Environment Canada | Ontario Region | Environmental Protection Branch

TABS ON CONTAMINATED SITES

Contaminated Sites Program - Federal Sites

This is one in a series of Technical Assistance Bulletins (TABs) prepared by Environment Canada-Ontario Region for Federal Facilities operating in Ontario.

TAB #23

Ex-Situ Remediation Technologies For Contaminated Sites

DESCRIPTION:
This TAB gives an overview of *Ex-situ* remediation technologies for contaminated soils. A brief description of each proven or innovative remediation technology is given. The contaminants treated, along with the advantages, disadvantages and limitations, are also addressed.

1. *EX-SITU* BIOREMEDIATION

The *Ex-situ* approach to hydrocarbon bio-remediation is carried out aboveground by physically extracting the impacted medium. It is commonly applied to dissolved-phase contamination via pumping and treatment with aboveground bioreactors. Soils are treated aboveground via land-farming, biopiling and composting. The primary advantage to these ex-situ approaches is the degree of control that can be exerted over the processes being used to manipulate the system. Generally, the primary disadvantage is the expense and disruption associated with removal, treatment, and disposal or replacement of the impacted medium.

Many factors affect the selection of potential remediation technologies. These include:

- contaminant type and characteristics (properties, volume, location, exposure risk);
- site characteristics (soil types, permeability, surface and ground water properties, climate, site infrastructures, topography, location);
- costs (capital, operating, maintenance);
- regulatory and public acceptance; and,
- remediation schedule.

The dominant factors that may affect the choice of a technology are summarized in the advantages and disadvantages section for each technology.

2. SOLID PHASE BIOLOGICAL TREATMENT

Solid phase biological treatment is a term used to describe a broad range of ex-situ biodegradation technologies such as biotreatment cells, soil piles, composting, and prepared treatment beds. The process requires putting excavated soil into above-ground enclosures or spreading it over treatment beds that may include leachate and aeration systems. The careful control of moisture, heat, nutrients, oxygen and pH can enhance biodegradation. Prepared treatment beds may be tilled, as in the case of land farming, to enhance aerobic biodegradation of the contaminants.

Technology: *Ex-situ* destruction
Status: Innovative (land farming: conventional)
Contaminants:

- Non-halogenated volatiles and semi-volatiles, fuel hydrocarbons.
- Less effective for some halogenated volatiles and semi-volatiles, pesticides.

Advantages:

- Simple to implement, low capital and low O/M

costs.
- Can be a permanent solution.
- Regulatory and public acceptance is generally high.

Disadvantages:
- A large amount of space is required.
- Atmospheric emissions may require treatment.
- Remediation may take several months to years.

3. SLURRY PHASE BIOLOGICAL TREATMENT

The slurry phase biological treatment system usually consists of a series of large tanks or bioreactor vessels in which water, nutrients, and other additives are mixed with excavated soils or sludges to produce an aqueous slurry. The biodegradation process is carefully controlled in the bioreactor vessel with nutrients, oxygen and pH.

Technology: *Ex-situ* destruction
Status: Innovative
Contaminants:
- Non-halogenated volatiles, fuel hydrocarbons.
- Less effective for some halogenated volatiles and semi-volatiles, non-Halogenated semi-volatiles, pesticides.

Advantages:
- Treats a wide variety of soils including fine grained material that remains suspended in the slurry.
- Treatment rates are better than other bioremediation methods.
- Can be a permanent solution.
- Regulatory and public acceptance generally high.

Disadvantages:
- High capital and high O/M costs.
- Reactor size will limit treatment rate.
- Treatment and disposal of wastewater are necessary.

4. SOIL WASHING

Soil washing remediates excavated soils by separating contaminants sorbed onto soil particles with an aqueous solution that may contain a basic leaching agent, surfactant, chelating agent, or pH adjustment. The treated soils are returned to the excavation site or removed to an off-site landfill.

Technology: *Ex-situ* separation
Status: Innovative
Contaminants:
- Semi-volatiles, fuel hydrocarbons, inorganics.
- Less effective for some volatiles, pesticides.

Advantages:
- The process is transportable to the site.
- Can be a permanent solution.
- Time to complete cleanup is relatively short.
- Regulatory and public acceptance is generally high.

Disadvantages:
- Silts and clays are difficult to remove from washing fluid.
- Optimizing the washing fluid becomes more difficult when mixtures of metals and organics are present.
- Treatment and disposal of wastewater and sludge are necessary.
- High capital and high O/M costs.

5. DEHALOGENATION

Dehalogenation of halogenated aromatic compounds is a batch reactor process whereby excavated contaminated soils are heated and mixed with an alkaline polyethylene glycolate (APEG) reagent. The reaction between the APEG reagent and halogenated compounds will render the halogenated compounds non-toxic through the replacement of halogen molecules (e.g. chlorine) by polyethylene glycol molecules.

Technology: *Ex-situ* destruction
Status: Innovative
Contaminants:
- Halogenated semi-volatiles, pesticides.
- Less effective for some halogenated volatiles.

Advantages:
- Successfully treats PCBs.
- Can be a permanent solution.

Disadvantages :
- High capital and high O/M costs.
- Not cost effective for large waste volumes.
- Treatment and disposal of wastewater are necessary.

6. CHEMICAL EXTRACTION

Chemical extraction processes use solvents to dissolve contaminants from excavated waste materials. The solvents are separated from waste materials and treated to remove any dissolved contaminants. Treated solvents are then recycled through the process.

Technology: *Ex-situ* separation
Status: Innovative
Contaminants:

- Semi-volatiles, pesticides.
- Less effective for some volatiles, fuel hydrocarbons.

Advantages:
- The process is transportable to the site.
- Effective for a wide range of contaminant concentrations.
- Can be a permanent solution.

Disadvantages:
- Residual solvents left in the soils may require secondary treatment before disposal or backfilling.
- High clay and high organic carbon content inhibits extraction.
- High capital and high O/M costs.

7. CHEMICAL REDUCTION/OXIDATION

Reducing/oxidizing agents are used to chemically convert toxic contaminants in excavated waste materials to less toxic compounds that are more stable, less mobile, and/or inert. Commonly used reducing/oxidizing agents are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide.

Technology: *Ex-situ* destruction
Status: Innovative
Contaminants:
- Inorganics.
- Less effective for some non-halogenated volatiles and semi-volatiles, fuel hydrocarbons, pesticides.

Advantages:
- Time to complete cleanup is relatively short.
- Low capital and low O/M costs.

Disadvantages:
- Incomplete oxidation may occur.
- Not effective for high contaminant concentrations.

8. LOW TEMPERATURE THERMAL DESORPTION

Low temperature thermal desorption is a process where excavated waste materials are heated from 95 °C to 315 °C to volatilize water and organic contaminants. Operating temperatures and residence times are designed to volatilize selected contaminants but not oxidize them. Volatiles in atmospheric gas are then commonly removed using carbon adsorption filters.

Technology: *Ex-situ* separation
Status: Innovative
Contaminants:
- Volatiles, fuel hydrocarbons.
- Less effective for semi-volatiles, pesticides.

Advantages:
- Separates a wider range of organic contaminants than in-situ soil vapour extraction.
- The process is transportable to the site.
- Can be a permanent solution.

Disadvantages:
- If operating conditions are not optimal, excessive particulate and volatile air emissions can occur.
- High moisture soils are difficult to treat effectively.
- High capital and high O/M costs.

9. HIGH TEMPERATURE THERMAL DESORPTION

High temperature thermal desorption is a process where excavated waste materials are heated from 315 °C to 540 °C to volatilize water and organic contaminants. The higher temperatures used in this process facilitate removal of less volatile compounds (< 0.01 mm Hg vapour pressure). Operating temperatures and residence times are designed to volatilize selected contaminants but not oxidize them. Volatiles in atmospheric gas are then commonly removed using carbon adsorption filters.

Technology: *Ex-situ* separation
Status: Innovative
Contaminants:
- Semi-volatiles, pesticides.
- Less effective for some volatiles, fuel hydrocarbons.

Advantages:
- Same as low temperature thermal desorption.
- Expanded range of volatiles treated, effectively compared with low temperature thermal desorption.

Disadvantages:
- Same as low temperature thermal desorption.
- Costs are higher than low temperature thermal desorption.

10. INCINERATION

Incineration is a process where excavated waste materials are heated from 870 °C to 1200 °C to volatilize and combust organic contaminants in the presence of oxygen. The most widely used incinerators are the rotary kiln, fluidized bed reactor, liquid injection combustor and infrared incinerator.

Technology: *Ex-situ* destruction
Status: Conventional
Contaminants:

- Semi-volatiles, pesticides.
- Less effective for some volatiles, fuel hydrocarbons.

Advantages:

- Can be a permanent solution.
- Applicable to a wide variety of contaminants and media types.

Disadvantages:

- Soils with volatile metals and salts are difficult to treat.
- High capital and high O/M costs. Off-site fixed facilities are available but will increase costs.
- Public acceptance is low.

11. EXCAVATION AND DISPOSAL

Contaminated material is excavated and transported to a licensed waste disposal facility or landfill. Contaminated material may require pre-treatment prior to disposal. Excavation and disposal is the most common remediation •technology• used for soils.

Technology: *Ex-situ* removal
Status: Conventional
Contaminants:

- All

Advantages:

- Usually a rapid method of dealing with contaminated material.
- Public acceptance is generally high.

Disadvantages:

- Alleviates the contaminant problem at the site but liability persists.
- Overall costs can be high due to transportation costs and landfill tipping fees.
- Regulatory acceptance is low because treatment of contaminants is preferred.

12. VITRIFICATION

Vitrification is a process where excavated contaminated soils and sludges are melted at high temperatures to form a vitreous slag with very low leaching characteristics. Non-volatile inorganics are encapsulated in the slag, rendering them immobile.

Technology: Ex-situ containment
Status: Innovative
Contaminants:

- Inorganics
- Pilot-scale work done on treating semi-volatile organics.

Advantages:

- The vitrified material is highly resistant to leaching and is stronger than concrete.
- Immobilization of inorganics is permanent.

Disadvantages:

- Off-gases need to be controlled.
- Use or disposal of the resultant slag is required.
- Accessibility to sufficient power supply is needed.
- High capital and high O/M costs.
- Regulatory and public acceptance is low.
- Effective for contaminants that float on water

13. COST ESTIMATES

Table 1 shows the relative capital and O & M costs for some of the individual remediation technologies that have been cited.

SOURCES

Canadian Council of Ministers of the Environment (1994). *Subsurface Assessment Handbook for Contaminated Sites*.

Canadian Petroleum Products Institute (1991). *Manual of Petroleum Contaminated Soil Treatment Technologies*, CPPI Report No. 91-9.

Malroz Engineering Inc. (1996). *Site Investigation and Remediation of Contaminated Sites*, course notes.

TABLE 1: EX-SITU REMEDIATION COSTS

Remediation Technology	Type	Status	Costs [1]
Solid Phase Biological Treatment	Ex-situ Destruction	Innovative Land farming Conventional	<$150/tonne design, installation, excavation, O/M costs.[2]
Slurry Phase Biological Treatment	Ex-situ Destruction	Innovative	$80-$230/tonne O/M costs.[3]
Soil Washing	Ex-situ Separation	Innovative	$55-$165/tonne O/M costs.[3]
Dehalogenation	Ex-situ Destruction	Innovative	>$450/tonne design, installation, excavation, O/M costs.[2]
Chemical Extraction	Ex-situ Separation	Innovative	$65-$300/tonne O/M costs.[3]
Chemical Reduction/Oxidation	Ex-situ Destruction	Innovative	$150-$450/tonne design, installation, excavation, O/M costs.[2]
Low Temperature Desorption	Ex-situ Separation	Innovative	<$150/tonne design, installation, excavation, O/M costs.[2]
High Temperature Desorption	Ex-situ Separation	Innovative	$150-$450/tonne design, installation, excavation, O/M costs.[2]
Incineration	Ex-situ Destruction	Conventional	$120-$1175/tonne O/M costs.[3]
Excavation and Disposal	Ex-situ Removal	Conventional	$70/tonne municipal landfill disposal. $550/tonne hazardous waste disposal.[3]
Solidification/Stabilization	In-situ and Ex-situ Containment	Conventional	$70-$200/tonne O/M costs.[3]
Vitrification	Ex-situ Containment	Innovative	$770/tonne design, installation, excavation, O/M costs.[2]

Notes:

1. Costs are changing and in many cases have decreased in the past few years.
2. U.S. Environmental Protection Agency (1993). "Remediation Technologies Screening Matrix and Reference Guide", Version I. Converted from US to Canadian dollars: $1.00 US = $1.40 CAN.
3. Canadian Petroleum Products Institute (1991). "Manual of Petroleum Contaminated Soil Treatment Technologies", CPPI Report No. 91-9.

Malroz Engineering Inc. (1994). *Evaluation of Remediation Options for Petroleum Contaminated Site*.

U.S. Environmental Protection Agency (1994). *Innovative Treatment Technologies*: Annual Status Report. Sixth Edition.

U.S. Environmental Protection Agency (1993). *Remediation Technologies Screening Matrix and Reference Guide*, Version I.

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