

VI. Remedial Action 2 — Soil Treatment Technologies For Contaminated Soils

A. Introduction

This section includes the soil treatment technologies that NJDEP considers to be effective or potentially effective in treating various categories of contaminants. These have been chosen based on USEPA documents and commercial availability. Effectiveness ratings, however, are based upon actual NJDEP case studies. Effectiveness is defined in the following manner:

1. Demonstrated Effectiveness — successful treatability test at some scale completed.
2. Potential Effectiveness — expert opinion that technology will work.

This section is intended to be used as a guide and is in no way meant to discourage the use of soil treatment technologies not included here. On any given site, site-specific conditions may result in other technologies being effective in remediating the contaminants. The person conducting the remediation is encouraged to pursue such technologies, especially if site-specific treatability studies indicate reasonable likelihood of success.

Every treatment technology discussed here may, in any given situation, be the sole treatment used on a site or it may be part of a treatment train using different technologies for different contaminants. Technologies which are not in situ (to be referred to as *ex situ*) will involve excavation at the very minimum. In situ technologies do not involve excavation but may still be part of a treatment train with one or more other technologies. There are three basic means of addressing contaminants: the first is to address the toxicity of a contaminant; the second is to reduce the volume of the contaminant; and, the third is to alter the mobility of the contaminant. The purpose of the latter can be to either increase the mobility of the contaminant or to decrease it. In soil flushing, for example, flushing increases the mobility of the contaminant by transporting the contaminant in a water matrix from which it is more easily recovered than from a soil matrix. In stabilization, on the other hand, the mobility of the contaminant is reduced and the threat of the contaminant leaching into the ground water is correspondingly reduced.

The treatability groups, along with the specific chemical contaminants they contain, are listed in Appendix B. For instance, if the contaminant under consideration is 1, 1, 1 trichloroethane, technologies that apply to halogenated volatiles (the contaminant group this belongs to) should be considered.

Throughout Section VI, a note such as “reference 1” means the first reference in Section E. References are at the end of this section.

Checklists for five technologies have been included in Appendix H. These checklists are helpful in evaluating the completeness of the corrective action plan (CAP) and in identifying areas that require closer scrutiny (reference 34).

B. Categories

1. Bioremediation

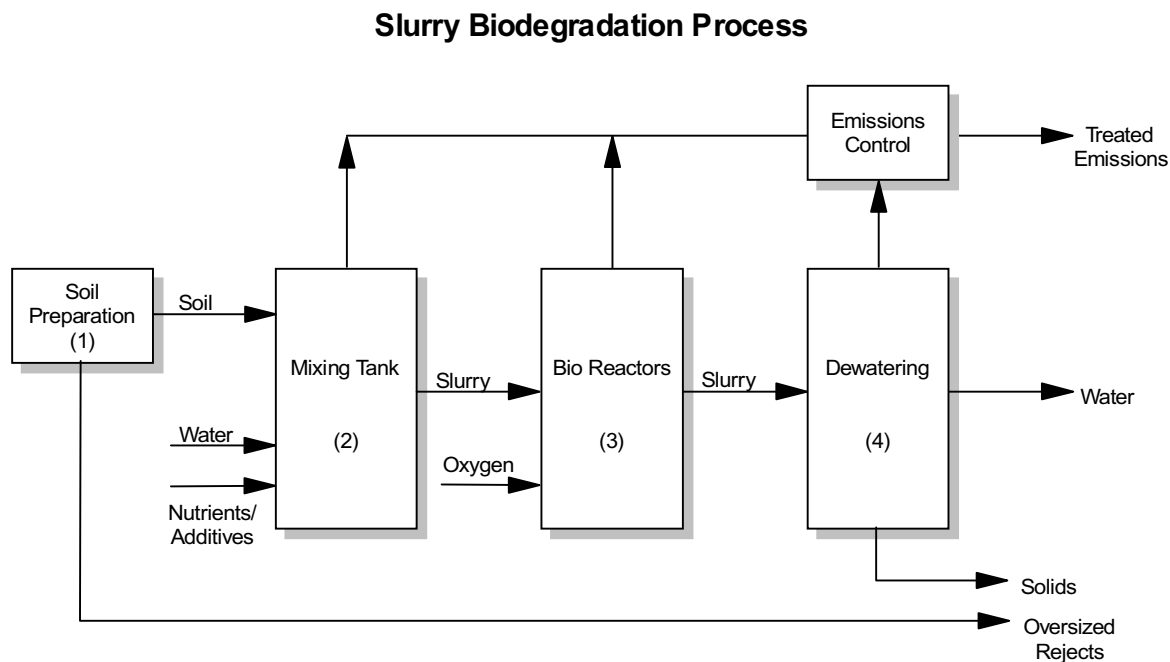
a. Slurry Biodegradation

Process Description:

Soil to be treated is mixed in a reactor with water, creating a slurry which maximizes contact between the contaminants and the microorganisms capable of degrading those contaminants. Usually, the treatment is aerobic, and is implemented in batches. Nutrients are added. Neutralizing agents also are added to adjust the pH to an acceptable range – 4.5 to 8.8. Temperature is maintained between 15 and 35 degrees Centigrade. Finally, bioactive microorganisms are added. After treatment is completed, the slurry is dewatered and the soil

may be redeposited on site. The residence time in the bioreactor is dependent on the soil/sludge matrix and the type of contaminant.

Flow Diagram of Slurry Biodegradation Process (reference 4):



Soil Preparation:

This includes excavation of the soil to be treated as well as screening to remove debris, rubble, and other large objects. Water is added; pH and temperature also are adjusted. The soil is mixed with water to create a slurry.

Waste Streams Generated:

1. The treated solids — if these do not meet target goals, they may be reprocessed;
2. Process water; and
3. Possible air emissions.

Treatability Group:

The treatment is demonstrated effective for fuel hydrocarbons.

It is potentially effective for halogenated volatiles, halogenated semivolatiles, non-halogenated volatiles, non-halogenated semivolatiles, and pesticides. However, the treatment may only be effective for some compounds within these categories. (reference 3).

Advantages and Ideal Conditions; Disadvantages and Limitations:

Advantages and Ideal Conditions –

1. Potential exists for contaminants to be completely destroyed, hence addresses the toxicity of contaminants;
2. Reduces volume of contaminated soil;
3. Available as a full scale technology; and

4. Treated soil may be redeposited on-site.

Disadvantages and Limitations –

1. Soil must first be excavated;
2. An acceptable method for disposal of wastes (water and air emissions discharges) must be present;
3. The treated soils need to be disposed of after treatment — however, they can possibly be redeposited on-site;
4. Presence of chlorides or inorganics, such as heavy metals, as well as some pesticides and herbicides, may reduce the effectiveness of the process by inhibiting microbial action;
5. Contaminants with low water solubility are harder to biodegrade; and
6. Non-uniform particle size can reduce effectiveness by inhibiting microbial contact.

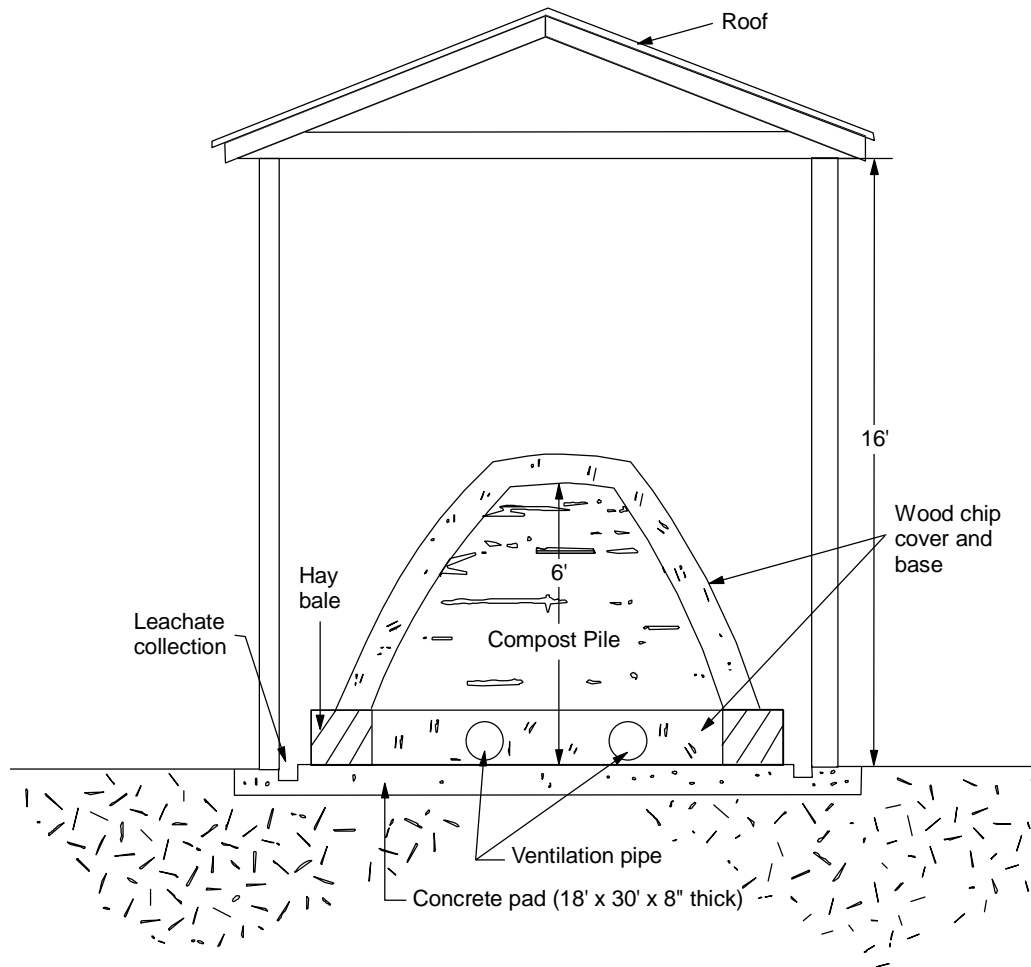
Treatability Matrix For Slurry Biodegradation:

Contaminant Group	Slurry Biodegradation	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles		X
Halogenated Semi Volatiles		X
Non Halogenated Volatiles		X
Non Halogenated Semi Volatiles		X
Fuel Hydrocarbons	X	
Pesticides		X
Inorganics		

b. Ex Situ Bioremediation and Landfarming**Process Description:**

The process basically involves periodically turning over or tilling the soils to aerate the waste. For landfarming, no special nutrients or microbes are added. In ex situ bioremediation, prepared biotreatment cells or beds are used. Moisture, heat, nutrients, oxygen, and pH may be controlled. For composting, wood chips may be added.

Schematic of ex situ bioremediation and composting (reference 23):

**Soil Preparation:**

In most cases, excavation of the existing soils is needed; surface contaminated soils may be treated in place without excavation. Screening for debris and rocks must take place.

Waste Streams Generated:

1. Leachate from the treatment process; and
2. Possible air emissions.

Treatability Group:

This has been demonstrated effective in treating fuel hydrocarbons.

The treatment is potentially effective for halogenated volatiles, halogenated semivolatiles, non-halogenated volatiles, non-halogenated semivolatiles, and pesticides. However, it may only be effective for some compounds within these groups (reference 3).

Advantages and Ideal Conditions; Disadvantages and Limitations:

Advantages and Ideal Conditions –

1. Contaminant toxicity is reduced or eliminated completely;
2. System maintenance is at a minimum; and
3. This is a full scale technology which is generally accepted without difficulty by the public.

Disadvantages and Limitations –

1. Contaminated soil must be excavated unless it is surficial contamination, in which case it may be landfarmed in place; and,
2. There is no control of volatile emissions during landfarming.

Treatability Matrix For Landfarming and Composting:

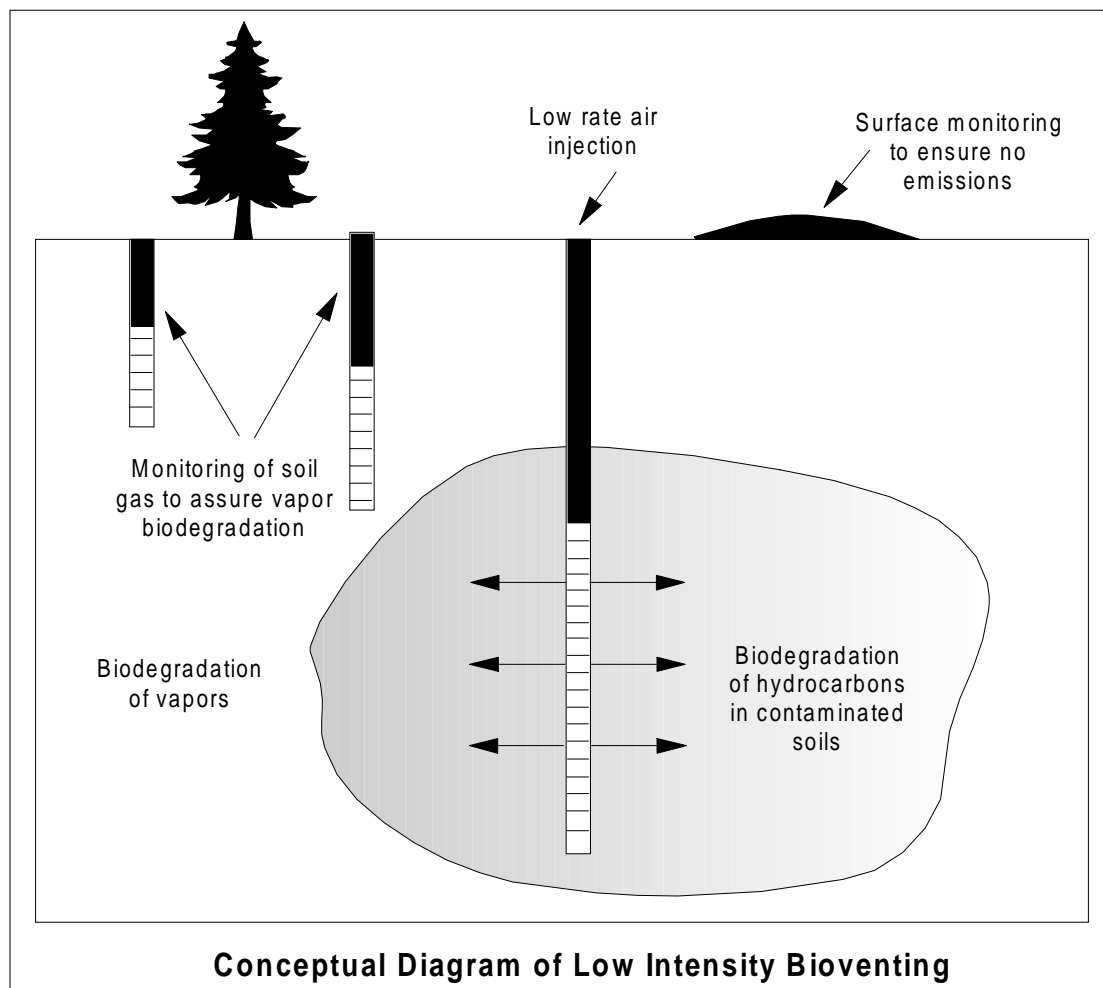
Contaminant Group	Landfarming & Composting	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles		X
Halogenated Semi Volatiles		X
Non Halogenated Volatiles		X
Non Halogenated Semi Volatiles		X
Fuel Hydrocarbons	X	
Pesticides		X
Inorganics		

c. In Situ Biological Treatment

Process Description:

In this process, the activities of naturally-occurring microbes are enhanced by circulating either (a) nutrient and oxygen enriched nutrient water-based solutions or (b) forced air movement which provides oxygen. The latter also is called bioventing. (references 3, 6, and 7). The air flow rate is much lower than in vapor extraction since the object is to deliver oxygen while minimizing volatilization and release of contaminants to the atmosphere.

Conceptual diagram of bioventing (reference 16):



Soil Preparation:

Minimal, since the process is in situ.

Waste Streams Generated:

1. Possible air emissions; and
2. Process water.

Treatability Group:

This is demonstrated effective for non-halogenated volatiles and fuel hydrocarbons.

Potentially effective for halogenated volatiles, halogenated semivolatiles, non-halogenated semivolatiles, and pesticides (reference 3).

Advantages and Ideal Conditions; Disadvantages and Limitations:

Advantages and Ideal Conditions –

1. Contaminant toxicity is reduced or even eliminated;
2. Soil preparation is minimal; and
3. This is a full scale technology with good community acceptability.

Disadvantages and Limitations –

1. As with most in situ systems, detailed site characteristics and treatability studies are needed prior to designing and implementing the system; and
2. Applicability in certain soil types, such as those with low permeabilities, may be limited.

Treatability Matrix for In Situ Biological Treatment:

Contaminant Group	In Situ Biological Treatment	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles		X
Halogenated Semi Volatiles		X
Non Halogenated Volatiles	X	
Non Halogenated Semi Volatiles		X
Fuel Hydrocarbons	X	
Pesticides		X
Inorganics		

2. Liquid Extraction Technologies

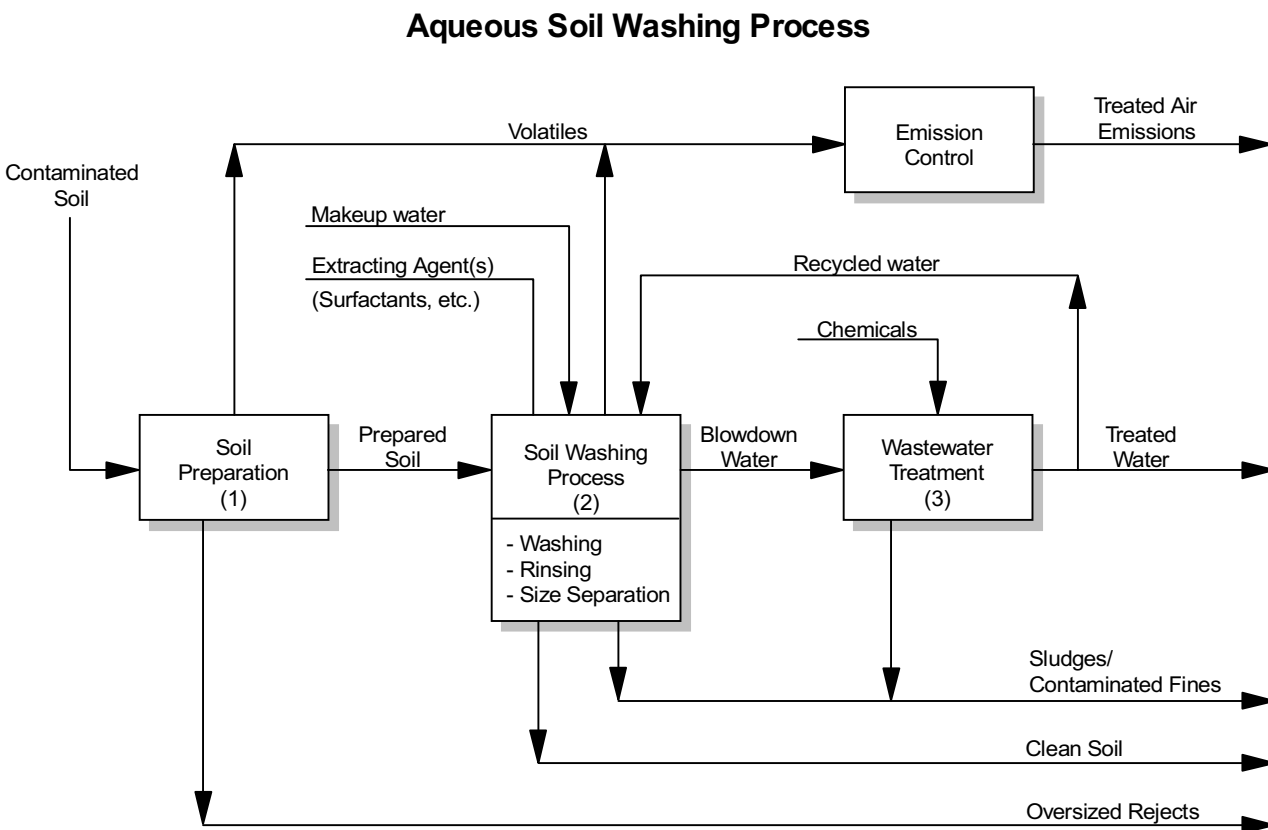
a. Soil Washing

Process Description:

Contaminants which have adsorbed onto soil particles are separated by washing with a leaching agent, and surfactant, chelating agents, or pH adjustment.

Soil is mixed with washwater in order to remove contaminants adsorbed onto soil particles. Sometimes, extraction agents may be added to enhance this process. Soil (now contaminant free or with reduced contaminants) and washwater are then separated. Suspended fines and sludges are recovered using either gravitational methods or flocculation. These may need to be further treated since they contain a higher concentration of contaminant than the original soil. The waste water can be treated and recycled into the process.

Flow diagram of soil washing (reference 11):



Soil Preparation:

Contaminated soil must be excavated and taken to the processor. It is then screened to remove debris, stones, and other large objects.

Waste Streams Generated:

1. Wastewater – this can be kept to a minimum by treating and recycling the wastewater;
2. Air emissions – in some cases;
3. Contaminated clays, fines and sludges resulting from the process; and

4. Spent carbon and spent ion exchange resin used to treat the wastewater (reference 11).

Treatability Group:

This is demonstrated effective for halogenated semivolatiles, fuel hydrocarbons, and inorganics.

It is potentially effective for some halogenated volatiles, some non-halogenated volatiles, non-halogenated semivolatiles, and pesticides (reference 3).

Advantages and Ideal Conditions; Disadvantages and Limitations:

Advantages and Ideal Conditions –

1. Reduces the volume of contaminant, so that further treatment or disposal is less problematic; and
2. Commercially available.

Disadvantages and Limitations –

1. Contaminant toxicity is unchanged, although volume is reduced;
2. Less effective when soil contains a high percentage of silt and clay-sized particles or a high organic content; and
3. Costs associated with the disposal of the subsequent waste streams must be considered.

Treatability Matrix for Soil Washing:

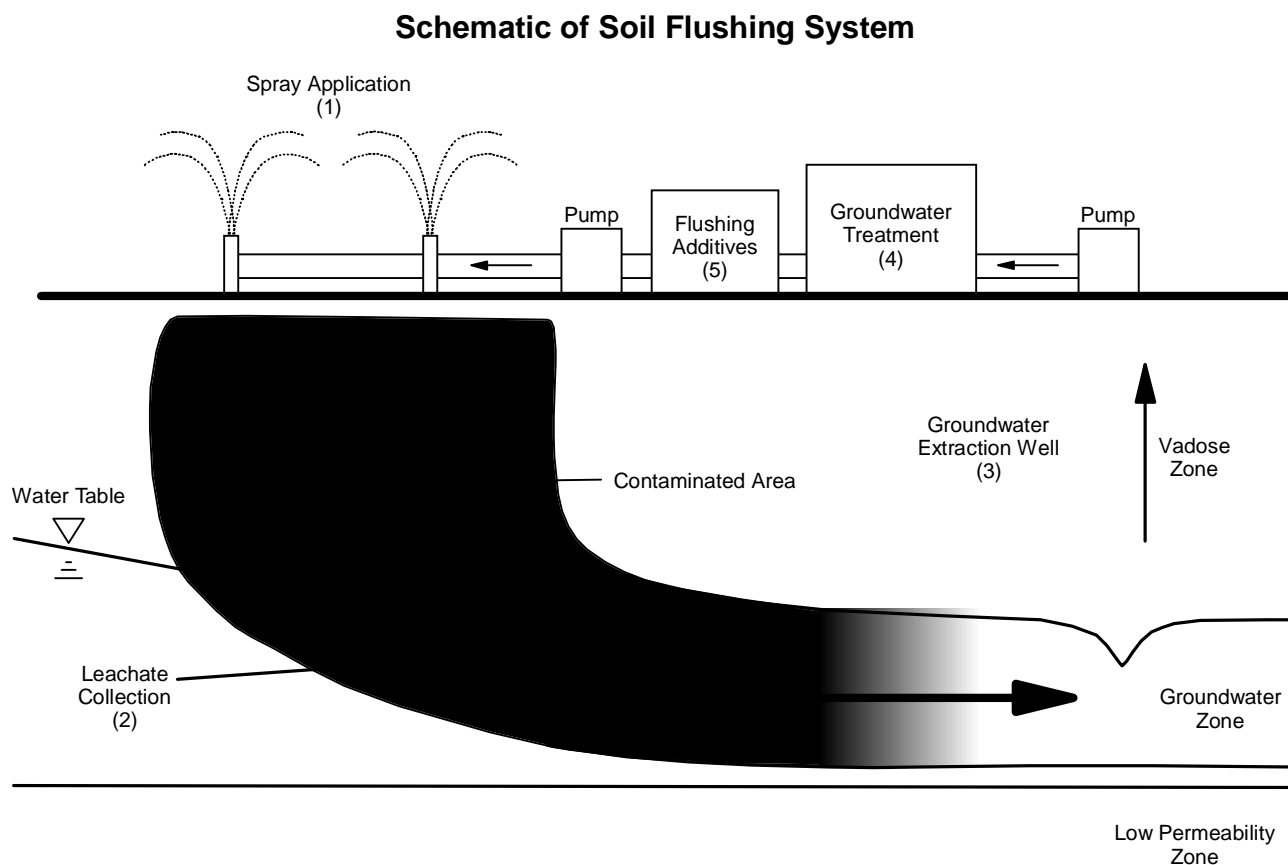
Contaminant Group	Soil Washing	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles		X
Halogenated Semi Volatiles	X	
Non Halogenated Volatiles		X
Non Halogenated Semi Volatiles		X
Fuel Hydrocarbons	X	
Pesticides		X
Inorganics	X	

b. Soil Flushing

Process Description:

A water-based solution, or water, is applied to the soil in order to enhance the solubility of the contaminant in question. The fluid is applied by injection wells, shallow infiltration galleries, or above-ground sprayers. The contaminants are mobilized by solubilization or through the chemical reactions with the liquid. This mixture leaches into the ground water and must be recaptured. In the diagram below, ground water is recaptured and pumped to the surface using standard ground water extraction wells. Appropriate wastewater treatment systems treat the contaminated ground water (reference 15).

Schematic of Soil Flushing (reference 15):



Soil Preparation:

None or minimal, as this is an in situ treatment.

Waste Streams Generated:

1. The contaminated ground water which, after undergoing the process, contains contaminants and flushing agents. The water may be treated and recycled into the process; and
2. Residuals from treating the contaminated ground water.

Treatability Group:

This treatment is demonstrated effective for non-halogenated volatile organics.

It is potentially effective for halogenated volatiles, halogenated semivolatiles, non-halogenated semivolatiles, fuel hydrocarbons, pesticides, and inorganics. However, it may be effective only for some compounds in these categories.

Advantages and Ideal Conditions; Disadvantages and Limitations:

Advantages and Ideal Conditions –

1. Contaminant volume is reduced and the resulting matrix, water, is easier to treat.

Disadvantages and Limitations –

1. Great care must be exercised to ensure that the contaminated ground water is recaptured and treated and not allowed to migrate off-site;
2. Contaminant toxicity is not reduced;
3. Soils with low permeability or with particles that strongly adsorb contaminants, such as clays, are less amenable to this treatment;
4. Treatment times are often lengthy; and,
5. If more than one contaminant is present in the soil, formulation of a single flushing fluid is complicated.

Treatability Matrix for Soil Flushing:

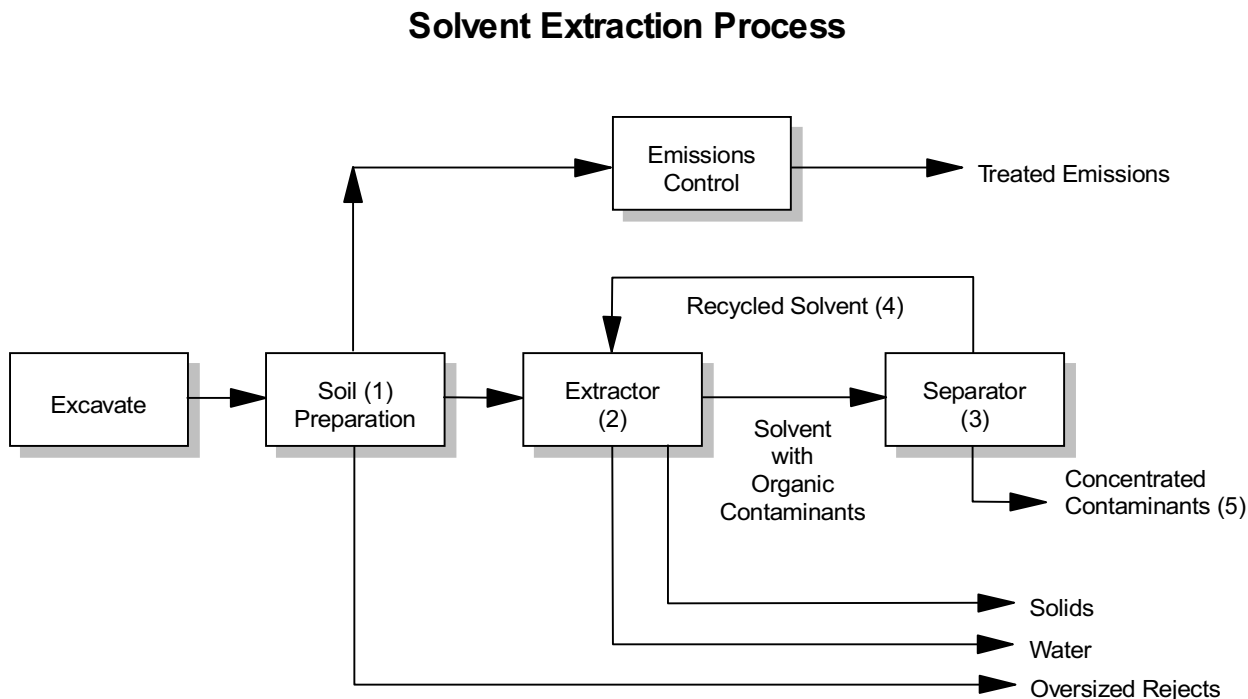
Contaminant Group	Soil Flushing	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles		X
Halogenated Semi Volatiles		X
Non Halogenated Volatiles	X	
Non Halogenated Semi Volatiles		X
Fuel Hydrocarbons		X
Pesticides		X
Inorganics		X

c. Solvent Chemical Extraction

Process Description:

Contaminated soil is mixed with a solvent. This results in the organic contaminant dissolving into the solvent, which is then separated from the soil. The separation is caused by temperature and pressure changes. The solvent is recycled and fed back to the extractor. Dewatering of the treated soil also may take place.

Flow diagram of solvent extraction (reference 12):



Soil Preparation:

Contaminated soil must be excavated and taken to the processor. It is then screened to remove debris, stones and other large objects.

Waste Streams Generated:

1. The concentrated contaminants;
2. The treated soil; and
3. Water generated after dewatering.

Treatability Group:

The treatment is demonstrated effective for halogenated semivolatiles and pesticides.

The technology is potentially effective for halogenated volatiles, non-halogenated volatiles, non-halogenated semivolatiles and fuel hydrocarbons. It may only be effective for some compounds in this group (reference 3).

Advantages and Ideal Conditions; Disadvantages and Limitations:

Advantages and Ideal Conditions –

1. Contaminant volume is reduced.

Disadvantages and Limitations –

1. Does not reduce contaminant toxicity; only volume;
2. Organically bound metals can co-extract with targeted organics, leading to their presence in the waste stream. This complicates disposal of the wastes; and
3. In general, solvent extraction is least effective on very high molecular weight organics and very hydrophilic substances.

Treatability Matrix for Solvent Extraction:

Contaminant Group	Solvent Extraction	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles		X
Halogenated Semi Volatiles	X	
Non Halogenated Volatiles		X
Non Halogenated Semi Volatiles		X
Fuel Hydrocarbons		X
Pesticides	X	
Inorganics		

3. Stabilization and Solidification Treatments

a. Stabilization

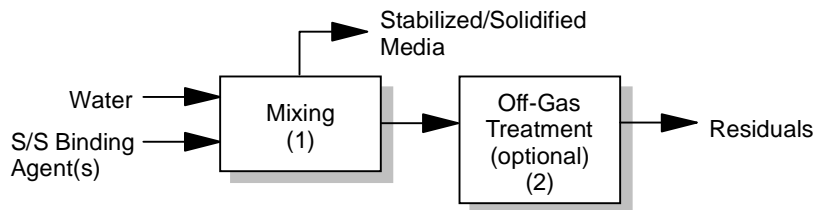
Process Description:

In Situ Treatment: The soil to be treated is mixed with binding/stabilizing materials (such as cement; fine-grained siliceous, or pozzolanic, materials; lime; thermoplastic binders), sorbents (such as activated carbon, clays, zeolites and silicates) and water in appropriate ratios. Surface area mixing is typically accomplished with standard construction equipment. For depths of up to approximately 100 feet, other techniques, including the injection system, auger/cassion system, and auger system, are necessary. Key operating parameters are fixative to waste ratio, length of time for setting and curing, required structural integrity, and minimized potential for leaching. Depending upon the particular process, the final product ranges from a loose, soil-like material to concrete-like molded solids.

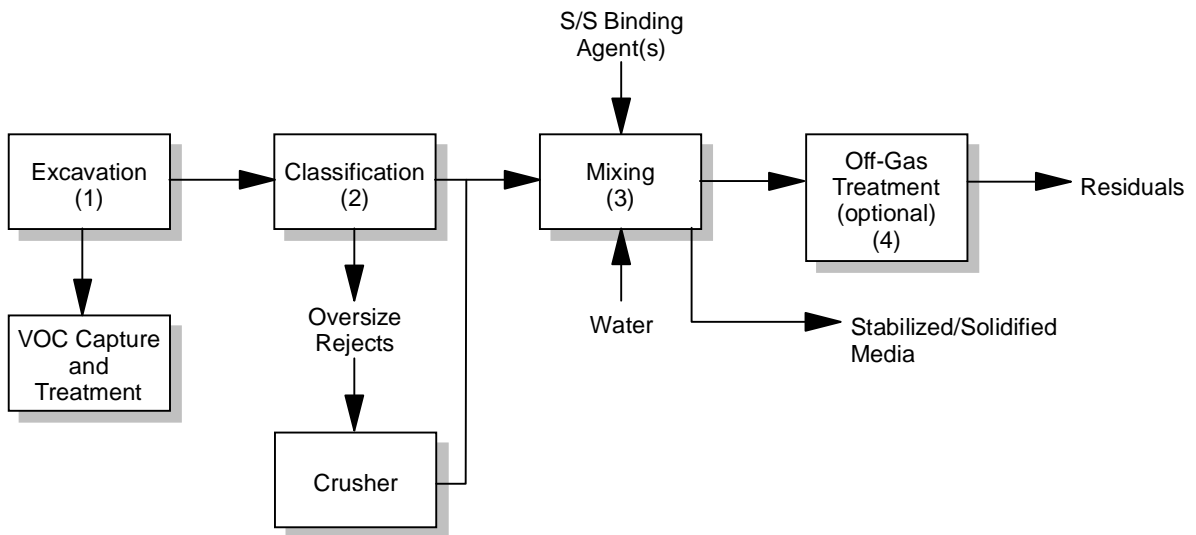
Ex Situ Treatment: The process is similar to the in situ method described above with the exception that contaminated soil is excavated and mixed via on-site cement-mixing and handling equipment.

Flow Diagram of stabilization and solidification (reference 20):

Generic Elements of a Typical In Situ S/S Process



Generic Elements of a Typical Ex Situ S/S Process



Soil Preparation:

Any cyanide and hexavalent chromium must be removed/pretreated prior to solidification. High concentrations of organics, sulfates or chlorides may interfere with the curing of the solidified product. Pretreatment also is required for wastes high in oil and grease, surfactants, or chelating agents. Ex situ processing requires removal of oversize debris.

Waste Streams Generated:

1. The treated solids; and
2. Air emissions of volatile compounds and fugitive dusts that may occur during procedures.

Treatability Group:

Solidification/stabilization is demonstrated effective for soils, sludges, or slurries contaminated with inorganics.

Modified clays and other binders are being studied for application with other organic contaminants.

Advantages and Ideal Conditions; Disadvantages and Limitations:

Advantages and Ideal Conditions –

1. In situ and ex situ solidification/stabilization is available as a full-scale technology for non-volatile heavy metals;
2. The technology is relatively simple, uses readily available equipment and has high throughput rates; and
3. Contaminant mobility is reduced.

Disadvantages and Limitations –

1. The volume of treated material will increase with the addition of reagents (up to double the original volume);
2. Organics are usually not effectively treated using standard binding/stabilizing agents. If organics are of concern, special proprietary binding agents may be necessary;
3. A high content of water, clay or organics can interfere with the mixing process; the clay surface may adsorb key reactants, interrupting the polymerization chemistry of the solidification/stabilization agents;
4. Delivering reagents to the subsurface and achieving uniform mixing and treatment in situ may be difficult;
5. Environmental conditions may affect the long-term immobilization of contaminants;
6. Treatability studies may be required; and
7. Contaminant toxicity is not reduced.

Treatability Matrix For Stabilization and Solidification:

Contaminant Group	Stabilization and Solidification	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles		
Halogenated Semi Volatiles		
Non Halogenated Volatiles		
Non Halogenated Semi Volatiles		
Fuel Hydrocarbons		
Pesticides		
Inorganics	X	

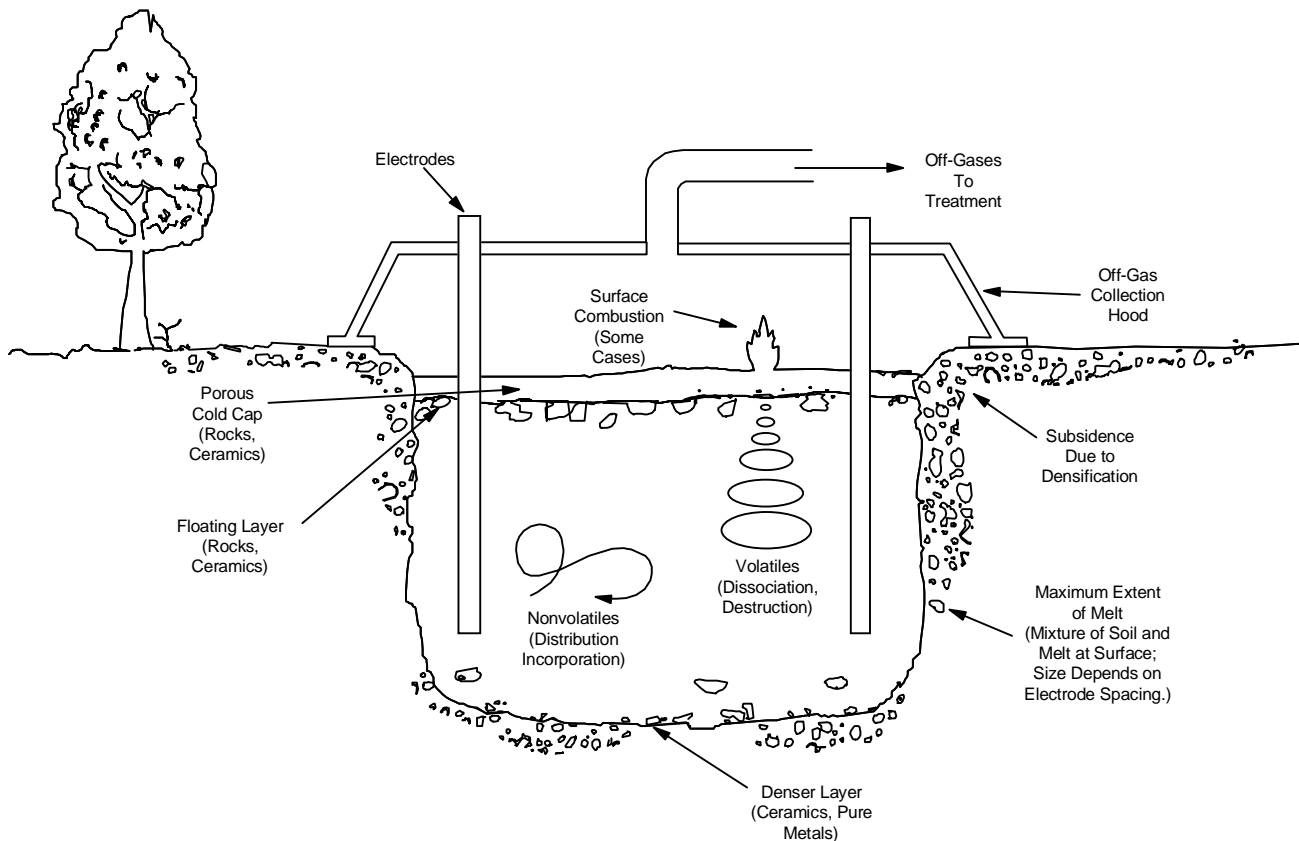
b. Vitrification – Electric Process Heating (Joule Heating)

Process Description:

In Situ Treatment: Large graphite electrodes are inserted into the soil to be treated. The electrodes are typically arranged in 30-foot squares. Graphite on the soil surface connects the electrodes. A high current of electricity passes through the electrodes and graphite. The heat causes a melt that gradually works downward through the soil. As the molten, or vitrified, zone grows, it incorporates inorganic contaminants into the melt and pyrolyzes organic components. After the process is terminated and the ground has cooled, the fused waste material will be dispersed in a chemically inert, stable, glass-like product with very low leaching characteristics.

Ex Situ Treatment: The theory is similar to the in situ method described above, with the exception that the soil is excavated and introduced into a joule-heated ceramic melter for processing.

Schematic of Vitrification (reference 21):



Soil Preparation:

For in situ treatment, a conductive mixture of flaked graphite and glass frit is placed on the soil surface between the pairs of electrodes as a starter path.

The process requires homogeneity of the media. The presence of large inclusions (e.g., highly concentrated contaminant layers, void volumes, containers, metal scrap, general refuse and debris, or other heterogeneous materials within the treatment area) can limit the use of the in situ process.

For ex situ treatment, the soil to be treated must be excavated.

Waste Streams Generated:

1. The inert, impermeable vitrified mass; and
2. Off gases, including volatilized organics and some inorganics.

Treatability Group:

Vitrification is potentially effective for halogenated volatiles, halogenated semivolatiles, non-halogenated volatiles, non-halogenated semivolatiles, fuel hydrocarbons, pesticides, and inorganics.

Advantages and Ideal Conditions; Disadvantages and Limitations:

Advantages and Ideal Conditions –

1. Ex situ vitrification is a full-scale technology; and
2. Contaminant mobility is reduced/eliminated; the vitrified mass resists leaching for geologic time periods. Organic contaminant toxicity is reduced/eliminated; inorganic contaminant toxicity is unchanged although availability is reduced/eliminated.

Disadvantages and Limitations –

1. The process is energy intensive, often requiring temperatures up to approximately 3000 degrees Fahrenheit for fusion and melting of the waste/silicate matrix;
2. Off-gases must be collected and treated before release;
3. Special equipment and trained personnel are required;
4. Water in soils affects operational time and increases the total cost of the process;
5. During in situ treatment, contaminants may volatilize and migrate to outside the boundaries of the treatment area instead of to the surface for collection;
6. In situ treatment is limited to the vadose zone, and only effective to a depth of approximately 30 feet; and
7. In situ vitrification is in pilot-scale development.

Treatability Matrix for Vitrification:

Contaminant Group	Vitrification	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles		X
Halogenated Semi Volatiles		X
Non Halogenated Volatiles		X
Non Halogenated Semi Volatiles		X
Fuel Hydrocarbons		X
Pesticides		X
Inorganics		X

4. Thermal Desorption

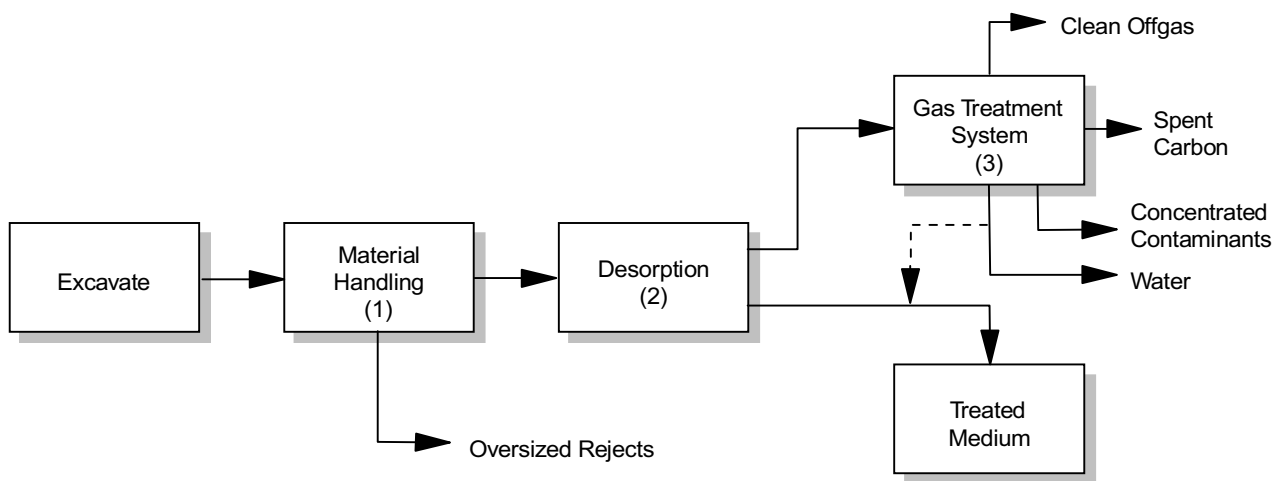
Low and High Temperature Thermal Desorption

Process Description:

This process heats wastes during a desorption process such that water and organic contaminants are volatilized. The contaminated soils are usually passed through zones of increasing temperature. The volatilized contaminants are then sent to a gas treatment system. This is therefore a physical separation system, and does not result in destruction of the contaminants. When the contaminated soils contain up to 10 percent organics only, thermal desorption can be the sole treatment.

Figure below is from reference 14.

Schematic Diagram of Thermal Desorption



Soil Preparation:

The contaminated soil must be excavated and screened to remove debris, stones and other large pieces. Dewatering of the soil may be needed (reference 3).

Waste Streams Generated:

1. Gaseous volatiles (collected on activated carbon, condensed, or burned in an afterburner);
2. Spent carbon; and
3. Condensed water with contaminants.

Treatability Group:

Halogenated volatiles and fuel hydrocarbons are effectively treated (demonstrated) with low temperature thermal desorption (200 - 600 degrees Fahrenheit or 93 - 315 degrees Centigrade).

Pesticides can be effectively treated (demonstrated) with high temperature thermal desorption (600 -1000 degrees Fahrenheit or 315 - 538 degrees Centigrade).

Low temperature thermal desorption is potentially effective for halogenated semivolatiles, non-halogenated volatiles, non-halogenated semivolatiles and pesticides (reference 3).

Similarly, high temperature thermal desorption is potentially effective for halogenated volatiles, halogenated semivolatiles, non-halogenated volatiles, non-halogenated semivolatiles, and fuel hydrocarbons.

Advantages and Ideal Conditions; Disadvantages and Limitations:

Advantages and Ideal Conditions –

1. Volume reduction of wastes

Disadvantages and Limitations –

1. Contaminant toxicity is not addressed by this treatment, although volume is reduced;
2. High moisture content increases heating costs; and
3. Less effective in tightly aggregated soils or those containing rock fragments or particles greater than an inch and a half.

Treatability Matrix for Low Temperature Thermal Desorption:

Contaminant Group	Low Temperature Thermal Desorption	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles	X	
Halogenated Semi Volatiles		X
Non Halogenated Volatiles		X
Non Halogenated Semi Volatiles		X
Fuel Hydrocarbons	X	
Pesticides		X
Inorganics		

Treatability Matrix for High Temperature Thermal Desorption:

Contaminant Group	High Temperature Thermal Desorption	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles		X
Halogenated Semi Volatiles		X
Non Halogenated Volatiles		X
Non Halogenated Semi Volatiles		X
Fuel Hydrocarbons		X
Pesticides	X	
Inorganics		

5. Thermal Destruction

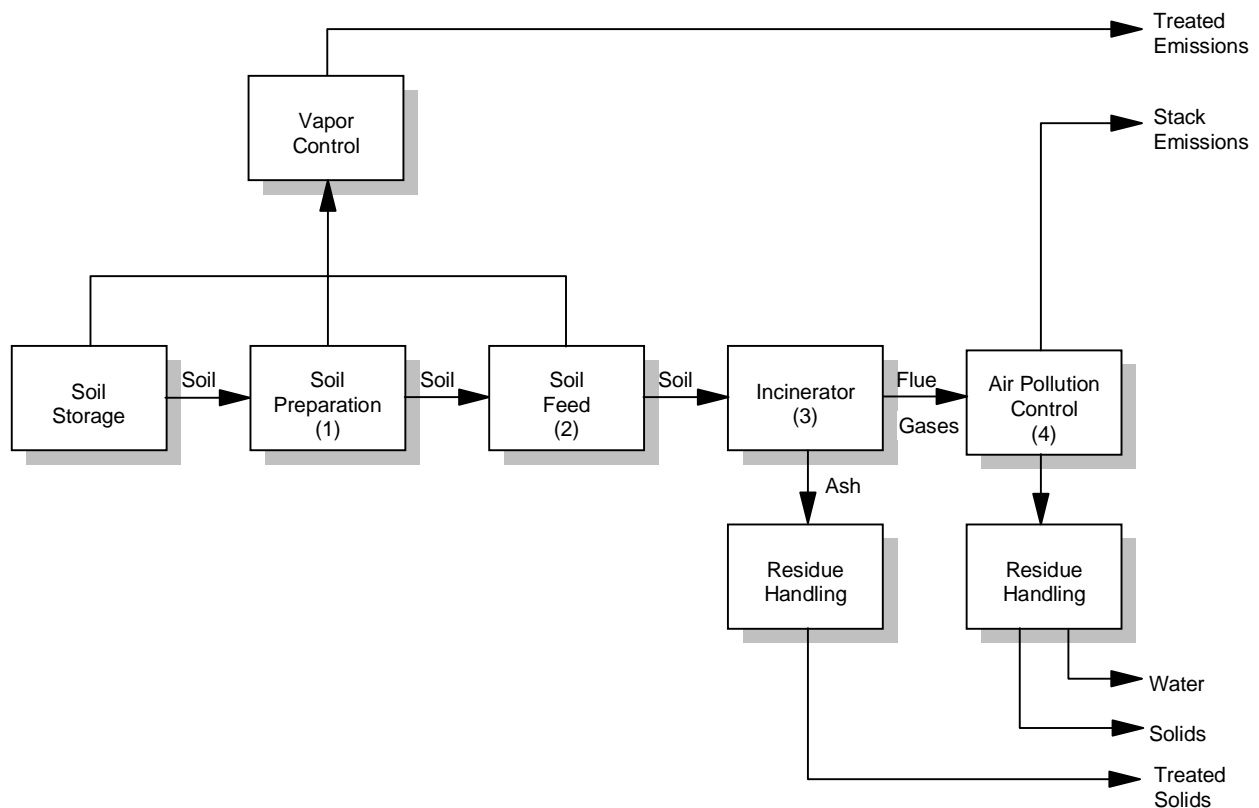
Incineration

Process Description:

Organic constituents in contaminated media are destroyed in the presence of oxygen at temperatures of 1600 - 2200 degrees Fahrenheit or 871-1204 degrees Centigrade. The incinerators may be either mobile or stationary. Different incinerator designs use different mechanisms to attain the high temperatures involved. Three common types of incinerator systems are rotary kilns, circulating fluidized bed, and infrared.

Prepared waste is fed into the incinerator and incinerated. Flue gases generated are handled by various air pollution control equipment, and residue solid (ash) needs are to be disposed of in accordance with appropriate regulations.

Flow diagram of incineration (reference 13):



Soil Preparation:

Contaminated soil must be excavated and taken to the incinerator site. Specific feed sizes are needed, hence screening and blending may be needed.

Waste Streams Generated:

1. Air emissions. The flue gases are treated using various air pollution control equipment such as venturi scrubbers or electrostatic precipitators (reference 13);
2. Ash and treated soil. These may contain residual metals; and,
3. Liquid wastes from the air pollution control operations.

Treatability Group:

This process is potentially effective for halogenated volatiles, halogenated semivolatiles, non-halogenated volatiles, non-halogenated semivolatiles, fuel hydrocarbons, and pesticides (reference 3).

Advantages and Ideal Conditions; Disadvantages and Limitations:

Advantages and Ideal Conditions –

1. Contaminant toxicity, as well as volume, are addressed by this technology. This is especially true for organic contaminants; and,
2. Widely used and available commercially.

Disadvantages and Limitations –

1. Metals (e.g., arsenic, mercury, lead, cadmium and chromium) are not destroyed, and end up in the flue gases or the ash;
2. Community resistance to incineration is often present;
3. The water content of the wastes can create the need to co-incinerate these materials with auxiliary fuels. Dewatering may be needed; and
4. Certain types of soils, such as clay soils or soil containing rocks, may need screening.

Treatability Matrix for Incineration:

Contaminant Group	Incineration	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles		X
Halogenated Semi Volatiles		X
Non Halogenated Volatiles		X
Non Halogenated Semi Volatiles		X
Fuel Hydrocarbons		X
Pesticides		X
Inorganics		

6. Vapor Extraction and Air Sparging

a. Soil-Vapor Extraction

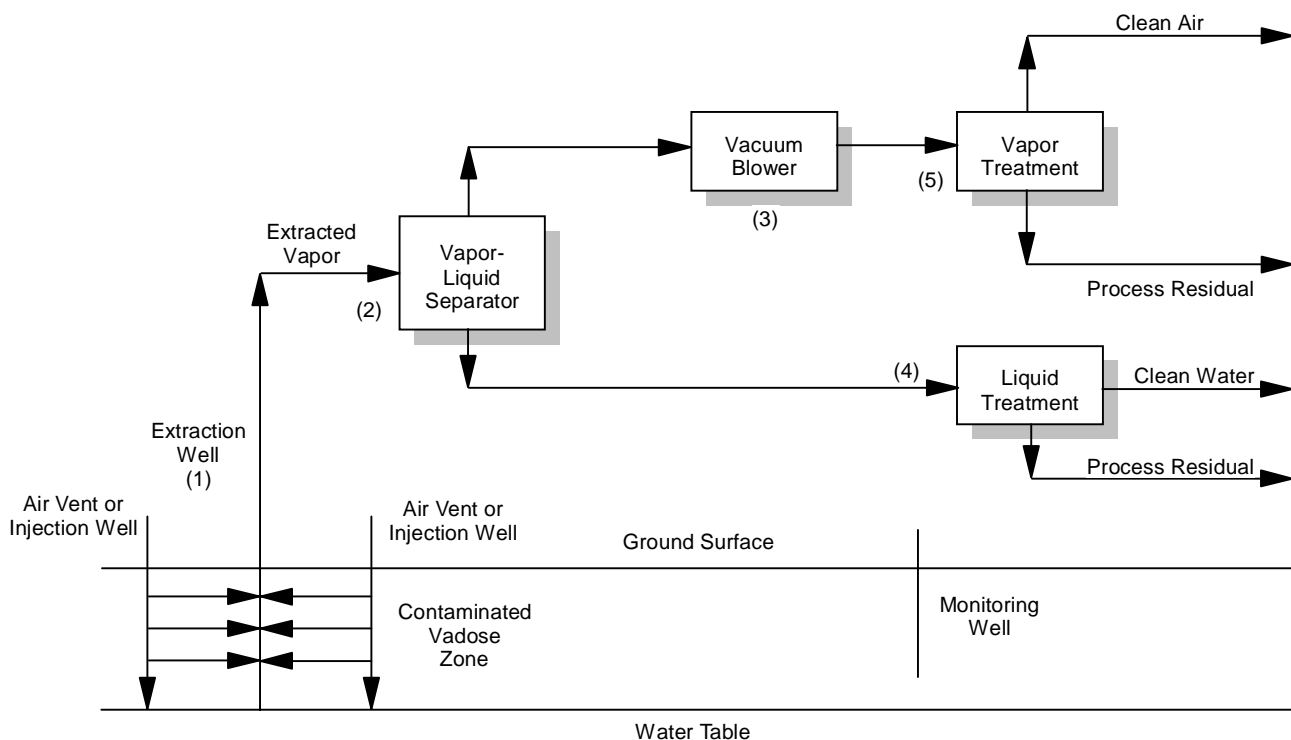
Process Description:

The treatment is generally used to remove volatiles from the vadose zone. The vadose zone includes the soil from the ground surface to the top of the water table.

Air flow through extraction wells creates a vacuum which in turn creates a pressure gradient inducing volatiles to diffuse through the soil to extraction wells. The volatiles are collected as gases. A system must be installed to collect and treat these gases. If the physical dimensions of a site are such that the depth to which the contamination extends is quite shallow, but the contaminated area is large, horizontal piping systems or trenches are used.

Flow diagram of soil vapor extraction (reference 10):

Process Schematic of the In Situ Soil Vapor Extraction System



Soil Preparation:

Minimal or no preparation is needed as the system is in situ.

Waste Streams Generated:

1. Volatile emissions; and,
2. Liquid treatment residuals (e.g., spent granular activated carbon [GAC]).

Treatability Group:

This process is demonstrated effective for halogenated volatiles and fuel hydrocarbons.

It is potentially effective for non-halogenated volatiles (references 3 and 10).

Advantages and Ideal Conditions; Disadvantages and Limitations:

Advantages and Ideal Conditions –

1. Cost effective when large volumes of soil are involved; and
2. Since treatment takes place on-site, risks and costs associated with transport of large volumes of contaminated soils are eliminated.

Disadvantages and Limitations –

1. Less effective in soils with low air permeability. Soils with high carbon content are less amenable to this treatment;
2. Low soil temperatures reduce the effectiveness of the process;
3. Contaminants are reduced in volume, but toxicity is not reduced; and
4. Prior to the design and cleanup, extensive site characterization studies are needed.

Treatability Matrix for Soil Vapor Extraction:

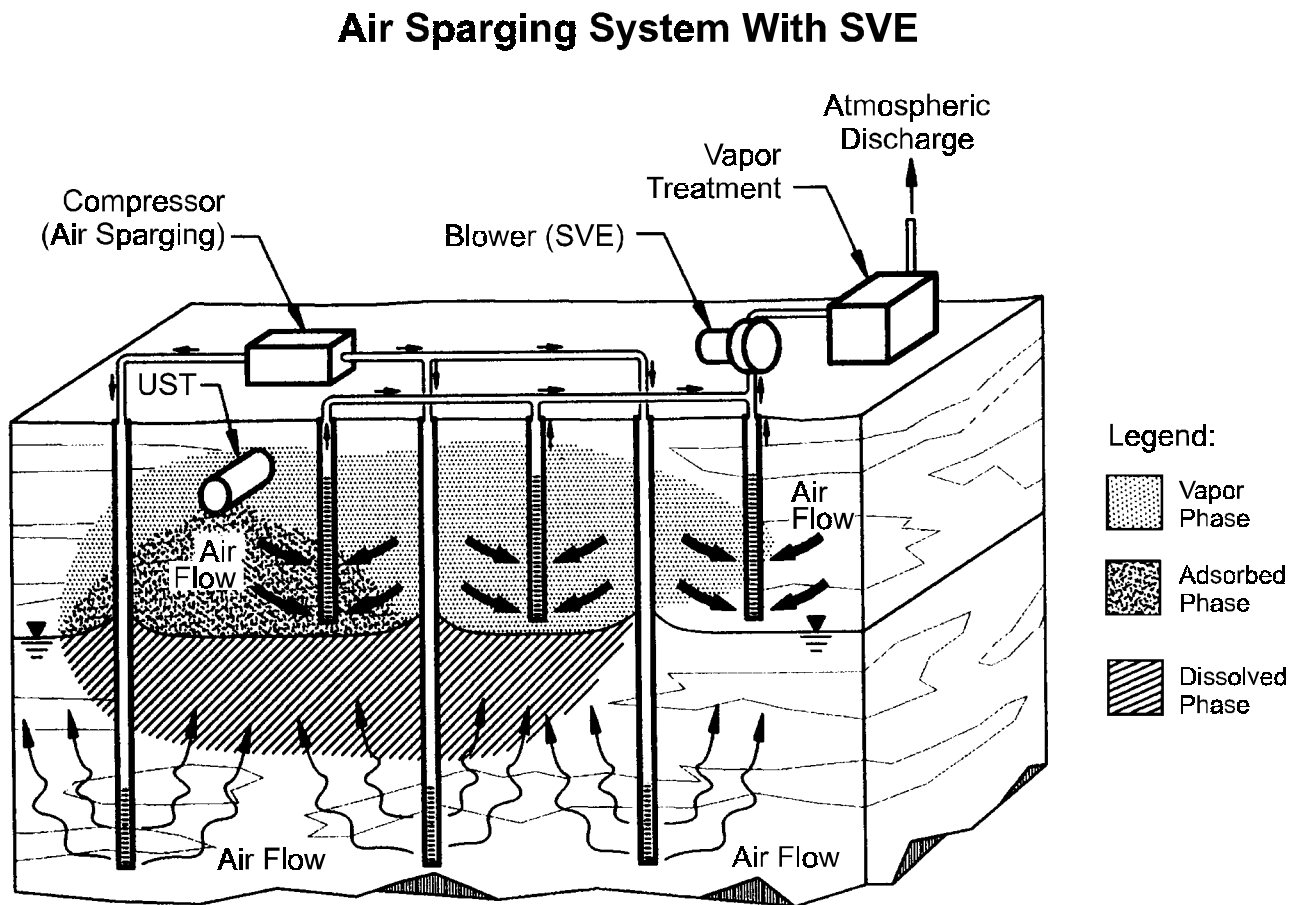
Contaminant Group	Soil Vapor Extraction	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles	X	
Halogenated Semi Volatiles		
Non Halogenated Volatiles		X
Non Halogenated Semi Volatiles		
Fuel Hydrocarbons	X	
Pesticides		
Inorganics		

b. Air Sparging

Process Description:

Air sparging (AS) is an in situ remedial technology that reduces concentrations of volatile constituents that are adsorbed to soils as well as dissolved in ground water. This technology, which is also known as “in situ air stripping” and “in situ volatilization,” involves the injection of contaminant-free air into the subsurface saturated zone, enabling a phase transfer of hydrocarbons from a dissolved phase to a vapor phase. The air is then vented through the unsaturated zone. Air sparging is most often used together with soil vapor extraction (SVE), but it can also be used with other remedial technologies. When air sparging is combined with SVE, the SVE system creates a negative pressure in the unsaturated zone through a series of extraction wells to control the vapor plume migration. This combined system is called AS/SVE (references 34 and 35).

Schematic of Air Sparging System with SVE (reference 34):



Soil Preparation:

Minimal, as the system is in situ.

Waste Streams Generated (as AS/SVE):

1. Volatile emissions; and,
2. Liquid treatment residuals (e.g., spent granular activated carbon [GAC])

Treatability Group:

This process is demonstrated effective for halogenated volatiles and fuel hydrocarbons.

It is potentially effective for non-halogenated volatiles.

Advantages and Ideal Conditions; Disadvantages and Limitations:

Advantages and Ideal Conditions –

1. Readily available equipment; easy installation.
2. Implemented with minimal disturbance to site operations.
3. Short treatment times; usually less than 1 to 3 years under optimal conditions.
4. In general, air sparging is less costly than aboveground systems.
5. Can enhance removal by SVE.

Disadvantages and Limitations –

1. Free product, if present, must be removed prior to air sparging.
2. Stratified soils may cause air sparging to be ineffective.
3. Potential for inducing migration of constituents.
4. Requires detailed pilot testing and monitoring to ensure vapor control and limit migration.

Treatability Matrix for Air Sparging:

Contaminant Group	Air Sparging	
	Demonstrated Effectiveness	Potential Effectiveness
Halogenated Volatiles	X	
Halogenated Semi Volatiles		
Non Halogenated Volatiles		X
Non Halogenated Semi Volatiles		
Fuel Hydrocarbons	X	
Pesticides		
Inorganics		

C. Treatability Matrix — Treatment Technologies by Contaminant Groups

Treatability Matrix

Contaminant Group	Treatment Technology												
	Slurry Biodegradation	Landfarming * & Composting	In Situ Biological *	Soil Washing	Soil Flushing	Solvent Chemical Extraction	Stabilization/ Solidification	Vitrification	Low Temperature Thermal Desorption *	High Temperature Thermal Desorption	Incineration	Soil Vapor Extraction *	Air Sparging *
Halogenated Volatiles	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>		<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>
Halogenated Semi Volatiles	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>		
Non Halogenated Volatiles	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Non Halogenated Semi Volatiles	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>		
Fuel Hydrocarbons	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>		<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>
Pesticides	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>		
Inorganics (Metals)				<input checked="" type="radio"/>	<input type="radio"/>		<input checked="" type="radio"/>	<input type="radio"/>					

<input checked="" type="radio"/>	= Demonstrated Effectiveness
<input type="radio"/>	= Potential Effectiveness

* Checklist Available — See Appendix I

D. Interstate Technology Regulatory Cooperation (ITRC)

The legal and regulatory uncertainties surrounding the cleanup of waste sites discourages the testing and use of innovative technologies and innovative applications of accepted technologies. Technology developers have difficulty gaining regulatory approval for the use of new technologies. Their difficulties are compounded by the requirement for developers to demonstrate a technology's performance in each state targeted for technology deployment.

In response to this concern, the Interstate Technology and Regulatory Cooperation (ITRC) Working Group was formed. The ITRC is made up of representatives of approximately twenty-five state environmental agencies and includes federal, industry, tribal and public stakeholders as well. The ITRC is exploring and developing mechanisms to more effectively deploy innovative environmental technologies for the cleanup of contaminated sites throughout the country. One of the mechanisms under review is the development of baseline regulatory requirements and standardized protocols for verifying a technology's cost and performance.

The ITRC has established several areas of technical focus and teams have been formed to establish reporting and demonstration protocols for specific technologies. Technical and regulatory guidelines have been developed for several technologies applicable for soil remediation, including: 1) Soil Washing, 2) Low Temperature Thermal Desorption and 3) In-Situ Bioremediation. Fact sheets for each are included in Appendix I. The ITRC has developed several informational reports applicable to such emerging technologies as phytoremediation, electrokinetics and in situ stabilization. Additional ITRC information is available on the ITRC Web Page (<http://www.westgov.org/ITRC>).

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