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# Ground Water Currents

Developments in innovative ground water treatment

## TRACERS DETECT AQUIFER CONTAMINATION

By Carl Enfield, EPA's National Risk Management Research Laboratory, Ada, Oklahoma

The EPA's National Risk Management Laboratory (NRMRL) at Ada, Oklahoma, along with the University of Florida and the University of Texas, have developed a tracer procedure to detect the amount of contamination in aquifer formations. The tracer procedure has been successfully applied in a highly controlled field experiment in a contaminated cobbly, sandy gravel aquifer at Hill Air Force Base in Layton, Utah. The tracer procedure should substantially improve our ability to remediate aquifers and is an improvement over the traditional reliance upon water samples from monitoring wells and core samples. To date, the extent and distribution of ground water contaminants have been decided by chemical analysis performed on water samples from monitoring wells. The hydraulic gradient and direction of water flow is determined by carefully analyzing water depth data from the monitoring wells. Although monitoring well data effectively show the existence and the extent of the contamination, they provide little of the data needed to design remedial alternatives. Core samples have been used to

determine the amount of contamination in the sediment at the measurement point(s). However, due to heterogeneities, cores are not effective in deciding the total amount of contamination without taking many samples and doing many expensive chemical analyses.

This is where the development of the tracer fits in. Tracer principles build upon the work of the past two decades in which researchers have learned how organic chemicals move in aquifers. Chemicals, dissolved in water, move at speeds equal to, or less than, the speed of water. The speed of those chemicals that move slower than water is directly proportional to the amount of organic matter associated with the sediments. Most uncontaminated geologic sediments which are low in organic matter do not retard the movement of solubilized chemical contaminants like benzene or trichloroethene. However, when soils are contaminated with nonaqueous phase liquids (NAPLs), like gasoline or fuel oil, the amount of organic matter increases dramatically. NAPLs, like naturally occurring organic matter, retard the movement of chemicals and also serve as a

source of contamination.

The tracer procedure involves injecting non-retarded tracers (like bromide) that move with the water along with tracers retarded by the NAPL (but which are not a component of the NAPL) making it possible to compute the amount of NAPL in the formation. The computation is based on the ratio of the travel times of the retarded and non-retarded tracer. Travel time is determined by measuring the tracer's concentration as a function of time at the monitoring well. The travel time is the time required for the tracer's center of mass to move from the injection well to the monitoring well (the larger the travel time ratio, the more NAPL in the formation). The computed amount NAPL present is based on a water to NAPL partitioning for the selected tracer(s). Analysis of known tracer compounds in water is easy, compared to the measurement of all the different contaminants in soil core samples.

Knowing the NAPL distribution in the subsurface will reduce the amount of remedial fluid/energy needed to achieve remedial objectives by directing remedial activities only at contaminated locations. Current approaches treat an aquifer as a homogeneously contaminated region.

On the test site at Hill Air Force Base, interpretation of tracer data provided logical descriptions of the contaminant distribution which were reproducible. In contrast, the interpretation of the core data is extremely difficult because representative core samples cannot be obtained due to the size and amount of cobbles in the formation. The researchers hope to provide a proven, cost-effective method of characterizing the amount and distribution of NAPL in a contaminated site. Additional tests will be run over the next year to perfect the procedure.

*For more information, call Carl Enfield at EPA's NRMRL at 405-436-8530.*

### THIS MONTH IN CURRENTS

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## NATURAL ATTENUATION OF HEXAVALENT CHROMIUM

By Robert W. Puls, EPA National Risk Management Research Laboratory, Ada, Oklahoma

Recent research findings support that there is natural attenuation of hexavalent chromium in ground water and soil. Chromium is an important industrial metal used in diverse products and processes. At many locations chromium has been released to the environment via leakage, poor storage or improper disposal practices. Concerns about the impact of chromium on human health and the environment require an evaluation of the potential risk of chromium entering the ground water flow system and being transported beyond compliance boundaries. At such sites where such potential exists, active remedial measures such as excavation or pump-and-treat have been undertaken. Experience at sites where pump-and-treat remediation of chromium-contaminated ground water is currently under way suggests that, although

it is feasible to remove high levels of chromium from the subsurface, as concentrations decrease it becomes more difficult to remove the remaining chromium. While several new remedial technologies are being investigated, there is still concern about the cost of such remediation technology; and, at many sites, there is a debate about the need for expensive remediation.

Researchers have identified natural reductants that can transform the more toxic hexavalent form of chromium [Cr(VI)] to the less toxic trivalent form [Cr(III)]. Under alkaline to slightly acidic conditions, this Cr(III) precipitates as a fairly insoluble hydroxide, thereby immobilizing it within the soil. Such "natural attenuation" of hexavalent chromium is of great interest because it suggests that strict water quality standards do not have to be attained every-

where within and beneath the site. If natural attenuation does occur, pump-and-treat remediation could desist after the most contaminated ground water has been removed, even if the maximum contaminant level (MCL) has not been achieved.

Under certain circumstances, expensive remedial measures may not even be necessary. However, before the natural attenuation option is adopted, it should be demonstrated that natural attenuation is likely to occur under the  
*(continued on page 4)*

## VISITOR'S DAY

The United States Department of Energy's (DOE) Ames Laboratory, teaming up with EPA and state regulators and Westinghouse Savannah River Company, will host environmental experts from around the nation when they gather in Augusta, Georgia, August 29, 1995 to evaluate an innovative methodology for streamlining the characterization of contaminated waste sites. The new method, Expedited Site Characterization (ESC), will be used as part of the regulatory-

approved remedial investigation at the D-Area Oil Seepage Basin on the Savannah River Site. The ESC brings geophysical, geotechnical, hydrologic, analytical and computer software technologies together at the site for concurrent analysis. If you want more details and/or wish to register for the August 29 Visitors Day, call Beth Weiser, ESC Logistics Coordinator at 515-294-4731 or email to [weiser@ameslab.gov](mailto:weiser@ameslab.gov), or FAX to 515-294-6963.

## NEW FOR THE BOOKSHELF

### NEW WELLHEAD ANALYTIC MODEL

A new computer program has been developed to determine time-of-travel capture zones in relatively simple geohydrological settings. The Wellhead Analytic Element Model (*WhAEM*) contains an advanced algorithm for determining capture zones for any well at any time based on precise knowledge of the locations of all stagnation points and dividing streamlines. No models currently in use for wellhead protection contain such an algorithm. *WhAEM* differs from existing analytical models in that it can handle fairly

realistic boundary conditions such as streams, lakes and aquifer recharge due to precipitation.

It has features that make the inclusion of open or closed, head-specified boundaries possible (for example to model streams). The newly developed model will serve ground water professionals who wish to determine capture zones in relatively simple geohydrological settings. *WhAEM* consists of two executables: the preprocessor GAEP and the flow model CZAM.

The preprocessor GAEP is

designed to simplify the procedures for getting data into a ground water model; specifically it facilitates the interactive process of ground water flow modeling that precedes capture zone delineation. GAEP separates the time consuming (but routine) task of digitizing hydrography data from the creation of conceptual models and subsequent analytic element input data files. With GAEP, the modeler is free to concentrate on interpretation of modeling results rather than the details of data modification and entry into

CZAEM. The new algorithms developed for the accurate delineation of capture zone boundaries are implemented in the computer code CZAEM, which accurately defines capture zone boundaries. The *WhAEM* package is documented in various ways. The primary documentation is contained in a program manual, which includes installation instructions, program descriptions and a tutorial for the integrated use of GAEP and CZAEM. Reference manuals for both GAEP and CZAEM

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## METAL-ENHANCED ABIOTIC DEGRADATION OF VOCs

By Chien T. Chen, EPA's National Risk Management Research Laboratory Edison, N.J.

**E**nvirometal Technologies, Inc. (ETI) of Canada has developed the metal-enhanced abiotic degradation technology to treat halogenated volatile organic compounds (VOCs) in water. The ETI technology can be installed and operated above ground in a reactor or in situ as a "funnel and gate" system. The above ground reactor can be an alternative to the air stripper and activated carbon as methods of remediating halogenated organic compounds. The Superfund Innovative Technology Evaluation (SITE) Program evaluated an above ground reactor for remediation of ground water from the SGL Printed Circuits site in Wayne, New Jersey for three months during 1994 and 1995. The technology was designed to lower chlorinated VOC concentrations below regulatory limits after one pass through the reactive iron medium. A reactive, zero-valent, granular iron medium conducts reductive dehalogenation of the VOCs, yielding simple organic compounds and halogen salts as by-products.

The above ground reactor design may be used to simulate the treatment process at pilot scale, allowing for measurement, control, modification and optimization of design and operating parameters, or may be

operated as a stand-alone treatment unit. Contaminated ground water enters the reactor through an air eliminator, 5-micron water filter (to remove suspended solids that may inhibit water flow through the reactive iron medium), and a flow meter. Water flows by gravity through the reactive iron medium and into the collector line at the bottom of the reactor and then exits through the effluent line. The effluent line is plumbed so that about one foot of influent water remains ponded above the surface of the reactive iron medium. A passive gas vent in the top of the reactor prevents accumulation of excess pressure. A manhole with a sight glass allows observation of the reactive iron surface and access to the tank interior. Reactor materials include the reactive iron medium, pea gravel or well sand, a reactor tank for above ground installations and appropriate ancillary pumps and piping, where necessary.

For the SITE evaluation, about 60,833 gallons of ground water were treated during 13 weeks of the demonstration. The reactor maintained a flow rate of about 0.5 gallons per minute throughout most of the demonstration. The primary objectives of the SITE demonstration were to

(1) determine whether or not effluent met New Jersey Department of Environmental Protection (NJDEP) and federal maximum contaminant level (MCL) requirements for all chlorinated VOCs detected and (2) determine the removal efficiency of tetrachloroethene (PCE) and other chlorinated VOCs. Initial contaminant concentrations were: 4,100 to 16,000 micrograms per liter ( $\mu\text{g/L}$ ) PCE, 54 to 590  $\mu\text{g/L}$  trichloroethene (TCE), up to 1,200  $\mu\text{g/L}$  cis-1,2-dichloroethene (cDCE). Removal efficiency for both TCE and PCE exceeded

99.98%. Vinyl chloride and cDCE were not detected until week 6 of the demonstration; and, they occasionally exceeded NJDEP regulatory limits, which may be attributed to unexpectedly high levels of PCE in the influent.

The SITE Program examined only chlorinated solvents, primarily TCE and PCE. However, the developer claims that its system is applicable to all halogenated VOCs in water.

*For more information about the SITE Demonstration, call Chien Chen at EPA's National Risk Management Research Laboratory at 908-906-6985.*

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are provided in the *WhaEM* manual. A tutorial for stand-alone use of the program *CZAEM* is available as a separate document. Finally, both *GAEP* and *CZAEM* codes support on-line help.

The *WhaEM* was developed under a cooperative agreement between EPA and Indiana University and the University of Minnesota. A Project Summary is available by calling CERl at 513-569-7562 and requesting Document Number EPA/600/SR-94/210. For a copy of the reports (while EPA stock lasts)

and associated software please send a letter of request and one formatted 3.5 inch high density PC diskette (specify DOS or Windows) to: CSMoS, Robert S. Kerr Environmental Research Laboratory, P.O. Box 1198, Ada, OK 74821, Attn: *WhaEM*. The two volume report only (Order No. PB95-194189, cost: \$19.50 and Order No. PB95-167375, cost \$27.00) are also available from: National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (telephone number: 703-487-4650). The cost is subject to change.

## GROUND WATER SAMPLING WORKSHOP

A summary of the EPA sponsored Ground Water Sampling Workshop, held in Dallas, Texas, November 30-

December 2, 1993, is now available. The primary objective of the workshop *(continued on page 4)*

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specific conditions at the site being investigated.

If natural attenuation is to be considered a viable option, then — ideally — it must be demonstrated that: (1) there are natural reductants present within the aquifer; (2) the amount of Cr(VI) and other reactive constituents does not exceed the capacity of the aquifer to reduce them; (3) the time scale required to achieve the reduction of Cr(VI) to the target concentration is less than the time scale for the transport of the aqueous Cr(VI) from source area to the point of compliance; (4) the Cr(III) will remain immobile; and (5) there is no net oxidation of Cr(III) to Cr(VI). The most difficult types of information to obtain are the time scales for the reduction and oxidation of chromium in the soil.

Demonstrating Cr(VI) reduction in aquifer by mass balances that rely primarily on

the aqueous concentrations from monitoring well networks are valid only if it is demonstrated that Cr(VI) precipitates are not forming in the aquifer. The monitoring network must be sufficiently dense that estimates of Cr(VI) are accurate.

In the research findings, several soil tests are described that are useful in determining the mass of Cr(VI) and Cr(III) in the source areas and the reduction and oxidation capacities of the aquifer materials. Some simple conceptual models are presented whereby this information, combined with knowledge of the residence time of the chromium between the source and the point of compliance, can be used to determine the feasibility of natural attenuation of Cr(VI). The major limitation to this approach is the lack of information about the rate of oxidation and reduction of chromium under conditions likely to be encountered by plumes emanat-

ing from chromium sources. Without better information about these rate processes under a wider range of conditions with respect to pH, the use of the natural attenuation option for contaminated soils will continue to be a highly debated issue.

The findings are presented in **GROUND WATER ISSUE; NATURAL ATTENUATION OF HEXAVALENT CHROMIUM IN GROUND WATER AND SOILS** (Document No. EPA/540/S-94/505). The document can be ordered from the EPA Center for Environmental Research Information (CERI) by calling 513-569-7562.

*For any additional information, call Bob Puls at EPA's National Risk Management Research Laboratory at 405-436-8543.*

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was to provide a forum for the presentation and discussion of recent research findings on ground water sampling in the context of continuing advances

in environmental monitoring technologies and changing environmental regulatory requirements. Secondary objectives of the workshop were to improve communication and the transfer of information between diverse groups, to encourage consistency in ground water sampling programs where appropriate and to identify research and technology transfer needs. Participants included researchers, practitioners, regulators and policy makers from governmental and non-governmental sectors, including universities, private industry and environmental consultants.

A copy of the workshop summary, "Ground Water Sampling — A Workshop Summary," which includes papers presented, can be ordered by calling CERI at 513-569-7562. Please refer to Document Number EPA/600/R-94/205 when ordering.

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*Ground Water Currents* welcomes readers' comments and contributions. Address correspondence to: *Ground Water Currents*, NCEPI, P.O. Box 42419, Cincinnati, OH 45242-2419.

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