TECHNICAL AND REGULATORY

GUIDELINES FOR

SOIL WASHING

-FINAL-

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EXECUTIVE SUMMARY

Soil washing is a process that uses physical and/or chemical techniques to separate contaminants from soil and sediments. This ITRC Metals in Soils Team document focuses on technical and regulatory issues associated with implementation of soil washing technology at sites contaminated with metals. The document provides guidelines to facilitate the deployment of soil washing technologies by users and regulators.

Initial sections of the document focus on a technology overview and status, and discuss issues which may be impeding the selection of soil washing as a remedial alternative at sites. Later sections present technical and regulatory guidelines for sampling both pre- and post-processed soils and discuss potential feed soil limitations. Technical discussions on soil handling and stockpiling, system operation, and dust control are included as guidance for project implementation. General discussions of water discharge requirements, concentrated treatment residue, record keeping, QA/QC and health and safety are included to provide guidelines for regulators and project managers responsible for oversight. This document also includes recommendations for regulatory change, and Appendix E contains a list of additional technical contacts for further assistance if necessary.

Members of the team developed the draft document. Technical and regulatory issues were discussed during conference calls and breakout sessions at ITRC meetings, and consensus was reached whenever possible. The document was distributed for peer review and comments were received from representatives of state and federal agencies, public stakeholders, industry, consultants, and vendors. Comments were discussed, evaluated and incorporated into the document as appropriate. This document is now under review by ITRC state agencies to determine the degree of concurrence on the technical and regulatory guidelines contained within.

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1.0 INTRODUCTION

1.1 Scope of Document

Soil washing is a process that uses physical and/or chemical techniques to separate contaminants from soil and sediments. Contaminants are concentrated into a much smaller volume of contaminated residue, which is either recycled or disposed. Washwater can consist of water only or can include additives such as acids, bases, surfactants, solvents, chelating or sequestering agents which are utilized to enhance the separation of contaminants from soils or sediments. Process water is typically recycled for reuse within the system. Figure 1-1 on the following page depicts a typical soil washing process.

Applicability of this document is limited to the removal of non-radioactive metals and organics from contaminated soil or sediment. Many of the technical and regulatory recommendations will be applicable to radioactive metals as well; the ITRC hopes to develop a future version of this document to address soils contaminated with radionuclides. The technical and regulatory recommendations included in this document are meant to apply to the treatment of both hazardous and non-hazardous soils.

This guidance should be applied with flexibility as soil washing technologies are rapidly developing to meet the needs of current remediation approaches and cleanup goals. It is hoped that users will respond with feedback to the ITRC on the utility of this guidance and provide suggestions for improvement.

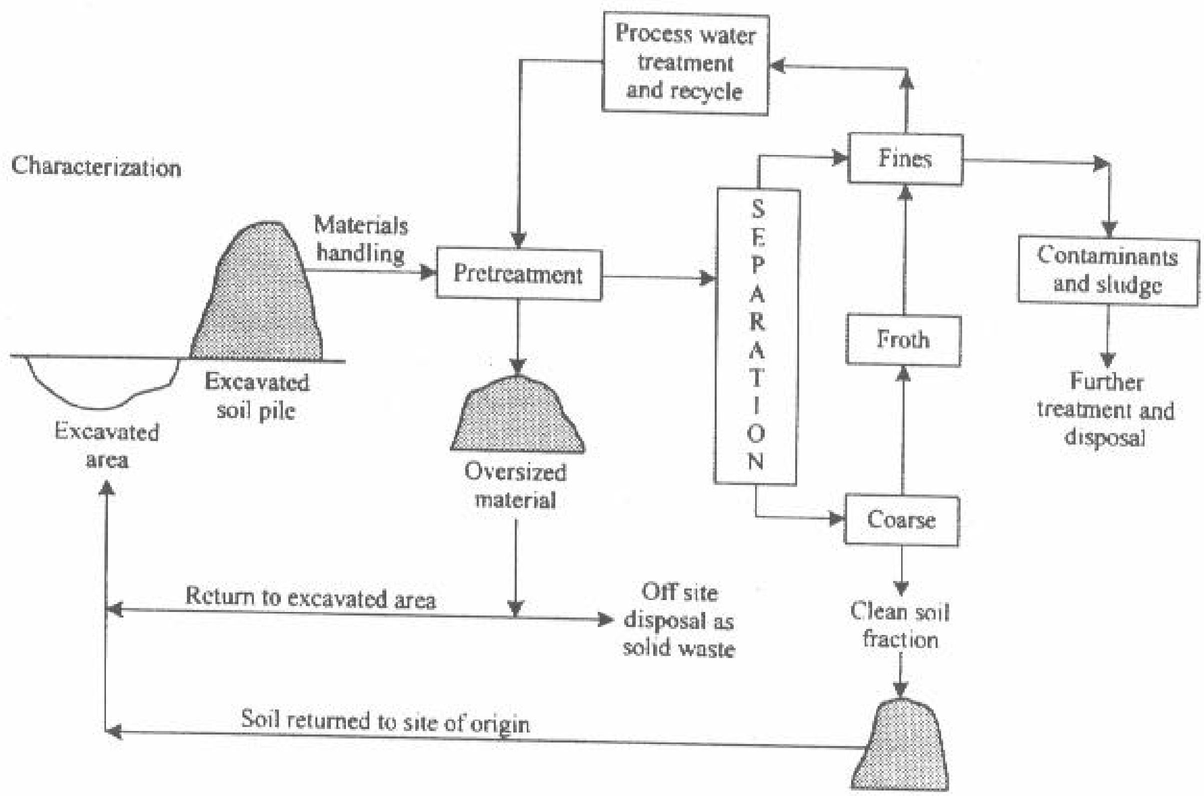
Many technical and regulatory issues were raised during the development of this document and discussed at breakout sessions of ITRC meetings, conference calls, and independent discussions of Team members with many interested parties, including vendors and other stakeholders. A summary of some of these issue discussions is included in Section 1.2 below, "Issues Discussion."

The remainder of the document is the working guidance which may be used by state regulatory agencies as a "model permit." It will assist in the deployment of a soil washing technology which has been demonstrated at another location but is still considered "innovative" because cost and performance information is not yet widely available.

The following basic assumptions were used to develop this document:

- The technical and regulatory guidelines in this document are meant to be applicable to most soil washing technologies. However, because there have been relatively few applications of soil washing technologies throughout the US, these guidelines should be applied with flexibility and the use of professional judgement.

Figure 1
Basic Soil Washing Flow Diagram



- These technical and regulatory guidelines were developed to provide all stakeholders (technology users, technology developers, the regulated community, and the public) with some degree of predictability and consistency in technology deployment from state to state. States reserve the right to go beyond these guidelines, but should have a rationale for doing so.
- Alternatives to the technical guidelines suggested in this document, such as sampling and analytical methods and procedures, may also be acceptable on a case specific basis, but there should be a technical basis for the alternative.
- Because of the wide variability among states, these guidelines do not include any emission criteria for air, or cleanup criteria for soil or water.

1.2 Issues Discussion

Many challenging technical and regulatory issues were raised during the development of this document. A summary of discussions of several issues is included in this Section.

1.2.1 Role of Regulators in Technology Verification

Many who commented on draft versions of this document felt that regulators should not try to compete technically with contractors to convince themselves that the technology works. Commenters believed that because regulators lack hands-on experience with a technology, the regulatory focus should be on the quality of the treated soils and the management of residual contaminated media.

The Metals Team recognized this concern. The Team believes that the regulator should attain sufficient knowledge about a technology to identify appropriate strategies for verification. If a regulator sets a cleanup goal but there are no guidelines for verification sampling, QA/QC etc., there is no assurance that the goals have been achieved. Furthermore, in order for data and information on technologies to be transferrable between locations and states, some consistency in how "success" is defined is necessary. This document attempts to set guidelines and practices for verification sampling and permit condition consistency that, hopefully, many states will follow.

1.2.2 Verification Sampling

The issue of verification sampling frequency (see Section 4) received much comment. Some commenters felt that the sample frequency was too minimal, and that statistical methods should be used to determine sample frequency. It is important to point out, as discussed in the "Introduction" above, that this verification sampling approach is not for an initial demonstration of a technology, but rather for a subsequent application of a technology that has been demonstrated. The Team felt that the sample frequency recommended in this document is appropriate when used in combination with mass balance calculations. Together, these two methods should provide an adequate degree of confidence that remedial objectives have been achieved. Statistical methods usually require extensive sampling and analysis. While this degree of rigor may be appropriate for initial demonstrations, the guidelines in this document are considered adequate for technologies that have already been demonstrated under similar site conditions.

1.2.3 Mass Balance Calculations

The recommendation to include mass balance calculations as part of the regulatory approval process generated a great deal of discussion. The accuracy of untreated soil contamination levels is critical for mass balance calculations. However, from a regulatory perspective, the untreated soil data would not be necessary as long as there was adequate confidence that remedial investigation data accurately represented average feed soil contaminant levels.

The mass balance approach should be flexibly applied. For sites where remedial investigation data is considered of high quality, regulators may not need additional untreated soil data for each treatment batch. However, it is likely that the field contractor will not be comfortable relying on remedial investigation data and will obtain untreated soil data for each influent batch to calculate mass balance. Regulators should allow for both approaches in consideration of site specific situations.

The 50 percent recovery goal recommended in Section 4 should be considered only as a guideline. For example, the level of contamination and the total mass to be removed should be considered along with soil matrix characteristics in order to determine a reasonable removal goal. If parties involved are uncomfortable with this mass balance approach, a more rigorous verification sample frequency could be used, or certain key process control parameter measurements could be reported along with the verification sampling data in order to provide the necessary degree of assurance that the cleanup objectives have been met.

1.3 Applicability of Soil Washing Technology

There are many factors that should be considered in the selection of soil washing as a remedy for contaminated soil. Soil washing technologies can be used independently or in conjunction with other treatment technologies. The following are general screening factors for soil washing technology, but no single factor listed should be used independently to eliminate the applicability of soil washing for a site.

- Soil Washing is considered feasible for the treatment of a wide range of inorganic and organic contaminants including heavy metals, radionuclides, cyanides, polynuclear aromatic compounds, pesticides and PCBs.
- Soil washing is most appropriate when soils consist of at least 50 to 70 percent sands. Soil washing will generally not be cost effective for soils with fines (silt/clay) content in excess of 30 to 50 percent (refer to Section 3 for more details on this factor).
- Typically, onsite treatment of soils using soil washing will not be cost effective unless the site contains at least 5000 tons of contaminated soil.
- Space requirements can be variable based on the design of the soil washing system, system throughput rate, and site logistics. A 20 ton per hour unit can be sited on approximately one half acre, including staging for untreated and treated soils. Some systems may require additional space, depending on system design.

1.4 Advantages and Limitations of Soil Washing Technology

The following is a brief summary of some advantages and limitations of soil washing technology. This is not a complete listing of all pertinent technology factors but is meant to provide a capsule overview of some of the key factors to be considered.

1.4.1 Advantages

- Soil washing can treat both organics and inorganics in the same treatment system.
- Generally, there are no air or wastewater discharges from the system, making permit processes easier than for many treatment systems. This attribute should also make the technology attractive to local community stakeholders.
- Soil washing is one of the few permanent treatment alternatives for soils contaminated with metals and radionuclides.
- Most soil washing technologies can treat a broad range of influent contaminant concentrations.
- Depending upon soil matrix characteristics, soil washing can allow for the return of clean coarse fractions of soils to the site at a very low cost.

1.4.2 Limitations

- After treatment, there is a relatively small volume of contaminated solid media and washwater that must be further treated or disposed.
- Soil washing will generally not be cost effective for soils with silt/clay content in excess of 30 to 50 percent (see Section 3 for more details).
- High humic content in the soil, complex mixtures of contaminants, and highly variable influent contaminant concentrations can complicate the treatment process.
- As for any ex-situ technology, there are space requirements for the treatment system (see Section 1.3).

1.5 Status of Soil Washing Technology

1.5.1 Onsite Treatment

While commonly used in Europe, soil washing has not been used extensively in the US. Of 300 innovative technologies selected through 1995, soil washing was selected at nine sites. Soil washing was successfully used at the King of Prussia Superfund site in New Jersey in 1993, the first full scale demonstration of the technology in the US. Soil washing is currently being demonstrated at several federal facilities. Goffredi, et. al. (1996) report on 29 different soil washing technologies, 16 of which have been applied full scale, six at pilot scale, and seven at bench scale. A summary table from this report has been included as Appendix E of this document for reference.

1.5.2 Fixed Facilities

There are many fixed facilities for soil washing in the Netherlands and Germany, and facilities have recently been sited in Canada. The Doe Run Mining Company began operating a fixed facility for soil washing in Boss, Missouri in late 1997. In Ashtabula, Ohio, a joint venture between ART and RMI has sited a soil washing plant for the remediation of soils contaminated with radionuclides. The state of New Jersey is currently attempting to facilitate the expansion of an existing fixed facility for thermal desorption of petroleum contaminated soil to include a soil washing unit for metals and organic contaminants. Please refer to the ITRC report "Fixed Facilities for Soil Washing" for more details on this subject. Areas addressed in the ITRC report include a discussion of factors which contributed to the success of fixed facilities in Europe and Canada, barriers to the deployment of fixed facilities in the US, and a discussion of several models for successful deployment of fixed facilities in the US.

1.6 The Need for Flexibility

The guidance in this document should be applied flexibly because soil washing technology is rapidly evolving. For some technology applications, states may choose to go beyond this set of guidelines. The technology user should determine whether there are additional or alternate requirements applicable; it is in the states' best interest to allow flexibility based on specific technology applications. Flexibility should also be provided to allow for the use of alternative sampling or analytical methods when appropriate. In general, alternate methods other than those recommended in this document for sampling or analytical methods should be approved if:

1. The method has previously been used successfully under similar site conditions, as documented by a regulatory agency;

2. The method has been tested successfully by an independent, non-regulatory verification entity; or

3. The method is approved by the agency, based upon site specific conditions or technology modifications.

1.7 The Need for Public Involvement

There is a critical need for community stakeholder involvement in the selection of technologies for the cleanup of contaminated sites. The ITRC has adopted the concepts put forward in "A Guide to Tribal and Community Involvement in Innovative Technology Assessment.” This guide clearly points out the desire and need for meaningful community involvement at the site implementation level.

Although emphasis is placed on public and tribal involvement at the site specific level, technology developers and field contractors who are responsible for the actual deployment of the technology need to be aware of the types of information the community will require for their decision making process. The guide can be used as a "checklist" by technology developers, users, contractors and regulators. Examples of community concerns related to technology deployment which can be considered in a generic sense include noise levels, heavy equipment transport and traffic to and from sites, dust generation and air emissions, health risk to the public from site operations, permanence of the remedy, and cost.

"A Citizens Guide to Soil Washing," EPA/542/F96/002 and /018, is included as Appendix F of this document to assist community stakeholders in understanding soil washing technologies.

1.8 Treatment Costs for Soil Washing

Treatment costs vary widely for soil washing technologies. The most important factor influencing cost is the fines (silt/clay) content of the soil. Other factors influencing cost include organic content of the soil and soil cation exchange capacity (CEC). If treatment goals can be achieved using physical treatment only, costs may approach $50 per ton. Costs in the range of $100-$200 per ton can be expected when treatment involves both physical and chemical separation. In Europe, costs in a more mature market range from $25-$125 per ton.

1.9 Cost and Performance Reporting

The ITRC has adopted the "Guide to Documenting Cost and Performance for Remediation Projects" as a model to standardize cost and performance reporting. The Metals Team further recommends that the data and information found in the EPA SITE Program "Cost and Performance Report" for the application of a soil washing technology at the King of Prussia Superfund Site in Winslow Township, New Jersey be used with some modifications by states to document innovative soil washing technology applications. Key elements of this report, modified to include additional reporting requirements for sampling and analytical methods, are provided in Appendix C.

2.0 UNTREATED SOIL SAMPLING

2.1 Sample Parameters

For purposes of this document, the objective of sampling untreated soil is to identify the range of soil types and contaminant concentrations expected on the site. This information is necessary in order to select the appropriate soil for the test runs. The soil washing process should be proven to demonstrate that the average soil feedstream can be treated to the cleanup objective.

Many sites contain "hot spots" of contamination, but these areas may only represent a small percentage of the total site contamination. When hot spots are encountered during treatment, any contaminant removed will contribute to the total mass removal measurement that should be a condition of the regulatory approval (see Section 4). Blending of hot spot soils with other soils for treatment may not be an effective solution for treatment of soils, and it may be appropriate to treat hot spot soils separately. In some cases, blending hot spot soils may render a larger volume of soil as untreatable.

It is assumed that the site has been adequately characterized during a remedial investigation. Therefore, sample frequency requirements for untreated soils are not addressed in this document. Limiting factors which influence the effective removal of metals from the soil should be identified and treatment studies conducted to identify the processing parameters required to meet cleanup objectives (see Section 3).

Detailed information on specific data needs for soil washing technologies can be obtained in "Contaminants and Remedial Options at Selected Metal-Contaminated Sites", EPA/540/R-95/512.

2.2 Analytical Methods

EPA/ASTM methods should be used for all analyses. Alternative analytical methods may be acceptable, on a case specific basis, if the following criteria are met:

1. The method has previously been used successfully for a similar sample matrix, and is approved by a state or federal regulatory agency or by an independent, non-regulatory verification entity; or
2. The method is approved by the agency, based upon site specific or method-specific considerations.

2.3 Sample Quality Assurance/Quality Control (QA/QC)

All QA/QC required by the analytical method should be completed. Lab QA/QC summary documentation (including non-conformance summary report and chain of custody) should be submitted with analytical results. Full QA/QC deliverables as specified by the analytical method should be maintained and should be available upon request for at least three years. Ultimate responsibility for QA/QC documentation belongs with the responsible party of a site or the vendor conducting a demonstration. However, the responsible party may contract with another entity, such as an analytical laboratory, to retain the QA/QC data.

3.0 FEED SOIL LIMITATIONS

This section does not contain regulatory guidelines but rather provides general information for regulators and other stakeholders regarding soil characteristics that may influence treatment efficiency. The information provided in this section should be viewed as generic to soil washing processes, but not applicable to every technology.

The key to successful soil washing is in the characterization and understanding of the soil matrix / contaminant relationship. Due to the heterogenous nature of soil and variability between sites, it is recommended that every soil washing project be qualified by a screening treatability study. As part of this study, representative soil samples should be collected throughout the site. The physical characteristics of the soil should be evaluated using an appropriate method for particle size distribution, such as ASTM D422. After separation, each fraction should then be analyzed for the target compounds. The chemical data should then be compared between fractions to determine appropriate treatment scenarios. The mode of contamination in each fraction (free, particulate, coated, bound, soluble, etc.) is also very important in determining the conceptual treatment system. The information gained from treatability studies, particularly the relationship between particle size and contaminant concentration, will determine the effectiveness of any soil washing technology at the site.

The effectiveness of soil washing technology is limited by several factors:

- *Percentage of fine material* - The percentage of soil fines (silt/clay, less than 63-74 microns) affects soil washing technology in several ways. If soil moisture content is low, fines present in a feed soil can cause physical handling problems such as clogging of feed equipment. Most contaminants concentrate in the fines fraction of soils. At or near the end of most soil washing processes, fine materials containing the contaminants of concern are separated from the larger particle size soil fractions. Depending upon the particular soil washing process, the contaminated fines may be disposed or undergo further treatment to remove the contaminants. Depending upon the technology, there will be a point at which the percentage of fines will be a limiting factor. Soil washing will generally not be cost effective for soils with silt/clay content in excess of 30 to 50 percent. For specific sites, factors such as contaminant type and concentration, along with other physical characteristics of the soils, will determine if soil washing is appropriate. It is important to emphasize that a high percentage of fines in soils does not preclude the use of soil washing, but rather is a factor influencing the cost of treatment. Soils with a high concentration of fines can be effectively treated using soil washing, but the treatment will be relatively costly compared to treatment of soils with a lower fines content. The specific information relevant to a site and treatment efficiency should be obtained from the treatability study performed prior to system design and implementation.

- *Hydrophobic compounds can be difficult to separate from the soil matrix*. Contaminants with high partitioning coefficients may require additives such as surfactants to the soil washing system. When additives are used there is generally an increase in water volume and additional treatment steps to remove or recycle the additive.

- *Complex mixtures of contaminants in the soil such as polynuclear aromatic hydrocarbons, volatile organics, and mixtures of metals make it more difficult to design a soil washing treatment system.* Variations in contaminant concentrations may make wash fluid and operational settings more critical, and can also require the use of additional techniques, such as blending of feed soils, to provide a more consistent feedstock.

- *The presence of soils with high humic content can also make the separation of contaminants from soils more difficult because humic matter has additional binding sites for metals and organics*.

- *Organic compounds with high viscosity, such as No. 6 heating oil, present particular problems for soil washing systems.*

- While soil washing is very effective in treatment of volatile compounds, because of their relatively high solubility and low partition coefficients, it is important to realize that *process components will need to be modified to limit emissions of the volatile organics to the air*. If concentrations of volatile organics in the soils are significant, the appropriateness of soil washing as opposed to other technologies should be investigated.

- *Chelating agents, surfactants, solvents, and other additives are often difficult and expensive to recover from the spent washing fluid.* The presence of these substances in the contaminated soil and treatment sludge residuals may cause added difficulty in disposing of these residuals.

Additional information on specific data needs for soil washing technologies can be obtained in "Contaminants and Remedial Options at Selected Metal-Contaminated Sites," EPA/540/R-95/512.

4.0 SOIL TREATMENT VERIFICATION SAMPLING

Once an innovative treatment technology has been successfully demonstrated at a site, the verification sampling and analysis for subsequent applications of the technology under similar site conditions should not require the same rigor.

This section contains a suggested approach for verification sampling for a soil washing process which has been demonstrated successfully at full scale but which is still considered an "innovative technology" because cost and performance information is not yet widely available, and state regulatory agencies do not yet have much experience with the technology (see Section 1.2 for a more detailed discussion of some of the issues in this section).

Verification sampling should answer the question "Does the treated soil meet the site cleanup objectives?" The concentration of the contaminant in the soil matrix is of primary concern to regulators; they must be confident that a representative sample has been taken from each batch of treated soil to ensure that cleanup objectives have been met.

4.1 Sample Parameters

Soil treatment verification sampling should be conducted for all the contaminants which the treatment system was designed to remove. Verification sampling should not be required for contaminants which the treatment system was not designed to remove. Verification sampling should also be considered for any chemical additives which may come into contact with the contaminated soil during the treatment process. The requirement for additive analysis may be waived if it can be demonstrated that the substance will have a minimal environmental or human health impact. Verification sampling should include pH analysis if any acids/bases come into contact with the contaminated soil during the treatment process. If additives have been used in the system to enhance desorption of metals or organics from soils, an appropriate leachability test should be conducted on the treated soil to ensure that any residual contaminants are not leachable from the soil.

Many soils contain oversize materials not suitable for soil washing. Natural materials such as roots and rocks, and man-made materials such as demolition debris and other fill materials are often found on sites. Such oversize material should be visually examined and natural materials separated from man-made materials. Soil clumps should be crushed and returned to the process. Unless contamination is suspected, natural materials should be returned to the site without the requirement for treatment or waste classification, and any man-made fill materials such as demolition debris should be separated for disposal as solid waste.

4.2 Sample Frequency

The following approach is recommended for verification sampling, and should be tested during pilot scale treatment and the initial stages of full-scale treatment:

1. Stockpile treated soil into piles of approximately 20 cubic yards;

2. Take a sample of approximately 1 liter (2-3 lbs) from each of 5 random locations in pile;

3. Combine these 5 samples into a single composite sample and mix thoroughly (ideally, this sample would be lab analyzed but this may be very costly since soil washing projects usually treat several thousand cubic yards of soil; the approach below incorporates field and lab analysis for verification);

4. Once 100 cubic yards of soil have been treated and 5 samples have been obtained, each of the 5 samples should be split using ASTM Method C 702-87 or equivalent. One portion of the split sample should be analyzed using XRF or another low cost field screening method, and the other portion should be lab analyzed;

5. Determine whether there is acceptable correlation between lab and field results. Suggested correlation guidelines include 20 percent or less relative percent difference between lab and field measurements, or a correlation coefficient between lab and field measurements over the concentrations of interest of at least 0.90. Alternate acceptability criteria could also be developed based on site specific conditions. If acceptable correlation between lab and field methods cannot be achieved, an alternate sampling verification approach must be developed;

6. If the field analytical method is determined to be reliable, the sampling protocol in steps 1-3 above should be used for the remainder of the treatment, but only 1 of the 5 samples should be submitted for lab analysis (the sample with the highest field measurement should be selected). This results in 1 lab analysis for each 100 cubic yards of treated soil. This sample frequency may be further reduced based on factors

1-4 below but, in general, lab sample frequency should not be less than 1 lab sample for each 200 cubic yards of soil. Regardless of reductions in lab sample frequency, field analysis should be maintained at a rate of 1 per 20 cubic yards of treated soil unless site specific data indicate that fewer samples are appropriate;

7. Both lab and field sample results should be reported for compliance, and field results should be used to determine if any soil batch needs further treatment.

The following factors can be considered as a basis for reduction of verification sample frequency:

1. homogeneous process stream;

2. low contaminant concentration in process stream relative to treatment goals;

3. low percentage of fines (less than 30 percent) and organic matter in the process stream (the suggested sampling frequency could be reduced because the likelihood of successful treatment of the soils is high. On the other hand, if the percentage of fines and organic matter is relatively high, it might be appropriate to increase the sampling frequency);
4. site specific data indicating low failure rate for treated batches.

If technology vendors, users and regulators can record and share performance data more efficiently, it may be possible to establish more specific guidance for verification sample frequency based on feed soil characteristics. The ITRC hopes to assist in this area by encouraging states to standardize cost and performance reporting as much as possible.

In some soil washing processes, further treatment of the separated fines may be conducted. It is typically more difficult to achieve cleanup objectives for fines than for coarse soils. If coarse and fine soils have been treated, and cleanup objectives *have not* been achieved for the fine fraction, but mass balance goals *have* been achieved, it may be appropriate to mix treated coarse soils with treated fine soils to achieve compliance with cleanup objectives. While regulators typically do not accept the "dilution solution," this approach falls into a gray area because the soils are being treated, not just mixed. This approach may allow for the achievement of cleanup goals at a reasonable cost. Mixing treated coarse and fine soils before returning treated soils to the site may also result in matching treated soil permeability more closely to that of the native site soil.

4.3 Mass Balance Recommendations

One regulatory concern regarding soil washing is that during processing, contaminated soils may be mixed with cleaner soils in a batch rather than treated to achieve compliance. This concern has raised questions regarding contaminant removal from soil. Therefore, it is recommended that contaminant mass balance be included as part of the regulatory approval process.

Soils that are processed in a soil washing system will vary significantly in particle size, contaminant concentrations, and other soil characteristics, making accurate mass balance calculations difficult to achieve. Mass balance calculations that indicate contaminant recovery in the 50 to 100 percent range should be considered acceptable to establish the effectiveness of soil washing, when used along with verification sampling data.

The approach for the determination of contaminant mass balance calculations should be determined on a site specific basis. Several approaches could be used to calculate contaminant mass balance. Typically, soil samples for mass balance calculations would be collected from individual process streams within the treatment system and analyzed for contaminant concentration. Additional data such as flow rate and percent moisture would usually be collected to develop the mass balance data. Alternately, mass balance data could be calculated based on average contaminant concentration in the soils targeted for treatment as determined during the remedial investigation, if there is an adequate degree of confidence that these data are representative of the soil contaminant levels at the site.

4.4 Analytical Methods

EPA/ASTM methods should be used for all analyses (see Section 2.2 for alternate method approach). For verification sampling, gas chromatography (GC) methods with a mass spectrometer (MS) detector system are required for analysis of volatile/semi-volatile contaminants. MS methods are not required if:

1. Contaminant identity is known;

2. The contaminant chromatographic peak is adequately resolved from any other peak; and

3. At least 10% of the sample analyses (minimum of one sample) are confirmed using the appropriate GC/MS detection system.

4.5 Sample QA/QC

All QA/QC required by the analytical method should be completed. Lab QA/QC summary documentation (including non-conformance summary report and chain of custody) should be submitted with analytical results. Full QA/QC deliverables as specified by the analytical method should be maintained and should be available upon request for at least three years. Ultimate responsibility for QA/QC documentation belongs with the responsible party of a site or the vendor conducting a demonstration. However, the responsible party may contract with another entity, such as an analytical laboratory, to house the actual QA/QC data.

5.0 SOIL HANDLING AND STOCKPILING

Untreated soil stockpiles should be stored on a surface such as concrete or an impermeable liner of appropriate thickness. Alternately, if contaminants are of low mobility and soils will be staged for a limited period of time, liners may not be necessary as long as subsurface soils in the staging area are sampled after the staged soils have been removed to ensure that contaminants from the staged soils have not migrated into the clean soils below grade.

The stockpile should be covered by a secured plastic cover of appropriate thickness or stored within the confines of a building. At a minimum, the staging area for the stockpiles should be constructed to prevent surface water and precipitation from entering the area and to collect leachate. All soil stockpiles should remain covered to prevent the generation of dust. Water spray or an equivalent method should be utilized as necessary to prevent dust generation. Treated soil should be stored in the same manner as untreated soil until analytical testing has confirmed that the soil has successfully been treated. A physical barrier, such as a curb or a wall, should be maintained to separate the treated from untreated soil stockpiles.

The pH of the treated "clean" soils should be restored to pH levels within the same range as untreated soils. Soil pH adjustments may not be required if growth support tests for the native species in the revegetation plan indicate that growth has not been inhibited. Soil nutrients are often removed during the soil washing process. Based on site reuse, it may be appropriate to restore soil nutrient levels to the untreated soil levels. The need to modify treated soil physical characteristics, such as compaction, should be evaluated based on the future use of the site.

All areas should be restored, to the extent practicable, to pre-remediation conditions with respect to topography, hydrology and vegetation, unless an alternate restoration plan is approved by the governing agency.

6.0 SYSTEM OPERATING REQUIREMENTS

6.1 System Operations

The soil washing system should be operated within the performance envelope generated during site specific test runs. If adverse feed soil conditions as listed in Section 3.0 exist, soils exhibiting these conditions should be treated during an appropriate number of test runs.

6.2 System Monitoring Parameters

There may be several key monitoring parameters the field contractor will identify to ensure that the treatment system is optimized. Depending on the treatment system and the soil matrix characteristics, monitoring parameters could include washwater pH and soil residence time in the treatment unit. From a regulatory perspective, the approach suggested in this document to provide assurance that soils have been effectively treated is to rely on a combination of soil verification sampling and mass balance calculations. When using the guidelines in this document, regulators are strongly discouraged from attempting to identify key system monitoring parameters and requiring that monitoring data be reported to provide an additional degree of assurance that the system is operating effectively. While it is important for regulators to understand the principles of treatment of the system, detailed knowledge and regulatory control of system operation should not be necessary.

7.0 AIR EMISSIONS AND DUST CONTROL REQUIREMENTS

Soil washing systems do not usually result in any discharges to the atmosphere. Most systems do not require air permits but are usually required to implement dust control measures. If volatile organics are being treated in the system, or if volatile compounds are used as additives, appropriate control and reporting measures may be required. Emission standards and limitations for certain contaminants and dust control can be identified from regulations such as the National Primary and Secondary Ambient Air Quality Standards, National Emission Standards for Hazardous Air Quality Pollutants, and state and local regulations.

8.0 WATER DISCHARGE REQUIREMENTS

Soil washing systems usually recycle water within the process so there are typically no water discharges from the system. Once the soil treatment is complete, there may be a volume of water remaining which may contain some contaminants and additives.

Whenever possible, contaminants in spent washwater should be recovered and recycled prior to disposal of the water. Washwater can usually be disposed at a permitted off-site commercial facility, a publicly owned treatment works (POTW) or on-site in accordance with a National Pollution Discharge Elimination System (NPDES) permit. As for any ex-situ soil treatment, storm water runoff and any soil stockpile leachate should be collected and treated, recycled or discharged in accordance with applicable regulations.

Soil washing systems may contain as much as 10,000 to 20,000 gallons of water in tanks or other units. Based on the volume of water in the system, the nature of additives, and the proximity of groundwater and surface water to the treatment units, a spill containment plan for a possible rupture of tanks containing liquids or a small volume water loss from the system as a result of daily operations is usually appropriate. Typically, soil treatment units should be placed on a bermed pad with a sump to collect and recycle water back into the treatment system. This containment system should be designed to prevent significant release to the environment in the event of a tank rupture. Such containment systems can be very simple and add little cost to the system.

9.0 CONCENTRATED TREATMENT RESIDUE

Any concentrated treatment residue generated during soil washing processes should be recycled or disposed of in accordance with applicable regulations. The recycling market for this concentrated treatment residue is currently not strong, in part because the residue is typically not sufficiently concentrated to recycle (refer to the ITRC report "Fixed Facilities for Soil Washing" for more details on this subject). However, advances are being made to improve chemical and physical treatment of fines which should produce more concentrated residues and increase the likelihood that the residues will be recycled rather than land-disposed. In addition, the Metals Team has developed suggestions that may encourage more recycling of this concentrated treatment residue (see Appendix D).

Sampling for characterization of concentrated treatment residue such as sludges and spent washwater should be based on test requirements for waste classification, transport and disposal or recycling requirements.

10.0 OPERATIONS RECORD KEEPING

The following records should be maintained onsite or at another approved location, and should be readily available for review upon request:

- Summary of soil treatment verification sample results;
- Daily mass balance results summary;
- Documentation of the re-treatment or disposal of failed batches.

11.0 GENERAL QA/QC

An independent certified laboratory (that is, a laboratory that has been licensed by an independent entity such as a state regulatory agency) should be used for all analytical testing for environmental media including air, soil and water. An in-house certified laboratory may be used if at least 10 percent of the samples are verified by an independent certified laboratory. These recommendations apply to both mobile and fixed laboratories.

12.0 HEALTH AND SAFETY

A written Health and Safety Plan should be developed and implemented in accordance with Occupation Safety and Health Administration (OSHA) regulations 20 CFR 1910.120, the Hazardous Waste Operations and Emergency Response Rule. The plan should address the following elements:

- Key Personnel
- Health and Safety Risks
- Training
- Protective Equipment
- Medical Surveillance
- Spill Containment
- System Maintenance Safety
- Air Monitoring
- Site Control
- Decontamination
- Emergency Response
- Confined Space Entry
- System Operation Safety
- System Maintenance Safety

13.0 REFERENCES

Federal Remediation Technologies Round Table, March 1995. Guide to Documenting Cost and Performance for Remediation Projects: EPA-542-B-95-002.

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Interstate Technology and Regulatory Cooperation Workgroup, Low Temperature Thermal Desorption Work Group, March 1996. Technical Requirements for Low Temperature Thermal Desorption of Petroleum and Manufactured Gas Plant Wastes.

Mann, Michael J. et. al., Wastech Monograph: Innovative Site Remediation Technology, Soil Washing/Soil Flushing, Volume 3, 1993. American Academy of Environmental Engineers (phone: 410-266-3311).

Participants of the *DOIT Tribal and Public Forum on Technology and Public Acceptance*, May 1995. A Guide to Tribal and Community Involvement in Innovative Technology Assessment.

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U.S. Environmental Protection Agency, January 1995. Applications Analysis Report: BESCORP Soil Washing System for Lead Battery Site Treatment, EPA/540/AR-93/502.

U.S. Environmental Protection Agency, April 1996. Citizens Guide to Soil Washing, EPA/542/F96/002 and /018.

APPENDICES

APPENDIX A

ACRONYMS

ART	Alternative Remedial Technologies, Inc.
ASTM	American Society for Testing and Materials
CEC	Cation Exchange Capacity
CFR	Code of Federal Regulations
GC	Gas chromatography
IINERT	In-Place Inactivation and Natural Ecological Restoration Technologies
ITRC	Interstate Technology and Regulatory Cooperation Working Group
mg/kg	milligrams per kilogram
MS	Mass spectrometer
NPDES	National Pollution Discharge Elimination System
OSHA	Occupational Safety and Health Administration
PCB's	Polychlorinated Biphenyls
pH	Measure of the acidity or alkalinity of a solution
POTW	Publicly owned treatment works
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RMI	RMI Environmental Services, Inc.
USEPA	United States Environmental Protection Agency
XRF	X-ray Fluorescence

APPENDIX B

ITRC Work Team Contacts
ITRC Fact Sheet
Product Information
User Survey

ITRC METALS IN SOILS TEAM PROJECT CONTACTS

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APPENDIX C

OUTLINE OF
COST AND PERFORMANCE REPORT

1. Executive summary

2. Site Information

   a. Identifying Information
   b. Background
      - Site History
      - Regulatory Context
      - Remedy Selection
   c. Site Logistics/Contacts

3. Matrix Description

   a. Matrix Identification
   b. Contaminant Characterization
   c. Matrix Characteristics Affecting Treatment Cost or Performance

4. Treatment System Description

   a. Soil washing system description and operation
   b. Operating parameters affecting treatment cost or performance
   c. Project timeline

5. Treatment System Performance

   a. Cleanup Goals/Standards
   b. Treatment Performance Data
      - Sampling/Analytical Methods
      - Sample Frequency/Location
      - Test Run Data Summary
      - Full scale Sustained Run Data Summary
   c. Performance Data Assessment
   d. Performance Data Completeness
   e. Performance Data Quality

6. Treatment System Costs

   a. Preparation Activities
      - Mobilization and Plant Erection
      - Site Preparation

- Excavation, Pre-screening, and Staging
- Plant Feeding

b. Soil Washing Activities
- Provision of Process Plant
- Plant Labor
- Plant Chemicals and other Consumables
- Utilities
- Process Analytical Costs

c. Product Management Activities
- Material Handling of Products
- Backfilling of Clean Products

d. Residual Management
- Loading of Sludge Cake
- Transportation
- Landfill Gate Rate
- Landfill taxes

e. Closure Activities
- Regrading and Vegetation
- Demobilization

7. Observations and Lessons Learned

a. Cost Observations and Lessons Learned
b. Performance Observations and Lessons Learned

8. References

9. Appendix

A. Treatability Study Results
- Objectives
- Test Description
- Performance Data
- Lessons Learned

B. Test Run Data
C. Full Scale Treatment Activity Soil Data

APPENDIX D

Recommendations For Regulatory Change

One of the goals of the Metals in Soil Team was to determine if there are regulatory impediments which interfere, or have the potential to interfere, with the implementation of innovative technologies for treating metals in soil, and to develop recommendations to address those impediments. The recommendations below have been forwarded to the ITRC Management Team and the ITRC Policy Team for evaluation and distribution.

1. *Issue: Containment remedies, which are, in effect, on-site disposal, create a strong disincentive to the use of innovative technologies.* This issue has been framed with respect to metals in soils, but it is pertinent to all treatment technologies. While prices today for many innovative technologies are competitive compared to landfilling offsite, none can compete with simply leaving the contaminated sediment/soil onsite.

Background: Metals which have been discharged onto sediment/soil do not typically migrate very far offsite in groundwater. However, because of their persistence in the environment, metals remain in the sediment/soil indefinitely. Many states allow high concentrations of metals in sediment/soil to be capped, as long as an "institutional control," such as a deed notice, is placed on the property to notify future owners of the contamination and to ensure that the containment system (i.e., cap) is properly maintained. The long term protectiveness of such containment remedies is highly questionable. Monitoring the effectiveness of containment remedies places a long term burden on state and local resources, as well as the responsible party.

Recommendation: When a site is converted from industrial use to commercial, recreational, or residential reuse, there should be a requirement to treat contaminated sediment/soil on the site to a level compatible with the projected reuse of the site. Requiring some degree of treatment when site use changes will assist in attracting technology oriented companies to do business in states and also demonstrate that states are committed to reliable, lasting improvement of human health and the environment. For some states, adopting this approach will require legislative and regulatory change. It is important to note that this regulatory approach has been successfully applied in the Netherlands (see Metals in Soils Team "Fixed Facilities for Soil Washing" report for more details).

2. *Issue: There is not always a good connection between problem holders and technology vendors.*

Background: The environmental consultant that assists the problem holder with remedial investigation work is not always familiar with new remediation technologies that may be applicable to the site. Furthermore, consultants may have no incentive to suggest their use due to potential liability or financial concerns.

Recommendations:

- States should explore mechanisms to facilitate more direct connection between problem holders and technology vendors. States should assist in making sure that reliable information on the cost, performance and status of innovative technologies, as well as their applicability to specific sites, is readily accessible to problem holders and other stakeholders.

- States should be made aware of successful approaches that other state and federal agencies have used to connect problem holders and technology vendors. For example, DOE supports successful deployment of innovative technology by facilitating interaction between regulators, site owners, operational contractors, and the local community.

3. *Issue: The sometimes strict adherence of regulators to numeric cleanup goals can restrict the use of innovative treatment technologies.*

Background: For example, a soil washing project was not approved because during pilot work the treatment goal for one of the site contaminants was missed by 2 parts per million. The technology, however, was successful in removing 80 percent of the contaminant mass.

Recommendation: Mass removal should be a major consideration in addition to achieving numeric media standards or criteria. Guidelines for this approach could be developed for multi-state consensus.

4. *Issue: In some states, there are restrictions on how clean sediment/soil from separation processes can be reused*.

Recommendation: If treated sediment/soil meets technical requirements for a "clean" designation, it should be acceptable for unrestricted reuse, and should not be restricted on the basis that it is a treated waste.

5. Issue: *There is little incentive for smelters and other metal processing facilities to accept metal concentrate from sediment/soil treatment*.

Background: Recycling the metal concentrate is desirable from both an economic and environmental perspective. However, metal concentrate from remedial processes is not an attractive feedstock for most metal processing industries such as smelters, because it has a low concentration of metals compared to other sources such as batteries, scrap metal, etc. In addition, smelters and other metal processors may have concerns about liability associated with accepting a "waste," even though under RCRA some recycled material is not considered to be "waste."

Recommendations:

- Since there is a limited market for metal concentrate from remedial processes, agencies should explore the use of regulatory or other relief such as tax incentives to encourage metal processors such as smelters to accept this material. Agencies should undertake formal communications with smelters and other metal processing facilities in their states to identify strategies which will allow for metal concentrate recycling. The ITRC could assist in this effort on the national level.

- If metal processing facilities which accept metal concentrate from remedial processes are identified in a state, an outreach effort should be made to ensure that remediation companies and state environmental agency staff are aware of the services provided.

- States should collaborate with each other to share information on metals recycling facilities which will accept metal concentrate from remedial processes and provide the same regulatory relief, where available, for out of state users of the facilities as for in state users. For example, if the site is located in State A, and regulatory relief for transporting metal concentrate is provided in State A, but the recycling facility is located in State B, it would be essential for both states to provide the regulatory relief to the generator.

6. *RCRA Issues*

a. *Issue: Only the recyclable metal concentrate from sediment/soil treatment processes is exempt from RCRA requirements, not the onsite treatment of the contaminated sediment/soil.*

Background: Several remediation technologies for sediment/soils contaminated with metals result in separation of the metals from the sediment/soil. The separated material is referred to below as "the metal concentrate." Examples of separation technologies include soil washing, phytoremediation, and electrokinetics.

Recommendation: If it can be determined, based on treatability studies, that the metal concentrate from remedial processes can be recycled and the clean soils returned to a site for unrestricted reuse, the treatment system should not require a RCRA permit, on the basis that the metal contaminants in the sediment/soil are being recycled. This regulatory change would require a substantive amendment to RCRA, 40 CFR 261.2.

In fact, a more general argument could be made that, if any onsite treatment of the sediment/soil will occur within a relatively short time frame (for example, two years or less) and the project is under state environmental agency oversight, a RCRA permit should not be required. Note that the Hazardous Waste Identification Rule (HWIR), proposed by EPA in April, 1996, intended to exempt contaminated media from RCRA permitting unless the media was heavily contaminated. However, this proposed regulatory change was not adopted.

b. *Issue: If a metal concentrate from a remedial process meets hazardous waste criteria, it must be transported as hazardous waste even if it is being transported to a recycling facility*.

Recommendation: Metal concentrates should be exempt from hazardous waste transportation requirements if the material is transported to a facility which will recycle the material. Documentation from the recycling facility could be required to verify that the material was actually recycled. Requiring receipts would address situations where the material was initially considered suitable for recycling, but was later determined to be unsuitable. As above, this would require a substantive amendment to RCRA section 261.2.

c. *Issue: Recycling metal concentrate from remedial processes may require a RCRA TSD permit.*

Background: If the metal concentrate must be pre-treated at the recycling facility, the recovered metal can be considered "reclaimed," meaning the recycling facility could be subject to RCRA per section 261.2. If the metal concentrate is hazardous, the facility then becomes a TSD, and a RCRA TSD permit is required.

Recommendations: Most facilities which are likely to recycle metal concentrate from remedial processes, such as smelters, are already highly regulated industries. If the amount of the metal concentrate accepted annually at the recycling facility is less than 1% of the amount of total feedstock handled by the facility annually, and the metal concentrate is in the same concentration range as feedstocks which are routinely handled by the facility, a RCRA TSD permit should not be required.

The concept here is that any metal concentrate from remedial processes that is accepted at a recycling facility would typically be only a very small percentage of the total material processed at the facility; therefore, the potential environmental impact of the material would be proportionally low as well. Since the recycling facility would fill a major void in the remedial process for metal contaminated soils, such regulatory relief is appropriate as there will be an overall beneficial effect on human health and the environment.

APPENDIX E

Soil Washing Processes and Contacts

Soil Washing Processes for Removing Heavy Metals From Soil
(From The Hazardous Waste Consultant, Nov-Dec 1996)

Soil washing technology	*Status of development*	*Developer*	*Technical contact*
Surfactant- and thickening polymer-based soil washing system removes heavy metals	Full scale	Alternative Remedial Technologies, Inc.	Michael Mann Alternative Remedial Technologies, Inc. 14497 North Dale Mabry Hwy., Suite 140 Tampa, FL 33618 (813) 264-3506
Physical soil washing system removes heavy metals	Full scale	Babcock & Wilcox	Richard Lynch B&W Nuclear Environmental Services, Inc. 2220 Langhorne Road Lynchburg, VA 24506 (804) 948-4673
Multistage elutriation system uses a weak acid to remove metals followed by adsorption of the metals on activated carbon	Pilot scale	BonCHEM	Robert Bender BenCHEM 803 South Negley Avenue, Suite 1 Pittsburgh, PA 15232 (412) 361-1426
Physical/chemical soil washing process uses a number of site-specific steps to remove the contaminated portion from the soil; the contaminated residue is then sent for treatment/disposal	Full scale	Bergmann USA	Jan Limaye Bergmann USA 1550 Airport Road Gallatin, TN 37066 (615) 452-5500
Soil washing system for lead battery site treatment uses physical processes to separate contaminated fines and metallic lead fractions form soil	Full scale	BESCORP	Craig Jones BESCORP P.O. Box 73520 3200 Shell Street Fairbanks, AK 99707 (907) 456-1955

Acid extraction treatment system removes metals and then regenerates the acid	Pilot scale	Center for Hazardous Materials Research	Stophen Paff Center for Hazardous Materials Research 320 William Pitt Way Pittsburgh, PA 15238 (412) 826-5321
Aqueous soil washing system uses chemical additives to remove metals from soil	Pilot scale	Chemcycle Environment, Inc.	Daniel Bourque Chemcycle Environment, Inc. 2630 Blvd. Industriel Chambly, Quebec Canada J3L 4V2 (514) 447-5252
TerraMet process leached metals from contaminated soils, then recovers the metals from the leachate--particularly good for lead	Full scale	The Doe Run Company	Louis Magdits The Doe Run Company P.O. Box 1395 Boss, MO 65440 (573) 626-3476
Ozonation technique removes heavy metals	Full scale	Divesco, Inc.	W. L. Strickland Divesco, Inc. 5000 Highway 80 East Jackson, MS 39208 (601) 825-4644
Leaching technique removes metals using proprietary, nonacidic solutions	Full scale	Barth Decontaminators, Inc.	Luis Pommier Earth Decontaminators, Inc. 2803 Barranca Parkway Irvine, CA 92714 (714) 262-2292
Selective acid extraction process extracts regulated metal contaminants from soil and leaves nonregulated metals; metal contaminants are discharged as 50%-99% concentrates	Full scale	Environmental Technologies International	Troy Duguay Environmental Technologies International 3 Park Plaza, Suite 215 Wyomissing, PA 19610 (610) 376-4104

Acid leaching process uses leaching solution to remove metals	Pilot scale	Flo Trend Systems, Inc.	Kinneth Slaughter Flo Trend Systems, Inc. 707 Lehman Houston, TX 77018 (800) 762-9803
Modified sodium silicate solution used in a proprietary soil washing machine removes metals	Full scale	Hydriplex, Inc.	John Crowley Hydriplex, Inc. 14730 Sandy Creek Drive Houston, TX 77070 (713) 370-2778
Chelation/electrodeposition process removes metals via chelation; the metals are subsequently separated from the chelating agent using an electromembrane reactor, which consists of an electrolytic cell with a cation transfer membrane separating the cathode and anode chambers	Bench scale	IT Corporation	E. Radha Krishnan IT Corporation 11499 Chester Road Cincinnati, OH 45246 (513) 782-4807
Batch steam distillation process removes metals using hydrochloric acid; the metal-laden acid stream is then batch distilled for recovery of acid; heavy metals contained in still bottoms are precipitated as hydroxide salts and drawn off as a sludge metal-laden acid stream is then batch distilled for recovery of acid; heavy metals contained in still bottoms are precipitated as hydroxide salts and drawn off as a sludge	Pilot scale	IT Corporation	Edward Alperin IT Corporation 312 Directors Drive Knoxville, TN 37923 (423) 690-3211
Chromated copper arsenate leaching process treats soil in a countercurrent stirred reactor with sulfuric acid for 30-60 minutes; the acid leaching stream is treated by granulated activated carbon followed by an electrolytic recovery system; process can treat arsenic, cadmium, chromium, copper, lead, and mercury	Bench scale	Lewis Environmental Services, Inc.	Tom Lewis Lewis Environmental Services, Inc. Preble and Columbus St. Pittsburgh, PA 15233 (412) 322-8100
GEMEP mercury removal system subjects mercury-contaminated soil to an aqueous halide-based extractant in an agitated vessel; the mercury/extractant stream is chemically reduced resulting in metallic mercury production	Full scale	Metcalf & Eddy, Inc.	Douglas Shattuck Metcalf & Eddy, Inc. 30 Harvard Mill Square Wakefield, MA 01880 (617) 224-6247

Ex situ water-based wash system used in conjunction with physical sizing and gravity separation	Full scale	Metcalf & Eddy, Inc.	Michael Warminsky Metcalf & Eddy, Inc. Rt 22 West & Station Rd Branchburg, NJ 08876 (908) 685-6067
GHEA Associates process uses additives and surfactants to remove metals from soil; water and surfactants are then separated, with the metals subsequently separated from the surfactant via desorption	Bench scale	New Jersey Institute of Technology	Itzhak Gotlich New Jersey Institute of Technology Newark, NJ 07102 (201) 596-5862
Site-specific soil washing system removes	Full scale	OHM Remediation	Dwight Gemar OHM Remediation Svc Corporation 5731 West Las Positas Bl Pleasanton, CA 94588 (510) 227-1105
Site-specific soil washing system removes metals	Full scale	Smith Environmental Technologies Corporation	Dave Ehlers Smith Environmental Technologics Corp. 304 Inverness Way South Suite 200 Englewood, CO 80112 (303) 790-1747
Rotating trommel and other physical separation processes remove metals	Bench scale	Soil Technology, Inc.	Richard Sheets Soil Technology, Inc. 7865 NE Day Road West Bainbridge Is, WA 98110 (206) 842-8977
Vitrokele process uses metal-seeking chelates to remove heavy metals from contaminated soils	Full scale	Tallon Metal Technologies, Inc.	Bruce Holbein Tallon Metal Tech., Inc. 5 Independence Way Suite 300 Princeton, NJ 08540 (609) 452-9417
Soil recycle treatment train consists of soil washing, biological treatment, and metals removal	Pilot scale	Toronto Harbour Commissioners	Carol Moore Toronto Harbour Commissioners 60 Harbour Street Toronto,Ontario Cananda, M5J 1B7 (416) 863-4830
Countercurrent auger soil washing system	Full scale	TVIES, Inc.	Randy hall TVIES, Inc. 440 Benmar, Suite 2250 Houston, TX 77060 (713) 447-5544

Acids and chelating agents remove metals	Bench scale	U.S. Army Engineers Waterways Experiment Station	C.Nelson Neale U.S. Army Engineer Waterways Experiment Station CEWES-EE-R 3909 Halls Ferry Road Vicksburg, MS 39180 (601) 634-3050
Supercritical carbon dioxide (CO2) extraction uses CO2-soluble chelates to remove heavy metals from soil	Bench scale	University of Pittsburgh	Ali Yazdi University of Pittsburgh Pittsburgh, PA 15213 (412) 624-4141
Concentrated-chloride lead extraction and recovery process uses an aqueous chloride solvent to extract lead from soil; lead is subsequently precipitated from the aqueous chloride solution by the addition of sodium hydroxide	Bench scale	University of Houston	Dennis Clifford University of Houston Houston, TX 77204 (713) 743-4260
High-intensity leaching/separation process removes metals	Full scale	Westinghouse Remediation Services, Inc.	William Norton Westinghouse Remed. Services, Inc. 675 Park North Blvd. Building F, Suite 100 Clarkston, GA 30021 (404) 299-4736

APPENDIX F

A Citizen's Guide To Soil Washing

United States Environmental Protection Agency | Solid Waste and Emergency Response (5102G) | EPA 542-F-96-002 April 1996

A Citizen's Guide to Soil Washing

Technology Innovation Office | Technology Fact Sheet

What is soil washing?

Soil washing is a technology that uses liquids (usually water, sometimes combined with chemical additives) and a mechanical process to scrub soils. This scrubbing removes hazardous contaminants and concentrates them into a smaller volume. Hazardous contaminants tend to bind, chemically or physically, to silt and clay. Silt and clay, in turn, bind to sand and gravel particles. The soil washing process separates the contaminated fine soil (silt and clay) from the coarse soil (sand and gravel). When completed, the smaller volume of soil, which contains the majority of the fine silt and clay particles, can be further treated by other methods (such as incineration or bioremediation) or disposed of according to state and federal regulations. The clean, larger volume of soil is not toxic and can be used as backfill.

How does soil washing work?

A simplified drawing of the soil washing process is illustrated in Figure 1 on page 2. The equipment is transportable so that the process can be conducted at the site. The first step of the process is to dig up the contaminated soil and move it to a staging area where it is prepared for treatment. The soil is then sifted to remove debris and large objects, such as rocks. The remaining material enters a soil scrubbing unit, in which the soil is mixed with a washing solution and agitated. The washing solution may be simply water or may contain additives, like detergent, which remove the contaminants from the soil. This process is very similar to washing laundry. The washwater is drained out of the soil scrubbing unit and the soil is rinsed with clean water. The larger scale soil washing equipment presently in use can process over 100 cubic yards of soil per day.

The heavier sand and gravel particles in the processed soil settle out and are tested for contaminants. If clean, this material can be used on the site or taken elsewhere for backfill. If traces of contaminants are still present, the material may be run through the soil washer again or collected for alternate treatment or off-site disposal. Off-site disposal may be regulated by the Resource Conservation Recovery Act (RCRA) or the Toxic Substance Control Act (TSCA).

A Quick Look at Soil Washing

- Separates fine-grained particles (silt and clay) from coarse-grained particles (sand and gravel).
- Significantly reduces the volume of contaminated soil.
- Is a relatively low-cost alternative for separating waste and minimizing volume required for subsequent treatment.
- Is a transportable technology that can be brought to the site.

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The contaminated silt and clay in the washwater settle out and are then separated from the washwater. The washwater, which now also contains contaminants, is treated by wastewater treatment processes so it can be recycled for further use. As mentioned earlier, the washwater may contain additives, some of which may interfere with the wastewater treatment process. If this is the case, the additives must be removed or neutralized by "pretreatment" methods before the washwater goes to wastewater treatment.

Once separated from the washwater, the silt and clay are tested for contaminants. If all the contaminants were transferred to the washwater and the silt and clay are clean, they can be used at the site or taken elsewhere for use as backfill. If still contaminated, the material may be run through the soil washing process again, or collected for alternate treatment or off-site disposal in a permitted RCRA or TSCA landfill.

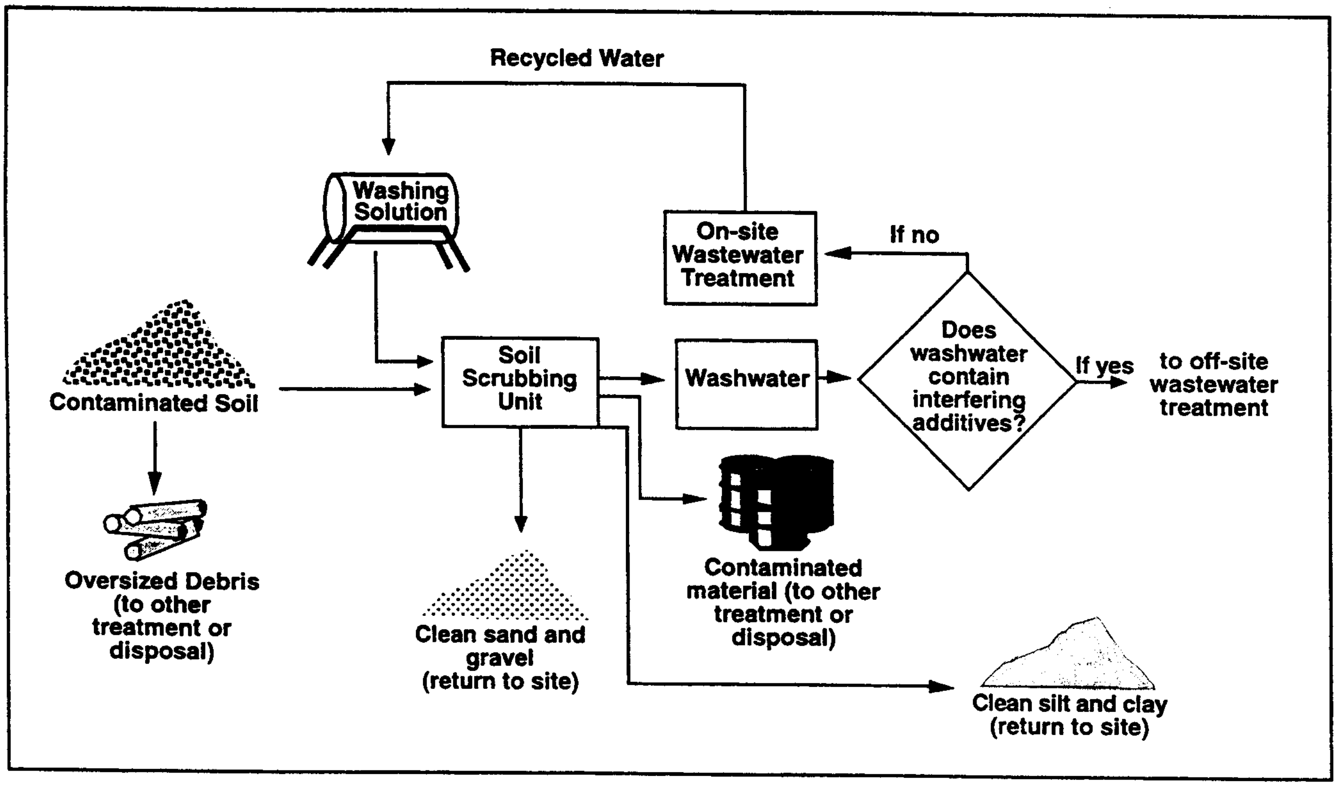
Not All Soil Is Created Equal

Soil is comprised of fine-grained (silt and clay) and coarse-grained (sand and gravel) particles, organic material (decayed plant and animal matter), water, and air. Contaminants tend to readily bind, chemically or physically, to silt, clay, and organic material. Silt, clay, and organic material, in turn, bind physically to sand and gravel. When the soil contains a large amount of clay and organic material, the contaminants attach more easily to the soil and, therefore, are more difficult to remove than when a small amount of clay and organic material is present.

Why consider soil washing?

Soil washing can be used as a technology by itself, but is often used in combination with other treatment technologies. Perhaps the principal use of soil washing is as a *volume reduction* technique in which the contaminants are concentrated in a relatively small mass of material. The larger the percentage of coarse sand and gravel in the material to be processed (which can be cleaned and perhaps returned to the site), the more cost-effective the soil washing application will be.

Figure 1
The Soil Washing Process



Ideally, the soil washing process would lead to a volume reduction of about 90% (which means only 10% of the original volume would require further treatment). Wastes with a high percentage of fine silt and clay will require a larger quantity of material to go on to subsequent, more expensive treatment. These soils may not be good candidates for soil washing.

Soil washing is used to treat a wide range of contaminants, such as metals, gasoline, fuel oils, and pesticides. There are several advantages to using this technology. Soil washing:

- Provides a closed system that remains unaffected by external conditions. This system permits control of the conditions (such as the pH level and temperature) under which the soil particles are treated.

- Allows hazardous wastes to be excavated and treated on-site.

- Has the potential to remove a wide variety of chemical contaminants from soils.

- Is cost-effective because it can be employed as a pre-processing step, significantly reducing the quantity of material that would require further treatment by another technology. It also creates a more uniform material for subsequent treatment technologies.

Will soil washing work at every site?

Soil washing works best when the soil does not contain a large amount of silt or clay. In some cases, soil washing is best applied in combination with other treatment technologies, rather than as a technology by itself.

Removal of contaminants can often be improved during the soil washing process by adding chemical additives to the washwater. However, the presence of these additives may cause some difficulty in the treatment of the used wastewater and the disposal of residuals from the washing process. Costs of handling and managing the additives have to be weighed against the amount of improvements in the performance of the soil washing process.

Where has soil washing been used?

At the King of Prussia site in New Jersey, soil washing was used to remove metal contamination such as chromium, copper, mercury, and lead from 19,000 tons of soil and sludge at a former industrial waste reprocessing facility. The soil washing process was able to clean the materials to meet clean-up goals for eleven metals. For example, chromium levels went from 8,000 milligrams chromium per kilogram of soil (mg/kg) to 480 mg/kg. Table 1 on page 4 lists some of the Superfund sites where soil washing has been selected.

What Is An Innovative Treatment Technology?

Treatment technologies are processes applied to hazardous waste or contaminated materials to permanently alter their condition through chemical, biological, or physical means. Treatment technologies are able to alter, by destroying or changing, contaminated materials so that they are less hazardous or are no longer hazardous. This may be done by reducing the amount of contaminated material, by recovering or removing a component that gives the material its hazardous properties or by immobilizing the waste. *Innovative treatment technologies* are those that have been tested, selected, or used for treatment of hazardous waste or contaminated materials but still lack well-documented cost and performance data under a variety of operating conditions.

Table 1
Examples of Superfund Sites Where Soil Washing Has Been Selected *

Name of Site	Status**	Medium	Contaminants
Myers Property, NJ	In design	Soil, sediment	Metals
Vineland Chemical, NJ	In design	Soil	Metals
GE Wiring Devices, PR	In design	Soil, sludge	Metals
Cabot Carbon/Koppers, FL	In design	Soil	Semi-volatile organic compounds (SVOCs), polyaromatic hydrocarbons (PAHs), metals
Whitehouse Waste Oil Pits	Predesign	Soil, sludge	Volatile organic compounds (VOCs), PCBs, PAHs, metals
Cape Fear Wood Preserving	Design complete	Soil	PAHs, metals
Moss American, WI	Predesign	Soil	PAHs
Arkwood, AR	In design	Soil, sludge	SVOCs, dioxins, PAHs

For a listing of Superfund sites at which innovative treatment technologies have been used or selected for use, contact NCEPI at the address in the box below for a copy of the document entitled ***Innovative Treatment Technologies: Annual Status Report (7th Ed.),*** **EPA 542-R-95-008.** Additional information about the sites listed in the Annual Status Report is available in database format. The database can be downloaded free of charge from EPA's Cleanup Information bulletin board (CLU-IN). Call CLU-IN at 301-589-8366 (modem). CLU-IN's help line is 301-589-8368. The database also is available for purchase on diskettes. Contact NCEPI for details.

* *Not all waste types and site conditions are comparable. Each site must be individually investigated and tested. Engineering and scientific judgment must be used to determine if a technology is appropriate for a site.*
** *As of August 1995*

For More Information

Publications with "EPA" document numbers can be ordered free of charge by either calling 513-489-8190, faxing your request to 513-489-8695, or writing to NCEPI at the address below. If NCEPI is out of stock of a document, you may be directed to other sources.

National Center for Environmental Publications and Information (NCEPI)
P.O. Box 42419
Cincinnati, OH 45242

Publications with "PB" document numbers are available from the National Technical Information Service (NTIS) at 1-800-553-6847. There is a charge for these documents. Mail orders can be sent to:

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161

- *Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation: A Bibliography of EPA Information Resources*, EPA 542-B-95-001. **A bibliography of EPA publications about innovative treatment technologies.**
- *Physical/Chemical Treatment Technology Resource Guide*, EPA 542-B-94-008. **A bibliography of publications and other sources of information about soil washing and other innovative treatment technologies.**
- *Engineering Bulletin: Soil Washing Treatment,* PB91-228056/XAB.
- *Abstracts of Remediation Case Studies*, EPA 542-R-95-001.
- WASTECH® Monograph on Soil Washing/Soil Flushing, ISBN #1-883767-03-2. Available for $49.95 from the American Academy of Environmental Engineers, 130 Holiday Court, Annapolis, MD 21401. Telephone 410-266-3311.