed to be the same.

3.4.4 Start-up and Fixed costs

The Lead recovery technology does require shakedown testing, since the lead recovery modules need to be connected following transport to a site. However, the equipment will be checked for proper assembly after setup. Shakedown testing is included under technology-specific site preparation.

The cost for the initiation of monitoring programs has not been included in this estimate. Depending on the site and the location of the system, however, local authorities may impose specific guidelines for monitoring programs. The stringency and frequency of monitoring required may have significant impact on the project costs.

Contingency costs allow for any unforeseen or unpredictable cost conditions, such as strikes, storms, floods, and price variations (Peters 1980) (Garrett 1989). Contingency costs, as well as annualized insurance and taxes are not included.

3.4.5 Labor Costs

Once the system is functioning, it is assumed to operate continuously at the designed flow rate except during routine maintenance, which EDA conducts (see Section 3.4.11 Facility Modification, Repair and Replacement Costs). One operator trained by EDA performs routine equipment monitoring and sampling activities. Under normal operating conditions, an operator is required to monitor the system 2 hours per day during the pilot study. This analysis assumes that the work is conducted by a full-time employee of the site owner who is assigned to be the primary operator to the perform system monitoring and sampling duty. Full-scale application will require two full-time operators. Operator labor costs are $50 per hour. Chemist/supervisory labor is assumed to be $70 per hour.

Based on SITE demonstration on Bin 4, it is assumed 18 weeks of operation are required during the pilot test to achieve the regulatory threshold limit, and 52 weeks of operation are required during the full-scale study to reach the same desired limit.

3.4.6 Supplies and Consumable Costs

Supplies costs are limited to health and safety supplies and drums for residuals and waste storage. Supply costs are assumed to be $4 to $15 per worker per operational day. Drums are estimated to cost $35 per drum, including freight charges. A total of 10 drums and 200 drums are assumed for the pilot study and full-scale study, respectively. Consumables are limited to chemicals and spare parts. Based on the SITE study, chemical cost is minimal and was not included. Spare parts include 2 to 4 replacement pumps at $500 per pump and $400 of miscellaneous items.

3.4.7 Utilities Costs

Utilities required are limited to electricity and water for the EDA lead recovery technology. For the pilot study, it was assumed that 1,000 kiloWatt-hours (kWh) are used weekly based on the demonstration project. Electricity rates are assumed to be $0.08/kWh. Water is required for the technology to be properly implemented. Water is assumed to cost $0.08 per 1,000 gallons and is included with the electricity estimate.

3.4.8 Effluent Treatment and Disposal Costs

Effluent treatment and disposal is limited to scrubber water. Effluent volumes are based on the capacity of the scrubber tank module for lead recovery technology. An estimated 55 to 1,100 gallons of scrubber water effluent will require disposal.

3.4.9 Residuals and Waste Shipping, Handling, and Transport Costs

It is assumed that the only residuals or solid wastes generated from this process will be used health and safety and miscellaneous solid waste, including debris from the treatment process (such as drop clothes), as well as small equipment. The disposal cost for solid waste is estimated at $200 per 55-gallon drum.

3.4.10 Analytical Costs

Required sampling frequencies are highly site specific and are based on treatment goals and contaminant concentrations. Analytical costs associated with an electrokinetics treatment project include the costs of laboratory analyses, data reduction, and QA/QC. This analysis assumes that samples were collected from each days operation, for each soil flush,; and 12 pre-treatment soil samples, 12 post-treatment soil samples, and associated QC samples (trip blanks, field duplicates, and matrix spike/matrix spike duplicates) will be analyzed for total lead and TCLP lead concentrations. The total analytical costs are estimated to be $2,000 for the pilot study and $14,500 for the full-scale study.

The analytical costs associated with environmental monitoring have not been included in this estimate due to the fact that monitoring programs are not typically initiated by EDA. Local authorities may, however, impose specific sampling and monitoring criteria whose analytical requirements could contribute significantly to the cost of the project.

3.4.11 Facility Modification, Repair and Replacement Costs

Maintenance costs are assumed to consist of maintenance labor and maintenance materials. Maintenance costs are not included, since they are assumed to be routine for the Lead recovery technology and are incorporated into the treatment time that accounts for an 80 percent run time efficiency. This assumption is made because the Lead recovery equipment is maintained by the operators during the runs and should require little to no repairs in addition to the 80 percent run-time efficiency. In addition, maintenance labor is included in the operating labor and the replacement part costs and tools are included in the total equipment cost lump sum so no additional replacement part costs are included.

3.4.12 Site Restoration Costs

Site restoration requirements will vary depending on the future use of the soil and are assumed to be the obligation of the responsible party. Therefore, the only site restoration costs included are for the demobilization and transportation of the recovery equipment, estimated at 2 man weeks for the pilot study and 4 man weeks for the full-scale study.

4.0 TREATMENT EFFECTIVENESS

This section addresses the effectiveness of the EDA lead recovery technology for treating soil contaminated with lead. Because the SITE demonstration provided extensive data on the EDA technology, the evaluation of the technology's effectiveness is based primarily on the demonstration results. This section provides an overview of the evaluation procedures and sampling/analytical methods; summarizes the evaluation objectives, and results; presents the conclusion of the EDA lead recovery treatment evaluation; and briefly discusses the data quality. Vendor claims regarding the treatment effectiveness of the EDA lead recovery technology are included in the appendix.

4.1 BACKGROUND

The EDA lead recovery technology was evaluated in two phases. Phase I was conducted from August 8 to September 28, 2001. Phase II was conducted from April 1 to July 22, 2002. During Phase I of the evaluation, pre-treatment soil samples were collected and analyzed for lead. Three bins (1, 2, and 4) were treated during the evaluation. Bin 1 was treated and sampled during Phase I, and bins 2 and 4 were treated and sampled during Phase II.

4.1.1 Site Description

The system was set up and maintained by EDA. Soil to be treated was characterized by AMEC based during the RI. The volume and extent of soil requiring remediation was defined during the EE/CA for the subject site (Ogden 1995, 1996); and by Tetra Tech during pre-treatment sampling for the proposed in-situ technology evaluation. Tetra Tech excavated approximately 20 cubic yards of soil to fill the five treatment bins for this demonstration; however, only three of the five bins were treated due to PACNAVENGCOM funding limitations.

4.1.2 Evaluation Objectives and Approach

Primary objectives were considered critical for evaluating the lead recovery technology. The primary objectives (P) of the SITE demonstration were to validate EDA's performance claims for the technology. These objectives focused on the ability of the lead recovery technology to remove the lead from the soil. Three primary objectives were selected for the SITE evaluation as follows:

- P1 Determine if the technology is able to reduce soil lead concentrations to less than the regulatory threshold limit of 2,000 mg/kg
- P2 Determine the removal efficiency of the EDA technology for lead within the soil treatment bin
- P3 Determine whether the post-demonstration soil meets the RCRA landban standards of 5.0 milligrams per liter (mg/L) for TCLP lead concentrations

Secondary objectives (S) provided additional information that was useful, but not critical, for the evaluation of the lead recovery technology. The secondary objectives of the demonstration were to collect and evaluate data that are useful in assessing system performance, cost, and applicability to other sites. Three secondary objectives were selected for the SITE evaluation as follows:

- S1 Evaluate the mass of lead recovered by the ESMS and estimate the recovery efficiency of the ESMS.
- S2 Document specific EDA system operation and maintenance parameters.
- S3 Estimate capital and operating costs for constructing a full-scale EDA system.

4.2 EVALUATION PROCEDURES

4.2.1 Evaluation Preparation

Tetra Tech excavated soil from different portions of the site in order to have soil with varying lead concentrations within each of the five proposed treatment batches. The goal was to have two high concentration batches, two medium concentration batches, and one low concentration batch. High, medium, and low concentrations are defined as the following:

1. High Soil Lead Concentration: 100,000 to 150,000 mg/kg lead
2. Medium Soil Lead Concentration: 25,000 to 50,000 mg/kg lead
3. Low Soil Lead Concentration: 10,000 to 20,000 mg/kg lead

4.2.2 Evaluation Design

The data analysis, like the sampling plan, was designed to address the objectives of the project. To evaluate the data, descriptive statistics, statistical tests, or construction of confidence intervals were used to evaluate the populations from which the samples were collected. Descriptive statistics included calculation of the range, upper and lower values, mean, median, and variance.

P1 Determine if the technology is able to reduce soil lead concentrations to less than the regulatory threshold limit of 2,000 mg/kg.

Twelve post-demonstration samples were collected from within each treatment batch. Samples were analyzed for total lead and the data was used to determine the post-treatment lead concentration in each sub-cell; concentrations were not averaged to obtain a mean concentration of lead within each grid-cell column. All samples must exhibit analytical lead concentrations less than 2,000 mg/kg, for the technology to be considered successful in removing lead from contaminated soils.

P2 Determine the removal efficiency of the EDA technology for lead within the treatment tank.

Twelve pre-treatment samples were collected from within the treatment tank. Samples were analyzed for total lead and the data were used to estimate the pre-treatment lead concentration in each sub-cell. The data was combined with the post-treatment data obtained for primary objective P1 in order to provide a total of 12 data pairs (before and after treatment lead concentrations for each sampled sub-cell). The RE of each sub-cell was calculated according to the following formula:

$$RE = \frac{C_{pre} - C_{post}}{C_{pre}} x100$$

Where:

RE	=	Removal efficiency (%)
C_{pre}	=	The concentration of lead in each sub-cell within a pre-treatment grid-cell column
C_{post}	=	The concentration of lead in each sub-cell within a post-treatment grid-cell column

The laboratory reporting limit for lead in soil is 10 mg/kg. Given that the soil used for this demonstration has previously been characterized as possessing very high lead concentrations, it was unlikely that many results below this reporting limit would be obtained.

P3 Determine whether the post-demonstration soil meets the RCRA landban standards for TCLP lead concentrations.

To determine whether the TCLP lead concentrations in the post-demonstration samples meet RCRA landban standards, post-demonstration samples were compared to the TCLP regulatory limit of 5.0 mg/L. A successful result required that all TCLP extracts are below 5.0 mg/L.

S1 Determine the mass of lead recovered by the ESMS and estimate the recovery efficiency of the ESMS.

The mass of lead removed by the system was determined by summing the weight of all metal electroplated out of solution for each test run and analyzing a composite sample of the metal for lead purity. Based on the weight of the plated out metal and its purity (lead concentration), the mass of solid lead removed is calculated for each test run. The mass of solid lead removed from the ESMS was calculated using the following equation:

$$M_p = WxC$$

Where:

M_p	=	Calculated mass of solid lead plated out from the ESMS
W	=	Total weight of metal removed from the ESMS
C	=	The purity of lead in the composite metal sample

In addition, the recovery efficiency of the ESMS was estimated. Samples of electrolyte solution were collected before the electrolyte solution entered the ESMS, and after the electrolyte solution exited the

ESMS. The concentrations of lead in solution entering and exiting the ESMS were used to estimate the recovery efficiency of the ESMS.

The recovery efficiency for each sampling event was calculated using the following equation, which was based on concentration since the flow volume in and out of the ESMS is the same:

$$RCE_i = \frac{C_{influent_i} - C_{effluent_i}}{C_{influent_i}} x100$$

Where:

RCE	=	Recovery efficiency (%)
$C_{influent}$	=	Concentration of lead in the influent stream composite sample
$C_{effluent}$	=	Concentration of lead in the effluent stream composite sample
i	=	{1, 2, ..., m} and m is the total number of sampling events

4.2.3 Sampling Methods

Each treatment tank was subdivided into 18 4-foot grid-cells and each grid-cell was assigned a unique number from 1 to 18. The sampling program for each treatment tank or batch included collecting samples from 6 of the 18 grid-cells. A single sampling location near the center of six randomly selected grid-cells was used to collect the pre-treatment samples. The total treatment depth was 4 feet; therefore, 2-foot core samples were collected from each 1-foot by 2-foot interval, or sub-cell, within each grid-cell. Each 2-foot core sample was fully homogenized in the field and then submitted to the laboratory for total lead analysis on a dry weight basis. The lead concentration measured in each sample represented the lead concentration for that sub-cell.

Post-treatment samples were collected as close to the proximity of the pre-treatment sample locations as possible. This variance was due to health and safety risks caused by sampling too close to the edge of the treatment bin siding. In treatment bin 1, post-treatment sample 9 was collected from grid-cell 8, post-treatment sample 12 was collected from grid-cell 11, and post-treatment sample 15 was collected from grid-cell 12. In treatment bin 2, post-treatment sample 9 was collected from grid-cell 8, post-treatment 12 was collected from grid cell 11, and post-treatment sample 15 was collected from grid-cell 12. In treatment bin 4, post-treatment sample 9 was collected from grid-cell 8, post-treatment sample 12 was collected from grid-cell 11, and post-treatment sample 15 was collected from grid-cell 12.

The same homogenization procedures were conducted for the post-demonstration samples to obtain a representative sample for each sub-cell after the demonstration. The data were used to determine if post-treatment lead concentrations within the treatment zone were less than the regulatory threshold and to determine the removal efficiency for lead within the treatment zone.

Separate post-treatment soil samples were collected from randomly-selected grid-cells within the treatment zone and analyzed for TCLP lead. These data were used to evaluate whether post-treatment TCLP lead concentrations meet RCRA landban regulatory criteria.

Electroplated Metal Weighing and Sampling

The total mass of metal electroplated out of the electrolyte solution was determined each time the electroplated metal was removed from the electrochemical cells for disposal. Prior to and after each batch treatment, each substrate was weighed and the weights recorded. After each batch treatment, the metal on each substrate was manually removed by EDA. The recovered lead was weighed directly. In general, 1 to 3 kilograms (kg) was recovered from each effort. Recovered material was kept in a tared container and allowed to dry for at least 18 hours before weighing. The lead scrapings were then placed in a container labeled with the date and the mass recovered. At the end of the project, all individual containers were emptied into lined, 5-gallons pails, and transported to a lead recycling facility. A sample of the metal removed from the substrates (approximately 5-10 grams) was collected and composited in a glass jar. The composite sample of metal was analyzed to determine lead purity, and the mass of lead recovered by the ESMS was calculated for Treatment Bin 4. The composite sample of lead for bins 1 and 2 was not completed in the field.

Electrolyte Solution Sampling

A small volume of electrolyte solution was extracted from the electrolyte streams entering and exiting the ESMS on a 4-hour interval and composited over each batch run. Electrolyte solution was extracted from both streams using an in-line automatic sampling device. Volumes extracted from each stream were composited separately in two separate holding containers. For each batch run, a representative grab sample was collected from each electrolyte solution composite batch. Samples were submitted to the laboratory and analyzed for total lead. Recovery efficiencies were calculated for each sampling event and an averaged total for each treatment batch.

4.2.3.1 Total Lead Analysis

Total lead analysis was determined by ICP-AES analysis in accordance with EPA SW-846 method 6010B. Soil samples and electrolyte solution samples were analyzed for lead only.

4.2.4 Quality Assurance and Quality Control Program

The overall QA objective for this evaluation was to produce well-documented data of known quality. Quality was measured by monitoring data precision and accuracy, completeness, representativeness, comparability, and reporting limits for the analytical methods. All laboratory data met the quality control criteria specified in the QAPP.

4.2.4.1 Field Quality Control Program

Field QC checks were collected to determine the quality of field activities, including sample collection, homogenization, handling, and shipment. In general, the QC checks assessed the representativeness of the samples and ensured that the degree to which the analytical data was representative of actual site conditions was known and documented. Field QC checks consisted of equipment blanks, field blanks, and field sample duplicates.

4.2.4.2 Laboratory Quality Control Checks

Laboratory QC checks were designed to determine analytical precision and accuracy, demonstrate the absence of interferences and contamination from glassware and reagents, and ensure the comparability of data. Laboratory QC checks consisted of laboratory control sample/ laboratory control sample duplicates (LCS/LCSD), method blank samples, matrix spike/matrix spike duplicates (MS/MSD) samples, and other checks specified in the methods section of the QAPP. The laboratory also completed the initial calibrations and continued throughout the process with calibration checks. Laboratory internal QC checks for critical parameters are summarized on a method-specific basis in the QAPP.

4.2.4.3 Field and Laboratory Audits

For this project, an internal technical systems audit (TSA) of field sampling and measurements systems was not conducted. The field audit conducted during the pre-treatment sampling event for the originally planned in-situ demonstration. Since the sampling and measurement methods for the proposed ex-situ demonstration are generally the same, the first field audit was considered adequate. The field audit was conducted by Dr. Greg Swanson, Tetra Tech's SITE QA Manager. Recommendations made by Dr. Swanson based on audit observations were implemented during the sampling events, or by modification to the QAPP. No significant findings were identified in the field audit.

Tetra Tech conducted laboratory audit of Severn Trent on May 10 and 11, 1999. Mr. John Schendel, the project chemist, performed the audit. No significant findings were identified. Nine minor observations were documented and discussed with laboratory staff. Appropriate corrective action was taken in response to all observations noted in the audit report.

4.3 EVALUATION RESULTS AND CONCLUSIONS

This section presents the performance data gathered for this evaluation by the testing methodology described above. The data analysis procedures and results associated with each of the project objectives are presented.

Table 4-1: Treatment Bin 1

SAMPLE DEPTH INTERVAL & ANALYSIS		GRID-CELL NUMBER											
Depth (bts)	Analysis & Results	4		6		11		14		16		18	
		Pre	Post	Pre	Post	Pre	Post*	Pre	Post	Pre	Post	Pre	Post
0 to 2	Lead (mg/kg)	20,100	15,400	17,300	5,770	18,500	6,620	19,600	9,390	14,600	13,300	18,000	8,620
	TCLP (mg/L)	8.1	71.5	NA	NA	7.6	35.0	NA	NA	NA	NA	8.5	105.0
	Dup (mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	moisture (%)	15.8	16.8	15.1	17.6	15.0	17.4	15.0	18.2	18.9	21.4	16.5	26.0
	Lead Reduction	4,700		11,530		11,880		10,210		1,300		9,380	
	Removal Efficiency	23.4		66.6		64.2		52.1		8.9		52.1	
2 to 4	Lead (mg/kg)	17,000	10,800	19,200	9,540	17,000	8,990	15,400	10,100	17,600	9,740	19,600	9,110
	TCLP (mg/L)	7.4	73.8	NA	NA	7.8	76.8	NA	NA	NA	NA	9.8	88.2
	Dup (mg/kg)	NA	NA	17,500	8,990	NA	NA	19,000	8,930	NA	NA	NA	NA
	moisture (%)	13.9	17.7	16.7	18.8	17.1	16.6	16.2	16.5	21.8	20.8	17.0	20.1
	Lead Reduction	6,200		9,660		8,010		5,300		7,860		10,490	
	Removal Efficiency	36.5		50.3		47.1		34.4		44.7		53.5	

Notes:

bts	Below top of surface
mg/kg	Milligram per kilogram
mg/L	milligram per liter
TCLP	Toxic Characteristics Leaching Procedure
Dup	Duplicate
Pre	Pre-treatment sample
Post	Post-treatment sample
NA	Not analyzed

* Post Treatment sample 12 was taken from grid-cell 11 due to safety issues.

Table 4-2: Treatment Bin 2

SAMPLE DEPTH INTERVAL & ANALYSIS		GRID-CELL NUMBER*											
Depth (bts)	Analysis & Results	1		2		8		14		12		15	
		Pre	Post	Pre	Post	Pre	Post*	Pre	Post	Pre	Post*	Pre	Post
0 to 2	Lead (mg/kg)	18500	3,720	19,600	9,460	19,600	19,200	23,700	41,500	13,600	15,400	12,100	10,200
	TCLP (mg/L)	7.5	25.1	NA	NA	8.2	78.9	NA	NA	NA	NA	8.0	74.2J
	Dup (mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	moisture (%)	15.2	18.0	11.8	20.2	13.6	21.8	15.8	7.8	10.8	13.6	12.7	11.7
	Lead Reduction	14,780		10,140		400		-17,800		-1,800		1,900	
	Removal Efficiency	79.9		51.7		2.0		-75.1		-13.2		15.7	
2 to 4	Lead (mg/kg)	23300	5,940	36,500	7,060	26,800	12,600	26,500	7,020	37,400	10,900	12,600	8,980
	TCLP (mg/L)	7.3	23.8	NA	NA	6.8	86.4	NA	NA	NA	NA	9.4	117J
	Dup (mg/kg)	NA	NA	32,800	4,350	NA	NA	27,200	8,110	NA	NA	NA	NA
	moisture (%)	12.6	20.8	16.8	21.3	17.5	31.2	16.2	8.0	16.7	14.5	11.7	19.4
	Lead Reduction	17,360		29,440		14,200		19,480		26,500		3,620	
	Removal Efficiency	74.5		80.7		53.0		73.5		70.9		28.7	

Notes:

bts	Below top of surface
mg/kg	Milligram per kilogram
mg/L	milligram per liter
TCLP	Toxic Characteristics Leaching Procedure
Dup	Duplicate
Pre	Pre-treatment sample
Post	Post-treatment sample
NA	Not analyzed

* Post treatment sample 9 was taken from grid-cell 8 and Post Treatment sample 15 was taken from grid-cell 12 due to safety issues.

Table 4-3: Treatment Bin 4

SAMPLE DEPTH INTERVAL & ANALYSIS		GRID-CELL NUMBER											
Depth (bts)	Analysis & Results	1		9		12		14		15		17	
		Pre	Post	Pre	Post	Pre	Post*	Pre	Post	Pre	Post	Pre	Post
0 to 2	Lead (mg/kg)	8270	2,080	53,900	2,620	21,100	6,390	18,400	3,630	21,000	2,520	23,100	2,100
	TCLP (mg/L)	5.4	1.6	NA	NA	9.3	2.9	NA	NA	NA	NA	13.9	0.6
	Dup (mg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	moisture (%)	6.7	12.7	17.0	11.2	11.2	13.7	11.9	13.6	13.1	13.3	12.3	10.6
	Lead Reduction	6,190		51,280		14,710		14,770		18,480		21,000	
	Removal Efficiency	74.8		95.1		69.7		80.3		88.0		90.9	
2 to 4	Lead (mg/kg)	24300	5,870	82,300	12,100	43,100	9,070	35,100	16,200	23,300	1,880	30,500	3,600
	TCLP (mg/L)	10.6	2.3	NA	NA	15.3	13.5	NA	NA	NA	NA	13.1	1.7
	Dup (mg/kg)	NA	NA	42,500	8,180	NA	NA	45,600	7,580	NA	NA	NA	NA
	moisture (%)	12.2	17.9	16.3	21.4	17.4	16.6	15.1	15.8	13.3	9.2	14.9	14.2
	Lead Reduction	18,430		70,200		34,030		18,900		21,420		26,900	
	Removal Efficiency	75.8		85.3		79.0		53.8		91.9		88.2	

Notes:

bts Below top of surface
mg/kg Milligram per kilogram
mg/L milligram per liter
TCLP Toxic Characteristics Leaching Procedure
Dup Duplicate
Pre Pre-treatment sample
Post Post-treatment sample
NA Not analyzed

* Post Treatment sample 15 was taken from grid-cell 12 due to safety issues.

4.3.1 Primary Objectives

To assess all of the primary objectives, 12 pre-treatment and post-treatment soil samples, from each of the three treatment bins, were collected and analyzed by EPA Method 6010B for total lead and TCLP. Details of the primary objective relating to the soil lead treatment efficiency are described below.

P1 *Determine if the technology is able to reduce soil lead concentrations to less than the regulatory threshold limit of 2,000 mg/kg.*

The primary objective was address by comparing the post-treatment soil samples for Total Lead to the regulatory threshold of 2,000 mg/kg. Twelve post-demonstration samples were collected from within each treatment batch. In Treatment Bin 1, post-treatment soil samples ranged from 5,770 mg/kg to 15,400 mg/kg. In Treatment Bin 2, post-treatment soil samples ranged from 3,720 to 41,500 mg/kg. In Treatment Bin 4, post-treatment soil samples ranged from 1,880 to 16,200 mg/kg (see Table 4-4). One of the post-treatment soil samples collected from the Treatment Bin 4 met the regulatory threshold. The average post-soil lead concentration for each bin was 17,285 mg/kg for Bin 1, 22,517 mg/kg for Bin 2, and 5,672 mg/kg for Bin 4.

Because the treatment goal was not achieved for 17 of the 18 post-treatment grid-cells, the primary objective was not met.

Table 4-4Results for Lead using EPA Method 6010B

Treatment Bin Number	Post-Treatment Range (mg/kg)	Grid-cells Meeting Regulatory Threshold (2,000 mg/kg)
1*	5,770 to 15,400	0 of 6
2*	3,720 to 41,500	0 of 6
4**	1,880 to 16,200	1 of 6

Notes: * Bin 1 and 2 was flushed with an EDTA solution originally mixed at 0.1M

** Bin 4 was extensively flushed with water, and a 0.2M concentration of EDTA solution.

P2 *Determine the removal efficiency of the EDA technology for lead within the treatment tank.*

The second primary objective was to determine the treatment efficiency of the EDA lead recovery technology for lead in the soil samples. The EDA lead recovery treatment process removed an average of 59 percent lead for all three bins. Bins 1 and 2 were treated with an EDTA solution with a 0.1M. Bin 4 was treated with an EDTA solution with an increased molarity of 0.2. In Bin 4, nine cycles were made, an increased amount of flush cycles. The average removal efficiency was lower in Bins 1 and 2, with percentages of 44.5 and 51.6, respectively. The average removal efficiency for treatment Bin 4 was 81.1 percent (See Table 4-5).

Table 4-5 Average Removal Efficiencies

Treatment Bin Number	Pre-Treatment Range (mg/kg)	Post-Treatment Range (mg/kg)	Average Removal Efficiency (%)
1*	14,600 to 20,100	5,770 to 15,400	44.5
2*	12,100 to 37,400	3,720 to 41,500	51.6
4**	8,270 to 82,300	1,880 to 16,200	81.1

Notes: * Bin 1 and 2 was flushed with an EDTA solution originally mixed at 0.1M
** Bin 4 was extensively flushed with water, and a 0.2M concentration of EDTA solution.

P3 *Determine whether the post-demonstration soil meets the RCRA landban standards for TCLP lead concentrations.*

To determine whether the TCLP lead concentrations in the post-demonstration samples meet RCRA landban standard, the TCLP extract lead concentration in each of the four post-demonstration samples from each batch were compared to the regulatory limit of 5.0 mg/L. Of 18 cells in the 3 treatment bins, only 5 of 6 grids from Bin 4 met the RCRA landban standards for lead by TCLP analysis. Bin 4 was flushed with water extensively (600 gallons) in comparison to procedures used for the other two bins.

Table 4-6 Results for Lead using TCLP

Treatment Bin Number	Pre-Treatment Range (mg/L)	Post-Treatment Range (mg/L)	Grid-cells Meeting TCLP Threshold (5 mg/L)
1*	7.4 - 9.8	35 - 105	0 of 6
2*	6.8 - 9.4	23.8 - 117	0 of 6
4**	5.4 - 15.3	0.6 - 13.5	5 of 6

Notes: * Bin 1 and 2 was flushed with an EDTA solution originally mixed at 0.1M
** Bin 4 was extensively flushed with water, and a 0.2M concentration of EDTA solution.

4.3.2 Secondary Objectives

Three secondary objectives were established to evaluate the lead recovery system. The secondary objectives are described below.

S1 *Evaluate the mass of lead recovered by the ESMS and estimate the recovery efficiency of the ESMS.*

Due to missing composite metal samples from Treatment Bins 1 and 2, the purity of lead is unknown. Thus, the mass of lead recovered for these bins could not be calculated. The mass of lead recovered by the ESMS was 12.8 kg for Treatment Bin 4 (see Table 4-7).

Table 4-7 Mass of Solid Lead Recovered by the ESMS

Treatment Bin Number	Total Weight of Metal Removed from the ESMS (kg)	Purity of Lead (mg/kg)	Mass of Solid Lead Plated Out from the ESMS (kg)
1	2.1	---	NA
2	58	---	NA
4	75.2	17%J	12.8

Notes: J Method blank contamination. The associated method blank contains the target analyte at a reportable level
kg kilogram
mg/kg milligram per kilogram
— missing sample data
NA not available

The recovery efficiency of the ESMS system has been calculated for each sampling event, during the different flushing cycles (See Table 4-8).

Table 4-8 The Recovery Efficiency of the ESMS

Treatment Bin Number	Number of Cycles	Electrolyte Solution Entering Bin (µg/L)	Concentration of Lead in the Influent Stream (µg/L)	Concentration of Lead in the Effluent Stream (µg/L)	Recovery Efficiency (%)	Average Total Recovery Efficiency (%)
1	1	159,000	179,000	154,000	14.0	14.0
2	1	197,000	1,390,000	1,290,000	7.2	
	2	1,310,000	1,250,000	1,190,000	4.8	
	3	402,000	432,000	509,000	-17.8	
	4	991,000	873,000	1,150,000	-31.7	
	5	124,000	261,000 L	422,000 L	-61.7	
	5		440,000 L	344,000 L	21.8	
	5		532,000 L	390,000 L	26.7	-7.2
4	1	20,100 L	307,000	388,000	-26.4	
	1		415,000	286,000	31.1	
	1		914,000	265,000	71.0	
	2	269,000				
	2	340,000	262,000	369,000	-40.8	
	3		8,640,000	8,580,000	0.7	
	3		7,630,000	7,550,000	1.1	
	3		9,050,000	8,350,000	7.7	
	3		7,500,000	7,360,000	1.9	
	3		7,350,000	7,300,000	0.7	
	3		6,290,000	6,320,000	-0.5	
	3		5,670,000	5,590,000	1.4	
	3		4,960,000	4,890,000	1.4	
	3		6,320,000	7,700,000	-21.8	
	4	4,320,000				

Table 4-8 The Recovery Efficiency of the ESMS

Treatment Bin Number	Number of Cycles	Electrolyte Solution Entering Bin (µg/L)	Concentration of Lead in the Influent Stream (µg/L)	Concentration of Lead in the Effluent Stream (µg/L)	Recovery Efficiency (%)	Average Total Recovery Efficiency (%)
4	4	4,310,000	6,120,000	5,950,000	2.8	
	4		5,670,000	5,120,000	9.7	
	4		4,510,000	4,550,000	-1.0	
	4		4,080,000	3,680,000	9.8	
	4		3,200,000	3,120,000	2.5	
	5	2,990,000	5,110,000	5,470,000	-7.1	
	5		4,690,000	4,370,000	6.8	
	5		582,000 J	664,000 J	-14.1	
	5		804,000 J	857,000 J	-6.6	
	5		676,000 J	580,000 J	14.2	
	5		772,000 J	911,000 J	-18.0	
	6	860,000 J				
	6	1,230,000 J	659,000 J	453,000 J	31.3	
	6		646,000 J	526,000 J	18.6	
	6		497,000 J	612,000 J	-23.1	
	6		527,000 J	665,000 J	-26.2	
	7	514,000 J				
	7	514,000 J	818,000 J	911,000 J	-11.4	
	8		603,000 J	525,000 J	12.9	
	8		277,000 J	805,000 J	-190.6	
	9	579,000 J				
	9	706,000 J	530,000 J	154,000 J	70.9	
	9		998,000 J	847,000 J	15.1	

Table 4-8 The Recovery Efficiency of the ESMS

Treatment Bin Number	Number of Cycles	Electrolyte Solution Entering Bin (µg/L)	Concentration of Lead in the Influent Stream (µg/L)	Concentration of Lead in the Effluent Stream (µg/L)	Recovery Efficiency (%)	Average Total Recovery Efficiency (%)
4	9		743,000 J	692,000 J	6.9	
	9		795,000 J	711,000 J	10.6	
	10	439,000 J				
	10	562,000 J	179,000 J			
	10		117,000 J	239,000 J	-104.3	
	10		42,800 J	48,500 J	-13.3	
	10		37,200 J	214,000 J	-475.3	
	10		91,400 J	53,400 J	41.6	-15.6

Notes: L Serial dilution of a digestate in the analytical batch indicates that physical and chemical interferences are present
µg/L micrograms per liter
J method blank contamination. The associated method blank contains the target analyte at a reportable level

S2 *Document specific EDA system operation and maintenance parameters.*

During the technology demonstration, the vendor collected and recorded data to monitor the proper operation and maintenance parameters of the technology. The operating parameters are those parameters that can be varied during the treatment process to achieve desired results and treatment goals. EDA claims the ETU system is able to run reliably with one daily visit requiring about 2 hours on-site. The principal factor affecting the lead recovery system performance is the rate lead is plated out of the soil and the maximum current used without causing other limitations to the system.

A normal amount or maintenance and repair activities of the system were performed during the SITE demonstration, requiring approximately 4 hours weekly. Spare parts included: replacement pumps, solenoid valves, motor valves, signal conditioners, and SSRs. Between one or two of each item was necessary to have on-site to minimize the replacement time to the system. Minor leakages in plumbing systems were expected and encountered, requiring small amounts of time for repair.

Maintenance of a full-scale system is estimated to require 8 hours weekly. This estimate is based on the assumption that the design of parts of the system that caused frequent shutdowns during the SITE demonstration, such as bladders and float switches, would be modified to eliminate problems.

S3 *Estimate capital and operating costs for constructing a full-scale EDA system.*

A detailed discussion of costs is included in Section 3.0 of this report.

4.3.3 Data Quality

A data quality review was conducted by Tetra Tech to evaluate the field and laboratory QC results, evaluate the implications of QC data on the overall data quality, document data use limitations for data users, and remove unusable values from the demonstration data sets. The results of this review were used to produce the final data sets used to assess the treatment technology and to draw conclusions. The QC data were evaluated with respect to the QA objectives defined in the project quality assurance project plan (QAPP [Tetra Tech 2001]).

The analytical data for the samples collected during the SITE demonstration were reviewed to ensure that they are scientifically valid, defensible, and comparable. A data quality review was conducted using both field QC samples and laboratory QC samples. The field QC samples included field blanks, rinseate blanks, trip blanks, MS/MSD, and sample duplicates. Laboratory QC checks included laboratory blanks, surrogate spikes, and LCS/LCSD. Initial and continuing calibration results were also reviewed to assure the quality of the data and that proper procedures were used. The review focused on assessing the precision, accuracy, completeness, representativeness, and comparability of the data. In addition to the above QC checks, reviews of sample chains of custody, holding times, and critical parameter identification and quantification were performed. All laboratory data met the quality control criteria specified in the QAPP. Please refer to the Technology Evaluation Report for data tables that present analytical results for field QC samples and MS/MSD results.

4.3.4 Conclusions

The primary evaluation objectives were to determine whether the lead recovery technology removed lead from soil, and if so, how efficiently they were moved.

- Approximately six percent of the total post-treatment soil samples met the regulatory threshold lead concentration of 2,000 mg/kg or less (1 of 18 post treatment samples).
- The average lead removal efficiency was 59 percent for all three bins. Due to variations in the treatment process for Bin 4, which included changing the concentration of the EDTA solution and extensively flushing the soil with water, the removal efficiency was 81 percent.
- TCLP lead concentrations did not meet the RCRA landban standard of the 5.0 mg/L for samples collected from Bin 1 and Bin 2 due to adsorption of the $Pb\text{-}EDTA^{2-}$ complex to soil particles during infiltration. Extensive flushing of water in Bin 4 effectively removed sorbed solution, which resulted in a reduction in TCLP lead concentrations and attainment of the RCRA landban standard.

5.0 TECHNOLOGY STATUS

The EDA lead recovery system SITE demonstration was modified several times over the history of the project. Data obtained from the demonstration allowed EDA to continue the engineering development for electrokinetic remediaiton. This will enhance the speed of the EDA lead recovery system. EDA has a goal of treating one ton of soil per hour.

Site information pertinent to electrokinetic remediation includes the following:

General Information

1. Contaminated area size and depth
2. Utilities layout
3. Soil type and moisture content profile

Chemical information

1. Contaminant type
2. Contaminant concentrations and distribution
3. Soil permeability

Other information

1. Maximum amount of electrical current
2. Surface area of electrode plates

At this time, the recovery process is not available on the open market.

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