



In-Situ Groundwater Bioremediation

An Online Continuing Education Course for Engineers

Course Number: EN-3031

Credit: 3 Hours / 3 PDH / 3 CPD

In-Situ Groundwater Bioremediation

Overview

In-situ groundwater bioremediation is a technology that encourages growth and reproduction of indigenous microorganisms to enhance biodegradation of organic constituents in the saturated zone. In-situ groundwater bioremediation can effectively degrade organic constituents which are dissolved in groundwater and adsorbed onto the aquifer matrix.

Bioremediation generally requires a mechanism for stimulating and maintaining the activity of these microorganisms. This mechanism is usually a delivery system for providing one or more of the following: An electron acceptor (oxygen, nitrate); nutrients (nitrogen, phosphorus); and an energy source (carbon). Generally, electron acceptors and nutrients are the two most critical components of any delivery system.

In a typical in-situ bioremediation system, groundwater is extracted using one or more wells and, if necessary, treated to remove residual dissolved constituents. The treated groundwater is then mixed with an electron acceptor and nutrients, and other constituents if required, and re-injected upgradient of or within the contaminant source. Infiltration galleries or injection wells may be used to re-inject treated water, as illustrated in Exhibits 1 and 2, respectively. In an ideal configuration, a "closed-loop" system would be established. All water extracted would be re-injected without treatment and all remediation would occur in situ. This ideal system would continually recirculate the water until cleanup levels had been achieved. If your state does not allow re-injection of extracted groundwater, it may be feasible to mix the electron acceptor and nutrients with fresh water instead. Extracted water that is not re-injected must be discharged, typically to surface water or to publicly owned treatment works (POTW).

In-situ bioremediation can be implemented in a number of treatment modes, including: Aerobic (oxygen respiration); anoxic (nitrate respiration); anaerobic (non-oxygen respiration); and co-metabolic (see Abbreviations and Definitions). The aerobic mode has been proven most effective in reducing contaminant levels of aliphatic (e.g., hexane) and aromatic petroleum hydrocarbons (e.g., benzene, naphthalene) typically present in gasoline and diesel fuel. In the aerobic treatment mode, groundwater is oxygenated by one of three methods: Direct sparging of air or oxygen through an injection well; saturation of water with air or oxygen prior to re-injection; or addition of hydrogen peroxide directly into an injection well or into reinjected water.

Exhibit 1

Schematic Diagram Of Typical In-Situ Groundwater Bioremediation System Using Infiltration Gallery

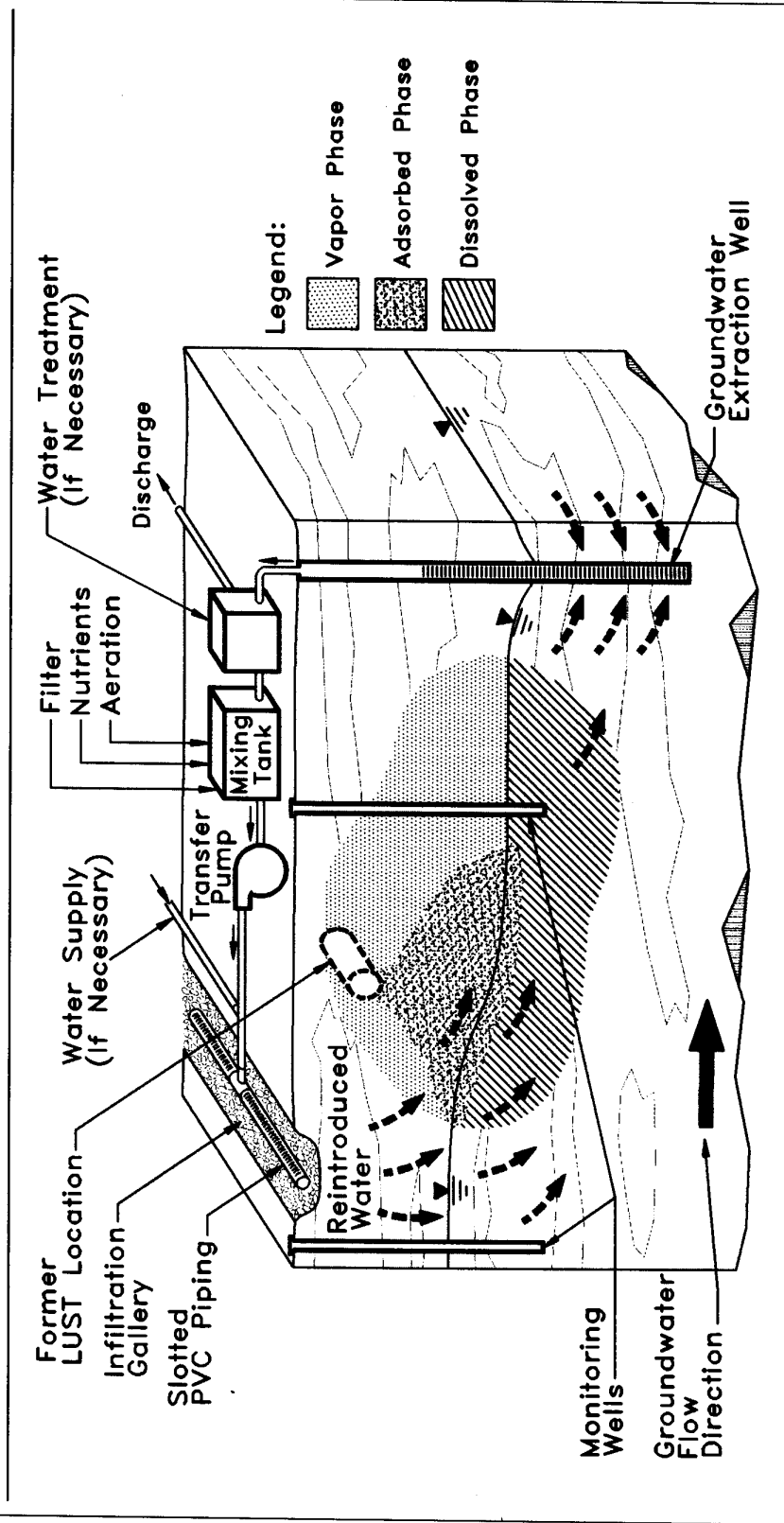
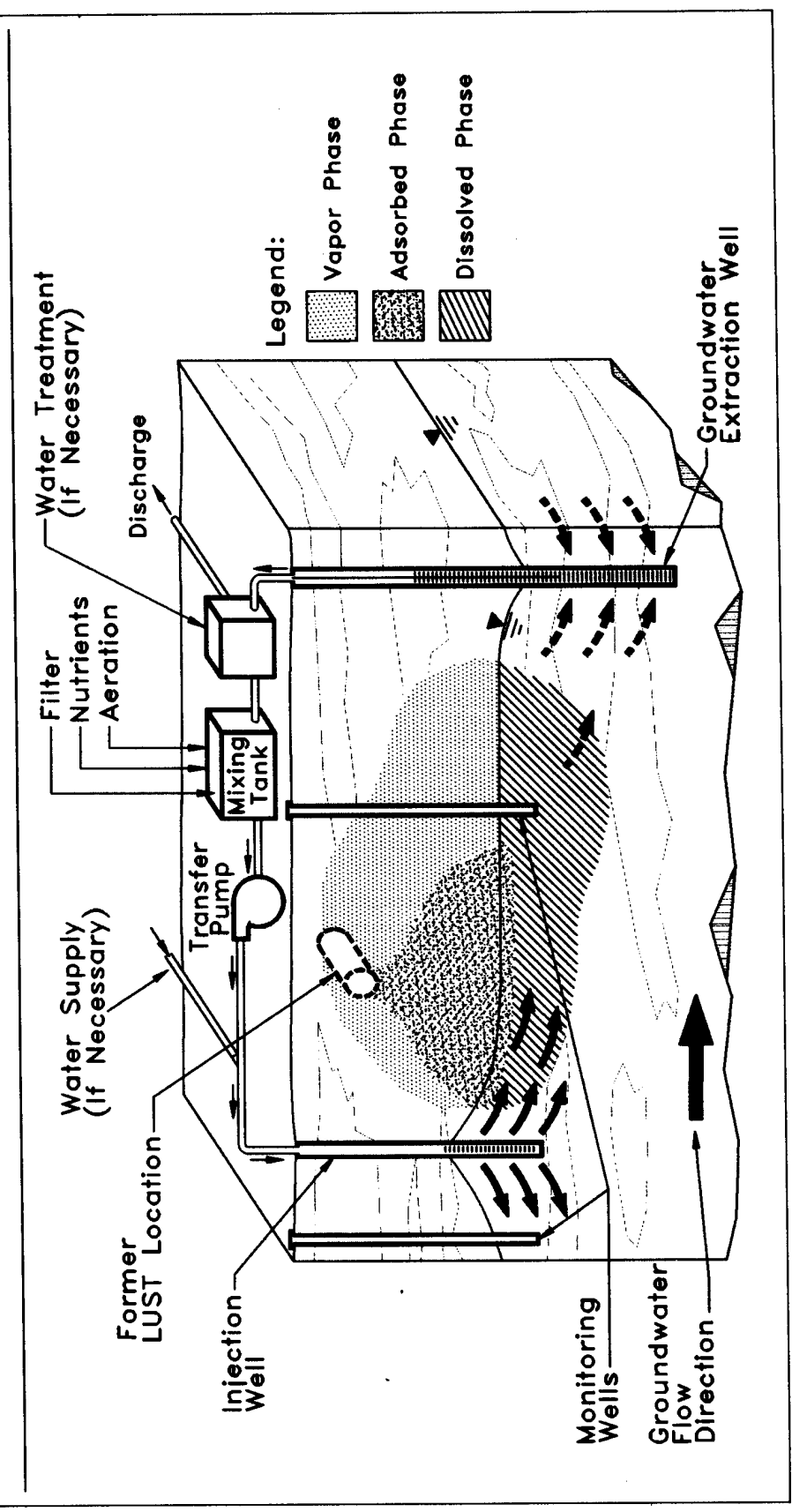


Exhibit 2

Schematic Diagram Of Typical In-Situ Groundwater Bioremediation System Using Injection Wells



Whichever method of oxygenation is used, it is important to ensure that oxygen is being distributed throughout the area of contamination. Anoxic, anaerobic, and co-metabolic modes are sometimes used for remediation of other compounds, such as chlorinated solvents, but are generally slower than aerobic respiration in breaking down petroleum hydrocarbons.

In-situ groundwater bioremediation can be effective for the full range of petroleum hydrocarbons. While there are some notable exceptions, such as MTBE, the short-chain, low-molecular-weight, more water soluble constituents are degraded more rapidly and to lower residual levels than are long-chain, high-molecular-weight, less soluble constituents. Recoverable free product should be removed from the subsurface prior to operation of the in-situ groundwater bioremediation system. This will mitigate the major source of contaminants as well as reduce the potential for smearing or spreading high concentrations of contaminants. A summary of the advantages and disadvantages of in-situ bioremediation of the saturated zone is shown in Exhibit 3.

In-situ bioremediation of groundwater can be combined with other saturated zone remedial technologies (e.g., air sparging) and vadose zone remedial operations (e.g., soil vapor extraction, bioventing).

This course will assist you in evaluating a corrective action plan (CAP) that proposes in-situ groundwater bioremediation for a petroleum-contaminated aquifer. The evaluation process, which is summarized in a flow diagram shown in Exhibit 4, will serve as a roadmap for the decisions you will make during your evaluation. You can use the checklist at the end of this course as a tool to evaluate the completeness of the CAP and to help focus attention on areas where additional information may be needed. The evaluation process can be divided into the following steps:

- **Step 1: An initial screening of in-situ groundwater bioremediation effectiveness**, which will allow to quickly gauge whether this technology is likely to be effective, moderately effective, or ineffective.
- **Step 2: A detailed evaluation of in-situ groundwater bioremediation effectiveness**, which provides further screening criteria to confirm the effectiveness of this technology and develop design standards and operating conditions. To complete the detailed evaluation, you will need to identify specific soil and constituent characteristics and properties, compare them to ranges where in-situ groundwater bioremediation is potentially effective, decide whether treatability studies are necessary to determine effectiveness, and conclude whether this technology is likely to be effective at a site.

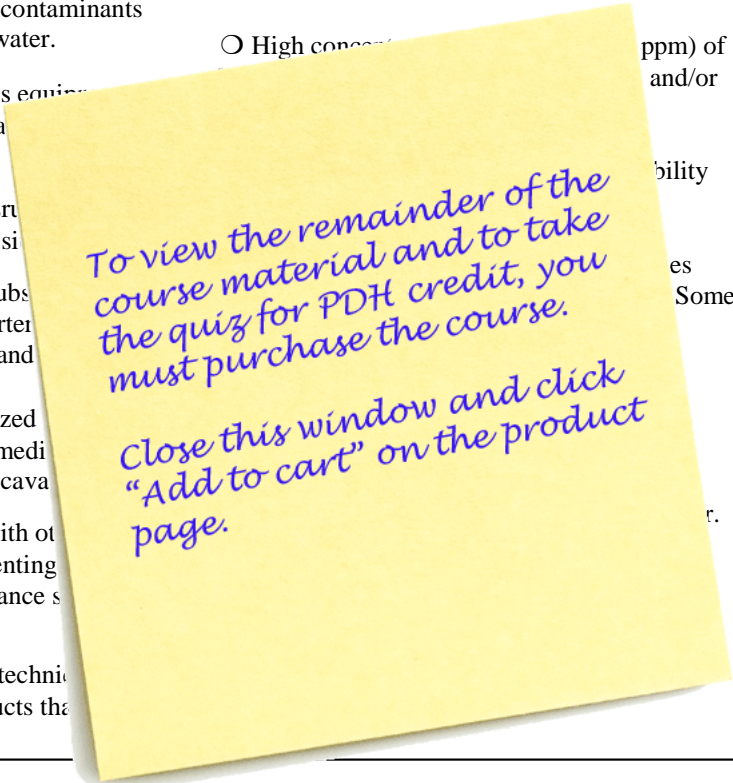
Exhibit 3
Advantages and Disadvantages of In-Situ Groundwater Bioremediation

Advantages

- Remediates contaminants that are adsorbed onto or trapped within the geologic materials of which the aquifer is composed along with contaminants dissolved in the groundwater.
- Application involves equipment that is widely available and easy to install.
- Creates minimal disturbance to on-going site activities.
- Time required for subsurface remediation may be shorter than other approaches (e.g., pump and treat).
- Is generally recognized as being less costly than other remediation techniques (e.g., pump and treat, excavation and treatment).
- Can be combined with other remediation technologies (e.g., bioventing, soil vapor extraction) to enhance subsurface remediation.
- In many cases, this technique does not produce waste products that need to be disposed of.

Disadvantages

- Injection wells and/or infiltration galleries may become plugged by microbial growth or mineral precipitation.
- High concentrations (e.g., ppm) of nutrients and/or oxygen may be required.



○ **Step 3: An evaluation of the in-situ groundwater bioremediation system design**, which will allow you to determine if the rationale for the design has been appropriately defined based on treatability study data, whether the necessary design components have been specified, and whether the construction process flow designs are consistent with standard practice.

○ **Step 4: An evaluation of the operation and monitoring plans**, which will allow you to determine whether plans for start-up and long-term system operation monitoring are of sufficient scope and frequency, and whether remedial progress monitoring plans are appropriate.