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Soil Treatability Study

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On-Site Remediation Alternatives

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On-Site Remediation Alternatives

- In order to reduce or eliminate the amount of soil that needs to be excavated, the following on-site remediation alternatives will be evaluated for their feasibility:
  - Phytoremediation
  - Bioremediation
  - Physical/Chemical
  - Thermal
  - Other - Nanotechnology

Phytoremediation

- Process whereby plants intake or hyperaccumulate contaminants into the plant, thereby reducing the concentrations of contaminants in the soil
- http://www.youtube.com/watch?v=OUYTK9B2RSw
- Ideal Application – Typically effective for clean up of metals, radionuclides, PCBs, solvents, explosives, and hydrocarbons
- Pros/Cons
  - Pros – Green technology, visually appealing, low impact, passive
  - Cons – Extended clean-up period, limited by depth and soil types, additional technology required for plant disposal, potential use of non-native plant species, maintenance of plants, select plants will phytorespire contaminants

Phytoremediation Examples

- Metals reduction utilizing indian mustard, paulownia trees, poplar trees, willow trees, vetvier grass, sunflowers, alpine pennycress (especially effective for nickel), and lupine (releases citrate that stimulates uptake by other species)
- Uranium reduction utilizing beet, indian mustard, and blue stem varieties
- Explosives and dioxin reduction utilizing poplar, cottonwood, and paulownia trees
- Solvent/TCE reduction utilizing poplar and paulownia trees
- PCB reduction utilizing osage orange and mulberry trees
- Hydrocarbon reduction utilizing wheat and gramma grasses
  - phytopet.usask.ca includes a list of hydrocarbon specific species

Bioremediation

- The use of microorganisms to enhance biodegradation or removal of contaminants; through stimulation of naturally existing species or introduction of non-natural species to enhance biodegradation.
- http://www.youtube.com/watch?v=VXoz8xpwJbU
- Ideal Application – Typically effective for clean up in low permeability soils (and possibly hard rock) for petroleum hydrocarbon, solvent, metals, and radioactive contaminants
- Pros/Cons
  - Pros – Relatively low impact, in-situ reduction of COIs, enhancement of natural processes
  - Cons – Limited by soil types, possible lack of control of stimulated microbes, introduction of bacteria

Bioremediation Examples

- Slurry-phase bioremediation - Soils are mixed in water to form a slurry to keep solids suspended and microorganisms in contact with the soil contaminants
- Solid-phase bioremediation - Soils are placed in a cell or building and tilled with added water and nutrients and include land farming, biopiles, and composting
- In-situ bioremediation - Techniques stimulate and create a favorable environment for microorganisms to grow and use contaminants as a food and energy source.
  - Digestion technology - a symbiotic consortium of anaerobic bacteria retained as an attached biofilm on a non-clogging vertical spindle array of geo-textile panels.

Physical/Chemical

- Physical/chemical treatment uses the physical properties of the contaminants or the contaminated medium to destroy (i.e., chemically convert), separate, or contain the contamination.
- Ideal Application – Typically effective for confined areas of well-defined soils with contamination that includes solvents, hydrocarbons, organics, and metals
- Pros/Cons
  - Pros – Effective, faster clean up alternatives that can be completed in-situ, and required equipment is typically readily available
  - Cons – Typically requires an extensive well network, treatment wall involves introduction of substances in-situ, select methods sensitive to soil type, treatment residuals will require treatment or disposal, extraction fluids from soil flushing will increase the mobility of the contaminants, so provisions must be made for subsurface recovery.

Physical/Chemical Examples

- Soil vapor extraction - Uses the contaminant's volatility to separate it from the soil.
- Soil flushing - Uses the contaminant's solubility in liquid to physically separate it from the soil, surfactants may be utilized to increase the solubility of a contaminant.
- Solidification/stabilization – Solidification encapsulates the contaminant, while stabilization physically alters or binds with the contaminant.
- Pneumatic fracturing - An enhanced technique that physically alters the contaminated media's permeability by injecting pressurized air to develop cracks in consolidated materials.
- Electrokinetic separation - Relies upon application of a low-intensity direct current between ceramic electrodes that are divided into a cathode array and an anode array. This mobilizes charged species, causing ions and water to move toward the electrodes.

Thermal

- In-Situ - Application of heat to polluted soil and/or groundwater in-situ to destroy or volatilize organic chemicals. As the chemicals change into gases, their mobility increases, and the gases can be extracted via collection wells for capture and cleanup in an ex situ treatment unit.
- Ex-Situ – Involves the destruction or removal of contaminants through exposure to high temperature in treatment cells, combustion chambers, or other means used to contain the contaminated media during the remediation process.
- Ideal Application – Typically effective for defined areas of contamination that include organics, PCBs, solvents, pesticides, and polyaromatic hydrocarbons (PAHs)
- Pros/Cons
  - Pros – Particularly useful for dense or light nonaqueous phase liquids (DNAPLs or LNAPLs), effective reduction/removal, short time periods (particularly for ex-situ)
  - Cons – Off-gas systems typically required, well network may be required, labor and energy intensive, select technologies are limited in depth and size of area

Thermal (In-Situ) Examples

- Electrical resistance heating - Uses arrays of electrodes installed around a central neutral electrode to create a concentrated flow of current.
- Hot air/steam/water injection - Completed via injection wells, heats the soil and ground water and enhances contaminant release. Hot water injection also displaces fluids and decreases contaminant viscosity.
- Radio frequency heating - Uses electromagnetic energy to heat soil and enhance soil vapor extraction.
- Thermal conduction/desorption - Supplies heat to the soil through steel wells or with a blanket (for shallow contamination) that covers the ground surface. As the polluted area is heated, the contaminants are destroyed or evaporated.
- Vitrification - Uses an electric current to melt contaminated soil at elevated temperatures. Upon cooling, the product is a chemically stable, leach-resistant, glass and crystalline material similar to obsidian or basalt rock. Vitrification can be conducted in situ or ex situ.

Thermal (Ex-Situ) Examples

- Thermal desorption - Application of heat to excavated wastes to volatilize organic contaminants and water.
- Incineration – High temperatures are used to volatilize and combust (in the presence of oxygen) halogenated and other refractory organics.
- Hot gas decontamination - Involves raising the temperature of contaminated solid material or equipment, and the gas effluent from the material is treated in an afterburner system to destroy all volatilized contaminants.
- Plasma high-temperature recovery - Uses a thermal treatment process applied to solids and soils that purges contaminants as metal fumes and organic vapors. The vapors can be burned as fuel, and the metals can be recovered and recycled.
- Pyrolysis - Chemical decomposition induced in organic materials by heat in the absence of oxygen, which forms gases that may require further treatment.
- Thermal off-gas treatment - Used to cleanse the off-gases generated from primary treatment technologies, such as air stripping and soil vapor extraction.
- Vitrification - Uses an electric current to melt and solidify contaminated soil.

Other - Nanotechnology

- Use of nanoscale materials and taking advantage of highly reactive materials because of the large surface area to volume ratio and the presence of a larger number of reactive sites. These properties allow for increased contact with contaminants, thereby resulting in rapid reduction of contaminant concentrations.
- Ideal Application – Research indicates effective clean-up for tetrachloroethene (PCE), TCE, cis-1,2-dichloroethylene (c-DCE), vinyl chloride (VC), and 1-1-1-tetrachloroethane (TCA), polychlorinated biphenyls (PCBs), halogenated aromatics, nitroaromatics, metals such as arsenic and chromium, and nitrate, perchlorate, sulfate, and cyanide.

Other - Nanotechnology

- Proven technology – Utilized since the early 1990s, properties of metallic substances such as elemental iron have been used to degrade chlorinated solvent plumes in groundwater.
- One example of an *in situ* treatment technology for chlorinated solvent plumes is the installation of a trench filled with macroscale zero-valent iron (ZVI) to form a permeable reactive barrier (PRB).