

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 #22



In-Situ Remediation Technologies For Contaminated Sites

DESCRIPTION:

This TAB presents an overview of *In-situ* remediation technologies for contaminated soils. Both proven and innovative remediation technologies are discussed. A brief description of the status of each technology, advantages, disadvantages, limitations, and contaminants treated, are included in the discussion.

1. SITE REMEDIATION

A site remediation program consists of five essential steps. These are:

- Identifying the remediation objectives.
- Identifying potential remediation technologies.
- Selecting preferred remediation technology.
- Designing, implementing and monitoring remediation.
- Confirming that the remediation objectives have been achieved.

2. TYPES OF REMEDIATION TECHNOLOGIES

Generally, remediation technologies are classified into four categories based on the process acting on the contaminant. These are:

1. *Removal*: a process that physically removes the contaminant or contaminated medium from the site without the need for separation from the host medium.
2. *Separation*: a process that removes the contaminant from the host medium (soil or water).

3. *Destruction*: a process that chemically or biologically destroys or neutralizes the contaminant to produce less toxic compounds.
4. *Containment*: a process that impedes or immobilizes the surface and subsurface migration of the contaminant.

Removal, separation, and destruction are processes that reduce or remove the contaminant. Containment technologies, on the other hand, control the migration of a contaminant to sensitive receptors without reducing or removing the contaminant.

A number of the technologies have been adapted from general commercial uses in other industrial sectors. These are considered “conventional” technologies. The term •innovative• refers to technologies that have been developed specifically for the site remediation industry.

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.

3. NATURAL ATTENUATION

Natural attenuation describes the processes that act on a contaminant in the natural environment to reduce contaminant concentrations. These processes may include dilution, volatilization, biodegradation, adsorption, and chemical reactions. Although not a technology per se, natural attenuation has been employed at sites where the potential for contaminant migration is low, or where other remedial measures are impractical.

Technology : In-situ destruction

Status : Conventional

Contaminants :

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

Advantages :

- Involves no handling of contaminated materials which could put workers at risk.
- No site disturbance, no capital costs.
- Can be a permanent solution.

Disadvantages :

- Modeling and long term monitoring generally required.
- Degradation products may be more mobile and toxic than the original contaminant.
- Risk that contaminants may migrate to sensitive receptors before being attenuated.
- Regulatory and public acceptance is low because it may be perceived as a "do-nothing" option.

4. IN-SITU BIODEGRADATION

Biodegradation involves stimulating naturally occurring microbes to convert contaminants into less toxic compounds such as carbon dioxide and water. Nutrients and oxygen are added to enhance the biodegradation.

Technology : In-situ destruction

Status : Innovative

Contaminants :

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

Advantages :

- Minimal site disturbance, low capital costs.
- Can be a permanent solution.
- Public acceptance is high.

Disadvantages :

- Contaminant mobility may increase due to microbe enhancement.
- Not effective in highly layered, clay, or bedrock sub-surfaces.
- Not effective at sites with high concentrations of heavy metals, inorganic salts, or chlorinated organics.
- Regulatory acceptance is low due to potential of increased contaminant mobility.
- Remediation may take several months to years.
- Not cost effective for small volumes.

5. BIOVENTING

Bioventing is a form of biodegradation in which oxygen in the form of air is delivered to contaminated unsaturated soils through a system of extraction and injection wells. Unlike soil vapour extraction, lower air flow rates are used to provide just enough oxygen to enhance biodegradation while minimizing volatilization of contaminants to the atmosphere.

Technology : In-situ destruction

Status : Innovative

Contaminants :

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

Advantages :

- Better oxygen delivery to less permeable formations.
- Minimal site disturbance, low capital and O/M costs.
- Can be a permanent solution.
- Regulatory and public acceptance is moderate to high.
- No off-gas treatment if there is a closed system operation.

Disadvantages :

- Not recommended where water table is near surface.
- Monitoring of off-gases at the soil surface may be required.

- Remediation may take several months to years.

6. SOIL VAPOUR EXTRACTION

Soil vapour extraction is a process of inducing air flow through unsaturated soils to remove volatilized contaminants. The air flow is induced by applying a vacuum to the soil through a network of extraction wells. The technology is applicable to volatile compounds with a high vapour pressure. The process requires a system for handling off-gases. Volatilization may be enhanced by heating the subsurface with injected steam or applied electrical currents.

Technology : In-situ separation

Status : Innovative

Contaminants :

- Volatiles, fuel hydrocarbons.

Advantages :

- Control vapour migration to structures, therefore inhalation/explosive risk reduced.
- Minimal site disturbance, low capital costs.
- Can be a permanent solution.
- Regulatory and public acceptance is high when off-gas is treated.

Disadvantages :

- Volatilization inhibited by high humic content of soil.
- Best suited for relatively permeable, homogeneous soils.
- Residual liquid from treated air requires disposal.
- Thermal enhancement of volatilization may sterilize the subsurface, killing microbes required for biodegradation.
- High O/M costs.
- Remediation may take many years.

7. SOLIDIFICATION/STABILIZATION

In solidification or stabilization, contaminants are physically or chemically bound to the medium to produce a non-leachate material. Commonly used binding agents include cement, lime, organic polymers, and silicates. This can be accomplished either in-situ or ex-situ. Commercially available off-site facilities are also available.

Technology: In-situ and Ex-situ containment

Status: Conventional

Contaminants:

- Inorganics.
- Less effective for some semi-volatiles, pesticides.

Advantages:

- Most soils can be treated.
- Time to complete cleanup is relatively short.
- Low O/M costs.

Disadvantages:

- Permanent immobilization of organic contaminants cannot be assured.
- Organic compounds may interfere with binding agents.
- Volume of contaminated material can increase 50 to 100% due to addition of Solidifying agents.
- High capital costs.

8. SURFACE CAPPING (Encapsulation)

Surface capping utilizes an impermeable ground cover to isolate the contaminants from the surface and redirect surface water percolation away from the contaminated soil. Surface caps are typically made of synthetic membranes, soil-bentonite mixtures, asphalt, steel or concrete. An extension of surface capping is encapsulation where impermeable barriers are extended vertically around and sometimes underneath the contaminated soils to redirect groundwater around the contaminated soils.

Technology : In-situ containment

Status : Conventional

Contaminants :

- All types.

Advantages :

- Easily installed.
- Reduces exposure/contact of public with contaminants.
- Low O/M costs.

Disadvantages :

- Long term liability.
- Periodic maintenance and monitoring may be required.
- Groundwater controls may be needed.

9. PHYTO-EXTRACTION

Phyto-extraction is a relatively new technique that exploits the property of some plants to absorb large amounts of heavy metals for storage in their roots and shoots. Phyto-extraction involves selecting and cultivating plants that are amenable to the local soil and climate in the contaminated zone. These plants may accumulate metals up to 1000 times greater than would the normal species. Their shoots may be harvested and subsequently treated as waste.

Technology : In-situ extraction
Status : Emerging

Contaminants :

- Inorganics.

Advantages :

- Low capital and O/M costs.
- Can treat large areas of contaminated soil.

Disadvantages :

- Long time period required.
- Not yet a recognized full scale treatment technology.
- Treatment only extends to the depth of the roots.
- Not effective for highly contaminated soils.
- Plants must be removed and properly disposed of.

10. 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. (1994). *Evaluation of Remediation Options for Petroleum Contaminated Site*.

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

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.

U.S. Environmental Protection Agency (1994). *Superfund Innovative Technology Evaluation Program, Technologies Profiles*. Seventh Edition.

Western States Petroleum Association (1990). *Onsite Treatment of Hydrocarbon Contaminated Soils*.

TABLE 1: SOIL REMEDIATION COSTS

Remediation Technology	Type	Status	Costs ⁽¹⁾
Natural Attenuation	In-situ Destruction	Conventional	No capital or O/M costs. Sampling, analysis, modeling, and monitoring costs.
Biodegradation	In-situ Destruction	Innovative	\$150-\$450/tonne design, installation, O/M costs. ⁽²⁾
Bioventing	In-situ Destruction	Innovative	\$30/cu m O/M costs. ⁽²⁾
Soil Vapour Extraction	In-situ Separation	Innovative	\$25,000-\$50,000 design, installation. \$75/tonne O/M costs. ⁽³⁾
Solidification/Stabilization	In-situ and Ex-situ Containment	Conventional	\$70-\$200/tonne O/M costs. ⁽³⁾

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.

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