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Engineering Bulletin
Soil Washing Treatment

Purpose

Section 121(b) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) mandates the Environmental Protection Agency (EPA) to select remedies that "utilize permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable" and to prefer remedial actions in which treatment "permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants, and contaminants as a principal element." The Engineering Bulletins are a series of documents that summarize the latest information available on selected treatment and site remediation technologies and related issues. They provide summaries of and references for the latest information to help remedial project managers, on-scene coordinators, contractors, and other site cleanup managers understand the type of data and site characteristics needed to evaluate a technology for potential applicability to their Superfund or other hazardous waste site. Those documents that describe individual treatment technologies focus on remedial investigation scoping needs. Addenda will be issued periodically to update the original bulletins.

Abstract

Soil washing is a water-based process for mechanically scrubbing soils ex-situ to remove undesirable contaminants. The process removes contaminants from soils in one of two ways: by dissolving or suspending them in the wash solution (which is later treated by conventional wastewater treatment methods) or by concentrating them into a smaller volume of soil through simple particle size separation techniques (similar to those used in sand and gravel operations). Soil washing systems incorporating both removal techniques offer the greatest promise for application to soils contaminated with a wide variety of heavy metal and organic contaminants.

The concept of reducing soil contamination through the use of particle size separation is based on the finding that most organic and inorganic contaminants tend to bind, either chemically or physically, to clay and silt soil particles. The silt and clay, in turn, are attached to sand and gravel particles by physical processes, primarily compaction and adhesion. Washing processes that separate the fine (small) clay and silt particles from the coarser sand and gravel soil particles effectively separate and concentrate the contaminants into a smaller volume of soil that can be further treated or disposed. The clean, larger fraction can be returned to the site for continued use. This set of assumptions forms the basis for the volume-reduction concept upon which most soil washing technology applications are being developed.

At the present time, soil washing is used extensively in Europe and has had limited use in the United States. During 1986-1989, the technology was one of the selected source control remedies at eight Superfund sites.

The final determination of the lowest cost alternative will be more site-specific than process equipment dominated. Vendors should be contacted to determine the availability of a unit for a particular site. This bulletin provides information on the technology applicability, the types of residuals resulting from the use of the technology, the latest performance data, site requirements, the status of the technology, and where to go for further information.

Technology Applicability

Soil washing can be used either as a stand-alone technology or in combination with other treatment technologies. In some cases, the process can deliver the performance needed to reduce contaminant concentrations to acceptable levels and, thus, serve as a stand-alone technology. In other cases, soil washing is most successful when combined with other technologies. It can be cost-effective as a pre-processing step in reducing the quantity of material to be processed by another technology such as incineration; it also can be used effectively to transform the soil feedstock into a more homogeneous condition to augment operations in the subsequent treatment system. In general, soil washing is effective on coarse sand and gravel contaminated with a wide range of organic, inorganic, and reactive contaminants. Soils containing a large amount of clay and silt typically do not respond well to soil washing, especially if it is applied as a stand-alone technology.

A wide variety of chemical contaminants can be removed from soils through soil washing applications. Removal efficiencies depend on the type of contaminant as well as the type of soil. Volatile organic contaminants often are easily removed from soil by washing; experience shows that volatiles can be removed with 90-99 percent efficiency or more. Semivolatile organics may be removed to a lesser extent (40-90 percent) by selection of the proper surfactant. Metals and pesticides, which are more insoluble in water, often require acids or chelating agents for successful soil washing. The process can be applicable for the treatment of soils contaminated with specific listed Resource Conservation and Recovey Act (RCRA) wastes and other hazardous wastes including wood-preserving chemicals (pentachlorophenol, creosote), organic solvents, electroplating residues (cyanides, heavy metals), paint sludges (heavy metals), organic chemicals production residues, pesticides and pesticides production residues, and petroleum/oil residues [1, p. 659][2, p. 15][4][7 through 13]*.

The effectiveness of soil washing for general contaminant groups and soil types is shown in Table 1 [1, p. 659][3, p. 13][15, p.1]. Examples of constituents within contaminant groups are provided in Reference 3, "Technology Screening Guide For Treatment of CERCLA Soils and Sludges." This table is based on currently available information or professional judgment where definitive information is currently inadequate or unavailable. The proven effectiveness of the technology for a particular site or waste does not ensure that it will be effective at all sites or that the treatment efficiency achieved will be acceptable at other sites. For the ratings used in this table, good to excellent applicability means the probability is high that soil washing will be effective for that particular contaminant and matrix. Moderate to marginal applicability indicates situations where care needs to be exercised in choosing the soil washing technology. When not applicable is shown, the technology will probably not work for that particular combination of contaminant group and matrix. Other sources of general observations and average removal efficiencies for different treatability groups are the Superfund LDR Guide #6A, "Obtaining a Soil and Debris Treatability Variance for Remedial Actions" (OSWER Directive 9347.3-06FS), [16] and Superfund LDR Guide #6B, "Obtaining a Soil and Debris Treatability Variance for Removal Actions" (OSWER Directive 9347.3-07FS) [17].

Information on cleanup objectives as well as the physical and chemical characteristics of the site soil and its contaminants is necessary to determine the potential performance of this technology and the requirements for waste preparation and pretreatment. Treatability tests are also required at the laboratory screening, bench-scale and/or pilot-scale level(s) to determine

Table 1
Applicability of Soil Washing on General Contaminant Groups for Various Soils

Contaminant Groups		*Matrix*	
		Sandy/ Gravelly Soils	*Silty/Clay Soils*
Organic	Halogenated volatiles	■	▼
	Halogenated semivolatiles	▼	▼
	Nonhalogenated volatiles	■	▼
	Nonhalogenated semivolatiles	▼	▼
	PCBs	▼	▼
	Pesticides (halogenated)	▼	▼
	Dioxins/Furans	▼	▼
	Organic cyanides	▼	▼
	Organic corrosives	▼	▼
Inorganic	Volatile metals	■	▼
	Nonvolatile metals	■	▼
	Asbestos	□	□
	Radioactive materials	▼	▼
	Inorganic corrosives	▼	▼
	Inorganic cyanides	▼	▼
Reactive	Oxidizers	▼	▼
	Reducers	▼	▼

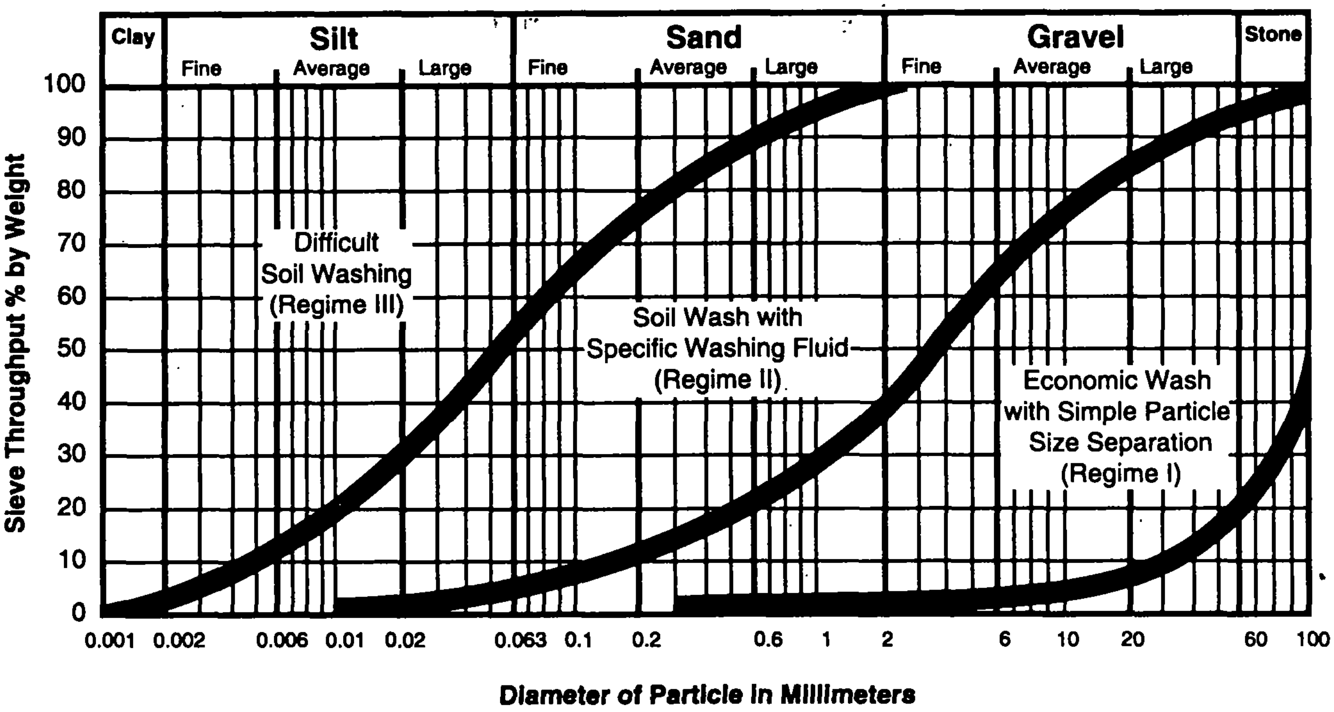
■ *Good to Excellent Applicability: High probability that technology will be successful*
▼ *Moderate to Marginal Applicability: Exercise care in choosing technology*
□ *Not Applicable: Expert opinion that technology will not work*

Table 2
Waste Soil Characterization Parameters

Parameter	*Purpose and Comment*
<u>Key Physical</u>	
Particle size distribution:	
>2 mm	Oversize pretreatment requirements
0.25-2 mm	Effective soil washing
0.063-0.25 mm	Limited soil washing
<0.063 mm	Clay and silt fraction—difficult soil washing
<u>Other Physical</u>	
Type, physical form, handling properties	Affects pretreatment and transfer requirements
Moisture content	Affects pretreatment and transfer requirements
<u>Key Chemical</u>	
Organics **Concentration** **Volatility** **Partition coefficient**	Determine contaminants and assess separation and washing efficiency, hydrophobic interaction, washing fluid compatibility, changes in washing fluid with changes in contaminants. May require preblending for consistent feed. Use the jar test protocol to determine contaminant partitioning.
Metals	Concentration and species of constituents (specific jar test) will determine washing fluid compatibility, mobility of metals, posttreatment.
Humic acid	Organic content will affect adsorption characteristics of contaminants on soil. Important in marine/wetland sites.
<u>Other Chemical</u>	
pH, buffering capacity	May affect pretreatment requirements, compatibility with equipment materials of construction, wash fluid compatibility.

* [reference number, page number]

Figure 1
Soil Washing Applicable Particle Size Range



the feasibility of the specific soil washing process being considered and to understand waste preparation and pretreatment steps needed at a particular site. If bench-test results are promising, pilot-scale demonstrations should normally be conducted before final commitment to full-scale implementation. Treatability study procedures are explained in the EPA's forthcoming document entitled "Superfund Treatability Study Protocol: Bench-Scale Level of Soils Washing for Contaminated Soils" [14].

Table 2 contains physical and chemical soil characterization parameters that must be established before a treatability test is conducted on a specific soil washing process. The parameters are defined as either "key" or "other" and should be evaluated on a site-specific basis. Key parameters represent soil characteristics that have a direct impact on the soil washing process. Other parameters should also be determined, but they can be adjusted prior to the soil washing step based on specific process requirements. The table contains comments relating to the purpose of the specific parameter to be characterized and its impact on the process [6, p. 90][14, p. 35].

Particle size distribution is the key physical parameter for determining the feasibility of using a soil washing process. Although particle size distribution should not become the sole reason for choosing or eliminating soil washing as a candidate technology for remediation, it can provide an initial means of screening for the potential use of soil washing. Figure 1 presents a simplistic particle size distribution range of curves that illustrate a general screening definition for soil washing technology.

In its simplest application, soil washing is a particle size separation process that can be used to segregate the fine fractions from the coarse fractions. In Regime I of Figure 1, where coarse soils are found, the matrix is very amenable to soil washing using simple particle size separation.

Most contaminated soils will have a distribution that falls within Regime II of Figure 1. The types of contaminants found in the matrix will govern the composition of the washing fluid and the overall efficiency of the soil washing process.

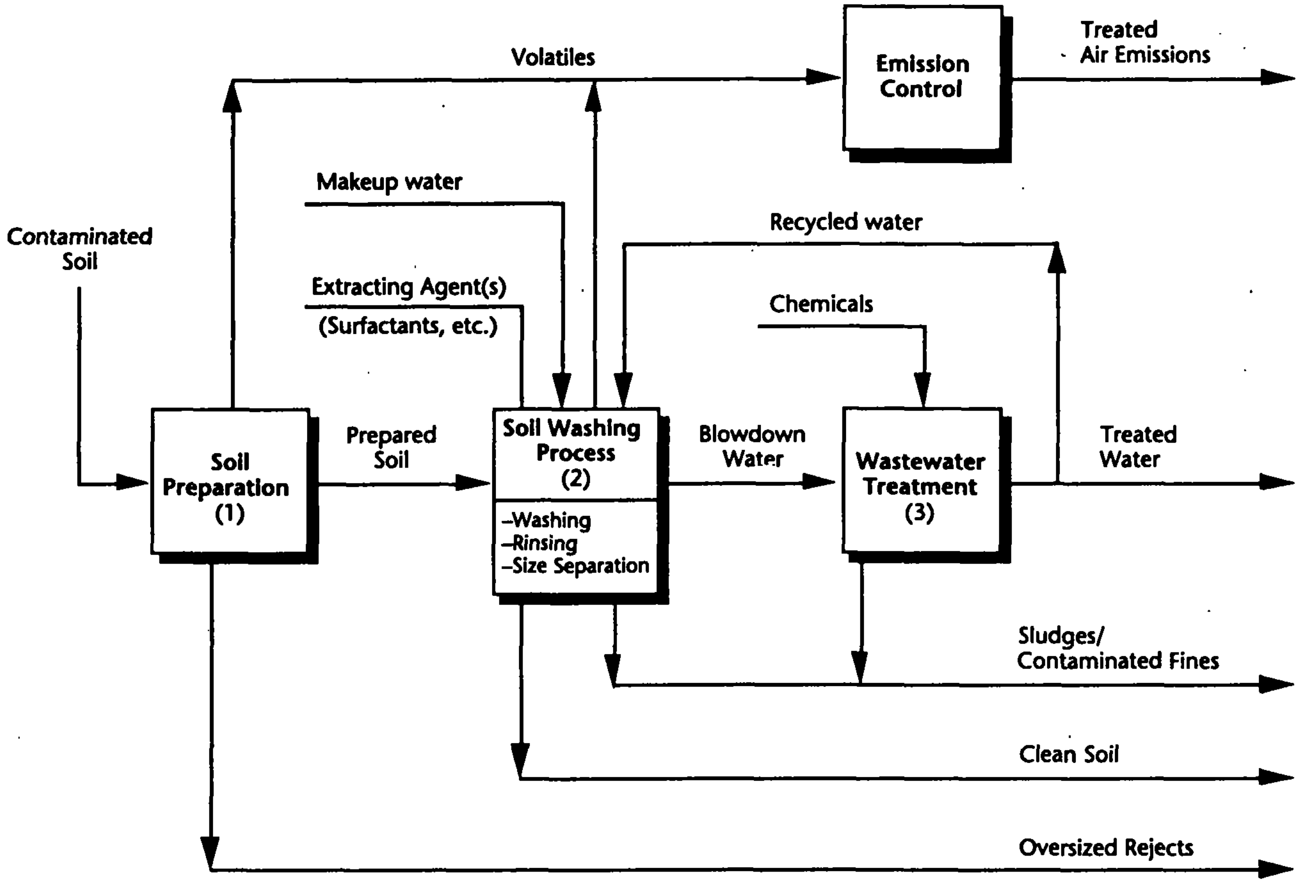
In Regime III of Figure 1, soils consisting largely of finer sand, silt, and clay fractions, and those with high humic content, tend to contain strongly adsorbed organics that generally do not respond favorably to systems that work by only dissolving or suspending contaminants in the wash solution. However, they may respond to soil washing systems that also incorporate a particle size separation step whereby contaminants can be concentrated into a smaller volume.

Limitations

Contaminants in soils containing a high percentage of silt- and clay-sized particles typically are strongly adsorbed and difficult to remove. In such cases, soil washing generally should not be considered as a stand-alone technology.

Hydrophobic contaminants generally require surfactants or organic solvents for their removal from soil. Complex mixtures of contaminants in the soil (such as a mixture of metals, nonvolatile organics, and semivolatile organics) and

Figure 2
Aqueous Soil Washing Process



frequent changes in the contaminant composition in the soil matrix make it difficult to formulate a single suitable washing fluid that will consistently and reliably remove all of the different types of contaminants from the soil particles. Sequential washing steps may be needed. Frequent changes in the wash formulation and/or the soil/wash fluid ratio may be required [3, p. 76][14, p. 7].

While washwater additives such as surfactants and chelants may enhance some contaminant removal efficiencies in the soil washing portion of the process, they also tend to interfere with the downstream wastewater treatment segments of the process. The presence of these additives in the washed soil and in the wastewater treatment sludge may cause some difficulty in their disposal [14, p. 7][15, p. 1]. Costs associated with handling the additives and managing them as part of the residuals/wastewater streams must be carefully weighed against the incremental improvements in soil washing performance that they may provide.

Technology Description

Figure 2 is a general schematic of the soil washing process [1, p. 657][3, p. 72][15, p. 1].

Soil preparation (1) includes the excavation and/or moving of contaminated soil to the process where it is normally screened to remove debris and large objects. Depending upon the technology and whether the process is semibatch or continuous, the soil may be made pumpable by the addition of water.

A number of unit processes occur in the soil washing process (2). Soil is mixed with washwater and possibly extraction agent(s) to remove contaminants from soil and transfer them to the extraction fluid. The soil and washwater are then separated, and the soil is rinsed with clean water. Clean soil is then removed from the process as product. Suspended soil particles are recovered directly from the spent washwater, as sludge, by gravity means, or they may be removed by flocculation with a selected polymer or chemical, and then separated by gravity. These solids will most likely be a smaller quantity but carry higher levels of contamination than the original soil and, therefore, should be targeted for either further treatment or secure disposal. Residual solids from recycle water cleanup may require post-treatment to ensure safe disposal or release. Water used in the soil washing process is treated by conventional wastewater treatment processes to enable it to be recycled for further use.

Wastewater treatment (3) processes the blowdown or discharge water to meet regulatory requirements for heavy metal content, organics, total suspended solids, and other parameters. Whenever possible, treated water should be recycled to the soil washing process. Residual solids, such as spent ion exchange resin and carbon, and sludges from biological treatment may require post-treatment to ensure safe disposal or release.

Vapor treatment may be needed to control air emissions from excavation, feed preparation, and extraction; these emissions are collected and treated, normally by carbon adsorption or incineration, before being released to the atmosphere.

Process Residuals

There are four main waste streams generated during soil washing: contaminated solids from the soil washing unit, wastewater, wastewater treatment sludges and residuals, and air emissions.

Contaminated clay fines and sludges resulting from the process may require further treatment using acceptable treatment technologies (such as incineration, low temperature desorption, solidification and stabilization, biological treatment, and chemical treatment) in order to permit disposal in an environmentally safe manner [16]. Blowdown water may need treatment to meet appropriate discharge standards prior to release to a local, publicly owned wastewater treatment works or receiving stream. To the maximum extent practical, this water should be recovered and reused in the washing process. The wastewater treatment process sludges and residual solids, such as spent carbon and spent ion exchange resin, must be appropriately treated before disposal. Any air emissions from the waste preparation area or the washing unit should be collected and treated, as appropriate to meet applicable regulatory standards.

Site Requirements

Access roads are required for transport of vehicles to and from the site. Typically, mobile soil washing process systems are located onsite and may occupy up to 4 acres for a 20 ton/hour unit; the exact area will depend on the vendor system selected, the amount of soil storage space, and/or the number of tanks or ponds needed for washwater preparation and wastewater treatment.

Typical utilities required are water, electricity, steam, and compressed air. An estimate of the net (consumed) quantity of local water required for soil washing, assuming water cleanup and recirculation, is 130,000-800,000 gallons per 1,000 cubic yards (2,500,000 lbs.) of soil (approximately 0.05-0.3 gallons per pound).

Because contaminated soils are usually considered hazardous, their handling requires that a site safety plan be developed to provide for personnel protection and special handling measures during soil washing operations.

Moisture content of soil must be controlled for consistent handling and treatment; this can be accomplished, in part, by covering excavation, storage, and treatment areas.

Fire hazard and explosion considerations should be minimal, since the soil washing fluid is predominantly water. Generally, soil washing does not require storing explosive, highly reactive materials.

Climatic conditions such as annual or seasonal precipitation cause surface runoff and water infiltration. Berms, dikes, or other runoff control methods may be required. Cold weather freezing must also be considered for aqueous systems and soil excavation operations.

Proximity to a residential neighborhood will affect plant noise requirements and emissions permitted in order to minimize their impact on the population and meet existing rules and regulations.

If all or part of the processed soil is to be redeposited at the site, storage areas must be provided until analytical data are obtained that verifies that treatment standards have been achieved. Onsite analytical capability could expedite the storage/final disposition process. However, soil washing might be applied to many different contaminant groups. Therefore, the analytes that would have to be determined are site specific, and the analytical equipment that must be available will vary from site to site.

Performance Data

The performances of soil washing processes currently shown to be effective in specific applications are listed in Table 3 [1][2][4][7 through 13]. Also listed are the range of particle size treated, contaminants successfully extracted, byproduct wastes generated, extraction agents used, major extraction equipment for each system, and general process comments.

The data presented for specific contaminant removal effectiveness were obtained from publications developed by the respective soil washing system vendors. The quality of this information has not been determined.

RCRA Land Disposal Restrictions (LDRs) that require treatment of wastes to best demonstrated available technology (BDAT) levels prior to land disposal may sometimes be determined to be applicable or relevant and appropriate requirements (ARARs) for CERCLA response actions. The soil washing technology can produce a treated waste that meets treatment levels set by BDAT, but may not reach these treatment levels in all cases. The ability to meet required treatment levels is dependent upon the specific waste constituents and the waste matrix. In cases where soil washing does not meet these levels, it still may, in certain situations, be selected for use at the site if a treatability variance establishing alternative treatment levels is obtained. EPA has made the treatability variance process available in order to ensure that LDRs do not unnecessarily restrict the use of alternative and innovative treatment technologies. Treatability variances may be justified for handling complex soil and debris matrices. The following guides describe when and how to seek a treatability variance for soil and debris: Superfund LDR Guide #6A, "Obtaining a Soil and Debris Treatability Variance for Remedial Actions" (OSWER Directive 9347.3-06FS) [16], and Superfund LDR Guide #6B, "Obtaining a Soil and Debris Treatability Variance for Removal Actions" (OSWER Directive 9347.3-07FS) [17]. Another approach could be to use other treatment techniques in series with soil washing to obtain desired treatment levels.

Technology Status

During 1986-1989, soil washing technology was selected as one of the source control remedies at eight Superfund sites: Vineland Chemical, New Jersey; Koppers Oroville Plant, California; Cape Fear Wood Preserving, North Carolina; Ewan Property, New Jersey; Tinkam Garage, New Hampshire; United Scrap, Ohio; Koppers/Texarkana, Texas; and South Cavalcade, Texas [18].

A large number of vendors provide a soil washing technology. Table 3 shows the current status of the technology for 14 vendors. The front portion of the table indicates the scale of equipment available from the vendor and gives some indication of the vendor's experience by showing the year it began operation.

Processes evaluated or used for site cleanups by the EPA are identified separately by asterisks in the Proprietary Vendor Process/EPA column in Table 3.

The following soil washing processes that are under development have not been evaluated by the EPA or included in Table 3. Environmental Group, Inc. of Webster, Texas, has a process that reportedly removes metals and oil from soil. Process efficiency is stated as greater than 99 percent for lead removal from soils cleaned in Concord, California; greater than 99 percent for copper, lead, and zinc at a site in Racine, Wisconsin; and 94 percent for PCB removal on a Morrison-Knudsen Company project. The process does not appear to separate soil into different size fractions. Detailed information on the process is not available. Consolidated Sludge Company of Cleveland, Ohio, has a soil washing system planned that incorporates their Mega-sludge Press at the end of the process for dewatering solids. The system has not yet been built.

Vendor-supplied treatment costs of the processes reviewed ranged from $50 to $205 per ton of feed soil. The upper end of the cost range includes costs for soil residue disposal.

EPA Contact

Technology-specific questions regarding soil washing may be directed to:

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Risk Reduction Engineering Laboratory
Woodbridge Avenue, Building 10
Edison, New Jersey 08837
Telephone FTS 340-6625 or (201) 321-6625.

Table 3. Summary of Performance Data and Technology Status - Part I

Proprietary Vendor Process/EPA	*Highest Scale of Operation*	*Year Operation Began*	*Range of Particle Size Treated*	*Contaminants Extracted From Soil*	*Extraction Agent(s)*
U.S. Processes					
(1) SOIL CLEANING COMPANY OF AMERICA [5][15, p. 2]	Full scale 15 tons/hr	1988	Bulk soil	Oil and grease	Hot water with surfactant
(2)* BIOTROL SOIL TREATMENT SYSTEM (BSTS) [4, p. 6][12]	Pilot scale 500 lbs/hr	Fall, 1987	Above clay size and below 0.5 in. Some cleaning of fine particles in bio-reactor	Organics - pentachlorophenol, creosote, naphthalene, pyrene, fluorene, etc.	Proprietary conditioning chemicals
(3) EPA'S MOBILE COUNTER-CURRENT EXTRACTOR [9][5, p. 5]	Pilot scale 4.1 tons/hr	Modified with drum washer and shakedown-1982 Full Scale–1986	2-25 mm in drum washer <2 mm in four-stage extractor	Soluble organics (phenol, etc.) Heavy metals (Pb, etc.)	Various solvents, additives, surfactants, redox acids and bases Chelating agent (EDTA)
(4)* EPA'S FIRST GENERATION PILOT DRUM SCREEN WASHER [10, p. 8]	Pilot scale	1988	Oversize (≥2 mm) removed prior to treatment	Petroleum hydrocarbons	Biodegradable surfactant (aqueous slurry)
(5)* MTA REMEDIAL RESOURCES [11][15, p. 2]	Bench scale	N/A	Oversize removed prior to treatment	Organics (oil) Heavy metals (inorganics) removed using counter-current decantation with leaching	Surfactants and alkaline chemicals added upstream of froth flotation cells. Acid for leaching.
Non-U.S. Processes					
(6) ECOTECHNIEK BV [2, p. 17]	Commercial 100 ton/hr max	1982	Sandy soil	Crude oil	None. Water-sand slurry heated to 90°C max. with steam.
(7) BODEMSANERING NEDERLAND BV (BSN) [2, p. 17]	Commercial 20 ton/hr	1982	>100 mm removed No more than 20% <63 µm Sludge <30 µm not cleaned	Oil from sandy soil	None. Uses high pressure water jet for soils washing.
(8) HARBAUER [2, p. 20][7, p. 5]	Commercial 15-20 tons/hr	Lab - 1985 Commercial -1986 With fines removal - 1987	15 µm - 5mm Pre-treatment: coarse screens, electromagnet blade washer	Mostly organics Limited heavy metals removal experience	Hydraulically produced oscillation/vibration Surfactants Acid/base
(9) HWZ BODEMSANERING BV [2, p. 17]	Commercial 20-25 tons/hr	1984	<10 mm and >63 µm	Cyanide, Chlorinated HC, some heavy metals, PNA	Sodium Hydroxide to adjust pH Surfactants
(10) HEIJMAN MILIEUTECHNIEK BV [2,p.17][7, p. 6]	Pilot scale 10-15 tons/hr	1985	<10 mm and no more than 30% <63 µm	Cyanide, heavy metals, mineral oil (water immiscible hydrocarbons)	Proprietary extraction agents. Hydrogen Peroxide (H_2O_2) added to react with extracted CN to form CO_2 and NH_3
(11) HEIDEMIJ FROTH FLOTATION [7, p. 8]	Full scale	N/A	<4 mm and no more than 20% <50 µm	Cyanide, heavy metals, chlorinated HCs, oil, toluene, benzene, pesticides, etc.	Proprietary Surfactants and other proprietary chemicals

*Process evaluated or used for site cleanup by the EPA. N/A = Not available.

Table 3. Summary of Performance Data and Technology Status - Part I (continued)

Proprietary Vendor Process/EPA	*Highest Scale of Operation*	*Year Operation Began*	*Range of Particle Size Treated*	*Contaminants Extracted From Soil*	*Extraction Agent(s)*
Non U.S. Processes (continued)					
(12) EWH ALSEN - BREITENBURG Dekomat System [2, p. 20]	Pilot scale 8-10 cu. m/hr	N/A	<80 mm Clays treated offsite	Oil from sandy soil	Proprietary
(13) TBSG INDUSTRIEVEITIETUNGEN Oil Crep I System [7, p. 7]	Pilot scale	1986	Sand <50 mm Particles <100 µm treated offsite	Hydrocarbon and oil	Proprietary combination of surfactants, solvents, and aromatic hydrocarbons
(14) KLOCKNER UMWELTECHNIK Jet-Modified BSN [2, p. 20]	Pilot scale	N/A	No more than 20% <63 µm	Aliphatics and aromatics with densities < water, volatile organics, some other hydrocarbons	None. Soil blasted with a water jet (at 5,075 psi)

Table 3. Summary of Performance Data and Technology Status - Part II

Proprietary Vendor Process/EPA	*Byproduct Wastes Generated*	*Extraction Equipment*	*Efficiency of Contaminant Removal*	*Additional Process Comments*
U.S. Processes				
(1) SOIL CLEANING OF AMERICA	Wet oil	Screw conveyors	*Contaminant* / *Removal Efficiency %* / *Residual ppm* Oil and grease 50-83 250-600	Three screw conveyors operated in series, hot water with surfactant injected into each stage. Final soil rinse on a fourth screw conveyor.
(2) * BIOTROL SOIL TREATMENT SYSTEM (BSTS)	Oil and grease Sludge from biological treatment	Agitated conditioning tank Froth flotation Slurry bioreactor	For the case presented: 90-95% for Pentachlorophenol; to residuals <115 ppm. 85-95% for most other organics; to residuals <1 ppm.	Dewatered clays and organics to be treated offsite by incineration, solidification, etc. Washed soil was approx. 78% of feed. Therefore, significant volume reduction was achieved.
(3) EPA's MOBILE COUNTER-CURRENT EXTRACTOR	Clay fraction Recovered organics (extractor skimmings) Spent carbon (oversize)	Drum screen Water knife Soil scrubber 4-Stage Counter-current chemical extractor	*Contaminant* / *Removal Efficiency %* / *Residual ppm* Phenol 90 from in. soil 1 80 from or. soil 96 AS_2O_3 50-80 0.5-1.3	Clay fraction treated elsewhere.
(4) * EPA's FIRST GENERATION PILOT DRUM SCREEN WASHER (PDSW)	Sludge Flocculated fines	Drum screen washer	*Contaminant* / *Soil Size Fraction mm* / *Removal Effic.%* / *Residual ppm* Oil and grease 0.25-2 99 <5 <0.25 90 2400	Process removal efficiency increases if extracting medium is heated. Install wet classifiers beneath the PDSW to remove waste water from treated soil. Auger classifiers are required to to discharge particles effectively.
(5)* MTA REMEDIAL RESOURCES (MTARRI) Froth Flotation	Flocculation froth	Reagent blend tank Flotation cells Counter-current decantation	*Contaminant* / *Removal Efficiency %* / *Residual ppm* Volatile organics 98-99+ < 50 Semivolatile organics 98-99+ < 250 Most fuel products 98-99+ < 2200	Flotation cells linked by underflow weir gates. Induced air blown down a center shaft in each cell. Continuous flow operation. Froth contains 5-10 wt% of feed soil.

*Process evaluated or used for site cleanup by the EPA. N/A = Not available.

Table 3. Summary of Performance Data and Technology Status - Part II (continued)

Proprietary Vendor Process/EPA	*Byproduct Wastes Generated*	*Extraction Equipment*	*Efficiency of Contaminant Removal*	*Additional Process Comments*
Non-U.S. Processes				
(6) ECOTECHNIEK BV	Wet oil	Jacketed, agitated tank	About 90% 20,000 ppm residual oil	Effectiveness of process dependent on soil particle size and type of oil to be separated.
(7) BODEMSANERING NEDERLAND BV (BSN)	Oil/organics recovered from wastewater fines	Water jet	Selected results: *Contaminant* *Removal Efficiency %* *Residual ppm* Aromatics >81 >45 PNAs 95 15 Crude oil 97 2300	No comments
(8) HARBAUER OF AMERICA	Carbon which may contain contaminants	Conditioning tank Low frequency vibration unit	*Contaminant* *Removal Efficiency %* *Residual ppm* Organic-Cl ND Tot. organics 96 159-201 Tot. phenol 86-94 7-22.5 PAH 86-90 91.4-97.5 PCB 84-88 0.5-1.3	Vibrating screw conveyor used. Cleaned soil separated from extractant liquor in stages; coarse soil by sedimentation, medium fraction in hydroclone, fines (15-20 µm) by vacuum filter press.
(9) HWZ BODEMSANERING BV	Fines Sludge containing iron cyanide Large particles — carbon, wood, grass	Scrubber (for caustic addition) Upflow classifier	*Contaminant* *Removal Efficiency %* *Residual ppm* CN 95 5-15 PNAs 98 15-20 Chlorin-HC 98 <1 Heavy metals 75 75-125	When the fines fraction (<63 µm) is greater than 20%, the process is not economical. HWZ has had some problems in extracting PNAs and oily material.
(10) HEIJMAN MILIEUTECHNIEK BV	Flocculated fines sludge Oil (if any) and silt	Mix tank followed by soils fraction equipment — hydroclones, sieves, tilt plate separators	*Contaminant* *Removal Efficiency %* *Residual ppm* Cyanide 93-99 <15 Heavy metal cations approx. 70 <200	Process works best on sandy soils with a minimum of humus-like compounds. Because no sand or charcoal filters are employed by Heijmans, the system does not remove contaminants such as chlorinated hydrocarbons.
(11) HEIDEMIJ FROTH FLOTATION	Contaminated float	Conditioning tank Froth flotation tanks	*Contaminant* *Removal Efficiency %* *Residual ppm* Cyanide >95 5 Heavy metals >90 avg >150 Chlorin-HC >99 0.5 Oil >99 20	Process has broad application for removing hazardous materials from soil. Most experience has been on a laboratory scale.
(12) EWH ALSEN - BREITENBURG Dekomat System	Recovered oil Flocculated fines (sludge)	High-shear stirred tank	About 95% oil removed	Cleaned soil from high shear stirred tank is separated into fractions using vibrating screens, screw classifiers, hydroclones, and sedimentation tanks.
(13) TBSG INDUSTRIEVEITIETUNGEN Oil Crep I System	Oil phase containing Oil Crep I	Screw mixer followed by a rotating separation drum for oil recovery	>95% Removal of hydrocarbons has been achieved. Results are influenced by other contaminants present.	Oil Crep system was used successfully in Flansburg, FRG (in 1986) to remove PCBs, PAHs, and other hydrocarbons.
(14) KLOCKNER UMWELTECHNIK High Pressure Water Jet-Modified BSN	Oil/organics recovered from wastewater fines Sludge	Water jet - circular nozzle arrangement	Selected results: *Contaminant* *Removal Efficiency %* *Residual ppm* HC 96.3 82.05 Chlorin-HC >75. <0.01 Aromatics 99.8 <0.02 PAHs 95.4 15.48 Phenol >99.8 <0.01	No comments

*Process evaluated or used for site cleanup by the EPA. N/A = Not available.

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