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EPA Ground Water Currents

Developments in innovative ground water treatment

UP-TO-DATE WAYS TO ASSESS WHEN BIOREMEDIATION WORKS

Robert S. Kerr Environmental Research Laboratory

When does in situ bioremediation work? And, how can you reliably predict success? An operational definition for judging success of in situ bioremediation at field scale is that it meet regulatory goals for ground water quality in a timely fashion and at a predictable cost. Further, in situ bioremediation is judged by its capacity to continue to meet regulatory goals for water quality after the active phase of remediation is complete. There are two factors to address in judging success. First bioremediation, particularly innovative bioremediation that uses an electron acceptor other than oxygen, can remove the compounds of regulatory concern from the subsurface while leaving significant amounts of oily-phase hydrocarbons. Second, the extent of weathering of residual oily-phase material and the hydrologic environment of the residual have a strong influence on the potential for ground water contamination after active remediation ceases. An important issue for determining short-term success and long-term protection is one of laboratory studies versus actual field conditions. The problem posed is that the current practice for characterizing sites does not adequately define the amount of contamination subject to bioremediation. As a result, laboratory studies which estimate the requirements at field scale for electron acceptors and mineral nutrients for bioremediation, and the time required for remediation, have much uncertainty when extrapolated to field scale. In contrast to laboratory studies, the extent of remediation achieved at field scale is influenced by dilution of compounds of regulatory concern in circulated water and partitioning between water and the residual oil.

Part of the problem with the transfer of laboratory research to the field is that there are different levels of inquiry in the laboratory and in the field. Laboratory studies deal with biochemical or physiological processes with appropriate controls to ensure that *only one mechanism* is responsible for the phenomena under study. However, during field-scale implementation of bioremediation technology, several processes operate concurrently. They may involve *several distinct mechanisms* for biological destruction of the contaminant, as well as partitioning of contaminants to immobile phases, dilution in ground water and volatilization. Therefore, if performance monitoring is limited to the concentrations of nutrients and electron acceptors, it cannot ensure that the biological process developed in the laboratory was responsible for contaminant removal at full-scale field conditions. Experimental controls are usually unavailable during full-scale implementation of in situ bioremediation because the technology is applied uniformly to the contaminated area. So, how do you know whether it was the biological process developed in the laboratory or something else that reduced contaminant concentrations? And, how do you know whether or not natural biodegradation will prevent the regeneration of a plume of contaminated ground water when active remediation ceases?

To overcome these problems, the appropriate equivalent of experimental controls is a detailed characterization of the site, the flow of remedial fluids and the flux of amendments. This characterization allows an assessment of the influence of partitioning, dilution or volatilization on remediation and provides a basis for evaluating the relative contribution of bioremediation.

Wells have traditionally been used to characterize sites. Ground water monitoring wells alone cannot estimate the total contaminant mass subject to remediation within an order of magnitude. Most plumes of organic contamination in ground water originate from spills of refined petroleum hydrocarbons, such as gasoline, or chlorinated solvents, such as trichloroethylene.

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This Month in Currents

THIS MONTH'S CURRENTS CONTAINS VENDOR AND BULLETIN BOARD INFORMATION.

GROUND WATER REMEDIATION CLUES

By Gary Turner, Technology Innovation Office, EPA

If you have not heard about, or lately have not been on the EPA's Clean-Up Information Bulletin Board System (CLU-IN), you may he missing out on some new information and new features. In the past year, CLU-IN has upgraded the software; and, we are still in the process of implementing new features and customizing prompts. As always, CLU-IN still has three main components — Bulletins, Files, Messages.

Bulletins. The bulletins are short text files that can be read online while you are connected to CLU-IN. CLU-IN has regularly updated bulletins containing TECH TRENDS and GROUND WATER CURRENTS articles, FEDERAL REGISTER updates and COMMERCE BUSINESS DAILY announcements. There are monthly regulatory reports from EPA's RCRA/CERCLA/OUST/EPCRA Hotline, as well as EPA Office of Solid Waste and Emergency Response training course schedules, announcements of workshops, meetings, publications and databases.

Files. The files available on CLU-IN can be in any format, including databases, publications, graphics files, utilities and spreadsheets. Although these files cannot be used online, they can be downloaded and used on the user's own computer. Among the files available for downloading on CLU-IN are the Hazardous Waste Superfund Database, the Risk Reduction Engineering Laboratory (RREL) Treatability Database, the Hyperventilate program from the Office of Underground Storage Tanks (OUST) and many publications from the Technology Innovation Office.

Messages. CLU-IN also has an electronic mail capability that allows users to exchange messages with individual users as well as to leave messages to all of the approximately 4,000 CLU-IN users to stimulate wider discussion. Many users use this feature to get advice from other users who have expertise with similar site conditions or contaminants.

In addition to these features that have always been part of CLU-IN, in the near future we will be implementing a major overhaul of the user interface to improve the user-friendliness of CLU-IN. We will be streamlining the Main Menu and creating sub-menus so that it will be easier to maneuver within CLU-IN. For instance, the bulletins will be sorted into a main bulletin menu and submenus to make it easier to find bulletins on a given topic. Users will still be able to search the text of bulletins for key words and display all bulletins that are new since the last time the user called into CLU-IN.

We will also be adding two new online databases to CLU-IN in the near future. One database will be a calendar of upcoming conferences, meetings and workshops on hazardous waste remediation that users will be able to search by conference date, location and topic. The other database will contain information on training courses offered by EPA. Users will be able to search it by topic to locate available training.

Changes will be taking place to CLU-IN content, interface and features throughout the fall. We will profile some of these changes in more detail in future articles. We encourage you to call into CLU-IN and try it out. Users do not need to pre-register — you can register and choose your own password on your first call.

The dial-in number for accessing CLU-IN is: 301-589-8366 (up to 9600 baud; communications settings are 8 data bits, 1 stop bit and no parity). EPA users can connect to CLU-IN using EPA's X.25 network without needing a modem. For more information about CLU-IN, call the CLU-IN Help Line at 301-589-8368.

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These substances enter the subsurface as nonaqueous-phase oily liquids, traveling separately from the ground water. Although wells have been used to define the extent of contamination in the subsurface environment through measurement of the contaminants in the ground water, they cannot reliably determine the extent of contamination by oily-phase materials. This monitoring deficit is particularly important because, as long as the oily-phase liquid is present in the subsurface, it can act as a continuing source of contamination. Recent research has documented that monitoring well data grossly underestimate the extent of contamination and that there is a need for site characterization techniques that can accurately estimate the total mass of contaminants subject to bioremediation.

The appropriate rigorous approach to characterize sites should include the collection and analysis of core samples to estimate total contaminant mass in the subsurface in order to predict the demand for nutrients and electron acceptor that must be met to complete the remediation. Then one can use the rate of supply of the limiting requirement to estimate the time required for the remediation. With core samples, it is recommended that they be subsampled and extracted in the field to preclude losses to volatilization and biodegradation during shipping to a laboratory. By using inexpensive headspace analyses in conjunction with field core

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GROUND WATER TECHNOLOGIES IN VISITT DATABASE

By Linda Fiedler, Technology Innovation Office, EPA

The U.S. Environmental Protection Agency has released VISITT 3.0, the latest update of its database on new cleanup technologies. VISITT (Vendor Information System for Innovative Treatment Technologies) lists current information on the availability, performance and cost of innovative technologies to remediate contaminated waste sites. VISITT now contains data on 277 innovative technologies, including 201 that are full-scale and commercially available.

This update includes 46 technologies which are designed to treat ground water in situ. They can be grouped into the following categories: air sparging (eight technologies); bioremediation (18 technologies); chemical treatment (three technologies); dual phase extraction (six technologies); and thermal enhancements (11 technologies). The three chemical treatment technologies include: surfactant solubilization; fixation of metals and radionuclides by pH and redox changes; and dechlorination of organics by redox changes. Thermal enhancements include radio frequency heating, electric resistive heating and steam injection. According to the technology vendors that submitted the information, 35 of the in situ ground water technologies are available for full-scale use and the remainder are in the bench or pilot scale.

To order VISITT 3.0 diskettes and the user manual and to become a registered user, provide your name, company, address, phone number and diskette size needed (3-1/2 inch or 5-1/4 inch) by mail to U.S. EPA/NCEPI, P.O. Box 42419, Cincinnati, OH 45242-2419 or by FAX to 513-489-8695.

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samples, results from a limited number of expensive core analyses can be extrapolated to a large number of field headspace analyses. Headspace analyses are inexpensive and generate data in real time, which also allows the screening information to be used to guide decisions about depth and location of subsequent cores.

When water is circulated through an oily-phase spill during bioremediation, the concentration of regulated compounds will drop because of simple dilution. Simple partitioning theory can be used to calculate the distribution of hydrocarbons of concern between the recirculating ground water and the residual oily-phase materials. Simple ground water models can estimate the volume of water circulated through a spill during the in situ bioremediation by predicting amended ground water flow paths from an infiltration gallery (sited above the spill) to recovery wells. This information can be coupled with simple partitioning theory to estimate the apparent attenuation due to dilution. Simple partitioning theory is also used to predict the concentrations of hydrocarbons that will remain in ground water that will be in contact with weathered oily-phase residual that frequently remains after bioremediation. The predictions give an indication as to whether the plume will be regenerated.

Seasonal variations and weathering can cause plumes to actually move away from monitoring wells, to possibly return at a later date. Additionally, pockets of fine textured oily-phase material may still contain high concentrations of contaminants because remedial fluids tend to pass around the fine-textured material. To supplement data from monitoring wells, many regulatory authorities require measurement of residual oily-phase material left after bioremediation. However, ground water quality is controlled by the ***relative concentration of organic contaminants* in the weathered oily-phase residual and not by the *absolute amount of weathered total petroleum hydrocarbons.* The relative concentrations of organic contaminants can** be used to predict the concentrations in ground water in contact with the oily-phase residual by using Raoult's law. The solution concentration in water should be proportional to the mole fraction of the hydrocarbon in the oily phase.

The issue now becomes whether any residual oily-phase hydrocarbon is capable of producing a plume of contamination at concentrations that exceed the cleanup goal. Mass transfer effects control the access of residual organic contaminants to moving ground water. When active remediation is stopped, the concentration of electron acceptor returns to ambient conditions in the aquifer, and the hydraulic gradient returns to the normal condition. As a result, the residence time of water in the spill area is longer than during active remediation; and, the total amount of hydrocarbon transferred to the water is greater, although the supply of electron acceptor for biological destruction of the hydrocarbon is less. Darcy's law can be used to estimate the interstitial flow velocity of the ground water and its residence time along the flow path. Under proper

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conditions, natural biodegradation supported by ambient concentrations of electron acceptors and mineral nutrients may destroy organic contaminants as fast as they escape from the oily-phase residual. However, currently no established procedures exist for determining under ambient conditions whether the mass transfer of hydrocarbons from oily residual material will exceed the supply of oxygen or other natural electron acceptors. At the present state of science, only long-term monitoring can determine if natural biodegradation will prevent the regeneration of a plume of contaminated ground water.

An assessment of natural hydrologic conditions at a site will be necessary to intelligently locate compliance monitoring wells and determine an appropriate schedule of monitoring. An understanding is required of the average natural hydraulic gradient and the hydraulic conductivity in the depth interval containing residual hydrocarbon in order to predict the velocity and trajectory of potential plumes of contaminated water. Frequency of monitoring can be adjusted to reflect the expected time required for ground water to travel through the area containing residual hydrocarbon to the point of compliance.

The summary of research findings discussed above draws heavily from, and is covered in more detail with research references, in a National Research Council report; the citation is: IN SITU BIOREMEDIATION; WHEN DOES IT WORK?, National Academy Press, Washington, D.C. 1993. This work was supported by the United States Air Force through Interagency Agreement RW 57935 114 between the Armstrong Laboratory Environics Directorate (U.S. Air Force) and the U.S. Environmental Protection Agency's (EPA) Robert S. Kerr Environmental Research Laboratory (RSKERL) and EPA's Bioremediation Field Initiative. It has not been subjected to EPA review and therefore does not necessarily reflect the views of the EPA, and no official endorsement should be inferred.

For more information, see the report referenced above and/or call John Wilson at RSKERL at 405-436-8632.

To order additional copies of *Ground Water Currents,* or to be included on the permanent mailing list, send a fax request to the National Center for Environmental Publications and information (NCEPI) at 513-489-8695.
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Managing Editor, Ground Water Currents (5102W), U.S. Environmental Protection Agency,
401 M Street S.W., Washington, DC 20460

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