In SITU Remediation of Contaminants in Ground Water and Soils using Permeable Reactive Barriers

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***ABSTRACT*-Until recently analysts estimate that the majority of groundwater remediation was done using "conventional technologies" (e.g., pump-and-treat systems), which have proven to increase from billions to trillions to meet applicable cleanup standards in the U.S. In the last few years, research on Permeable reactive barriers (PRBs) has increased because of the reduced water and energy demands and the potential to be more economical than conventional methods. (Scherer et al., 2000). While the reactivity of common PRB materials with chlorinated compounds has long been recognized, *in situ* applications were not considered until recently. PRB's have shown great promise as an alternative to pump and treat for the remediation of groundwater containing a wide array of contaminants including organics, metals, including organics metals and radionuclides. This research is intended to explore needed laboratory techniques for assessing *in situ* contaminant remediation in ground water and soils, and to illustrate the innovative techniques at pilot and full field-scale. In addition, the research will also indicate the mechanisms responsible for chemical transformations and the efficiency of these systems**

***Keywords- groundwater remediation, permeable reactive barriers , chlorinated compounds, radionuclides*.**

1. INTRODUCTION

Permeable reactive barriers (PRBs) are a promising remediation option involving a hydraulically permeable reactive medium down gradient of a plume of contaminated groundwater. As the water flows through it under the natural hydraulic gradient, the reactive medium degrades or traps the contaminants. PRB also referred to as a permeable reactive treatment zone (PRTZ), is a developing technology that has been recognized as being a cost-effective technology for *in situ* (at the site) groundwater remediation. PRBs are barriers which allow some—but not all—materials to pass through. One definition for PRBs is an *in situ* treatment zone that passively captures a plume of contaminants and removes or breaks down the contaminants, releasing uncontaminated water (Gillham et al., 2010). The PRBs offer the possibility of in situ plume capture and treatment, obviating the need to manage large volumes of water containing low concentrations of contaminants and the waste generated from the treatment of such water(Blowes et al., 1999), the simultaneous treatment of multiple types of contaminant such as metals, organics, and radionuclides, low operation and maintenance costs (Powell et al., 1998) they are an alternative remediation technology that has received considerable attention as of late (EPA, 2002; Tratnyek, 2002) .

The primary removal methods include: (1) sorption and precipitation, (2) chemical reaction, and (3) reactions involving biological mechanisms (Tratnyek et al.,2003). *Sorption and precipitation* are potentially reversible and may thus require removal of the reactive medium and gathered products in order to continue with remediation. Organic compounds tend to be undergo sorption due to hydrophobic expulsion from the surrounding water. Metals, however, tend to sorb through electrostatic attraction or surface complexation reactions. Many environmental pollutants are highly reduced, thus, the oxidation of these pollutants to harmless compounds is thermo-dynamically viable. The *chemical reaction* is the process in which contaminant is reduced to a less harmful or non-toxic form. Pollutants such as chlorinated solvents, are highly oxidized and as such are easily reduced. The reactions involving *biological mechanisms* include Zerovalent Iron to be used in PRBs for groundwater remediation. It continues to be the main material used in the construction of these barriers.

GENERAL METHODOLOGY AND PROCEDURE PILOT STUDY DESIGN

The field-scale application of Permeable Reactive Barriers (PRBs) in groundwater remediation will be done at the Environmental Laboratory, Newyork Institute of Technology, Old Westbury, NY. The NYIT PRB will use a funnel and gate design, with the funnel being composed of interlocking steel sheet piles, while the gate consisted of granular zero-valent iron. The funnels are non-permeable, and the simplest design consists of a single gate with walls extending from both sides. The main advantage of the funnel and gate system is that a smaller reactive region can be used for treating the plume, resulting in a lower cost. In addition, if the reactive media needs to be replaced, it is much easier to do so because of the small gate. Field-scale installation of a reactive barrier requires careful design based on the site-specific hydrogeology and on contaminant plume characteristics. Important parameters to take into account when designing reactive barriers are essentially its position with regard to the contaminant plume, the hydraulic site characteristics, the characteristics of the gate (type of reactive material, geometry), and the depth of the substratum into which the barrier is keyed. Groundwater flow modeling is a useful tool to understand the hydraulic behavior of the site and to optimize the reactive barrier design. The designate, typical of many PRBs, consists of a treatment zone that will be filled with a mixture of granular iron and sand, and will be treated as an *in situ*, permeable, iron-bearing treatment zone. Four types of Fe-bearing solids, siderite[$FeCO_3$], pyrite [FeS_2] coars-grained elemental iron [Fe^0], and fine-grained Fe^0, were assesses for their ability to remove dissolved Cr(VI) and chlorinated ethylenes(PCE and TCE) from solution at flow rates typical of those encountered at sites of remediation .The contaminants will be removed, to become part of the immobile matrix and/or transformed to a nontoxic chemical form leaving, for the most part, fully dechlorinated groundwater. Permeable reactive redox walls, placed below the ground surface in the path of flowing groundwater, provide an alternative remediation approach for removing electro-active chemicals from contaminated groundwater

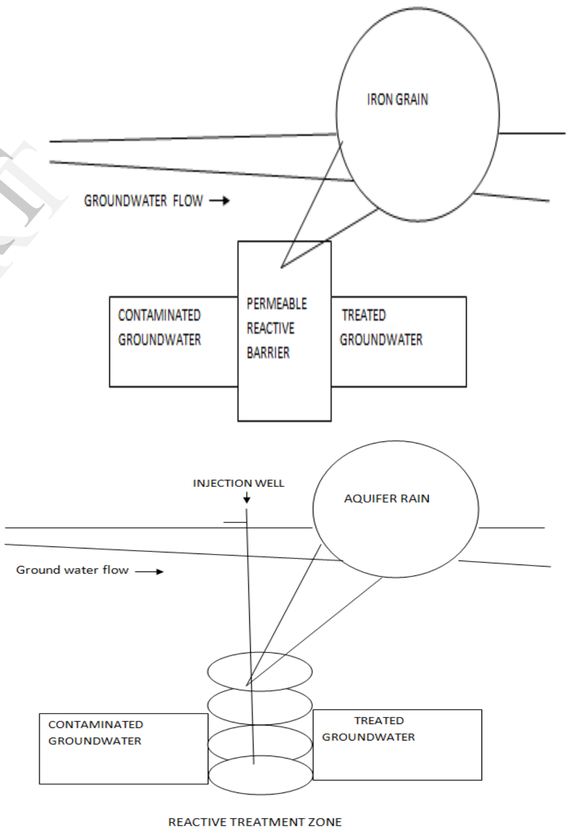
MULTI-GATE SYSTEM DESIGN

If the capture zone obtained at the end of the stage is not satisfactory, the designer can increase the number of gates and begin again the design at the step of his choice It should not be forgotten to re-evaluate the necessary filter length for each gate. One has to check that the capture zones of the gates do not overlap. If this is the case, the length of the wall between the gates must be increased. The main objective of the multi-gate System is to split up the desired total capture zone into multiple capture zones of smaller size assigned to several gates. This method allows an identical capture zone to be obtained with reactive filters of lower permeability and higher length. Ail gates are supposed to be exactly the same : filter properties and drains.

GROUNDWATER MODELING

Modeling groundwater flow is important for optimizing the design of a PRB. Most importantly, by modeling the flow, the hydraulic capture zone width (HCZW) and the residence time can be determined. The HCZW is the width of the zone of groundwater that will pass through the reactive cell or gate (for funnel-and-gate configurations). The residence time is the time that the contaminated groundwater will spend in the treatment zone for decontamination. Contamination outside the capture zone or that does not have a long enough residence time will not be properly decontaminated. Groundwater modeling can also be used for the following:

1. To determine the location of the PRB
2. To determine a suitable configuration
3. To determine the width of the reactive cell (and funnel for funnel-and gate)
4. To evaluate potential for underflow, overflow, or flow across aquifers
5. To provide knowledge of groundwater flow fluctuations (velocity and direction) for use in the design
6. To determine reactive media selection (based on hydraulic conductivity) to match the conductivity of the aquifer
7. To evaluate possibilities for flow bypass due to reduced porosity
8. To determine monitoring well locations and monitoring frequencies[9]



CONVENTIONAL PRB SEQUENTIAL INJECTION OF NANO-SIZED

The accompanying figure shows an approach to application of iron particles for groundwater remediation: Fig. 1, a conventional PRB made with mm-sized granular iron and Fig. 2, a "reactive treatment zone" formed by sequential injection of nano-sized iron to form overlapping zones of particles absorbed by the grains of native aquifer material. In A, groundwater flows through the barrier and is remediated.

IMPLEMENTATION

PRBs are typically installed by digging a long trench in the path of the flow of the contaminated groundwater. The trench is then filled with the reactive materials (typically iron, carbon, or limestone). Sand can be mixed with the reactive material to aid in allowing the water to flow through the materials. Sometimes, there will be a wall that directs the groundwater to the reactive parts of the barrier. After the trench has been filled with reactive material, soil will typically be used to cover the PRB, thus eliminating visibility from the surface.(EPA., 2001).

PERFORMANCE ASSESMENT

The key component for assessing the success of a PRB is whether it satisfactorily removes the contaminants. This can be done by monitoring the levels in the water immediately downstream of the PRB. If the levels are below maximum contaminant levels, then the PRB has performed its function.

In analyzing PRBs, emphasis has been placed on losses of reactivity and permeability in the reactive well; however, flawed hydraulic characterization of the few PRB failures that have been reported. Oxidation-reduction potential, influent [pH], and influent concentrations of [alkalinity], [nitrate NO_3^-], and [chloride Cl^-] are the strongest predictors of possible diminished performance of PRBs. The reactivity of the media, rather than a reduction in permeability is more likely the factor that limits field PRB longevity. Because this technology is relatively new, it is still hard to predict the longevity of sites. Depending on assumptions of controlling factors, longevity estimates can differ by an order of magnitude of 10–100 years(National Research Council. 1994) .

NEW AND UNUSUAL TECHNIQUES

An innovative RDBMS is developed for site specific contaminants with specific remediation technologies. An algorithm is developed for each and every specific remediation technology which can be adapted to any contaminants in ground water. An application interface is developed using ArcMap and a theoretical regretion model that creates the module enabling the analysis that creates necessary raster layer .The results indicate the degradation rate of the contaminants in the ground water in real time on-line and on-demand from the database.

EXPECTED RESULTS AND SIGNIFICANCE AND APPLICATION

This research is intended to explore needed laboratory techniques for assessing *in situ* contaminant remediation in ground water and soils, and to illustrate the innovative techniques at pilot and full field-scale. In addition, the research will also indicate the mechanisms responsible for chemical transformations and the efficiency of these systems. A information data base using Oracle RDBMS will be developed , and a simulation model for an environmental assessment of the proposed remedial design will be implemented in the pilot study using parameters such as the contaminants , the remedial process, the hydraulic site characteristics, the characteristics of the gate (type of reactive material, geometry), and the depth of the substratum into which the barrier is keyed. This database will be of significant nature in the challenges facing In Situ Remediation of Contaminants in Ground Water and Soils Using Permeable Reactive Barriers . The results will indicate the degradation rate of the contaminants in the ground water in real time on-line and on-demand from the database.

CONCLUSION

The design method of the PRBs equipped with drain panel system, was conceived by NYIT for USEPA using many numerical simulations of barrier installation on simple cases of groundwater flows . The method is organized into 8 steps, which allows, according to the configuration of a contamination plume in groundwater, the design of the reactive filters, the length of the watertight walls and of the drains, and determination of the number of gates. This method was validated, always using numerical simulations, by modeling real cases. In addition, a prediction method of the contamination migration was conceived using two analytical solutions. These solutions allow to predict the evolution of the contaminant concentrations upstream of the reactive barrier, in order to evaluate the life-time of the filters.

FUTURE TRENDS

A information data base using Oracle RDBMS will be developed , and an environmental assessment of the proposed remedial design for will be implemented in the pilot study.

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