“Capacity Building and Strengthening Institutional Arrangement”

Workshop: “Hazardous Substances and Wastes”

Management Options and Strategies

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APAT

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Index

1. Introduction

Key factors in remediation technology selection

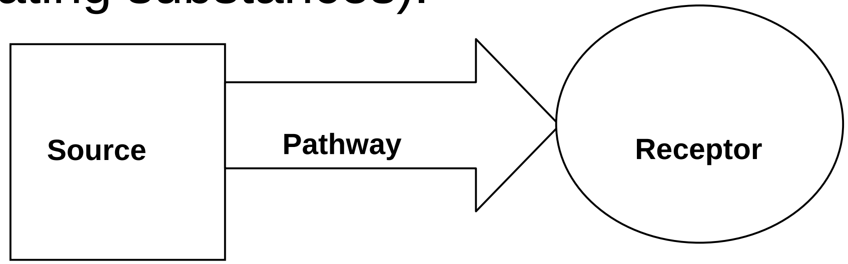
- Driving forces to remediate and goals for the remediation:
  - to protect human health and the environment
  - to enable redevelopment
  - to repair problems at newly developed sites
  - to limit potential liabilities
- Risk management
- Sustainable development
- Stakeholders' views
- Cost effectiveness
- Technical feasibility

1. Introduction

Risk management

The management of land contamination risks involves three main components:

- The source of contamination (e.g. metal polluted soils, a leaking oil drum);
- The receptor (i.e. the entity that could be adversely affected by the contamination e.g. humans, groundwater, ecosystems etc.); and
- The pathway (the route by which a receptor could come into contact with the contaminating substances).



The pollutant linkage (including source, pathway and receptor) analysis needs to be addressed when considering the risk of a contaminated site. Remediation includes any action taken to break the linkage.

1. Introduction

Sustainable development

Remediation processes will achieve sustainable development goals, by:

- helping to conserve land as a resource
- preventing the spread of pollution to air and water
- reducing the pressure for development on green field sites by redeveloping brownfield sites

Sustainability of remedial regime is assessed by:

- evaluation of wider environmental impacts:
  - Traffic and emissions (e.g. volatile organic compounds), Noise, dust, odour , Loss of soil and groundwater function ,Use of material resources (e.g. Aggregates) and energy , Use of landfill resources, waste production, Accidents on personell and machinery, Physical surroundings,
- cost/benefit analysis
- evaluation of wider economic/social impacts
- evaluation of after care commitments

1. Introduction

Stakeholder views

Depending on the size and prominence of the site, stakeholders will include several of the following:

- Land owners,
- Problem holders,
- Regulatory authorities,
- Planning authorities,
- Site users, workers, visitors,
- Financial community (banks, founders, lenders, insurers),
- Site neighbours (tenants, dwellers, visitors),
- Campaigning organisations and local pressure groups,
- Consultants, contractors, and possibly researchers

Costs

1. Introduction

Indicative Costs of Remediation, UK experience (year 2000)

Remediation technology	Indicative unit price
Engineering capping	£15-£30/ m²
Excavation and disposal to landfill	£50/m³
Encapsulation (shallow cut-off wall)	£40-£60/ m²
Encapsulation (deep cut-off wall)	£70-£120/ m²
'Typical' landfill gas control system	£200,000? per site
'Typical' grout curtain/ vent trench	£220,000? per site
Bioremediation	£35-£45/ tonne
Vitrification	£40/ tonne
In-situ vitrification (5t/hr)	£150 - £215/ tonne
Incineration (special wastes)	£750 - £1,000+/ tonne
Dechlorination	£100 - £300/ tonne
Soil vapour extraction	£40-60/m³ vadose zone
Soil washing	£30 - £35/ tonne
Enhanced Thermal Conduction	£35-45/m³
Six phase heating	£20-30/m³
In situ chemical oxidation	£40-80/m³
Pump and treat	£20-30/m³
Free product recovery	£10-20/m³ vadose zone
Air sparging	£45-55/m³ groundwater
Oxidation of cyanide	£400/ tonne
Solvent extraction and incineration	£400/ tonne
Thermal desorption (including excavation and pre treatment)	£35 – 150/ tonne

1. Introduction

Technical feasibility

A suitable technology is one that meets the technical and environmental criteria for dealing with a particular remediation problem. However, it is also possible that a proposed solution may appear suitable, but is still not considered feasible, because of concerns about:

- Previous performance of the technology in dealing with a particular risk management problem;
- Ability to offer validated performance information from previous projects;
- Expertise of the purveyor (service provider);
- Ability to verify the effectiveness of the solution when it is applied;
- Confidence of stakeholders in the solution;
- Cost; and
- Acceptability of the solution to stakeholders who may have expressed preferences for a favoured solution or have different perceptions and expertise.

1. Introduction

Risk Management actions

Classification of Risk Management actions taken at contaminated sites

- Safety actions (in situ source containment)
  - emergency/temporary
  - permanent
- Clean-up actions (source reduction)
  - in situ (contaminated material is left in place)
  - ex situ (material is excavated)
    - on-site (material is treated on the site)
    - off-site (material is treated outside of the site)
- Monitoring (in and post-operam)
- Land use control

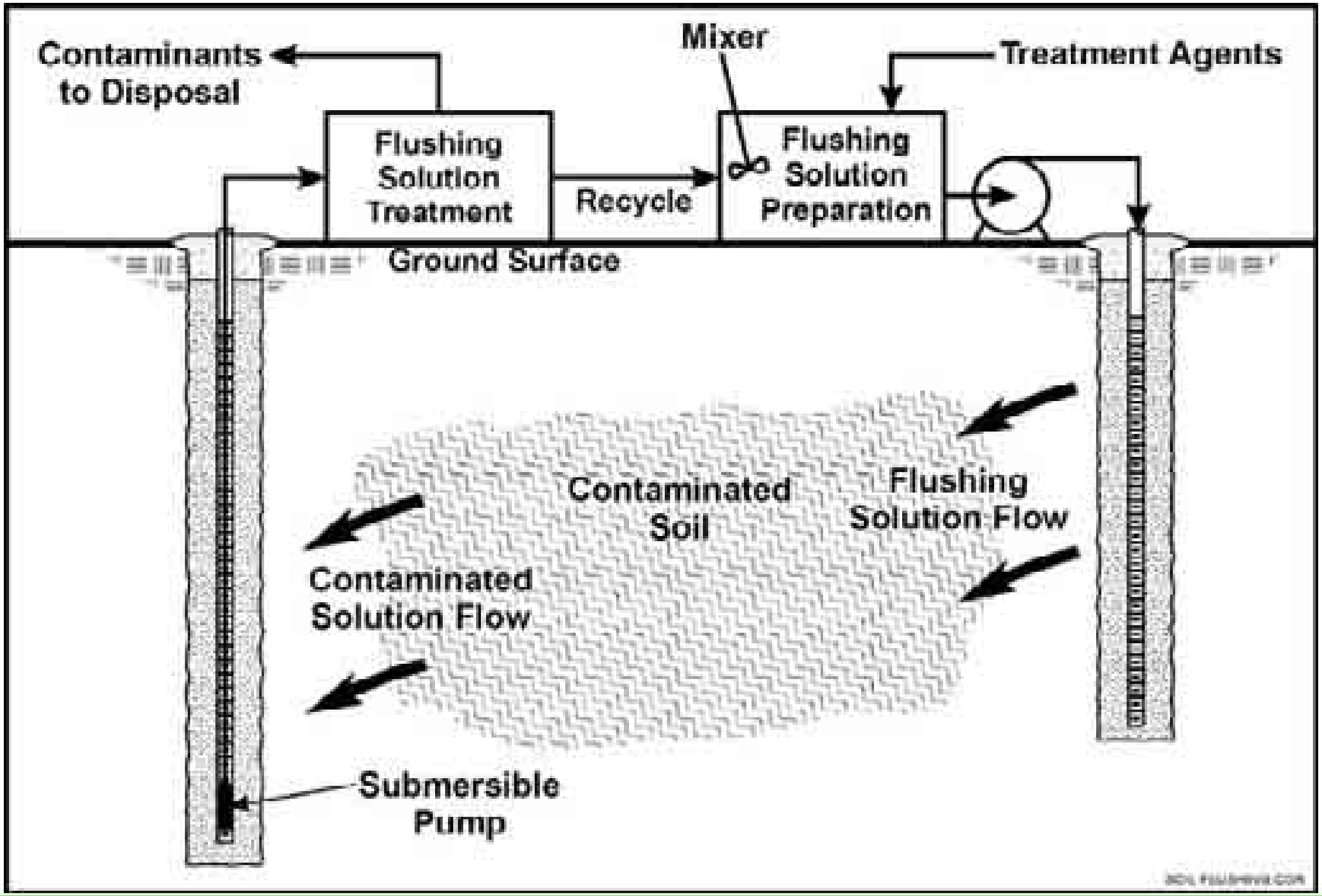
In the following, clean-up technologies are classified as in situ and ex situ.

Technology	Description	Type
Bioremediation	Remediation by altering *in situ* conditions, typically by *in situ* flushing (see below) to optimise biodegradation rate. Examples include the addition of nutrients, oxygen, etc.	Bio
Biosparging / Air sparging	Injecting air (or other gases) into the saturated zone to strip volatile contaminants and/or stimulate biodegradation. The latter process is often termed “biosparging”.	Bio/ Phys-chem
Bioslurping	Multiphase extraction of groundwater, free-phase contamination and soil gas to achieve bulk contaminant removal and supply oxygen for enhanced biodegradation.	Bio & phys
Bioventing	Movement of air or other gas through soil to stimulate biological destruction of contaminants, possibly in combination with their removal in the gas phase (c.f., soil vapour extraction)	Bio & phys
Chemical destruction	Use of highly reactive reagents to convert contamination to environmentally acceptable end-products *in situ*. An example is the use of Fenton’s reagent (iron-catalysed hydrogen peroxide).	Chem
Electroremediation	Use of electric fields to move or contain contaminants.	Phys-chem
Flushing	Enhanced pump and treat to remove contaminants, for example addition of surfactants or solvents to re-circulated water.	Phys-chem
Hydrofracture	Hydraulic or pneumatic techniques to induce fracturing of subsurface zones to increase permeability for other treatments.	Phys
In situ heating	Use of steam or microwaves (radio-frequency heating) to heat the soil, for example to increase the range of contaminants recoverable by soil vapour extraction.	Thermal
Landfarming	Cultivation of surface soils (typically the top 50cm) to stimulate biodegradation. Usually includes the addition of various amendments (e.g., fertiliser).	Bio
Natural attenuation	Monitored use of naturally occurring *in situ* processes to remediate contamination without enhancement. Often, and more accurately, called monitored natural attenuation (MNA).	Bio, phys & chem
Permeable reactive barriers	A single or combination of biological, chemical or physical process(es) in a specific portion of the subsurface that treats a carrier as it passes through but does not unacceptably impede flow.	Bio / chem / phys
Phytoremediation	Use of plants to recover contaminants and/or stimulate *in situ* biodegradation/stabilisation.	Bio
Pump and treat	Treatment mediated by the pumping of groundwater. The term “P & T” is sometimes used to mean technologies where groundwater is treated above ground. The term is also used to refer to true *in situ* processes involving groundwater pumping.	Phys
Soil vapour extraction (SVE)	Movement of air or other gas through unsaturated soil to remove contaminants through enhanced volatilisation. Sometimes called “venting “ or “stripping”.	Phys
Stabilisation/ Solidification	*In situ* mixing (e.g., by augering) of chemical agents into the soil to solidify the ground or otherwise reduce mobility of contaminants.	S/S
Vitrification	Use of high temperature to melt subsurface minerals. Organic contaminants are thermally destroyed; inorganic contaminants are immobilised in the glassy residue.	S/S & thermal

2. In situ technologies

example – Soil treatment

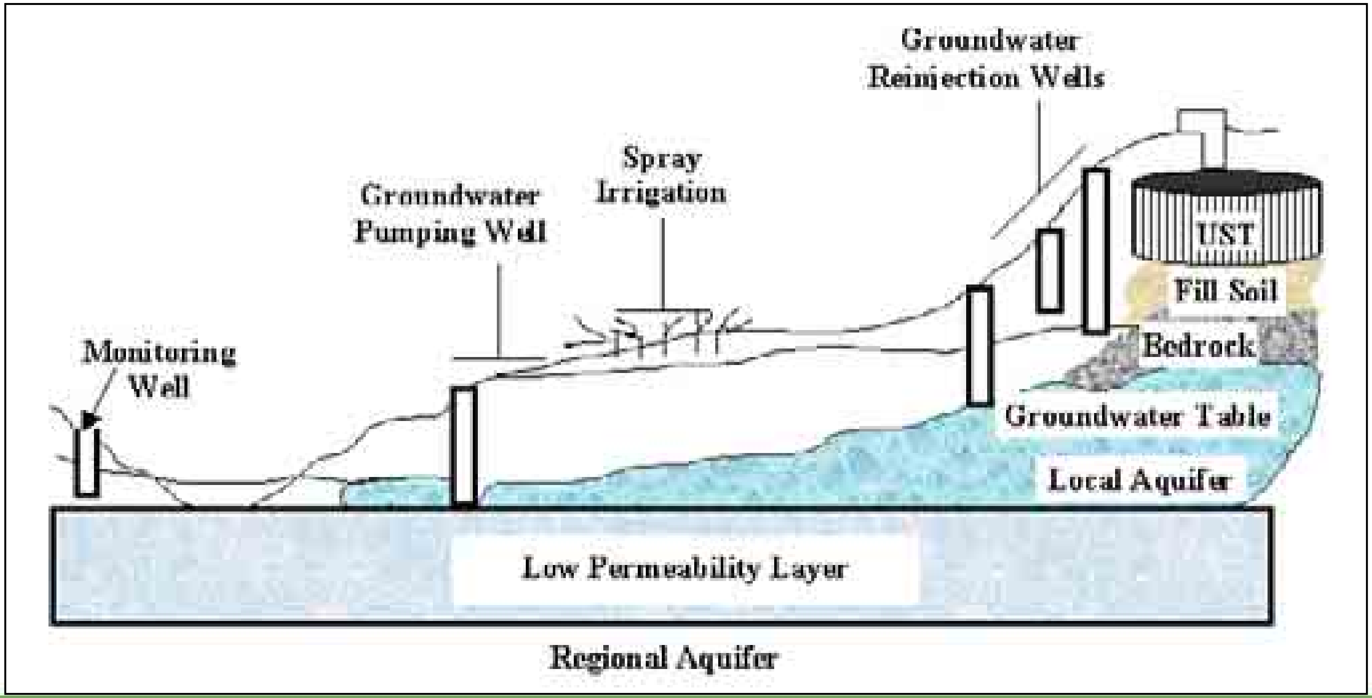
Soil-flushing



2. In situ technologies

(Enhanced) bioremediation

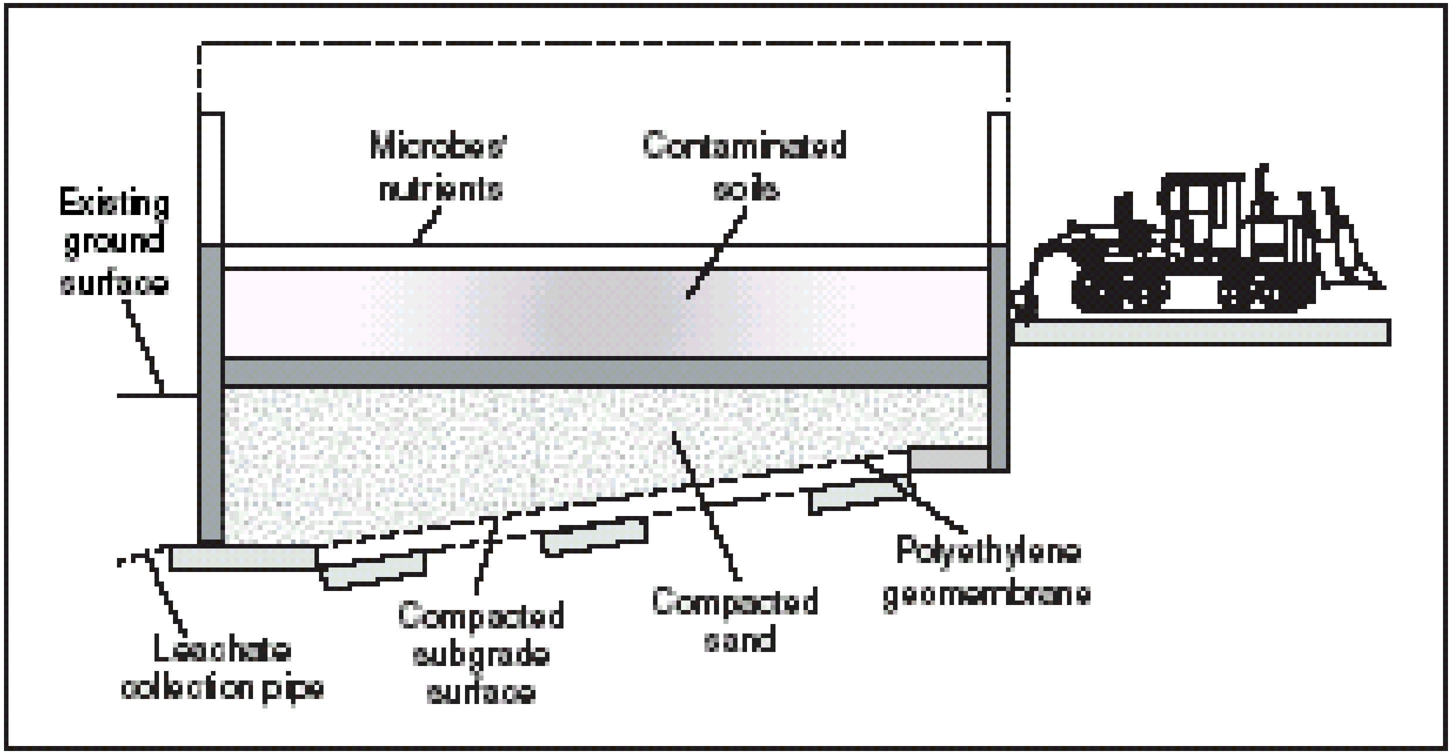
The activity of naturally occurring microbes is stimulated by circulating water-based solutions through contaminated soils to enhance in situ biological degradation of organic contaminants or immobilization of inorganic contaminants. Nutrients, oxygen, or other amendments may be used to enhance bioremediation and contaminant desorption from subsurface materials.



2. In situ technologies

Soil treatment

Landfarming

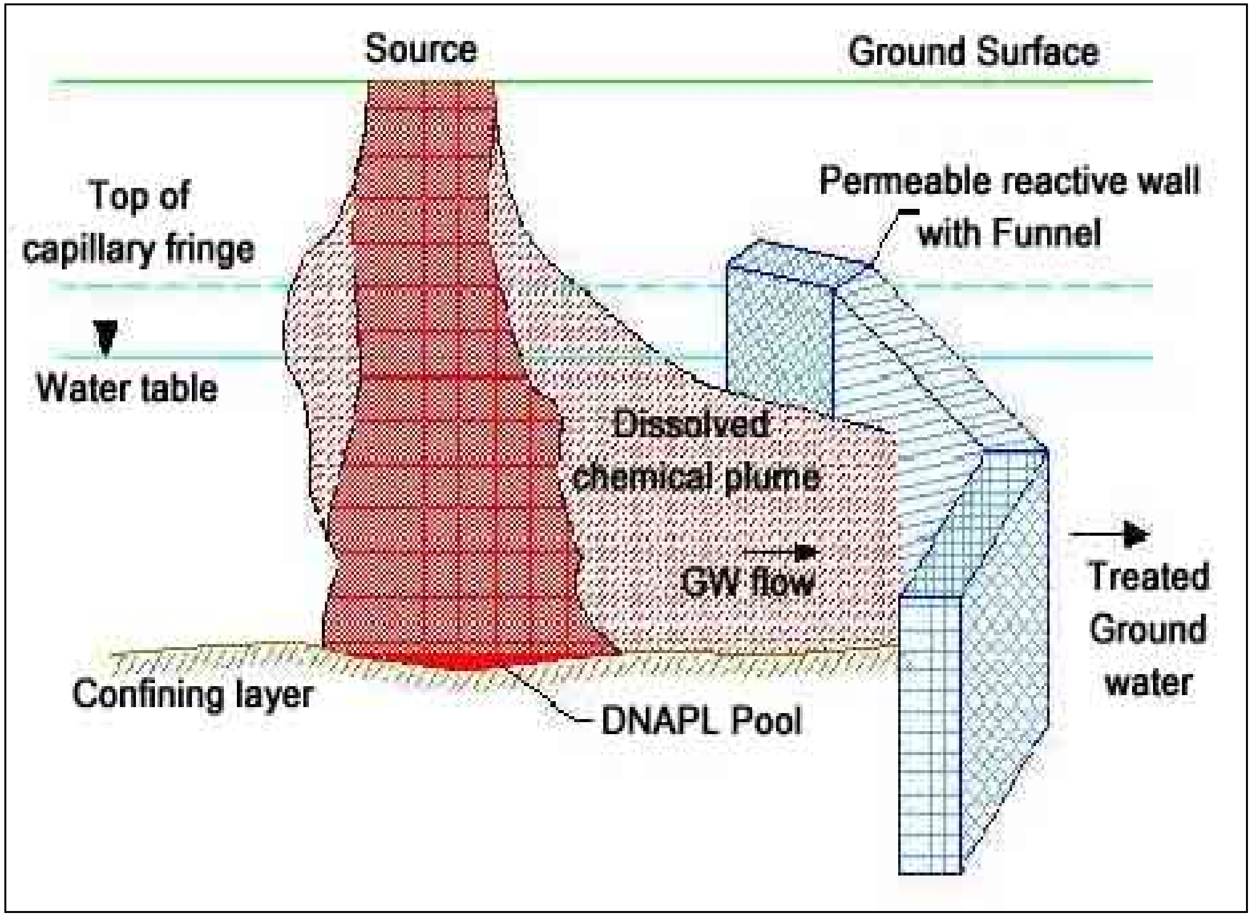


Treatment of aerobically degradable contaminants

2. In situ technologies

Groundwater treatment

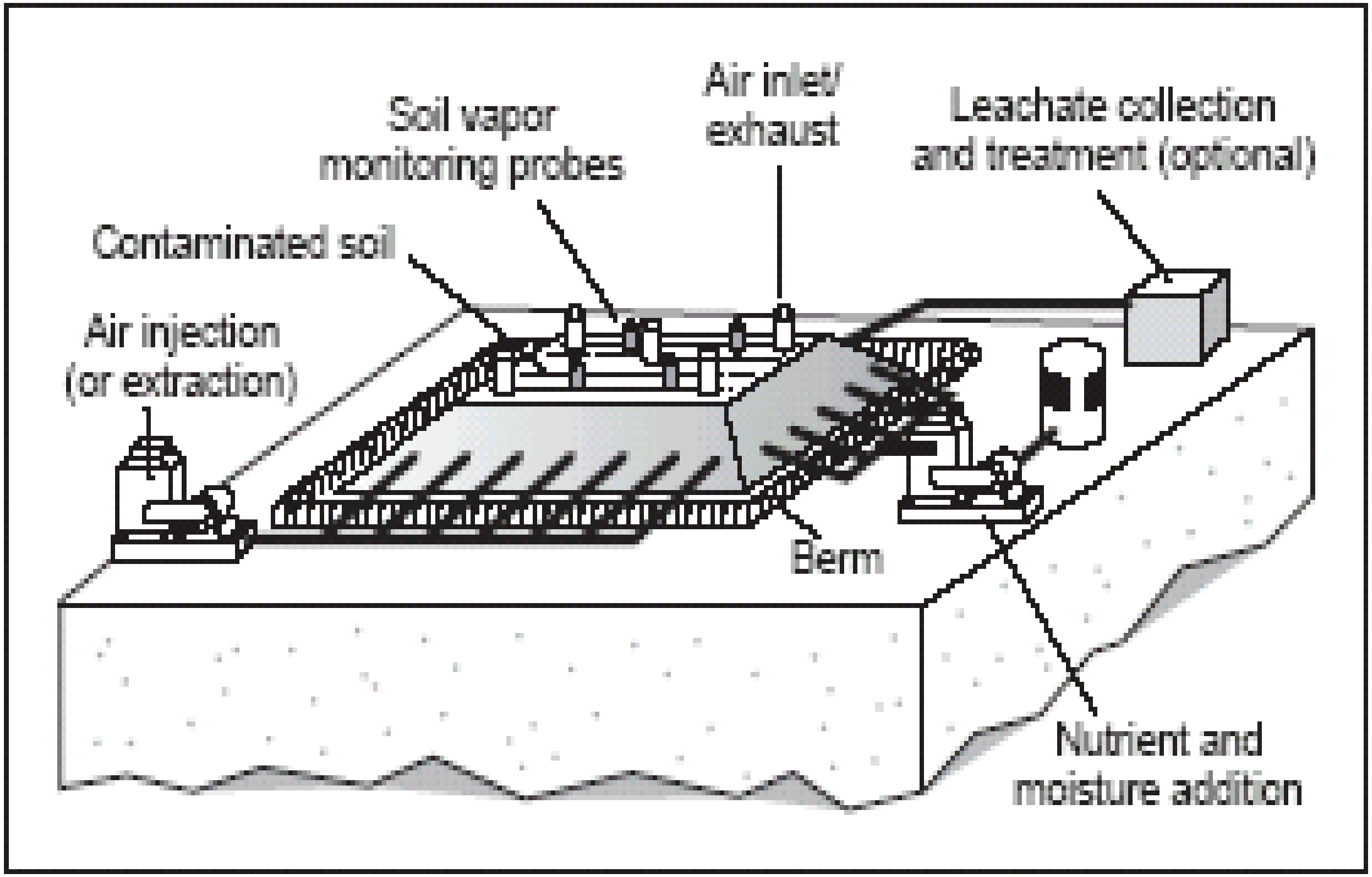
Permeable reactive barrier



Technology	Description	Type
Biopiles	Excavated soil is built into a heap within which is a network of perforated pipes to aerate the soil.	Bio
Bioreactors	Soil (dry or slurried) is treated in a enclosed reaction vessel to which nutrients, air water and microbes are added as necessary. Bioreactors are also used to treat groundwater.	Bio
Biological treatment beds	shallow cultivation, where contaminated soil is cultivated in a contained treatment bed on a specially prepared area of a contaminated site	Bio
Chemically enhanced soil washing	Physical processes are integrated with chemical processes such as leaching or extraction.	Chem/phys
Chemical Leaching/ Chemical extraction	Transfer of contaminants from the soil into an aqueous solution. The soil is dewatered and the aqueous solution plus contaminants is further processed.	Chem
Groundwater treatments (non-biological)	Various including: airstripping, carbon adsorption, chemical oxidation, filtration, ion exchange, neutralisation, precipitation, reverse osmosis, steam stripping,	Chem/phys
Incineration	High temperature destruction of contaminants (eg in rotary kiln incinerators or fluidised bed systems). Pre-treatment is to obtain suitable particle size. Thermal desorption occurs during incineration. An *ex situ* process.	Thermal
Soil washing	Primarily a physical technique involving size separation and washing of contaminants using aqueous based solutions.	Phys
Solvent extraction	Uses non-aqueous solvent to transfer contaminants from soil into solution.	Chem
Stabilisation/ Solidification	Mixing of chemical agents into the soil to solidify the ground or otherwise reduce mobility of contaminants.	S/S
Thermal desorption by combustion of organics in vapour phase	Two stage process comprising low temperature transfer of contaminants from soil to vapour phase via volatilisation followed by destruction or removal of contaminants from gas stream. *Ex situ* process needs extensive pre-treatment e.g. screening, de-watering, neutralisation, blending. Partial combustion often occurs during process.	Thermal
Thermal desorption by condensation	Heating of soil to volatilise volatile metals (so far principally mercury), which is then condensed from exhaust gases downstream.	Thermal
Vitrification	Excavation of soil, transport to (usually off site) facility. Soil plus other materials used for glass making (silica, fusing agents) are placed in a smelter, which heats to about 1500ºC. Molten material is continuously removed and cooled to produce granular solids or monolithic mass.	S/S & Thermal
Windrow turning	Piles of contaminated soil often mixed with organic materials such as bark are turned on a regular basis to aerate the soil and improve the soil structure.	Bio

3. Ex situ technologies

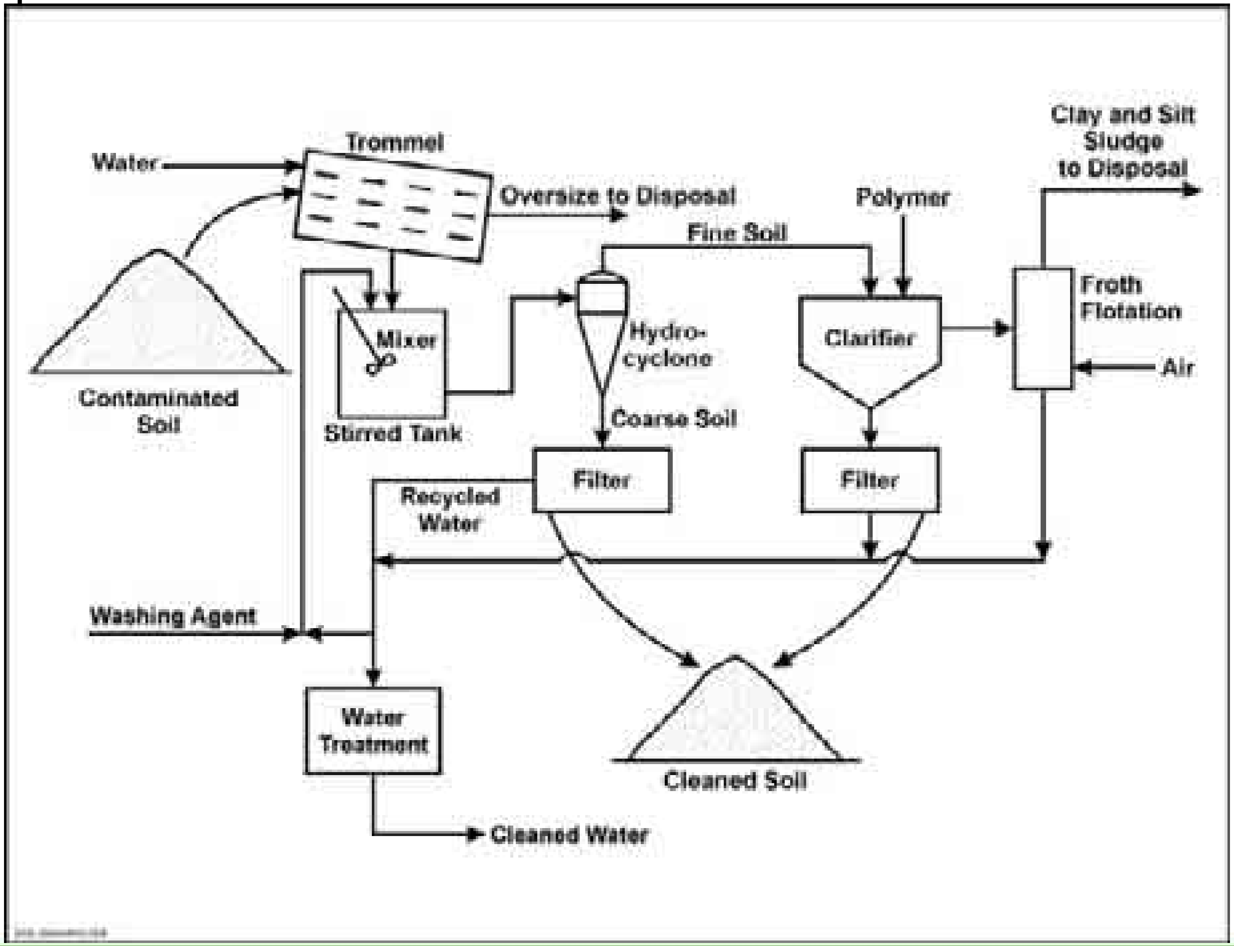
example – Biopile



3. Ex situ technologies

example – Soil washing

Primarily a physical technique involving size separation and washing of contaminants using aqueous based solutions. Applicabile to SVOC, fuels and inorganic compounds



4. Technologies and contaminants

Contaminants treated	**Suitable Remediation Technologies**
	Soil, sediments and sludge
VOCs SVOCs Inorganic compounds Petroleum Fuel Oil Explosives	*Ex situ* bioremediation; *In situ* bioremediation; *In situ* soil flushing, SVE, Thermal Desorption, *In situ* Vitrification Thermally Enhanced SVE; Soil washing; Solvent Extraction; Thermal Desorption Soil flushing; Soil washing; Electrokinetic Separation; Solvent Extraction; Chemical treatment and Phytoremediation. *Ex situ* bioremediation; In situ bioremediation; Soil washing; SVE; Thermal Desorption *Ex situ* bioremediation; In situ bioremediation; Soil washing; Solvent Extraction; Thermal Desorption
	Groundwater, surface water and leachate
VOCs SVOCs Inorganic compounds Fuels Explosives	Air sparging; Dual-Phase Extractiom; Fluid/Vapor Extraction; *In Situ* Bioremediation; Bioreactors; Permeable Reactive Barriers *In situ* bioremediation; Bioslusping; Permeable Reactive Barriers; Phyto Remediation Adsorption; Permeable Reactive Barriers; Phytoremediation Air sparging; Dual-Phase Extraction; *In Situ* Bioremediation, Bioreactor; Bioslurping; Fluid /Vapor Extraction Bioreactor; Permeable Reactive Barriers; Phytoremediation

VOC= Volatile Organic Compounds; SVOC= Semi-Volatile Organic Compounds;

SVE= Soil Vapor Extraction

Effectiveness of technologies

Demonstrated effectiveness of biological treatment technologies for soil, sediment, sludge

Contaminant Type	In Situ Treatment Technologies										Ex Situ Treatment Technologies[1]				
	Intrinsic	Enhanced													
	Soil / Ground Water	Vadose Zone			Surficial Soil		Ground Water / Saturated Soil				Solids			Solid–Liquid Mixtures	Liquids
	Monitored Natural Attenuation	Aerobic Bioventing	Cometabolic Bioventing	Anaerobic Bioventing	Land Treatment	Composting	Anaerobic Reductive Dechlorination	Aerobic Treatment	Biological Reactive Barriers	Biosparging/ Bioslurping	Land Treatment	Composting	Biopiles	Slurry Bioreactors	Constructed Wetlands
Non-halogenated VOCs	♦	♦	■	■	♦[2]	♦[2]	■	♦	♦	♦	♦[2]	♦[2]	♦[2]	♦[2]	♦[2]
Halogenated VOCs	♦	■	♦	▲	■[2]	■	♦	■	♦	♦	■[2]	■[2]	■[2]	■[2]	■[2]
Non-halogenated SVOCs	▲	♦	■	■	♦	♦	■	♦	▲	▲	♦	♦	♦	♦	♦
Halogenated SVOCs	▲	■	▲	▲	■	■	▲	■	♦	■	■	■	■	■	■
Fuels	♦	♦	■	■	♦[2]	♦[2]	■	♦	♦	♦	♦[2]	♦[2]	♦[2]	♦[2]	♦[2]
Inorganics	■	●	●	■	■	■	■	■	♦	■	■	■	■	■	♦
Radionuclides	■	■	■	■	■	■	■	■	♦	■	■	■	■	■	■
Explosives	■	▲	■	▲	♦	♦	■	▲	♦	■	♦	♦	▲	♦	▲

[1] Not generally applicable to rocks and bedrock.
[2] Volatilization must be controlled.

♦ **Demonstrated Effectiveness:** *Successfully treated at pilot or full scale and verified by an independent agency.*

▲ **Potential Effectiveness:** Successfully treated at laboratory or bench scale, or similar contaminant types have been successfully demonstrated at pilot or full scale.

■ **No Expected Effectiveness:** No successful treatments documented at any scale, and expert opinion notes that the contaminant in question is not likely to be effectively treated by the technology.

● **Potential Adverse Effects:** Adverse effects are documented at any scale, or expert opinion notes that the treatment technology may result in adverse effects to the environment.

Adapted from information in EPA (1998a, 2000, 2004b, 2004c), FRTR (2003, 2004), ESTCP (2001, 2004a, 2004b), ITRC (2004), and AFCEE (1996).

Site characterization and long term monitoring are necessary to support system design and sizing as well as to verify continued performance. There are also regulatory requirements to be addressed regarding system design, implementation, operation, and performance, including the disposition of liquid effluents and other wastes resulting from the treatment process.

5. References

- http://www.frtr.gov/

- http://www.clu-in.org/
- http:/www.clarinet.at