

Subject: Calcium Phosphate for Environmental Remediation

From: Angela Hassell Date: 7 May 2013

Project: Water Quality Control Board – Reagent Evaluation

The Los Angeles Region of the California Regional Water Quality Control Board (WQCB) is in the process of evaluating chemistries for addition to the list of approved reagents for *in situ* remediation. The following sections describe the use of calcium phosphate for *in situ* metals stabilization for consideration of inclusion into the Los Angeles Region permit.

Source of Submission: ReSolution Partners, LLC

Identity of Reagent: Calcium phosphate [$\text{Ca}(\text{H}_2\text{PO}_4)_2$], CAS # 65996-95-4, typically sold under the trade name EnviroPhos by Premier Magnesia, LLC, or under other names by other industrial chemical suppliers.

Number of Field-scale Applications to Date: The product has been applied in hundreds of applications for remediation of metals in soil, groundwater, and waste material since the late 1980s.

Brief Rationale for Inclusion in New WDR: See general chemistry information below.

General Chemistry Information

Calcium phosphate is a granular product that is typically used for heavy metals remediation, often in combination with a pH buffer (e.g., magnesium oxide [MgO]). It can be mechanically mixed into soil or injected as a slurry for metals stabilization. The product pH is approximately 2.5 S.U. in a 10% aqueous slurry. As shown on the Material Safety Data Sheet (MSDS) in Attachment 1, the product has low toxicity, is non-combustible, and is not harmful to the environment. The product can contain 0-1% phosphoric acid and 0-1% quartz. The phosphoric acid will react with alkaline agents and convert to phosphate in most settings. Quartz sand contains silica, which has toxicological concerns (refer to the MSDS). Reaction with water will cause the product to swell when stored. When properly dosed in remedial applications the phosphate will combine with the target metals. The calcium will remain in solution unless other site

conditions result in the precipitation of calcium mineral phases or result in calcium adsorption.

Theoretical Basis for Phosphate Treatment Technology

Phosphate treatment of hazardous wastes was developed as a treatment alternative to conventional solidification processes. The theoretical basis for metals treatment using a phosphate stabilization approach can be explained in terms of the solubilities of the metals of concern as a function of pH.

Figure 1 shows the solubilities of various lead species versus pH, for a system containing sulfate, phosphate, carbonate, and hydroxide ions. At low values of pH, free lead ion and cationic hydroxide complexes are the predominant soluble species. In the mid-pH range (7-9), the solubility of lead reaches a minimum. At high pH (pH > 11), the solubilities of the tri- and tetrahydroxy complexes $[Pb(OH)_3^-]$ and $[Pb(OH)_4^{2-}]$ govern the soluble lead concentration.¹ Under both low pH conditions (pH < 4) and high pH conditions (pH > 11), the lead may be soluble at environmentally significant concentrations.

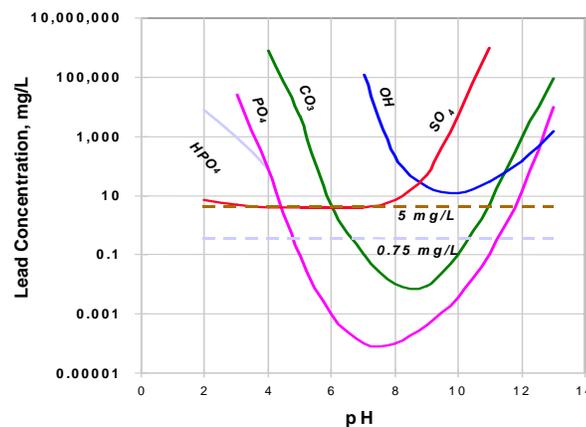


Figure 1. Solubility of Various Lead Compounds as a Function of pH

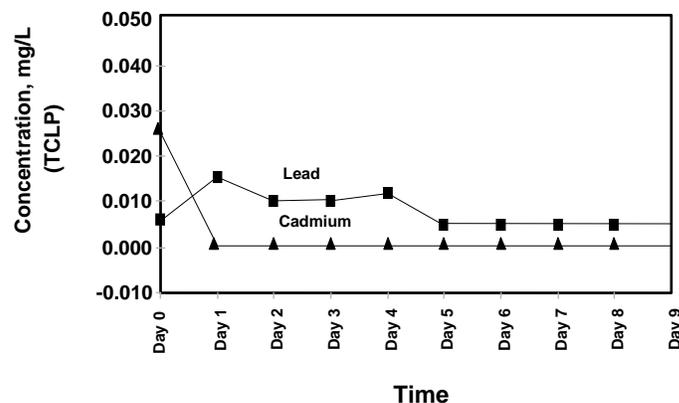
As shown on Figure 1, the concentrations associated with the horizontal dotted lines correspond to the current threshold toxicity characteristic concentration for lead (5.0 mg/L), and the universal treatment standard (UTS) for lead. Wastes treated with phosphate can meet both of these criteria. The performance of the phosphate treatment system can be enhanced by including a buffering compound to maintain the pH of the treated waste in the range of 7 to 10. Not only does this reduce the leachability of the lead immediately, but buffered wastes resist attack by acids. For example, waste or soil buffered with as little as 1 percent magnesium oxide can theoretically resist leaching by

acid rain for more than 1,000 years. This assumes a pH of acid rain of 5, 40 inches of rain per year, a waste depth of 10 feet, and a waste porosity of 30 percent.

USEPA-funded studies conducted by Ma, *et al*, have shown phosphate remediation to be a preferred method of stabilizing lead-impacted wastes²⁻⁴. The results of leaching tests, electron microscopy, and various other investigations support their conclusion. Attachment 2 provides a technical paper summarizing EPA's evaluation methods for chemical based stabilization processes.

Treatment of wastes with the buffered phosphate system has been demonstrated to result in effective long-term treatment. The USEPA's Multiple Extraction Procedure (MEP) has been used to test the long-term stability of treated wastes. The MEP, according to USEPA scientists, was designed to simulate 1,000 years of leaching with acid rain. It consists of an initial TCLP, with the leached solids being subjected to nine successive SPLPs. The results of an MEP performed on foundry waste treated with buffered phosphate are presented in Figure 2. The TCLP lead in the untreated material was 50 mg/L and the TCLP cadmium was initially 6 mg/L. The leachability of the treated waste decreased with time.

Figure 2
MEP Performed on Foundry Waste Treated with Buffered Phosphate



Project Examples

Calcium phosphate has been applied *in situ* for metals stabilization at several sites across the United States alone and in combination with other reagents. Calcium phosphate is

also used routinely in the foundry industry for stabilization of heavy metals in baghouse dusts rendering the dust non-hazardous for off-site solid waste disposal.

Remediation project examples for soil and groundwater applications are provided in Attachment 3.

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1. Lindsay, W. L., *Chemical Equilibria in Soils*. John Wiley and Sons. New York. 1979.
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Memorandum

Attachment 1

MSDS

MATERIAL SAFETY DATA SHEET

PREMIER CHEMICALS

MSDS No.: EnviroPhos

Phone: PREMIER CHEMICALS: 1-419-986-5126
CHEMTREC, 24-Hr Emergency Assistance: 1-800-424-9300

Date Prepared: 3/04
This Revision:

SECTION 1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Material/Product Names: ENVIRO-PHOS®

CAS Number: Mixture

Chemical family: Inorganic Oxide

Description/use: Enviro-Phos is a product composed primarily of a special grade of calcium phosphate and is manufactured for use in treatment of hazardous waste.

Manufacturer / Supplier: PREMIER CHEMICALS
Research Center
495 Emma Street
PO Box 392
Bettsville, OH 44815 Phone: 1-419-986-5126

SECTION 2. INGREDIENTS / COMPOSITION

Table with 5 columns: Ingredient name, CAS Number, Percent, IARC/NTP/OSHA, Exposure Limits. Rows include Nonhazardous Ingredients (calcium phosphates), Phosphoric Acid, and Quartz (SiO2).

1Quartz, a polymorph of crystalline silica, is classified by IARC as "Known Human Carcinogen - Group 1". NTP lists respirable crystalline silica amongst substances which may "reasonably be anticipated to be carcinogens".

SECTION 3. HAZARDS IDENTIFICATION

HMIS

Table with 2 columns: Hazard Category, Rating. Rows include HEALTH HAZARD (1 - SLIGHT), FLAMMABILITY HAZARD (0 - MINIMAL), REACTIVITY HAZARD (1 - SLIGHT), PERSONAL PROTECTION (B - Glasses, Gloves).

EMERGENCY OVERVIEW:

A gray to off-white powder or crushed material available in various sizes. Product is of low toxicity. Dust is classified as a "nuisance particulate". Not a fire, spill, or environmental hazard.

Target Organs: Chronic overexposure to respirable dust may cause lung damage.

Primary route(s) of entry: Inhalation

Acute effects: Excessive exposure to airborne particulate may cause eye and upper respiratory irritation.

Chronic effects: Product dust is classified as a "nuisance particulate, not otherwise regulated" as specified by ACGIH and OSHA. The excessive, long-term inhalation of mineral dusts may contribute to the development of industrial bronchitis, reduced breathing capacity, and may lead to the increased susceptibility to lung disease.

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HAZARD IDENTIFICATION continued from page 1

Signs & symptoms of overexposure:

Eye contact: Particulate is a physical eye irritant.

Skin contact: Low toxicity by skin contact.

Inhalation: Chronic overexposure by inhalation of airborne particulate may irritate upper respiratory system as well as the throat.

Ingestion: An unlikely route of exposure. If ingested in sufficient quantity, may cause gastrointestinal disturbances. Symptoms may include irritation, nausea, vomiting and diarrhea.

SECTION 4. FIRST AID MEASURES

Eye contact: Flush eyes, including under the eyelids, with large amounts of water. If irritation persists, seek medical attention.

Skin contact: Wash affected areas with mild soap and water.

Inhalation: Remove victim to fresh air. If not breathing, give artificial respiration. Get immediate medical attention.

Ingestion: Ingestion is an unlikely route of exposure. If ingested in sufficient quantity and victim is conscious, give 1-2 glasses of water or milk. Never give anything by mouth to an unconscious person. Leave decision to induce vomiting to qualified medical personnel, since particles may be aspirated into the lungs. Seek immediate medical attention.

SECTION 5. FIRE FIGHTING MEASURES

NFPA code: Flammability: 0, Health: 0, Reactivity: 1, Special: 0.

Flash point: Not Combustible

Unusual Fire Hazard / Extinguishing Media: Use extinguishing media appropriate to combustibles in immediate area of fire.

Hazardous Decomposition Products: None

Firefighting Instructions: Firefighters should wear NIOSH-approved, positive pressure, self-contained breathing apparatus and full protective clothing when appropriate.

SECTION 6. ACCIDENTAL RELEASE MEASURES

Spill procedures: Product is not harmful to the environment. Carefully, clean up and place spilled material into a suitable container, being careful to avoid creating excessive dust. If conditions warrant, clean up personnel should wear approved respiratory protection, gloves, and goggles to prevent irritation from contact and/or inhalation.

SECTION 7. HANDLING AND STORAGE

Storage: Store in dry, protected storage. Do not allow water to get inside containers; reaction with water will cause product to swell, generate heat, and burst its container. Minimize dust generation during material handling and transfer.

SECTION 8. EXPOSURE CONTROLS AND PERSONAL PROTECTION

Engineering controls: Provide sufficient ventilation, in both volume and air flow patterns to control mist/dust concentrations below allowable exposure limits.

Personal protective equipment: The use of eye protection, gloves and long sleeve clothing is recommended.

Respiration protection: Provide workers with NIOSH approved respirators in accordance with requirements of 29 CFR 1910.134 for level of exposure incurred.

Hygienic Practices: Avoid contact with skin, eyes and clothing. After handling this product, wash hands before eating or drinking.

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SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance: The product is a gray to off-white. Available in powder or crushed and sized granules. Product is odorless.

Boiling Point: Not Applicable

Specific Gravity (g/cc): Mixture

Melting Point: >976°C (>1788°F)

% Volatile by volume: 0

Water Solubility: Slight <1%

Evaporation rate: Not Applicable

pH (10% aqueous slurry): 2.3 - 2.6

SECTION 10. STABILITY AND REACTIVITY

Hazardous Polymerization: Will not occur

Chemical Incompatibilities: None

Hazardous Decomposition Products: None

SECTION 11. TOXICOLOGICAL INFORMATION

Calcium Phosphate CAS#65996-95-4. Produced by addition of phosphoric acid to phosphate rock. Can contain up to 1% phosphoric acid. Phosphoric acid is cited as a human poison by unspecified route. Moderately toxic by ingestion and skin contact. A corrosive irritant to eyes, skin, mucous membranes and a systemic irritant by inhalation.

Toxicity Data: No LD₅₀ or LC₅₀ found for oral, dermal, or inhalation routes of administration.

Quartz CAS #14808-60-7. Toxic and Hazard Review (Sax): Experimental poison by intratracheal and intravenous routes. An experimental carcinogen, tumorigen, and neoplastigen. Human systemic effects by inhalation: cough, dyspnea, liver effects. Listed by IARC as a "Known Human Carcinogen" Group 1. Listed by NTP.

TOXICITY DATA: No LD₅₀ in RTECS. ihl-hmn: TCLo 16 mppcf / 8 hrs / 17.9Y-I; PUL; ihh:hmh LCLo: 300 µg / m³ / 10 Y-I;LVR; Other species toxicity data (NIOSH RTECS): inv-rat LDLo: 90mg/kg; itr-rat LDLo: 20mg/kg; ivn-mus LDLo: 40mg/kg; inv-mus: 20mg/kg.

SECTION 12. ECOLOGICAL INFORMATION

Ecotoxicological / Chemical Fate Information:

No data available on any adverse effects of this material on the environment.

SECTION 13. DISPOSAL INFORMATION

Waste Management/Disposal: This product, as manufactured will not exhibit any characteristics of a hazardous waste, and is suitable for landfill disposal. Pleas be advised, however, that state and local requirements for waste

disposal may be more restrictive or otherwise different from federal regulations. Consult state and local regulations regarding the proper disposal of this material. If, however, the product has been altered or contaminated with other

hazardous materials, appropriate waste analysis may be necessary to determine proper method for disposal. Waste characterization and disposal/treatment methods should be determined by a qualified environmental professional in accordance with applicable federal, state and local regulations.

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SECTION 14. TRANSPORT INFORMATION

US Department of Transportation: Not regulated by DOT as a hazardous material. No hazard class, no label or placard required, no UN or NA number assigned.

Canadian TDG Hazard Class & Pin: Not regulated.

SECTION 15. REGULATORY INFORMATION

SARA TITLE III:

Section 302: NO (Extremely Hazardous Substances)

Section 304: NO (Emergency Release)

Section 311: YES (*Community Right-to-Know*, MSDSs or List of Chemicals)

Section 312: YES (*Community Right-to-Know*, Inventory and Location, (Tier I/II))

Section 313: NO (Toxic Chemicals, Toxic Chemical Release Reporting, Form R)

TSCA: All substances in this product are listed in the Chemical Substance Inventory of the Toxic Substances Control Act.

CERCLA Hazardous Substance List, RQ:No

California Proposition 65: This product contains chemicals known to the State of California to cause cancer, birth defects or other reproductive toxins.

SECTION 16. OTHER INFORMATION

ACRONYMS AND REFERENCES USED IN PREPARATION OF MSDS':

ACGIH: American Conference of Governmental Industrial Hygienists

CAS#: CAS Registration Number is an assigned number to identify a material. CAS stands for Chemical Abstracts Service.

CERCLA: Comprehensive Environmental Response, Compensation & Liability Act

EPCRA: Emergency Planning and Community Right-to-Know Act of 1986

HMIS™: Hazardous Materials Identification System (National Paint & Coatings Association)

IARC: International Agency for Research on Cancer

MSHA: Mine Safety and Health Administration

mg/m³: Milligrams per cubic meter

NIOSH: National Institute for Occupational Safety and Health

NFPA: National Fire Protection Association

NTP: National Toxicology Program

OSHA: Occupational Safety and Health Administration

PEL: Permissible Exposure Limit (OSHA)

REL: Recommended Exposure Limit (OSHA)

SARA: Superfund Amendments and Reauthorization Act

TITLE III: Emergency Planning and Community Right-to-Know Act

Section 302: Extremely Hazardous Substances

Section 304: Emergency Release

Section 311: *Community Right-to-Know*, MSDSs or List of Chemicals

Section 312: *Community Right-to-Know*, Inventory and Location, (Tier I/II)

Section 313: Toxic Chemicals, Toxic Chemical Release Reporting, Form R

TLV: Threshold Limit Values (ACGIH)

TWA: Time Weighted Average

29CFR1910.134: OSHA Respiratory Protection Standard

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This Revision:

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Manufacturers / Suppliers, Material Safety Data Sheets on Raw Materials Used
American National Standard for Hazardous Industrial Chemicals - Material Safety Data Sheets - Preparation, American National Standards Institute, Inc., 11 West 42nd St, New York, NY 10036.

Prepared/revised: J.E. ROWELL March 11, 2004

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Memorandum

Attachment 2
EPA Technical Paper

EVALUATION METHODS FOR CHEMICAL BASED STABILIZATION PROCESSES

Proceedings of the
International Congress
on Waste Solidification-
Stabilization Processes

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John J. Barich**

Nancy, France
Nov. 28 - Dec. 1, 1995

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ABSTRACT

Cement based processes have been the most common solidification/stabilization (S/S) processes for metal immobilization used in industrial sludge treatment or land reclamation projects. These processes may rely on a silica gel, free hydroxide, and cement structure to immobilize soluble metals. As the mining industry finds certain mineral forms to present special challenges in extraction, the waste management industry can benefit from incorporating target contaminants into similar waste forms. Chemical based stabilization processes, without cement addition, have been utilized to immobilize metals by precipitation, sorption, or altering the chemical nature of the waste. These stabilization processes include the use of phosphates, carbonates, sulfides, and iron rich clays.

Many of the physical tests that are used to evaluate cement based solidification/stabilization processes may not be appropriate for chemically based processes, since the cement based processes also rely on the physical structure to impede movement of soluble metals. Since soil stabilization can be considered as a metal immobilization process, chemical based testing methodology such as buffering capacity and competing ion availability may be more useful in predicting stabilization process performance over time.

The purpose of this paper is to overview chemical based stabilization processes and present testing methodology for evaluating the chemical durability of the resulting materials.

INTRODUCTION

The waste management industry recognizes that there is an important distinction between the terms solidification and stabilization. Solidification generally means the conversion to a more solid state by the reduction of surface area, which usually results in volume increase. Stabilization generally refers to a conversion of the metal contaminants to a less soluble chemical form. The physical properties of the stabilized-only material may not be changed, nor would volume increases be of the magnitude of cement based solidification processes.

In cement based applications, both solidification and stabilization phenomena may occur. These occur because of the hydroxide available (from the cement) for metal precipitation and the encapsulating silica gel and physical structure produced during hydration. Cement may also include various amounts of carbonate. One potential drawback of such systems, is the rather high range of pH values that can occur in pore fluids, which can result in the solubilization of amphoteric metals.

In chemical stabilization processes, insoluble compounds may be formed, or the metal may be sorbed. These processes may also use the addition of a buffering system to minimize changes from the optimum pH domain for metal insolubility.

DISCUSSION

Phosphate based processes

Orthophosphate forms compounds with many heavy metals that have low solubilities in water at most naturally occurring pH ranges. The lead phosphates have lower solubilities than lead hydroxide or lead carbonate. Phosphates used in waste stabilization processes to reduce soluble lead include hydroxyapatite and triple superphosphate (TSP).

Laboratory studies and geochemical modelling have shown that phosphate immobilizes lead in soils (Ma, et. al., 1993, Ruby, et. al., 1994). An addition of one per cent TSP to a foundry sludge reduced lead levels below regulatory criterion (Etzel, 1988). An addition of one to four per cent TSP reduced metal availability from several leaching/extraction tests for five foundry sludges (Contos and Regan, 1995).

Phosphate has also been effectively used in conjunction with magnesium oxide for metal immobilization. In this system, the magnesium oxide serves to buffer the pH of pore water at levels below about 10.5 (Stanforth, 1991). This process was used to remediate 55,000 cubic yards of soil contaminated by a battery cracking operation. Less than five per cent phosphate was used (Hasbach, 1995).

Sulfide based processes

In general, metal sulfides have lower solubilities than metal hydroxides. Sulfide has been used to stabilize several heavy metal sludges (Conner, 1990). A sulfide based stabilization system reduced leachable levels of lead and copper in sandblasting grit (Means, et. al., 1992). The disposal environment should be reducing for sulfide based processes.

Carbonate based processes

Cadmium carbonate is more insoluble than cadmium hydroxide, therefore cadmium from industrial operations can preferentially precipitate as a carbonate salt at near neutral pH with carbonate present (Patterson, 1985). Cadmium was found to be carbonate bound in several foundry sludges (Contos and Regan, 1995).

Iron rich clays

Approximately 20,000 cubic yards of arsenic contaminated soil from a site in Richmond, Virginia was attenuated with the addition of iron rich clay (Scovazzo, et. al., 1992). Certain soluble metals can co-precipitate with solid phases that contain iron (Patterson, 1985). Arsenic immobilization may be more favored under oxidizing conditions.

EVALUATION METHODS FOR CHEMICAL BASED STABILIZATION PROCESSES

Many solidification/stabilization processes use both physical entrapment and reduction in metal solubility to immobilize metals. Solidification processes have measurable properties including reductions in hydraulic conductivity and an increase in unconfined compressive strength from the original state. Test methods for evaluating these physical properties do not have direct application for stabilization processes.

Stabilization methods should therefore be evaluated with chemical tests that indicate both chemical state and durability. The following broad categories of test methods are suggested:

Buffering Capacity

Buffering capacity tests indicate the ability of the stabilized waste to maintain a pH value when exposed to either an acidic or basic solution. The larger the buffering capacity, the greater the possibility of maintaining the optimal condition for amphoteric metal retention.

pH

While pH control has been presented for controlling metal solubility, it is also an important control parameter for potential emission problems, such as hydrogen sulfide from a poorly buffered sulfide stabilization process that is exposed to acidic conditions.

Analysis for other competing ions

Soluble ligands such as cyanide, acetate, nitrate, or EDTA may be stronger chelators than other stabilization compounds. Even common stabilization compounds such as sulfide or phosphate can compete with each other for metal retention. Therefore these specific ions or compounds should be analyzed in the leachate test(s).

Stabilization compound concentration

Total or un-reacted stabilization compound content analysis in the treated material may be important for several reasons. The reasons for total content include potential ecological impact, amphoteric metal behavior, or process quality assurance. More specifically for phosphorus, excess phosphorus that is un-reacted and available for leaching could be released to ground water or contained in erodible sediment and ultimately contribute to a eutrophication problem in surface water.

Amphoteric metal behavior was observed at TSP dosages less than one percent and higher than five per cent for the treatment of foundry sludge (Regan, 1991). Excess compound may influence the system equilibria.

For process quality assurance, total phosphorus analysis, normally performed by acid hydrolysis, may be used to determine if treated samples are homogeneous for the design phosphorus loading.

Leaching tests

The more comparable the leaching medium is to disposal conditions, the more reasonable the estimate of short-term durability. A broad array of leaching tests exists and a variety of these should be considered rather than focusing on or

mimicking a single release scenario (USEPA, 1991). The release scenario of acid rain increasing the threat of contaminant releases to ground water may be important, however, and should be considered. The Synthetic Precipitation Leaching Procedure (SPLP) (USEPA, 1995) is an example of such a leaching test.

Bioavailability

The bioavailability of a stabilized contaminant may not be accurately predicted using aqueous based leaching tests. At a site contaminated with copper, zinc, and arsenic, diethylenetriaminepentaacetic acid (DTPA) extracts of contaminated soils were found to correlate with metal levels in plant tissue better than did water extracts (Schafer and Smith, 1989). DTPA-triethanolamine and ethylenediaminetetraacetic acid (EDTA) extracts were found to provide a better correlation with seedling emergence in zeolite amended soils contaminated with lead and zinc than did extracts using de-ionized water and 0.1 M hydrochloric acid (Greene and Barich, 1994). Simple whole-organism bioassays can be used to evaluate the relative toxicity of stabilized waste before and after treatment (Barich, et. al., 1992).

CONCLUSIONS

Several chemical parameters may be used for evaluating the long term chemical durability of chemical based stabilization processes. The combination of several of these chemical testing methodologies offer a more realistic evaluation of chemical stability than generic leaching test or physical parameters which do not have direct application to the disposal environment.

REFERENCES

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USEPA Science Advisory Board, Leaching Phenomena: Recommendations and Rationale for Analysis of Contaminant Release by the Environmental Engineering Committee, EPA-SAB-EEC-92-003, 1991

USEPA, Test Methods for Evaluating Solid Waste (SW-846), Method 1312, Washington, DC, 1995



Memorandum

Attachment 3
Project Examples

Remediation Projects using Calcium Phosphate
TREATED SOIL APPROVED FOR ON-SITE DISPOSAL

CLIENT	FACILITY TYPE	CONTAMINANT OF CONCERN	APPROVING AGENCY	PROJECT DESCRIPTION
City of Edina Shooting Range, Minnesota	Shooting Range	Lead	MPCA	Stabilized approximately 2,000 cubic yards of soil in stockpiles <i>ex situ</i> with backhoes. Stabilized material was left on-site.
Riley County Kansas	Battery Casings	Lead	KDHE	Performed <i>in situ</i> treatment and stabilization of 3,700 cu. yd. of soil impacted with lead from crushed batteries. Although the treated material was approved to remain on-site, the client decided to dispose of the material off-site.
GNB Technologies, Inc. Illinois	Battery Mfg.	Lead	IEPA	Remediated 30,000 tons of soil <i>in situ</i> and <i>ex situ</i> . Received permission from IEPA to beneficially reuse the stabilized soil on-site through Illinois' Pre-Notice program. The reuse of soil on-site saved the client about \$600,000 as compared to treatment with cement and hauling to a Subtitle D landfill.
Confidential Client Indiana	Foundry	Lead, Cadmium	IDEM	Treated 69,000 cu. yd. of soil <i>in situ</i> and capped it on-site with USEPA and state approval. Resulted in client savings of approximately \$15 million.
NIBCO, Inc. New York	Foundry	Lead, Cadmium	NYSDEC	Treated 6,000 cu. yd of soil for on-site disposal. <i>In situ</i> treatment was completed with a Mobile Injection Treatment Unit (MITU).
Wausau Steel Wisconsin	Battery and Scrap Recycling	Lead	WDNR	Treated 3,000 cu. yd. of material <i>in situ</i> and consolidated on-site within 100-year flood plain. Used SPLP to demonstrate groundwater protection.

Remediation Projects using Calcium Phosphate
TREATED SOIL APPROVED FOR ON-SITE DISPOSAL

CLIENT	FACILITY TYPE	CONTAMINANT OF CONCERN	APPROVING AGENCY	PROJECT DESCRIPTION
Wisconsin Dept. of Transportation	Former Battery Cracking Facility	Lead	WDNR	Remediated 55,000 cu. yd. of battery reclaiming residue <i>in situ</i> using conventional construction equipment, including some material below the water table. Demonstrated groundwater protection and left the treated material on-site.
City of Wausau - Bopf Street, Wisconsin	Foundry Waste	Lead	WDNR	Remediated 1,200 cubic yards of material <i>in situ</i> on slope, then regraded to 3:1 and left on-site.
Home Depot (Future Site) Pennsylvania	Former Shooting Range	Lead	PADEP	Remediated approximately 400 cu. yd. of lead-impacted soil <i>in situ</i> . The treated material remained on-site.
NVF Delaware	Fiber Board	Lead	DNREC	Treated over 1,600 cu. yds. of lead-impacted soil <i>in situ</i> . The treated material was left in-place next to a river.