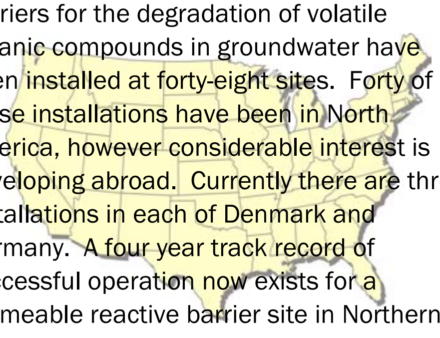
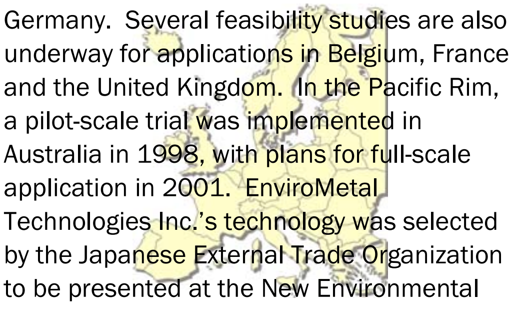
Permeable Reactive Barrier Update

solutions for groundwater remediation

May 2000

Around The Globe





To date, granular iron permeable reactive barriers for the degradation of volatile organic compounds in groundwater have been installed at forty-eight sites. Forty of these installations have been in North America, however considerable interest is developing abroad. Currently there are three installations in each of Denmark and Germany. A four year track record of successful operation now exists for a permeable reactive barrier site in Northern Ireland. Plans are also developing for installation of a pilot test in Sweden in spring 2000, in addition to two full-scale systems in Germany. Several feasibility studies are also underway for applications in Belgium, France and the United Kingdom. In the Pacific Rim, a pilot-scale trial was implemented in Australia in 1998, with plans for full-scale application in 2001. EnviroMetal Technologies Inc.'s technology was selected by the Japanese External Trade Organization to be presented at the New Environmental Exposition 2000 in Tokyo.

Inside this Issue:

R&D Update

EnviroMetal Technologies Inc. (ETI) provides partial support for the Natural Science and Engineering Research Council (NSERC) Industrial Research Chair held by Dr. R.W. Gillham at the University of Waterloo, Waterloo, Ontario, Canada. Major industrial support is provided by Motorola Inc., and NSERC provides matching funds for both the Motorola and ETI contributions. In addition to Dr. Gillham, the Chair supports one Research Assistant Professor (Dr. Rick Devlin), four Research Associates, and twelve graduate students.

The mission of the Chair is to undertake both basic and applied research for the purpose of advancing our understanding of the reaction geochemistry and enhancing the applicability of the technology. Particular projects include studies of the applicability of the technology to a wider range of compounds, presently involving nitrosodimethylamine (NDMA) and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX). These tests generally include measures of degradation rates, kinetic characteristics and degradation products. Several additional tests are in progress to evaluate losses of activity and permeability, of granular iron material, which could obviously affect the long-term performance of installed systems. One experiment of particular relevance was undertaken to examine influence of carbonate precipitation formation on permeability. These results are encouraging in that under the conditions of the test, formation of carbonate precipitates had a relatively minor influence on permeability. A second experiment is nearing completion in which the rate and cause of passivation of a nickel-iron bimetal catalyst was examined. On the same general topic, yet another study is examining both the rate of reduction of nitrate in the presence of iron and the effect of nitrate on the rate of passivation of iron surfaces.

Considerable resources have been directed towards the development of bimetal catalyst materials. While the exceedingly rapid degradation rates that these material offer are very encouraging, they have been plagued by inconsistency, uncertain rates of passivation, concerns regarding the release of toxic metals, and a poor understanding of the reaction mechanisms. A comprehensive set of laboratory tests was recently initiated in an attempt to resolve some of these issues. The final study that will be mentioned here concerns the use of granular iron for degradation/removal of pure phase solvents. Both laboratory and field tests have given very

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encouraging results, suggesting that the iron technology may be applicable for in-situ source zone treatment.

ETI is also supporting research at the University of Sheffield on the use of granular iron in fracture dominated aquifers, and at the University of Central Florida on ultrasonic regeneration of permeable treatment walls.

Placing Granular Iron Through Biopolymer Slurry

Several construction methods are available for installing permeable reactive barriers (PRBs) in the subsurface. Method selection depends on several factors including PRB design, depth of installation, geological conditions, health and safety considerations and construction cost. One of the more recent PRB construction methods that has been used in full-scale construction is biopolymer (BP) slurry trenching. BP slurry trenching has been used for many years for constructing collection trenches and drains where the need for excavating controlled, narrow trenches without dewatering is required. Recently, EnviroMetal Technologies Inc. (ETI) and others have undertaken research and development to examine the interactions between granular iron and BP in anticipation of using this construction method for PRB installation.

"BP slurry trenching extends our ability to install PRBs to greater depths, at reasonable cost"

Installation of a treatment zone of granular iron using BP is similar to constructing a conventional impermeable slurry wall. The polymer used in a BP installation is typically guar gum. As the trench is excavated, the BP provides stability to the trench walls. Granular iron can then be placed into the trench through the slurry. After the trench is complete, an enzyme is circulated through the treatment zone to break down the BP, causing the fluid to become less viscous and thus allowing groundwater to flow through the iron treatment zone.

Ideally, the BP selected should not result in long-term reductions in permeability or PRB reactivity. Laboratory testing of iron and BP has indicated that short-term VOC degradation rates are slower, however the effect of BP has diminished with time in some tests. These tests, however, have been conducted in the relatively sterile conditions of the laboratory rather than the complex environment of an in-situ field environment.

One pilot-scale (see photograph) and two full-scale PRBs were constructed in 1999 using the BP method. The use of BP allowed for the installation of these PRBs to depths of 30 to 40 ft (9 to 12 m). Monitoring and testing of samples from the pilot-scale installation has shown that after a few weeks, VOC degradation rates at this site were similar to those expected if BP was not used. The data gained from these sites is encouraging and several more PRB installations are planned for the current year using BP. These installations include a California site where BP is being considered for installation of a granular iron treatment zone to a depth of about 120 ft (37 m) below ground surface. BP slurry trenching extends our ability to install PRBs to greater depths, at reasonable cost while maintaining a high degree of construction quality assurance.

Pilot-Scale PRB Installation using Biopolymer Slurry Trench, Somersworth, New Hampshire

The Cost of PRBs—Consider the Long Term

An important step in evaluating permeable reactive barriers (PRBs) for application at a particular site is the long-term or life cycle cost of the technology. Several cost comparisons of PRBs with pump and treat (P&T) systems have been reported in the literature. For five such comparisons, estimated cost savings over a 30-year period ranged from $3 million to $8.3 million[a,b,c] United States (US) dollars. A primary reason for selecting PRB technology is the passive nature of the system. Thus there are no costs for maintenance and replacement of mechanical equipment and no salary costs for operators. Furthermore, PRBs operate continuously, while P&T systems invariably have downtime as a consequence of mechanical failures and maintenance.

Rejuvenation or possible replacement of the granular iron is the only operation and maintenance (O&M) activity that may have to be undertaken on PRBs. This O&M may be required due to the formation of carbonate and/or hydroxide precipitates within the PRB. The evidence to date suggests that precipitates may not have a significantly adverse effect on the hydraulic conductivity of PRBs. Nevertheless, it is well established that precipitates form and thus the long-term consequences cannot be ignored. Based on field experience, laboratory tests and theoretical calculations, depending on the inorganic chemistry and groundwater flow velocity, it is estimated that PRBs should require no maintenance for periods of up to 10 to 20 years.

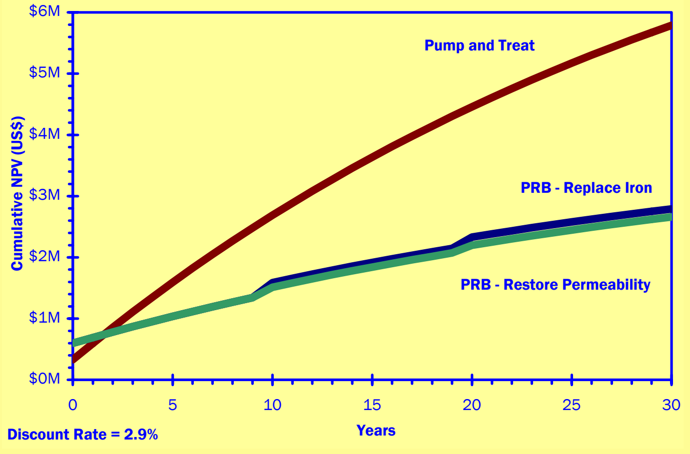
Potential methods for restoring the permeability include techniques such as hydraulic or mechanical agitation. A conservative approach for costing purposes would be to assume that at some time the iron will have to be removed and replaced. Though other methods may be more cost effective, they have not been demonstrated or proven and thus replacement provides the most reliable and conservative assumption.

A common method for comparing costs of remediation alternatives is to complete a net present value (NPV) analysis for the life cycle of the systems. Cost-effectiveness analysis does not consider the dollar value of the benefits, only the costs. In comparing PRBs to P&T, it is assumed that the primary benefit of both systems, i.e. protection/remediation of a groundwater resource is comparable. In addition to no “downtime”, other benefits of PRBs which are not captured in an NPV analysis, include 1) VOCs are transformed into non-toxic end products, 2) energy resources are not consumed in the process, 3) no waste product is produced, and 4) no aboveground structures are required.

The life cycle for remediation could be in the range of several decades to hundreds of years. NPV analyses are commonly completed for the projected remediation time or for 30 years, whichever is less. In NPV analyses, future costs are discounted to reflect the time value of money. The real discount rate (i.e. not adjusted for inflation) for U.S. Government projects for 1999 for a 30-year life cycle is 2.9 percent per year. The real discount rate for corporations will vary from corporation to corporation. The NPV is calculated by summing the capital investment with the present value of the O&M costs. O&M costs typically include the groundwater monitoring activities as well as the cost of rejuvenation or replacement of the iron every 7 to 10 years.

Figure 1 shows a NPV analysis based on actual P&T and PRB cost data from a site[b]. The cumulative NPV for the P&T system and for the PRB, with costs to rejuvenate the granular iron every 10 years and also to replace the iron every 10 years, are plotted on the Y-axis. In this example, the capital cost of the P&T system was less than the PRB but the NPV costs were equal after 2 years. For a 30-year project life, and assuming rejuvenation of the PRB every 10 years, the NPV of the PRB is $3 million less than the NPV of the P&T system.

Figure 1: Former Manufacturing Site, CA[b]



References:

a) Krug, T.A, Vogan, J.L. and Major, D.A., 1996. Cost-Effective In-Situ Remediation of Chlorinated VOCs Using Permeable Iron Reactive Walls. Presented at Hazmat Conference, Atlantic City, New Jersey.

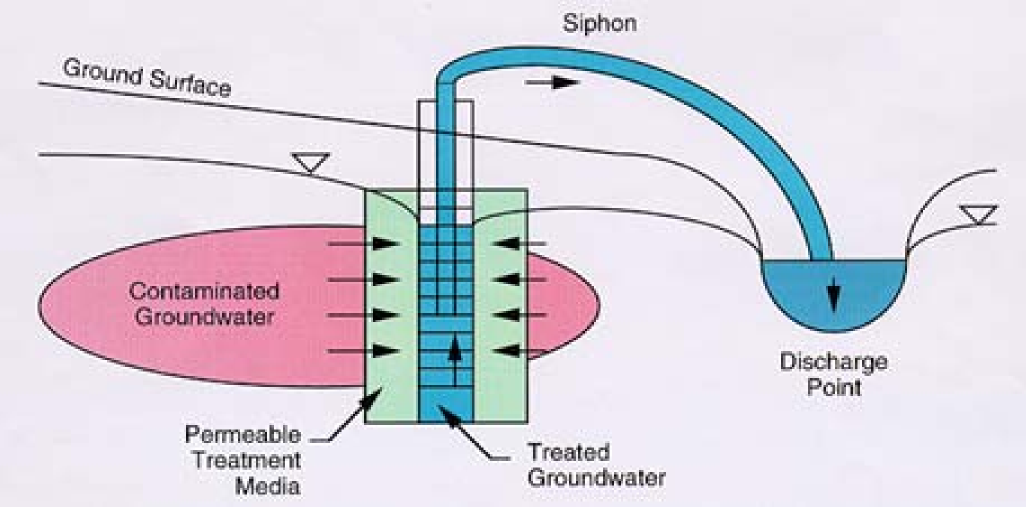
b) US EPA, 1999a. Groundwater Cleanup: Overview of Operating Experience at 28 Sites, EPA/542/R/99/006

c) ESTCP Cost and Performance Report, July 1999. *Permeable Reactive Wall Remediation of Chlorinated Hydrocarbons in Groundwater*, Environmental Security Technology Certification Program, U.S. Department of Defense.

New and Innovative Configuration

EnviroMetal Technologies Inc. (ETI) is excited to be a licensee of the GeoSiphon™ technology developed and patented by Westinghouse Savannah River Company. The GeoSiphon™ provides an alternative to a continuous wall or funnel and gate configuration. The GeoSiphon™ induces the passive flow of contaminated groundwater through an in-situ treatment cell containing granular iron (or other materials) by use of a siphon from the cell to a discharge point. Once the siphon is established, passive flow is maintained by the natural hydraulic head difference between the GeoSiphon™ and a downgradient stream or recharge well. This configuration was first installed as a pilot demonstration at a Department of Energy site in Aiken, South Carolina in July 1997 and ETI has identified several potential applications for this technology over the past 12 months.

GeoSiphon™ Cell



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