RSK

BROWNFIELD REMEDIATION SEMINAR ISTANBUL 14TH NOVEMBER 2018

Remediation Technologies

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- Over 25years global experience in soil and groundwater risk assessment, remediation design, execution and major project management.
- Formerly worked with Shell Group Companies for 16years prior to joining RSK.
- Subject Matter Expert in environmental liability management and HSSE due diligence.

Objective of Presentation

- Give a broad overview of the available technologies which can be used to remediate contaminated land and bring it back into beneficial use.
- The presentations deals with technologies specifically applicable to soil and groundwater impact, as well as those which aim to remediate both simultaneously.
- Indicative cost ranges for remedial technologies are identified for typical EU projects.

Soil Remediation Technologies

Civil Engineering Approaches

- Cover Systems
  - Inexpensive for use on marginally contaminated sites
- Containment by Capping and Lateral Containment
  - Potential issues of blight
- Solidification (chemical stabilisation)
- Landfill disposal

Cover Systems

- Only suitable for marginally contaminated sites
- Has no affect on volatiles or groundwater
- Cost in range of $30 to $50/m^2

Stabilization

- To reduce/eliminate leachate from contaminated soils
- Involves mixing soils with E-Clays
- Potential geotechnical problems as mixed soils have a high moisture content
- Costs approx. $ 60-80 per m^3

Stabilization Equipment for mixing E-clays

Relay Mixing

Landfill Disposal

- Maybe uneconomic depending on environmental legislation and taxes, such as in the UK.
- Limited availability of appropriately licenced landfill sites to take hazardous wastes in some Countries.
- Possible use of stabilisation prior to disposal to reduce cost
- Chain of Custody from site to licenced facility very important to avoid illegal dumping of wastes and consequential fines/legal actions.

Thermal Treatment Technologies

- Low Temperature thermal treatment
  - Volatilises contaminants in inert atmosphere and incinerates off-gas
- High Temperature Incineration
  - Incinerates entire soil mass in oxygen containing atmosphere – most usually off-site
- Treats organic contaminants that cannot be simply treated with other methods (i.e. PCB's/Pesticides)
- Both expensive and high mobilisation costs – only suitable for large sites
- Costs in range of $100 - $500/$m^3$

Bio-remediation Approaches

- Ex-situ
  - Costs circa $40-50 per m^3
  - Hydrocarbon degrading bacteria remove light and medium hydrocarbons and some solvents
  - The most common and economic techniques currently in use
  - 3 to 6 months
  - Slow with PAH
  - Not effective for PCB's/Pesticides
- In-situ
  - Takes longer

Bio-degradation (windrows) – Ex situ

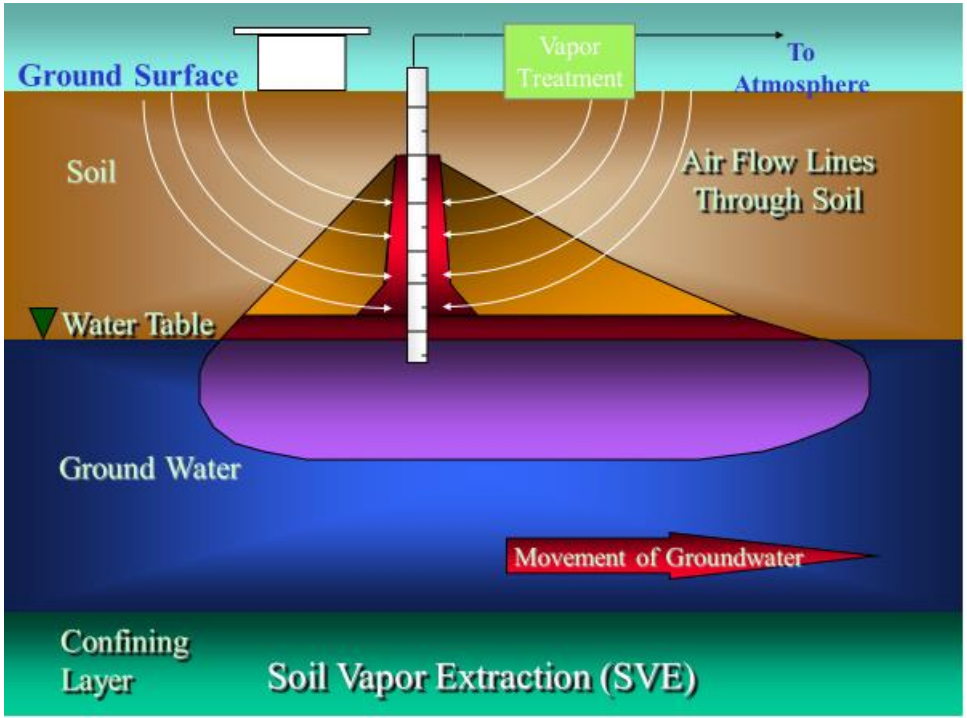
Windrow Turning

Soil Washing

- Relies on contaminants being adsorbed on fine soil particles
- Techniques involves separating out the fine material for off-site disposal
- Equipment fairly large with high mobilisation costs hence most suited to large sites
- Costs circa $50 - $400 per m^3 (very dependant upon off-site disposal cost of fine material)

Soil Vapour Extraction

- Objective is to strip volatile organic compounds from the soil column above the water table.
- Commonly used on petroleum retail sites.
- Highly dependent on soil conditions for effectiveness.
- Can take 18 to 24 months to be effective.
- Relatively low cost, depending on the off gas treatment of the volatiles stripped from the soil.
- Cost circa $30 – 80 per m^3.



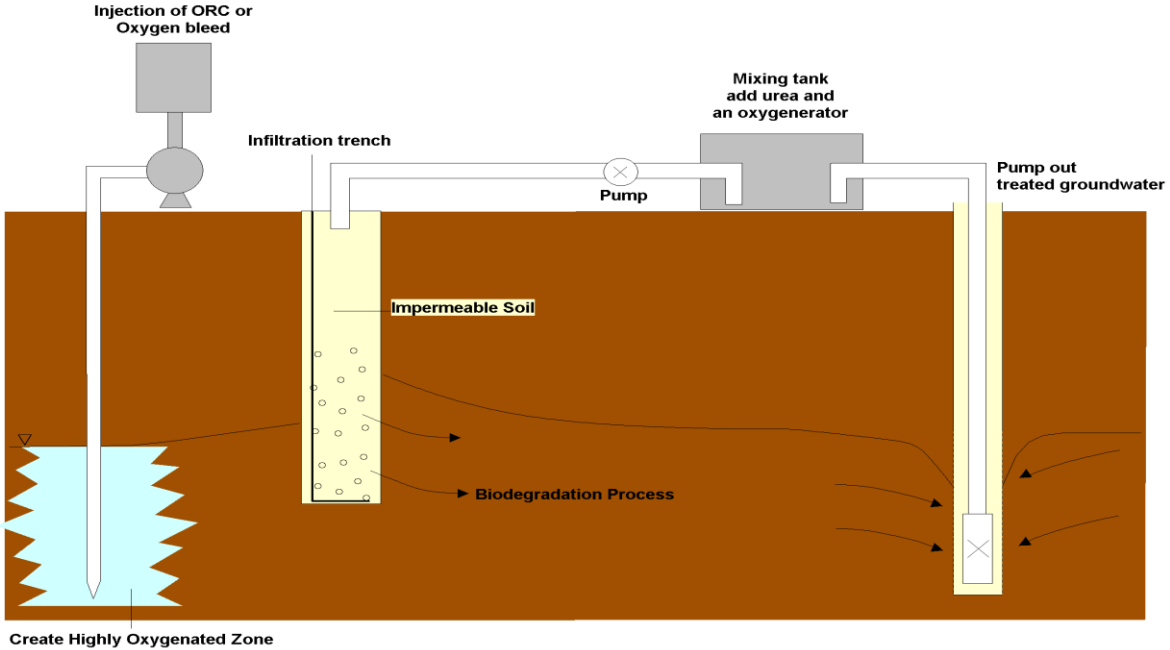
Soil Vapour Extraction in Field

Groundwater Remediation Technologies

In-situ Aerobic Degradation

- Introduction of oxygen to stimulate aerobic degradation.
- Suitable for dissolved phase hydrocarbon compounds including BTEX and short to medium chain alkanes.
- Aerobic degradation generally much faster than anaerobic, and is preferred approach for this reason.
- Costs circa $40–60 per m^3

In-situ Aerobic Degradation



In-situ Anaerobic Degradation

- Treatment for groundwater impacted by chlorinated organic compounds and hydrocarbons in source zone, where oxygen is often not present.
- In situ technique consists of the addition of organic substrates such as molasses, lactate (electron donors) to ensure highly reducing conditions and to provide the hydrogen needed by dechlorinating organisms
- Reduces dissolved phase metals in-situ to insoluble sulphates.
- Costs circa $40 – 60 per m^3;

Anaerobic Plume Degradation

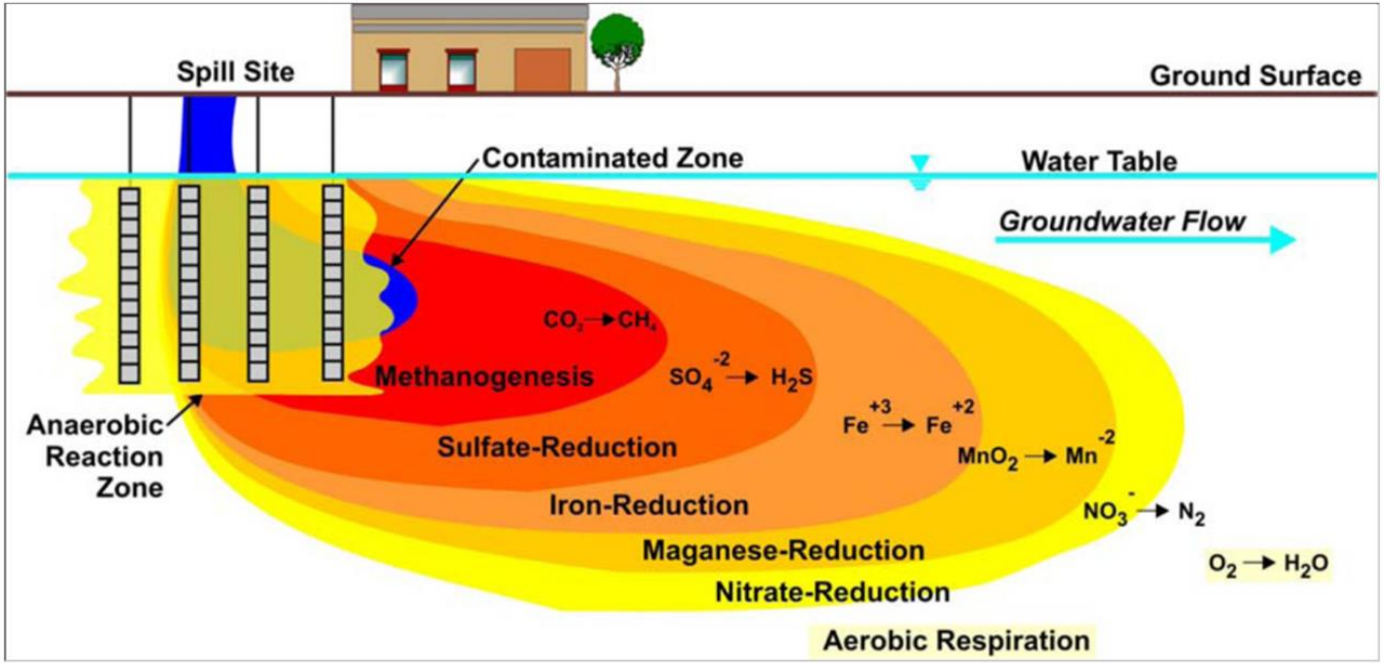
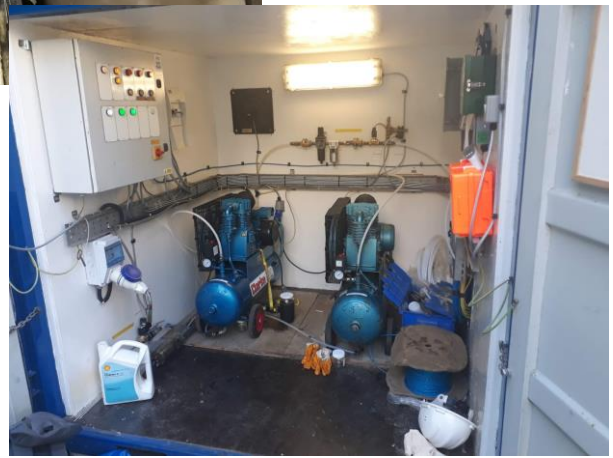


Figure 2. Anaerobic microbes use electron acceptors in preferential order: nitrate, manganese, ferric iron oxyhydroxides, sulfate, and carbon dioxide (Source: Parsons 2004).

Injection of Substrate for Anaerobic Degradation via Geoprobe

Free Phase Oil Recovery

- Objective here is to remove floating hydrocarbons such as diesel/petrol from the water table via skimming/pumping.
- Recovery is dependent on the oil type, soil strata and product thickness.
- Recovery of free product from risk perspective if preferred over dissolved phase impact.
- Relatively inexpensive



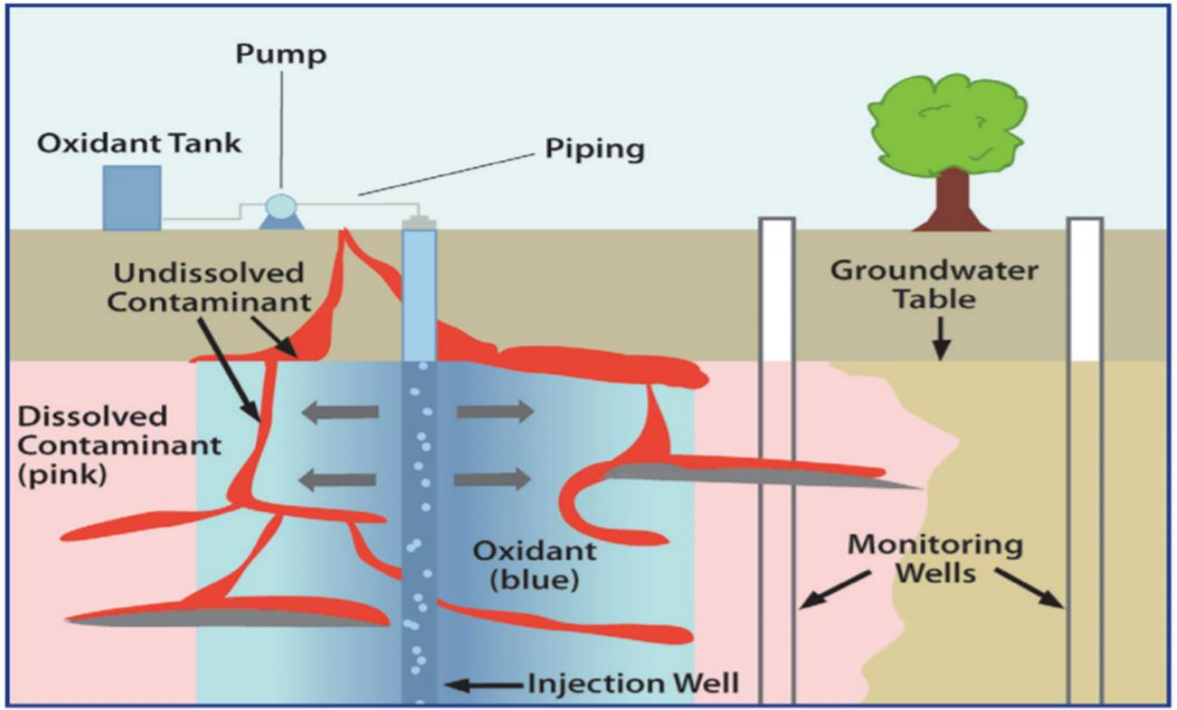
Chemical Remediation Technologies

- In-situ Chemical Oxidation
- Permeable reactive barriers

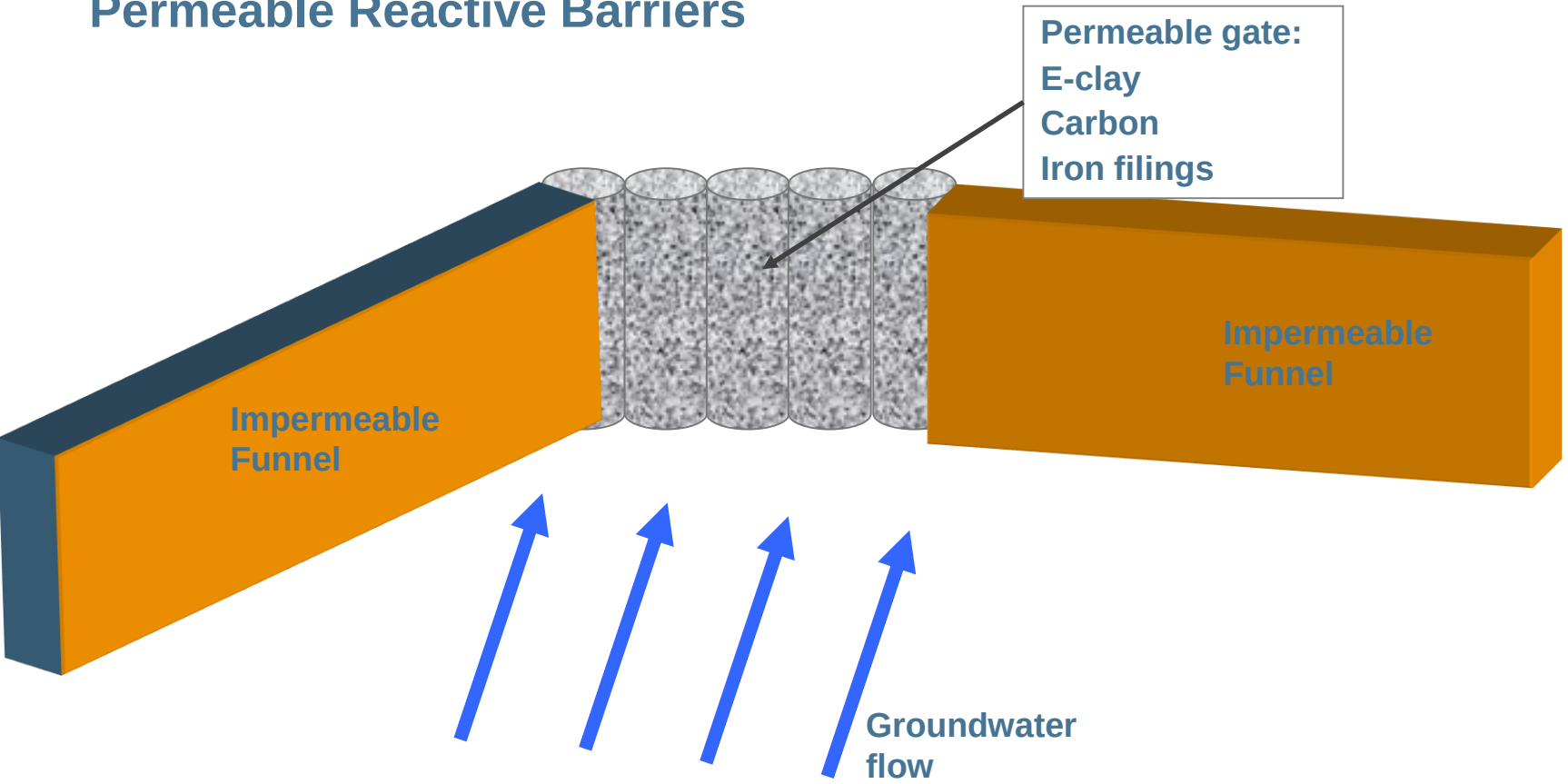
In Situ Chemical Oxidation (ISCO)

- ISCO involves addition of an aggressive chemical oxidant (fentons reagent, ozone, chlorine dioxide, sodium persulfate) which chemically destroy the contaminant.
- Hazardous components require strict H&S control.
- Will achieve remedial targets quickly (i.e. within 3-6 months).
- Applied to chlorinated hydrocarbons, organic hydrocarbons and other semi volatile organic contaminants.
- Costs are highly variable depending on soil type and contaminant ($80 – 200 per m^3)

In-situ Chemical Oxidation - schematic



Permeable Reactive Barriers

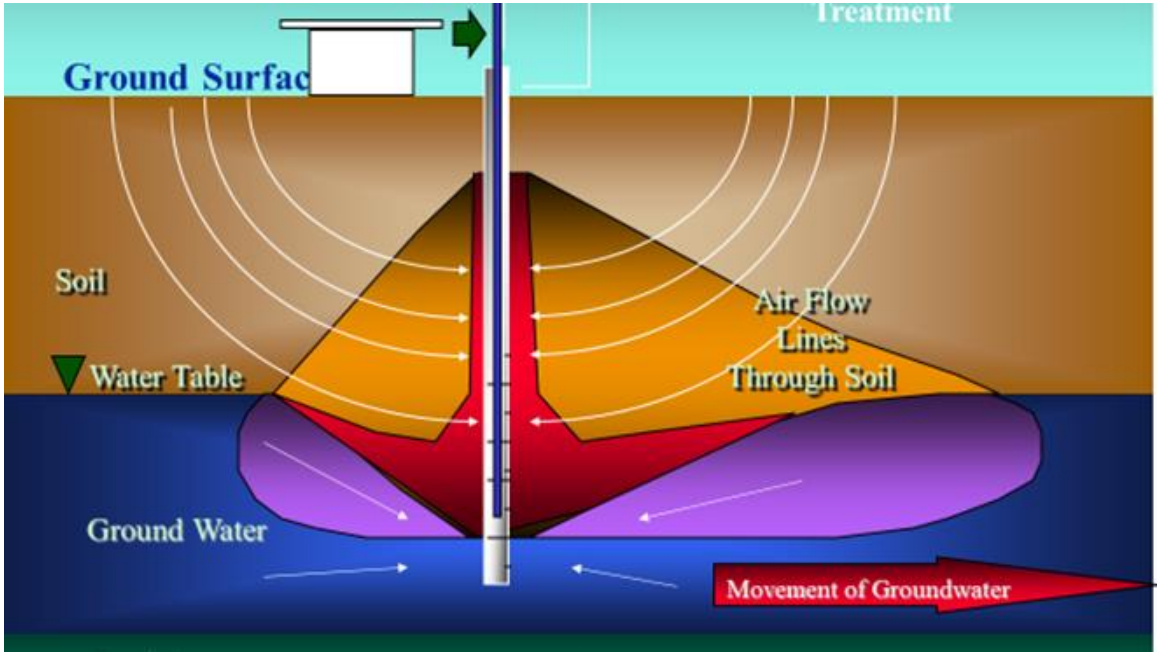


Containment

- Concept is to contain mobile contaminants to prevent them from reaching sensitive receptors.
- Does not deal with volatiles migrating to surface, other options are required for this.
- Vertical barriers such as cement / bentonite walls or sheet piling can prevent lateral migration, but need careful design and groundwater modelling to determine impacts of interrupting normal groundwater flow patterns.
- Hydraulic isolation by pump and treat can be effective but will often require many years of operation.
- Problem with site licensing as contaminant remains in-situ for many years
- Cost circa $70 - $140 per m^2

Monitored Natural Attenuation

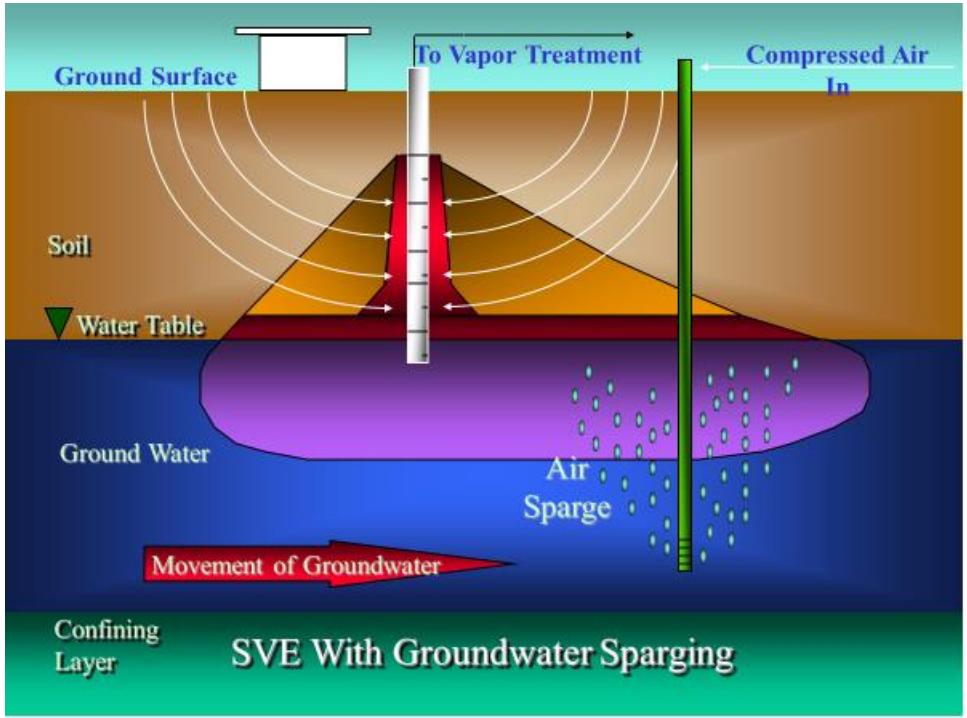
- The 'do nothing approach'?
- Suitable for Groundwater Plumes undergoing natural degradation.
- Not suitable if a significant risk of harm to sensitive receptors is immediately present.
- Relatively inexpensive.
- Need common understanding with Regulators when targets have been met and monitoring can be stopped and wells decommissioned.
- Often used to close out project after an initial phase of intrusive or active remediation for soils and or groundwater.



Combined Treatment Systems

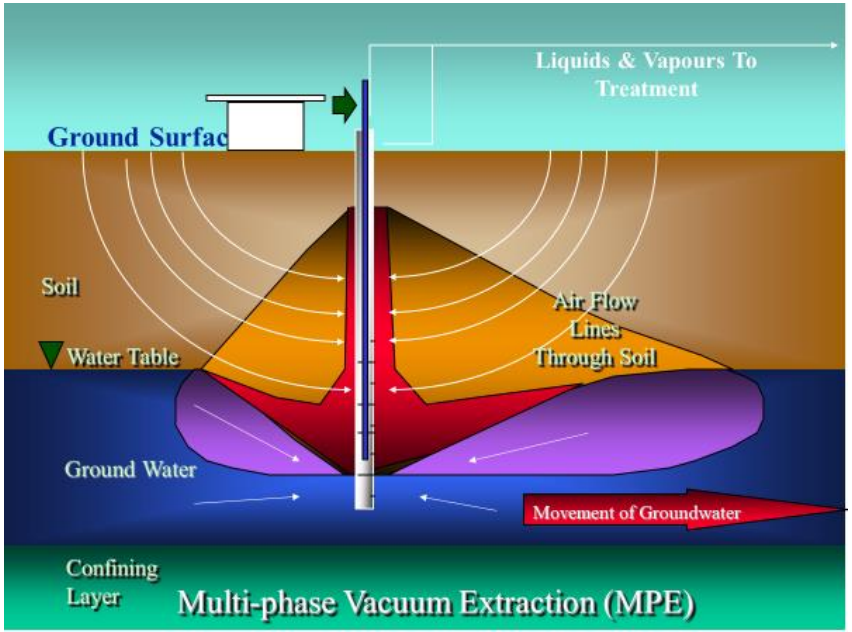
Soil Vapour Extraction with Groundwater Sparging

- Objective is the same as SVE, but with the addition of compressed air into groundwater plume to release volatiles, which are captured by the SVE system.
- Commonly used on petroleum retail sites.
- Highly dependent on soil conditions for effectiveness.
- Can take 18 to 24 months to be effective.
- Relatively low cost, depending on the off gas treatment of the volatiles stripped from the soil.
- Cost circa $40 – 80 per m^3.



Multi-Phase Vacuum Extraction

- Volatiles in soil are removed in the same way as SVE, but with the addition of groundwater extraction to remove dissolved and free phase hydrocarbons.
- Commonly used on petroleum retail sites.
- Highly dependent on soil conditions for effectiveness.
- Can take 18 to 24 months to be effective.
- Relatively low cost, depending on the off gas treatment of the volatiles stripped from the soil.
- Cost circa $40 – 80 per m^3.



Summary of Soil Options

Remedial Strategy	VOC		SVOC (PAH)		TPH		Metals	PCB
	Halogens		Light	Heavy	BTEX	Long (heavy)		
Physical Containment	✓		✓	✓	✓	✓	✓	✓
Excavate and Dispose	✓		✓	✓	✓	✓	✓	✓
Chemical Stabilisation			✓	✓	✓	✓	✓	✓
Thermal Desorption			✓	✓		✓		
Incineration				✓		✓		✓
Ex-Situ Aerobic degradation			✓	✓	✓	✓		✓
In-Situ Aerobic degradation			✓	✓	✓	✓		
In-Situ Anaerobic degradation	✓						✓	
Chemical Oxidation						✓		✓
Soil Vapour Extraction	✓				✓			
Soil Wash				✓		✓		

Summary of Groundwater Options

Remedial Strategy	VOC		SVOC		TPH		Metals	PCB
	Halogen		Light	Heavy	BTEX	Long (heavy		
In-Situ Aerobic degradation			✓		✓	✓		
In-Situ Anaerobic degradation	✓						✓	
Air Sparge	✓				✓			
Multi Phase Extraction	✓				✓			
Chemical Oxidation	✓		✓	✓	✓	✓		
Pump and Treat								
Floculate							✓	
Bio degrade			✓	✓	✓	✓		
RC Aerate / GAC	✓				✓			
Permeable Reactive Barrier								
Dechlorinate	✓							
GAC	✓		✓	✓	✓	✓	✓	✓
Chemical Fixation							✓	✓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