Ground Water Remediation Technologies

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ABSTRACT:

Ground water is the major and perennial source for drinking as well as for agricultural and industrial sectors in both urban and rural areas. But use of thousands of inorganic and organic chemicals increased since the advent of industrial revolution, uncontrolled release of domestic and industrial effluents and infiltrations/percolations and transfer and transport of such contaminants in the aquifers have turned the water beneath the ground polluted. Hence issues of groundwater pollution and effective and feasible alternatives for its clean up have made the technical experts thinking since last three decades. Present study focus on the various available ground water remediation technologies used to recover its quality for various applications.

Key Words: Ground water remediation, Ground water, contaminants

INTRODUCTION:

Groundwater is the water locked beneath the ground surface that saturates the pore space in the subsurface. Since last few decades it has come up as a sustainable source of water. Due to various anthropogenic activities and illegal dumping or disposal of untreated industrial effluents, this perennial source has been degraded up to the extent in some regions that sincere and immediate remediation efforts are highly required to restore its quality. Groundwater remediation is the process used to remove/reduce concentration of contaminants up to the level that ground water can be safely used for various applications. Remediation can be done by applying various physical, chemical and biological techniques thereby making it safe for use.

PHYSICAL TREATMENT TECHNOLOGIES *[11]*

1) PUMP AND TREAT [1,2,3]

This involves removing contaminated groundwater from strategically placed wells, treating the extracted water after it is on the surface to remove the contaminates using mechanical, chemical, or biological methods, and discharging the treated water to the subsurface, surface, or municipal sewer system.

Applications:

This method can be designed for removal of any contaminants or combination of contaminants. Common contaminants are

- Volatile and semi volatile organic compounds (including Diesel range organics (DRO) & Petroleum range organics (PRO)).
- Heavy metals like Lead, Chromium, etc.
- Pesticides
- pH

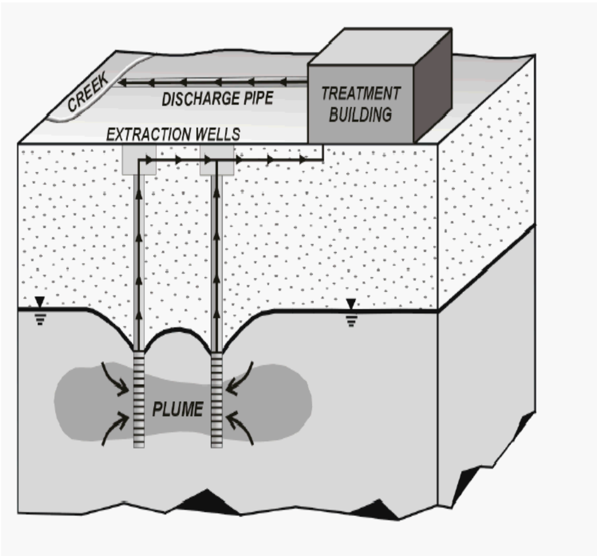

FIGURE 1 SET UP FOR PUMP AND TREAT METHOD

Limitations:

- Its effectiveness depends on the geology of the aquifer and the type of contaminant.
- It is slow, taking decades to centuries to remove all contaminated water
- It is very costly.
- It treats only ground water. Some contaminants stick to soil and rock and Non-Aqueous Phase Liquids NAPLs cannot be removed.

2) AIR SPARGING /SOIL-VAPOR EXTRACTION (SVE)[4]

Air sparging is an in situ remedial technology which involves the injection of fresh air/ hot air directly into the subsurface saturated zone. As the bubbles rise in the ground water, the contaminants are removed from the groundwater by physical contact with the air and are carried up into the unsaturated zone (i.e., soil). As the contaminants move into the soil, a SVE system is usually used to remove vapors.

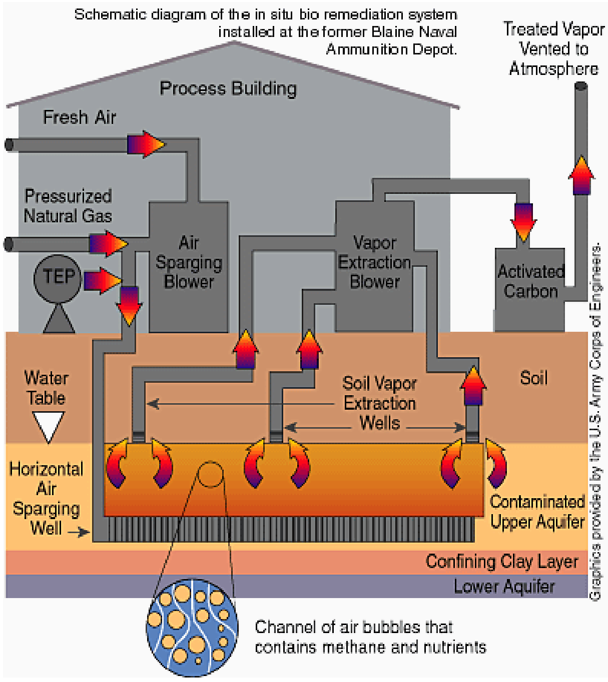

FIGURE 2 SET UP FOR AIR SPARGING METHOD

Applications:

Air Sparging has been found to be effective in reducing concentrations of

- Volatile organic compounds found in petroleum products like gasoline, diesel, etc.
- BTEX components.
- Chlorinated solvents like PCE, TCE, DCE, etc.

Limitations:

- The main limitations for air sparging are controlling the distribution of the injected air and off-site vapor migration.
- There is a potential of enhanced dissolved/free phase contaminant migration and aquifer clogging, both physically and chemically, if it is not controlled.
- The site must be capable of supporting drilling operations in the locations where the vapor extraction and air sparging wells are desired.
- Some lithologies are not conducive to this type of treatment. For example, a layer of low permeability soil overlying the saturated zone may prevent the injected air from being scavenged by the vapor extraction system installed above it.

- Existing underground utilities may limit installation in some areas.

3) DUAL PHASE VACUUM EXTRACTION [5,6,7,8,9]

Dual-phase Vacuum extraction (DPVE), is an in-situ technology in which vacuum applied to the subsurface with DPE systems creates vapor-phase pressure gradients toward the vacuum well. In response to the imposed gradients the subsurface liquids present and those liquids existing in a continuous phase (*e.g.*, water and "free" petroleum product)will flow toward the vacuum well. Extracted liquids and vapor are treated and collected for disposal, or re-injected to the ground.

FIGURE 3 SET UP FOR DUAL PHASE EXTRACTION AT TRAVAINI LRP

Applications:

- The DPE systems are more effective in removing separate-phase product/free products from the subsurface.
- They are typically designed to maximize the effectiveness of soil vapor extraction (SVE) by lowering the water table and therefore increasing air-phase permeability in the vadose zone.

Limitations:

- Site geology and contaminant characteristics influence the effectiveness of this technology.
- Complementary technologies, such as pump-and-treat, may be combined with DPE.
- DPE requires both water treatment and vapor treatment.
- Two-phase extraction requires an oil/water separator.

CHEMICAL TREATMENT TECHNOLOGIES [10]

1) CHEMICAL PRECIPITATION [12,13]

Chemical precipitation is a conventional technology which involves addition of chemical precipitants, coagulants, and flocculants in pumped ground water stream in a stirred reaction vessel to increase particle size through aggregation, either batch wise or with steady flowfollowed by the separation of the precipitated solids from the cleaned water.

Applications:

- It can remove hardness, heavy metals, fats, oils and greases (FOG), suspended solids and some organics from ground water. It can also be used to remove phosphorus, fluoride, ferrocyanide and other inorganics.
- It is applicable to the following situations:
    - mining-influenced water
    - high or low volume of material
    - solo technology or in conjunction with others
    - multiple contaminants of concern

Limitations:

- High cost
- Not applicable for all cases
- Requires operation and maintenance (O&M)
- Requires power
- It may generate waste products.

2) ION EXCHANGE[14]

Ion exchange for ground water remediation is virtually always carried out by passing the water downward under pressure through a fixed bed of resins or granular medium (either cation exchange media or anion exchange media) or spherical beads bed where ions cations and anions in the resins are exchanged by the cations and anions in contaminated water. Ion exchange media most often used for remediation are zeolites (both natural and synthetic) and synthetic resins. After the resin capacity has been exhausted, some can be regenerated for re-use, while others are meant for single use.

Applications:

- Ion exchange can remove dissolved metals (chromium), radionuclides and other inorganic chemicals from water.
- It can also be used to remove non-metallic compounds such as perchlorate, nitrate, and ammonia.

Limitations:

- Oil and grease in the groundwater may clog the exchange resin.
- The acidity or alkalinity of the incoming water may limit ion exchange capability. This can usually be controlled.
- Oxidants in groundwater may damage the ion exchange resin.
- Wastewater is generated during the regeneration step and requires additional treatment and disposal.
- The process does not destroy the contaminants; it transfers them to a different medium which must be treated or disposed of.
- If the system is designed as a single-use system, resin must either be disposed in a landfill or incinerated.

3) CARBON ADSORPTION[15,16,17,18]

Liquid phase carbon adsorption is a full-scale technology in which ground water is pumped through one or more vessels containing activated carbon to which dissolved organic contaminants are adsorbed. When the concentration of contaminants in the effluent from the bed exceeds a certain level, the carbon can be regenerated in place or at an off-site facility.The most common activated carbon used for remediation is derived from bituminous coal.

Applications:

- The target contaminant groups for carbon adsorption are hydrocarbons, SVOCs and explosives.
- Liquid phase carbon adsorption is effective for removing contaminants at low concentrations (less than 10 mg/L) from water at nearly any flow rate, and for removing higher concentrations of contaminants from water at low flow rates (typically 2 to 4 liters per minute or 0.5 to 1 gm).
- It is particularly effective for polishing water discharges from other remedial technologies to attain regulatory compliance.
- This system can be deployed rapidly, and contaminant removal efficiencies are high.

Limitations:

The presence of multiple contaminants can impact process performance. Bench tests may be conducted to estimate carbon usage for mixtures.

- Streams with high suspended solids (> 50 mg/L) and oil and grease (> 10 mg/L) may cause fouling of the carbon and may require frequent treatment.
- It is costly if used as the primary treatment on waste streams with high contaminant concentration levels.
- Type, pore size, and quality of the carbon, as well as the operating temperature, will impact process performance.
- Carbon used for explosives- or metals-contaminated ground water is not regenerated.
- Highly Water-soluble compounds and small molecules are not adsorbed well.
- All spent carbon eventually needs to be properly disposed.

4) CHEMICAL OXIDATION[19,20,21]

In the process called In Situ Chemical Oxidation or ISCO, oxidants such as air , ozone or certain chemical oxidants chemicals such as hydrogen peroxide, permanganate and persulfateare delivered in the subsurface in the form of liquids or gases to destroy the organic contaminants or to neutralize contamination caused by petroleum and volatile organic compounds (VOCs) in soil and groundwater . Chemical oxidation has proven to be an effective technique for dense non-aqueous phase liquid or DNAPL when it is present.

FIGURE 4 SET UP FOR IN-SITU CHEMICAL OXIDATION

Applications:

- Chemical oxidation is most often deployed at sites contaminated with petroleum-based fuels, chlorinated and non-chlorinated solvents, polychlorinated biphenyls, organic pesticides and other organic contaminants in ground water and saturated soil.

Limitations:

- Requirement for handling large quantities of hazardous oxidizing chemicals due to the oxidant demand of the target organic chemicals and the unproductive oxidant consumption of the formation.
- Some COCs are resistant to oxidation.
- There is a potential for process-induced detrimental effects. Further research and development is ongoing to advance the science and engineering of in situ chemical oxidation and to increase its overall cost effectiveness.

BIOLOGICAL TREATMENT TECHNOLOGIES

1) BIOVENTING[22,23,24,25]

Bioventing is an in situ remediation technology that uses the supply of oxygen and nutrients through direct air injection into residual contamination in soil (unsaturated zone) and ground water to enhance the activity of indigenous bacteria and to simulate the natural in situ biodegradation of hydrocarbons (adsorbed fuel residues & VOCs).

Applications

Bioventing has proven to be very effective in remediating the releases of

- All aerobically biodegradable constituents
- Petroleum products including gasoline, jet fuels, kerosene, and diesel fuel.
- Mid-weight petroleum products (i.e., diesel fuel and jet fuel. Heavier products (e.g., lubricating oils) generally take longer to biodegrade than the lighter products.
- Nonchlorinated solvents, some pesticides, wood preservatives, and other organic chemicals.

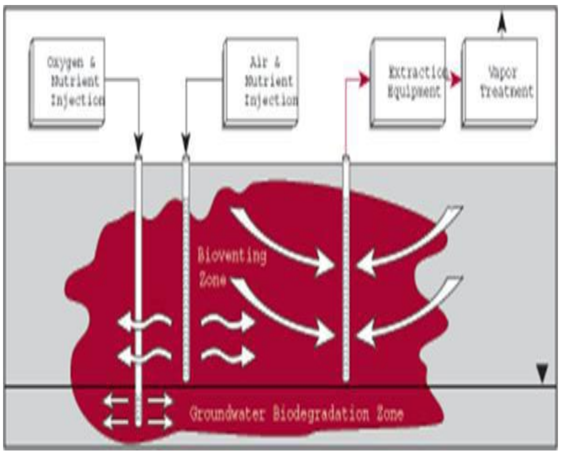

FIGURE 5 SET UP FOR TYPICAL BIOVENTING SYSTEM

Limitations

Factors that may limit the applicability and effectiveness of the process include:

(1) Low permeability soils (reduce bioventing performance).

(2) Air near the structure of concern has to be extracted in order to avoid vapor build up in basements within the radius of influence of air injection wells.

(3) Monitoring of off-gases at the soil surface may be required.

(4) Aerobic biodegradation of many chlorinated compounds may not be effective.

(5) Low soil moisture content, limits biodegradation.

2) BIOSLURPING [26,27,28,29,30,31]

Bioslurping, an in situ remediation technique is combination of the two remedial approaches of bioventing and vacuum-enhanced free-product recovery technologies to simultaneously recover free product without extracting large quantities of ground water and bioremediatevadose zone soils.

Vacuum-enhanced pumping involves the application of negative pressure to a well point to increase the rate of flow of groundwater and soil gas into the wells. Bioventing of vadose zone soils isachieved by drawing air into the soil due to withdrawing soil gas via the recovery well.

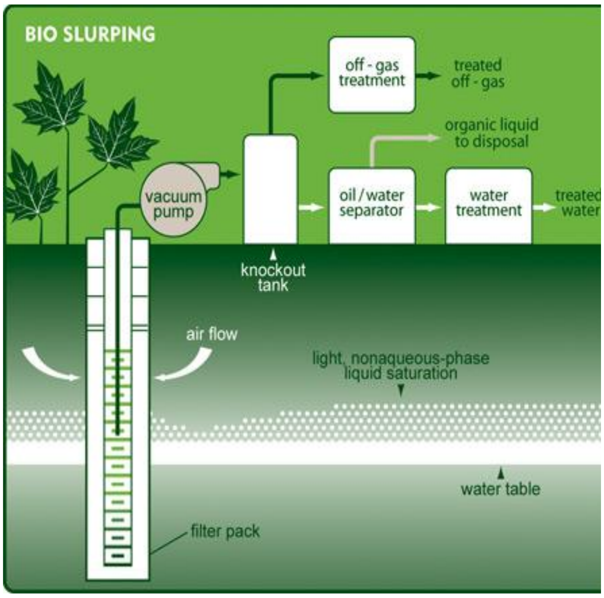

FIGURE 6 SET UP FOR TYPICAL BIOSLURPING SYSTEM

Applications

Bioslurping can be successfully used to remediate oils contaminated by petroleum hydrocarbons.

- It is a cost-effective in situ remediation technology that simulataneously accomplishes LNAPL Removal and soil remediation in the vadose zone.
- It is also applicable at sites with a deep ground water table (>30ft.).

Limitations:

- Bioslurping is less effective in tight (low-permeability) soils.
- Low soil moisture content may limit biodegradation and the effectiveness of bioventing.
- Aerobic biodegradation of many chlorinated compounds may not be effective unless there is a co-metabolite present.
- Low temperatures slow down remediation.
- The off-gas from the bioslurper system requires treatment before discharge. However, treatment of the off-gas may only be required shortly after the startup of the system as fuel rates decrease.
- At some sites, bioslurper systems can extract large volumes of water that may need to be treated prior to discharge depending on the concentration of contaminants in the process water.
- Since the fuel, water and air are removed from the subsurface in one stream, mixing of the phases occurs. These mixtures may require special oil/water separators or treatment before the process water can be discharged.
- Bioslurping does not treat residual contamination in saturated soils.
- Liquid ring pumps (and other high-velocity pump systems) tend to form emulsions, especially when diesel is part of recovered fluids and hence Biofouling of well screens is possible due to active aeration of bioslurping wells.

3) PHYTOREMEDIATION[32, 33, 34]

Phytoremediation is the application of plant-controlled interactions with groundwater and organic and inorganic molecules at contaminated sites to remove pollutants like metals, pesticides, explosives, and oil from soils, sludge, sediments, surface water, or ground water. This process can be carried out in areas where the roots can tap the ground water.

Plants remove harmful chemicals from the ground when their roots take in water and nutrients from polluted soil, streams, and groundwater. Once inside the plant, chemicals can be stored in the roots, stems, or leaves; changed into less harmful chemicals within the plant; or changed into gases that are released into the air as the plant transpires (breathes). If the chemicals are not taken into the plant by the roots, they can stick or sorb to plant roots.

Examples:

- Chinese Ladder fernPterisvittata, also known as the brake fern, is a highly efficient accumulator of arsenic.
- Genetically altered cottonwood trees are good absorbers of mercury from the contaminated soil in Danbury Connecticut.
- Transgenic Indian mustard plants to soak up dangerously high selenium deposits in California.
- Thlaspicaerulescens (alpine pennycress, a small, weedy member of the broccoli and cabbage family) can accumulate up to 30,000 ppm zinc and 1,500 ppm cadmium in its shoots.

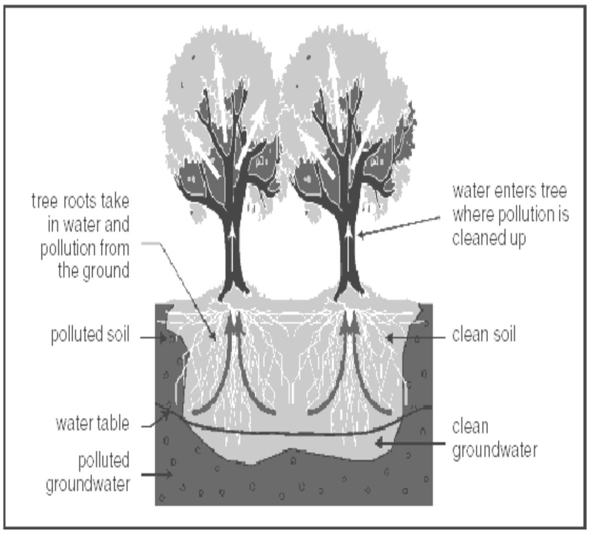

FIGURE 7 SET UP FOR PHYTOREMEDIATION METHOD

Applications:

- Phytoremediation works best at sites contaminated with low to medium amount of pollution.
- Heavy metals and metals like elements, such as arsenic, lead, uranium, selenium, cadmium, and other toxins such as nutrients, hydrocarbons and chlorinated hydrocarbons can be removed by Phytoremediation.

Limitations:

- This method is limited to remediation of ground water that is close enough to the surface that if can be reached by plant roots.

Discussion:

Technology to be used for ground water remediation, depends on types and quantity of contaminants, cost, area to be remediated, water quality to be achieved, hydro-geological condition of that region,etc.

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