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Permeable Reactive Barrier: Technology Update (PRB-5)

EXECUTIVE SUMMARY

The Permeable Reactive Barrier (PRB): Technology Update Team of the Interstate Technology & Regulatory Council (ITRC) produced this document to provide an update on information pertinent to the design and use of PRBs for treating contaminants in groundwater. *Permeable Reactive Barrier: Technology Update* is the fifth document published by ITRC, since 1999, to investigate the development of PRBs as an emerging remediation technology. It is a comprehensive resource that incorporates elements from previous documents and provides updates on additional types of reactive media, contaminants that can be treated, PRB longevity issues, and new construction/installation approaches and technologies.

The definition of the PRB as an in situ permeable treatment zone designed to intercept and remediate a contaminant plume is now standard in the remediation industry and is not changed in this document. PRBs have become an important component among the various technologies available to remediate groundwater contamination. Since the first implementation in the early 1990s, more than 200 PRB systems have been installed.

Since inception, the PRB has remained an evolving technology with new and innovative reactive materials introduced to treat different contaminants as well as innovative construction methods. "New" reactive materials include mulch for treating chlorinated solvents, metals, and energetic and munitions compounds, zeolites for treating radionuclides and heavy metals, and "transformed redmud" (a waste material formed from bauxite ore during the production of alumina that has been used to treat acid-rock drainage), but other materials such as carbon/zero-valent iron (ZVI) combinations also are being tested and used. Installation innovations include the use of single-pass trenchers, large-diameter boring installations, and injection methods.

The PRB system is typically intended to perform using hydraulically passive means; that is, the PRB is designed to allow groundwater and the target chemicals to flow through the PRB without mechanical assistance. After construction, PRB technology fits the concept of green and sustainable technology. In keeping with the green concept, effects from construction of a PRB also can be minimized. Reactive materials frequently are waste products (e.g., mulch, some iron ore slags) or are recycled (e.g., iron scrap). The actual installation of a PRB is the largest energy expenditure, but even this can be minimized if the work is completed in one mobilization and local equipment and contractors are used.

New developments have shown that ZVI also is effective in treating other contaminants, including dissolved metals and energetic compounds, such as hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), and 2,4,6-trinitrotoluene (TNT). Biowalls using solid organic materials (mulch) also have been applied to treat energetic

and munitions compounds as well as for treating nitrate-impacted groundwater. PRBs have evolved with respect to arsenic treatment, and new media, including carbon-rich organic/iron combinations, emulsified ZVI, and organophilic clays, have been applied as reactive treatment media.

We have learned that inadequate performance of a PRB typically stems from incomplete site characterization and inadequate hydraulic design. The nature and extent of the contaminant plume(s) must be well characterized to design an effective PRB and should consider the nature and anticipated persistence of the contaminant source. The vertical extent of contamination is particularly important. The contaminant discharge (mass flux) through the PRB should be sufficiently characterized so that the upgradient concentrations can be accommodated by the PRB design. It is also imperative to understand the contaminant plume shape and variability in the direction of groundwater flow over time.

ZVI PRBs have been installed and performing in place for 15 years in a variety of geochemical environments. Data gathered have shown that the major effect of inorganic constituents on the technology involves the formation of mineral precipitates on the iron surface; this can passivate reactive sites and clog the PRB. Calcium carbonate, iron carbonate, iron hydroxide, and iron sulfide precipitates may form in the media as the pH of the groundwater increases in response to corrosion of the iron metal. Geochemical changes to ZVI from the presence of sulfate, nitrate, and oxygen also are widely observed, and more research into prevention of performance loss is an ongoing area of research.

This document provides the basics for understanding what a PRB is and what it can—and can't—do, but it also provides updates on the technology. Section 2 covers regulatory considerations; Section 3 covers remediation considerations, including setting performance objectives. Section 4 looks at the various reactive media now in use, while Sections 5 and 6 cover design and construction of PRB systems. Section 7 discusses monitoring and how to design a monitoring program that will allow the system to work optimally so remediation goals can be met. Section 8 introduces the concept of longevity and discusses the useful life of PRB systems while also looking at how and when to rejuvenate PRBs already in use. Section 9 discusses the green and sustainable concept as related to PRBs.

While many important lessons have been mastered, it is obvious that continued research and practical applications will yield a much greater understanding of the technology. Site characterization must continue to improve so that as much data as reasonably possible for a given site can be collected and worked into a PRB design. Construction methods must continue to expand if PRBs are to be deployed in more and different conditions. Also, cost and performance data must be collected from a greater number of sites, in particular those involving novel reactive media, to better confirm the long-term efficacy of PRB technology for treating groundwater plumes.

The PRB: Technology Update Team believes that the reader will, through the use of this guidance, be better equipped to evaluate PRB technology as a remedial alternative at contaminated sites. The document provides readers a better understanding of the advantages and limitations of PRBs and helps them navigate the associated regulatory, hydraulic, and engineering challenges. This guidance ultimately allows users to optimize and more closely match the needs of the site to the selected remedy, whether or not it includes a PRB.