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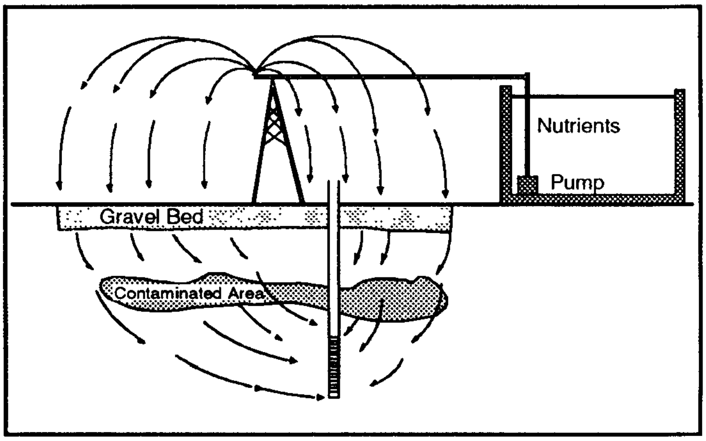

In Situ Bioremediation of Contaminated Vadose Zone Soil

Introduction

The Robert S. Kerr Environmental Research Laboratory (RSKERL) has developed a number of *Issue Papers* and *Briefing Documents* which are designed to exchange up-to-date information related to the remediation of contaminated soil and ground water at hazardous waste sites. In an attempt to make the content of these documents available to a wider audience, RSKERL is developing a series of *Summary Papers* which are condensed versions of the original documents.

In situ bioremediation of subsurface soils contaminated with organic chemicals is an alternative treatment technology that, in certain cases, can meet the goal of achieving a permanent cleanup at hazardous waste sites. Consideration of such alternatives is encouraged by the EPA for implementing its requirements at Superfund sites. In many cases, in situ bioremediation techniques can be used in conjunction with chemical and physical treatment processes (i.e., "treatment trains") as effective means for comprehensive site-specific remediation.

Bioremediation has been shown to be effective in reducing overall mass of a variety of organic contaminants. Full scale systems have been utilized to remediate soil contaminated with both crude and refined petroleum hydrocarbons (i.e., diesel fuel, gasoline, etc.) and wood treating chemicals (i.e., creosote and pentachlorophenol). To date, bioremediation has not been shown to effect significant removal of highly structured and insoluble organic compounds such as polychlorinated biphenyls and dioxins.

In Situ Systems

Effective in situ bioremediation often requires implementation of biodegradation enhancement methods. Appropriate methods of enhancing in situ bioremediation efforts for a particular site depends on the phase(s) in which contaminants occur, i.e., solid, aqueous, gaseous, or non-aqueous phase liquid (NAPL); heterogeneity of subsurface matrix; and types of recovery/delivery systems being utilized. Bioremediation enhancement at a specific site may be achieved by: increasing bioavailability of contaminants of concern; reducing toxicity to microorganisms; delivering adequate supplies of moisture, nutrients, and electron acceptors (i.e.,oxygen); and/or by introducing specific substrates that stimulate appropriate indigenous microbial degradative activity.

A variety of strategies may be implemented to maximize biodegradation activity in contaminated subsurface soils; however, success of the in situ bioremediation effort for any given site is often determined by effectiveness of the recovery/delivery systems employed to remove major sources of contaminants and to transport appropriate amendments (i.e., nutrients, electron acceptors,etc.) to the location of the remaining contaminants. Overcoming effectiveness limitations to biodegradation is the primary goal of a delivery system, and development of adequate delivery technologies continues to be the major challenge associated with effective implementation of in situ bioremediation for contaminated subsurface soils.

Superfund Technology Support Center for Ground Water
Robert S. Kerr Environmental Research Laboratory
Ada, Oklahoma

Technology Innovation Office
Office of Solid Waste and Emergency Response, US EPA, Washington, D.C.

Walter W. Kovalick, Jr., Ph.D.
Director

At the present time, systems utilized to deliver required amendments to the subsurface can be divided into two categories: 1) gravity/forced hydraulic delivery, and 2) extraction/injection air delivery methods. Both systems are impacted in effectiveness by the soil type. Gravity delivery methods include flooding, ponding, ditches, and sprinkler systems which deliver water and amendments to the contaminated subsurface by applying solutions to the soil directly over the contaminated area. Gravity systems also may be installed in the subsurface just above the contaminated soil zone. Subsurface-installed gravity methods include infiltration galleries (or trenches) and infiltration beds. Forced hydraulic delivery systems are used to deliver fluids under pressure into a contaminated area through well points. Air delivery systems are associated with bioventing, an in situ bioremediation technology which utilizes oxygen contained in the air phase to enhance biodegradation of subsurface organic contaminants. Air can be delivered either via extraction or injection methods. Extraction systems incorporate soil vacuum extraction techniques, where a low flow of fresh air is continually pulled through the contaminated zone. Injection systems deliver fresh air under pressure through well points to the contaminated subsurface zone, and the air is allowed to permeate out through the contaminated zone and back to the surface. An injection system can be installed with one or several companion extraction wells to achieve more extended horizontal flow. Soil bioventing has been demonstrated in several field applications for fuel hydrocarbon contaminants; however, the technology has not yet been demonstrated at field scale for other types of organic contaminants(i.e., polycyclic aromatic hydrocarbons, pesticides, etc.). The bioremediation of contaminants in soil is often greater than that in ground water because more oxygen is contained in air than can be dissolved in water. In comparison to bioventing, other problems encountered in saturated media are the hydraulic limitations to providing oxygen and nutrients to the zone of biological activity, and a tendency for anaerobic conditions to develop in saturated versus unsaturated materials.

This *Summary Paper* has been developed from the *Engineering Issue Paper* (EPA/540/S-93/501) titled "In situ Bioremediation of Contaminated Unsaturated Subsurface Soils" by Sims, et al. For further information concerning this document, contact: John Matthews (405) 436-8600.

For information on the availability of RSKERL publications, contact:

Publications
RSKERL
P.O. Box 1198
Ada, Ok 74820
(405) 436-8651

For information on the Technology Support Center itself, contact:

Mr. Don Draper
RSKERL
P.O. Box 1198
Ada, Ok 74820
(405) 436-8603

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Environmental Protection Agency
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