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How To Evaluate Alternative Cleanup Technologies For Underground Storage Tank Sites

A Guide For Corrective Action Plan Reviewers

Appendix

Abbreviations And Definitions

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AS	Air Sparging
ASTM	American Society of Testing and Materials
atm	atmosphere (pressure)
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
Btu	British thermal unit
CAP	Corrective Action Plan
CFU	Colony Forming Units
cm/sec	Centimeters Per Second
COC	Contaminant Of Concern
CPT	Cone Penetrometer Testing
DNAPL	Dense Non-Aqueous Phase Liquid
DO	Dissolved Oxygen
DPE	Dual-Phase Extraction
DPT	Direct Push Technology
EAOB	Enhanced Anaerobic Oxidative Bioremediation
FID	Flame Ionization Detector
GAC	Granular Activated Carbon
GC	Gas Chromatograph
gpm	Gallons Per Minute
HDPE	High Density Polyethylene
Hg	Mercury, elemental
HRSC	High-Resolution Site Characterization
K	Hydraulic Conductivity
LEL	Lower Explosive Limit
LIF	Laser-Induced Fluorescence
LNAPL	Light Non-Aqueous Phase Liquid
LTTD	Low Temperature Thermal Desorption
LUST	Leaking Underground Storage Tank
mg/L	Milligrams Per Liter
MIP	Membrane Interface Probe
MS	Mass Spectrometer
MTBE	Methyl Tertiary-Butyl Ether
NAPL	Non-Aqueous Phase Liquid
NPDES	National Pollutant Discharge Elimination System
O&M	Operation And Maintenance
OUST	Office of Underground Storage Tanks (USEPA, Washington, DC)

PAH	Polyaromatic Hydrocarbon
PID	Photoionization Detector
PNA	Polynuclear Aromatic Hydrocarbon
ppb	parts per billion
ppm	parts per million
PRB	Permeable Reactive Barrier
psi	pounds per square inch (pressure)
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
ROI	Radius of Influence
SVE	Soil Vapor Extraction
TBA	Tertiary Butyl Alcohol
TCLP	Toxicity Characteristic Leaching Procedure (EPA Method 1311)
TDS	Total Dissolved Solids
TEA	Terminal Electron Acceptor
TPH	Total Petroleum Hydrocarbons
TRPH	Total Recoverable Petroleum Hydrocarbons (EPA Method 418.1)
UEL	Upper Explosive Limit
UST	Underground Storage Tank
VOC	Volatile Organic Compound

Definitions

abiotic: not biotic; not formed by biologic processes.

absolute viscosity: A measure of a fluid's resistance to tangential or shear stress. Also referred to as dynamic viscosity; see also viscosity. Units are usually given in centipoise.

absorption: the penetration of atoms, ions, or molecules into the bulk mass of a substance.

Actinomycetes: any of numerous, generally filamentous, and often pathogenic, microorganisms resembling both bacteria and fungi.

adsorption: the retention of atoms, ions, or molecules onto the surface of another substance.

advection: the process of transfer of fluids (vapors or liquid) through a geologic formation in response to a pressure gradient that may be caused by changes in barometric pressure, water table levels, wind fluctuations, or infiltration.

aeration: the process of bringing air into contact with a liquid (typically water), usually by bubbling air through the liquid, spraying the liquid into the air, allowing the liquid to cascade down a waterfall, or by

mechanical agitation. Aeration serves to (1) strip dissolved gases from solution, and/or (2) oxygenate the liquid. The rate at which a gas transfers into solution can be described by Fick's First Law.

aerobic: able to live, grow, or take place only when free oxygen is present.

afterburner: an off-gas posttreatment unit for control of organic compounds by thermal oxidation. A typical afterburner is a refractory-lined shell providing enough residence time at a sufficiently high temperature to destroy organic compounds in the off-gas stream.

aggregate: coarse mineral material (e.g., sand, gravel) that is mixed with either cement to form concrete or tarry hydrocarbons to form asphalt.

algae: chiefly aquatic, eucaryotic one-celled or multicellular plants without true stems, roots and leaves, that are typically autotrophic, photosynthetic, and contain chlorophyll. Algae are not typically found in groundwater.

aliphatic: of or pertaining to a broad category of carbon compounds distinguished by a straight, or branched, open chain arrangement of the constituent carbon atoms. The carbon-carbon bonds may be either saturated or unsaturated. Alkanes, alkenes, and alkynes are aliphatic hydrocarbons.

alkanes: the homologous group of linear saturated aliphatic hydrocarbons having the general formula C_nH_{2n+2}. Alkanes can be straight chains, branched chains, or ring structures. Also referred to as paraffins.

alkenes: the group of unsaturated hydrocarbons having the general formula C_nH_{2n} and characterized by being highly chemically reactive. Also referred to as olefins.

alkynes: the group of unsaturated hydrocarbons with a triple Carbon-Carbon bond having the general formula C_nH_{2n-2}.

ambient: surrounding; the surrounding environment and conditions.

anaerobic: able to live, grow, or take place where free oxygen is not present.

analog: in chemistry, a structural derivative of a parent compound.

anisotropic: the condition in which hydraulic properties of an aquifer are not equal when measured in all directions.

anoxic: total deprivation of oxygen.

aqueous solubility: the extent to which a compound will dissolve in water. The log of solubility is generally inversely related to molecular weight.

aquifer: a geologic formation capable of transmitting significant quantities of groundwater under

normal hydraulic gradients.

aquitard: a geologic formation that may contain groundwater but is not capable of transmitting significant quantities of groundwater under normal hydraulic gradients. In some situations aquitards may function as confining beds.

aromatic: of or relating to organic compounds that resemble benzene in chemical behavior. These compounds are unsaturated and characterized by containing at least one 6-carbon benzene ring.

asymptote: a line that is considered to be the limit to a curve. As the curve approaches the asymptote, the distance separating the curve and the asymptote continues to decrease, but the curve never actually intersects the asymptote.

attenuation: the reduction or lessening in amount (e.g., a reduction in the amount of contaminants in a plume as it migrates away from the source).

Atterberg limits: the moisture contents which define a soil's liquid limit, plastic limit, and sticky limit.

auger: a tool for drilling/boring into unconsolidated earth materials (soil) consisting of a spiral blade wound around a central stem or shaft that is commonly hollow (hollow-stem auger). Augers commonly are available in flights (sections) that are connected together to advance the depth of the borehole.

autoignition temperature: the temperature at which a substance will spontaneously ignite. Autoignition temperature is an indicator of thermal stability for petroleum hydrocarbons.

autotrophic: designating or typical of organisms that derive carbon for the manufacture of cell mass from inorganic carbon (carbon dioxide).

bacteria: unicellular microorganisms that exist either as free-living organisms or as parasites and have a broad range of biochemical, and often pathogenic, properties. Bacteria can be grouped by form into five general categories: cocci (spherical), bacilli (rod-shaped), vibrio (curved rod-shaped), spirilla (spiral), and filamentous (thread-like).

baghouse: a dust-collection chamber containing numerous permeable fabric filters through which the exhaust gases pass. Finer particulates entrained in the exhaust gas stream are collected in the filters for subsequent treatment/disposal.

ball valve: a valve regulated by the position of a free-floating ball that moves in response to fluid or mechanical pressure.

Bentonite: a colloidal clay, largely made up of the mineral sodium montmorillonite, a hydrated aluminum silicate. Because of its expansive property, bentonite is commonly used to provide a tight seal around a well casing.

berm: a sloped wall or embankment (typically constructed of earth, hay bales, or timber framing) used to prevent inflow or outflow of material into/from an area.

bioassay: a method used to determine the toxicity of specific chemical contaminants. A number of individuals of a sensitive species are placed in water containing specific concentrations of the contaminant for a specified period of time.

bioaugmentation: the introduction of cultured microorganisms into the subsurface environment for the purpose of enhancing bioremediation of organic contaminants. Generally, the microorganisms are selected for their ability to degrade the organic compounds present at the remediation site. The culture can be either an isolated genus or a mix of more than one genera. Nutrients are usually also blended with the aqueous solution containing the microbes to serve as a carrier and dispersant. The liquid is introduced into the subsurface under natural conditions (gravity fed) or injected under pressure.

bioavailability: the availability of a compound for biodegradation, influenced by the compound's location relative to microorganisms and its ability to dissolve in water.

biocide: a substance capable of destroying (killing) living organisms.

biodegradability (or **biodegradation potential**)**:** the relative ease with which petroleum hydrocarbons will degrade as the result of biological metabolism. Although virtually all petroleum hydrocarbons are biodegradable, biodegradability is highly variable and dependent somewhat on the type of hydrocarbon. In general, biodegradability increases with increasing solubility; solubility is inversely proportional to molecular weight.

biodegradation: a process by which microbial organisms transform or alter (through metabolic or enzymatic action) the structure of chemicals introduced into the environment.

biomass: the amount of living matter in a given area or volume.

biostimulation: providing nutrients needed by microorganisms to enhance the conditions for bioremediation.

boiling point: the temperature at which a component's vapor pressure equals atmospheric pressure. Boiling point is a relative indicator of volatility and generally increases with increasing molecular weight.

Btu: "British Thermal Unit"; the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at 39 degrees F; used as the standard for the comparison of heating values of fuels.

bubble radius: the maximum radial distance away from a biosparging well where the effects of sparging are observable. Analogous to radius of influence of an air sparging well.

bulk density: the amount of mass of a soil per unit volume of soil; where mass is measured after all

water has been extracted and total volume includes the volume of the soil itself and the volume of air space (voids) between the soil grains.

butterfly valve: a shut-off valve usually found in larger pipe sizes (4 inches or greater). This type of valve can be used for non-critical flow control.

capillary fringe: the zone of a porous medium above the water table within which the porous medium is saturated by water under pressure that is less than atmospheric pressure.

capillary suction: the process whereby water rises above the water table into the void spaces of a soil due to tension between the water and soil particles.

catalytic oxidizer: an off-gas posttreatment unit for control of organic compounds. Gas enters the unit and passes over a support material coated with a catalyst (commonly a noble metal such as platinum or rhodium) that promotes oxidation of the organics. Catalytic oxidizers can also be very effective in controlling odors. High moisture content and the presence of chlorine or sulfur compounds can adversely affect the performance of the catalytic oxidizer.

chemotrophs: organisms that obtain energy from oxidation or reduction of inorganic or organic matter.

coefficient of permeability: see hydraulic conductivity.

cometabolism: the simultaneous metabolism of two compounds, in which the degradation of the second compound (the secondary substrate) depends on the presence of the first compound (the primary substrate). For example, in the process of degrading methane, some bacteria can degrade hazardous chlorinated solvents that they would otherwise be unable to attack.

complexation: a reaction in which a metal ion and one or more anionic ligands chemically bond. Complexes often prevent the precipitation of metals.

condensate: the liquid that separates from a vapor during condensation.

conductivity: a coefficient of proportionality describing the rate at which a fluid (e.g., water or gas) can move through a permeable medium. Conductivity is a function of both the intrinsic permeability of the porous medium and the kinematic viscosity of the fluid which flows through it.

cone of depression: the area around a discharging well where the hydraulic head (potentiometric surface) in the aquifer has been lowered by pumping. In an unconfined aquifer, the cone of depression is a cone- shaped depression in the water table where the media has actually been dewatered.

confined aquifer: a fully saturated aquifer overlain by a confining layer. The potentiometric surface (hydraulic head) of the water in a confined aquifer is at an elevation that is equal to or higher than the base of the overlying confining layer. Discharging wells in a confined aquifer lower the potentiometric surface which forms a cone of depression, but the saturated media is not dewatered.

confining layer: a geologic formation characterized by low permeability that inhibits the flow of water (see also aquitard).

conservative: (a) in the case of a contaminant, one that does not degrade and the movement of which is not retarded; is unreactive. (b) in the case of an assumption, one that leads to a worst-case scenario, one that is most protective of human health and the environment.

constituent: an essential part or component of a system or group (e.g., an ingredient of a chemical mixture). For instance, benzene is one constituent of gasoline.

cyclone: a type of separator for removal of larger particles from an exhaust gas stream. Gas laden with particulates enters the cyclone and is directed to flow in a spiral causing the entrained particulates to fall out and collect at the bottom. The gas exits near the top of the cyclone.

Darcy's Law: an empirical relationship between hydraulic gradient and the viscous flow of water in the saturated zone of a porous medium under conditions of laminar flow. The flux of vapors through the voids of the vadose zone can be related to a pressure gradient through the air permeability by Darcy's Law.

degradation potential: the degree to which a substance is likely to be reduced to a simpler form by bacterial activity.

denitrification: bacterial reduction of nitrite to gaseous nitrogen under anaerobic conditions.

density: the amount of mass per unit volume.

diffusion: the process by which molecules in a single phase equilibrate to a zero concentration gradient by random molecular motion (Brownian motion). The flux of molecules is from regions of high concentration to low concentration and is governed by Fick's Second Law.

dispersion: the process by which a substance or chemical spreads and dilutes in flowing groundwater or soil gas.

dissolution: dissolving of a substance in a liquid solvent (e.g., water).

downgradient: in the direction of decreasing static head (potential).

drawdown: lowering the water table due to withdrawal of groundwater as from a well.

dynamic viscosity: a measure of a fluid's resistance to tangential or shear stress.

effective porosity: the amount of interconnected pore space in a soil or rock through which fluids can pass, expressed as a percent of bulk volume. Some of the voids and pores in a rock or soil will be filled with static fluid or other material, so that effective porosity is always less than total porosity.

effluent: something that flows out, especially a liquid or gaseous waste stream.

electron acceptor: a chemical entity that accepts electrons transferred to it from another compound. It is an oxidizing agent that, by virtue of its accepting electrons, is itself reduced in the process. See also terminal electron acceptor and oxidation-reduction.

electron donor: a chemical entity that donates electrons to another compound. It is a reducing agent that, by virtue of its donating electrons, is itself oxidized in the process. (see also electron acceptor and oxidation-reduction.)

empirical: relying upon or gained from experiment or observation.

entrained: particulates or vapor transported along with flowing gas or liquid.

enzyme: (a) any of numerous proteins or conjugated proteins produced by living organisms and functioning as biochemical catalysts. (b) a protein that a living organism uses in the process of degrading a specific compound. The protein serves as a catalyst in the compound's biochemical transformation.

eucaryote: an organism having one or more cells with well-defined nuclei.

evaporation: the process by which a liquid enters the vapor (gas) phase.

ex situ: moved from its original place; excavated; removed or recovered from the subsurface.

extraction well: a well employed to extract fluids (either water, gas, free product, or a combination of these) from the subsurface. Extraction is usually accomplished by either a pump located within the well or suction created by a vacuum pump at the ground surface.

facultative: used to describe organisms that are able to grow in either the presence or absence of a specific environmental factor (e.g., oxygen). See also facultative anaerobe.

facultative anaerobes: microorganisms that can grow in either the presence or the absence of molecular oxygen. In the absence of oxygen these microorganism can utilize another compound (e.g., sulfate or nitrate) as a terminal electron acceptor.

Fick's First Law: an equation describing the rate at which a gas transfers into solution. The change in concentration of gas in solution is proportional to the product of an overall mass transfer coefficient and the concentration gradient.

Fick's Second Law: an equation relating the change of concentration with time due to diffusion to the change in concentration gradient with distance from the source of concentration.

field capacity: the maximum amount of water that a soil can retain after excess water from saturated conditions has been drained by the force of gravity.

flow tube: a calibrated flow measuring device made for a specific range of flow velocities and fluids.

flux: the rate of movement of mass through a unit cross-sectional area per unit time in response to a concentration gradient or some advective force.

free product: a petroleum hydrocarbon in the liquid ("free" or non-aqueous) phase (see also non-aqueous phase liquid, NAPL).

friable: easily crumbled, not cohesive or sticky.

fungi: aerobic, multicellular, nonphotosynthetic, heterotrophic microorganisms. The fungi include mushrooms, yeast, molds, and smuts. Most fungi are saprophytes, obtaining their nourishment from dead organic matter. Along with bacteria, fungi are the principal organisms responsible for the decomposition of carbon in the biosphere. Fungi have two ecological advantages over bacteria: (1) they can grow in low moisture areas, and (2) they can grow in low pH environments.

gate valve: a valve regulated by the position of a circular plate.

globe valve: a type of stemmed valve that is used for flow control. The valve has a globe shaped plug that rises or falls vertically when the stem handwheel is rotated.

gradient: the rate of change in value of a physical or chemical parameter per unit change in position. For example, hydraulic gradient is equal to the difference in head measured at two points (usually wells) divided by the distance separating the two points. The dimensions of head and distance are both lengths, therefore the gradient is expressed as a dimensionless ratio (L/L).

groundwater: the water contained in the pore spaces of saturated geologic media.

grout: a watery mixture of cement (and commonly bentonite) without aggregate that is used to seal the annular space around well casings to prevent infiltration of water or short-circuiting of vapor flow.

heat capacity: the quantity of energy that must be supplied to raise the temperature of a substance. For contaminated soils heat capacity is the quantity of energy that must be added to the soil to volatilize organic components. The typical range of heat capacity of soils is relatively narrow, therefore variations are not likely to have a major impact on application of a thermal desorption process.

Henry's law: the relationship between the partial pressure of a compound and the equilibrium concentration in the liquid through a proportionality constant known as the Henry's law constant.

Henry's law constant: the ratio of the concentration of a compound in air (or vapor) to the concentration of the compound in water under equilibrium conditions.

heterogeneous: varying in structure or composition at different locations in space.

heterotrophic: designating or typical of organisms that derive carbon for the manufacture of cell mass

from organic matter.

homogeneous: uniform in structure or composition at all locations in space.

hose barb: a twist-type connector used for connecting a small diameter hose to a valve or faucet.

hydraulic conductivity: a coefficient of proportionality describing the rate at which water can move through a permeable medium. Hydraulic conductivity is a function of both the intrinsic permeability of the porous medium and the kinematic viscosity of the water which flows through it. Also referred to as the coefficient of permeability.

hydraulic gradient: the change in total potentiometric (or piezometric) head between two points divided by the horizontal distance separating the two points.

hydrocarbon: chemical compounds composed only of carbon and hydrogen.

hydrogen peroxide: H_2O_2. Hydrogen peroxide is used to increase the dissolved oxygen content of groundwater to stimulate aerobic biodegradation of organic contaminants. Hydrogen peroxide is infinitely soluble in water, but rapidly dissociates to form a molecule of water [H_2O] and one-half molecule of oxygen [O]. Dissolved oxygen concentrations of greater than 1,000 mg/L are possible using hydrogen peroxide, but high levels of D.O. can be toxic to microorganisms.

hydrophilic: having an affinity for water, or capable of dissolving in water; soluble or miscible in water.

hydrophobic: tending not to combine with water, or incapable of dissolving in water; insoluble or immiscible in water. A property exhibited by non-polar organic compounds, including the petroleum hydrocarbons.

hypoxic: a condition of low oxygen concentration, below that considered aerobic.

indigenous: living or occurring naturally in a specific area or environment; native.

infiltration: the downward movement of water through a soil in response to gravity and capillary suction.

infiltration gallery: an engineered structure that facilitates infiltration of water into the subsurface. Infiltration galleries may consist of one or more horizontal or vertical perforated pipes, a single gravel-filled trench or a network of such trenches, or a combination of these.

injection well: a well used to inject under pressure a fluid (liquid or gas) into the subsurface.

inlet well: a well through which a fluid (liquid or gas) is allowed to enter the subsurface under natural pressure.

in-line rotameter: a flow measurement device for liquids and gases that uses a flow tube and specialized

float. The float device is supported by the flowing fluid in the clear glass or plastic flow tube. The vertical scaled flow tube is calibrated for the desired flow volumes/time.

inoculate: to implant microorganisms onto or into a culture medium.

in situ: in its original place; unmoved; unexcavated; remaining in the subsurface.

intergranular: between the individual grains in a rock or sediment.

intrinsic permeability: a measure of the relative ease with which a permeable medium can transmit a fluid (liquid or gas). Intrinsic permeability is a property only of the medium and is independent of the nature of the fluid.

isotropic: the condition in which hydraulic properties of an aquifer are equal when measured in any direction.

kinematic viscosity: the ratio of dynamic viscosity to mass density. Kinematic viscosity is a measure of a fluid's resistance to gravity flow: the lower the kinematic viscosity, the easier and faster the fluid will flow.

K_{oc}: see soil organic carbon partition coefficient.

K_{ow}: see octanol/water partition coefficient.

liquidity index (LI): quantitative value used to assess whether a soil will behave as a brittle solid, semisolid, plastic, or liquid. LI is equal to the difference between the natural moisture content of the soil and the plastic limit (PL) divided by the plasticity index (PI).

liquid limit (LL): the lower limit for viscous flow of a soil.

lithology: the gross physical character of a rock or rock types in a stratigraphic section.

lower explosive limit (LEL): the concentration of a gas below which the concentration of vapors is insufficient to support an explosion. LELs for most organics are generally 1 to 5 percent by volume.

magnehelic gauge: a sensitive differential pressure or vacuum gauge manufactured by Dwyer Instrument Co. that uses a precision diaphragm to measure pressure differences. This gauge is manufactured in specific pressure or vacuum ranges such as 0 to 2 inches of water column. Magnehelic gauges are typically used to measure SVE system vacuums.

manifold: a pipe with several apertures for making multiple connections.

manometer: an instrument for measuring fluid pressure. Typically a U-shaped tube in which opposing fluid pressures reach an equilibrium. The pressure is equal to the differences in the levels of the fluid on either side of the tube.

mass flux: the flow rate of contaminant mass through a defined area, usually a portion of a plume cross section; expressed as mass per time per area.

matrix back-diffusion (rebound): increase in contaminant concentrations after initial treatment has reduced contaminant levels in high permeability zones; caused by low permeability zones releasing contaminants into high permeability zones.

metabolism: a term that encompasses all of the diverse reactions by which a cell processes food material to obtain energy and the compounds from which new cell components are made.

methanogenic: referring to the formation of methane by certain anaerobic bacteria during the process of anaerobic fermentation.

methyl tertiary-butyl ether (MTBE): a fuel oxygenate. It and other fuel additives (such as tertiary butyl alcohol (TBA), ethanol, and methanol) are highly soluble in water and highly mobile in the subsurface.

microaerophilic: obligate aerobes that function best under conditions of low oxygen concentration.

microcosm: a diminutive, representative system analogous to a larger system in composition, development, or configuration. As used in biodegradation treatability studies, microcosms are typically constructed in glass bottles or jars.

microorganisms: microscopic organisms including bacteria, protozoans, yeast, fungi, mold, viruses, and algae.

mineralization: the release of inorganic chemicals from organic matter in the process of aerobic or anaerobic decay.

moisture content: the amount of water lost from a soil upon drying to a constant weight, expressed as the weight per unit weight of dry soil or as the volume of water per unit bulk volume of the soil. For a fully saturated medium, moisture content equals the porosity.

molecular diffusion: process whereby molecules of various gases tend to intermingle and eventually become uniformly dispersed.

molecular weight: the amount of mass in one mole of molecules of a substance as determined by summing the masses of the individual atoms which make up the molecule.

monoaromatic: aromatic hydrocarbons containing a single benzene ring.

non-aqueous phase liquid (NAPL): contaminants that remain as the original bulk liquid in the subsurface (see also free product).

nutrients: major elements (e.g., nitrogen and phosphorus) and trace elements (including sulfur, potassium, calcium, and magnesium) that are essential for the growth of organisms.

obligate aerobes: organisms that require the presence of molecular oxygen (O_2) for their metabolism.

obligate anaerobes: organisms for which the presence of molecular oxygen is toxic. These organisms derive the oxygen needed for cell synthesis from chemical compounds.

occlude: to cause to become obstructed or closed and thus prevent passage either into or from.

octanol/water partition coefficient (K_{ow}): a coefficient representing the ratio of the solubility of a compound in octanol (a non-polar solvent) to its solubility in water (a polar solvent). The higher the K_{ow}, the more non-polar the compound. Log K_{ow} is generally used as a relative indicator of the tendency of an organic compound to adsorb to soil. Log K_{ow} values are generally inversely related to aqueous solubility and directly proportional to molecular weight.

off-gas treatment system: refers to the unit operations used to treat (i.e. condense, collect, or destroy) contaminants in the purge gas from the thermal desorber.

olefins: see alkenes.

orifice plate: a flow measurement device for liquids or gases that uses a restrictive orifice plate consisting of a machined hole that produces a jet effect. Typically the orifice meter consists of a thin plate with a square edged, concentric, and circular orifice. The pressure drop of the jet effect across the orifice is proportional to the flow rate. The pressure drop can be measured with a manometer or differential pressure gauge.

oxidation-reduction (redox): a chemical reaction consisting of an oxidation reaction in which a substance loses or donates electrons, and a reduction reaction in which a substance gains or accepts electrons. Redox reactions are always coupled because free electrons cannot exist in solution and electrons must be conserved.

oxidation-reduction (redox) potential: a measure of an aqueous solution's tendency to either release or accept electrons. Oxidizing systems tend to accept electrons; reducing systems tend to release electrons.

paraffins: see alkanes.

partial pressure: the portion of total vapor pressure in a system due to one or more constituents in the vapor mixture.

permeability: a qualitative description of the relative ease with which rock, soil, or sediment will transmit a fluid (liquid or gas). Often used as a synonym for hydraulic conductivity or coefficient of permeability.

pH: a measure of the acidity of a solution. pH is equal to the negative logarithm of the concentration of hydrogen ions in a solution. A pH of 7 is neutral. Values less than 7 are acidic, and values greater than 7

are basic.

phototrophs: organisms that use light to generate energy (by photosynthesis) for cellular activity, growth, and reproduction.

pilot test: operation of a small-scale version of a larger system to gain information relating to the anticipated performance of the larger system. Pilot test results are typically used to design and optimize the larger system.

pitot tube: a device used to measure the total pressure of a fluid stream that is essentially a tube attached to a manometer at one end and pointed upstream at the other.

plastic limit (PL): the lower limit of the plastic state of a soil.

plasticity index (PI): the range of water content in which soil is in a plastic state. PI is calculated as the difference between the percent liquid limit and percent plastic limit.

plastic soil: one that will deform without shearing (typically silts or clays). Plasticity characteristics are measured using a set of parameters known as Atterberg Limits.

polyaromatic hydrocarbon: aromatic hydrocarbons containing more than one fused benzene ring. Polyaromatic hydrocarbons are commonly designated PAH.

polynuclear aromatic hydrocarbon: synonymous with polyaromatic hydrocarbon. Designated PNA.

pore volume: (1) the total volume of pore space in a given volume of rock or sediment. Pore volume usually relates to the volume of air or water that must be moved through contaminated material in order to flush the contaminants. (2) the volume of water (or air) that will completely fill all of the void space in a given volume of porous matrix. Pore volume is equivalent to the total porosity. The rate of decrease in the concentration of contaminants in a given volume of contaminated porous media is directly proportional to the number of pore volumes that can be exchanged (circulated) through the same given volume of porous media.

porosity, effective: a measure of the connected aquifer void space within the aquifer. Effective porosity is lower than total porosity in most geological settings.

porosity, total: the volume fraction of a rock or unconsolidated sediment not occupied by solid material but usually occupied by water and/or air. Primary porosity is the percentage of the voids in the rock at the time of formation, and secondary porosity refers to the void space from fractures and dissolution.

pressure gradient: a pressure differential in a given medium (e.g., water or air) which tends to induce movement from areas of higher pressure to areas of lower pressure.

procaryote: a cellular organism in which the nucleus has no limiting membrane.

protozoa: single-celled, eucaryotic microorganisms without cell walls. Most protozoa are free-living although many are parasitic. The majority of protozoa are aerobic or facultatively anaerobic heterotrophs.

psi (pounds per square inch): a unit of pressure or pressure drop across a flow resistance. One psi is equivalent to the pressure exerted by 2.31 feet of water column.

psig (pounds per square inch (gauge)): 0 psig = 14.696 psia (psi absolute) = 1.0 atmosphere.

pugmill: a chamber in which water and soil are mixed together. Typically mixing is aided by an internal mechanical stirring/kneading device.

radius of influence: the maximum distance away from an air injection or extraction source that is significantly affected by a change in pressure and induced movement of air.

reagent: a substance or solution used in a chemical reaction, especially those used in laboratory work to detect, measure, or produce other substances.

recalcitrant: unreactive, nondegradable; refractory.

recirculation system: a type of in-situ bioremediation system designed to increase the hydraulic gradient and accelerate the distribution of amendments across the contaminated area. Recirculation systems typically have extraction wells drawing groundwater from downgradient locations and injection wells injecting water with amendments into the source area.

redox: short for oxidation-reduction.

refractory index: a measure of the ability of a substance to be biodegraded by bacterial activity. The lower the refractory index, the greater the biodegradability.

retardation: preferential retention of contaminant movement in the subsurface resulting from adsorptive processes or solubility differences.

saturated zone: the zone in which all the voids in the rock or soil are filled with water at greater than atmospheric pressure. The water table is the top of the saturated zone in an unconfined aquifer.

sentinel well: a groundwater monitoring well situated between a sensitive receptor downgradient and the source of a contaminant plume upgradient. Contamination should be first detected in the sentinel well which serves as a warning that contamination may be moving closer to the receptor. The sentinel well should be located far enough upgradient of the receptor to allow enough time before the contamination arrives at the receptor to initiate other measures to prevent contamination from reaching the receptor, or in the case of a supply well, provide for an alternative water source.

septa fitting: a special fitting used to seal vials (a liner for a threaded cap) or gas chromatographs (GCs)

to provide closure. Septas can be manufactured in single, double, or triple layers of silicone rubber and other plastic materials. A syringe with a measured quantity of contaminant can be injected through a septa closure and into a GC column for separation analysis.

sequester: to undergo sequestration.

sequestration: the inhibition or stoppage of normal ion behavior by combination with added materials, especially the prevention of metallic ion precipitation from solution by formation of a coordination complex with a phosphate.

SESOIL: a one-dimensional model for estimating pollutant distribution in an unsaturated soil column. SESOIL results are commonly used to estimate the source term for groundwater transport modeling of the saturated zone.

short circuiting: the entry of ambient air into an extraction well (used for SVE and bioventing) without first passing through the contaminated zone. Short circuiting may occur through utility trenches, incoherent well or surface seals, or layers of high permeability geologic materials.

soil moisture: the water contained in the pore spaces in the unsaturated zone.

soil organic carbon partition coefficient (K_{oc}): a constant that describes a compound's equilibrium condition between organic carbon and the contaminant concentrations in an aqueous solution. Higher K_{oc} values indicate more contaminant mass is likely to be retained in soil and therefore less readily bioavailable.

solubility: the amount of mass of a compound that will dissolve in a unit volume of solution.

sorbent canisters: gas-tight canisters typically filled with activated carbon (charcoal) for collection and transport of vapor samples. In the laboratory the vapors are desorbed and analyzed to identify the organic compounds and quantify their concentration.

sorbent tubes: glass tubes filled with a sorbent material that reacts chemically with specific organic compounds. Based on the nature of the sorbent and the extent of the chemical reaction, organic compounds can be identified and their concentration quantified.

sorption: a general term used to encompass the processes of absorption, adsorption, ion exchange, and chemisorption.

sparge: injection of air below the water table to strip dissolved volatile organic compounds and/or oxygenate the groundwater to facilitate aerobic biodegradation of organic compounds.

specific gravity: the dimensionless ratio of the density of a substance with respect to the density of water. The specific gravity of water is equal to 1.0 by definition. Most petroleum products have a specific gravity less than 1.0, generally between 0.6 and 0.9. As such, they will float on water--these are

also referred to as LNAPLs, or light non-aqueous phase liquids. Substances with a specific gravity greater than 1.0 will sink through water--these are referred to as DNAPLs, or dense non-aqueous phase liquids.

sticky limit: the limit at which a soil loses its ability to adhere to a metal blade.

stratification: layering or bedding of geologic materials (e.g., rock or sediments).

stratum: a horizontal layer of geologic material of similar composition, especially one of several parallel layers arranged one on top of another.

sump: a pit or depression where liquids drain, collect, or are stored.

Tedlar bags: gas-tight bags constructed of non-reactive material (Tedlar) for the collection and transport of gas/vapor samples.

terminal electron acceptor (TEA): a compound or molecule that accepts an electron (is reduced) during metabolism (oxidation) of a carbon source. Under aerobic conditions molecular oxygen is the terminal electron acceptor. Under anaerobic conditions a variety of terminal electron acceptors may be used. In order of decreasing redox potential, these TEAs include nitrate, manganic manganese, ferric iron, sulfate, and carbon dioxide. Microorganisms preferentially utilize electron acceptors that provide the maximum free energy during respiration. Of the common terminal electron acceptors listed above, oxygen has the highest redox potential and provides the most free energy during electron transfer.

thermal desorber: describes the primary treatment unit that heats petroleum-contaminated materials and desorbs the organic materials into a purge gas or off-gas.

thermal desorption system: refers to a thermal desorber and associated systems for handling materials and treated soils and treating offgases and residuals.

total petroleum hydrocarbons (TPH): a measure of the concentration or mass of petroleum hydrocarbon constituents present in a given amount of air, soil, or water. The term total is a misnomer, in that few, if any, of the procedures for quantifying hydrocarbons are capable of measuring all fractions of petroleum hydrocarbons present in the sample. Volatile hydrocarbons are usually lost in the process and not quantified. Additionally, some non-petroleum hydrocarbons may be included in the analysis.

total recoverable petroleum hydrocarbons (TRPH): an EPA method (418.1) for measuring total petroleum hydrocarbons in samples of soil or water. Hydrocarbons are extracted from the sample using a chlorofluorocarbon solvent (typically Freon-113) and quantified by infrared spectrophotometry. The method specifies that the extract be passed through silica gel to remove the non-petroleum fraction of the hydrocarbons.

travel time: the time it takes a contaminant to travel from the source to a particular point downgradient.

tripolyphosphates: Salts with $P_3O_{10}^{-5}$ anion. Most common is sodium tripolyphosphate [$Na_5P_3O_{10}$].

turbine wheel: a rotor designed to convert fluid energy into rotational energy. Hydraulic turbines are used to extract energy from water as the water velocity increases due to a change in head or kinetic energy at the expense of the potential energy as the water flows from a higher elevation to a lower elevation. The fluid velocity tangential component contributes to the rotation of the rotor in a turbomachine.

unconfined aquifer: an aquifer in which there are no confining beds between the capillary fringe and land surface, and where the top of the saturated zone (the water table) is at atmospheric pressure.

unsaturated: the characteristic of a carbon atom in a hydrocarbon molecule that shares a double bond with another carbon atom.

unsaturated zone: the zone between land surface and the capillary fringe within which the moisture content is less than saturation and pressure is less than atmospheric. Soil pore spaces also typically contain air or other gases. The capillary fringe is not included in the unsaturated zone.

upgradient: it the direction of increasing potentiometric (piezometric) head.

vacuum draft tube: a narrow tube lowered into an extraction well through which a strong vacuum is pulled via a suction pump at ground surface. Fluids (gas, water, and/or free product) are drawn into the draft tube and conveyed to the surface for treatment or disposal. Depending upon the configuration of the extraction system, the inlet of the draft tube may be either above or below the static level of the liquid in the well.

vadose zone: the zone between land surface and the water table within which the moisture content is less than saturation (except in the capillary fringe) and pressure is less than atmospheric. Soil pore spaces also typically contain air or other gases. The capillary fringe is included in the vadose zone.

vapor density: the amount of mass of a vapor per unit volume of the vapor.

vapor pressure: the force per unit area exerted by a vapor in an equilibrium state with its pure solid, liquid, or solution at a given temperature. Vapor pressure is a measure of a substance's propensity to evaporate. Vapor pressure increases exponentially with an increase in temperature.

venturi: a short tube with a constricted throat for determining fluid pressures and velocities by measuring differential pressures generated at the throat as a fluid traverses the tube.

viscosity: a measure of the internal friction of a fluid that provides resistance to shear within the fluid. The greater the forces of internal friction (i.e., the greater the viscosity), the less easily the fluid will flow.

volatilization: the process of transfer of a chemical from the aqueous or liquid phase to the gas phase.

Solubility, molecular weight, and vapor pressure of the liquid and the nature of the gas-liquid interface affect the rate of volatilization.

water table: the water surface in an unconfined aquifer at which the fluid pressure in the pore spaces is at atmospheric pressure.

weathering: the process during which a complex compound is reduced to its simpler component parts, transported via physical processes, or biodegraded over time.

wellhead: the area immediately surrounding the top of a well, or the top of the well casing.

windrow: a low, elongated row of material left uncovered to dry. Windrows are typically arranged in parallel.