

PHYSICAL AND CHEMICAL ON SITE REMEDIATION PROCESSES

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INTRODUCTION

This paper contains a summary of several of the many technologies that utilize physical and chemical processes to treat hazardous wastes. In general, the physical and chemical remedial processes can be considered as those technologies that do not use biological or thermal means to achieve their end. That definition make this group of remedial processes the most numerous and technically extensive and diverse. Since each remedial process using physical and chemical techniques has been the subject of numerous papers, the objective of this paper is to provide a general overview of representative processes the reader may want to consider when faced with the task of site remediation. Therefore, the purpose of this paper is to give the reader an oversight of the science and engineering foundation of the selected technologies and to provide insight on their application, advantages, and limitations as related to on site treatment.

The physical treatment processes can be separated into three general groupings based on the physical mechanisms by which these processes treat wastes. They are gravity separation, phase change, and size characteristic. In the gravity separation group, the paper details sedimentation, centrifugation, and flotation. Air stripping/vapor extraction, steam stripping, and distillation are outlined for phase change processes. Representative processes that operate on differences in size characteristics are screening, filtration, and reverse osmosis.

Three processes fall into a category defined as physical-chemical because their basic mechanisms overlap both of the basic sciences, physics and chemistry. These remedial technologies are carbon adsorption, ion exchange, and immobilization.

Processes defined as chemical treatment are those which cause the target contaminants, and added chemical reagents, to exchange electrons and atoms, thereby forming new compounds leading to the reduction in waste volume, toxicity, or mobility. The selected chemical processes outlined are neutralization, precipitation, oxidation/reduction, soil washing/flushing, chemical extraction, and dechlorination.

SEDIMENTATION

Media: Liquids and soil slurries.

Contaminant: Nonspecific adsorbed compounds, oil, and precipitated metals.

Description: Centrifugation is a physical separation process in which an enhanced gravity settling (centripetal force) separates both the dissolved and suspended solids from a liquid by differences in density. A typical equipment configuration consists of introducing a liquid into a chamber containing a rapidly rotating basket or bowl that can create a force of several thousand gravities. Solid particles, denser than the liquid, are deposited farther from the rotation axis based on their individual densities, potentially causing a stratification of solids that are discharged separately from the liquid. A modification of the centrifuge is the hydrocyclone that consists of a non rotating conical vessel with a tangential inlet causing the liquid to rotate at high velocity.

Applications: Centrifugation can be used for separating soil from slurries, fats and oils from water, and small solids from wastewater, and for dewatering sludges.

Advantages: Centrifugation is generally better suited for dewatering sticky or gelatinous sludges than vacuum filters. Disc centrifuges can separate three component wastes, such as liquids, solids, and oil. The small and relatively inexpensive hydrocyclones can be used for larger particles.

Limitations: Centrifugation may not separate suspensions composed of very small solids and liquids having low densities. Centrifugation can have high maintenance due to high speed rotation.

FLOTATION

Media: Liquids with oil or suspended solids, and soil slurries.

Contaminant: Nonspecific adsorbed compounds, oil, heavy metals, and radionuclides.

Description: Flotation is a physical process used for gravity separation. Froth flotation uses air or mechanical agitation to suspend and remove fine particles or oil from an aqueous stream. Dissolved air floatation achieves the same end using the dissolution of air, or another gas, to form micro bubbles which adsorb on to oil or suspended solids causing floatation. The froth or air floated particles are skimmed or removed off the top of the floatation tank, the settled heavy solids are removed from the bottom, and the clarified liquid exits at the opposite end. To enhance floatation of the particles of choice, an optimum pH is maintained and chemical additives, called promoters or collectors, are added. Additional chemicals, called depressants, can be added to assist in the selectivity of separation or to stop undesired compounds from floating.

Applications: Flotation can be used for particles having densities close to water and having small size, 0.01 to 0.1 mm.

Advantages: Flotation can have high separation rates for small particles.

Limitations: Air emissions may be required if volatile organics are present.

AIR STRIPPING AND VAPOR EXTRACTION

Media: Air stripping - aqueous liquids. Vapor extraction - soil.

Contaminant: Volatile organic compounds (VOCs).

Description: Air stripping and vapor extraction are physical processes that use a phase change to separate volatile contaminants from water and soil, respectively. Air stripping involves the evaporation of VOCs from the liquid phase into the vapor phase. The removal of a compound or set of compound can be predicted by Henry's Law, the distribution coefficient or tendency for a compound to pass from the liquid or solid phase into the vapor phase. The contaminated aqueous stream is introduced at the top of a tower and flows countercurrent to the rising air. The result is an air emission containing VOCs that should receive further treatment and a stripped liquid. The most common devices used for stripping are tray towers and packed towers which provide the high air-water interfacial area necessary for efficient mass transfer. Packed towers are less expensive, hold up less liquid, have lower pressure drop, and are suitable for viscous, foaming, or corrosive liquids. Tray towers can operate over a wide range of flow rates, and are more adaptable. Vapor extraction is a passive in situ process that removes soil vapors by strategically placed vacuum extraction wells. The vapors containing VOCs and must be treated at the surface.

Applications: Air stripping removes VOCs from dilute aqueous streams, such as groundwater, wastewater, and leachates.. The VOCs should have a relatively high volatility and a low water solubility or a Henry's Constant $> 3.0 \times 10^{-3}$ atm-m³/mole. Vapor extraction can be used to recover VOCs from subsurface soil.

Advantages: Air stripping and vapor extraction are relatively simple and inexpensive treatment options, although treatment of the vapor stream to meet air quality regulations can add significant costs.

Limitations: Packed towers can plug and may require water pretreatment. Vapor extraction may leave local spots of relatively high concentration and may fail to achieve low cleanup levels.

STEAM STRIPPING AND EXTRACTION

Media: Steam stripping - aqueous liquids. Steam and steam/hot air extraction - soil.

Contaminant: Volatile organic compounds (VOCs).

Description: Steam stripping and extraction are physical processes that use a phase change to separate volatile contaminants from water and soil, respectively. Steam stripping involves the evaporation of VOCs through the continuous distillation of an aqueous liquid with steam which directly heats the liquid. The aqueous liquid is introduced near the top of a tower and flows countercurrent to the rising steam. The steam and VOCs exit the top of the tower and go to a condenser and a coalescer. The result is a concentrated VOC, a contaminated steam condensate, and a stripped liquid. Two types of towers can be used for steam stripping, tray towers and packed towers. Packed towers are less expensive, hold up less liquid, have lower pressure drop, and are suitable for viscous, foaming, or corrosive liquids. Tray towers have more historical design data, can operate over a wide range of flow rates, and are adaptable to various feed streams. Steam extraction is a passive in situ process that uses well point steam injection to introduce heat into the subsurface. The condensate and vapors are removed by strategically placed extraction wells and must be treated at the surface. Steam/hot air extraction is an active in situ process that uses two, 5-foot diameter, counter rotating auger to introduce steam and hot air into the subsurface. The vapors are removed at the surface above the injection area by a vacuum shroud and are treated by a trailing process trailer.

Applications: Steam stripping removes VOCs in non miscible liquids and separates low solubility, higher boiling compounds when the compounds form low boiling azeotropes with water. Steam stripping can be used to recover high boiling material and material where an ignition or explosive hazard exists. Steam and steam/hot air technology can be used to recover VOCs and some semi VOCs from soil.

Advantages: Steam stripping eliminates fouling of heat transfer surfaces to recover wastes. Compared to air stripping, steam stripping is more economical and effective at recovering high concentrations of VOCs, less volatile or higher boiling organics, and more soluble VOCs. Steam/hot air extraction mixes the soil while delivering heat energy.

Limitations: Energy costs should be considered. Miscible organics such as ketones and alcohols are difficult to separate and suspended solids may affect operation. Steam extraction is restricted to geology with an impermeable layer to prevent migration of renegade condensate; a condensate treatment system must be included. Steam/ hot air extraction is a high cost, complex process with a modest throughput that is hindered by subterranean obstructions > 18" in diameter.

DISTILLATION

Media: Miscible organic liquids and aqueous wastes.

Contaminant: Volatile organic compounds (VOCs).

Description: Distillation is a physical process that uses a phase change to separate components of different volatiles. The more volatile components are concentrated in the vapor or distillate by heating while less volatile components are concentrated in the bottoms. Distillation can be of the simple or fractional type and be operated in a batch or continuous mode. The batch type boils the waste in a still to separate the waste into two streams. Fractional distillation takes place in a column containing internal stages provided by trays or packing with each stage providing greater purity of the distillate. When operated in a continuous mode, the section of the column above the feed entrance is the enriching section where vapor exits the top of the column into a condenser and a portion of the liquid condensate (reflux) is recycled back to the top of the column. The section of the column below the feed entrance is called the stripping section, the bottom of which is connected to the reboiler that provides heat needed for added reflux and better fractionation.

Applications: Distillation can be used for: the removal of halogenated and non halogenated VOCs in spent solvents, the separation and enrichment of low boiling compounds for recovery and waste volume reduction, and aqueous wastes heavily contaminated (up to 10,000 ppm) with organics.

Advantages: This technology provides high purity separation of individual components.

Limitations: Wide fluctuations in waste compositions can cause difficulties in this feed-sensitive technology. Components can form an azeotrope mixture which limits purity or can be expensive to further separate. High viscosity and a high solids liquids, polyurethanes, and inorganics are not suitable for fractional distillation. This process must be operated at temperatures below the autoignition point to minimize risk of explosion or at temperatures to minimize thermal decay.

SCREENING

Media: Soils.

Contaminant: Nonspecific adsorbed compounds.

Description: Screening is a physical process that mechanically separates particles based on size exclusion. Particles larger than the screen aperture are retained; smaller particles pass through the screen. Media is fed to the screen either wet or dry. Wet screening provides the best separation, but dewatering and drying increases costs; therefore, dry screening is more economical. A reduced feed rate and longer retention time achieves increased separation. Screen types include: grizzly, sieve bend, vibration, rotary sifters, shakers, and trommel

Applications: Screening is used for the separation of coarser particles from finer particles for particle sizes ranging from 12 inches to 50 microns, although smaller particle sizes may be better separated by classifiers.

Advantages: Screening is a relatively inexpensive, trouble-free conventional technology.

Limitations: Screening does not reduce the toxicity of the waste, only the waste volume. Slightly oversized particles may cause plugging of the screen, especially fine screens. Screening may require noise control and dry screening may require dust control.

FILTRATION

Media: Fluids and sludges.

Contaminant: Suspended solids and nonspecific adsorbed compounds.

Description: Filtration is a physical process that separates and removes solids from a fluid based on size exclusion. Fluid flow is accomplished by gravity, by positive or negative pressure on one side of the media, or by mechanical pressure. The fluid is passed through a porous medium that may be comprised of cloth or paper fabric, screen, or a bed of granular media. The treated fluid is called the filtrate, the solids are left behind. Typical filtration methods include: vacuum filtration, belt filter press, chamber pressure (plate and frame) filtration, granulated bed filtration.

Applications: Granular media filtration is generally used to remove suspended solids. Vacuum, belt and chamber filtration are primarily used to dewater sludges. Filtration can be used as a dewatering pretreatment for sludges or slurries, as a or as a polishing step after waste treatment to remove suspended solids. Filtration can also be used as a pretreatment step before reverse osmosis, ion exchange, and carbon adsorption to prevent plugging of these processes.

Advantages: Filtration is a relatively inexpensive conventional technology.

Limitations: Filtration does not reduce the toxicity of the waste, only the waste volume. Sticky or gelatinous sludges may cause plugging of the filter media. Sludges less than 5% solids may require dewatering before filtration for economic treatment. If suspended solids are greater than 100 ppm, granular media should be preceded by gravity separation, such as sedimentation.

REVERSE OSMOSIS

Media: Aqueous wastes

Contaminant: Heavy metals, colloidal particles, and large and/or polar organics.

Description: Membrane separation is a physical process that separates and removes chemical compounds (solute) and very small solids from a liquid (solvent) using semi-permeable membranes. These membranes selectively reject contaminants, using size exclusion, co-precipitation, and charge, and allow the liquid stream to permeate through the membrane relatively solute free. The most common membrane separation processes are reverse osmosis (RO), ultrafiltration, and electrodialysis, with RO the most frequently used membrane separation for aqueous wastes. Liquid is pumped into an RO system under hydrostatic pressure, exceeding the osmotic pressure of the liquid, to provide a driving force through the membrane for the solvent. Bulk liquid flow is tangential to the membrane surface providing a natural scouring action that reduces fouling of the membrane surface. The liquid remaining behind the membrane (the concentrate) becomes more concentrated with the solute(s).

Applications: RO is used to concentrate brackish waters and aqueous wastes containing heavy metals and multi-charged anions. Other waste streams that can be treated are: landfill leachates, wastewater with high BOD levels, and groundwater with PCBs, insecticides/herbicides, and higher molecular weight chlorinated organics.

Advantages: The concentrate and/or the permeate stream may be recycled. Different membrane material have different solute selectivity which provides process flexibility.

Limitations: Conventional pretreatment can minimize fouling and extend membrane life by removing suspended solids and oils. Some compounds may react with the membrane and pH extremes may damage membrane materials. The solute concentration inside the process may exceed the solubility product of individual salts leading to precipitation and membrane fouling.

CARBON ADSORPTION

Media: Aqueous and gaseous wastes.

Contaminant: Organics.

Description: Carbon adsorption is a physical-chemical process that removes organic compounds from contaminated media using a surface binding of target compounds to activated carbon. Activated carbon is a nonpolar adsorbent that contains a high surface area to weight ratio (500 to 1400 m²/g) resulting from a large network of internal pores. This large surface area exposes a large quantity of carbon atoms to act as adsorbers to attract and bind solutes. These binding forces are weaker and less specific than chemical bonds and are reversible. Activated carbon may show preferential adsorption of particular compounds in mixtures of organics requiring adsorption isotherm tests to predict performance. The isotherm data is evaluated using the Freundlich Equation. A carbon adsorption system typically consists of multiple columns containing activated carbon in parallel and/or series.

Applications: Removal of organics from aqueous and gaseous wastes, especially compounds with high molecular weight, high boiling points, low solubility, and low polarity. Compounds with low ionic structure, branch-chain compounds, organic acids at low pH, organic bases at high pH, and aromatics have decreased water solubility and, hence, increased adsorptivity. Other waste streams include organic liquids with metals, organic nitrogen compounds, and chelated metals.

Advantages: Carbon adsorption is a commonly used adsorbent and a conventional technology.

Limitations: Carbon adsorption is limited by: organic compounds > 10,000 ppm, suspended solids > 50 ppm, and oil and grease > 10 ppm. Carbon adsorption is not recommended for unassociated metals and high humidity gas streams and not effective for compounds with low molecular weights,

ION EXCHANGE

Media: Dilute aqueous wastes and leachates.

Contaminant: Metal anions and cations, radionuclides, inorganic cations, and organic acids and bases.

Description: Ion exchange is a physical-chemical process that removes anions and cations from solution by the surface binding of target compounds to a solid resin material.. Initially, the resin surface is coated with exchangeable monovalent anions or cations held with weak ionic bonds. A dilute aqueous waste with divalent and trivalent contaminants, which have a greater affinity for the charged sites on the resin surface, are passed over the bed of resin and an exchange of anions or cations occurs. After most exchangeable sites are filled with contaminants, the process is reversed by exposing the spent resin to a concentrated solution of the initial exchange anion or cation. This results in a regenerated bed and a concentrated solution of target compounds for recovery or reuse. The ion exchange system is usually operated in a flow-through column mode and can include a standby exchanger column available for operation during bed regeneration of the spent column to provide continuous service. Zeolites, clays, activated alumina, chitin and other natural materials can be used instead of resins.

Applications: Ion exchange removes ions from aqueous wastes, such as plating baths, process effluents, and leachates.

Advantages: Ion exchange is a conventional technology that can recycle contaminants with selective resins.

Limitations: Waste streams containing > 2500 ppm dissolved ions and 50 ppm suspended solids will rapidly exhaust and clog the bed, respectively. Other limitations include ion selectivity/competition, solution pH, and oxidizing agents > 50 meq/l. Process residuals are spent regenerant solution and resins.

IMMOBILIZATION

Media: Soils, sludges, and debris.

Contaminant: Heavy metals, radionuclides, inorganics, and some organics.

Description: Immobilization is a physical-chemical process that involves the use of one or both of two general techniques, stabilization/fixation and solidification. Stabilization techniques alter the contaminants chemically to limit their solubility, mobility, or chemical reactivity. Reagents or materials are added to the waste matrix to maintain the contaminants in their least mobile or toxic form. Examples of this technique are the conversion of metals into their lower mobility hydroxide or sulfide species, or the change of the metal's valence or oxidation state to one of lower solubility. Solidification is the result of treatment that produces a solid mass of waste material that has high structural integrity. The resulting product is often called a monolith. A mechanical (physical) enclosure of contaminants by reagents, called microencapsulation, generally takes place during solidification. A chemical interaction between reagents and contaminants may also occur. The contaminant loss from the solidified matrix is limited by the encapsulating mechanism, which locks and isolates the waste from the environment, and by the reduction of surface area, which lowers the amount of waste exposed to environmental affects.

Applications: Immobilization has wide application among waste containing solids.

Advantages: Immobilization can be performed on site quickly, simply and relatively inexpensively.

Limitations: The finished product, an immobilized waste, generally retains most or all of the original contaminant which may leach to some degree from the immobilized matrix thereby creating a potential future liability. Waste streams containing significant quantities of oils may be difficult to immobilize and wastes containing volatile organic should not be immobilized. Phenols may be difficult to immobilize with alkaline wastes. Waste may require pretreatment.

NEUTRALIZATION

Media: Solid, sludge, and aqueous wastes.

Contaminant: Excess hydrogen ions (H^+) and hydroxyl ions ($-OH$).

Description: Neutralization is a chemical process, using an acid-base reaction, designed to remove excess hydrogen ions or hydroxyl ions until there is a balance between the two ions, as measured by pH. An excess of hydrogen ions causes acidity (pH 0 to 7), while an excess of hydroxyl ions causes alkalinity (pH 7 to 14). Neutrality is pH 7. Typical chemical reagents for neutralization include other acid/alkali wastes, lime, caustic soda, and mineral acids. Equipment for neutralization usually consists of a chemical addition and a rapid mixing systems.

Applications: Neutralization can be used to treat caustic and acidic wastes groundwater, leachate, and wastewater treatment or pretreatment.

Advantages: Neutralization is a conventional technology that uses simple equipment and may be able to use waste acids and bases as neutralizing agents.

Limitations: Concentrated wastes may give off a large heat of exothermic reaction and toxic gases. Solids and sludges may require excessive chemical dosage due to difficulty to completely mix and potentially high buffering capacity. Corrosion-resistant equipment may be necessary. Residuals may result including insoluble and dissolved salts and metal hydroxide sludge.

PRECIPITATION

Media: Aqueous wastes.

Contaminant: Dissolved metals.

Description: Precipitation is a chemical process, using an acid-base reaction, similar to neutralization, to remove soluble metal ions from solution. Acid or alkali reagents are added to a solution to change the pH to the point where the target contaminant has its lowest solubility. Metal cations are transformed into the solid phase and drop out from solution (precipitation) with a corresponding anion that depends on the chemical reagent used. Chemical reagents for precipitation are similar to neutralization. Precipitation is generally followed by flocculation and sedimentation. Chemical flocculating agents transform small particles of precipitated metals into larger particles that easily settle. Sedimentation, discussed above, provides gravity settling of the precipitate. Equipment for precipitation usually consists of chemical addition, rapid mixing, and flocculation systems and a sedimentation tank.

Applications: Precipitation can be used for treatment or pretreatment of groundwater, leachate, and wastewater.

Advantages: Precipitation is a conventional technology that uses simple equipment, and may be able to use waste acids and bases as chemical reagents.

Limitations: For solutions containing different metal species, not all metals have a common optimum pH. Chelating and complexing agents can interfere with precipitation. The residual sludge may be considered a hazardous waste and require further treatment. The treated effluent may have elevated pH and excess sulfide and may require additional treatment.

OXIDATION/REDUCTION

Media: Aqueous wastes, sludges, and soils.

Contaminant: Many organics and heavy metals.

Description: Oxidation/reduction (redox) is a chemical process uses the addition of chemical reagents to destroy contaminants, transform them into less hazardous forms, or change their solubility and separability. During a redox reaction, the oxidation state of one compound is raised (oxidation, the loss of electrons) and the oxidation state of another compound is lowered (reduction, the gain of electrons). Common oxidizing agents are: ozone, UV/ozone, hypochlorite, hydrogen peroxide, chlorine, and potassium permanganate. Common reducing agents are: ferrous sulfate, sodium sulfate, sulfur dioxide, iron (+2), zinc, sodium hydrosulfite, and sodium borohydride. For efficient redox reactions, thorough mixing of reagents and media is necessary. Ex situ equipment requirements are enclosed reaction tanks with chemical addition and mixing systems. In situ processes require intimate mixing of reagents and soil.

Applications: Oxidation can be used for phenols, aldehydes, aromatics, alcohols, unsaturated alkyl compounds, ketones, acids, esters, amines, cyanide, arsenic, iron, and manganese. Reduction can be used for chromium (+6), mercury, lead, silver, and chlorinated organics. Redox can be used as a pretreatment or polishing step for waste treatment. Electrolytic redox may be substituted for liquid or dissolved reagents.

Advantages: Redox is a conventional technology with ease and simplicity of operation. An oxidation-reduction potential electrode can be used to follow the reaction.

Limitations: This nonspecific process may lead to unwanted side reactions if used on media with a wide range of contaminants. Strong oxidizers do not discriminate between natural organics and target contaminants; therefore, excess reagents may be necessary. Oil and grease > 1% and suspended solids > 3% may interfere with reagent-waste mixing. Reactions can be exothermic/explosive and may be pH sensitive. Some oxidants require catalysts for effective treatment.

SOIL WASHING/FLUSHING

Media: Soils and some debris.

Contaminant: Organics, oil, heavy metals, and radionuclides.

Description: Soil washing is an ex situ chemical process and physical process that consists of removing soil-bound contaminants with liquid extraction agents. The extraction agents are placed in contact with the excavated soil matrix to mobilize contaminants that are chemically or physically attached to the soil particles. The contaminants are mobilized from the soil phase so that they may be more easily treated in the liquid phase. Common extraction solutions are alkaline, acidic (mineral and organic), organic solvents, surfactant, and chelation. Soil washing may also include a volume reduction component which segregates the more contaminated and difficult to remediate fine fraction of soil from the coarser fraction. Soil washing with volume reduction requires a more complex process including initial soil conditioning, soil handling, soil classification, soil extraction, soil-liquid separation, and wastewater treatment. In contrast, soil flushing is performed in situ on unexcavated soil and consists of injecting an extraction solution to enhance the contaminant mobility, resulting in recoverable contaminants in the leachate or groundwater. The soil flushing system consists of injection and extraction wells and a wastewater treatment unit.

Applications: Soils containing a small proportion of fines and organic content are best suited for washing/flushing.

Advantages: Treated soil can be left on site with little or no future liability. Contaminants may be recycled.

Limitations: Soil with a high organic content and a high cation exchange capacity competes with the extraction agent for contaminants. Extraction solutions should have good partition coefficients, low volatility and toxicity, be safe, and be recoverable. Soil washing with volume reduction requires a complex process. For soil flushing, care should be taken not to clog soil pores, and site geology should minimize the possibility of the migration of renegade leachate.

CHEMICAL EXTRACTION

Media: Soils, sludges, and aqueous streams.

Contaminant: Oil or high molecular weight organics, radionuclides, and metals.

Description: Chemical extraction is a chemical process that separates contaminated liquids into two phases, aqueous and organic, and contaminated soils and sludges into three phases, aqueous, organic, and solids.

For liquids, simple extraction is a two-step process, extraction followed by stripping. During extraction, there is a partitioning of contaminants between the media (aqueous and/or solid phase) and the extractant (organic phase) to remove contaminants. Stripping recovers the concentrated contaminant into a second aqueous phase - the strip liquid, then the extractant is recycled back to the extraction step. If recovery of a contaminant for reuse is desired, an additional scrubbing step is used between the extraction and the stripping steps to return unwanted co-extracted compounds to the aqueous phase.

Various types of chemical reagents are used during treatment, including extractants, diluents, and modifiers. Extractant choice is a key factor.

For soils and sludges, a secondary or tertiary amine solvent, such as triethylamine (TEA), extracts the organic contaminants, usually oil or high molecular weight organics, from the particles and is miscible with the water phase at cool temperatures. The resulting mixture is centrifuged to remove the solids, and the solids are subsequently dried to recover the solvent. The solid-free solvent/contaminant/water solution is heated to lower the solubility of the organic and aqueous phases and to separate the two phases. The solvent is then separated from the oil or high molecular weight organic in a stripping tower.

Applications: Chemical extraction can be used for soils, sludges, wastewater, leachates, and corrosives. This technology is applicable when the contaminant is non biodegradable, when the contaminant concentration may provide an economic recovery, when low volatility or azeotrope formation hinders steam stripping, or when high contaminant concentration increases the cost of alternative treatment options like carbon adsorption.

Advantages: The contaminants and solvents may be recycled and the waste media can be recovered. Soils contaminated with heavy metals are not suitable for TEA extraction.

Limitations: To make soil pumpable, it may be necessary to add solvent or water to and to screen the soil. Treated soils may contain residual solvents.

DECHLORINATION

Media: Soils, and oil and organic liquid wastes.

Contaminant: PCBs, dioxins and chlorinated organics.

Description: Dechlorination is a chemical process that displaces chlorine atoms from chlorinated organics. Two types of processes exist with several variations of each: alkali metal dechlorination and alkali metal/polyethylene glycol (APEG) dechlorination. In alkali metal dechlorination, sodium naphthalene (or proprietary substitute) in tetrahydrofuran strips the chlorine atoms from PCBs and polymerize the biphenols into a sludge. The result is chloride salts, polymers, and, possibly, heavy metals. In APEG dechlorination, an alkali metal anion and polyethylene glycol, in the presence of an enhancer, displaces the chlorine atoms and form a PEG ether that may decompose into a phenol.

Applications: Alkali metal dechlorination is intended for transformer fluids, oil, and organic liquid wastes containing PCBs. APEG is intended for soils and sludges containing PCBs, dioxin, and chlorinated hydrocarbons; chlorinated acids and thiols have also been treated.

Advantages: Dechlorination is less expensive than incineration for transformer fluid. Reactions are rapid.

Limitations: Treatment of PCB concentrations exceeding 5,000 ppm may not be cost effective. Moisture content of media adversely affects the reaction. Complete contact between reagents and soil is necessary. Heavy metal residuals may result. High clay and organic content in soil increase reaction time. Low pH soil may detrimentally affect the alkaline APEG reaction.

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