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EPA Ground Water Currents

Developments in innovative ground water treatment.

# Funnel and Gate System Directs Plumes to *In Situ* Treatment

By Robert C.Starr and John C.Cherry, Waterloo Centre for Groundwater Research

The Waterloo Centre for Groundwater Research has developed Funnel-and-Gate systems that isolate contaminant plumes in ground water and funnel the plumes through *in situ* bioreactors. The Funnel-and-Gate consists of low hydraulic conductivity cutoff walls with gaps that contain *in situ* reactors (such as reactive porous media), which remove contaminants by abiotic or biological processes. The cutoff walls (the funnel) modify flow patterns so that ground water flows primarily through high conductivity gaps (the gates). Ground water plumes are thus directed through the *in situ* reactors in the gates where physical, chemical or biological processes remove contaminants from ground water. Remediated ground water exits the downgradient side of the reactor. Funnel-and-Gate systems can be installed at the front of plumes, to prevent further plume growth, or immediately downgradient of contaminant source zones to prevent contaminant3 from developing into plumes.

This approach is largely passive in that after installation, *in situ* reactors are intended to function with little or no maintenance for long periods. This contrasts with the energy and maintenance-intensive character of pump-and-treat systems. Additionally, the Funnel-and-Gate system can overcome limitations of the pump-and-treat method, which is usually not effective for restoring aquifers, particularly if lighter than water nonaqueous-phase liquids (LNAPLs) and dense nonaqueous-phase liquids (DNAPLs) are present.

Funnel-and-Gate systems can be built in several configurations. They include straight walls with one or more gates, V-shaped funnels with the gate at the point and wide U-shaped funnels with one or more gates along the bottom of the U. The sides of the U extend upstream and can partially surround a contaminant source. A contaminant source zone can be completely surrounded by cutoff walls, except for a gate in the wall on the downstream side. With this configuration, the cutoff wall on the upstream side deflects clean ground water around the contaminant source. Any water that infiltrates into the enclosure or flows through the cutoff walls then flows through the gate and out of the enclosure. This configuration minimizes the amount of water that flows through the contaminant source zone and hence the amount of contaminated ground water that must be treated. This configuration also maximizes the residence time of ground water in the gate, which leads to a more complete treatment.

A variety of plume configurations and contaminants can be treated. An arrangement of multiple gates in parallel can be used to intercept an exceptionally wide plume. Or, a complex plume containing a number of different contaminants can be treated by passing through a series of gates aligned in sequence, each containing a different reactive porous medium. For example, a plume at an electroplating facility that contains both chlorinated hydrocarbons and metals can be treated using one reactor to degrade the organics and a second to precipitate the metals. Multiple parallel treatment gates and gates in series can also be combined.

Funnel-and-Gate systems can be constructed through the entire thickness of an aquifer if ground water plumes extend from top to bottom of the aquifer as mightbe the case for DNAPL contamination. If a ground water plume occupies only the uppermost portion of an aquifer (e.g., if the contaminant source is a LNAPL or a volatile liquid in the vadose zone), then an installation that extends only through the upper portion of the aquifer will be sufficient.

The Waterloo modelling analysis is intended to advance the general understanding of funnel-and-gate systems. It provides insight into factors that influence plume containment using these systems and the residence time of contaminants in the gate. Therefore, the system can be located so that all of the water that flows through a contaminant source zone subsequently flows

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## This Month in Currents

***This month s Currents features news and events from our friends North of the Border.***

# Innovative Remediation of Chromium

## By Robert W. Puls, Robert S. Kerr Environmental Research Laboratory

Researchers at EPA's Robert S. Kerr Environmental Research Laboratory (RSKERL). in cooperation with researchers at the University of Oklahoma, are pursuing several different innovative technologies for the remediation of chromium-contaminated ground water and soil. Remediation techniques being evaluated at both the laboratory and field scale include the following: (1) *in situ* application of a geochemical barrier to chromium transport in ground water using elemental iron mixed with site aquifer materials; (2) *in situ* immobilization of chromium in ground water through stimulation of indigenous microbial populations to promote biotic reduction of chromate [Cr(VI)]; (3) mobiiization of Cr(VI) from highly contaminated source area soils where a solubility-controlling equilibrium limits the effectiveness of chromate removal via traditional pump-and-treat technology: (4) use of above-ground polyelectrolyte ultrafiltration technology to remove Cr(VI) from contaminated ground water pumped to the surface; and (5) assessment of the natural attenuation capacity of the system for chromium immobilization through adsorption and reduction processes.

The field site used for pilot field-scale studies and the source of soils and aquifer sediments for laboratory-based work is located at the U.S. Coast Guard (USCG) Support Center near Elizabeth City, North Carolina. The USCG is also cooperating in the research.

The first two technologies are *in situ* immobilization techniques which take advantage of the fact that chromium exists in either the +3 (reduced) or +6 (oxidized) oxidation states in natural systems. In the oxidized form, as chromate or bichromate, chromium is toxic and mobile, whereas in the reduced form as chromium+3, it is non-toxic (actually a micronutrient) and immobile. The latter species is extremely insoluble and adsorbs to mineral surfaces almost irreversibly. In most subsurface environments, the trivalent reduced species forms an insoluble mixed chromium-iron hydroxide solid phase. The incorporation of elemental iron into aquifer sediment mixtures creates highly reducing conditions which reduce the chromium to the +3 state and result in the formation of the insoluble hydroxide. Laboratory batch and column studies using site materials have demonstrated this to be a very efficient and promising technology. Microbial stimulation in laboratory batch and column studies have likewise demonmated reduction of chromium to the insoluble non-toxic formusing benzoate as an electron donor/carbon source. The benzoate microcosms have effectively reduced Cr(VI) levels from 6 parts per million (ppm) to less than detection (0.1 ppm). Column experiments have likewise shown similar results.

The third technology has also been laboratory-based to this point. Soil washing studies using various anionic surfactants have shown promise in desorbing and dissolving sediment-bound and precipitated forms of chromate in source area soils. It is expected that soil washing of source area soils will enhance the efficiency of pump-and-treat of chromium-contaminated ground waters in the source area, which otherwise may be in equilibrium with these chromate-laden solid phases at aqueous concentrations exceeding ground water cleanup standards.

The fourth technology was recently successfully field-tested. A polyelectrolyte ultrafiltration (PEUF) pilot plant was constructed for the selective removal of chromate (toxic hexavalent chromium) from ground water at the USCG site. The system was installed during March, 1993. Ground water from three wells having the highest chromium concentrations (3-5 mg/L) was pumped directly and continuously through the PEUF system. PEUF effluent chromate concentrations, monitored on-site using ion chromatogra phy, were less than 0.07 mg/L. The PEUF system produces significantly less waste mass for ultimate disposal compared to other conventional treatment systems; and, processed ground water may be reinjected into the aquifer.

The final approach involves an Investigation of the precipitation-dissolution, adsorption-desorption and oxidation-reduction processes which govern chromium transport and transformation in subsurface systems. In a sense this research comprises the baseline data against which the other treatments are compared and evaluated. In many natural systems, these chemical interfacial processes can naturally attenuate inputs of hexavalent chromium to the subsurface. In particular, reduction of the toxic hexavalent form to the reduced trivalent form often occurs to significant extent due to the presence of organic material and iron-bearing minerals in soil and aquifer sediments.

Future research will hopefully include full-scale field evaluation of approaches I-3. Plans are underway to scale up the above-ground PEUF system and use it to reduce chromium concentrations in the most contaminated portions of the aquifer at the USCG site

For more information, call Bob Puls at RSKERL at 405-436-8543.

**New Publication**

**EPA has published *Laboratory Study on the Use of Hot Water to Recover Light Oily Wastes from Sands* (Document No. EPA/600/R-93/021), which can be ordered from CERI at 513-569-7562.**

# Waterloo Barrier-Containment Wall for *In Situ* Treatment

**By John Cherry and Robert C. Starr, Waterloo Centre for Groundwater Research**

A new type of containment wall composed of sealable steel sheet piling has been developed at the University of Waterloo's Institute for Groundwater Research. The Waterloo Barrier serves the same general functions as other types of containment wails. However, it has a number of unique advantages over conventional sheet piling for containing polluted ground water. The materials and construction techniques make the Waterloo Barrier less prone to leaking than other types of containment walls, thus providing a greater degree of confidence in its performance.

The joints of conventional sheet piling are designed for mechanical strength but not watertightness. Leakage of water through the unsealed joints is acceptable for most civil engineering applications, but generally not for environmental applications. With the Waterloo- Barrier, the interlocking joints between individual sheet piles incorporate a cavity that is filled with sealant after driving to prevent leakage through the joints. The sealable cavities can be formed in two ways. An internal cavity can be formed as the sheet pile itself is manufactured. Or, an external cavity can be produced adjacent to each joint by attaching a steel 'L' section to conventional sheet piling. At sites where a very high degree of watertightness is desired, the Waterloo Barrier can be constructed with both an internal and external cavity at each joint. Cavities at the joints provide access for inspection after the sheets have been driven to confirm that the sheet piles were not damaged during construction.

With the Waterloo Barrier, excavation of subsurface materials is not required, thus there is less damage to the site and disruption of normal site activities. Also, since workers are not exposed to contaminated soil, health and safety precautions can be reduced. Disposal of large volumes of contaminated soil is avoided. Installation is relatively clean and rapid; and, comers and irregular wall geometries can be easily constructed. Topography and depth to water table have little effect on installanon techniques; and, the Barrier can even be installed through surface water bodies.

The Waterloo Barrier offers a number of design options not available with other types of containment walls. Various options, such as single or double sealable joints, and single or double walls, can be combined on a single project where parts of the wall have one design and other parts have another design. The Barrier can be used for containment purposes only or used in combination with various *in situ* remediation techniques, such as Funnel-and-Gate systems. The volume of sealant required is relatively small, so it is feasible to use special sealants that are particularly resistant to chemical degradation, but are too expensive to use in large quantities. The integrity of the barrier can be confirmed by inspection during construction. Potential leak paths

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# NEW FOR THE BOOKSHELF

## DNAPL Site Evaluation

The EPA's Robert S. Kerr Environmental Research Laboratory has published a manual that is designed to guide investigators involved in the planning and implementation of characterization studies at sites suspected of having subsurface contamination by dense nonaqueous-phase liquids (DNAPLs). DNAPLs, especially chlorinated solvents, are among the most prevalent subsurface contaminants identified in ground water supplies and at waste disposal sites. There are several site characterization issues specific to DNAPL sites including (a) the risk of inducing DNAPL migration by drilling, pumping or other field activities; (b) the use of special sampling and measurement methods to assess DNAPL presence and migration potential; and (c) development of a cost-effective characterization strategy that accounts for DNAPL chemical transport processes, the risk of inducing DNAPL movement during field work and the data required to select and implement a realistic remedy. This manual provides informanon to address these issues and describes and evaluates activities chat can be used to determine the presence, fate and transport of subsurface DNAPL contamination. The manual discusses the scope of the DNAPL problem, the properties of DNAPLs and subsurface media affecting DNAPL transport and fate, objectives and strategies for DNAPL site characterization, invasive and non-invasive methods of site characterization and laboratory methods for characterizing fluid and media properties. The manual concludes with several case histories illustrating problems specific to DNAPL sites and priority research needs for improving DNAPL site characterization.

The manual entitled *DNAPL Site Evaluation* (Order No. PB93-150217) will be available only from: National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22 16 1 (telephone: 703-487-4650); the cost, subject to change, is $44.50. A free project summary (Document No. EPA/600/ SR-93/002) can be ordered from EPA's Center for Environmental Research Informanon, Cincinnati, OH 45268 (telephone: 513-569-7502).

## Funnel and Gate
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through the gate. The residence time that is critical to the selection and design of reaction media for the gates can be better calculated; and, the least amount of cutoff wall and number of gates can be chosen in order to minimize cost.

The modelling analysis does not depend on the type of *in situ* reactor. Also, the type of cutoff wall used is not critical as long as the gate area does not become plugged with low hydraulic conductivity material during wall construction. The Waterloo Barrier, a sealable joint sheet piling, developed at the Waterloo Centre for Groundwater Research, is particularly well suited to Funnel-and-Gate construction because it can be easily connected to screens that house *in situ* reactors; and, the area around the cutoff wall does not become plugged with low conductivity material. (The Waterloo Barrier is discussed in more detail in this issue of *Ground Water Currents,* p. 2.)

*In situ* treatment reactors and Funnel-and-Gate systems are concepts developed very recently; and, research on *in situ* reaction media is in its infancy. Rapid advances on *in situ* reactors are expected in the next few years. See the previous issue of *Ground Water Currents,* Document No. EPA/542/N-93/003, pp. 1-2, for a discussion of one such development—the permeable reaction wall. Examples of other *in situ* reactor research in progress include: a biotic treatment medium in a removable basket or cassette; an oxygenating medium in a gate for treating hydrocarbons; and processes for the treatment of nitrate, phosphate and chromium.

For more information on the Funnel-and-Gate concept and modelling analyses and the reactor research, contact Dr. John Cherry at 5 19-888-45 16 or Dr. Robert C. Starr at 519-M-1211, ext. 6750, at the Waterloo Centre for Groundwater Research.

## Waterloo Barrier
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through the Barrier are limited to the sealed joints; so, the joints are the focus of quality control procedures. Rigorous, post-construction hydraulic testing is possible with double-walled configurations or small enclosures. The use of a removable sealant, such as a bentonitic grout, allows the sheet piles to be removed from the ground and used elsewhere once a site has been successfully remediated. The ability to remove the sheet piles makes it easy to: (1) isolate portions of a site for pilot scale tests; (2) progressively remediate a site in sections; or (3) temporarily install the piling for construction purposes. The design specifications of each Waterloo Barrier containment system must be customized to meet the site requirements. The design is dependent on: surficial geology; nature and depth of contamination and plume morphology; and flow rate.

The Waterloo Barrier offers considerable versatility. It can be installed to completely enclose a site to prevent off-site migration of contaminants until a remedial plan can be implemented, or, to isolate a site while remedial actions are in progress. In some situations an open ended Barrier can be effectively used in conjunction with extraction wells to provide hydraulic containment. The Barrier can be used to direct or funnel a contaminant plume into a subsurface treatment gate. At new industrial sites the Waterloo Barrier can be installed to enclose the site as a preventive or security measure to control chemical releases that could occur in the future. Enclosures around new landfills can be coupled with caps or infiltration systems to manage the race of waste degradation and leachate production.

For more information, call John Cherry (519-888-4516) or Robert C. Starr (519-885-1211, ext. 6750) at the Waterloo Centre for Groundwater Research.

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