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CONTAMINANTS AND REMEDIAL OPTIONS AT SELECTED METALS CONTAMINATED SITES - A TECHNICAL RESOURCE DOCUMENT

Michael D. Royer
Technical Support Branch/RREL
U.S. EPA
Bldg.# 10 (MS-104)
2890 Woodbridge Avenue
Edison, NJ 08837-3679
Phone: 908-321-6633

Lawrence A. Smith
Battelle
505 King Avenue
Columbus, OH 43201-2693
Phone: 614-424-3169

INTRODUCTION

A technical resource document, Contaminants and Remedial Options at Selected Metals-Contaminated Sites, has been produced to assist site remediation managers to select treatment technologies for contaminated soils, sludges, sediments, and waste deposits at sites where inorganic arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), or lead (Pb) are the primary contaminants of concern. These five metals have been addressed because of their toxicity, industrial use, and frequency of occurrence at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites and in Resource Conservation and Recovery Act (RCRA) hazardous wastes. This document should prove useful to all remediation managers, whether their efforts fall under federal, state, or private authority, and whether they are applying standards from RCRA, CERCLA, and/or state programs.

METHODOLOGY

A diligent effort was made (subject to the key limitations noted below), to identify, collect, analyze, and organize information, data, and pertinent references that a remediation manager would find useful for identifying and selecting remedial alternatives for soils, sediments, sludges, and waste deposits in which the principal contaminants are As, Cd, Cr, Hg, or Pb and selected inorganic compounds of these metals. The types of information collected to support preparation of this document include the following.

- Background information on As, Cd, Cr, Hg, Pb, and associated inorganic compounds regarding mineral origins, processing, uses, common matrices, chemical forms, behavior, transport, fate, and effects.

- Existing remediation performance data, listed below, in rough order of desirability: (a) full-scale remediation of As, Cd, Cr, Hg, and Pb contaminated sites; (b) technology demonstrations on As, Cd, Cr, Hg, or Pb contaminated sites under the EPA Superfund Innovative Technology Evaluation Program; (c) RCRA As, Cd, Cr, Hg, and Pb bearing hazardous wastes for which Best Demonstrated Available Technologies have been established; (d) waste applicability/capacity information for treatment technologies as described in technology guides and the EPA Vendors' Inventory of Superfund Innovative

Treatment Technologies (VISITT) database; (e) feedstock specification information for primary or secondary smelting or recycle/re-use markets; (f) Records of Decision (RODs) and corresponding summaries for As, Cd, Cr, Hg, and Pb contaminated sites; (g) Treatability test data on As, Cd, Cr, Hg, and Pb contaminated matrices where the results are well-documented and in an accessible form (e.g., Alternative Treatment Technology Information Center [ATTIC] and the Risk Reduction Engineering Laboratory treatability database) (h) Superfund National Priority List sites where As, Cd, Cr, Hg, or Pb contaminated media is a primary concern and remedial options are or will be under evaluation.

It is assumed that the remediation manager is familiar with appropriate policy issues (RCRA, CERCLA, and state), site characterization, sampling methods, analytical methods, risk assessment, determination of cleanup levels, and health and safety plans. It is also assumed that the manager or available support staff is familiar with widely available references from which physical and chemical data for the 5 metals of interest and their compounds can be obtained.

Containment and water treatment technologies are primarily addressed by reference, since they are well described and evaluated in recent, available documents, which are referenced in Section 4 of the technical resource document.

To avoid overlap with existing or forthcoming documents, information collection and coverage of four specific types of metals sites [lead battery recycling, wood preserving (As, Cr), pesticides (As, Hg), and mining] was intentionally limited to selected cases where innovative technologies have been chosen or applied.

In the interests of simplicity, brevity, and due to constraints imposed by limited project resources, the reference document does not attempt to systematically address remediation of organometallic compounds, organic-metal mixtures, and multi-metal mixtures. For example, while incineration is noted as a potential pretreatment for an organic-metal-soil mixture, the effects of As, Cd, Cr, Hg, or Pb on the technical and economic feasibility of incineration are not discussed. Another example is that several RCRA Best Demonstrated Available Technologies are cited for multi-metal wastes, but there is no discussion on how, in general, one should select a remedial technology for a multi-metal waste.

RESULTS

An approximately 200-page technical resource document has been produced. Section 4 (Remedial Options) and the appendices cited therein form the heart of the document. This section begins with a brief general discussion of the key applicable or relevant and appropriate regulations that influence cleanup goals. Soil and groundwater action levels and risk goals are tabulated for 24 metal-contaminated sites. TCLP limits for metals in selected metal-bearing RCRA characteristic hazardous wastes are also tabulated.

The bulk of Section 4 addresses the immobilization, and separation/ concentration technologies that are potentially applicable for remediating metal-contaminated solids, with the main emphasis on soils. Each technology is addressed in a similar manner.

- A technology description is provided, followed by a discussion of typical treatment trains, and a discussion of the applicability of the technology to various wastes. Specific reference is made to the 5 metals of interest, when applicable information is available.

- The status (e.g., bench, pilot, full-scale, applications to Superfund remediation) and performance of the technologies are also discussed and, where sufficient examples exist, tabulated.

- Cost factors and costs are also discussed with cost estimates often being drawn from applicable Superfund Innovative Technology Evaluation (SITE) program Applications Analysis Reports.

- Finally, data needs for assessing the applicability of each type of technology are tabulated.

The sub-section on immobilization addresses solidification/ stabilization (cement-based and polymer microencapsulation) and vitrification (*in situ and ex situ*) technologies. Containment technologies (capping and vertical and horizontal barriers) are noted, but only addressed by reference since: (1) the type of metal contaminant is not crucial to containment system selection, and (2) there is a recent, readily available EPA document (EPA 625/6-91/026) that already addresses the topic at the desired level.

Separation/concentration technologies are subdivided into two categories:

- Technologies applicable for excavated solids:

  -- physical separation technologies [i.e., screening, classification, gravity separation, magnetic separation, and flotation];

  -- soil washing technologies [i.e., extraction via water, solvents, or solutions containing surfactants, chelating agents, acids, or bases], and

  -- pyrometallurgical separation technologies [i.e., Waelz kiln, flame reactor, molten metal bath, secondary lead smelting via reverberatory and blast furnaces, submerged arc furnace, and mercury roasting and retorting], and

- Technologies applied in situ (i.e., soil flushing, and electrokinetics).

Water treatment options are very briefly discussed, and a summary table is provided. As with containment options, limited coverage is provided due to the availability of other recent, available EPA documents that address the topic in an adequate manner.

Section 4 on Remedial Options is complemented by a number of key appendices.

- Appendix B summarizes 68 technologies applicable to metals-contaminated media that are undergoing evaluation in the SITE program.

- Appendix C summarizes 67 innovative metals-contaminated technologies from 16 technology categories. This information was excerpted from EPA's Vendor Inventory of Superfund Innovative Treatment Technologies (VISITT) database version 2.0.

- Appendix D lists and briefly describes 44 selected metals-contaminated National Priority List Sites.

- Appendix E summarizes Best Demonstrated Available Technologies (BDAT) for 60 RCRA hazardous wastes that contain As, Cd, Cr, Hg, and Pb.

- Appendix F supplements the separation/concentration technology portions of Section 4 by providing a review of metal recycling options for metal-contaminated wastes from CERCLA Sites.

Section 2 briefly identifies typical mineral origins, industrial uses, and Superfund matrices of inorganic As, Cd, Cr, Hg, and Pb. Section 3 addresses possible chemical forms for the 5 metals under various conditions. Also described in Section 3 are typical environmental transport, partitioning, and transformation phenomena for the 5 metals in air, soil and sediment, and surface water and ground water. Section 3 also includes a brief overview of the human and environmental toxicity of the five metals and some of their compounds.

CONCLUSIONS

1. The technical resource document consolidates and organizes a substantial body of information pertinent to the remediation of As, Cd, Cr, Hg, and Pb contaminated soils, sediments, and sludges. During the development of remedial investigation and feasibility study (RI/FS) reports, users should be able to considerably reduce time and effort required to identify, describe, and make preliminary assessments of remedial technologies applicable to metals-contaminated sites.

2. The chemistry of these metals, particularly arsenic, mercury, and chromium, is quite complex. Significant differences in solubility, volatility, or toxicity are observed for various species of all five metals. These property differences may have a substantial impact (positive or negative) on the effectiveness, implementability, and cost of remedial alternatives. The technical resource document (Sections 2, 3, and portions of 4) clearly indicates the potential difficulties and thus alerts the RPM to the critical need for early and continuous consideration of the chemistry of these metals by a knowledgable person during site characterization, and remedy evaluation, selection, design, and implementation.

3. In addition to no action and excavation/offsite disposal, thirteen technologies were identified as be- ing potentially applicable to the remediation of metals-contaminated soils, sediments, and sludges.

   - Although by no means appropriate for all metal-matrix combinations, the mostly broadly applicable technologies for metals-contaminated soils are capping (not addressed in TRD), vertical barriers (not addressed in TRD), cement-based solidification/ stabilization, screening, gravity separation, and soil washing/acid extraction.

   - A second tier of technologies is applicable to a much narrower range of situations due to either effectiveness, implementability, or cost limitations. This second tier of technologies includes horizontal barriers, vitrification, polymer microencapsulation, flotation, pyrometallurgical separation, soil flushing, and electrokinetics.

   - The beneficial role of chemical treatment (e.g., oxidation, reduction, neutralization) is recognized, but not addressed as a separate technology, since it is always closely coupled with another technology (e.g., solidification/ stabilization, vitrification) when treating metal contaminated soils.

   - Biotreatment (e.g., extraction of metals from soils using bacteria) was considered for inclusion in the technical resource document, but rejected due to its early stage of development.

   - Only a very limited number of facilities recover the five metals in forms and concentrations likely to be arising from Superfund site remediation. Appendix F lists pertinent facilities, enabling the reader to easily identify and contact recyclers closest to the site to determine interest, acceptance criteria, and costs. Sixteen potential recyclers were identified for lead wastes and 7 for mercury wastes. For 18 other RCRA and specialized metal-bearing wastes containing one or more of the 5 metals of interest, only 18 additional potential recyclers were identified.

4. Inorganic arsenic is difficult to treat successfully. It has multiple valences and can interconvert between species depending on pH and oxidation/reduction potential and species present. Care must be taken during treatment processes to ensure that volatile arsenic compounds are not formed. Arsenic forms anionic compounds in water, and thus does not form insoluble hydroxides during cement-based stabilization/ solidification. Solidification/stabilization may be applied in instances where arsenic is present in low concentrations. Polymer microencapsulation is an option for arsenic, but no instances of its application were identified. Best Demonstrated Available Technology (BDAT) for arsenic-bearing RCRA hazardous wastes is vitrification, but no Superfund applications of this technology have occurred to date. Potentially viable separation/concentration options include screening, gravity separation, and soil washing/acid/base extraction. These technologies have been selected for remediation of several wood preserving sites. Recycling of recovered arsenic is not very promising -- there is little demand and therefore little or no capacity for recycling arsenic.

5. Inorganic mercury also tends to be difficult to treat. It may be converted by microorganisms under some conditions to volatile organomercury compounds. It is amenable to stabilization/solidification, but only at very low concentrations (e.g., for RCRA hazardous wastes, S/S is a BDAT for Hg < 260 mg/Kg). Mercury does not form insoluble hydroxides, and is not amenable to cement-based S/S at higher concentrations. Polymer microencapsulation is a potential option for mercury immobilization. Physical separation techniques (e.g., screening or gravity separation) and soil washing should be applicable to removal of mercury from soils. These technologies are being evaluated by the Gas Research Institute and U.S. Department of Energy. Given its low solubility in glass and low boiling point, mercury is not a good candidate for vitrification. However, mercury's high vapor pressure, low boiling point, and ready decomposition of its oxides enables it to be separated from soils via thermal desorption and roasting. Only seven facilities appear to be potentially applicable to processing mercury recovered from Superfund remediation.

6. Chromium (III) forms insoluble hydroxides and is amenable to cement-based stabilization/solidification. Chromium (VI) does not form insoluble hydroxides, but it can be subjected to S/S after reduction to Chromium (III). Vitrification may be technically feasible, but cost is likely to pose a problem. Physical separation and soil washing are potentially applicable and have been selected for several wood preserving sites. Soil flushing has been applied at two chromium-contaminated sites. Electrokinetics shows some promise, particularly if success is demonstrated for in situ treatment of clayey soils.

7. Inorganic lead forms insoluble hydroxides, and cement-based solidification/stabilization has been applied full-scale to numerous lead-contaminated soils. Lead is amphoteric, so pH must be carefully controlled during S/S processing to ensure that lead solubility remains at a minimum. Although vitrification and polymer microencapsulation would appear to be technically feasible for lead-contaminated soils, solidification/stabilization would be expected to cost less to implement. Screening, gravity separation, and soil washing/acid extraction have been implemented at two lead-contaminated sites. Whether these separation/concentration technologies can economically attain treatment goals must be determined on a site specific basis. Recycling of lead has been accomplished as part of some lead site remeditions, but the value of the recovered lead typically does not offset processing costs. Soil flushing may be applicable in some circumstances. Electrokinetics may prove to be useful for clayey soils.

8. Inorganic cadmium occurs mostly in the +2 valence state and does not exhibit amphoteric behavior. It is amenable to stabilization/solidification, although pH must be maintained in the alkaline range to ensure that leaching does not occur. Although vitrification and polymer microencapsulation would appear to be technically feasible for cadmium-contaminated soils, solidification/ stabilization would be expected to cost less to implement. Screening, gravity separation, and soil washing/acid leaching are commercially available and would appear to be applicable, but examples of implementation where cadmium was a key contaminant were not found. Facilities that will take cadmium-concentrate from a Superfund remediation are scarce. Soil flushing and elecrokinetics may be applicable for special circumstances.

9. While this technical resource document consolidates information from the past in an attempt to accelerate and improve decisions in the future, it is recognized that site-specific factors ultimately drive the selection of the remedial alternative for any particular site. The remedial action objectives should be clearly established and cleanup levels designated. It is of particular importance to develop reasonable estimates of the volume, distribution, and physical and chemical composition of each significant contaminant/co-contaminant/medium combination at the site that will require remediation. It is similarly important to clearly define the parameters (e.g., total metal(s) concentration, leachable metals, filtered/ unfiltered aqueous metal concentrations), test methods (e.g., TCLP, EP Toxicity Test, other leaching test, total waste analysis), and numerical goals that will be employed to measure treatment effectiveness. A risk assessment should consider transport and fate of contaminants using the best methods available including Eh-pH, equilibrium and/or transport models where applicable.

REFERENCES

Battelle - Columbus Division. Contaminants and Remedial Options at Selected Metals-Contaminated Sites. EPA # Not Assigned Yet,
U.S. Environmental Protection Agency, Cincinnati, Ohio, 1995. 200 pp.

FOR MORE INFORMATION:

Michael D. Royer, Technical Support Branch/RREL,
U.S. EPA, Bldg. #10, (MS-104), 2890 Woodbridge Avenue,
Edison, NJ 08837-3679. Phone (908) 321-6633, FAX (908) 321-6640.
or
Lawrence A. Smith, Battelle, 505 King Avenue, Columbus, OH 43201-2693
Phone: 614-424-3169

OVERVIEW OF TECHNICAL RESOURCE DOCUMENT FOR SOLVENT CONTAMINANTS AND REMEDIAL OPTIONS AT SUPERFUND SITES

Uwe Frank, Daniel Sullivan, Kenneth Wilkowski
U.S. EPA
2890 Woodbridge Avenue
Edison, New Jersey 08837
(908) 321-6626
Fax (908) 906-6990

INTRODUCTION

Solvent contamination is a persistent problem found at numerous Superfund sites. Solvents at Superfund sites are usually halogenated or nonhalogenated organic liquids whose source can be traced to many manufacturing, industrial and commercial processes and uses. Almost half of all Superfund sites listed in the record of decision (ROD) summary database contain solvents as a contaminant.

The contamination usually emanates from the improper disposal of solvents used in a wide variety of industrial and commercial applications such as manufacturing of chemicals, preparation of products and use as cleaning agents. Also the inadequate storage, mishandling and improper applications of solvents have significantly contributed to the problem. Consequently, this has resulted in affecting every medium including soil, sediment, sludge, sub-surface strata, and secondary contamination into air and water, both surface and groundwater. This persistence throughout the environment and the mobility of solvents has created a potentially serious health hazard from toxic exposures to humans. To mitigate this threat, a remedial project manager (RPM) is faced with the challenge of selecting a remedial technology which will achieve established cleanup goals.

Consequently, EPA's Office of Research and Development (ORD) developed a technical resource document (TRD) to assist RPMs and other remedial personnel in making this decision. This TRD was published November 1994, and is available through EPA's Center for Environmental Research Information (EPA/600/R-94/203). The publication discusses solvents, their properties as environmental contaminants and most importantly, the selection of treatment technologies available to reach established cleanup levels in soil at solvent contaminated Superfund sites.

The TRD classifies the appropriate remedial technologies for solvent contaminated soil into 3 main categories; separation, destruction and immobilization. "Separation" includes a group of technologies that extract or separate the contaminant from the soil matrix and form a concentrate or medium that can be more effectively treated. Therefore, this group of technologies prepare or treat solvent contaminated soil matrices for further treatment by either destruction or recovery.

The "destruction" technologies aim to permanently remove the contamination problem and includes those processes that destroy the contaminant by the use of thermal, chemical or biological means. "Immobilization" is the category that includes those methods that stop the spread or minimize the migration of solvent contamination either through the construction of physical barriers, through chemical reactions, or by a combination of both. The remediation of most Superfund solvent sites usually requires a combination of treatment technologies and contaminant control methods. Even if only a single compound type or chemical class is present, generally no single technology is capable of remediating an entire site. As a result, a treatment train is developed which may include immobilization, separation and destruction technologies to achieve site specific objectives and prerequisite cleanup levels.

The technologies discussed in this TRD are in different development stages; proven, innovative, and emerging. For example, some such as incineration and capping, have been proven