DEMONSTRATION SUMMARY

STORAGE AREA 413
NAVY SUPPORT ACTIVITY
MECHANICSBURG, PENNSYLVANIA

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LIST OF ACRONYMS

ASTM	American Society for Testing and Materials
AASHTO	American Association of State Highway and Transportation Officials
CALTRANS	California Department of Transportation
CFR	Code of Federal Regulations
cm/sec	Centimeters per second
DoD	U.S. Department of Defense
DoE	Department of Energy
EPA	U.S. Environmental Protection Agency
ESTCP	Environmental Security Technology Certification program
ITS	Initial Treatability Study
LFR	Levine Fricke
mg/l	milligrams per liter
NSF	National Science Foundation
NSA	Naval Support Activity
PADEP	Pennsylvania Department of Environmental Protection
PAH	Polynuclear Aromatic Hydrocarbons
RCRA	Resource Conservation and recovery Act
SSO	Site Safety Officer
TCLP	Toxicity Characteristic Leaching Procedure
UTS	Universal Treatment Standards

EXECUTIVE SUMMARY

The contamination of metals in soil has created a large backlog of sites awaiting remediation at Navy installations. At many of these sites, soil fails the federal leachability hazardous waste determination. As a result, it must be handled and disposed of by following a strict set of protocols. Previous remedial efforts have consisted of excavating the affected soil, transporting it to a hazardous waste landfill, treating it to meet Universal Treatment Standards, placing it in the landfill, followed by a lengthy period of monitoring. The administrative burden of hazardous waste disposal is enormous since the generating entity responsible for its disposal has to obtain a series of local, state and federal permits as well as fees per ton of soil disposed. Usually, the legal liability of the generator does not terminate with the soil disposal. As result, the costs of disposal of soil as hazardous waste are exceedingly high with current estimates ranging from $200 to $400 per ton of soil disposed. This cumbersome process makes it imperative that the Navy evaluate more economical, in situ, hazardous waste treatment and disposal alternatives.

The Navy's Environmental Security Technology Certification Program supported an evaluation of the Encapco patented asphalt and pitch emulsion soil stabilization technology to treat, stabilize and recycle contaminated soil into a product that, among other uses, can be utilized as road construction base. One demonstration project was conducted at Naval Support Activity (NSA) Mechanicsburg installation where approximately 500 tons of soil contaminated with inorganics were treated and converted into a product utilized as the base for a proposed expanded parking lot.

Sampling data obtained post treatment and placement of the soil proved that the recycled product does not exceed the federal toxicity characteristic leaching procedure (TCLP) for characterization of hazardous waste and is thus free of any post application Resource Conservation and Recovery Act (RCRA) monitoring requirements.

The cost assessment performed for this demonstration project demonstrates that utilization of the patented Encapco process is substantially more cost effective than disposing of the soil as hazardous waste in a permitted landfill.

1.0 INTRODUCTION

The United States Department of the Navy is faced with the assessment and remediation of many sites contaminated with a variety of inorganic compounds, including lead. When a contaminant release occurs, inorganic compounds may be present in any or all of three phases: adsorbed to soil, in free-phase form or dissolved in groundwater. Soil contaminated with lead is of great concern due to its toxicity and the potential to leach and contaminate drinking water sources.

Lead, used primarily for ammunition, comprises one of the most common soil contaminants found in federal installations. Lead may mobilize from soil when lead-bearing soil particles run off to surface waters during periods of heavy precipitation. Lead may also mobilize from soil to atmosphere by downwind transport of smaller lead containing particles entrained in the prevailing wind. The latter process may be an important contributor to the atmospheric burden of lead around sites with high levels of lead in soil (ASTDR, 1997).

The U. S. Navy's Environmental Security Technology Certification Program (ESTCP) supported several demonstration projects of Encapco's patented asphalt and pitch emulsion soil stabilization technology to treat, stabilize and recycle contaminated soil. Naval Support Activity (NSA) Center Mechanicsburg (Storage Area 413) was one of the three eastern sites selected as the demonstration for a variety of reasons: (1) due to former storage activities, NSA Mechanicsburg had the potential of significant contamination of soil; (2) previous studies performed by Encapco demonstrated that the process could be successfully applied to treat levels of contaminants found at the site; and (3) the U.S. Department of the Navy expressed interest in the technology.

The purpose of this demonstration was to evaluate the effectiveness and cost associated with the Encapco process for treating lead and zinc contaminated soil. The demonstration serves to disseminate new information about the patented Encapco process and to assist DOD environmental managers with the task of evaluating remedial proposals for soil contaminated with inorganic compounds. The following were specific project objectives:

- Evaluate lead and zinc levels in the surface soil;
- Determine a suitable emulsion design for the clayey soil conditions at the site;
- Evaluate the ability of the emulsion design in reducing lead and zinc leaching from treated soil to below leachability standards; and
- Estimate costs and compare them with the costs of traditional soil disposal at a hazardous waste landfill.

The regulatory drivers for management and disposal of soil contaminated with metals are driven mainly by the Resource Conservation and Recovery Act (RCRA) and its applicable Toxicity Characteristic Leaching Procedure (TCLP) concentrations which are the criteria utilized to determine whether a waste containing metals is hazardous or not. Additionally, States may impose supplemental criteria depending on site specific and risk management situations.

At the Naval Support Activity (NSA) Mechanicsburg demonstration site, surface soil in Area 413, a former lead and zinc ingot storage area, was selected to test the effectiveness of the Encapco process. Pre-demonstration soil assessment activities determined that soil contained a high amount of clays. Laboratory analyses determined that surface soil was contaminated with lead and zinc exceeding human health residential and industrial exposure levels. Subsequent toxicity characteristic leaching procedure (TCLP) results confirmed that soil was determined to be hazardous by characteristic due to its leachability.

Encapco conducted laboratory-scale tests on hazardous waste soil and a series of emulsions created from asphalt, tall oil pitch, water, surfactants and additives were selected to enhance the immobilization of the inorganic compounds. Upon selecting an appropriate ratio of the above compounds, Encapco and NSA Mechanicsburg decided to implement the process on approximately 1,000 tons of soil excavated from Ingot Storage Area 413. Due to favorable field conditions, the original soil mass was reduced to approximately 500 tons.

Soil samples obtained before and after treatment confirm that the Encapco asphalt-based emulsion process was shown to effectively treat soil to non-hazardous levels and to be able to use the treated soil and asphalt as road base construction material. Analytical and physical data collected from this field demonstration will provide information for future use of this technology at this and other Navy and Department of Defense (DoD) facilities.

The cost evaluation of the Encapco asphalt emulsion soil stabilization process indicates it is more cost-effective than to excavate, transport and dispose the soil at a hazardous waste landfill. As long as the asphalt is undisturbed, the only recurring cost expected is occasional maintenance of the wearing course of the pavement, a typical activity required for any paving surface.

2.0 TECHNOLOGY DESCRIPTION

Asphalt-based emulsions have been used extensively in the construction industry to stabilize roadway base material and surface soil for dust control. These same emulsions have been modified to encapsulate soil contaminated with heavy metals (Conway et al., 1993; and Hubbard et al., 1990). Asphalt processes, both cold and hot mix, have successfully treated petroleum and mercury contaminated soil (Tarefder et al., 2001; and EPA, 1998). In July 2000, the U.S. EPA issued a determination that the Encapco process qualifies as recycling under Resource Conservation and Recovery Act (RCRA) characteristic waste and should be considered a preferred technology and/or response action for sites with similar characteristics (EPA, 1997, 2000; and Warminsky, 2003). The incorporation of petroleum-contaminated soils into asphalt for reuse is becoming more common; however, the incorporation of metal contaminated soil is less common, possibly due to the fact that early process development did not use chemical stabilizers for the reduction of leachability from metals, instead relying strictly on encapsulation.

The Encapco emulsion stabilization process is a new process that uses chemical binders to permanently stabilize heavy metals by a mineralization process. The treated soil contains stable metal compounds that reduce the leaching of metals.

Organic emulsions consist of intimate mixtures of the organic base material, water and an emulsifying agent composed of a surfactant and a proprietary mix of binding material. The physical and chemical properties of the emulsion depend on the emulsifying agent's chemical type and molecular structure. When the emulsifying agent is mixed with asphalt and water, its molecules align with those of the organic and water to form an emulsion with a negative (anionic) or positive (cationic) surface charge. The presence of charged chemicals in the emulsion improves the adhesion of asphalt to aggregate over the adhesion that occurs in asphalt concrete. The surfaces of an aggregate carry a charge; if this charge is opposite that of the emulsion, a stronger bonding will take place (Doyle, et al 2003). After given sufficient time to set and cure, the resulting solid asphalt has the waste uniformly distributed and has a relatively low hydraulic conductivity.

2.1 TECHNOLOGY DEVELOPMENT AND APPLICATION

Encapco's patented emulsion recycling is a process that converts contaminated soil into construction products such as asphalt cold mix, asphaltic concrete, low-permeability landfill liner or cap material and stabilized road base material. The recycling process combines water-based asphalt, setting agents and other proprietary reagents with contaminated soil and transforms the resulting mixture into a highly stable, non-leaching material that can be used for construction. Asphalt emulsion recycling is applicable to soil that is contaminated with heavy metals, polynuclear aromatic hydrocarbons (PAH), creosote, crude oil, diesel fuel, and other organics. For its application for heavy metals contaminated soil, the emulsion process includes the use of additional reagents to chemically fix the metals by mineralizing them into stable, non-leachable phases thus reducing their solubility in the final construction material.

The Encapco technology for the remediation of contaminated soil was patented in 1999 under U.S. Patent No. 5,968,245. In the treatment of lead and zinc-contaminated soil, the soil is mixed with the asphalt emulsion, which then coalesces and encapsulates the soil particles. If hydrocarbons are present in the soil, they are preferentially absorbed into the organic phase. The result is a blending of the contaminant with the asphalt into an asphalt emulsion that is chemically enhanced to bind and stabilize the target contaminants. As the asphalt emulsion coalesces, cures, and solidifies and with the addition of fixating chemicals, soluble metals in the soil can be chelated or mineralized into insoluble compounds hence permanently immobilizing the metals within the emulsion mix. A typical emulsion formulation is provided in Table 1.

Table 1. Typical Emulsion Formulation

Material	Volume
Asphalt	50%
Non-Ionic Surfactant	2%
Water	42%
Proprietary Additives	6%

The specific mineralogy of the compounds formed depends upon the additives used. In addition, to reduce curing times and optimize mixing and strength characteristics, lime, cement or other additives may also be added to the emulsion mix. The product is then put into place and, upon curing, retains the adhesive, durability, and water-resistant properties of the organic base from which it was produced. The characteristics of a soil dictate the type of product that can be produced. Sandy, silty, and cobbly soils are generally more suitable for recycling into road construction products. Conversely, clay-rich soils are most cost effectively recycled into a low permeability liner or cap material. Drying of the soil by adding quicklime or adding soil or rock aggregate can be used to supplement a clayey contaminated soil to improve the structural properties of the treated product. Based on soil characteristics, an emulsion and reagent mix design is developed to meet the stability, strength, and permeability requirements of the specific product application and target contaminant leachability levels.

2.2 PROCESS DESCRIPTION

Encapco's stabilization method can be implemented either ex-situ or in situ. Tasks associated with the operation of the Encapco process are relatively simple and require minimal operator experience. A total of four field persons are necessary to effectively operate the treatment process. Figure 1 presents a simplified process flow diagram of a typical Encapco process.

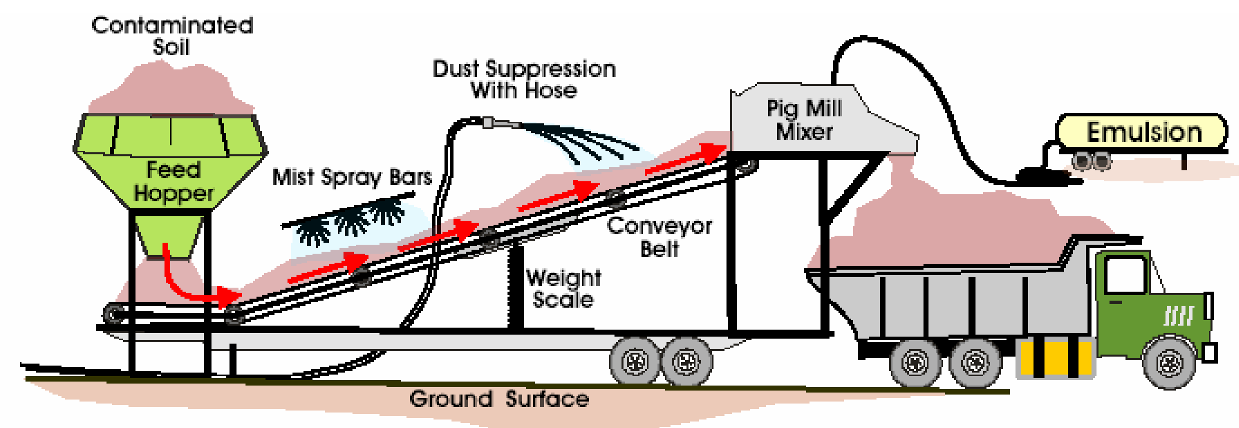

Figure 1. Schematic of Encapco Treatment Process

The equipment involved in soil excavation for ex-situ treatment process is readily available and consists of a loader, a backhoe and/or a bulldozer. Soil to be treated is excavated and stockpiled in an exclusion zone where runoff is controlled. A feed hopper is used to supply excavated soil and a tanker truck is used to hold the asphalt emulsion. A pug mill is then used to blend and thoroughly mix the soil and emulsion. An array of spray mists and hoses are used for dust control. After treatment, the final product is a recycled structural material comprised of the original contaminated soil and emulsion. This material can then be used as sub-base/base for most paving construction purposes carried out in situ or can be transported to another paving job site.

2.3 PREVIOUS TESTING OF THE TECHNOLOGY

The technology is applicable to sites that have soil contaminated with a variety of compounds. Inorganic contaminants previously tested include arsenic, lead, uranium, zinc and other inorganics. Various treatability tests and two full-scale projects have been performed in California. One full-scale project involved treating a hydrocarbon-contaminated soil with the asphalt based emulsion and its end use as a road construction material in conformance with recycling regulations (Harding Lawson & Associates, 1994). The second, which involved lead contaminated soil, was for the California Department of Transportation (CalTrans) on an Interstate 80 Highway Project. Approximately 11,000 tons of lead contaminated soil were excavated and treated with the emulsion technology. In both cases, the recycled product met project specifications.

As part of this Navy demonstration program, treatability tests have been completed on PCB-affected soils from Camp Pendleton. In that case, the process reduced the solubility of PCBs in these soils by 30% to 70% (Encapco 2002). The Encapco process is also being tested on radionuclide contaminated sites at two DoD facilities in New Mexico and Arizona and one Department of Energy (DoE) facility in Nevada. The radionuclides targeted for stabilization consist of plutonium (Pu), americium (Am), and thorium (Th). The technology has been successful in treating depleted uranium (DU) contaminated soil in the laboratory for the U.S. Army (Encapco 2000).

2.4 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The Encapco technology has the following main advantages:

- Demonstrated capability to reduce the mobility of inorganics in soil by blending with emulsified asphalt so that the end product has optimum re-use capabilities as a construction material.
- Cost, onsite remediation and/or recycling, process speed relative to other treatment technologies, conversion of an onsite liability to an onsite asset and elimination of hazardous waste generator liability through conversion of waste to a product. Cost

comparisons relative to other treatment options are detailed in the aforementioned Hunter Liggett report. Similarly, the aforementioned CalTrans project generated savings to project participants over conventional waste disposal techniques exceeding one million dollars.

- In many areas where aggregate materials are not locally available and must be imported, the cost savings from recycling contaminated soils, which would otherwise not be useable, can be substantial. Recycling of contaminated soils can reduce the time that land remains non-productive. Further, these recycled soils can be used as structural fill or replace other base materials, such as untreated granular base, sub-base, cement-treated base or bituminous-treated base in roadway construction.
- A technological solution that converts a potential hazardous source of environmental liability into a re-usable product that can meet Federal non-hazardous leachability standards and the RCRA (Resource Conservation and Recovery Act) recycling exemption.
- Reduced health and environmental risks as well as elimination of potential liability when compared with simply excavating and disposing the soil at a hazardous waste landfill.

The application of the technology and the data collected thus far indicate that the Encapco process has very few limitations in its application or scalability to full-scale field operation. The fact that a pre-treatment evaluation is conducted to produce an appropriate emulsion formulation greatly limits the possibility of obtaining false-positive data. In spite of this, the Encapco process may be limited by the following considerations:

- Subject to site-specific treatability and design work, it is possible that contaminant concentrations could exceed the technology's ability to meet federal and state statutory criteria for disposal of hazardous wastes. In those rare cases where regulatory criteria are not directly applicable, site-specific negotiations for the management and disposal of contaminated soil should be undertaken with the applicable regulatory agencies.
- Use of this technology may require long-term tracking of the treated soils so future demolition or reconstruction of the area where treated soils were used is managed properly.

3.0 DEMONSTRATION DESIGN

3.1 PERFORMANCE OBJECTTIVES

To determine whether a waste exhibits a RCRA toxicity characteristic, it is necessary to determine whether threshold toxicity characteristic leaching procedure (TCLP) concentrations listed in 40 CFR 261.24 are exceeded. If the threshold TCLP value is exceeded, then the waste is classified as hazardous waste and strict protocols must be adhered to for management, treatment, and disposal at a commercial hazardous waste landfill. Prior to disposal, soil must be treated to levels below TCLP concentrations, and if the treated soils meet Universal Treatment Standards (UTS), the soil may qualify as a recycled Hazardous Waste and be exempt from further RCRA regulation. In addition, and for purposes of this demonstration, the Marshall asphalt mix design method would be utilized to evaluate the suitability of the asphalt emulsion mix as a potential base material. The method was developed approximately 50 years ago and has been adopted as the standard mix design test method for the majority of state highway agencies. Standard Marshall methods have been published by both the American Society of Testing and Materials (ASTM) and by the American Association of State Highway and Transportation Officials (AASHTO).

The Encapco technology performance objectives are detailed in Table 2.

Table 2. Performance Objectives

Type of Performance Criteria	Description	Expected Metric	Primary or Secondary
Contaminant Mobility	Reduce Contaminant Mobility	Must be below federal TCLP criteria	Primary
Contaminant Reduction	Meet Universal Treatment Standards	Lead = <0.75 mg/l TCLP Zinc = <4.3 mg/l TCLP	Primary
Material Use	Reduce Permeability and Increased Resistance to Flow	As determined by ASTM D1599 and D3637	Secondary

3.2 SELECTION OF TEST SITE

Encapco subcontractor personnel (LFR Levine·Fricke) conducted a site visit at NSA Mechanicsburg, Pennsylvania on June 11, 2002. The purpose of this site visit was to meet with Navy personnel to determine which area of the facility would be suitable for conducting the proposed Encapco process field demonstration. Upon review of site investigation information, conversations with Navy personnel, and the performance criteria presented in section 3.1, Encapco and the Navy agreed that Storage Area 317 would be an appropriate location for the proposed process field demonstration. Subsequently, and due to the proposed expansion of an existing parking lot, the Navy requested to move the location to Area 413.

A previous site investigation around Storage Area 413 verified lead and zinc contamination in surface soils at concentrations of up to 20,400 milligrams per kilogram (mg/kg) and 3,720 mg/kg respectively (EA Engineering Science, 1990). In addition, TCLP data from one soil sample collected during Encapco's site visit in June 2003 showed a concentration of 6.4 milligrams per liter (mg/l) of lead in the leachate, which would exceed the hazardous waste by characteristic threshold. Based on data presented in the investigation reports, it appeared that over 1,000 tons of soil contaminated with elevated levels of lead and zinc were present in Area 413. Lead and zinc were the only soil contaminants known to exceed human health exposure criteria in Area 413.

3.3 FACILITY HISTORY

Naval Support Activity (NSA) Mechanicsburg is located in Mechanicsburg, Pennsylvania. It was commissioned as an inland supply depot to support Navy operations worldwide during World War II. The primary mission of NSA Mechanicsburg is to procure, store and maintain certain strategic and critical materials important to the Navy's national defense mission. The facility is home to numerous commands such as the Naval Inventory Control Point which manages the inventory control for a broad range of goods and services used in ships, submarines, ship weapon systems, naval aircraft, and aircraft weapon systems. Another important tenant unit is the Navy Ammunition Logistics Center responsible for maintaining a ready supply of lead and zinc destined to become part of the U.S. Navy's ammunition. NSA Mechanicsburg has served as a repository for 90,000 tons of lead and zinc ingots. As part of activities at the facility, pure lead and zinc ingots were stored outdoors since the early 1950's in four storage areas numbered 317, 413, 414, and 606 (Figure 2). This practice left the ingots exposed to decades of weathering, resulting in surrounding soil being contaminated with lead and zinc. The ingots were removed from all outdoor storage areas in 2002 and placed in covered warehouses.

3.4 INITIAL TREATABILITY STUDY SUMMARY

This section summarizes the results of the Initial Treatability Study (ITS) conducted on a soil sample collected from Storage Area 413. The purpose of the ITS was to provide Encapco personnel with sufficient data to determine whether an effective emulsion design could be developed with the given soil and contaminants, and if so, what treatment levels were possible. In October of 2002, Encapco personnel conducted a site visit at Area 317 of the facility. During this site visit, seven soil samples were collected and submitted for analysis using USEPA Method 6010 for lead and zinc and US EPA Methods 1311 and 6010 for TCLP analysis. The maximum concentration of total lead and zinc detected in the soil samples were 3,000 and 1,200 mg/kg, respectively. The maximum TCLP result was 6.4 mg/l. Untreated composite soil subsamples were then collected and treated with the emulsion and analyzed for TCLP. The concentrations of lead and zinc were 0.4 mg/l and 0.75 mg/l, respectively. Both levels are below the hazardous waste determination by characteristic Universal Treatment Standard. Grain size analysis indicated that the soil was classified between a silty and a clayey gravel.

As result of the U.S. Navy's requirement to extend an existing parking lot, and to utilize the treated soil as asphalt road base, the ITS was switched to Area 413 where a similar pre-treatment process was followed. Based on the two pre-treatment results, Encapco concluded that its emulsion-based treatment technology would be capable of meeting the treatment objectives.

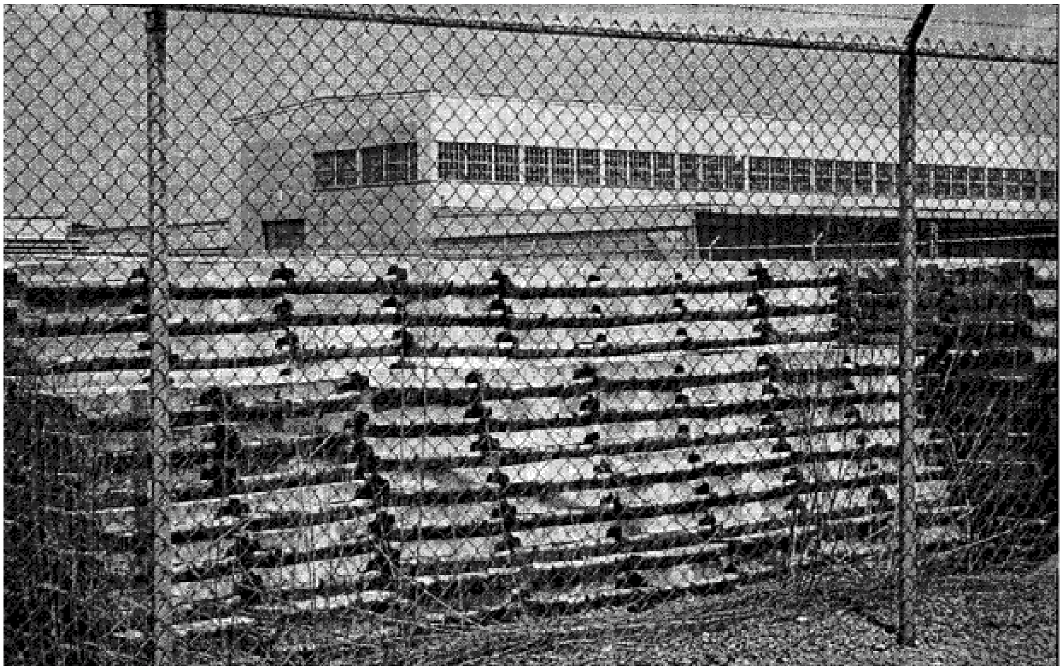

Figure 2. Previous Storage of Lead and Zinc Ingots at NSA Mechanicsburg

Figure 3. Soil Excavation and Screen Process

3.5 SUMMARY OF THE SUPPLEMENTAL SOIL ASSESSMENT

In June 2003, the Pennsylvania Department of Environmental Protection requested that the U.S. Navy conduct a supplemental assessment at Area 413. To comply with this request, a total of 20 clayey soil samples plus additional QA/QC samples were obtained and analyzed for TAL metals. Initial samples collected at 1 foot below ground surface (bgs) indicated that lead and zinc levels were below applicable criteria; therefore, subsequent soil samples were collected at the surface and at 4 inches bgs. The locations are shown on Figure 4. As result of soil lead levels being below applicable criteria at 1-foot bgs, the initial treatment's soil mass estimate of 1,000 tons was reduced to approximately 500 tons. The data presented in Table 3 shows that excavating to an approximate depth of four inches into the clayey soil removed most of the soils impacted with levels of metals deemed unsuitable for human contact.

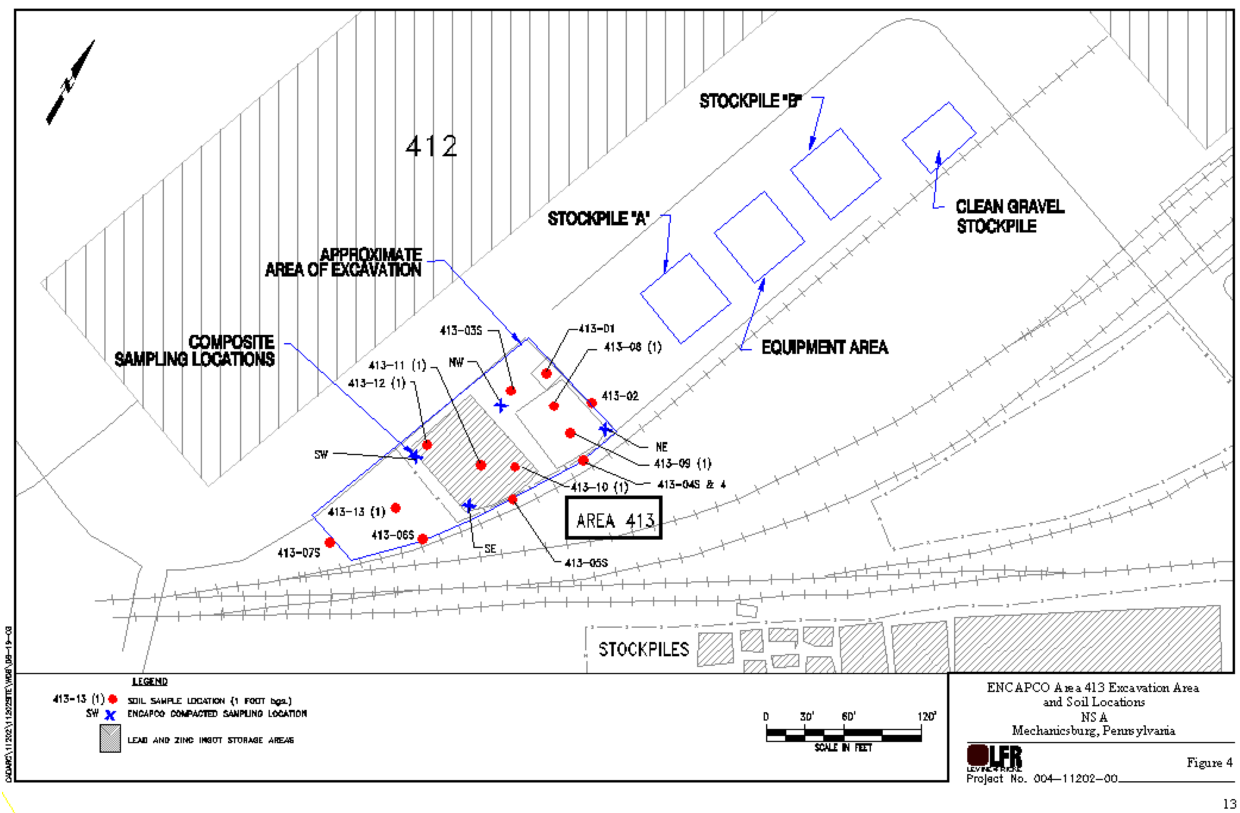

Figure 4. Soil Excavation and Screen Process

Table 3. Excavation Confirmatory Sample Results

Sample	Lead (mg/kg)	Zinc (mg/kg)	Arsenic (mg/kg)	Chromium (mg/kg)
413-03 Surface	43	73	14	25.1
413-04 Surface	603	567	42	12.3
413-04-4”	32	85	21	65
413-05-4”	28	60	17	35
413-05 Surface	4870	162	25	6.9
413-05-4”	28	60	17	35
413-06-Surface	152	65	8	12.1
413-07-Surface	80	204	31	15.3
413-08-4”	24	72	19	44.7
413-08-1 foot	31	99	19	43.1
413-09-4”	42	94	14	53
413-09-1 foot	54	67	14	33
413-10-4”	30	65	9	34.3
413-10-1 foot	30	57	17	31
413-11-4”	51	77	7	18.4
413-11-1 foot	86	71	11	21
413-12-4”	17	51	5	19.9
413-12-1 foot	102	70	14	39
413-13-4”	34	612	11	45.3
413-13-1 foot	30	62	14	27.2

Soil analyses by U.S. EPA Method 6010.

3.6 FIELD ACTIVITIES AND PERIOD OF OPERATION

Encapco subcontracted with an environmental construction/contractor (Heritage Industrial Services) to implement the field demonstration, which lasted from October 6 through October 17, 2003. The initial fieldwork consisted of excavating approximately 700 tons of soil (Figure 3). After passing the soil through a screen and removing pieces of soil and gravel greater than one inch, approximately 500 tons of lead and zinc contaminated soil were deemed suitable for processing.

Following excavation, the soil was placed in a temporary stockpile and quicklime was added to remove excess moisture. Subsequently, a tanker truck delivered the patented Encapco emulsion which was mixed with the soil in a pug mill (Figures 5 and 6). The liquid emulsion was delivered to the job site at a temperature not exceeding 120°F was proportioned and mixed at a temperature between 90°F and 120°F. The quantity of water added to the mixture was adjusted to produce the optimum moisture content of the soil (Encapco, 2003).

As the soil was mixed, and following the accepted scope of work, a total of 10 pre- and post-treatment grab samples were obtained from the first 100-ton test run and at every 100-ton batch thereafter to provide data on the performance of the process. The samples were submitted for total lead and zinc and TCLP analysis.

Upon mixing, the soil was placed in a second temporary stockpile, covered with visquene and the plans to use the asphalt mix as parking lot sub-base/base were implemented. The treated soil was laid down in the excavated area in 8-inch lifts and compacted with an 8-ton Ingersoll-Rand smooth wheel compactor. After compaction was completed, Encapco collected four treated in-place soil samples from the compacted sub-base/base. The samples were analyzed using USEPA Method 6010 for total lead and zinc and 1311/6010 for TCLP lead and zinc concentrations. Figure 6 shows the treated soil being used as sub-base/base and awaiting compaction and surfacing.

Figure 5. View of Pug Mill and Emulsion Tanker Truck

Figure 6. View of Treated Soil Awaiting Compaction and Surfacing

4.0 PERFORMANCE ASSESSMENT

The performance assessment of the demonstration project was based on an authoritative set of parameters. The primary performance criterion was to verify the structural material's reduced contaminant mobility and leachability by subjecting the Encapco process grab samples to RCRA TCLP analysis. Supplemental criteria were to evaluate the permeability of the emulsified treated base as well as its stability and flow under heavy loads. The purpose of the last test is to compare the suitability of the structural material as a base for paved roads subject to heavy load traffic.

4.1 PERFORMANCE DATA

The demonstration produced comparison data to support the effectiveness of the Encapco process. A summary of pre- and post- soil treatment levels is provided in Table 4. The table shows total and TCLP lead concentrations determined for each of the five 100 ton batches. The possible explanation for obtaining TCLP concentrations below applicable standards before treatment is that quicklime was added to the soil to reduce moisture. Quicklime likely increased the pH of the soil which resulted in the laboratory method not being able to extract sample leachate in spite of the treated sample being subject to an acidic fluid bath.

Upon completion of the soil mixing process, the asphalt treated soil was stockpiled on top of visquene and subsequently placed back in the excavation pit to be used as base material for the proposed parking lot. Compaction followed; however, before applying the final surface, solid matrix samples were obtained from four selected locations and subjected to Total Lead and Zinc using EPA Method 6010B and TCLP analysis using EPA Method 1311. Table 5 shows that in spite of lead and zinc being present in the compacted emulsified treated base, none of the four compacted samples exceeded TCLP concentration criteria for hazardous waste determination.

Likewise, specific asphalt material tests were carried out on the asphalt treated soil. The Marshall Test is used to establish the plastic flow of hot asphalt mixes subject to varying loads. The criteria employed to determine the suitability of an asphalt mix is for asphalt plastic flow not to exceed 0.010 to 0.020 of an inch for loads exceeding 700 inch-lbs. Table 6 shows the results of the Marshall test.

Encapco also collected treated soil samples for permeability tests using American Society for Testing and Materials (ASTM) Method D5084. This method measures the hydraulic conductivity of saturated porous materials using a falling head permeameter. The invasion of water into a pavement mix can adversely affect its durability. Hence, a high permeability, which results in percolation of water into the asphalt structure, usually results in asphalt cracking and surface raveling. Table 7 shows the results of permeability tests performed on the asphalt mix.

Table 4. Total and TCLP Lead and Zinc Concentrations in Pre and Post Treatment Batches

Samples	Pb (TCLP) mg/l	Pb Total mg/kg	Zn (TCLP) mg/l	Zn Total mg/kg
Before				
1st 100-ton test run	18.7	2750	< 0.33	111
2nd 100-ton batch	< 0.11	838	< 0.33	111
3rd 100-ton batch	0.227	932	< 0.33	113
4th 100-ton batch	< 0.11	673	< 0.33	118
5th 100-ton batch	< 0.11	926	< 0.33	150
After				
1st 100-ton test run	0.321	2100	< 0.33	93
2nd 100-ton batch	0.454	830	< 0.33	136
3rd 100-ton batch	< 0.11	953	< 0.33	145
4th 100-ton batch	< 0.11	839	< 0.33	127
5th 100-ton batch	< 0.11	800	< 0.33	115

Detection Limits:
Total Lead = 1 mg/kg Total Zinc = 2 mg/kg
TCLP Lead = 0.11 mg/l TCLP Zinc = 0.33 mg/l
Performance Criteria: Pb< 0.75 mg/l; Zn < 4.3 mg/l

Table 5. Total and TCLP Lead and Zinc Concentrations on Compacted Samples

Sample ID	Pb (TCLP) mg/l	Total Pb mg/Kg	Zn (TCLP) mg/l	Total Zn mg/Kg
Northwest	< 0.11 mg/l	746	< 0.33 mg/l	115
Northeast	< 0.11 mg/l	742	< 0.33 mg/l	121
Southwest	< 0.11 mg/l	761	< 0.33 mg/l	105
Southeast	< 0.11 mg/l	789	< 0.33 mg/l	130

Detection Limits:
Total Lead = 1 mg/kg   Total Zinc = 2 mg/kg
TCLP Lead = 0.11 mg/l TCLP Zinc = 0.33 mg/l
Performance Criteria: Pb< 0.75 mg/l; Zn < 4.3 mg/l

Table 6. Marshall Test Results

Marshall Test @ 60 degrees C	Load inch-pounds	Flow hundreths of an inch
100 ton test run sample	234/214*	**
300 ton batch sample	4044	19
500 ton batch sample	2507	15

Stability was low. It appears no cement was added to the test run.
** could not be determined
Performance Specifications: Load: >700 lbs
Flow: 0.10-0.20 hundreths of an inch

Table 7. Permeability Test Results

Permeability (ASTM D5084)	centimeters/second (cm/s)
100 ton test run	$2.20x10^{-5}$
300 ton batch sample	$2.21x10^{-5}$
500 ton batch sample	$5.16x10^{-5}$

Performance Specifications: $< 1x10^{-5}$ cm/sec or one order of magnitude less than untreated soils

4.2 PERFORMANCE CRITERIA AND CONCLUSIONS

The data presented in the tables above provides a realistic comparison to evaluate the demonstration's objectives. The primary performance criteria of this demonstration was to determine the performance of the patented Encapco process in reducing lead and zinc contaminated soil from leaching into groundwater. The TCLP results shows that, in spite of lead and zinc being present in the solid matrix, the leachate obtained from the asphalt containing the treated does not exceed the RCRA hazardous waste by characteristic standard.

Since the treated soil can be used as construction material or road base, secondary performance criteria for this demonstration were to evaluate the Encapco technology/process for being able to meet or exceed commonly accepted asphalt testing performance parameters. While the first 100-ton test run was not able to meet the Marshall resistance to flow objective, it is likely that not enough cement was added to the first test run. According to personnel experienced in proportioning emulsion mixtures, it also appears that soils with a higher clay content need to have a larger fraction of cement added before treatment (Escobar, 2003). Subsequent tests performed on the 300 and 500-ton batch samples met or exceeded performance criteria for asphalt plastic flow under loads comparable to those found on roads subject to heavy traffic. Permeability data shows that the asphalt treated soil is slightly outside acceptable criteria. Since the flow of water in hot mix asphalt pavements occurs through interconnected air voids, it is likely that the percentage of air voids in the samples was higher than anticipated leading to the conclusion that the asphalt mix probably had a coarser gradation. The laboratories performing the total and TCLP metal analyses as well as specific ASTM analyses on the emulsified treated base (EBT) did not report data quality assurance and/or control issues.

On the basis of the laboratory results obtained, the following conclusions can be made:

1. The patented Encapco emulsified treated asphalt base process is an effective technology in encapsulating metal contaminants in soil. For soil contaminated with lead and zinc, the process can significantly reduce leachate concentrations to concentrations below enforceable standard.

2. While the Encapco process has been successfully demonstrated with soil containing a higher fraction of granular materials, the results of this demonstration proved that the process is suitable for soil containing a large fraction of fine-grained material such as clays.

3. Once the mixing process is completed, the emulsified treated base can be utilized as a recycled product whose applications vary from structural road base material, structural backfill, landfill caps or building pad construction. The specific asphalt laboratory tests confirm that subject to heavy loads, the asphalt flow complied with established standards.

5.0 COST ASSESSMENT

The cost of environmental remedial demonstration pilot projects have a tendency to be high on a per-unit cost basis since fixed costs such as mobilization/demobilization and equipment set up are generally constant for small as well as larger volumes of media to be treated and/or remediated. For the Mechanicsburg site, and since there are no scalability issues, the cost of utilizing the machinery used for this demonstration project would be the same whether 500 or 50,000 tons of soil were to be treated. However, in the classical definition of economies of scale, as production, or the volume of soil treated, increases, the per-unit cost decreases (cost of production). Possibly, at an as-yet not determined volume, the cost of treating soil approaches the per-unit cost of a ton of asphalt emulsion. To illustrate this concept, 500 tons of contaminated soil are used as the minimum quantity of soil that could be treated by the Encapco process and likely be more cost effective than transporting, pre-treating and disposing of the soil as a hazardous waste. As the volume of soil to be treated increases, the unit cost of treatment begins to assume an asymptotic curve, typical of volume vs. unit cost projects (Figure 7).

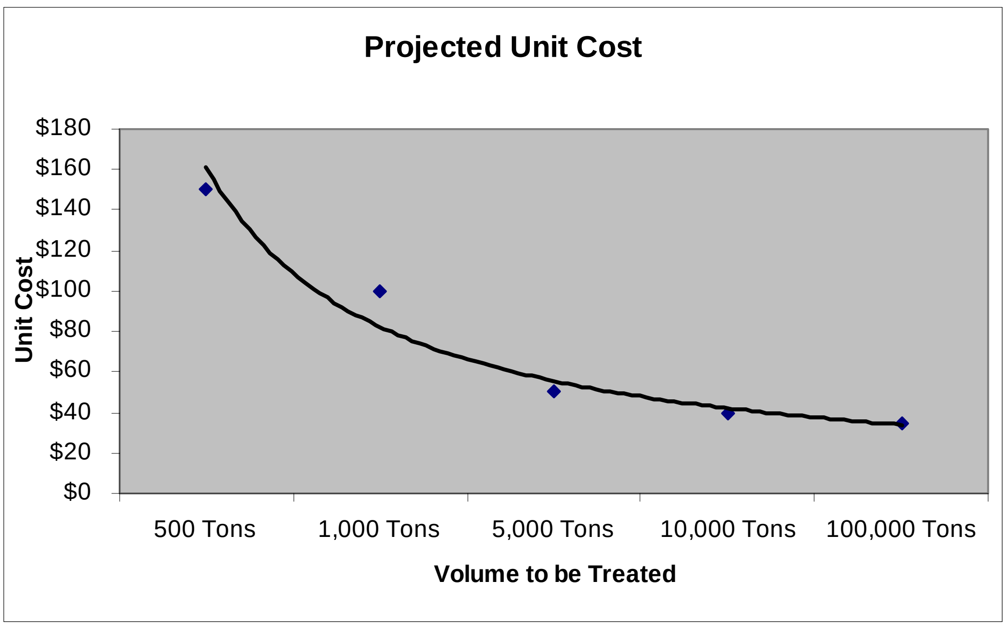

Figure 7. Expected Reduction Costs

In reporting costs below, costs that would stay constant, should a large volume of media be treated, have been omitted. The per-unit cost reporting is the quotient of variable costs divided by the output.

5.1 COST REPORTING

The reported unit costs per ton are shown in Table 8.

Table 8. NSA Mechanicsburg, PA. Demonstration Costs

Task Description	Cost ($)
Treatability Study	5,800.00
Mobilization/Demobilization	5,878.92
Site Preparation and Excavation	11,811.36
Load, Screen, and Treat Soils	11,651.75
Backfill and Site Restoration	1,171.16
Labor, Overhead, and Profit	25,394.60
Asphalt	17,784.03
Total	**$79,491.82**
Output	**500 tons**
Unit Cost Per Ton	**$158.98**

5.2 COST ANALYSIS AND PROJECTION

Major cost drivers for the Encapco process include equipment charges (including capital rental equipment costs, equipment repair, maintenance, and fuel), labor, material (including the Encapco mixture), permitting, utilities location, location surveying, oversight, and work plan/report preparation.

A cost projection for applying the Encapco technology over a larger mass of soil is shown in Table 9. Assumptions made with regard to operating parameters, operating capacity factor, and feed/processing rate will affect the results of the economic projection. Other costs such as fuels/utilities are variable and can also affect the overall project cost. The projection was done for treating 7,000 tons of soil at a processing rate of 600 tons per day or approximately 12 days of 10 hours per day. Fixed Costs such as Site Screening, Treatability Study, Project Management Oversight, Data Evaluation, Work Plan preparation and Regulatory Interface are assumed to be consistent with charges made by Encapco's engineering subcontractor, Levine-Fricke, for a project of the same duration. Equipment costs are estimated from daily rates invoiced by Encapco's excavation subcontractor Heritage Industrial Services. For labor, it was assumed there would be four-full time employees assigned to the operation lasting a total of 14 days. Costs include living expenses and account for two extra days for travel/mobilization. Screening, loading, and running the soils through the pug mill are estimated based on invoices submitted by Heritage. Following commonly accepted practice, a 12% markup (7% overhead and 5% profit) is applied to mobilization, labor and equipment costs, screening, loading as well as treatment of soil.

It must be noted that the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) guidance on the preparation of Feasibility Studies recommends that estimated costs be assigned a percentage variable of +/- 30%; therefore, on a unit cost basis, the cost of treating 7,000 tons of soil can range from $30.30 to $56.27 per ton.

Table 9. Cost Projections for Treating 7,000 Tons

FIXED CAPITAL COSTS	$
Site Screening	3,000.00
Treatability Study and testing	6,000.00
Data Evaluation, Design, Workplan Preparation, Regulatory Interface, Permits, and Report Writing	20,000.00
Project Management and Required Oversight	18,000.00
EQUIPMENT Backhoe/Dozer/Loader Rental $660/day x 12 days Pug Mill Rental $500/day x 12 days Screen/Decon Equipment Pick UpTrucks (3 at $40/day)	 8,000.00 6,000.00 3,000.00 1,440.00
Encapco Asphalt Mixture 1,700 tons @ $20/ton Mobilization/Demobilization (includes equipment)	 35,000.00 6,000.00
VARIABLE COSTS	
Labor Cost 4-full time employees for 14 days @ $350/Day Load, Mix and Treat Soil @ $16/ton x 7,000 tons	 20,000.00 112,000.00
Markup	21,000.00
24 soil samples for TCLP @ $300/sample Fuel Costs ($150.00/Day x 12 days)	7,200.00 1,800.00

SUBTOTAL	**$276,500.00**
Contingency of 10%	**$27,000.00**
TOTAL	**$303,000.00**
Unit Cost per Ton of Treated Soil	**$43.00/Ton**

5.3 COMPARISON WITH SOIL DISPOSAL AS HAZARDOUS WASTE AND SOLIDIFICATION/STABILIZATION

This cost comparison presents costs assuming soil will be regulated as a RCRA hazardous waste. Costs associated with conventional soil excavation and disposal at a commercial hazardous waste landfill tend to be very high on a unit cost basis and are dependent on a variety of factors such as excavation depth and on-site stockpiling, facility fees and pre-treatment, state taxes, local taxes, generator fees, transportation and handling. Reviewed literature reports the cost of transportation and disposal of soil contaminated with hazardous waste levels of lead at approximately $200.00/ton although this cost does not account for soil treatment prior to landfilling. The Federal Remediation Technologies Reference guide estimates that costs for excavation and disposal of hazardous waste soil ranges from $270 to $460 per ton. This estimate includes excavation/removal, transportation, and disposal at a permitted facility. Although disposal costs can vary by approximately 30%, the range of unit cost of $250 to $400/ton associated with disposal of soil as hazardous waste appears to represent an accurate estimate that would cover not only disposal but also treatment prior to emplacement as well as applicable state and local fees and taxes.

While disposal of hazardous wastes at a permitted RCRA hazardous waste landfill remains an option, a more accurate comparison of the Encapco technology would be against a treatment method such as Solidification/Stabilization (S/S) which is designed to encapsulate a waste in order to restrict contaminant migration. S/S involves the use of (1) Portland cement; or (2) lime/pozzolans (e.g., fly ash and cement kiln dust) to reduce the leachability of the metal or inorganic. S/S remains as one of the top five source control treatment technologies at Superfund remedial sites and it is expected this trend will continue (EPA, 2000). Most of the contaminant groups treated by S/S are metals and out of a total of 235 projects where S/S was the final remedy, 200 were capping or on-site disposal. The following parameters were selected for comparison: Operational Time, Post-Cure Performance, Cost and regulatory issues.

According to the US EPA, operational time is defined as the period from when operations began (following design and installation) to the time the project was determined to be completed by the project manager. Assuming treatment of 760 tons (1,000 cubic yards) of waste, the average operations time for S/S projects was 1.1 months (EPA, 2000). In contrast, the Encapco emulsion treatment process operational time for 500 tons was much shorter. In the NSA Mechanicsburg case, the total time from when operations began, mixing, placement and demobilization lasted 11 days. The Encapco process is limited only by the capacity of the pug mill to blend the emulsion with the soil and the emulsion's availability. When compared with the Encapco process, S/S is at a disadvantage since the resultant product has to cure to meet Universal Treatment Standards. Quite the opposite, and based on pre-treatment analysis not counted as operational time, the Encapco product is ready for application as soon as processed in the pug mill.

The performance of S/S often is measured after the solidified material has cured. In general, the stabilized material complies with the TCLP standards. However, recent studies (Klich, et al.) have shown that cement-based wastes are vulnerable to the same physical and chemical degradation process as concrete and other cement-based materials (that is, in some situations have the potential to disintegrate over a period of 50 to 100 years). In contrast, and as verified by laboratory testing, the result of the Encapco process is a hydrophobic product with a very low hydraulic conductivity.

The U.S. EPA has reviewed the cost of using S/S to treat wastes at 29 completed Superfund remedial sites. The average cost per cubic yard was $264, including two projects with relatively high costs (approximately $1,200 per cubic yard). Excluding those two projects, the average cost per cubic yard was $194 presumably excluding post-placement monitoring if a RCRA listed waste (EPA, 2000). While costs reported for the Encapco demonstration project are given per ton, it is clear that on a unit cost basis, the Encapco process is a more economical alternative.

Finally, it is worth noting that the Encapco process is fundamentally a recycling process whereas the S/S process is not. Proposed RCRA regulations exempt a material that has been recycled and reclaimed within the same industry from further compliance with sometimes very cumbersome regulations and lengthy monitoring requirements. The Encapco process, as part of a road construction process, recycles the soil into a valuable commodity: roadbase or engineered fill thus meeting the proposed RCRA exemption. In contrast, S/S, particularly in situ, could still be considered disposal and would still be subject to lengthy monitoring requirements if the contaminant in the concrete-stabilized soil is from a RCRA-listed waste.

This demonstration has focused on comparing the effectiveness of the Encapco emulsion treatment process on reducing the characteristics of contaminated soils from hazardous waste to non-hazardous. The costs savings realized from utilizing the Encapco process compared with conventional hazardous waste excavation and disposal are due to: (1) treatment and placement of the treated soil in-situ; (2) the ability of the process to produce a material capable of rendering hazardous waste to non-hazardous waste levels; and (3) the potential to re-use the soil for a variety of construction purposes. This alone is a great saving that cannot be factored into costs per unit basis. In addition, no scale-up issues are anticipated in moving from demonstration to full-scale implementation. When compared on a unit costs basis, the Encapco technology shows considerable costs savings versus conventional disposal methods.

REFERENCES

1. Agency for Toxic Substances and Disease Registry (ASTDR). (1997). " Toxicological Profiles for Lead." US Department of Human Health and Human Services. Atlanta, Georgia.

2. Conway, Michael.1993. "Bench Scale Evaluation of Asphalt Emulsion Stabilization of Contaminated Soil." *Journal of Soil Contamination*.

3. Doyle, M. P.; Page, B. W.; Barth, E. F. (2003). "Utilization of Asphalt Encapsulated Metal Contaminated Soils for Construction Purposes". Encapco Publication.

4. EA Engineering Science. (1990). "Final Report on Site Inspection Studies for the Navy Ships Parts Control center, Mechanicsburg, PA." EA Project 10800-07

5. Encapco (2000). "Stabilization of Depleted Uranium Contaminated Soils with Organic Based Emulsions." US Army TACOM/ARDEC/Picatinny Arsenal. Heavy Metals Office. Contract DAAE 30-00-C-1020.

6. Steven Escobar, Asphalt Pavement and Recycling Technologies, Inc (2004). Personal Communication.

7. Harding Lawson & Associates (1995). "An Overview of an Asphalt Stabilization Pilot Study at Fort Hunter Liggett, California.

8. Hubbard, J., Tsadwa, S., Willis, N. and Evans M. (1990). "Site Sampling and Treatability Studies for Demonstration of Waste Chemical Asphalt Encapsulation technology under the EPA SITE Program." *Journal of Air Waste Management Association*. 40(1).

9. Klich, I; Wilding, L.P.; Drees, L.R.; Landa, E.R. (1999). "Importance of Microscopy in Durability of Solidified and Stabilized Contaminated Soils." Soil Science of America Journal 63:1274-1283.

10. Tarefder, R., Ruckbager, M., Zamman, M., and Patton, D. (2001). "Formulation of Mix Design for Asphaltic Incorporation of Hydrocarbon Contaminated Soil." University of Oklahoma Department of Civil Engineering. Submitted to the ASCE Journal of Materials in Civil Engineering.

11. U.S. Environmental Protection Agency (1998). " Technologies for Immobilizing High Mercury Subcategory Wastes in Coal Tar/Asphalt Emulsion." EPA No. 68-W4-005, WA R 11032

12. U.S. Environmental Protection Agency (1997). “ Best Management practices for Soil Treatment technologies.” EPA OSWER No. 530/R-97/007.

13. Warmisnky, M. (2003). “Enhancing Range Sustainability Through Innovative Technology Application. Air Force Center for Environmental Excellence Technology Transfer Workshop.