United States
Environmental Protection
Agency

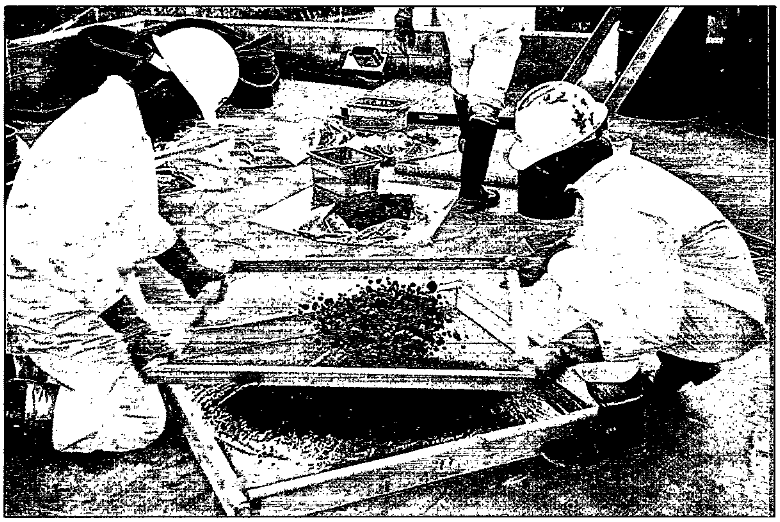
Office of Research and
Development
Washington DC 20460

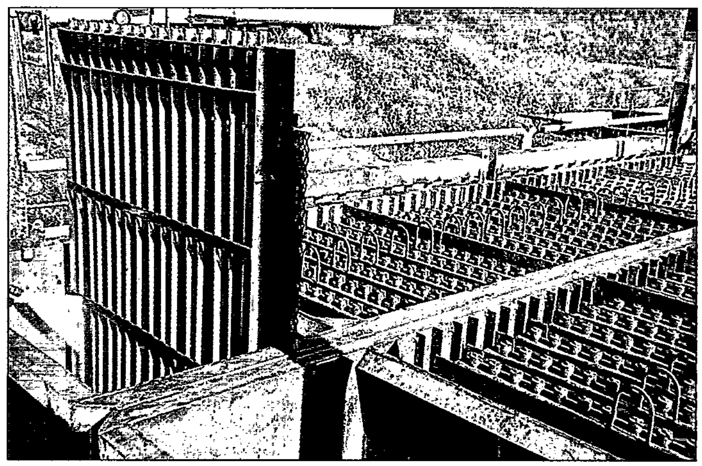
EPA/540/R-96/535
September 1996

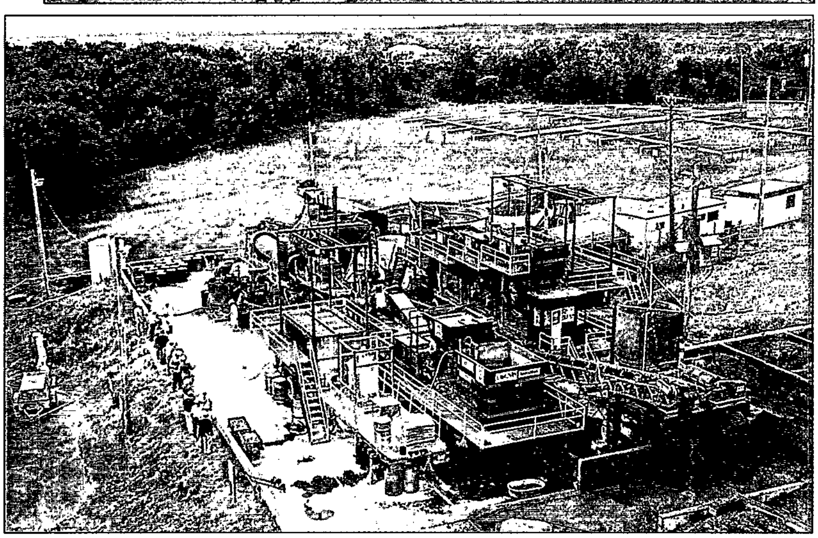
EPA

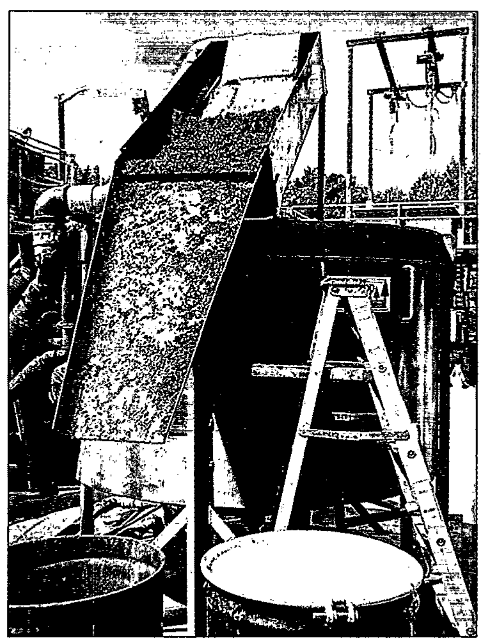
COGNIS TERRAMET®
Lead Extraction Process

Innovative Technology
Evaluation Report









SITE
SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

EPA/540/R-96/535
September 1998

COGNIS TERRAMET®

Lead Extraction Process

Innovative Technology Evaluation Report

National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Printed on Recycled Paper

Notice

The information in this document has been funded by the U. S. Environmental Protection Agency (EPA) under Contract No. 68-C5-0037 to Tetra Tech EM Inc. (formerly PRC Environmental Management, 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 or recommendation for use.

Foreword

The U.S. Environmental Protection Agency (EPA) is charged by the U.S. Congress with protecting the nation's land, air, and water resources. Under a mandate of national environmental laws, EPA strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and 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 (NRMRL) is EPA's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of NRMRL'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 Innovative Technology Evaluation Report has been produced as part of NRMRL'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 Innovative Technology Evaluation Report documents an evaluation of the removal of lead from sands and fines fractions of contaminated soils by the COGNIS TERRAMET® lead extraction process (COGNIS process). The COGNIS process was developed by COGNIS, Inc., of Santa Rosa, California. The evaluation was performed under the U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Program. The performance information upon which this report is based is derived primarily from process samples that were collected during the 4-day SITE demonstration period (August 2 to 5, 1994) during operation of the COGNIS process on sands and fines separated from about 400 metric tons (tons) of contaminated soils. The contaminated soils were extracted from a small arms ammunition burning/ disposal area (Site F) at the Twin Cities Army Ammunition Plant (TCAAP) in New Brighton, Minnesota. Before, during, and after the 4-day SITE demonstration sampling activity, the COGNIS system was operated in fulfillment of a full-scale remediation contract for TCAAP Site F. About 20,000 tons of soil were processed under contract during 11 months of operation. The COGNIS process was not specifically configured or operated during the 4-day SITE demonstration to maximize lead removal, but rather to economically meet cleanup goals (for example, 300 milligrams per kilogram [mg/kg] for lead). Also, the SITE demonstration sampling points, analytical procedures, and data reduction methods were established independently, and differed substantially in some areas, from those employed for process control by COGNIS, Inc., and for oversight of the full-scale TCAAP Site F soil remediation effort by the U.S. Army and the State of Minnesota.

The COGNIS process, as configured for TCAAP Site F, uses two parallel leaching systems — one for sand-sized particles, and one for fines. The COGNIS process is expected to typically require pretreatment to classify the soil into sands and fines fractions for the respective leaching systems, and to remove lead particulates amenable to size and density separation. During TCAAP Site F remediation, Brice Environmental Services Corporation (BESCORP) performed the required separations. The sands and fines streams produced by the BESCORP system were fed immediately and directly to the COGNIS process.

Some key results from the 4-day SITE demonstration include the following:

- The particle size distribution of the untreated soil consisted of 17 percent oversized material, 54 percent sands, and 28 percent fines.
- The 824 mg/kg mean lead concentration in untreated soil was reduced by 63 to 84 percent after treatment by both the BESCORP and COGNIS processes.
- The mean daily lead concentration in the untreated sands stream (ranging from 292 to 434 mg/kg after BESCORP process) was decreased by 21 to 45 percent after treatment by the COGNIS process.
- The mean daily lead concentration in the untreated fines stream (ranging from 342 to 548 mg/kg after BESCORP process) was decreased by 72 to 83 percent after treatment by the COGNIS process.
- Of 35 untreated sands samples, 20 samples exceeded lead concentration of 300 mg/kg; of the 35 treated sands samples, 27 samples were less than or equal to a lead level of 300 mg/kg.
- Of the 35 untreated fines samples, 27 samples exceeded 300 mg/kg; of the 35 treated fines samples, all 35 samples were less than 300 mg/kg.
- The mean daily lead concentrations of the treated soil (by combining 2 parts sands to 1 part fines, based on the sands to fines ratio noted in the untreated soil) were less then 300 mg/kg on all 4 days during the SITE demonstration.

Contents

Contents (continued)

Figures

Tables

Acronyms, Abbreviations, and Symbols

ARAR	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
ATTIC	Alternative Treatment Technology Information Center
BESCORP	Brice Environmental Service Corporation
CAA	Clean Air Amendments
CAMU	Corrective Action Management Unit
CBR	California Bearing Ratio
CEC	Cation Exchange Capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERI	Center for Environmental Research Information
CFR	Code of Federal Regulations
CSCT	Consortium for Site Characterization Technology
CWA	Clean Water Act
dL	Deciliter
DOT	U.S. Department of Transportation
ft^2	Square Foot
ITER	Innovative Technology Evaluation Report
kg	Kilogram
kW	Kilowatt
kWh	Kilowatt Hour
L	Liter
LDR	Land Disposal Restriction
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
mg	Milligram
mm	Millimeter
MPCA	Minnesota Pollution Control Agency
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NA	Not Applicable or Not Available
NCP	National Contingency Plan

Acronyms, Abbreviations, and Symbols (continued)

ND	Not Detected
PPE	Personal Protective Equipment
ppm	Part Per Million
PSD	Particle Size Distribution
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
ROC	RCRA Off-Site Coordinator
RPD	Relative Percent Difference
SARA	Superfund Amendments and Reauthorization Act
SD	Standard Deviation
SDWA	Safe Drinking Water Act
SG/RE	Seed Germination/Root Elongation
SITE	Superfund Innovative Technology Evaluation
SWDA	Solid Waste Disposal Act
TBC	To Be Considered
TCAAP	Twin Cities Army Ammunitions Plant
TCLP	Toxicity Characteristics Leaching procedure
TU	Temporary Unit
VISITT	Vendor Information System for Innovative Treatment Technologies
µg	Microgram
µm	Micron

Conversion Factors

	To Convert From	*To*	*Multiply By*
Length	inch	centimeter	2.54
	foot	meter	0.305
	mile	kilometer	1.61
Area:	square foot	square meter	0.0929
	acre	square meter	4,047
Volume:	gallon	liter	3.78
	cubic foot	cubic meter	0.0283
Mass:	pound	kilogram	0.454
Energy:	kilowatt-hour	megajoule	3.60
Power:	kilowatt	horsepower	1.34
Temperature:	(°Fahrenheit - 32)	°Celsius	0.556

Acknowledgments

This report was prepared under the direction of Mr. Michael Royer, the EPA SITE project manager at the National Risk Management Research Laboratory (NRMRL) in Edison, New Jersey. This report was prepared by Dr. Pinaki Banerjee, Ms. Therese Gioia, and Mr. Jeff Swano of PRC Environmental Management, Inc. (PRC). The report was typed by Ms. Cheryl Vaccarello; edited by Ms. Cheryl Finnegan of PRC; and reviewed by Ms. Ann Kern, Mr. Samuel Hayes, Mr. Michael Borst, Mr. Richard Griffiths, and Mr. Ronald Turner of EPA, Mr. Dan Card of the Minnesota Pollution Control Agency (MPCA), Mr. Pete Rissell of the U.S. Army Environmental Center, and Dr. Kenneth Partymiller and Mr. Peter Zelinskas of PRC. Significant contributions were also made by the U.S. Army, COGNIS, BESCORP, Wenck Associates, Inc., Federal Cartridge Corporation, and Mr. Tom Barounis from EPA Region 5. Bioassay testing was planned and executed by Ms. Lina W. Chang, Mr. John Meier, and Dr. M. Kate Smith of Ecological Monitoring Research Branch, National Exposure Research Laboratory, EPA.

Executive Summary

The COGNIS TERRAMET® lead extraction process (COGNIS process) was evaluated at a Superfund Innovative Technology Evaluation (SITE) demonstration at the Twin Cities Army Ammunition Plant (TCAAP) site in New Brighton, Minnesota. The SITE demonstration was conducted during the course of a much larger full-scale remediation under the Resource Conservation and Recovery Act (RCRA) hazardous waste management unit closure process. The results of the demonstration and an evaluation of the technology are provided below.

The U.S. Environmental Protection Agency (EPA) developed the SITE Program in response to the Superfund Amendments and Reauthorization Act of 1986. The program's primary purpose is to maximize the use of alternative treatment technologies. To this end, reliable performance and cost data on innovative technologies are developed during demonstrations where the technology is used to treat a specific waste.

After completing each demonstration, EPA publishes an Innovative Technology Evaluation Report (ITER) designed to aid decision-makers in evaluating the technology for consideration as an applicable cleanup option. This report includes a description of the technology and environmental requirements the technology may need to meet, an economic analysis of treatment costs using the technology, and the results of the demonstration.

The COGNIS process extracts and recovers lead and other metals from contaminated soil, dust, sludge, or sediment. In the full-scale remediation and SITE demonstration at TCAAP, the COGNIS process was used in conjunction with the Brice Environmental Services Corporation (BESCORP) soil washing and size separation process. The BESCORP process removes and washes oversized material and then separates the remaining soil into sands and fines fractions. The sands fractions are further treated by density separation to isolate particulate metals as a concentrate. Evaluation of the BESCORP process was not an objective of this SITE demonstration. However, measurements of feed soil to the BESCORP process and product streams from it were necessary to characterize the contaminated soil, the feed streams to the COGNIS process, and the overall lead reduction produced by the combined processes. The BESCORP process was previously evaluated by the SITE demonstration program (EPA/540/AR-93/503) during operation at an Alaskan lead battery breaking site.

In the COGNIS portion of the process, the sands and fines fractions are then separately leached by a proprietary leachant. Leached metals are recovered through electrochemical cells, producing a metal concentrate, while regenerating the leachant for recycling. The recovered lead can be recycled at a smelter. The washed sands and fines are neutralized and blended with treated oversized material before final disposition. The wastewater can be disposed of in a publicly owned treatment works (POTW) at the conclusion of treatment or at the season's end.

The SITE demonstration showed that implementing the remediation processes, which include site preparation, mobilization, operation of the BESCORP and COGNIS process equipment, waste disposal, and demobilization, proceeded mostly without any major problems. The feed soil was composed of 17 percent oversized material, 54 percent sand, and 28 percent fines. The BESCORP soil washing process alone achieved lead removal efficiencies ranging from 38 to 62 percent. The combined removal efficiency of the COGNIS and BESCORP processes ranged from 63 to 84 percent. The COGNIS sands leaching process reduced lead concentrations by an overall average of 28 percent and the COGNIS fines leaching process reduced lead concentrations by an overall average of 78 percent. Treated soil lead concentrations were all less than 300 milligrams per kilogram (mg/kg). Three of

the eight oversized material samples, separated and washed by BESCORP, did not meet the maximum allowable lead concentrations in the toxicity characteristics leaching procedures extracts, and therefore require further treatment before disposal. Recovered lead was recycled at a lead smelting facility and the wastewater was discharged to a POTW. The cost of soil treatment at TCAAP was found to be $182 per ton for treating 10,000 metric tons (tons) of soil; this unit cost includes the costs of soil washing, soil leaching by the COGNIS process, site preparation, and residuals shipping and handling.The COGNIS process was also evaluated based on the nine criteria used for decision-making in the Superfund feasibility study process. This evaluation against the nine criteria considers both the information generated from and observations made during the SITE demonstration and the overall TCAAP Site F remediation. Table ES-1 presents the evaluation.

Table ES-1. Criteria Evaluation for the Terramet® Lead Extraction Technology

Criteria	Evaluation		
Overall Protection of Human Health and the Environment	Protects human health and the environment by eliminating exposure to contaminants in soil	Prevents further contamination of groundwater and off-site migration by removing contaminants from soil	Requires measures to protect workers and community during excavation, handling, and treatment of soil
Compliance with Federal ARARs	Requires compliance with RCRA treatment, storage, and disposal regulations of a hazardous waste	Excavation, as well as construction and operation of on-site treatment unit, may require compliance with local ARARs	Wastewater generated at the conclusion of treatment requires compliance with Clean Water Act
Long-Term Effectiveness and Permanence	Effectively removes metals contaminants from soil; treated waste could be handled as fill material; site may be suitable for reuse after remediation	Provides reliable, irreversible treatment of contaminated soil	Involves some residuals treatment or disposal (precipitated metals, wastewater); process generates high toxic concentrations of salts in treated soil that can be effectively reduced with rinsing
Reduction of Toxicity, Mobility, or Volume Through Treatment	Significantly reduces the volume of metals contaminants in soil through treatment	Reduces the toxicity of the soil by removing lead to acceptable levels; residual salt toxicity in treated soil may require dilution in the form of rinsing or rainfall to enable successful revegetation	Lead in soil is reclaimed, resulting in resource recovery
Short-Term Effectiveness	Presents potential short-term risks to workers and community including exposure to noise and contaminants released to the air during excavation and handling	Short-term risks are readily manageable through common site health and safety practices	Achieves cleanup objectives in fairly short amount of time
Implementability	Typically requires pretreatment of contaminated soil to produce separate sands and fines fractions for treatment in separate leaching circuits	High clay content in soil may cause clay ball formation, and require increased residence time for leaching and soil/water separation; multiple metals present treatment and recycling difficulties; process is limited by cold or freezing weather	Availability of material and services limited because of limited vendors; equipment is transportable; mobilization and demobilization each take approximately 2 weeks
Cost	$182 per ton of soil based on 10,000 tons of soil treated; this includes the cost for soil washing, removing ordnance, preparing the site, and soil leaching	Labor cost is major part of the total cost; other significant cost items include equipment, proprietary chemicals, and residuals management	Disposal costs are reduced by lead recovery smelters, depending on the percent of lead in the material
State Acceptance	Provides a permanent solution to contamination that is preferable to other soil remediation technologies	State regulatory authorities may require that certain permits be obtained before implementing the system, if conducted as part of a RCRA corrective action; such as a permit to operate a treatment system, and a permit or approval to potentially store contaminated soil for more than 90 days	Minnesota Pollution Control Agency approved implementation of the COGNIS process for soil treatment at TCAAP as part of RCRA corrective action process
Community Acceptance	Minimal and manageable short-term risks to the public may increase community acceptance	Permanence and long-term effectiveness of technology may increase community acceptance	Resource recovery (reclaiming lead) may increase community acceptance

Section 1
Introduction

This section provides background information about the Superfund Innovative Technology Evaluation (SITE) program, discusses the purpose of this Innovative Technology Evaluation Report (ITER) and describes the COGNIS TERRAMET® lead extraction process (COGNIS process). Additional information about the SITE Program, this technology, and the demonstration site can be obtained by contacting individuals listed in Section 1.5 of this report.

1.1 Brief Description of Program and Reports

The SITE Program is a formal program established by the U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response (OSWER) and Office of Research and Development (ORD) in response to the Superfund Amendments and Reauthorization Act of 1986 (SARA). The SITE Program promotes the development, demonstration, and implementation of new or innovative technologies at Superfund sites across the country.

The primary purpose of the SITE Program is to maximize the use of alternatives in cleaning hazardous waste sites by encouraging the development and demonstration of new, innovative treatment and monitoring technologies. The SITE Program consists of the following programs: the Consortium for Site Characterization Technology (CSCT), the Demonstration Program, and the Technology Transfer Program.

Existing technologies that improve field monitoring and site characterizations are identified in the CSCT program, formerly the Monitoring and Measurement Technologies Program. This program supports new technologies that provide faster, more cost-effective contamination and site assessment data. The CSCT Program also formulates the protocols and standard operating procedures for demonstrating methods and equipment.

The objective of the SITE Demonstration Program is to develop reliable performance and cost data on innovative technologies so that potential users may assess the technology's site-specific applicability. Technologies evaluated are either currently available or close to being available for remediation of Superfund sites. SITE demonstrations are conducted on hazardous waste sites under conditions that closely simulate full-scale remediation conditions, thus ensuring the usefulness and reliability of the information collected. Technologies chosen must be at the pilot- or full-scale stage, must be innovative, and must have some advantage over existing technologies. Data collected are used to assess the performance of the technology, the potential need for pre- and posttreatment processing of wastes, potential operating problems, and the approximate costs. The demonstrations also allow for evaluation of long-term risks and operating and maintenance costs.

Cooperative arrangements between EPA, the site, and the developer establish responsibilities for conducting the demonstrations and evaluating the technology. The developer is responsible for demonstrating the technology at the selected site and is expected to pay any costs for transport, operations, and removal of the equipment. EPA is responsible for project planning, sampling and analysis, quality assurance and quality control, preparing reports, disseminating information, and the site is responsible for transporting and disposing of treated waste materials and site logistics.

The Technology Transfer Program disseminates technical information on innovative technologies through various activities in the Demonstration, and CSCT Programs. These activities increase the awareness and promote the use of innovative technologies for assessment and remediation at Superfund sites. The goal of technology transfer activities is to develop communication among individuals requiring up-to-date technical information.

The results of the COGNIS process demonstration are published in two documents: the SITE Technology Capsule and the ITER. The SITE Technology Capsule provides relevant information on the technology, emphasizing key features of the results of the SITE field demonstration. Both the SITE Technology Capsule and the ITER are intended to be used by remedial managers making a detailed evaluation of the technology for a specific site and waste.

1.2 Purpose of the ITER

The ITER provides information on the COGNIS process and includes a comprehensive description of the demonstration and its results. The ITER is intended for use by EPA remedial project managers, contractors, and other decision-makers for implementing specific remedial actions. The ITER is designed to aid decision-makers in evaluating specific technologies for further consideration as an applicable option in a particular cleanup operation. This report serves as a critical step in the development and commercialization of a treatment technology.

To encourage the general use of demonstrated technologies, EPA provides information regarding the applicability of each technology to specific sites and wastes. The ITER includes information on cost and site-specific characteristics.

Each SITE demonstration evaluates the performance of a technology in treating a specific waste. The waste characteristics at other sites may differ from the characteristics of the treated waste. Therefore, successful field demonstration of a technology at a particular site does not necessarily ensure that it will be applicable at other sites. Data from the field demonstration may require extrapolation to estimate the operating ranges in which the technology will perform satisfactorily. Only limited conclusions can be drawn from a single field demonstration.

1.3 Background

In August, 1994, a demonstration of the COGNIS process was conducted at the Twin Cities Army Ammunition Plant (TCAAP) site in New Brighton, Minnesota. Since 1941, operations at the TCAAP facility included the manufacturing, testing, destroying, storing, and disposing of small arms ammunition and related materials. Until the 1980s, Site F, which is located within the facility, was used to destroy various explosives and tracer compounds. Ordnance and scrap materials were also buried at Site F. As a result, soils at the 10-acre site are contaminated with lead and other metals. Site F is being addressed through a Resource Conservation and Recovery Act (RCRA) corrective action with the Minnesota Pollution Control Agency (MPCA) serving as the lead agency for oversight.

TCAAP solicited proposals from technology vendors and selected COGNIS to treat contaminated soils at Site F. COGNIS began treating soils beginning in the fall of 1993 and treated about 20,000 tons of soil over an 11-month period ending in July, 1995. TCAAP's contractor, Wenck Associates, Inc. (Wenck), prepared a report documenting the overall operation (Wenck 1995a).

The COGNIS process treats metal-contaminated soil using two separate leaching systems. The first system treats soil of larger particle size, defined as sands. The second system treats soil of smaller particle size, defined as fines. For the COGNIS process, sands are defined as particles that range in size from less than 6.35 millimeters (mm) in diameter to 106 microns (μm) in diameter, and fines are defined as particles of less than 106 μm in diameter. Contaminated soil may need to be pretreated before treatment by the COGNIS process to achieve acceptable particle size separation. The sands and fines leaching systems use proprietary aqueous leaching solutions to remove metals from soil particles. Metallic ions are then recovered from the aqueous leachant. The recovered metallic ions are recycled at a smelter or disposed of, and the aqueous leachant is recycled through the treatment process.

During the demonstration, which was conducted as part of an ongoing, full-scale cleanup, soils were excavated and staged at Site F. The treatment equipment was placed at Site D, 500 yards northwest of Site F. Before placing equipment at Site D, the area was graded, paved, and bermed. TCAAP also built containment areas where treated soils were placed. Site D preparation occurred as part of a previous incineration project at Site D. Soil treatment was interrupted during the winter and began again in early summer of 1994. The SITE demonstration was conducted over a 4-day period, from August 2 through 5, 1994.

As part of the remedial investigation at Site F, soil samples were collected from various depths and analyzed for several metals. The average concentration of lead detected in the soil was approximately 700 milligrams per kilogram (mg/kg). Other metals detected at levels above the cleanup goal that are considered to be contaminants of concern at the site include the following: antimony, cadmium, chromium, copper, mercury, nickel, and silver. The cleanup standards for this site are listed in Table 1-1. These remediation goals are the enforceable standards established by MPCA. The MPCA lead remediation goal was established in accordance with a state standard that existed at the time. This lead level in the soil does not address leaching to groundwater at Site F, because lead leaching to groundwater is not a concern based on depth to groundwater and soil and groundwater sampling data. Since that time the state standard changed from 300 mg/kg to 100 mg/kg and EPA has established soil lead screening levels of 400 mg/kg (residential use) and 1,200 mg/kg (industrial use). The other metals remediation goals were established at two standard deviations above calculated background levels. Soils that meet the remediation goals and are below the toxicity characteristics leaching procedure (TCLP) standards are not considered RCRA hazardous waste.

Table 1-1. Cleanup Goals for TCAAP Site F (mg/kg)

Metal	Remediation Goals[a]
Antimony	4.0
Cadmium	4.0
Chromium	100.0
Copper	80.0
Lead	300.0
Mercury[b]	0.3
Nickel	45.0
Silver[b]	5.0

Notes:

a Remediation goals are the enforceable cleanup standards

b Mercury and silver were not evaluated during this project

The objectives of the SITE Program evaluation of the COGNIS technology were:

- To determine the effectiveness of the COGNIS process in removing total lead from sands and fines particles and leachable lead from oversized materials
- To determine the potential need for pre- and post-treatment of soils that are treated by the COGNIS process
- To evaluate implementability of the treatment system
- To determine capital, operating, and maintenance costs

COGNIS claims to have treatment systems capable of removing most metals from contaminated soils. At TCAAP Site F, the treatment system was configured to treat the contaminants specific to Site F soil. Site F soil was contaminated primarily with lead, but contained other metals. The COGNIS process was proposed, selected, and evaluated under the SITE Program as a lead extraction process. Therefore, because lead was the primary contaminant in Site F soils and lead leaching was the focus of the SITE demonstration, lead is the critical parameter for this project. The effectiveness of the COGNIS process was evaluated by determining the degree to which total lead in the feed soil, sands, and fines was reduced. Reduction of TCLP leachable lead in oversized material and treated soil was also evaluated. The effectiveness of the process in reducing toxicity was assessed based on (1) reduction in lead concentration in soil via the Uptake Biokinetic Model, and (2) bioassay test results of various types, such as seed germination, root elongation, and earthworm mortality. Because the COGNIS process removes metals other than lead, the demonstration also monitored concentrations of other metals in various media.

The COGNIS process requires feedstock that is separated into sands (<6.35 mm and >106 µm in diameter) and fines (<106 µm in diameter). Site F soil required pretreatment for particle size separation. BESCORP conducted pretreatment processing of soils that consisted of soil washing and size separation. BESCORP's pretreatment system was monitored to provide background information and key data for calculating COGNIS performance parameters such as feed rate of soil and particle size distribution. During the SITE demonstration, clay balls were observed in the oversize material from the BESCORP system. These clay balls were not treated by the COGNIS process. The need for posttreatment of treated soil was determined by comparing concentrations of lead and other metals with remediation goals. The need for posttreatment of residuals other than the treated soil was evaluated by reviewing the types and quantities of residuals and whether or not they required additional treatment or disposal. The types of residuals generated during the SITE demonstration included live ordnance, inactive ordnance components, oversized material from the BESCORP process, lead concentrates from the BESCORP and COGNIS processes, leachant, process water, and rain water. Residuals handling is discussed in Section 2.9 of this report.

The technology consists of a two-stage process. BESCORP conducts the first stage, and COGNIS conducts the second stage of the process. The first stage is the physical separation stage during which oversized material is removed by screening the untreated soil to separate sands and fines. In addition to size separation, the BESCORP process plays a role in removing particulate lead, thereby reducing initial lead concentrations before introduction to the COGNIS process. This preliminary reduction saves COGNIS reagents and probably increases the chances of meeting remedial goals at a given processing rate. The second stage is the leaching and lead recovery stage that results in the dissolution of metal attached to the fines and sands and the recovery of the metallic ions from the aqueous leachant. End products include treated soils, rocks, debris, and metallic fragments from soil washing; precipitated metals from the acid leachant; and the leaching solution, which is recycled through the process.

1.4 Technology Description

According to COGNIS, the system can treat most types of metal contaminations including soluble ions or insoluble metal oxides and salts bound by fine soil constituents such as clays. These constituents can be treated by matching the leachant with a specific substrate and type of metallic contaminant.

A schematic of the COGNIS and BESCORP processes is shown in Figure 1-1. The major components of the combined system include the following:

Trommel. The trommel separates untreated soil that is less than 6.35 mm (0.25 inch) in diameter from the remaining soil. Soil less than 6.35 mm in diameter passes through the screen and is processed further while the larger oversized material is manually screened for ordnance and debris and is then transferred to the treated soil pile.

Wet classifier. Fines are separated from sands within the wet classifier. The fines are advanced to a clarifier and the sands are transferred to the density separator.

Density separator. Each sands fraction is treated in a density separator to remove lead and other dense particles. The underflow is recovered as lead concentrate while the overflow solids are advanced to the sands leaching unit.

Sands leaching unit. Sands are mixed with an acidified leaching solution in the sands leaching unit. After flocculation and clarification, the leachant containing lead is advanced to the lead recovery cells. The leached sand is neutralized and added to the treated soil pile.

Fines leaching unit. Fines are mixed with the leachant in the fines leaching unit. The leachant containing lead is flocculated and clarified and is advanced to the lead recovery cells. The leached fines are neutralized and sent to the fines dewatering unit.

Fines dewatering unit. The leached fines are dewatered in the fines dewatering unit. The dewatered solids are delivered to the treated soil pile while the leachant is regenerated and reused as leachant.

Lead recovery cells. The lead-containing leachant passes through lead recovery cells on which elemental lead is deposited. The recovered lead is periodically washed from the cells as lead concentrate. The regenerated leachant is recycled and reused in the process.

The physical separation process begins when excavated soil is hand-sorted for ordnance. Ordnance at Site F is comprised of the metallic components associated with military rifle ammunition. The soil is then moved from the excavation site to a storage pile near the treatment equipment. The soil is then loaded into a front-end loader that is used to place contaminated soil into a feed hopper. Soil continuously feeds from the feed hopper onto a conveyor belt, where it is weighed and elevated into a large rotating drum called a trommel. The trommel contains a screen with holes measuring 6.35 mm in diameter. The soil within the trommel is sprayed with water and particles measuring less than 6.35 mm in diameter pass through the screen. The oversized material empties onto a conveyor belt.

The smaller particles that pass through the holes within the trommel are transferred into a classifier and are suspended in an upward flow of water. The fines that are smaller than 106 μm in diameter exit at the top of the classifier, while two sand streams consisting of particles larger than 106 μm in diameter exit from the middle and bottom of the classifier. The fines are advanced to a clarifier where a flocculent is added and the mixture is allowed to settle. The overflow from the clarifier is returned to the water surge tank while the fines that settle to the bottom of the clarifier are pumped to the fines leaching unit. The sand streams then flow to a density separator (see Figure 1-1).

Each sand fraction is treated in a density separator to remove lead and other dense particles. The underflow from the density separation process is recovered as lead concentrate. Overflow solids from the density separators are combined and advanced by a sand screw to the sands leaching unit.

Sands within the sands leaching unit are mixed with an acidified leachant. The leachant, which contains lead, is flocculated, clarified, and advanced to two electrochemical cells that comprise the lead recovery system in the sands leaching unit. Lead is deposited in the lead recovery cells thereby preparing the leachant for reuse following refortification with additional leaching agent. The leached sand is (1) removed by a sand screw, (2) neutralized by adding lime, and (3) added to the treated oversized material on a conveyor belt. The resulting material is transported to the treated soil pile on the conveyor belt.

The fines within the fines leaching unit are mixed with acidified leachant in four mixer-clarifiers. Two streams of leachant, both of which contain lead, are advanced to the lead recovery system. The underflow solids from the last mixer-clarifier are neutralized with lime and then dewatered in a continuous centrifuge. The solids that result from the centrifuge are transferred to the treated soil pile, while the aqueous portion from the centrifuge is returned to the leachant surge tank. The lead-containing leachant within the lead recovery system passes through six lead recovery cells where elemental lead is deposited and lead-depleted leachant is produced. The lead-depleted leachant is refortified with leaching agent and returned to the leaching unit. The lead that collects in the cell cassettes is periodically dewatered and drummed as lead concentrate.

As part of the RCRA corrective action at Site F, upgrades were made to the combined BESCORP/ COGNIS system. The following upgrades were made in 1994:

- Spiral classifier
- Lifter bars to trommel
- Vegetative organic separation screens
- Acid storage tank
- Second centrifuge

The following upgrades were made in 1995:

- Log washer to deagglomerate clay balls, when required
- Second clarifier and pre-acidification vessel
- New flocculent
- Fifth clarifier was added

1.5 Key Contacts

Additional information on the COGNIS process and the SITE Program can be obtained from the following sources:

The COGNIS Process

Phillip Mattison
Henkel Corporation
300 Brookside Ave.
Ambler, PA 19002
215-628-1000
Fax: 215-628-1200

William E. Fristad
Parker Amchem.
32100 Stephenson Hwy.
Madison heights, MI 48071
248-588-4719
Fax: 248-583-2976

Lou Magdits
TERRAMET Mgr.
Raw Materials Manager
Buick Resource Recycling Facility
Hwy. KK
HC 1Box 1395

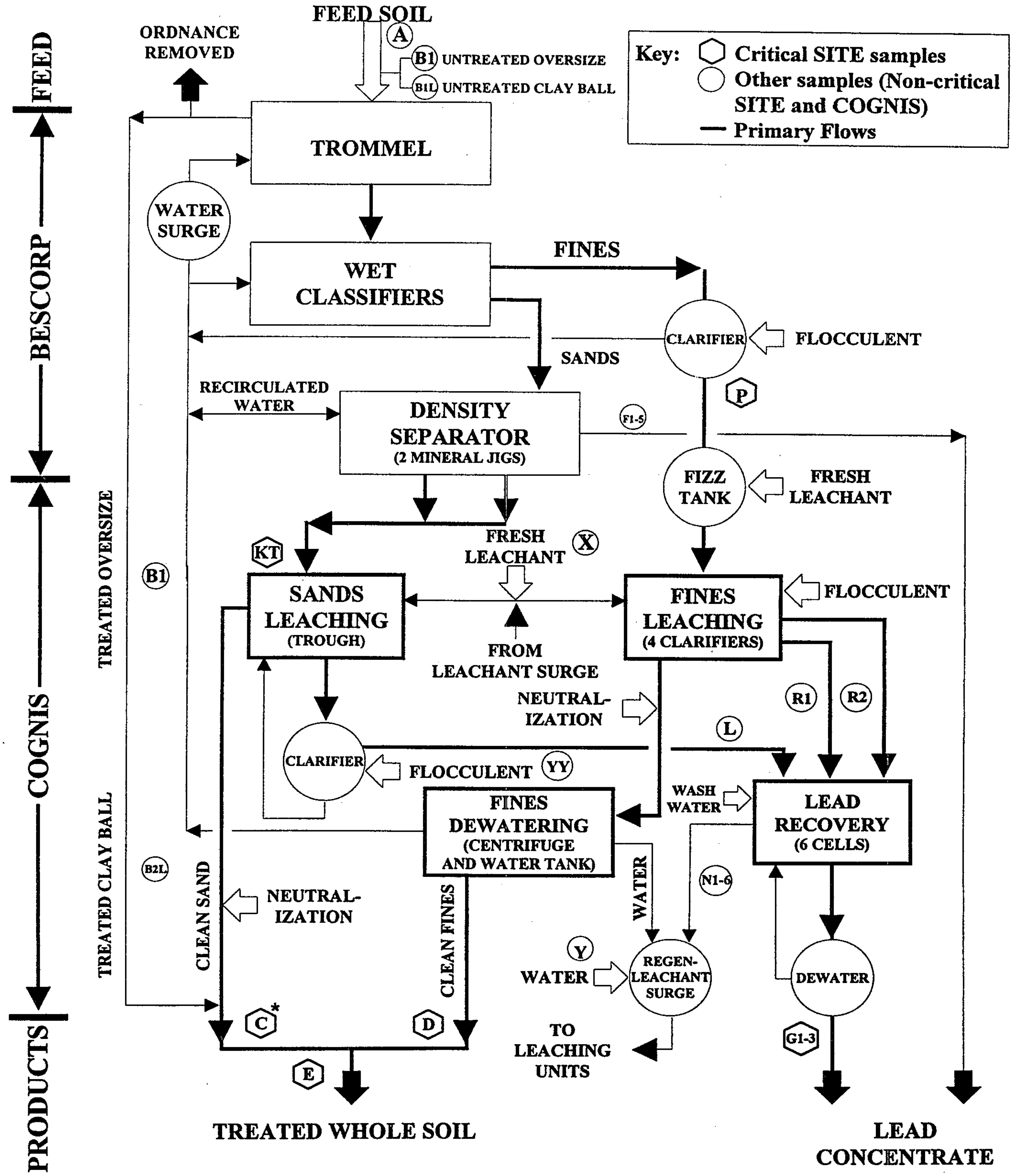


Figure 1-1. Schematic of the COGNIS process.

Boss, MO 65440
573-626-3476
Fax: 573-626-3405
1magdits@misn.com

The SITE Program

Michael D. Royer
U. S. Environmental Protection Agency
Building #10 (MS-104)
2890 Woodbridge Ave.
Edison, NJ 08837-3769
732-321-6633
Fax: 732-321-6640

Annette Gatchett
LRPCD, NRMRL
U.S. Environmental Protection Agency
26 W. Martin Luther King Blvd.
Cincinnati, OH 45268
513-569-7697
Fax: 513-569-7620

Information on the SITE Program is available through the following on-line information clearinghouses:

The Alternative Treatment Technology Information Center (ATTIC) System is a comprehensive, automated information retrieval system that integrates data on hazardous waste treatment technologies into a centralized, searchable source. This database provides information summaries on innovative treatment technologies. The on-line access number is 513-569-7610. Technical support number is 513-569-7272.

The Vendor Information System for Innovative Treatment Technologies (VISITT) (Hotline: 800-245-4505) database contains information on technologies offered by developers.

The OSWER CLU-IN electronic bulletin board contains information on the status of SITE demonstrations. Homepage: http://www.clu-in.com.

Technical reports may be obtained by contacting the Office of Research and Development Publications at 26 W. Martin Luther King Drive, Cincinnati, Ohio 45268, or by calling 800-490-9198.

Section 2
Environmental Requirements Analysis

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by SARA, directs that for wastes left on site, remedial actions must comply with federal laws and regulations and more stringent state requirements that apply or are relevant and appropriate under circumstances of the release or potential release. Potentially applicable or relevant and appropriate requirements (ARAR) are identified throughout the remedial investigation and feasibility study process and are selected in the record of decision. Several technical factors must be considered in determining whether the COGNIS process can be applied to any particular site problem. Sections 2.1 through 2.3 provide analyses of the potential ARARs used in evaluating the performance of the COGNIS process. Sections 2.4 through 2.9 discuss technical factors that should be considered in determining the applicability of the COGNIS process.

2.1 ARARs Defined

ARARs are the federal and state environmental requirements with which a remedial action at a CERCLA site must comply. The more stringent of the state or federal requirements will prevail, but only those state requirements that are legally enforceable and consistently enforced statewide may be established as ARARs (EPA 1988). Other nonpromulgated federal or state criteria, advisories, and guidance, are "to be considered" (TBC). TBCs do not have the same legal impact as ARARs, but in some instances, TBCs may be useful in developing CERCLA remedies if no ARARs exist for a particular hazardous substance or for a particular situation.

An ARAR may be either applicable or relevant and appropriate, but not both. According to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 Code of Federal Regulations [CFR] Part 300), the terms applicable and relevant and appropriate requirements are defined as follows:

Applicable requirements are those cleanup standards, standards of control, or other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and that are more stringent than federal requirements may be relevant and appropriate.

The NCP identifies the following three categories of ARARs in 40 CFR §300.400(g):

Chemical-specific ARARs are usually health- or risk-based numerical values or methodologies used to determine acceptable concentrations of chemicals that may be found in or discharged to the environment (for example, maximum contaminant levels [MCL] that establish safe levels in drinking water). The remediation goals and targets listed in Table 1-1 in Section 1.3 are chemical-specific ARARs.

Location-specific ARARs restrict actions or contaminant concentrations in certain environmentally sensitive areas. Areas regulated under various federal laws include flood plains, wetlands, and locations where endangered species or historically significant cultural resources are present.

Action-specific ARARs are usually technology- or activity-based requirements, limitations on actions, or conditions involving special circumstances.

The major federal environmental statutes that typically provide ARARs are RCRA, the Clean Air Act (CAA), the Safe Drinking Water Act (SDWA), and the Clean Water Act (CWA). Most states have passed laws similar to federal environmental statutes and may have authorization to implement federal laws. In addition, both federal and state agencies have TBCs.

2.2 Other Non-ARAR Requirements

A number of requirements are not considered to be ARARs because both the administrative and substantive requirements are applicable to the remediation, and therefore may not be waived. These additional requirements include the Occupational Safety and Health Administration (OSHA) worker protection requirements; U.S. Department of Transportation (DOT) requirements for transportation of hazardous materials; RCRA requirements for off-site transportation of hazardous waste (including compliance with the manifest requirements); and the CERCLA Off-Site Rule.

CERCLA remedial actions and RCRA corrective actions and closures must be performed in accordance with OSHA requirements detailed in 29 CFR Parts 1900 through 1926. Part 1910.120 is of particular importance because it 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 performed in accordance with Part 1926 of OSHA, which provides safety and health regulations for construction sites. State OSHA requirements, which may be significantly stricter than federal standards, must also be met.

The DOT has promulgated packaging and labeling requirements for shipping hazardous materials. All off-site shipments of hazardous materials must comply with DOT requirements. In a related matter, all RCRA manifesting requirements must be followed for off-site shipments of hazardous waste.

The CERCLA Off-Site Rule regulates off-site disposal of CERCLA wastes. CERCLA wastes (hazardous and nonhazardous) can only be treated and disposed of at a facility that is in compliance with the Off-Site Rule. Each EPA regional office maintains a list of acceptable facilities.

2.3 Major ARARs and TBCs for the COGNIS Project

This section discusses the specific environmental regulations pertinent to the operation of the COGNIS process including the transport, treatment, storage, and disposal of wastes and treatment residuals and analyzes these regulations in view of the demonstration results. The SITE demonstration of the COGNIS process was conducted as part of RCRA closure of Site F. RCRA closures must comply with applicable RCRA requirements. This section also discusses potential ARARs when the COGNIS process is used at a CERCLA site. Remedial managers must also address state and local regulatory requirements, which may be more stringent. The ARARs and TBCs were identified using the operable unit feasibility study that was conducted for TCAAP and are based on current regulatory and policy developments. This section presents ARARs and TBCs for soil and surface water. ARARs and TBCs are presented for these media because (1) contaminated soil is the primary medium treated by the COGNIS process and (2) the wash water used in the treatment system must be handled to ensure that surface water is protected. Section 2.3.1 presents the major chemical-specific ARARs and TBCs, Section 2.3.2 discusses the major location-specific ARARs and TBCs, Section 2.3.3 presents the major action-specific ARARs, and Section 2.3.4 discusses other requirements that may apply to the COGNIS process. Table 2-1 lists federal and state ARARs and TBCs and discusses whether they are applicable to the COGNIS process.

2.3.1 Chemical-Specific ARARs and TBCs for the COGNIS Process

This section describes the chemical-specific ARARs and TBCs for the COGNIS process. MPCA has a lead abatement standard for residential property of 100 parts per million (ppm) established in Part 4761.0300, Subparagraph 4 of the Minnesota Rules. "Bare soil" in the

Table 2-1. ARARs and TBCs for the COGNIS Process

Medium or Action	Citation	Description	ARAR/TBC Basis	Response
Soil	Minnesota R. 4761.0300, sub p. 4	Current Minnesota levels are 100 ppm for lead under its lead abatement program	State levels may be relevant and appropriate	State soil lead level at the time the closure plan for Site F was approved was 300 mg/kg
Water	SDWA 40 CFR Part 141 or state equivalent (Minnesota R. 4717.7150 to 4717.7800)	For lead, the MCL value of 15 micrograms per liter (μg/L) is the maximum permissible level of a contaminant in water that is delivered to a free-flowing outlet to the ultimate user of a public water system. Minnesota has promulgated Health Risk Limits (HRL) for groundwater cleanup.	These requirements are not ARARs or TBCs because the COGNIS process treats soil, not groundwater.	Soil cleanup levels should consider the possibility of leaching contaminants to groundwater. Soil cleanup levels should be established at a level that ensures leaching of contaminants to groundwater does not exceed SDWA MCLs. At Site F, it was determined that groundwater would not be affected by leaching of lead.
Waste characterization	RCRA 40 CFR Part 261 or state equivalent (Minnesota R. 7045)	Identifying and characterizing waste prior to and after treatment	Soil and waste to be treated may be RCRA hazardous wastes.	Chemical and physical analyses must be performed.
Soil excavation	CAA 40 CFR Part 50.6, and 40 CFR Part 52 Subpart K or state equivalent	Management of toxic pollutants and particulate matter in the air	Fugitive air emissions may occur during excavation and material handling and transport.	If necessary, the waste material should be watered down or covered to eliminate or minimize dust generation.
	RCRA 40 CFR Part 262 or state equivalent (Minnesota R. 7045)	Standards that apply to generators of hazardous waste	Soil excavation may trigger RCRA generator requirements.	If possible, soils should be fed directly into the wash unit for treatment.

Table 2-1. ARARs and TBCs for the COGNIS Process (continued)

Medium or Action	Citation	Description	ARAR/TBC Basis	Response
Soil Excavation (cont.)	CWA 40 CFR Part 122.26 or state equivalent (Minnesota R. 7045 and 7050)	Storm water runoff management from landfills, construction sites, and industrial sites consisting of greater than 5 acres.	Soil excavation and treatment may involve more than 5 acres.	Silt fence would be constructed to control runoff from the excavation area.
Storage prior to processing	RCRA 40 CFR Part 264 or state equivalent (Minnesota R. 7045)	Standards applicable to the storage of hazardous waste	Excavation may generate a hazardous waste that must be stored in a waste pile, containment building, or corrective action management unit (CAMU). Waste piles are land disposal units which require compliance with land disposal restrictions (LDR).	If in a waste pile, the material should be placed on and covered with plastic that is tied down to minimize fugitive air emissions and volatilization. The time between excavation and treatment should be kept to a minimum.
Waste processing	RCRA 40 CFR Parts 264 and 265 or state equivalent (Minnesota R. 7045) equivalent	Standards applicable to the treatment of hazardous waste at permitted and interim status facilities	Treatment of hazardous waste may occur.	Equipment must be operated and maintained daily. Air emissions must be characterized by continuous emissions monitoring.
Waste characterization (treated waste)	RCRA 40 CFR Part 261 or state equivalent (Minnesota R. 7045)	Standards that apply to waste characterization	It must be determined if treated soil is a RCRA hazardous waste.	Chemical and physical tests must be performed on treated soils prior to disposal.

Table 2-1. ARARs and TBCs for the COGNIS Process (continued)

Medium or Action	Citation	Description	ARAR/TBC Basis	Response
On-site/off-site disposal	RCRA 40 CFR Part 260 CAMU and temporary unit (TU) rule or state equivalent (Minnesota R. 7045)	Standards that apply to management of remediation wastes	Untreated and treated soil can be considered to be remediation wastes.	The CAMU designation allows for on-site disposal without triggering LDR or minimum technology requirements. TUs can be used to avoid stringent RCRA treatment and storage technical requirements.
	RCRA 40 CFR Part 268 or state equivalent (Minnesota R. 7045)	Standards that restrict the placement of certain wastes in or on the ground	Treated soil may be subject to the LDRs.	Wastes subject to LDRs must be treated to a specified level or with a specific technology before being disposed of on land.
Wastewater discharge	CWA Act 40 CFR Parts 301, 304, 306, 307, 308, 402, and 403 or state equivalent (Minnesota R. 7045)	Standards that apply to discharge of wastewater to a POTW or to surface water body.	Point source discharges of wastewater are regulated through the National Pollutant Discharge Elimination System (NPDES) program and discharges to POTWs are regulated through the pretreatment program.	Obtain discharge limitations for point source discharge to surface water body and pretreatment standards for discharge to a POTW. Discharge to a POTW requires a permit while discharge to surface water may or may not require a permit depending upon the proximity of the surface water body to the CERCLA site.

Minnesota rules refers to soil within the top 2 centimeters of the ground surface. When the Site F closure plan was approved, the residential bare soil standard was 300 mg/kg of lead. MPCA therefore set the lead remediation goal at that time at 300 mg/kg. Regardless of the 100 mg/kg residential bare soil standard that now exists, Site F was backfilled with treated soils meeting the remediation goals and vegetated with 6 inches of top soil. The remediation goals for lead and other metals are listed in Table 1-1 in Section 1.3.

During the 11 months of site remediation, Wenck Associates, Inc. (Wenck), subcontractor for TCAAP, collected one sample from each batch of soil. Each batch typically consisted of 30 tons of soil. Beginning in 1994, soils from all batches that failed remediation goals were tested with TCLP. If the leachate from TCLP analyses did not meet maximum allowable concentrations, then that batch of soil was reprocessed. Overall, 134 out of the 406 batches that were tested with TCLP did not meet maximum allowable concentrations for lead, and required reprocessing (Wenck 1995a). At the end of the project, all treated soil met remedial goals.

EPA recommends site-specific health risk models that use lead levels in soil to determine lead levels in blood and has established a soil-lead screening level of 400 ppm to indicate if a potential problem exists. If lead is present in site soils at levels of 400 ppm or higher, then EPA recommends collecting additional information in order to run the Uptake Biokinetic Model to establish soil cleanup levels. For current and probable future industrial land use conditions, a remediation goal of 1,200 ppm for soil-lead in an industrial setting would be considered to be appropriate in accordance with EPA's new soil-lead guidance (EPA 1994c).

In addition, the cleanup level for lead in soil should be established to ensure groundwater does not contain lead in excess of federal or state standards in drinking water through the leaching of residual lead in the remediated soils to the groundwater. The federal action level of 15 μg/L of lead is the relevant and appropriate requirement for lead in drinking water. State groundwater standards, such as Minnesota HRLs, may be relevant and appropriate for establishing soil cleanup levels. The state of Minnesota, as may other states, has groundwater levels for some contaminants, including HRLs for nonlead metals at Site F.

2.3.2 Location-Specific ARARs and TBCs for the COGNIS Process

No location-specific ARARs were identified for the COGNIS process demonstration. The technology was not demonstrated in a flood plain or near a wetland and the area contained no identified historical or cultural resources. Disposal of treated material may be subject to state waste disposal facility siting requirements if the treated material is categorized as solid or hazardous waste. At TCAAP Site F, RCRA closure regulations were followed because Site F was a permitted facility under RCRA.

2.3.3 Action-Specific ARARs and TBCs for the COGNIS Process

The principal action-specific requirements for CERCLA sites are based on the regulatory definitions and classifications of the materials at the site. This section describes the waste classifications and indicates the action-specific requirements associated with each type of material that may be involved in implementing the COGNIS process at a CERCLA site. These ARARs are triggered by the particular remedial activities selected to accomplish a remedy.

The presence of RCRA-defined hazardous waste determines whether RCRA regulations apply to the COGNIS process. If soils are determined to be hazardous according to RCRA, all RCRA requirements regarding the management and disposal of hazardous wastes will need to be addressed. However, RCRA itself provides waivers to some requirements, such as LDR treatment levels. RCRA regulations define hazardous wastes and regulate their transport, treatment, storage, and disposal. Wastes defined as hazardous under RCRA include characteristic and listed wastes. Criteria for identifying characteristic hazardous wastes are included in 40 CFR Part 261 Subpart C. Listed wastes from nonspecific and specific industrial sources, off-specification products, spill cleanups, and other industrial sources are itemized in 40 CFR Part 261 Subpart D.

After contaminated soils are treated by the COGNIS process, the treated soils may still contain hazardous constituents at levels above required cleanup action levels or may still be considered a RCRA hazardous waste. Such soils need to be properly managed. Proper management of soils that do not consist of hazardous waste, but whose constituent levels exceed cleanup levels, may require disposal and long-term management, including property deed restrictions or notices. The type of disposal should be tailored to the site-specific situation by considering a variety of information including the types and levels of constituents, future land use, and state requirements. Treated soils still considered to be a hazardous waste are subject to LDRs under RCRA unless a CAMU is designated, or the soils may require further treatment, recycling, or disposal. Applicable RCRA requirements could include the following: a uniform hazardous waste manifest if the treated soils are transported; restrictions on placing the treated soils in land disposal units (if a CAMU is not designated); time limits on accumulating treated soils; permits for storing treated soils; and storage requirements, such as storm water runoff prevention.

At most sites, ARARs relevant to soil excavation are applicable because soils may need to be excavated and stockpiled in the soil staging area. In addition, plastic liners may be required under the stockpiled soil. At TCAAP, runon and runoff from the soil staging area was controlled by a bermed concrete pad. ARARs relevant to underground injection wells did not apply at TCAAP because all wastewater was discharged to a POTW. After treatment, the soil was again stockpiled in the treated soil holding area, which also consisted of a bermed concrete pad. Some soils stockpiled in the holding area required reprocessing due to exceedence of lead concentrations in the TCLP leachate. However, following reprocessing, treated soil did not meet either the RCRA or state definitions of hazardous waste. Therefore, ARARs applicable to the disposal of hazardous wastes are not applicable to this SITE demonstration.

RCRA requirements may also apply to any concentrated waste streams that result from the COGNIS process. In the case of the COGNIS process demonstration at TCAAP, the concentrated waste stream was sent under a hazardous waste manifest to a lead smelting facility for recovery.

The COGNIS process uses water in applying its soil washing technology. During the treatment process, water is recycled through the system. When the treatment is complete, some contaminated water remains and is discharged to a POTW. In order to be discharged to a POTW, the contaminated water must meet the pretreatment standards established by the POTW. These pretreatment standards are specific to the particular POTW. Rainwater falling in the uncovered treatment and storage area is pumped to a holding tank. Water from this holding tank is occasionally used as make-up water. During the demonstration, about 15,000 liters of rainwater was used as make-up water. Wastewater was recycled through the COGNIS and BESCORP processes. At the season's end, wastewater including rainwater generally did not meet the pretreatment standards and required treatment before disposal. However, wastewater generated during the season when the demonstration was conducted met the pretreatment standards for discharge to a POTW.

The COGNIS process is an ex situ technology that requires excavation of contaminated soil. When contaminated soil is excavated, the potential exists for the soil to contribute to the transport of contaminants through surface water runon and runoff during rainstorms. Storm water runon and runoff must therefore be controlled at the site excavation.

The CAA provides requirements for the control of fugitive emissions. In accordance with the CAA, fugitive dust emissions from the excavation and storage of contaminated soil to be used in the COGNIS process must be controlled. During the closure at Site F, dust emissions were controlled by wetting down the soils with water. Sprinkler systems were installed to suppress dust. Soil piles were also covered with tarps while awaiting transport and during transport between Sites F and D. Safety zones were established and enforced and air monitoring was performed.

2.3.4 Other Requirements of the COGNIS Process

All technicians operating the COGNIS process are required to have completed an OSHA training course and must be familiar with all OSHA requirements relevant to hazardous waste sites. For most sites, the minimum personal protective equipment (PPE) for technicians will include gloves, hardhats, steel-toed boots, and coveralls. Depending on the types and concentrations of the contaminants, additional PPE may be required. Noise levels should be monitored to ensure that workers are not exposed to noise levels above a time-weighted average of 85 decibels over an 8-hour day. If operation of the COGNIS process causes noise levels to increase above this limit, then workers will be required to wear hearing protection.

Shipping material off site for refining (concentrated waste stream) or disposal (treatment residues) must be conducted in accordance with applicable DOT regulations. DOT regulations for packaging and labeling of hazardous materials may apply.

Off-site disposal of wastes generated from the treatment process must comply with the CERCLA Off-Site Rule. The RCRA Off-Site Coordinator (ROC) in EPA regions where wastes may be disposed of must be consulted to ensure that any facility designated to receive waste from the treatment process is acceptable under the CERCLA Off-Site Rule. The CERCLA ROC was not consulted in off-site disposal actions related to TCAAP Site F because the action was a RCRA closure, not a CERCLA response.

Table 2-2 summarizes other non-ARAR requirements that apply to the COGNIS process.

2.4 Implementability of the Technology

Implementing remedial activities at hazardous waste sites requires numerous activities to be performed prior to, during, and after waste treatment. These activities include preparing the site, arranging for utilities, mobilizing, operating treatment equipment, disposing of residues, and demobilizing. Information regarding all these activities was collected to determine implementability.

Wenck prepared the site, which included grading the site, constructing a treatment pad, and installing cells for holding treated soil. TCAAP's contractors also arranged for utilities to be connected and residual waste disposal. COGNIS and BESCORP were responsible for mobilization, demobilization, and operation of their respective equipment. According to Wenck, mobilization and demobilization activities were carried out on schedule (Wenck 1995b). During the SITE demonstration, all equipment operated with only minor mechanical problems.

2.5 Applicable Wastes

COGNIS claims that its process can treat soil, sediment, and sludge contaminated by lead and other heavy metals or metal mixtures by using a physical separation process and a chemical leaching and metal recovery process. Appropriate sites include contaminated ammunition testing areas, firing ranges, battery recycling centers, scrap yards, metal plating shops, and chemical manufacturers. The system can treat metallic lead as well as lead salts and oxides. Certain lead compounds, such as lead sulfide, are not amenable to treatment because of their exceedingly low solubilities. The process can be modified to leach and recover other metals, such as cadmium, zinc, copper, and mercury, from soils. However, treatment through the 1995 season of the Site F RCRA closure had difficulty meeting remediation goals (two standard deviations above calculated background levels) for copper, mercury, or antimony. Three hundred ninety of the 790 batches, about 49 percent, failed remediation goals set for one of the metals. The average concentrations for these metals in treated soils were copper (116 mg/kg), mercury (0.29 mg/kg), and antimony (1.72 mg/kg) (Wenck 1995a).

2.6 Key Features of the COGNIS Process

The COGNIS process has several unique features, which include the following:

The leachant is recycled and reused within the treatment system. Because no process wastewater is generated during processing, water is disposed of only upon completion of treatment or at the season's end. The process is a net consumer of water, but at TCAAP the water exited the system as increased soil moisture, not as process water requiring treatment.

The lead-containing leachant passes through lead recovery cells on which elemental lead is deposited and later is recovered as lead concentrate.

2.7 Availability and Transportability of Equipment

The COGNIS process equipment is mounted on several flat-bed trailers and transported to the site. Once on site, it requires 8 days for a four-person operating staff to unload and assemble the system and to hook up water and electricity. Demobilization activities include decontaminating on-site equipment, disconnecting utilities, disassembling equipment, and transporting equipment off site. Currently, COGNIS has one commercial unit. The proprietary leaching solution used in the process is available through COGNIS.

Table 2-2. Other Requirements for the COGNIS Process

Title	Requirement	Rationale for Implementation
OSHA Worker Protection Requirements 29 CFR Parts 1904 and 1910	These regulations establish requirements to protect workers who could be exposed to noise, hazardous wastes, or other contaminants or hazards at the remediation site.	Compliance with 29 CFR Part 1910.120 is required for all sites undergoing remediation by 40 CFR Part 300.150.
DOT requirements for packaging, labeling, and transporting hazardous materials	These regulations establish requirements for the packaging, labeling, and transporting of hazardous materials off site.	Compliance with DOT regulations apply to off-site shipments of untreated waste, treatment residuals, and concentrated waste streams considered to be hazardous materials and shipped off site.
CERCLA Off-Site Rule, 40 CFR Part 300	Requires consultation with region-specific ROC to determine if proposed off-site facilities are in compliance with the CERCLA Off-Site Rule.	Any off-site shipments of waste from a CERCLA site must comply with the CERCLA Off-Site Rule.

2.8 Site Support Requirements

Technology support requirements for providing suitable site conditions, utilities, facilities, and equipment for the COGNIS and BESCORP processes are discussed below.

Surface requirements for the process units include a level graded area capable of supporting the equipment. The foundation must support the weight of the process unit. The process unit requires a concrete pad area measuring approximately 8,000 square feet. The process unit requires stable access roads that can accommodate oversized and heavy equipment.

At some sites, pretreatment of soils, in addition to soil washing, is required. Sites contaminated primarily with lead typically contain ordnance or battery casings. The presence of ordnance or battery casings requires sorting of these materials before soil is transferred to the feed hopper for washing.

Both the COGNIS and BESCORP processes require water and electricity. Water is also needed to decontaminate the equipment. Water consumption during processing depends, among other variables, on the incoming soil moisture content because treated soil will exit the plant saturated with water. During the demonstration, approximately 190 liters of water was used per 1 ton of treated soil. A 275-ampere, 440-volt, three-phase electrical circuit is also required.

Support facilities include a staging area for contaminated soil and material handling, a treated soil holding area, a rainwater holding tank, a leachant storage tank, and a drum storage area. Treated soil is stored in roll-off containers or a soil pile. Fifty-five-gallon drums containing lead concentrate are stored in the drum storage area. In addition, a tank storage area to store process water may be required at some sites. All support facilities must be designed to control surface runon and runoff. Support equipment includes excavation and transport equipment such as backhoes, front-end loaders, dump-trucks, forklifts, roll-off boxes, and storage tanks. Decontamination, changing, and other support facilities should be made available to personnel. An on-site office for reviewing operations information is also useful.

2.9 Limitations of the Technology

The COGNIS process would not typically operate as a standalone technology. The process will likely need integration with a soil washing process that removes debris and separates sands and fines. Soil washing will remove some lead particulates from the contaminated soil, thereby playing a role in contaminant reduction. During this demonstration, ordnance and lead shards within the soil posed major difficulties, from both safety and analytical precision perspectives. The presence of unexploded ordnance within the soil required that ordnance experts sort and remove ordnance from the soil before treatment. The presence of lead shards within the soil samples collected for analysis can result in "hot spots," affecting the precision of the analysis. It was decided that crushing the coarse grained samples such as the feed soil, treated and untreated sands, and density separated lead concentrates prior to analysis would create a more homogenous mixture. During Site F remediation, oversized material was not crushed prior to TCLP analysis.

The COGNIS process is only effective for treating metal-contaminated media and is not amenable to treating organics. The contaminated media must be excavated and staged before treatment. Another limitation posed by the process is that residuals generated by soil treatment, including used leachant and reclaimed lead, require additional treatment and disposal. The following residuals may be generated and may require additional treatment:

Reclaimed lead, which must be recovered at a smelter or stabilized and disposed of in accordance with RCRA LDRs

Process water remaining after treatment and rain water collected from the storage and treatment area may need treatment to meet POTW pretreatment standards before discharge to a POTW

Oversized material from soil feedstock that may contain ordnance and other hazardous substances, depending on the site conditions, which must be disposed of

The clay content of the feedstock soil may limit the operation of the COGNIS process. During the SITE demonstration, clay balls formed during the BESCORP soil washing and were removed from the system as oversized material. Deagglomeration of clay balls that may be formed is necessary to ensure contaminated fines are leached. In addition, as the clay content in the feedstock soil to the COGNIS process increases, the treatment rate will tend to decline due to additional time or equipment required for fines-water separation in the leaching system.

The elevated salt content of the treated soil due to the addition of leachant may limit the options for placement of the soil. Leachant and salt concentrations can be reduced through rinsing or natural dispersion. Soil fertility will likely be adversely affected for several months due to elevated salt content and degradation of organic matter, especially if natural dispersion is used to address elevated salt concentrations. However, this temporary loss of fertility should be viewed in light of other lead treatment technologies, such as solidification and capping, which permanently reduce soil fertility.

Section 3
Economic Analysis

This economic analysis presents cost estimates for operating the COGNIS process. Costs have been placed into 13 categories, 12 of which are applicable to operating the COGNIS process at RCRA and Superfund sites (Evans 1990). A thirteenth category was added to present the cost of soil pretreatment before delivery as partially cleaned sands and fines for further treatment by the COGNIS process. Costs are presented in January, 1995 dollars.

Cost data were compiled from several sources including the SITE technology demonstration at the TCAAP site where the soil was contaminated with lead from ordnance testing, burning, and destruction activities. Information collected during the SITE demonstration was recorded in logbooks and used in this analysis when applicable. Wenck, the TCAAP oversight contractor, provided cost and operating data specific to COGNIS operations at TCAAP (Wenck 1995c). Cost data were also obtained from various independent supply vendors to present actual costs in preference to cost estimates for such items as fencing and mobile trailer rentals. Other cost estimates presented in this analysis are drawn from the R.S. Means Company, Inc. (Means); construction cost data sources; and engineering estimates (Means 1994). Cost data obtained from COGNIS are used in this analysis when independent costs could not be acquired and when COGNIS was the only reliable source for costs of a technology-specific nature.

This economic analysis discusses the issues addressed and assumptions used in defining a base case scenario, each of the 13 cost categories, and conclusions of the economic analysis.

3.1 Issues and Assumptions

This section summarizes the major issues addressed and assumptions used in this economic analysis of the COGNIS process. Operating issues and assumptions about the COGNIS process are based on information that COGNIS provided. Issues are presented in text and primary assumptions for each are presented as bullets at the end of each subsection. Certain assumptions were made to account for variable site and soil contamination parameters, others were applied to simplify cost estimating where complex engineering or financial functions would be required. A hypothetical base-case scenario, provided at the end of this section, was developed from the issues and assumptions outlined below.

3.1.1 Equipment and Operating Parameters

This analysis provides cost estimates for treating TCAAP Site F soils, which were primarily contaminated with lead. As a result, the COGNIS system was operated to optimize treatment of TCAAP Site F soil by cost effectively achieving treatment goals established for Site F.

COGNIS will provide and operate the system for its clients as part of an overall on-site soil treatment service. The cost of using the equipment is not based on time but rather is a lump-sum price of providing a complete soil treatment service. That price is determined by the volume of the soil remediation job. COGNIS will calculate the price on a site-by-site basis.

A soil washing subcontractor will be needed to pretreat the soil before the soil enters the system. COGNIS procures the soil washing subcontractor and includes this cost in the total price of providing a complete soil treatment service. For this analysis, costs for a soil washing subcontractor are presented as a separate cost category, because this analysis focuses on the costs specific to using the COGNIS process. COGNIS customers will incur soil washing costs as a result of using the treatment system, but the cost is not directly associated with the operation of the COGNIS process. While numerous soil washing subcontractors exist, BESCORP was retained for the TCAAP SITE demonstration. For this analysis, subcontractor costs are based on using the BESCORP soil washing system.

A depreciation value is applied to the costs presented in this analysis because COGNIS owns the equipment. In accordance with EPA guidance, insurance and other company-specific overhead costs, except for labor wage rates, are not included in this estimate (Evans 1990). No other equipment configuration alternatives are presented in this section because the COGNIS system at TCAAP was the first available commercial unit. This analysis presents fixed and variable costs for operating the full-scale commercial COGNIS unit.

Based on observations made at TCAAP, the combined BESCORP and COGNIS system can continuously treat contaminated soil at a rate of 12 tons per hour. This analysis assumes the system operates at an average rate of 10 hours per day, 6 days per week at 90 percent efficiency. This average includes unscheduled and weather-related downtime. This results in a real treatment rate of about 11 tons per hour or 108 tons of soil per day or 648 tons per week. At this rate, treating 10,000 tons of contaminated soil through the combined BESCORP and COGNIS system would require over 15 weeks to complete. The estimated 15 weeks does not include time required for mobilization and demobilization. Further, this system can only operate during nonfreezing weather conditions. This will affect the treatment season depending on a site's geographical location (see the following section) unless the entire system is operated in an enclosed, heated building.

Equipment and operating parameter assumptions and rates include the following:

- The COGNIS personnel and soil washing subcontractor personnel are licensed to operate all heavy equipment and are trained in proper health and safety procedures

- The treatment system operates 10 hours per day, 6 days per week

- The operating efficiency is 90 percent, including unscheduled and weather-related downtime

- The real rate of treatment through the combined BESCORP and COGNIS system is 648 tons per week

- The lead removal efficiency is 75 percent, which was observed at TCAAP for the combined BESCORP and COGNIS system

- Treatment personnel work in Modified Level D PPE

- Rainwater is collected from the treatment pad, stored in a tank, and used as process water

- Air emissions monitoring is not necessary

3.1.2 Site-Specific Factors

Site-specific factors affect the costs of using the COGNIS system and can be divided into the following two categories: contaminated soil factors and site factors. Contaminated soil factors affecting costs include soil mass, contaminant types and concentrations, treatment goals, and regulatory requirements. Soil mass affects variable costs by increasing the amount of supplies, treatment, and labor (through an increase in the duration of a treatment project) needed to complete a remediation project. However, projects with larger soil masses tend to achieve economies of scale, on a cost-per-ton basis, because the relatively constant fixed costs are distributed over the larger soil quantity. The mass of soil, number of contaminants, concentration in the soil, and frequency of sampling will affect time-dependant costs and sample analysis costs. Regulatory requirements will determine cleanup target levels. Treatment costs nearly double if treated soil fails to meet treatment goals and requires a second round of processing.

Site factors affecting costs include soil particle size distribution, site area, accessibility, availability of utilities, and geographical location. Soil clay content affects the effectiveness of the soil washing system because high-clay soils tend to form dense clumps that are not easily treated. Soils with a large amount of readily cleanable, oversized material will increase total throughput for the treatment system because the soil washing subcontractor will be treating this material. Conversely, the COGNIS process will treat more material as the mass of finer soil particles increases. Site preparation costs are affected by the mass of contaminated soil, the size of the site, and the availability of utilities and access roads. Mobilization costs are affected by the distance that treatment and rented equipment must be transported from its point of origin to the site. Cold weather climates will restrict the number of months in a year during which treatment can be performed, because freezing water prevents the soil washing and treatment systems from operating.

Based on results from the SITE demonstration, the treated soil achieved the 300 mg/kg standard set by MPCA on all 4 days during the SITE demonstration. Therefore, this analysis assumes that treated soil meets MPCA enforceable remediation goals and will not require posttreatment.

Site-specific assumptions include the following:

Contaminated Soil Factors

- Treated soil is backfilled at the site
- Contaminant levels in the feed soil are 825 mg/kg; with a removal efficiency of 75 percent for the combined BESCORP and COGNIS treatment system, 618 mg/kg is recovered
- Cleanup goal is 300 mg/kg

Site Factors

- Appropriate access roads exist
- Utility lines, such as electricity and telephone lines, exist on site
- The site is located in the Midwest region of the United States, which results in a treatment season consisting of the 8 months from April 1 to November 30, inclusive
- Foreign objects are hand sorted from the soil by the soil washing subcontractor prior to treatment in the COGNIS system
- Oversized material is washed and separated by the soil washing subcontractor and this material is backfilled at the site
- Feed soil type is the same as TCAAP Site F soil

3.1.3 Base-Case Scenario

A hypothetical base-case scenario has been developed using the issues and assumptions described in this section for the purposes of formulating this economic analysis. The costs presented in text are for a 10,000-ton treatment job processed through the combined BESCORP and COGNIS system. The table at the end of this section also includes the costs for a 5,000-ton and a 50,000-ton treatment job. Excluding mobilization and demobilization, the 5,000-ton scenario will require nearly 8 weeks to complete treatment. The 50,000-ton scenario will require about 77 weeks to complete treatment, which will cover nearly three 8-month treatment seasons and will require several partial mobilization and demobilization efforts. As a result, an explanation will be provided in the text when certain costs associated with this scenario are higher than those for the 10,000-ton scenario.

Additional assumptions used for this base case scenario include the following:

- About 41.8 tons of lead concentrate will be recovered from the entire 10,000 tons of soil
- Total costs for each category are rounded to the nearest 10 dollars
- The COGNIS system will be mobilized to the remediation site from a location within 500 miles of the site
- Front-end loaders and other soil-moving equipment will be supplied and operated by the soil washing subcontractor
- In addition to routine operations, total labor costs during treatment operations include collecting samples and providing maintenance
- Insurance and overhead costs are not included in this cost estimate because they are used in a market environment to competitively price the system. Cost evaluation under the SITE Program typically presents the cost of technologies, not the market dictated price, which varies from job to job

Table 3-1. Costs Associated with the COGNIS Process[a]

Cost Categories	Mass of Soil Treated (tons)					
	5,000		10,000		50,000	
	Itemized	Total	Itemized	Total	Itemized	Total
Site preparation[b]	--	$249,800	--	$249,800	--	$249,800
Administrative	35,000	--	35,000	--	35,000	--
Treatment area preparation	184,800	--	184,800	--	184,800	--
Treatability study	30,000	--	30,000	--	30,000	--
Permitting and regulatory[b]	--	5,260	--	5,260	--	15,780
Mobilization and startup[b]	--	29,670	--	29,670	--	42,630
Transportation	5,850	--	5,850	--	12,050	--
Assembly	20,440	--	20,440	--	20,440	--
Shakedown	3,380	--	3,380	--	10,140	--
Equipment[c]	--	63,450	--	125,320	--	624,960
COGNIS treatment equipment	33,350	--	66,700	--	333,500	--
Rented treatment support equipment	29,150	--	56,670	--	281,810[d]	--
Rented auxiliary equipment	950	--	1,950	--	9,650	--
Labor[c]	--	137,450	--	274,890	--	1,376,240
Supplies[c]	--	113,910	--	227,810	--	1,139,000
Proprietary chemicals	106,250	--	212,500	--	1,062,500	--
Disposable PPE	4,840	--	9,670	--	48,350	--
55-gallon drums	1,750	--	3,500	--	17,500	--
Diesel fuel	1,070	--	2,140	--	10,700	--
Utilities[c]	--	3,750	--	7,500	--	37,500
Electricity	2,500	--	4,990	--	24,950	--
Water	1,250	--	2,510	--	12,550	--
Effluent treatment and disposal[c]	--	0	--	0	--	0
Residual waste shipping and handling[c]	--	86,440	--	194,780	--	972,600
Lead concentrate	7,740	--	15,480	--	77,400	--
Debris	75,000	--	150,000	--	750,000	--
Disposable PPE	3,700	--	29,300	--	145,200	--
Analytical services[c]	--	2,500	--	5,000	--	25,000
Equipment maintenance[c]	--	30,000	--	60,000	--	300,000
Site demobilization[b]	--	93,800	--	99,100	--	160,700
Disassembly	21,400	--	21,400	--	40,600	--
Site restoration	72,400	--	77,700	--	120,100	--
Soil washing subcontractor[e]	--	305,510	--	543,210	--	2,465,870
Mobilization	17,030	--	17,030	--	31,310	--
Equipment	60,350	--	87,870	--	313,010	--
Labor	204,820	--	409,640	--	2,050,860	--
Supplies	1,650	--	3,260	--	15,280	--
Utilities	3,750	--	7,500	--	37,500	--
Maintenance	1,560	--	1,560	--	1,560	--
Site demobilization	16,350	--	16,350	--	16,350	--
Total costs	--	$1,121,540	--	$1,822,340	--	$7,410,080
Total one-time costs[b,f]	--	$378,530	--	$383,830	--	$468,910
Total variable costs[c,f]	--	$437,500	--	$895,300	--	$4,775,300

Notes:

[a] Costs are in January 1995 dollars
[b] Fixed costs
[c] Variable costs
[d] Only a prorated cost is presented; the contractor may elect to buy the equipment for large jobs
[e] Fixed and variable costs combined
[f] Excluding soil washing subcontractor costs

3.2 Cost Categories

Table 3-1 presents a breakdown of the costs considered within each of the 13 cost categories. Costs for a soil washing subcontractor are presented in Section 3.2.13, an additional cost category for this technology. Table 3-1 presents a breakdown of costs for the base case scenario of the 10,000-ton remedial action site; costs for 5,000- and 50,000-ton scenarios are provided for comparison purposes.

Cost data associated with the COGNIS technology have been assigned to the following 13 cost categories: (1) site preparation; (2) permitting and regulatory; (3) mobilization and startup; (4) equipment; (5) labor; (6) supplies; (7) utilities; (8) effluent treatment and disposal; (9) residual waste shipping and handling; (10) analytical services; (11) equipment maintenance; (12) site demobilization; and (13) soil washing subcontractor. Each of these cost categories is discussed below.

3.2.1 Site Preparation Costs

Site preparation costs include administrative, treatment area preparation, and treatability study costs. For this analysis, administrative costs for site preparation, such as legal searches, access rights, and other site planning activities, are estimated to be $35,000 (Means 1994).

Site preparation costs may not be incurred at every site. At TCAAP, an area was prepared at Site D to house an incineration unit. This area was later made available for treating soil from Site F. However, for this analysis, it was assumed that a suitable treatment area needs to be prepared. Treatment area preparation includes erecting a security fence and constructing a bermed concrete pad on which to site the COGNIS process, the soil washing equipment, and soil staging and storage areas. The bermed concrete pad consists of the following three separate areas: an 8,000 square foot (ft^2) area for treatment equipment; a 6,000 ft^2 soil staging area for contaminated soil; and an 8,000 ft^2 storage area for treated soil. Each area will be connected to form one large area, sealed with an epoxy coating, and equipped with berms and sumps to prevent cross contamination and to define clean-area boundaries. Each area will have specific design features applicable to its function. Construction costs are estimated to be $8 per ft^2 Based on a quote from a fencing company, the fence will cost about $8,800 including all materials and labor. This analysis assumes that treatment goals will be met. As a result, the cost of restricting access to treated soil is not presented.

COGNIS conducts treatability studies in two phases. The first phase tests the feasibility of the metallurgical aspects of the process to determine if the contaminant can be adequately leached and removed under practical conditions. COGNIS charges about $10,000 for this phase of testing. The second phase tests the physical handling properties, such as settling rates and dewatering conditions, to be incurred under treatment conditions. These tests cost about $20,000. Total treatability study costs are estimated to be $30,000.

Total site preparation costs are estimated to be $249,800.

3.2.2 Permitting and Regulatory Costs

Remedial actions must be consistent with ARARs of environmental laws, ordinances, regulations, and statutes, including federal, state, and local standards and criteria. In general, ARARs must be determined on a site-specific basis.

Permitting and regulatory costs include fees for highway permits for oversized vehicles traveling no more than 500 miles. These fees are assumed to total about $5,000. Oversight costs incurred by regulatory agencies are not included in this analysis because such costs depend on the extent of oversight activities, which are negotiable between the site owner and the regulatory agencies. Furthermore, such oversights extend over several tasks and may not be based on the volume of media requiring remediation or the time required for remediation.

Permits will be needed to discharge process water to a POTW. According to Wenck, the cost for discharging the total amount of water generated at TCAAP to the POTW was about $8 per 4,000 liters of water (Wenck 1995b). The combined BESCORP and COGNIS plants contain about 1.3×10^5 liters of water. The cost for discharging this water to a POTW is $260.

Total permitting and regulatory costs are estimated to be $5,260. Costs for the 5,000-ton scenario will be the same as the 10,000-ton scenario. Costs for the 50,000-ton scenario includes fees for highway permits to be paid three times and the cost for discharging process water to the POTW three times, for a total cost of $15,780.

3.2.3 Mobilization and Startup Costs

Mobilization and startup costs include transporting the COGNIS system and rental equipment to the site, assembling the COGNIS system, and performing the initial shakedown of the treatment system. COGNIS will provide trained personnel to deliver, assemble, operate, and maintain the COGNIS system and any necessary support equipment. COGNIS personnel are assumed to be trained in proper health and safety procedures for a hazardous waste site, so training costs are not incurred as a direct startup cost.

Transportation costs are site-specific and will vary depending on the location of the site in relation to all equipment vendors, including COGNIS. COGNIS will mobilize its equipment to a customer's site. For this analysis, the COGNIS equipment is assumed to be transported 500 miles. COGNIS charges $5.50 per mile for a total cost of $2,750. Permit costs for oversized vehicles were presented in Section 3.2.2. Vendors of rented treatment system support equipment (see Section 3.2.4) add delivery charges to the equipment. According to independent vendors, delivery charges are about $1,000 for two mobile office trailers; $300 for an acid tank; and $1,800 for heavy equipment that includes one excavator, one dump truck, and two front-end loaders or backhoes. The cost for the initial supply of proprietary acid is covered in Section 3.2.6, Supply Costs. Total transportation costs will be about $5,850.

Assembly costs include the costs of unloading equipment from the trailers, assembling the COGNIS system, and hooking up water and electricity. The four-person crew that operates the system will work two 10-hour days unloading and assembling the system. Total labor costs, including overtime, will be about $11,440 (see Section 3.2.5 for labor rates). A crane must be rented for 4 days. Vendors typically charge about $130 per hour or about $1,000 per day. Therefore, the total cost of renting the crane for 4 days is $4,000. After assembly, equipment must be hooked up to water and electrical utilities, which is estimated to cost about $5,000. Total assembly costs are estimated to be $20,440. Some of the assembly costs such as crane rental and connecting utilities are shared between COGNIS and BESCORP. There are several other activities where costs are to be shared by COGNIS and the soil washing subcontractor. However, due to the low cost of such activities, there is minimal impact on COGNIS' or BESCORP's cost for each ton of soil treated. Therefore, all such costs are assigned to the prime contractor, COGNIS.

Initial shakedown costs include filling the system with water to check for leaks and verifying that the electrical and air-powered equipment is working. The four-person crew that operates the system will work two 10-hour days to provide initial startup activities. Total shakedown costs, including overtime, will be about $3,380.

For the 50,000-ton scenario, rented auxiliary equipment will need to be delivered to the site at three different times. In addition, equipment will need to go through initial shakedown activities three separate times. As a result, these partial mobilization and startup activities costs are incurred three times. Depending on site location and soil conditions, the contractor may elect to operate the COGNIS system 24 hours per day on a regular operating day, without seasonal downtime. This analysis uses a prorated cost based on activities observed during site remediation at TCAAP, where seasonal downtime was encountered and the system was operated for 10 hours per day, 6 days a week.

Total mobilization and startup costs for treating 10,000 tons of soil are estimated to be $33,670.

3.2.4 Equipment Costs

Equipment costs include the COGNIS treatment system, rented support equipment, and rented auxiliary equipment.

COGNIS will provide the complete COGNIS treatment system to its clients as part of the overall on-site soil treatment service. The equipment is not leased to clients on a time-based rate, but rather as a lump sum included in the price of providing the treatment service. That price is determined by the size of the soil remediation job and is not based on time, and therefore will be calculated by COGNIS on a site-by-site basis. COGNIS estimates the capital equipment depreciation for this base case analysis costs about $66,700.

Rented treatment system support equipment includes an air compressor, centrifuge, acid tank, two 8-foot by 20-foot mobile trailer offices, and heavy equipment. Rental equipment vendors provided the following costs: $1,500 per month for an air compressor; $12,000 per month for a centrifuge; and $745 per month for an acid tank. Mobile office trailers cost about $640 per month to rent. At a minimum, heavy equipment will include one 1.5-cubic-yard hydraulic backhoe excavator; one 12-cubic-yard dump truck; and two 1-cubic-yard capacity, hydraulic front-end loaders or backhoes to be used for soil excavating, transporting, and regrading activities, respectively. Based on Means estimates and equipment vendor quotes, this heavy equipment can be rented for a total cost of about $12,000 per month. The equipment is necessary for the duration of the remediation and for an additional 5 weeks to cover earth-moving activities during mobilization and demobilization. To treat 10,000 tons of soil, costs for rental support equipment are estimated to be $113,350. Rented treatment system support equipment costs are to be shared by COGNIS and the soil washing subcontractor. Therefore, COGNIS' share of this cost is $56,670. In the 50,000-ton case, where treatment covers several seasons, the contractor may elect to operate the COGNIS system in a different manner to reduce costs. One option would be to buy the equipment. Only a prorated cost was used in this analysis.

Rented auxiliary equipment includes a steam cleaner and a portable toilet. The steam cleaner will be used to decontaminate equipment and to keep the work areas clean. A steam cleaner can be rented for $300 per month. A portable toilet can be rented for $200 per month and will also be needed during mobilization and demobilization activities. Total rental auxiliary equipment costs are estimated to be $1,950. This cost is also expected to be shared between COGNIS and the soil washing subcontractor. In the 50,000-ton case, where treatment covers several seasons, purchasing the auxiliary equipment would be more cost effective, but this analysis does not consider this option.

Total equipment costs for treating 10,000 tons of soil are estimated to be $125,320. Equipment costs for the 5,000-ton and 50,000-ton scenarios are amortized costs based on the amount of soil treated.

3.2.5 Labor Costs

Labor costs include the operating staff needed to operate and maintain the COGNIS system, and site managerial staff. Wage rates in this analysis include overhead and fringe benefits. Operating staff includes one plant manager (at $45 per hour), one foreman (at $35 per hour), and two technicians (at $25 per hour). Managerial staff includes one project manager (at $55 per hour), one health and safety officer (at $45 per hour), and one administrator (at $25 per hour). Labor costs required for site preparation, mobilization, and demobilization are discussed under Sections 3.2.1 and 3.2.3. Excavating and soil hauling is provided by the soil washing subcontractor.

For this analysis, the total treatment time needed to treat 10,000 tons of soil will be over 15 weeks. To accomplish this, the COGNIS system will be operated 10 hours per day, 6 days per week. Wage rates increase to time-and-one-half for every weekly hour over 40 hours. Labor costs to treat 10,000 tons of soil are estimated to be $140,140 for operating staff and $134,750 for managerial staff. No lodging or per diem costs are included in this analysis because it is negotiable and may not always be charged to a customer.

Total labor costs for treating 10,000 tons of soil are estimated to be $274,890.

3.2.6 Supply Costs

Supplies include proprietary leachants that are mixed at the treatment site, disposable PPE, 55-gallon steel drums, and diesel fuel. The quantities of all supplies will depend on the amount of soil treated, the oversized material-to-soil ratio, the lead concentration in feedstock soil, and the duration of the treatment activities.

According to COGNIS, the types and quantities of proprietary acid and leachant will vary in cost depending on site-specific treatment goals. Based on the contaminated soil and treatment goals for the TCAAP project, COGNIS estimates the cost of these proprietary agents will be about $21.25 per ton of soil treated. For this analysis, total proprietary agent costs will be about $212,500.

The four-person operating staff will operate the COGNIS system wearing modified Level D disposable and nondisposable PPE. Other personnel will wear PPE when entering the treatment area. Disposable PPE includes gloves, booties, and disposable coveralls. The operating staff will change disposable PPE about four times per day at a cost of about $6.50 per change or $104 per day. The total time required to treat 10,000 tons of soil will be 93 days. Total disposable PPE costs will be $9,670.

Steel 200-liter (55-gallon) drums are needed to store recovered lead prior to off-site smelting and to dispose of used PPE. The rate of lead concentrate production is dependent on the rate of lead recovery, which can vary within a site. Thus, the number of 55-gallon drums needed will be highly site-specific and will be difficult to determine in advance. Lead concentrates consist of those recovered through the density separation process and the cell lead concentrates. A total of 2,695 kg of lead concentrate was collected during the demonstration. Based on observations made during the demonstration, one 55-gallon drum can hold approximately 300 kg of lead concentrate. Thus, about nine 55-gallon drums will be filled with lead concentrate during every 6-day week. This estimate compares well with the amount of lead concentrate recovered during the entire remediation, when about 15 drums of lead concentrates were recovered per 6-day week.

About one 55-gallon steel drum per day will be required to dispose of used PPE. The 55-gallon steel drums cost about $15 each. To treat 10,000 tons of soil, a total of 93 55-gallon drums will be needed to dispose of PPE and a total of 14 drums will be needed for disposal of lead concentrate. Total drum costs for this analysis are estimated to be $3,500.

Diesel fuel is used to operate all earth moving equipment and the air compressor. Fuel costs are site-specific and will vary depending on the market price of diesel fuel and the extent of equipment usage at the site. Diesel fuel is estimated to be consumed at a rate of 460 liters per week. Diesel fuel costs about $0.30 per liter for a total cost of about $2,140. Costs for drums and diesel fuel are expected to be shared between COGNIS and the soil washing subcontractor.

Total supply costs are estimated to be $227,810.

3.2.7 Utility Costs

Utilities used by the COGNIS system include electricity and water. This analysis assumes that electrical power lines and water lines will be available at the site. Electrical and water costs can vary extensively depending on the geographical location and local utility rates. This analysis assumes that the rate of electricity and water consumption is constant and based on the amount of soil treated. The costs presented in this section are for the COGNIS system without soil washing. The soil washing utilities costs are presented in Section 3.2.13.

Electricity is used to operate the COGNIS system, the soil washing equipment, the mobile office trailers, and the centrifuge; however, most of the electric power is consumed by the treatment equipment. COGNIS considers the exact electrical requirements of its components to be confidential information. COGNIS provided an estimate that at TCAAP, the combined power requirement for the COGNIS system and soil washing equipment is 121 kilowatts (kW) (i.e., 275 amps at 440 volts)

The actual electric energy usage by the COGNIS system and the soil washing subcontractor at TCAAP between August and September, 1994, averaged 21,280 kW-hr per month (Federal Cartridge Company 1994). Assuming 240 hours of operation per month, the average electrical power requirement is about 90 kW. This analysis takes the higher of the two estimates (i.e., 121 kW from COGNIS instead of 90 kW based on the cited meter readings) and assumes the COGNIS system uses about one-half of this electrical power, which is 60 kW, which is drawn for 60 hours per week for a total of 15.4 weeks. Based on an average cost of power in the midwestern region of the United States,

Costs Per Ton Summary

Activity	5,000 Tons	10,000 Tons	50,000 Tons
Leaching activities only (includes equipment, labor, supplies, and utilities)	$70	$70	$70
Leaching and soil washing	$157	$138	$124
All activities, including leaching, soil washing, site preparation, and residual handling[a]	$224	$182	$148

Note:

[a] Profit and insurance are not addressed

power is assumed to cost $0.09 per kWh including demand and usage charges. Total electricity costs, excluding soil washing activities, to treat 10,000 tons of soil are estimated to be about $4,990.

Water is used for both the COGNIS system and for soil washing activities. During the demonstration, the water meter recorded a total of 53,000 liters of water during 3 days, in which about 324 tons of soil was treated. This would result in a project water consumption rate of about 160 liters of water per ton of soil for the combined BESCORP and COGNIS processes. This usage includes plant process water as well as dust control at the excavation site. Water usage can also be estimated from an increase in moisture content in treated soil to that in the feed soil. Average moisture content of the feed soil was 6 percent. Average moisture content of the treated soil, combining moisture contents of treated sands and fines in a 2 to 1 ratio, was 29 percent. Therefore, a net increase of 23 percent in moisture content in the treated soil was realized. The treated soil with increased moisture content does not include the oversized material. Therefore, assuming that the feed soil is composed of 17 percent oversized material, 10,000 tons of soil results in 8,300 tons of treated soil with about 1.9 million liters of water, and a water consumption rate of 190 liters per ton. The water consumption rates estimated by the two procedures are comparable. For this analysis, the more conservative rate of 190 liters per ton of soil was selected. It was also assumed that BESCORP and COGNIS use equal amounts of water. Therefore, a water consumption rate of 95 liters per ton of soil was assumed for both COGNIS and BESCORP. Water costs are assumed to be $0.01 per gallon. Total water costs, excluding soil washing activities, to treat 10,000 tons of soil are estimated to be $2,510.

Rainwater will be collected from the treatment area, stored in tanks, and used for process water. At TCAAP, about 15,000 liters of rainwater was used for process water during the demonstration. This constitutes about 40 liters of water per ton of soil treated. This would indicate that the combined BESCORP and COGNIS processes used 160 liters per ton (based on water meter readings) plus the 40 liters per ton of rainwater for a total of 200 liters per ton. Because this value is comparable to the 190 liters per ton value and the use of rainwater can vary widely, this analysis considers 190 liters of water used per ton of soil.

Total utility costs are estimated to be $7,500.

3.2.8 Effluent Treatment and Disposal Costs

The COGNIS system at TCAAP did not produce effluent during the SITE demonstration requiring further treatment or disposal. Rainwater from the treatment area was collected in sumps and stored in a tank and used as process water. Hence, it is not treated separately or discharged frequently. It will be discharged only upon completion of treatment or, in case of large soil treatment projects, during seasonal shutdown. Discharge may also be necessary after extraordinarily large precipitation events when the amount of rain water collected is greater than storage capacity and process water requirements. Process wastewater is neutralized, treated, and discharged to a POTW at the season's end or at the completion of treatment. At TCAAP, this cost was included in the cost of obtaining the discharge permit. Continuous monitoring of perimeter dust at TCAAP did not identify potentially harmful air emissions.

As a result, no cost will be incurred for effluent treatment and disposal.

3.2.9 Residual Waste Shipping and Handling Costs

The residuals produced by using the combined BESCORP and COGNIS system to perform lead extraction include metal concentrate, sorted debris, and drummed disposable PPE. The total amount of residuals generated depends on the amount of debris (such as ordnance, wood, twigs, and metal fragments) in the soil and whether posttreatment of soils will be needed. The actual amount of metals concentrate generated will depend on the concentration of the contaminant in the soil. The total costs for disposing of metals concentrate will depend on whether a recycling market exists, and if so, recycling may partially off set total disposal costs.

This analysis assumes lead concentrate will be generated from the combined soil washing and leaching system as the only metals residual. Disposal of lead waste from TCAAP incurred a processing fee and received a metals credit. The value of the metals credit is based on the lead content of the waste and the current market price for lead. At TCAAP, a lead smelter processed the lead concentrate for metal recovery. The smelter operates an EPA-certified laboratory to test incoming materials for lead content.

Disposal costs are $400 per ton for processing and a metals credit of 80 percent of the current metals market price for lead. Wastes delivered in drums incur an additional $15 fee per drum (Gopher Smelting 1995). Based on disposal of 41.8 tons of lead concentrate in 140 55-gallon drums, net lead concentrate disposal costs, inclusive of lead content credits, are about $300 per ton plus a $15 drum disposal fee. Total disposal costs for lead concentrate for this analysis are estimated to be $15,480.

At many sites where lead contamination is present, debris such as battery casings, ordnance, and other oversized material will need to be sorted from the soil before soil washing and lead extraction. The amount of debris generated and disposal costs will be highly site-specific. Based on observations made during the demonstration, this analysis defines debris as the ordnance, oversized wood, and metal fragments sorted from the feedstock soil after excavation and assumes the soil washing subcontractor will hand sort the debris prior to washing. At TCAAP, about 50 kg of debris was generated for every ton of soil treated. While oversized wood and metal fragments could probably be classified as nonhazardous materials and disposed of in a solid waste landfill, ordnance will require special handling. For this analysis, it was assumed that debris will require disposal in a RCRA Subtitle D landfill. For this analysis, disposal costs will be about $300 per ton, including transportation, which is the average cost of disposing of RCRA hazardous waste in a Subtitle D landfill. Therefore, about 500 tons of debris will be disposed of for a total cost of $150,000.

Drummed disposable PPE is assumed to fill a total of 93 drums. These drums will require off-site disposal at a licensed hazardous waste landfill. This analysis assumes the drums will be transported off site in two separate loads. Transportation costs are estimated to be $700 per trip, and disposal costs will be about $300 per 55-gallon drum. Total disposal costs for drummed PPE are estimated to be $29,300.

Total residual waste shipping and handling costs are estimated to be $194,780.

3.2.10 Analytical Services Costs

Samples are collected to determine if clean-up levels are being achieved. If clean-up levels are not met, the results are useful for optimizing the leaching system. Sampling frequency and quantity are highly site specific and are based on treatment goals, contaminant concentrations, and regulatory agency requirements. Analyses will typically be performed for the metals of concern at a site. This analysis assumes that one sample will be collected for every 50 tons of soil treated and will be analyzed for one metal of concern, which is lead. Costs for analyzing lead following SW 846 Methods 3020 and 6010 (EPA 1991a) are about $25 per metal per sample (General Testing Corporation 1993). This analysis does not include costs for TCLP analyses or an on-site laboratory because these elements will vary from site to site.

Total analytical costs are estimated to be $5,000.

3.2.11 Equipment Maintenance Costs

Maintenance labor has been included in labor costs (see Section 3.2.5). COGNIS estimates that maintenance material costs will be about $6 per ton of soil treated. COGNIS incurs costs for design adjustments, facility modifications, and equipment replacements, because COGNIS is responsible for remediating faulty design problems.

Total maintenance costs of equipment used to treat 10,000 tons of soil are estimated to be $60,000.

3.2.12 Site Demobilization Costs

Site demobilization includes treatment system disassembly and site restoration activities. Disassembly includes shutdown, decontamination, rental equipment return, and utilities disconnection. According to COGNIS, the four-person crew that operates the system will work ten 10-hour days to decontaminate, disassemble and load the system. Total labor costs, including overtime, will be about $14,300 (see Section 3.2.5 for a breakdown of labor costs). A crane must be rented for 4 days at about $1,000 per day for a total cost of $4,000. All rented treatment system support equipment will be returned for a total cost of $3,100. Total disassembly costs are estimated to be $21,400.

Site restoration activities include demolishing constructed pads, placing topsoil over treated areas, and reseeding backfilled and bare spots. Demolition of the concrete pad will be about $3.05 per square foot for a total cost of $67,100 (Means 1994). About 205 tons of soil will be needed to cover an area measuring 50 feet by 50 feet with

6 inches of soil. The cost of topsoil and grading is about $35 per ton (Means 1994). Reseeding will cost about $39.25 per 1,000 square feet including mulch and fertilizer to cover an estimated 2-acre area (Means 1994). Total site restoration costs are $77,700.

For the 50,000-ton scenario, rented support equipment will need to be returned three separate times in order to avoid rental costs for the nontreatment months. In addition, multiple shutdowns will occur: two partial shutdowns in addition to the one complete system shutdown. Labor for the partial shutdowns is assumed to require the four-person operating staff to work five 10-hour days. As a result, these portions of site demobilization costs will be higher in this case.

Total site demobilization costs are estimated to be $99,100.

Soil Washing Subcontractor Costs

This section presents the costs of subcontracting a soil washing service. This section is typically not presented in the economic analysis section of an ITER because it is not a specific cost category. It is also specific to the COGNIS process in that a soil washing service is required prior to treating soil in the COGNIS system. A soil washing service is required before leaching to remove oversized material (<6.35 mm) and to separate sands and fines from each other. Soil washing costs are provided in this section in order to focus the analysis of the preceding 12 sections solely on the COGNIS system. As such, this estimate is brief and its primary purpose is to illustrate the types of costs that may be incurred.

The following subsections present only the cost categories that are expressly incurred as a result of using a soil washing service to augment the lead extraction service. For example, no site preparation costs will be incurred because it is assumed that the site will be prepared to support lead extraction activities, which are accounted for in Section 3.2.1. At some sites, the soil washing contractor may be the primary contract and will be responsible for activities that are common to both soil washing and leaching. Incremental costs of adding an acid leaching unit to soil washing are listed in Table 3-1.

Actual costs of procuring a soil washing service will vary depending on several economic conditions, including local competition levels, local wage rates, and subcontractor comparative advantages. This soil washing cost analysis uses all base-case scenario assumptions and additional assumptions when necessary. BESCORP served as the soil washing subcontractor for the TCAAP project. Much of the cost data provided in this analysis is based on using a BESCORP commercial-scale unit because they are published cost figures (EPA 1994a). Total costs are presented for treating 10,000 tons of soil. This analysis assumes that soil washing will maintain the same rate of soil throughput as the COGNIS system, which is 108 tons of soil per day.

For this analysis, total subcontractor costs for soil washing are estimated to be $486,540 which are detailed in the sections below.

Soil Washing Mobilization and Startup Costs

Subcontractor mobilization and startup costs will include transporting soil washing equipment to the site and the labor for assembling the equipment and for conducting initial shakedown activities.

The soil washing equipment is assumed to be transported 500 miles at $5.50 per mile for a total cost of $2,750. Assembly and shakedown requires a 10-person crew that operates the equipment, working seven 6-hour days for a total cost of $14,280 (EPA 1994a). For the 50,000-ton scenario, shakedown activities will occur two additional times but are estimated to be completed in one-half the amount of time previously required.

Total costs for mobilization of soil washing equipment are estimated to be $17,030.

Soil Washing Equipment Costs

The soil washing treatment system must be modified for site-specific conditions on a case-by-case basis. The soil must first be characterized and other factors, including contaminant type and level and cleanup criteria, must be considered when designing the system. The costs of these activities are presented in Section 3.2.1. The BESCORP commercial-scale unit appropriate for the base-case scenario is estimated to use a depreciation value of about $31,200 (EPA 1994a). This equipment is assumed to operate at a rate that meets the COGNIS system feed rate. The soil washing subcontractor is assumed to operate heavy equipment. The rental cost of this equipment is $56,670 for a total equipment cost of $87,870.

Soil Washing Labor Costs

Labor costs include the site managerial staff and the operating staff needed to operate and maintain the soil washing equipment and the heavy equipment. Wage rates in this analysis include overhead and fringe benefits. Operating staff includes one excavation site presorter with ordnance experience (at $40 per hour), two post-washing sorters (at $35 per hour), one post-washing sorter with ordnance experience (at $40 per hour), three system operators, including laboratory personnel (at $35 per hour), and two equipment operators (at $35 per hour). Managerial staff includes one project manager (at $55 per hour). Manual sorting activities are assumed to be incurred at lead-contaminated sites. The soil at lead-contaminated sites is typically mixed with debris, such as battery cases and bullets, that must be removed from the soil before washing. Because the TCAAP project is located on a military base and ordnance was being hand sorted, two of the sorting personnel had ordnance experience and were not BESCORP personnel. As a result, labor costs presented in this analysis may be higher than at other sites requiring fewer hand sorters. All staff are assumed to work the same hours as COGNIS personnel.

Total labor costs for soil washing, including overtime hours, are estimated to be $409,640.

Soil Washing Supplies Costs

Supplies required by the soil washing subcontractor include proprietary chemicals. Proprietary chemicals for soil washing will vary among subcontractors. Proprietary chemical usage observed during the SITE demonstration constituted about one 55-gallon drum of chemicals during every day. The cost of these chemicals will be about $35 per 55-gallon drum.

Total costs for soil washing supplies are estimated to be $3,260.

Soil Washing Utilities Costs

Soil washing activities use electricity and water. This analysis assumes the COGNIS system and the BESCORP equipment used the same amount of electricity and water. Based on observed electricity usage at the SITE demonstration, the BESCORP system is assumed to draw 60 kW. Power is estimated to cost $0.09 per kWh including demand and usage charges. Based on water usage at the SITE demonstration, total water usage is assumed to be 95 liters per ton of soil treated. Water is estimated to cost $0.01 per gallon.

Total utility costs will be $4,990 for electricity and $2,510 for water.

Soil Washing Equipment Maintenance Costs

Equipment maintenance costs are estimated to be 5 percent of the capital equipment. Although this cost is expected to vary over time, the variations are expected to be insignificant.

For this analysis, total equipment maintenance costs are estimated to be $1,560.

Soil Washing Site Demobilization Costs

Site demobilization includes equipment shutdown, disassembly, decontamination, and return transportation of 500 miles. This analysis assumes the 10-person operating staff that assembled the system will perform site demobilization, which is assumed to require five 8-hour days to complete. All soil washing equipment is assumed to remain on site during the seasonal downtime incurred in the 50,000-ton scenario.

Total demobilization costs are estimated to be $16,350.

3.3 Conclusions of the Economic Analysis

This analysis presents cost estimates for treating lead-contaminated soil using the COGNIS lead extraction treatment system. The base-case scenario used for this analysis includes treating 10,000 tons of soil containing 825 mg/kg lead to a residual concentration of 206 mg/kg. No pretreatment other than soil washing, hand sorting of foreign objects, and removing oversized material is required. Soil washing costs are presented individually in order to focus on the direct costs associated with using the COGNIS process.

For the base-case scenario, total costs including soil washing are estimated to be $1.8 million. Excluding soil washing activities, total costs are estimated to be $1.3 million. Total fixed costs for leaching are $383,830. Of this amount, $249,800 or 65 percent is for site preparation costs. Estimated total variable costs for leaching are $895,300. Of this amount, labor, supplies, and residual waste disposal costs account for about 31, 25, and 22 percent, respectively.

Total costs per ton of soil treated, presented in the following table have been divided into three categories: (1) leaching activities only, (2) leaching and soil washing activities only, and (3) all costs considered in this analysis. The estimated cost per ton of soil treated is $70. Costs for leaching and soil washing activities only is estimated to be $138. The cost per ton of soil treated for all activities of this analysis is estimated to be $182.

Wenck reported costs monitored during the 11 months of remediation (Wenck 1995a). Wenck divided costs into three primary categories: pretreatment, treatment, and posttreatment. Pretreatment and posttreatment activities, which include site preparation, soil excavation, oversight, sampling and analyses, and waste handling and disposal, were primarily conducted by Wenck. The price of soil treated by BESCORP and COGNIS was reported at $179 per ton of soil treated (COGNIS 1996).

This analysis of a base-case scenario using the COGNIS process shows that large jobs that require more than one treatment season to complete will incur additional costs due to the need to mobilize, start up, and demobilize certain equipment more than one time. Table 3-1 shows the estimated costs of treating 50,000 tons of soil. Based on the assumptions used in the base-case scenario, remediation of 50,000 tons of soil would require two entire 8-month treatment seasons plus 3 additional months. Despite higher fixed costs, the following economies of scale are realized: the estimated cost per ton of treated soil is $148 per ton and $124 per ton, excluding site preparation and residual handling.

Section 4
Treatment Effectiveness

This section documents the methodology, discusses the physical and chemical analytical results, and draws conclusions for evaluating the effectiveness of the COGNIS process in removing lead from soils. Treatment effectiveness for the SITE demonstration did not consider removal of other metals of concern. All sampling and analyses were conducted in accordance with the EPA-approved quality assurance project plan (QAPP) developed for this project. All sample analyses met the quality control acceptance criteria listed in the QAPP.

4.1 Methodology

Samples were collected from several locations in the treatment process. These include the material in the feed hopper, the washed oversized material exiting the trommel, the washed (untreated) sands and fines entering the COGNIS process, the treated sands and fines exiting the COGNIS process, and the lead concentrate exiting the density separator and the electrochemical cells. Throughout this report, the term "untreated" sands and fines are used to define sands and fines treated through BESCORP's washing process and entering COGNIS's leaching process. Feed soil samples were screened with a 6.35-mm-diameter sieve; the portions remaining in the sieve were designated as untreated oversized material. During the demonstration, it was observed that the oversized material is composed of rocks and clay balls. Some of these clay balls did not break down in the trommel. Clay balls were hand sorted from the treated and untreated oversized material and samples were collected. Table 4-1 presents sampling locations and frequencies. Sample locations are also shown in Figure 1-1.

During the demonstration, feed soil samples were collected once during each hour from a point immediately before soil enters the soil feed conveyor. This soil was hand screened through a 6.35-mm-diameter screen. Once during every 2 to 3 hours, screened samples were composited so that three composite samples were collected each day to be analyzed for lead. Hourly samples were composited to create one sample per day that was analyzed for other metals, TCLP metals, percent moisture, particle size distribution (PSD), load bearing capacity, cation exchange capacity (CEC), and pH. In addition, on the third day, a sample was collected for bioassay tests to evaluate the toxicity of treated and untreated soil. All compositing was conducted following the procedure described in ASTM Method C 702-75 (ASTM 1994).

Samples of the treated and untreated sands and fines were collected once during every hour to be analyzed for lead. Hourly samples were composited into one daily sample to be analyzed for other metals, TCLP metals, PSD, percent moisture, CEC, pH, and alkalinity. One sample per day was collected for determining load bearing capacity by combining four parts treated sands with one part treated fines. In addition, on the fourth day, a sample of the mixed sands and fines was also collected for bioassays. It should be noted that TCAAP and MPCA believed that treated soil generated during the entire remediation effort would be composed of four parts sand and one part fines. TCAAP and MPCA determined if remediation goals were attained by analyzing a mixture of four parts of treated sands to one part of treated fines and comparing the contaminant levels in the mixture with the remediation goals.

Oversized material samples were collected hourly and were composited to collect one sample per day to be analyzed for TCLP metals. Samples of clay balls were also collected to be analyzed for TCLP metals and total lead content. One sample per day was collected from the coarse sands and the density separated lead concentrates for lead analysis. Samples of lead concentrates were collected once at the conclusion of the demonstration. Liquid samples from the leaching circuits were collected once per day to be analyzed for lead.

Table 4-1. Outline of Sample Collection and Field Measurement Program

	Sample and Location	Parameter	Sampling Method	Sample Matrix	No. of Samples	Blanks[a]	Matrix Spikes[b]	Matrix Spike Duplicates[b]	Total Samples
1.	Feed soil (A)	Lead[c]	C	S	12	1[d]	2	2	17
		Metals	C	S	4	1[d]	1	1	7
		TCLP[c]	C	S	4	NA	NA	NA	4
		PSD	C	S	4	NA	NA	NA	4
		% Moisture	C	S	12	NA	NA	NA	12
		Load bearing capacity	C	S	3	NA	NA	NA	3
		Alkalinity	C	S	4	NA	NA	NA	4
		CEC	C	S	4	NA	NA	NA	4
		pH	C	S	4	NA	NA	NA	4
		Bioassay[g]	C	S	1	NA	NA	NA	1
		Mass[e]	G	S	NA	NA	NA	NA	NA
2.	Untreated oversize soil (B1)	TCLP[c]	C	S	4	NA	NA	NA	4
3.	Treated oversize soil (B2)	TCLP[c]	C	S	4	NA	NA	NA	4
4.	Untreated clay ball (B1L)	Lead[c]	C	S	4	NA	NA	NA	4
		TCLP[c]	C	S	4	NA	NA	NA	4
5.	Treated clay ball (B2L)	Lead[c]	C	S	4	NA	NA	NA	4
		TCLP[c]	C	S	4	NA	NA	NA	4
6.	Treated sands[f] (C)	Lead[c]	C	S	34	4[d]	4	4	46
		Metals	C	S	4	1[d]	1	1	7
		TCLP[c]	C	S	4	NA	NA	NA	4
		PSD	C	S	4	NA	NA	NA	4
		% Moisture	C	S	34	NA	NA	NA	34
		CEC	C	S	4	NA	NA	NA	4
		pH	C	S	4	NA	NA	NA	4
		Alkalinity	C	S	4	NA	NA	NA	4
		Bioassay[g]	C	S	1	NA	NA	NA	1
		Load bearing capacity[g]	C	S	3	NA	NA	NA	3

Table 4-1. Outline of Sample Collection and Field Measurement Program (continued)

Sample and Location	Parameter	Sampling Method	Sample Matrix	No. of Samples	Blanks[a]	Matrix Spikes[b]	Matrix Spike Duplicates[b]	Total Samples
7. Treated fines[d] (D)	Lead[c]	C	S	35	4[d]	4	4	47
	Metals	C	S	4	1[d]	1	1	7
	TCLP[c]	C	S	4	NA	NA	NA	4
	PSD	C	S	4	NA	NA	NA	4
	% Moisture	C	S	35	NA	NA	NA	35
	CEC	C	S	4	NA	NA	NA	4
	pH	C	S	4	NA	NA	NA	4
	Alkalinity	C	S	4	NA	NA	NA	4
	Bioassay[g]	C	S	1	NA	NA	NA	1
	Load bearing capacity[g]	C	S	3	NA	NA	NA	3
8. Density separated lead concentrate[f] (F1-F5)	Lead[c]	C	S	15	NA	NA	NA	15
	Mass	C	S	15	NA	NA	NA	15
9. Cell lead concentrate (G1-G3)	Lead[c]	C	S	3	NA	NA	NA	3
	Mass	C	S	1	NA	NA	NA	1
10. Sands before leaching[f] (KT)	Lead[c]	C	S	33	4	4	4	45
	Metals	C	S	4	1	1	1	7
	PSD	C	S	4	NA	NA	NA	4
	% Moisture	C	S	33	NA	NA	NA	33
	CEC	C	S	4	NA	NA	NA	4
	pH	C	S	4	NA	NA	NA	4
	Alkalinity	C	S	4	NA	NA	NA	4
11. Fines before leaching (P)	Lead[c]	C	S	33	4	4	4	45
	Metals	C	S	4	1	1	1	7
	TCLP[c]	C	S	4	NA	NA	NA	4
	PSD	C	S	4	NA	NA	NA	4
	% Moisture	C	S	33	NA	NA	NA	33
	CEC	C	S	4	NA	NA	NA	4
	pH	C	S	4	NA	NA	NA	4
	Alkalinity	C	S	4	NA	NA	NA	4

Table 4-1. Outline of Sample Collection and Field Measurement Program (continued)

Sample and Location	Parameter	Sampling Method	Sample Matrix	No. of Samples	Blanks[a]	Matrix Spikes[b]	Matrix Spike Duplicates[b]	Total Samples
12. Pregnant sands leachant (L)	Lead[c]	G	L	16	2	2	2	22
13. Regenerated leachant from dewatering (N1-N6)	Lead[c]	G	L	46	4	4	4	58
	Metals	G	L	46	2	NA	NA	48
	pH	G	L	46	NA	NA	NA	46
14. Pregnant fines leachant (R1, R2)	Lead[c]	G	L	17	1	1	1	20
15. Leachant (X)	Mass	TI	S	4	NA	NA	NA	4
16. Water (Y)	Volume	TI	L	1	NA	NA	NA	1
17. Neutralizer (Z)	Mass	TI	S	4	NA	NA	NA	4
18. Flocculent (YY)	Mass	TI	S	4	NA	NA	NA	4

Notes:

NA = Not applicable
C = Composite sample
TI = Time integrated sample
G = Grab sample
S = Solid sample
L = Liquid sample

[a] One solid stream equipment rinsate blank was generated from the sampling equipment after final decontamination (after each run).
[b] Field duplicates, field blanks, and matrix spikes/matrix spike duplicates (MS/MSD) were analyzed for 5 percent of the total number of samples per matrix type. The quality control analyses concentrated on the primary sampling points.
[c] Critical parameters; TCLP tests were conducted for lead, chromium, and mercury.
[d] Eight rinsate blanks for all parameters; the SITE team analyzed only those blanks necessary to give a blank to sample frequency of 5 percent.
[e] COGNIS monitored the mass of the feed soil by using a scale on the conveyor belt.
[f] An additional four composite samples, one during each day, were collected from these media for grinding, screening, and lead analysis.
[g] These tests were conducted by compositing treated sands and treated fines.

The feed soil, untreated and treated sands, and density separated lead at this site all contained lead shards. Concerns arose regarding homogeneity of these samples. Laboratory analysts typically collect a 1- to 2-gram sample from the sample container to be analyzed for metals. Lead shards present in these containers can weigh more than 2 grams. Therefore, potential bias may be introduced when collecting and analyzing samples. It was determined that grinding all of the soils in the sample container from these sample streams before analysis would be the most appropriate method for obtaining representative samples. A Retsch/Brinkmann centrifugal grinding mill, Model ZM-1, with a carbide-coated rotor, cyclone collection chamber, and carbide-coated ring sieve, was used. Approximately 1 kg of dry weight sample was ground for 2 minutes. Between samples, all parts of the grinder that had come in contact with the sample were washed with soap and water, rinsed with hot water, and then rinsed with methanol. About 500 grams of laboratory grade Ottawa sand was ground and analyzed after every 10 samples.

An experiment was conducted to determine if a representative sample could be collected from ground material. Sand samples were spiked with lead balls and ground to pass through a sieve with 425 μm mesh. Ten replicate samples of the ground material were collected and analyzed for lead. The results indicated that the grinding procedure produces a well mixed sample. The recovery ranged from 84 to 93 percent and met the MSD analysis acceptance criterion of 25 percent relative percent difference (RPD) established for this project in the QAPP.

4.2 Physical and Chemical Analyses

Physical and chemical parameters that determine characteristics of the soil that may affect treatment were monitored for this project. These parameters were also monitored to determine if significant changes occur in soil characteristics due to treatment. The physical and chemical parameters that were monitored include PSD, percent moisture, CEC, pH, alkalinity, load bearing capacity, and mass.

PSD data for the feed soil, treated and untreated sands, and treated and untreated fines are presented in Table 4-2. According to COGNIS, treatability data shows that fines are defined as particles smaller than 106 μm in diameter. For this project, particles larger than 6.35 mm in diameter were defined as oversized material. Sands are defined as particles that are smaller than the oversized material yet are larger than the fines. PSD data available from the laboratory were used to determine percent sands, fines, and oversized material.

The PSD data showed that, over the 4-day demonstration, the average composition of the feed soil was 17 percent oversized material, 54 percent sand, and 28 percent fines. These data show that the sands to fines ratio for the soil tested during the demonstration is about 2 to 1. Although lead concentrates obtained through the density separation process were removed from the treated sand stream, the weight of this material is insignificant when compared to the weight of the treated sand. Therefore, it is likely that the treated soil is also composed of a sands to fines ratio of almost 2 to 1.

The untreated and treated sands fractions were similar in PSD composition with average PSD distributions of 90.5 and 93.5 percent sand content, respectively. The average PSD distribution for the untreated fines was 80 percent fines and 20 percent sands, which is different from that found in the treated fines. The treated fines stream is composed of 68 percent fines and 32 percent sands. The increase in sand sized particles in the treated fines samples may be due to the addition of flocculents in the fourth mixer-clarifier found in the fines leaching process. The flocculents result in the formation of agglomerates. Large amounts of sands were not expected in the fines fractions. The terms sands and fines for this project were defined based on project definition of sands composed of particles larger than 106 μm in diameter.

Moisture content was monitored in the feed soil, treated and untreated sands, and treated and untreated fines samples. Moisture content in the feed soil ranged from 3.9 to 13.4 percent, with an average of 6 percent. Moisture content in the untreated samples was generally about 50 percent, indicating that at this stage the soils were carrying excess water from the washing process. Average moisture content in the treated sands and fines was 23.2 and 41 percent, respectively. Combining two parts sands to one part fines in treated soil yields a moisture content of 29 percent. This indicates an increase of 23 percent in the moisture content of treated soil compared to that in the feed soil.

The California Bearing Ratio (CBR) test was used to determine the effect of soil washing and leaching on the load bearing capacity of the soil. The CBR is primarily used to determine the strength of the soil for use as a

Table 4-2. Particule Size Distribution Data (percent)

Sample Stream	Day	Oversized Material[a]	Sands[b]	Fines[c]
Feed soil	1	20	50	30
	2	24	48	28
	3	8	60	32
	4	17(18)[d]	58(59)	25(23)
Untreated sands	1	2	92	6
	2	2	87	11
	3	1	92	7
	4	1	92	7
Treated sands	1	2	95	3
	2	2	93	5
	3	3	94	3
	4	4	94	2
Untreated fines	1	0	20	80
	2	0	20	80
	3	0	16	84
	4	0	23	77
Treated fines	1	0	30	70
	2	0	29	71
	3	0	30	70
	4	0	38	62

Notes:

[a] Particles > 6.35 mm in diameter
[b] 6.35 mm < particles > 106 μm
[c] Particles < 106 μm
[d] Values in parentheses are for results of duplicate samples analyses

structural fill material. Feed soil and treated soil samples were collected during days 2, 3, and 4 of the demonstration. On day 2, a duplicate sample of the feed soil was also tested. The CBR values for the feed soil indicate that it is suitable for use as fill material. The CBR increases by 2 to 4 times after soil washing and leaching. The greatest increase in CBR occurs at the higher composition rates (that is, up to 100 percent composition). The increase in CBR indicates that due to removal of oversized material, the treated soil is more compact compared to the feed soil, and its load bearing capacity increases significantly after being washed. This indicates that the treated soil can be used as structural fill.

Alkalinity and pH were monitored to characterize soils. Liquid stream samples showed pH levels of about 2 in most samples. Only two samples collected from the sand leaching circuit had a pH above 3. The COGNIS leaching process is designed to be effective at a low pH. These pH values above 3 show that COGNIS may have been unable to lower the pH to optimum levels in one of the six leaching circuits. In treated sands and fines, pH levels were all near or above 7, indicating that the COGNIS process was able to neutralize the treated soil. Alkalinity in the feed soil ranged from 1,800 to 3,700 mg/kg, with an average value of 2,700 mg/kg. The pH in the feed soil ranged from 7.9 to 8.1. The average alkalinity of the treated sands and fines was 4,250 and 5,325 mg/kg, indicating that COGNIS was able to counter the effect of acidic leachant on the soils.

Average CEC values in the sand stream were 2 and 4 milliequivalent (meq) per 100 grams (g) compared to 20 meq/100 g in the fines. CEC values for sand streams were much lower than those for the fines. CEC values for feed soil samples were comparable to each other (ranging from 8.1 to 11.7 meq/100 g).

Mass of feed soil monitored by COGNIS indicated that about 432 tons of soil was processed by the combined BESCORP and COGNIS processes during the 4 days of the SITE demonstration. This corresponds to a soil treatment rate of about 11 tons per hour (12 tons per hour with 90 percent efficiency), which corresponds well with the 9.3 tons per hour rate observed during the entire remediation (Wenck 1995a). Based on PSD data, 17 percent of this soil consists of oversized material, and was not treated by COGNIS. Therefore, based on laboratory data on oversized material, although BESCORP treated 432 tons of soil, COGNIS treated about 360 tons of soil during the 4-day demonstration. However, the laboratory data on oversized material is expected to only include rocks and not the clay balls. The amount of oversized material in the feed soil was monitored on four occasions during the demonstration. The amount of oversized material in the feed soil, composed of rocks and clay balls, was measured at 15, 27, 36, and 42 percent, for an average composition of 30 percent. Also, the percent of rocks and clays monitored in the feed soil and the treated and untreated material indicate that rocks comprised from 21 to 33 percent of the oversized material. The rest of the oversized material, therefore, are composed of clay balls which was not measured in the laboratory. It apppears that the percentage of oversized material in the feed soil was higher than the laboratory reported value of 17 percent. Therefore, the actual amount of soil treated by COGNIS during the 4-day SITE demonstration was less than 360 tons.

4.3 Chemical Analyses

Analytical results for all media are presented in this section.

4.3.1 Feed Soil

The analytical results for lead in the feed soil to the BESCORP soil washing unit are presented in Table 4-3. The daily average lead concentrations range from a low of 530 mg/kg to a high of 1,027 mg/kg. The individual composite samples collected during the demonstration ranged from 380 mg/kg to 1,800 mg/kg, indicating considerable heterogeneity in the feed soil. Lead concentrations in all composite feed soil samples were above the target remediation levels. The average lead concentration in all feed soil composite samples is 824 mg/kg.

Table 4-4 presents the analytical results for other metals in feed soil to the BESCORP soil washing unit; treated and untreated sands; and treated and untreated fines from and to the COGNIS process. Data presented in Table 4-4 show that chromium and nickel concentrations in untreated and treated sand samples are approximately 4 to 5 times higher than in the feed soil. The ring sieves and the carbide-coated rotor associated with the grinder are made of stainless steel that contains chromium and nickel (Brinkmann 1996). Furthermore, high chromium, copper, and nickel concentrations were observed in sand blanks used in evaluating the grinder. It appears that elevated concentrations of chromium and nickel in sand samples that were ground are due to contamination from grinding equipment. Chromium, nickel, and copper data for feed soils, which were also ground, are also of questionable quality. Therefore, the impact of soil washing and leaching on removal of chromium, nickel, and copper on feed soil and sand-sized soils is not discussed further in this report.

Concentrations of heavy metals in composite feed soil samples collected daily show that antimony was not detected above 9 mg/kg. Results presented in Table 4-4 indicate that cadmium was not detected in the feed soil or any other medium sampled during the demonstration.

TCLP test results conducted with feed soil to the BESCORP soil washing unit, oversized material from the BESCORP unit and, treated and untreated fines, and treated sands from the COGNIS process are presented in Table 4-5. All four TCLP tests conducted with the feed soil to the BESCORP soil washing unit showed lead concentrations in excess of the 5 mg/L maximum allowable concentration.

In all 29 TCLP extracts collected from material to and from both the BESCORP soil washing unit and the COGNIS process, cadmium and chromium concentrations were below their maximum allowable concentration of 1 and 5 mg/L, respectively.

Table 4-3. Lead Concentration in the Feed Soil to the BESCORP Soil Washing Unit (mg/kg)

Day	Composite Number	Lead Concentration	Daily Average Lead Concentration ± SD[a]
1	1	720	817 ± 443
	2	430	--
	3	1,300	--
2	1	1,800	1,027 ± 715
	2	890	--
	3	390	--
3	1	800	923 ± 200
	2	1,700(810)(950)[b]	--
	3	740(890)[c]	--
4	1	380	530 ± 195
	2	750	--
	3	460	--
Overall Average			824 ± 424

Notes:

a SD = Standard deviation
b Values in the parentheses are for replicate soil samples; the daily average ± SD was calculated following calculation of the average value for each composite sample
c Values in the parentheses are for results of duplicate analyses

Table 4-4. Non-Lead Metal[a] Concentrations in Soil Samples (mg/kg)

Remediation Goals		4.0	4.0	100.0	80.0	45.0
Medium	Day	Antimony	Cadmium	Chromium	Copper	Nickel
Feed soil	1	0.77	ND[b]	**37**	**150**	**47**
	2	0.78	ND	**37**	**240**	**41**
	3	4.5	ND	**48**	**300**	**54**
	4	0.33	ND	**43**	**310**	**58**
Untreated sands	1	1.0(0.42)[c]	ND(ND)	**160(140)**	**140(270)**	**160(170)**
	2	0.81	ND	**120**	**460**	**140**
	3	1.4	ND	**150**	**340**	**170**
	4[d]	5.2	ND	**7.5**	**79**	**9**
Treated sands	1	1.3	ND	**230**	**280**	**200**
	2	2.0	ND	**190**	**370**	**160**
	3	3.7	ND	**190**	**160**	**160**
	4	1.2	ND	**170**	**91**	**140**
Untreated fines	1	ND	ND	41	360	40
	2	0.53	ND	40	480	44
	3	ND	ND	93	360	38
	4	ND	ND	38	340	36
Treated fines	1	ND	ND	22	54	23
	2	ND	ND	24	93	22
	3	ND	ND	25	78	27
	4	ND	ND	25	81	28

Notes:

[a] Mercury was not analyzed because all samples exceed holding times
[b] ND = Not detected
[c] Values in the parentheses are for duplicate analytical results
[d] Sample may have been mislabeled and therefore is not used in the evaluation

Bolded values indicate samples may have been contaminated during grinding

Table 4-5. Toxicity Characteristic Leaching Procedures Test Results (ug/L)

TCLP Maximum Allowable Concentration[a] (μg/L)		5,000	1,000	5,000
Medium	Day	Lead	Cadmium	Chromium
Feed soil	1	**6,200**	ND[b]	27
	2	**17,000**	ND	ND
	3	**6,300**	ND	20
	4	**12,000**	ND	ND
Untreated oversized material	1	NA[c]	NA	NA
	2	3,400	ND	11
	3	1,800	ND	ND
	4	140	ND	ND
Treated oversized material	1	**11,000**	ND	10
	2	**5,300**	ND	ND
	3	410	ND	ND
	4	NA	NA	NA
Untreated clay balls	1	**36,000**(180)[d]	ND(ND)	ND(ND)
	2	NA	NA	NA
	3	1,200	ND	ND
	4	170(8,600)[e]	ND(ND)	ND(ND)
Treated clay balls	1	NA	NA	NA
	2	NA	NA	NA
	3	230	ND	ND
	4	ND(**7,600**)	ND	ND
Untreated fines	1	780	14	22
	2	2,700	40	16
	3	1,600	24	21
	4	1,600	24	23
Treated fines	1	100	ND	15
	2	150	ND	10
	3	140	ND	28
	4	240	16	31
Treated sands[f]	1	3,400	ND	14
	2	**7,100**	ND	34
	3	4,600	ND	22
	4	**5,200**	ND	13

Notes:

a Bolded value indicates sample exceeds maximum allowable TCLP concentration

b ND = Not detected

c NA = Not available

d These two samples were different in appearance; one consisted of clay balls, the other was made up of broken clumps.

e Values in the parentheses are for duplicate soil samples

f Untreated sand samples contained substantial amount of water, which could not be consistently sampled. Therefore, TCLP analyses of untreated sand streams were not conducted.

4.3.2 Oversized Material

Oversized material is defined as any material handled by the soil washing subcontractor that exceeded 6.35 mm in diameter, whether that was determined before (untreated) or after (treated) the trommel portion of the BESCORP soil washing process (see Figure 1-1). Daily composite samples of untreated and treated oversized material were collected for TCLP analysis. Oversized samples for TCLP tests during the SITE demonstration and the overall site remediation were not crushed. TCLP extracts of untreated oversized material showed lead, cadmium, and chromium at concentrations all below their respective maximum allowable concentration. However, for treated oversized material, lead concentrations in TCLP extracts were greater than 5 mg/L in two of the three samples. It was decided to collect clay ball samples on the third and the fourth days and to analyze these samples for TCLP metals, lead, and other metals. Lead concentrations in TCLP extracts exceeded the maximum allowable concentration in two of the six untreated samples and in one of the five treated clay ball samples. The wide variation of concentrations in the duplicate soil samples indicates the heterogeneity of these clay balls. The lead content of the untreated and treated clay balls ranged from 38 to 310 mg/kg and 26 to 150 mg/kg, respectively. Cadmium and chromium concentrations in TCLP extracts were either not detected or were below the maximum allowable concentrations. Metal concentrations in all treated oversized clay ball samples were below remediation goals, except for the treated sample from the third day. The COGNIS process did not treat the oversized materials. Exceeding the TCLP maximum concentrations in some of the oversized material samples indicates that soil washing alone was not always sufficient to clean oversized material to concentrations considered nonhazardous under RCRA. Some of this material may require further treatment before final disposition.

4.3.3 Untreated Sands

Untreated sand is defined as the sand (particle size less than 6.35 mm in diameter and greater than 106 μm in diameter) from the density separator portion of the BESCORP soil washing unit. Samples were collected from the untreated sand before treatment by COGNIS. The untreated sands samples contained large amounts of liquids that were decanted and filtered. The residues from the liquid were added to the solid portion of the samples. The liquid and the solid portions were analyzed separately. The solid portions were weighed and the volume of the liquids was recorded. Concentrations in the liquid portions were much smaller than concentrations in the solid portions. Only the results of analyses for solids are listed. Table 4-6 presents the results of lead analyses when hourly samples were collected from untreated sands. Lead concentrations in all treated and untreated sand samples are shown in Figure 4-1. The daily average lead concentrations in treated and untreated sands are shown in Figure 4-2. Lead concentrations in the untreated sand samples ranged from 140 to 670 mg/kg. Lead concentrations in untreated sand samples collected on day 2 were higher than lead concentrations observed on the other days, and all concentration values for untreated sand on that day were above the remediation goal of 300 mg/kg. Thirteen of the 26 samples collected on days 1, 3, and 4 were below the remediation goal. Considerable variations occurred in lead concentrations in each day's samples. The daily average lead concentrations for untreated and treated sands and fines are presented in Table 4-7. The average lead concentration in untreated sands was 339 mg/kg.

As shown in Table 4-4, results of metal analyses of untreated sands for the composite sample collected on day 4 are, for some metals, orders of magnitude different than the analytical results for untreated sand samples collected on other days. This sample may have been mislabeled, and therefore was not used for this evaluation. Cadmium was not detected in any of the untreated sand samples. Antimony concentrations ranged from 0.81 to 1.4 mg/kg, with none of the samples above the remediation goal of 4.0 mg/kg. The quality control samples indicated poor recoveries for antimony; therefore, antimony values reported in this document may be biased low.

4.3.4 Treated Sands

Lead concentrations in the treated sand samples ranged from 71 to 640 mg/kg. Seven of the 35 treated sand samples exceeded the remediation goal of 300 mg/kg. The overall average lead concentration in treated sands collected during the demonstration was 243 mg/kg.

A comparison of lead concentrations in untreated and treated sands shows that during each of the 4 days of the demonstration, lead removal efficiency was 44, 25, 27, and 21 percent, respectively. Removal efficiency refers to the estimate of the percentage of total lead that is removed by the treatment process. The percentage removal is

Table 4-6. Lead Content in Treated and Untreated Sands and Fines (mg/kg)

Day	Hour	Untreated Sands	Treated Sands	Untreated Fines	Treated Fines
1	1	180	120	220	54
	2	220	76	250	51
	3	140	71	200	54
	4	180	71	210	64
	5	320	130	460	50
	6	330	230	450	74
	7	630	270	610	87
	8	360	350	340	84
	9	270	150	NA	77
2	1	670	640	770	62
	2	500	420	720	100
	3	380	370	780	130
	4	360	210	510	150
	5	380	250	430	110
	6	460	220	430	91
	7	400	340	490	78
	8	430	410	340	95
	9	330	150	410	90
3	1	380	320	440	79
	2	NA	200	550	100
	3	340	230	490	140
	4	280	210	570	120
	5	220	250	450	120
	6	240	180	390	110
	7	420	220	510	110
	8	330	240	520	190
	9	NA	NA	NA	90
4	1	220	180	320	97
	2	270	200	260	77
	3	180	300	340	99
	4	290	290	430	92
	5	340	260	420	120
	6	490	290	550	93
	7	410	240	360	99
	8	240	160	350	140

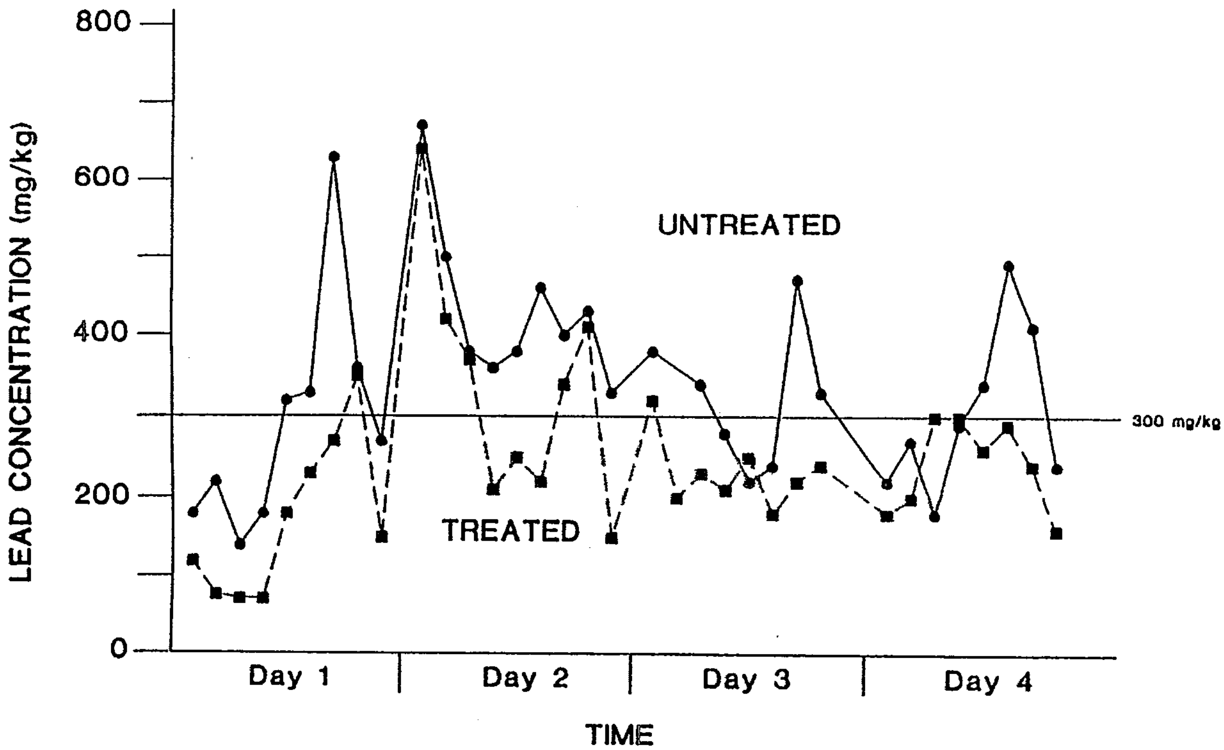


Figure 4-1. Lead concentration in sand samples.

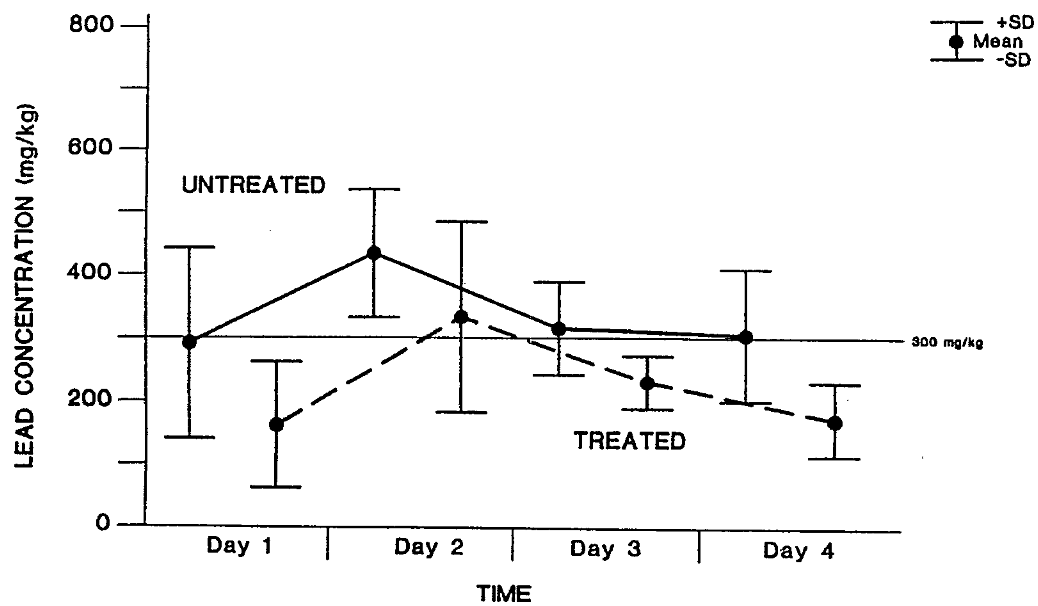


Figure 4-2. Daily average lead concentration in treated and untreated sands.

Table 4-7. Daily Average Lead Concentrations with Standard Deviations (mg/kg)

Day	Untreated Sand	Treated Sand	Untreated Fines	Treated Fines
1	292 ± 148	163 ± 99	342 ± 150	66 ± 15
2	434 ± 102	334 ± 149	548 ± 162	101 ± 26
3	316 ± 73	231 ± 42	490 ± 60	118 ± 32
4	305 ± 104	241 ± 56	379 ± 88	103 ± 21
Overall Average ± SD[a]	339 ± 122	243 ± 113	443 ± 145	96 ± 30

Note:

[a] SD = Standard deviation

calculated using daily averages for lead in untreated and treated material. The average lead levels were calculated using nine samples collected over a 9-hour period in a day. Removal efficiency was calculated using the following calculation:

$$\frac{UM_{lead} - TM_{lead}}{UM_{lead}} \times 100 = \text{Removal Efficiency}$$

where:

UM_{lead} = Average daily lead concentration in untreated material

Tm_{lead} = Average daily lead concentration in treated material

The removal efficiencies are presented graphically in Figure 4-3. It should be noted that the BESCORP and COGNIS soil treatment process is conducted in a continuous mode and is not conducted in batches of soil.

Results of other metal analyses listed in Table 4-4 show that antimony concentrations in treated sand ranged from 1.2 to 3.7 mg/kg; all treated sand samples met the benchmark value of 4.0 mg/kg for antimony.

TCLP results show that cadmium and chromium concentrations were either not detected or below the maximum allowable concentrations. Leachable lead concentrations were, however, detected in excess of 5 mg/L in two of the four daily composite samples. Treated soils composed of oversized material, sands, and fines were not tested for TCLP leachable metals. TCLP data presented for treated sands and treated fines do not allow any conclusion regarding the leachability of treated soil.

4.3.5 Untreated Fines

Lead concentrations in all fines samples are presented in Figure 4-4. The daily average lead concentrations in treated and untreated fines are presented in Figure 4-5. Lead concentrations in the untreated fines sample stream ranged from 200 to 780 mg/kg. Results showed the three highest lead concentrations in samples collected on day 2 when compared to samples collected during other days. Only five of the 34 samples collected had concentrations below the remediation goal. The daily average lead concentrations ranged from 342 to 548 mg/kg, with an overall average lead concentration of 443 mg/kg.

Cadmium was not detected in any of the samples and antimony was detected in only one sample at a concentration of 0.5 mg/kg. Copper concentrations ranged from 340 to 480 mg/kg, indicating that all results were above the remediation goal. Chromium and nickel concentrations ranged from 38 to 43 mg/kg and 36 to 44 mg/kg, respectively. This indicates that all results are below remediation goals.

TCLP tests indicated lead, cadmium, and chromium concentrations in all extract samples were below the maximum allowable concentrations.

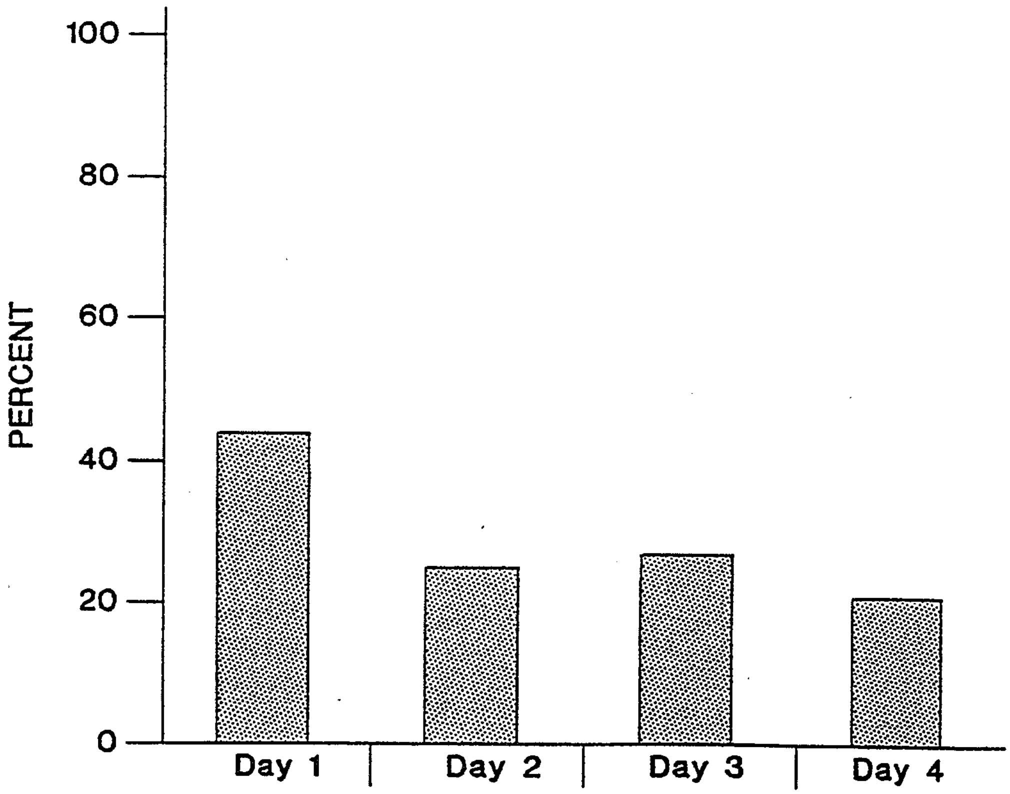


Figure 4-3. Removal efficiencies.

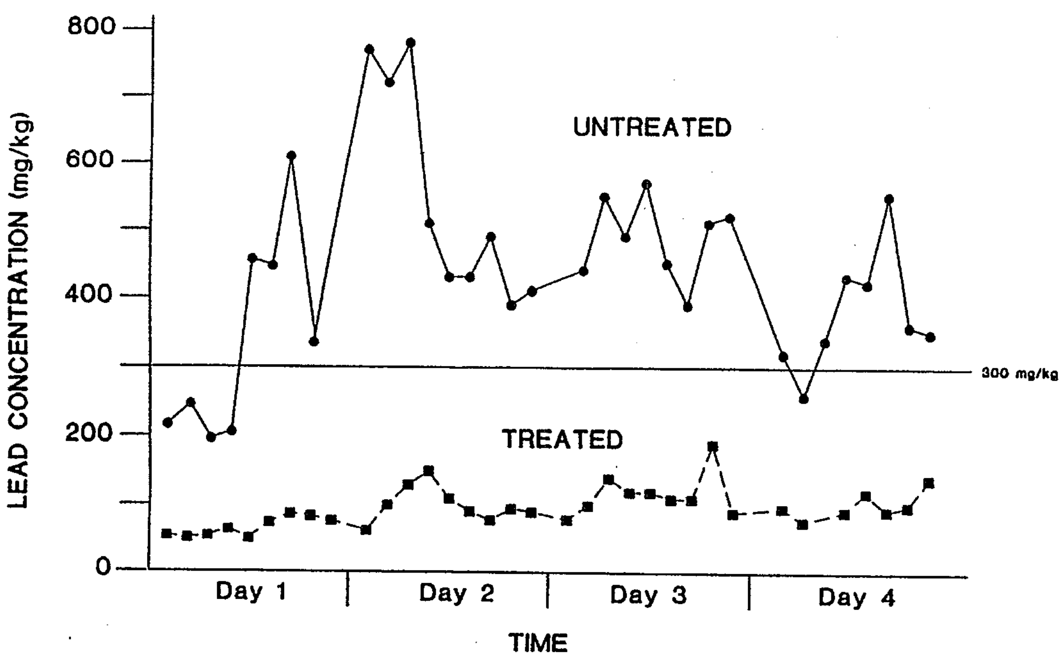


Figure 4-4. Lead concentrations in fines samples.

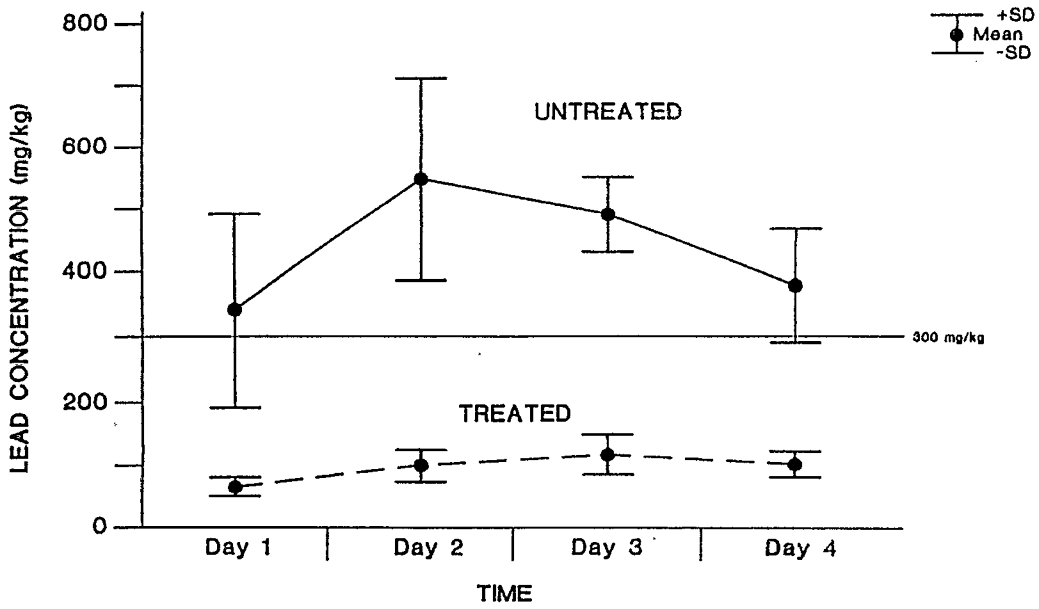


Figure 4-5. Daily average lead concentration in treated and untreated fines.

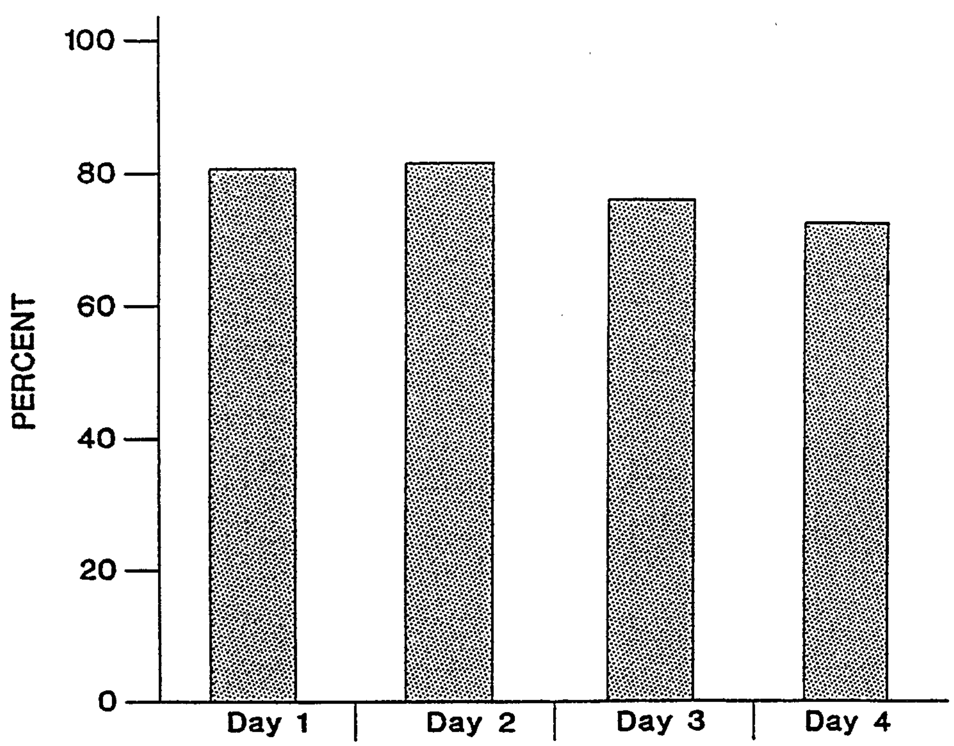


Figure 4-6. Removal efficiencies.

4.3.6 Treated Fines

Data presented in Table 4-6 show that lead concentrations during the 4 days of the demonstration ranged from 50 to 190 mg/kg, with only one sample being above the remediation target and all samples being below the remediation goal. The daily average concentration ranged from 66 to 118 mg/kg, with an overall average of 96 mg/kg. Comparison of daily average lead concentrations in untreated and treated fines show that removal efficiencies of the fines leaching process ranged from 72.8 percent on day 4, to 81.6 percent on day 2. The removal efficiencies are presented in Figure 4-6.

Data for non-lead metals analyses presented in Table 4-4 show that antimony and cadmium were not detected in the daily composite samples of treated fines. Copper, chromium, and nickel concentrations were all below their respective remediation goals. Average removal efficiencies in the fines leaching process are 40, 80, and 36.7 percent, respectively. Lead, cadmium, and chromium concentrations in the TCLP extracts were all below their respective maximum allowable concentrations of 5, 1, and 5 mg/L, respectively.

4.3.7 Lead Concentrates

The lead concentrates were recovered through the BESCORP density separation process and the COGNIS electrochemical deposition process. All recovered lead was transported to a lead smelting facility.

The density separated lead concentrates were composed of five different size fractions (designated as F1 through F5). The smallest (F1) and the largest particle size fractions (F5) were deposited in the same container and were analyzed as a combined size fraction. Based on observations made during the demonstration, the mass of the F5 fraction was much smaller than the mass of the F1 fraction. The total weight of F1 and F5 sample streams (1,029 kg) was more than the F2, F3, and F4 streams combined. Approximately 1,300 kg of density separated lead concentrate was collected during the week of the demonstration. During the demonstration, average lead concentrations for fractions F1 through F4 werE 45,500 mg/kg; 49,500 mg/kg; 31,111 mg/kg; and 4,200 mg/kg, respectively. During the demonstration, approximately 48 kg of lead was collected through the density separation process.

The lead concentrate samples from the sands and fines leaching circuit were sampled at the end of the demonstration to determine the amount of lead recovered by the COGNIS process. Approximately 694 kg of lead concentrate, with an average concentration of 74,000 mg/kg was recovered from the sands leaching circuit. Approximately 714 kg of lead concentrate, with an average concentration of 156,700 mg/kg, was recovered from the fines leaching circuit. The COGNIS process recovered a total of about 153 kg of lead. These lead recovery values from the sands and fines leaching circuit may not reflect actual recovery during the demonstration. COGNIS periodically cleans the lead cassettes in the leaching circuits. During the week of the demonstration, COGNIS did not recover any leached lead. Lead was recovered on the Monday following the week of the demonstration. The weights of lead concentrates reported in this paragraph were based on data collected on the Monday following the demonstration. However, it is not known when lead was recovered before the demonstration. Therefore, this at least represents 6 days of activities at the site. During the 4 days of the demonstration, at least 100 kg of lead was recovered.

4.3.8 Overall Treatment of Soils

Daily average values for treated soils were determined by combining daily average lead concentrations in treated sands and treated fines in a 2 to 1 sands to fines ratio. A 2 to 1 sands to fines ratio was used because data from the demonstration indicate that the soil from the TCAAP Site F soil is made up of 2 parts sand to 1 part fines. These data are presented in Table 4-8.

The data collected during the SITE demonstration show that the soil treated through the combined BESCORP and COGNIS processes were less than 300 mg/kg during all 4 days. It should be noted that TCAAP and MPCA assumed that the treated soil was composed of four parts sands and one part fines. TCAAP and MPCA determined attainment of remediation goals and targets by a sampling, preparation, and analysis protocol that was independent from the SITE demonstration. Under their protocol, four parts treated sands to one part treated fines were mixed and the contaminant concentrations were compared with the remediation goals. When daily average lead concentrations for the SITE demonstration were combined at a 4 to 1 ratio, the values were comparable to those listed in Table 4-8 with all treated soil concentrations below the remediation goals. Comparison of the TCAAP and SITE data over the demonstration week shows that TCAAP data (generated by a different sampling and analysis protocol) was substantially lower (76 mg/kg) than SITE data (194 mg/kg). Evaluation of data in Table 4-8 shows that the daily average removal efficiencies through the COGNIS process range from 40.9 percent on day 4 to 57.6 percent on day 1. Comparing the daily average lead concentrations of untreated sands and fines with those for the feed soil indicates that size separation and soil washing through BESCORP's process achieved lead removal efficiencies ranging from 37.7 percent on day 4 to 62.2 percent on day 1. Comparison of the treated soil data with the daily average lead concentrations in feed soil shows that the combined removal efficiencies of the BESCORP and COGNIS processes range from 63.2 percent on day 4 to 84 percent on day 1. These average removal efficiencies are presented in Figures 4-7 and 4-8. These lead removal efficiency values compare well with those reported by Wenck (1995a) of 55 to 90 percent observed during remediation. Also during the demonstration, three of the eight oversized material samples (36 percent) did not meet the maximum allowable concentrations determined by TCLP testing. Wenck (1995a) reported that 33 percent of the samples tested for TCLP did not meet maximum allowable concentrations after the first pass through the treatment system and were successfully treated by a second pass through the treatment system.

The feed soil and the treated material contained oversized particles. However, the removal efficiencies presented in this report are limited to the sands and fines, which were treated by the COGNIS process. Observation of COGNIS' operations made before the SITE demonstration showed minimal contamination associated with the oversized material. It was assumed that contamination associated with the oversized material would be insignificant during the demonstration. Therefore, attainment of cleanup objectives for oversized material during the SITE demonstration and the overall site remediation period was designed to be determined by TCLP.

4.3.9 Liquid Samples

Liquid samples consisting of the pregnant sands leachant, pregnant fines leachant, and the regenerated leachant, were collected to provide information on the lead recovery system. One pregnant sands leachant stream and two pregnant fines leachant streams were introduced into six electrochemical cells; two of the cells received pregnant sands leachant and four received pregnant fines leachant. Data for daily average lead concentrations are presented in Table 4-9. Concentrations in the pregnant sands leachant stream varied by about a factor of 5, ranging from 21 to 100 mg/L. The daily average lead concentrations ranged from 51.5 to 80.5 mg/L, with an overall average of 66.5 mg/L. Average concentrations in the two fines streams were 40.4

Table 4-8. Combined Average Lead Concentrations for COGNIS Process Soil[a,b] (mg/kg)

Day	Untreated Sands and Fines	Treated Sands and Fines
1	309	131
2	472	256
3	374	193
4	330	195
Overall Average	371	194

Notes:

[a] Includes size separated soil from the BESCORP soil washing unit that was feedstock for the COGNIS process

[b] Combining sands and fines data at a ratio of two parts sand and one part fines

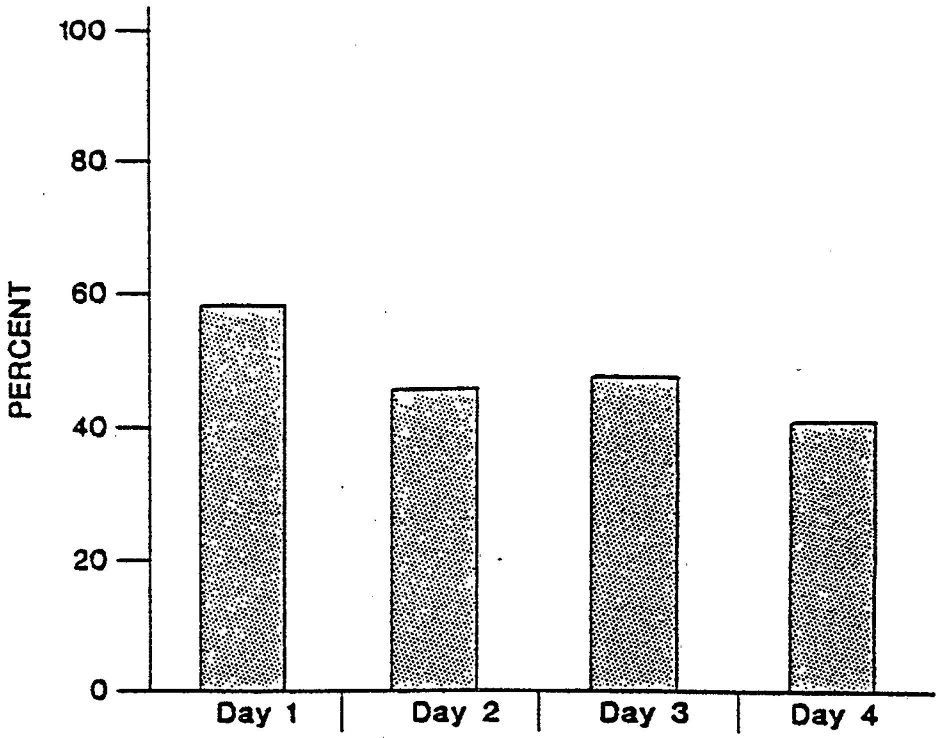


Figure 4-7. Average removal efficiencies of the COGNIS process.

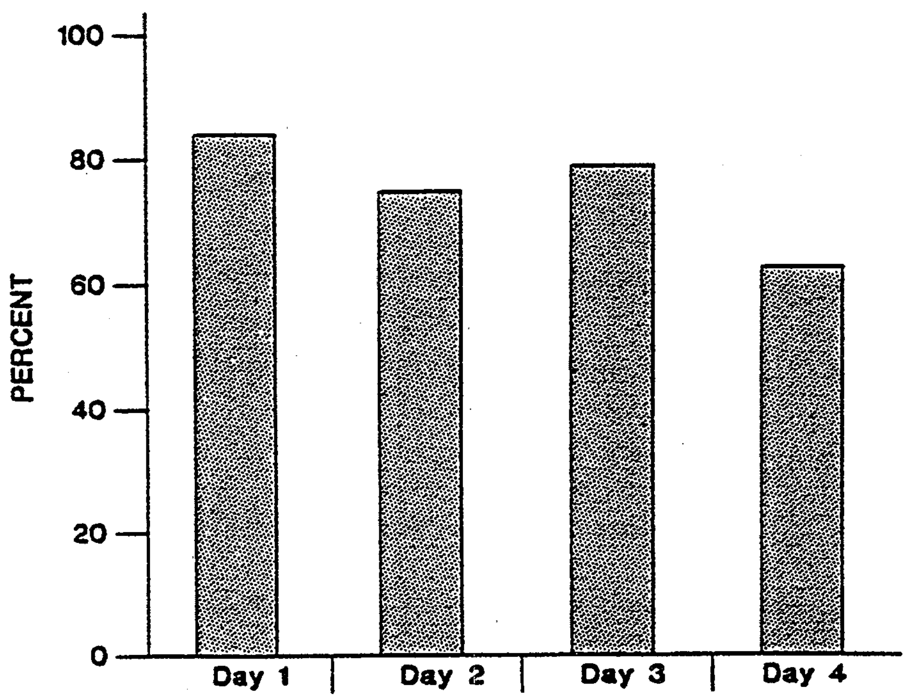


Figure 4-8. Average removal efficiencies of the COGNIS and BESCORP processes.

Table 4-9. Average Lead Concentrations in the Liquid Streams (mg/L)

Day	Pregnant Sands Leachant	Pregnant Fines Leachant No.1	Pregnant Fines Leachant No. 2	Regenerated Leachant from Sands	Regenerated Leachant from Fines
1	51.5	29.5	17.0	3.6	2.9
2	71.5	51.5	27.5	2.9 [a]	3.9
3	80.5	46.0	25.5	14.3	7.0
4	62.5	34.5	21.0	7.5	4.7
Overall Average	66.5	40.4	22.8	7.0	4.6

Note:

[a] Two of three data points were below the detection limit. The average was calculated by assigning a value of 25 μg/L, one-half the lead detection limit, to the nondetected samples.

and 22.8 mg/L. Overall patterns in all pregnant liquid streams are similar; concentrations on days 1 and 4 are comparable but lower than those on days 2 and 3. This pattern corresponds well with the trend observed in the feed soil and the untreated sands and fines soil streams where lead concentrations were also higher on days 2 and 3 when compared to days 1 and 4.

Lead concentrations in the regenerated leachant streams are also highly variable. Lead concentrations ranged from below the detection limit to 26 mg/L in the sands leaching system and from 1.6 to 26 mg/L in the fines leaching system. Most of the concentrations were below 10 mg/L; concentrations above 10 mg/L were found only on days 3 and 4. Comparing lead concentrations in pregnant streams with the regenerated streams shows a reduction of 89 percent in the sands leaching system and a reduction of 85 percent in the fines leaching system.

Lead removed from the leaching system was recovered as lead concentrates. The wastewater generated at the season's end met pretreatment standards for disposal in a POTW.

4.3.10 Results of Toxicity Studies

In addition to meeting treatment goals and measuring removal efficiencies, reduction of toxicity is another indicator of determining effectiveness of a treatment process.

Uptake Biokinetic Model Results

EPA recommends using the Uptake Biokinetic Model for lead to determine the total lead uptake for children 0 to 6 years old, from such exposure pathways as inhalation, diet, soil and dust ingestion, and maternal exposure. However, the Uptake Biokinetic Model was not used at Site F because RCRA closure regulations require a background-based cleanup. A blood lead concentration, in micrograms per deciliter (μg/dL), can then be estimated based on the total lead uptake. EPA (1991b) recommends a maximum blood-lead concentration of 10 μg/dL, which is at the low end of the range of concern for adverse health effects in children (10 to 15 μg/dL). The Uptake Biokinetic Model (EPA 1994b) estimates the percentage of population that is expected to develop blood-lead concentrations above and below 10 μg/dL. The Uptake Biokinetic Model was run at the average feed soil concentration of 824 mg/kg, the average concentration in soil treated through BESCORP's process of 371 mg/kg, and the average concentration in soil treated through the COGNIS process of 194 mg/kg. The model was run with default values for lead concentrations in air, drinking water, plant intake, and maternal contribution. The results of the model runs are presented in Figures 4-9 through 4-11. The figures show that for exposure to soil lead concentrations of 824 mg/kg, 371 mg/kg, and 194 mg/kg, percentages of children expected to have blood-lead concentrations of less than 10 μg/dL are 68, 94, and 99 percent, respectively. It is evident that the percent of the population exposed to blood-lead concentration in excess of 10 μg/dL decreases as the soil is treated through the BESCORP process and further decreases following treatment by COGNIS.

Bioassay Results

Bioassay tests were conducted on samples from the feed soil and from mixed treated sands and fines in a ratio of four parts sands to one part fines. In addition, tests were also conducted after rinsing the treated soil with water to simulate conditions encountered after about 3 months of exposure to rains when treated soil is used as fill material. The earthworm 14-day acute toxicity bioassay using Eisenia fetida and Lumbricus terrestris and the seed germination/root elongation (SG/RE) tests using lettuce, oats, and two local grass seeds were conducted by following EPA's National Risk Management Research Laboratory (NRMRL) Standard Operating Procedures to evaluate the toxicity of the three soil samples. The earthworm toxicity test results show that the feed soil and the treated soil after rinsing were not toxic to the earthworm, while the treated soils without rinsing showed significant toxicity. In the SG/RE tests, lettuce showed significant inhibitions with all three soils, while the treated soil without rinsing was the most toxic. For tests with oats and grass seeds, the treated soil without rinsing was the most toxic and the treated soil after rinsing was the least toxic. Plant genotoxicity bioassays conducted with Allium (common onion) showed that the feed soil and the treated soil induced similar concentrations of genetic damage to root tip cells. However, after rinsing, the treated soil was found not to be genotoxic. These results show that in general, toxicity increases after treatment with the COGNIS process, and decreases after treatment and rinsing. High concentrations of salt generated during the remediation process seems to be responsible for the increased toxicity of unrinsed soil in both plants and earthworms.

4.4 Conclusions

Based on the SITE demonstrations, the following conclusions may be drawn about the performance of the COGNIS and BESCORP processes for soil contaminant matrices found at TCAAP:

- The combined removal efficiencies of the BESCORP and COGNIS processes ranged from 63.2 to 84 percent, with an overall average removal efficiency of 76.4 percent. Treated soil (combining treated sands and fines data) met the lead remediation goal of 300 mg/kg on all 4 days of the demonstration.
- Daily average lead removal efficiencies of the COGNIS process alone range from about 41 percent to about 58 percent.
- The COGNIS sands leaching process achieved lead removal efficiencies ranging from 21 to 45 percent. Lead concentrations in untreated sands ranged from 140 mg/kg to 670 mg/kg. Lead concentration in treated sand ranged from 71 mg/kg to 640 mg/kg. The overall average lead concentration in untreated sand is 339 mg/kg. The overall average lead concentration in treated sand is 243 mg/kg. Based on an average concentration, lead was reduced in the sand leaching process by 96 mg/kg. Of the 35 samples collected of untreated sand, 20 samples exceeded 300 mg/kg. Of the 35 samples collected of treated sand, 7 samples exceeded 300 mg/kg. However, due to differences in sampling, preparation, and analysis protocol, SITE demonstration data differs from MPCA compliance data. Nine percent of the compliance samples did not meet the MPCA remediation goal for lead.
- Lead removal efficiencies in the fines leaching process ranged from 72.8 to 81.6 percent. Lead concentrations for untreated fines ranged from 200 mg/kg to 780 mg/kg with an overall average of 443 mg/kg. Lead concentrations in treated fines ranged from 50 mg/kg to 190 mg/kg. Based on average concentrations, lead was reduced in the fines leaching process by 347 mg/kg. Of the 35 samples collected of untreated fines, 27 samples exceeded 300 mg/kg. Of the 35 samples collected of treated fines, all samples were below 300 mg/kg.

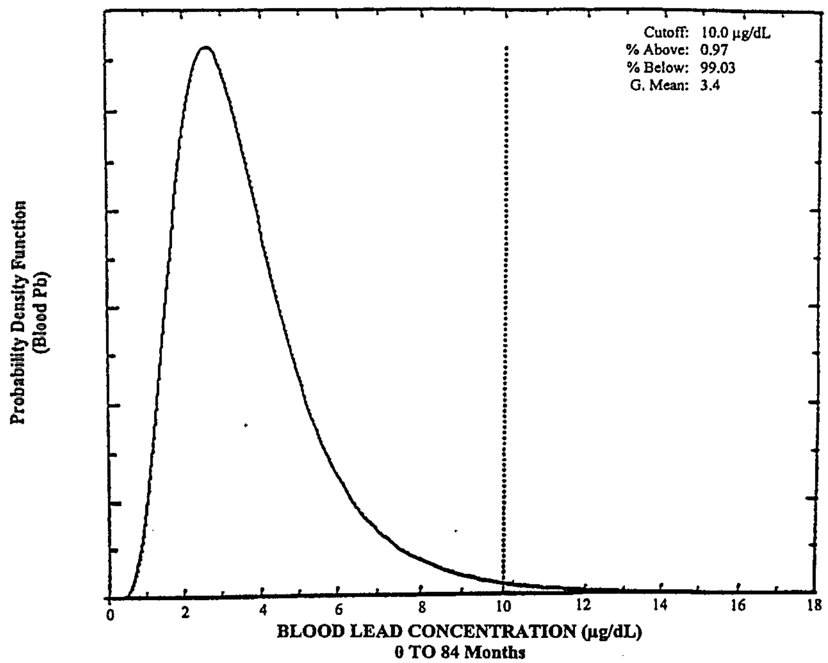


Figure 4-9. Blood-lead probability density in children (age 0 to 6 years) exposed to 194 mg/kg soil-lead concentration.

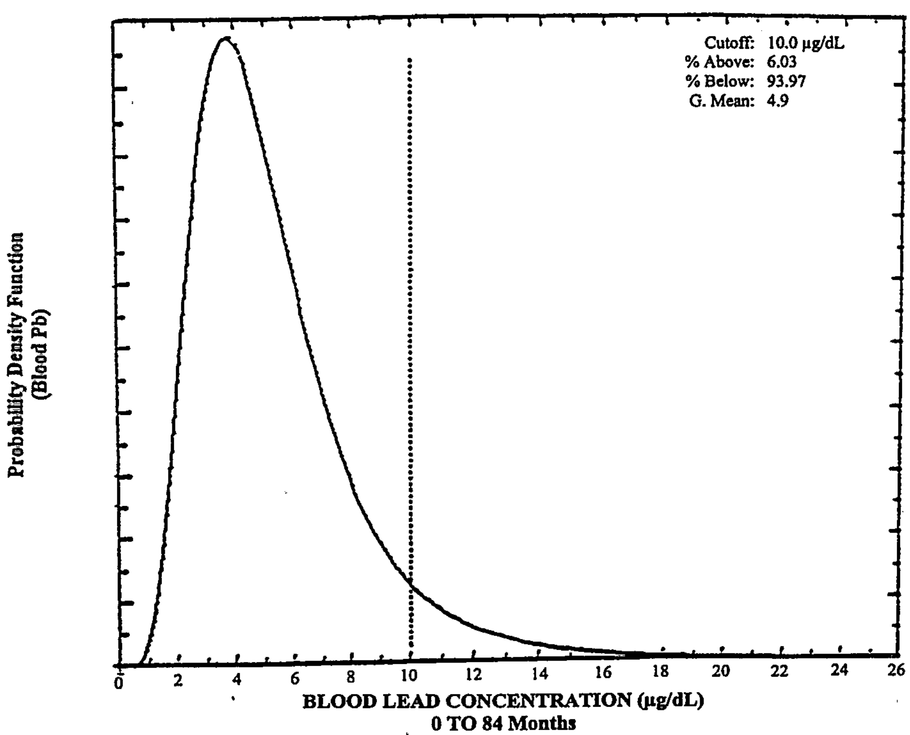


Figure 4-10. Blood-lead probability density in children (age 0 to 6 years) exposed to 371 mg/kg soil-lead concentration.

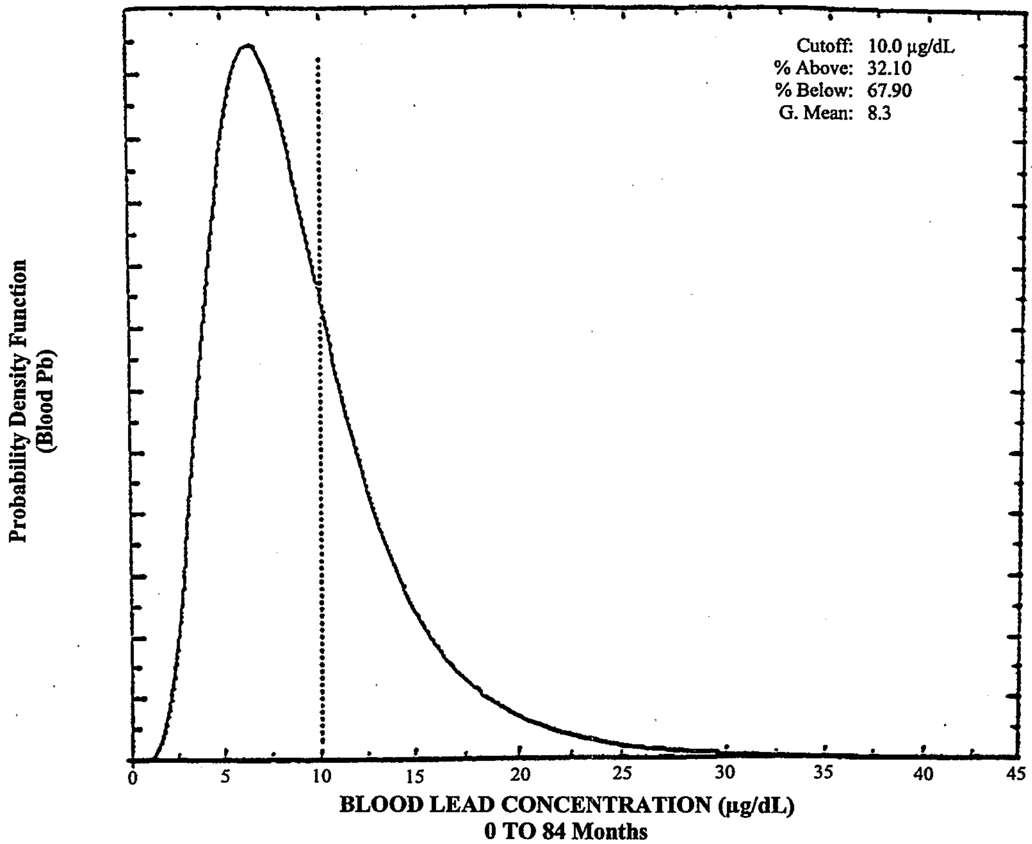


Figure 4-11. Blood-lead probability density in children (age 0 to 6 years) exposed to 824 mg/kg soil-lead concentration.

- Three of the eight TCLP extracts of the oversized material exceeded the maximum allowable concentrations for lead. Therefore, some of this oversized material may need further treatment to be removed from consideration as a hazardous waste under RCRA.

- The COGNIS process likely requires pretreatment of soils because it separately treats sand and fines. For TCAAP Site F remediation, pretreatment for the COGNIS process included BESCORP's soil washing and size separation process. In addition, removal of ordnance and other debris from feed soil is considered to be pretreatment.

- BESCORP's physical separation and soil washing stage was effective in removing oversized material, recovering lead concentrates, and separating sands and fines. However, BESCORP was not successful in addressing clay balls. Clay balls were removed from the system as oversized material. Clay balls may represent a significant source of lead. Because clay balls by passed treatment, the COGNIS process treated a reduced amount of fines. According to COGNIS, clay ball formation was not a typical problem during the long-term treatment. The BESCORP process achieved lead removal efficiencies ranging from 37.7 percent to 62.2 percent during the 4 days of operation.

- TCLP results for the treated sands indicate exceedance of the lead maximum allowable concentration of 5 mg/L in two of the four samples. There were no exceedances of the TCLP maximum allowable concentrations for lead, cadmium, or chromium in the four treated fines samples.

- It is evident from the Uptake Biokinetic Model runs that toxicity of soil was reduced due to treatment. Bioassay results indicated that increased soil toxicity for earthworms and plants was due to the increased salt content of the treated soil compared to the feed soil. After treatment and rinsing that simulates rainfall, soil is less toxic.

- COGNIS and BESCORP processes generate several treatment residues. The wastewater, generated at the conclusion of treatment or at the season's end, requires treatment prior to disposal. The lead concentrates can be recycled at lead smelting facilities. Treated soils at TCAAP met the MPCA enforceable remediation goals. Some of the oversized material did not meet the RCRA enforceable standards for TCLP extracts and may require further treatment. Ordnance and other debris removed from the soil may require disposal at off-site facilities.

- Activities such as site preparation, arrangements for utilities, waste disposal, mobilization, and demobilization were carried out on schedule and according to plan. All BESCORP and COGNIS equipment operated smoothly during the SITE demonstration.

- Based on treating 10,000 tons of soil, the cost of treatment is $182 per ton. At sites that do not require site preparation and residual shipping and handling costs, the cost for treatment is $138 per ton. The cost for leaching activities only is $70 per ton for treatment of 10,000 tons of soil.

Section 5
Technology Status

The information in this section was provided by COGNIS, Inc., which is the technology developer, and Doe Run Company, which now owns the equipment and the license.

As noted in the text, the SITE program evaluation of the COGNIS process occurred during four days of a much longer full-scale cleanup operation that COGNIS was contracted to complete at TCAAP. Below is an article from *Remediation* by William E. Fristad, who worked in the area of technology development, laboratory operations and plant support for COGNIS, Inc., that describes the overall cleanup effort by COGNIS, Inc., at TCAAP. This article is reprinted with permission of John Wiley and Sons, Inc.

The TERRAMET® process equipment and license to the technology was sold to The Doe Run Company when Henkel Chemical Company, the parent of COGNIS, INC., exited the remediation market. Upon completion of the Twin Cities Army Ammunition Plant project the equipment was demobilized from Minnesota to Doe Run's Buick Resource Recycling Facility in Boss, Missouri.

The Doe Run Company has been producing lead for the past 140 years. Seven years ago, Doe Run completed the construction on a new facility that would recover and recycle lead from scrap. Doe Run is committed to the recycling of metals, particularly lead, at the Buick Resource Recycling Facility. Each year the facility recovers and recycles lead from over 175,000 tons of lead bearing products, by-products, wastes and residues. Buick has recovered and recycled lead from over 25 firing ranges from National Guard units around the country. Soil and other waste streams have been treated at the facility from Department of Energy, Naval Facilities Engineering Command, and Government Owned/Contractor Operated (GOCO) facilities.

The Doe Run Company integrated the equipment into its existing RCRA Part B permitted facility. The TERRAMET process complements Doe Run's existing capability to process lead contaminated sands and soils through its pyrometallurgical circuit. The new process is called TERRAMET Services. The purpose is to provide a low cost permanent solution to metals contaminated soil and other solid waste streams. Contaminated soil can be shipped to the facility, the metals removed and reused to form lead and lead alloy ingots, and the soil put to beneficial reuse as part of the mining operation. Shipping contaminant offsite to a permitted facility benefits those who require fast reuse and transfer of clean parcels. If required, TERRAMET equipment can still be mobilized to projects. Special projects, such as the separation of lead from depleted uranium at Lake City Army Ammunition Plant in Independence, Missouri, will require the plant to move onsite to the project.

TERRAMET Services offers flexibility in treating waste on or offsite plus in choosing the treatment process at Buick Resource Recycling to minimize cost.

Waste Classification - Determine if the soil or waste stream should go straight to the lead smelter, thereby classifying the waste as nonhazardous based on the RCRA recycling exemption. This classification greatly reduces transportation costs, storage requirements, and turnaround time.

Soil Washing - If the metals can be removed physically, the soil will only undergo soil washing. The lead concentrate will go directly to the smelter. The soil with lead below the state's required lead concentration will be declared clean and used as cover in the mining operation.

Soil Washing/Soil Leaching - If the metals cannot be removed by soil washing alone because the lead or other metals have weathered or have been smeared into the soil, then the soil will be washed to remove particulate metal and leached to remove the remainder required to reach state requirements. Again, the lead concentrate would go to the smelter and the soil would be reused.

Pyrometallurgical - Some metals and minerals are required in the smelting process. The soil can go directly to the smelter depending on the operation and the feed material make up.

Selective Processing - Doe Run personnel can work with generators to custom fit a treatment process for a particular waste. There are instances, driven by regulation or waste characterization, that require a certain process step, end use, or remediation goal. Doe Run will combine unit operations, segregate and process "hot spots," or modify its system (in compliance with the Part B permit) to accommodate special needs.

The price of soil treatment at Buick is lower than the field price because there is no mobilization, no per diems, and the labor force required to treat the soil is already in place manufacturing lead. Raw material handling, health and safety activities, material handling, and maintenance are all performed at a much lower rate at a fixed facility than in the field.

American Society for Testing and Materials (ASTM). 1994. Methods Published Annually by ASTM.

Doe Run Contact

Lou Magdits, TERRAMET Manager/Raw Materials Manager
The Doe Run Company
Buick Resource Recycling Facility
Hwy KK
HC 1 Box 1395
Boss, MO 65440
(573) 626-3476
(573) 626-3405 Fax
lmagdits@misn.com

Reprinted by permission of John S. Wiley & Son, Inc. from Remediation, Autumn 1995, pp. 61-72, copyright 1995.

Case Study: Using Soil Washing/Leaching for the Removal of Heavy Metal at the Twin Cities Army Ammunition Plant

William E. Fristad

Dr. William E. Fristad is Director of TERRAMET® Technology for COGNIS, Inc., of Santa Rosa, California. Over the past four years he has been responsible for technology development, laboratory operations, and plant support. His background is in organic and inorganic chemistry, and he has worked in those fields for COGNIS and its parent company, the Henkel Group, in both the United States and Germany.

COGNIS TERRAMET® soil leaching and Bescorp soil washing systems have been successfully combined to remediate an ammunition test burn area at the Twin Cities Army Ammunition Plant (TCAAP), New Brighton, Minnesota. This cleanup is the first in the country to successfully combine these two technologies, and it offers a permanent solution to heavy metal remediation. Over 20,000 tons of soil were treated in the project. The cleaned soil remained on-site, and the heavy metal contaminants were removed, recovered, and recycled. Eight heavy metals were removed from the contaminated soil achieving the very stringent cleanup criteria of <175 ppm for residual lead and achieving background concentrations for seven other project metals (antimony, cadmium, chromium, copper, mercury, nickel, and silver). Initial contaminant levels were measured as high as 86,000 ppm lead and 100,000 ppm copper, with average concentrations over 1,600 ppm each. In addition, both live and spent ordnance were removed in the soil treatment plant to meet the cleanup criteria. By combining soil washing and leaching, COGNIS and Bescorp were able to assemble a process which effectively treats all the soil fractions so that all soil material can be returned on-site, no wastewater is generated, and the heavy metals are recovered and recycled. No hazardous waste requiring landfill disposal was generated during the entire remedial operation.

Heavy metal contamination is the misplacement of a useful natural resource into a location where the metals are viewed as toxic contaminants rather than the useful products they can and should be. Solidification and landfill of metal-contaminated soil only immortalizes the waste and guarantees the owner perpetual liability. Combining COGNIS's 35 years of experience in metal leaching and recovery processes with the fact that heavy metals represent the majority of the top ten pollutants in the United States, and lead is ranked number one,[1] we set out to develop a permanent

CCC 1051-5658/95/0504061-12

heavy metals removal, recovery, and recycle process. COGNIS has now completed a 20,000 ton cleanup of a metal-contaminated site where the soil was cleaned to RCRA-mandated standards and returned to the site, while all contaminant metals were recovered and recycled through a lead smelter.

The Twin Cities Army Ammunition Plant (TCAAP), the Army, and the Minnesota Pollution Control Agency (MPCA) saw the value in a permanent treatment remedy which would remove the contaminants, and thereby limit the human and environmental health threat, long-term liability, and restrictions on real estate reuse. All parties were adamant in seeking an alternative that minimized or eliminated material requiring permanent off-site landfilling. This led to the selection of COGNIS to prime the soil washing/TERRAMET® soil leaching process to remediate Site F, an ammunition open burning/open detonation area.

A treatment train of soil washing and TERRAMET® soil leaching was developed and assembled in less than one year from treatability study to full-scale operation on-site by a team of COGNIS, Inc., and Brice Environmental Services Corp. (Bescorp). The physical separation and chemical leaching stages allow both particulate and ionic metal contaminants to be removed, recovered, and recycled in a single integrated plant. Live and spent small arms ordnance was also washed and removed for proper disposal within the soil treatment plant.

TCAAP HISTORY

The Twin Cities Army Ammunition Plant, New Brighton, is an industrial complex covering 2,370 acres in the greater metropolitan Twin Cities of Minneapolis and St. Paul, Minnesota. It was built in 1941 and operated as a government-owned, contractor-operated (GOCO) manufacturing facility by Federal Cartridge Company. In the early years it produced primarily .30 and .50 caliber ammunition and 105-mm and 155-mm projectile casings. During the Vietnam era, TCAAP also produced 7.62-mm and 5.56-mm cartridges.

The health concerns were VOCs in the drinking water and heavy metals in the soil.

In 1982, TCAAP was included on the National Priorities List. The health concerns were VOCs in the drinking water and heavy metals in the soil. The practice throughout the production life of the plant was to bury material on-site in specific disposal areas. Off-spec ordnance material and ordnance test components were burned or detonated at Site F, the area being remediated in this project. Through the remedial investigation process, 14 additional sites within the TCAAP facility have been identified as contaminated areas.

TCAAP has a history of applying innovative environmental solutions to their contaminated areas. TCAAP entered into the first Federal Facilities Agreement (FFA) in history during 1987. The objectives were to investigate, monitor, and exchange information concerning historical pollution and to provide a forum for setting future actions. Under the FFA, TCAAP implemented one of the first applications of in-situ volatilization (ISV) for a TCE plume in 1986. In 1987 TCAAP signed a contract to have soil contaminated with PCBs burned on-site. Starting in 1993 TCAAP began demonstrating the TERRAMET® technology for metals removal and recovery. An ongoing project elsewhere on the plant is the biodegradation of creosote-soaked utility poles. The property is currently under modified caretaker status and will eventually be turned over for redevelopment.

STATE OF SOIL WASHING/LEACHING TECHNOLOGY

Soil washing has been a proven technology in Europe for over a decade. In 1992, when the laboratory phase of this project began, no full-scale soil washing job had yet been performed in the United States. In the meantime several full-scale soil washing projects have been conducted which effected significant volume reduction. Soil leaching with dissolution and recovery of metals had not yet been successfully demonstrated and documented full-scale anywhere in the world. The TCAAP project was the first to implement soil washing and soil leaching whereby the contaminants were removed and recycled and the cleaned soil was returned on-site. Acid leaching with acetic acid[2] and hydrochloric acid[3] leachants had been investigated and described in bench-scale experiments for a number of years.[4] Previous unsuccessful attempts to leach lead with chelating agents (EDTA) have been documented at the Lee's Farm (Woodville, Wisconsin) and ILCO (Leeds, Alabama) sites.[5] Other examples of soil washing with water, surfactants, and EDTA solutions as a volume reduction method before stabilization have also been studied,[6] while the commercial drawbacks of EDTA leaching were also described.[7] The U.S. Bureau of Mines had developed a bench-scale process by 1992; however, that process had not yet been scaled up beyond the laboratory.[8] Since then, the Bureau of Mines has modified their leaching process and performed pilot-scale runs on lead-contaminated soil at firing ranges.

Standard soil washing is the use of physical techniques to wash the surfaces of soil particles and to separate soil particles into clean and contaminated fractions.

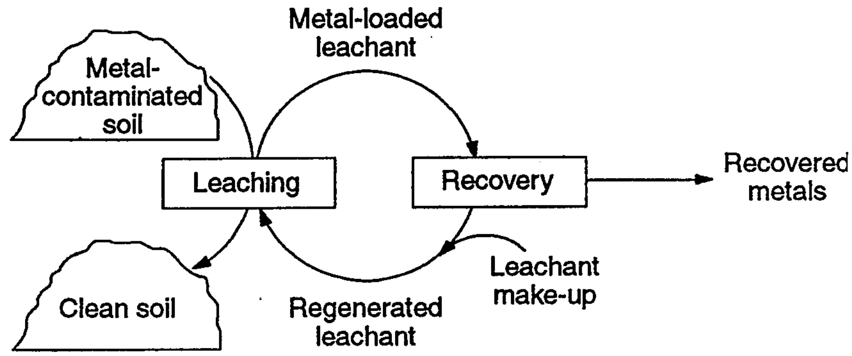
Standard soil washing, as defined here, is the use of physical techniques to wash the surfaces of soil particles and to separate soil particles into clean and contaminated fractions. The goal is normally to generate clean gravel and sand fractions, while concentrating the contaminants into the fines (silt and clay) fraction. Physical separation techniques based on magnetic, density, or flotation principles can also be utilized to selectively remove fractions for specific further treatment. We define "soil leaching" as the use of chemical leaching solutions to dissolve metal contaminants, remove the metals from the soil constituents, and recover the dissolved metals from solution.

FROM BENCH-SCALE TO FULL-SCALE

Federal Cartridge Company commissioned a treatability study on soil washing/leaching in the fall of 1992. COGNIS recognized that most soils contaminated with metals were going to contain small pieces of metal which would show up in a sand-sized soil fraction as well as metallic compounds which would be adsorbed into soil fines. Therefore, in the TERRAMET® treatment scheme, sand and fines would need to be leached separately. COGNIS sought a team member who could perform the task of separating the soil into sand and fines fractions and provide physical separation of any metal pieces. Bescorp was chosen because of their

Exhibit 1. Leaching-Metal Recovery Concept

TERRAMET® Soil Remediation Systems



experience with density separation of placer gold deposits and battery debris. When the samples arrived from TCAAP, COGNIS and Bescorp simultaneously processed the soil and tested combinations of density separation, leachant, and residence time.

The COGNIS TERRAMET® soil remediation concept uses a leaching-metal recovery process to leach metals from contaminated soil with one of several proprietary aqueous acidic leaching solutions. The leachant is specifically matched with the soil and type of metallic contaminants by incorporating oxidants, reductants, or complexing agents. By proper additive control the system can solubilize most chemical forms of lead contamination including lead sulfate, lead dioxide, and lead metal. The leaching-metal recovery concept is illustrated in **Exhibit 1**. Lead-contaminated soil is contacted with the leaching solution to dissolve the contaminant. The metal-loaded leachant then flows to a patented electrochemical metal recovery unit where the dissolved lead is removed. The lead-free leachant is then recycled within the plant for additional leaching. The approach recycles the leachant solution, and no liquid waste streams are generated during full-scale operation of the TERRAMET® plant. Leachant make-up chemicals are added to replenish those which exit the plant in treated, neutralized, and dewatered soil. The neutralized leachant residuals in treated soil have been determined to be safe by the MPCA.

In the treatability study, a composite soil sample from the ammunition test burn area at TCAAP was studied. At Site F both metallic lead fragments as well as ionic lead species were found. Because of the high density of lead relative to most other native soil constituents, the incorporation of density separation into the physical stages of soil washing was a logical pretreatment to leaching. Soil was first attrited, screened, and rinsed to remove and clean the oversize ordnance and rock. The undersize soil material was then separated into sand and fines fractions. The sand fraction was then subjected to density separation using standard mineral processing equipment (jigs, tables, panning) to remove heavy lead and other metal

Exhibit 2. Density Separation of Lead Particles

Sand Particle Size (Mesh)	Lead Concentration before and after Density Separation (ppm)					
	Trial 1 Before	Trial 1 After	% Pb Removed	Trial 2 Before	Trial 2 After	% Pb Removed
+8	2050	996	51	NA	NA	NA
+30	4190	389	91	1436	168	88
+50	2410	494	80	1025	187	82
+100	4060	842	79	901	138	85
+200	2900	2960	0	940	416	56
-200	4360	2490	43	679	739	0

fragments. The results of density separation lowered the lead concentration in the sand significantly (**Exhibit 2**).

Once the larger metal pieces were removed, the remaining fine lead particles and ionic lead species adsorbed into the soil particles could be removed cost-effectively by chemical leaching. **Exhibits 3** and **4** show the results of leaching the fines and density pretreated sand fraction. Leaching the fines was very effective and gave residual lead concentrations of <20 ppm with leachant #2. A number of leachants were tested, and leachant #2 was eventually chosen for the full-scale remediation. The results on the sand were equally satisfactory. A residual lead concentration of <70 ppm was also achieved with leachant #2. It was important to show in the treatability study that lead could be leached from both the fines and the sand fractions.

After the small bench-scale experiments proved the success of the multiple leaching concept, additional larger-scale continuous leaching experiments verified the leaching results. The continuous-scale apparatus more closely approximated full-scale treatment. It employed an agitated leaching vessel in which a soil slurry was continuously leached. The metal loaded leachant was continuously pumped to the metal recovery unit where the lead was removed from the leachant and lead recovered as a solid lead product. The lead-depleted leachant was then returned to the leaching vessel for continued leaching. After leaching was complete, the soil-leachant slurry was dewatered and neutralized. Thus, the entire leaching, clarification, and metal recovery process operated continuously on the batch of soil in the leaching vessel. **Exhibit 5** illustrates typical data on TCAAP soil. Routinely <100 ppm residual lead and TCLP passage was

Exhibit 3. Leaching* of TCAAP -200 Mesh Fines

	Cumulative % Pb Leached					Initial**	Final***
	Leaching Contact #					[Pb]	[Pb]
Leachant	1	2	3	4	5	(ppm)	(ppm)
2	59	90	96	97	97	575	16
2	64	92	97	98	98	608	11

* Data are from five consecutive contacts of soil samples with leachant.
** Based on the total Pb detected in leachant plus Pb retained in soil as determined by nitric acid digestion.
*** Based on EPA acid digestion of treated soil.

Exhibit 4. Leaching* of TCAAP Density-Pretreated -200 Mesh Sand

	Cumulative % Pb Leached					Initial**	Final***
	Leaching Contact #					[Pb]	[Pb]
Leachant	1	2	3	4	5	(ppm)	(ppm)
2	49	71	81	85	88	585	69
2	75	87	90	92	93	190	14

* Data are from five consecutive contacts of soil samples with leachant.
** Based on the total Pb detected in leachant plus Pb retained in soil as determined by nitric acid digestion.
*** Based on EPA acid digestion of treated soil.

observed. The lead concentrations shown under the influent and effluent columns were the concentrations of lead in the leachant entering and exiting the metal recovery unit.

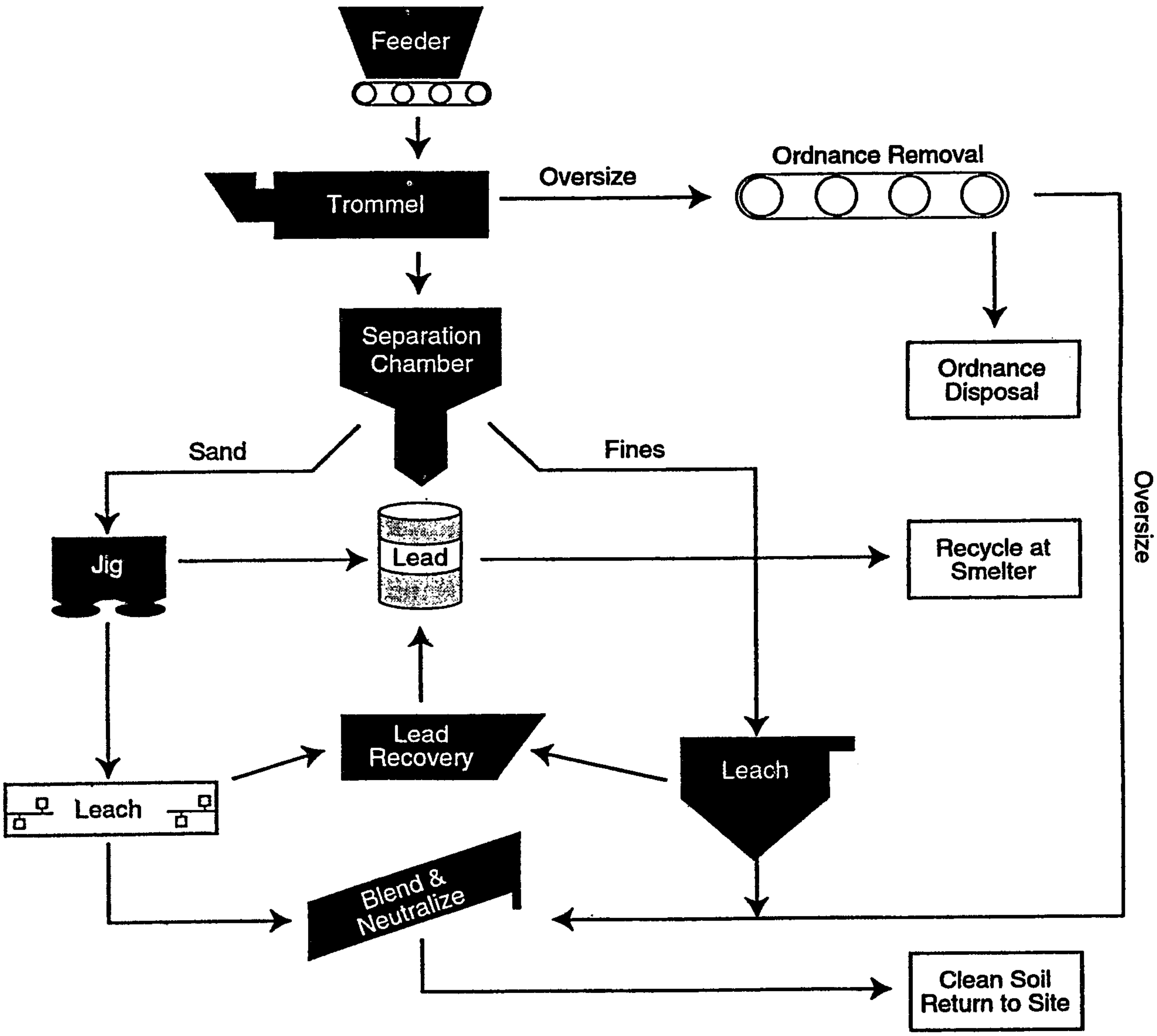
A flow chart for the full-scale COGNIS-Bescorp remediation process which resulted from the treatability study is shown in **Exhibit 6**. Bescorp was responsible for the physical separation steps, and COGNIS was responsible for the chemical leaching and metal recovery technology. The soil is fed into the trommel where attrition breaks the soil material down into its constituent particles of rock, gravel, sand, silt, and clay. The clean

Exhibit 5. Continuous-Scale Leaching Experiment TCAAP Soil (Density Pretreated)

Matrix	Lead Concentration (µg/g) Pre-Leaching	Lead Concentration (µg/g) Leached
Soil (Avg)	250 - 350	31.1
Replicate 1		32.6
Replicate 2		28.2
Replicate 3		33.2
Leachate	**Influent (µg/mL)**	**Effluent (µg/mL)**
Sample 1	15.4	2.5
Sample 2	10.6	2.1
Sample 3	4.6	1.3
Sample 4	2.5	0.7
Sample 5	1.4	<0.5
Sample 6	0.9	<0.5
Sample 7	0.5	<0.5

oversize rock, gravel, and ordnance are rinsed and removed by a 1/4-inch screen. The oversize is sorted on a conveyer belt, and ordnance is removed for proper disposal. The clean oversize rock and gravel exits the plant. The sand and silt/clay fines are separated in a patented vertical separation chamber which separates the sand from the fines by hydraulic settling forces. The metal-containing fines are swept into a clarifier where they are flocced and allowed to settle. The settled fines are pumped through a series of leaching clarifiers. The leached fines are dewatered and neutralized before being combined with the clean oversize and sand fractions. The coarse-sand fraction is run through a mineral jig while the finer sand is run down a spiral to remove the bulk of the metallic lead and copper particles, flecks, and dust. The pretreated (metal particle free) sand fraction is then subjected to counter-current leaching. The leached sand is dewatered and neutralized before being combined with the fines and oversize. The metal

Exhibit 6. COGNIS/Bescorp Full-Scale Process Diagram: Soil Washing/Soil Leaching Process



loaded leachant is fed into the metal recovery units where the dissolved contaminant metals are electrochemically reduced out of the leachant solution and recovered in solid metallic form for recycle.

FULL-SCALE RESULTS

Remedial operations at the site began with clearing the site: burning of the vegetation and removing trees, small buildings, and underground utilities. All of these materials were decontaminated before removal from the site. The excavation of the site proceeded in six-inch lifts across the surface of the site. Much of the contamination was in the top one to two feet of the three-acre site. Disposal trenches were also located during the excavation, and 16 such burial trenches down to a depth of 15 feet were eventually characterized, excavated, and treated. The extent of all excavation was directed by X-ray fluorescence (XRF) spectroscopy, and decisions to stop excavation were confirmed by laboratory analysis. Use of XRF in defining excavation limits helped to contain soil treatment costs by minimizing unnecessary over-excavation.

COGNIS and Bescorp built an integrated mobile trailer-mounted field-scale soil treatment plant and drove it on six flatbed trailers to the TCAAP site. All soil processing was conducted on a preexisting concrete pad located approximately 100 yards from the excavation at Site F. The treatment pad provided secondary containment for a small feed soil stockpile, the processing equipment, and the treated soil stockpile. During all operations, rainwater which collected on the treatment pad was collected and either used as process water or treated before disposal to the sanitary sewer system.

Feed soil was loaded into the process equipment by a front-end loader.

Feed soil was loaded into the process equipment by a front-end loader. After-treatment soil was sampled approximately every 10 tons and samples composited into 30- or 60-ton batches for laboratory analysis before loading into storage bunkers. Samples were analyzed for all eight project metals (EPA 3050 digestion for total metals content). Analytical results were returned within 24 hours, clean soil was returned to Site F, and soil which failed to meet cleanup criteria was reprocessed.

The first week of soil processing constituted an acceptance period for the MPCA. During this period all the output of the treatment plant was carefully monitored to ensure that all the regulatory goals were being achieved and that the plant operated in a safe manner. The analytical data for the acceptance period runs are summarized in **Exhibit 7**. Each run represented 60 tons of processed soil. The treatment plant was operated for several weeks in the fall of 1993 before shutting down for the winter. In the summer of 1994 treatment was resumed, and **Exhibit 8** summarizes the treatment results for both 1993 and 1994 at which point over 12,000 tons of soil had been treated. By the end of the job in June 1995, over 20,000 tons of soil had been treated. Final 1995 data were not available at the time of this writing.

As a result of the soil treatment, over 20 tons of lead were recovered and recycled through the local secondary lead smelter where the lead had originally been purchased by TCAAP to manufacture the ordnance. Ordnance removed from the oversize fraction was also separated into live ordnance, spent ordnance, and inert projectiles. Approximately 250 tons of ordnance materials were recovered for demilitarization.

An important part of the COGNIS/Bescorp process is that no process water is discharged during the operation; all process water/leachant is recycled within the plant. Process water at the end of each treatment season was neutralized, clarified, and analyzed for all the project metals, and after meeting the Metropolitan Waste Water Commission's criteria, it was discharged to the sanitary sewer system. The sanitary sewer discharge criteria were met each time.

Exhibit 7. TCAAP Acceptance Period Results

Metal	RCRA Cleanup Goal	Acceptance Period Run Number (ppm)				
		1	2	3	4	5
Antimony	4.0	<1	<1	<1	<1	<1
Cadmium	4.0	0.8	1.8	<0.02	3.0	0.2
Chromium	100	3.5	0.6	2.6	6	5
Copper	80	23.7	12.6	9.8	12.7	16.1
Lead	175	19	60	30	60	60
Mercury	0.3	<0.02	0.04	0.03	<0.02	<0.02
Nickel	45	8.9	6.2	4.6	5.4	6
Silver	5.0	<0.1	<0.1	<0.1	<0.1	<0.1

Exhibit 8. TCAAP 1993–1994 Results

Metals of Interest	RCRA Cleanup Goal	Avg. Residual Metal in Treated Soil (ppm)	
		1993	1994
Antimony	4	<0.5	0.9
Cadmium	4	0.8	0.2
Chromium	100	6	6
Copper	80	39	65
Lead	175	173	90
Mercury	0.3	0.1	0.3
Nickel	45	9	7
Silver	5	<0.05	<0.1

Minimization of hazardous waste was the primary goal at the outset of this project. By the end of the 1994 treatment season, no soil or process material left the TCAAP facility as hazardous waste for landfill. All contaminant metals were recycled through a secondary lead smelter, all process water was discharged to the sanitary sewer, and all soil remained on the TCAAP facility.

At the close of the project, the process equipment was decontaminated, and the treated soil was backfilled over the site, covered with topsoil, and revegetated with prairie grasses.

LESSONS LEARNED

As COGNIS looks at its next opportunities—and as generators of metal-contaminated soil ready themselves for soil treatment—a few lessons can be shared from TCAAP.

Know the Site

Site characterization is difficult and expensive, particularly when the site involves disposal areas. The best way to characterize a site is to excavate the soil before treatment and final treatment pricing. At that point the true nature of the site will be apparent, and both the client and the technology vendor will better know what lies ahead. A considerable amount of time and effort was spent characterizing Site F, and despite millions of dollars spent, 15 of the 16 burial trenches were only identified during the excavation/treatment. Considerable client money could have been saved by taking fewer soil borings and excavating the site before committing to final remedial contract terms.

Performing under a Fixed-Price Contract

Fixed-price contracts are dangerous when the problem is difficult to define. By their very nature, disposal areas will tend to include materials which nobody wanted to see again. The unearthing of these surprises can lead to undesired change orders, require on-the-fly plant modifications, and possibly lead to unfulfilled goals. Changed conditions should be anticipated in the contracting mechanism. Productivity can remain high if the contract is structured so that remediation can continue while details of changed conditions are worked out.

Facilities should make every effort to debrief employees on disposal practices during their employment.

Chemical Company versus Remedial Contractor Perspective

COGNIS is a company made up of people who have been commercializing chemical technologies for over 25 years. This background helped COGNIS continuously improve the process throughout the job duration, so that the level of metal removal increased steadily over the course of the project. Chemical companies measure their success in terms of productivity, not billability.

Don't Lose Valuable Historical Information

Facilities should make every effort to debrief employees on disposal practices during their employment. Thirty years later, a considerable amount of detective work must be done to try to second-guess likely actions. Somehow, the employer should provide immunity from prosecution to encourage the full disclosure of information. Once that source of history is gone, excavation efforts will be inefficient and processing costs will be higher than necessary because of unexpected surprises in the feed soil.

The COGNIS/Bescorp soil washing/TERRAMET® soil leaching process was an example of the client, the regulator, and the technology vendor all aiming for a common goal—completing metal-contaminated soil treatment with no hazardous waste generation for off-site disposal. Under these conditions, innovative technologies can succeed on their first full-scale demonstration. The TERRAMET® process was shown to be uniquely applicable on projects where the land will have high reuse possibilities or where human exposure pathways are high, the treatment goals are very strict, and a permanent solution with minimal liability is desired. ■

NOTES

1. "Cleaning Up the Nation's Waste Sites: Markets and Technology Trends," U.S. EPA, Office of Solid Waste and Emergency Responses, EPA Doc. No. EPA/542R/R-92/012, Washington, DC, 1993.

2. Dumont, E., EP 291,746 (1988).

3. Deconta A.G., EP 72,885 (1982); Wallbank, P., Barckman, C., Piske, G., DE 3,703,922 (1987); Siemans A.G., EP 278,328 (1988); Weber, M., EP 402,737 (1990).

4. Raghavan, R., Coles, E., Dietz, D. "Cleaning Excavated Soil Using Extraction Agents: A State-of-the-Art Review," U.S. EPA, Res. Dev. [Rep.] EPA-600/2-89/034, 1988.

5. Basu, T.K., Selvakumar, A., Gaire, R., Royer, M.D. "Selection of Control Technologies for Remediation of Lead Battery Recycling Sites," Report by Foster Wheeler Envirosponse, Inc., Contract No. 68-C9-0033, RREL, EPA, Cincinnati, Ohio; Rayford, R., Evangelista, R., Unger, R., "Lead Extraction Process," *Draft Report to EPA*, Contract No. 68-03-8255, U.S. EPA, Emergency Response Branch, Edison, New Jersey, 1986; U.S. EPA, "Engineering Treatment Forum Technical Assistance Report: Lead Battery Reclamation Sites," EPA/600/X-88/242, Haz. Waste Res. Eng. Lab., Cincinnati, Ohio, 1988.

6. Barth, E.F., Traver, R.P., "Treatment of Lead Battery Contaminated Soil Utilizing Soil Washing and Solidification/Stabilization Technology," Proc. 1990 EPA/A&WMA Int. Symp., Haz. Waste Treatment: Treatment of Contaminated Soils, Cincinnati, Ohio, 1990.

7. Schmidt, B.W., "Assessment of Treatment Techniques at Superfund Battery Sites," Int. Symp. Haz. Waste Treatment: Treatment of Contaminated Soils, Cincinnati, Ohio, 1989.

8. Id.

Section 6
References

Brinkmann Instruments. 1996. Telephone Conversation Regarding Retsch/Brinkmann ZM-1 Grinder. Between Joseph Plurad and Pinaki Banerjee, PRC Environmental Management, Inc. (PRC). March 18.

COGNIS, Inc. (COGNIS). 1996. Letter from William E. Fristad, COGNIS to Pinaki Banerjee, PRC. Dated April 5.

Evans, G.E. 1990. "Estimating Innovative Technology Costs for the Superfund Innovative Technology Evaluation (SITE) Program." *Journal of Air Waste Management Association*. Volume 40, No. 7. July.

Federal Cartridge Company. 1994. David Fuller. Facsimile Regarding Electrical Usage by Soil-Treatment Activities at the Twin Cities Army Ammunition Plant (TCAAP). Sent to Jeff Swano, PRC. December 13.

General Testing Corporation. 1993. Pricing Policy. August 1.

Gopher Smelting. 1995. Telephone Conversation Regarding TCAAP Lead Disposal Costs. Between John Tapper, Plant Manager, and Jeff Swano, PRC. April 18.

R.S. Means Company, Inc. 1994. *Means Heavy Construction Cost Data*. 8th Annual Edition.

U.S. Environmental Protection Agency (EPA). 1988. CERCLA Compliance with Other Laws Manual: Interim Final. EPA/540/G-89/006. August.

EPA. 1991a. Test Methods for Evaluating Solid Waste, Volumes IA-IC: Laboratory Manual, Physical/Chemical Methods; and Volume II: Field Manual, Physical/ Chemical Methods SW-846, Third Edition. Office of Solid Waste. EPA Document Control No. 955-001-00000-1. With Subsequent Technical Additions. Revision 1. July.

EPA. 1991b. Technical Support Documents on Lead. ECAO-CIN-757. January.

EPA. 1994a. "Applications Analysis Report of the BESCORP Soil Washing System for Lead Battery Site Treatment." November.

EPA. 1994b. "Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children." EPA/540/R-93/081. February.

EPA. 1994c. Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities. OSWER Directive Number 9355.4-12. July.

Wenck Associates, Inc. (Wenck). 1995a. TCAAP Site F Soil Washing/Soil Leaching Technology Evaluation Draft Report. September.

Wenck. 1995b. Personal Conversations Between Bill Johnsen and Matt Bower, Wenck, and Pinaki Banerjee, PRC.

Wenck. 1995c. Letter Regarding TCAAP Site F Data Request. From William P. Johnsen, CPG. To Pinaki Banerjee, PRC. April 7.

United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268

Please make all necessary changes on the below label, detach or copy, and return to the address in the upper left-hand corner.

If you do not wish to receive these reports CHECK HERE ☐; detach, or copy this cover, and return to the address in the upper left-hand corner.

BULK RATE
POSTAGE & FEES PAID
EPA
PERMIT No. G-35

Official Business
Penalty for Private Use
$300

EPA/540/R-96/535