# IN-SITU BIOREMEDIATION OF CONTAMINATED GROUNDWATER USING BIOLOGICAL PERMEABLE BARRIERS

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Abstract: We developed and examined a new in situ biological system that takes advantage of a unique immobilized cells technique for treatment of organic compounds in groundwater. This technology is called Biological Permeable Barrier (BPB). BPB is an innovative combination of two cost effective in-situ remediation technologies: in-situ bioremediation and permeable barrier walls. This unique system was evaluated for over 300 days to biodegrade a selected target compound, 2,4,6 trichlorophenol (TCP) from groundwater under different operating conditions.

The effects of different concentrations of TCP, different influent flow rates, availability of dissolved oxygen and nutrients were examined extensively. The immobilized cells system (BPB) biodegraded TCP to harmless end products with removal efficiencies of 91% to 100% at applied loading of 600 mg/L-d to 300 mg/L-d, respectively.

BPB system shown to have significant advantages over conventional biological system by maintaining much higher cell density resulting in high rates of biodegradation activity per unit volume of reactor. Furthermore, an immobilized cell system (BPB) does not require separation of the biomass from the liquid phase and provides greater operational flexibility to the system relative to suspended or attached growth systems. Immobilized microbial cells embedded in BPB technology have also been shown to be more resistant to high concentrations of toxic or inhibitory chemicals. BPB technology has exceeded the researcher's expectations and is currently being considered to successfully biodegrade many dissolved organic compounds in groundwater such as explosives, TCE, PCE, MTBE and Perchlorate.

The most common approach for large-scale bioremediation has been to inject nutrients or bacteria to encourage in situ bioremediation of contaminated groundwater. This approach has not proven to be reliable due to biofouling, inhibition of the biodegradation reaction, and the difficulty of bringing the stimulated population and contaminants into contact. Furthermore, the microorganisms responsible for degrading organic compounds are exposed to the stress conditions in the environments where they are introduced. The losses of viable microorganisms as a result of stress conditions and migration of microorganisms are the major problems with this technology.

The BPB examined in this research intended to overcome some of the problems associated with today's in situ remediation technologies by providing the best possible environment for microorganisms. Immobilization embedded in BPB shields the viable microorganism from environmental stresses. Not only BPB prevents the migration of viable cells by immobilization but also provides adequate time and contact between microorganisms and contaminant(s) in groundwater. BPB entails immobilizing organic-degrading bacteria, which are acclimated to the target compound, encapsulated in

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unique polymeric beads. The “activated” beads (Bio-beads) are then placed in an engineered trench (in-situ) across the flow path of the organic-contaminated groundwater. Organic-contaminated groundwater enters the BPB (via the natural gradient) to which electron donor and nutrients are supplied, and the remediated groundwater exits the BPB.

To examine BPB concept, we conducted a series of column experiments under a variety of operating conditions. The column experiments were design to simulate BPB and to account for any significant changes in hydraulic retention time (HRT), applied loading, availability of dissolved oxygen, and nutrient added to the groundwater.

After 300 days of continuous operation, BPB (Bio-beads) was able to biodegrade 2,4,6 trichlorophenol (TCP) from groundwater under different operating conditions (Shirazi, F., 2000). The effects of TCP

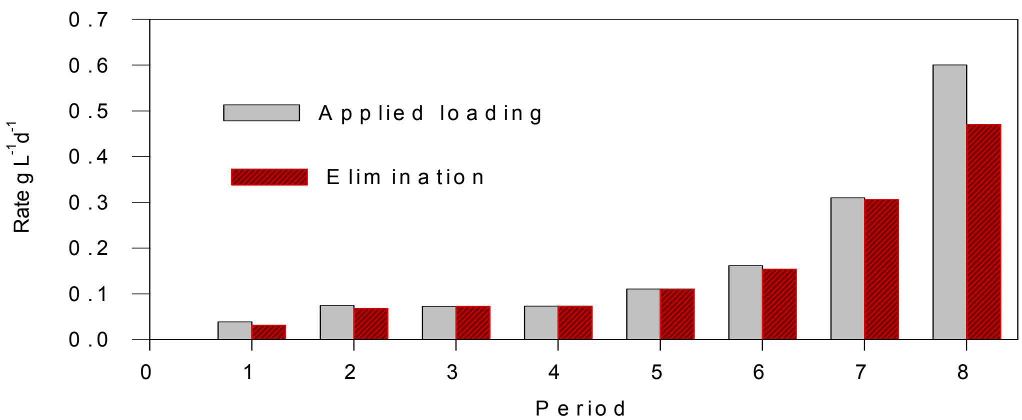


Figure 1. Removal Efficiency of BPB System Under Variety of Operating Conditions

loading rate on elimination capacity of the Bio-beads column are shown in Figure 1. The TCP loading increase during period 5 had no effect on either of the column. Bio-beads column showed an increase in TCP concentration in the effluent during period 6, after the TCP loading rate from 0.11 to 0.15 g L$^{-1}$d$^{-1}$. An increase in TCP concentration in the Bio-beads column was observed (during period 7) after increasing the flow rate from 2 to 4 mL/min, with the corresponding increase in TCP loading rate from 0.15 to 0.3 g L$^{-1}$ d$^{-1}$. During period 8, both Bio-beads column experienced the highest loading rate, 0.6 g L$^{-1}$ d $^{-1}$, during the entire column studies (due to increase in TCP concentration to 40 mg/L). The removal efficiency of the Bio-beads column was reduced to 81%, during this period due to short HRT. The oxygen consumption, chloride release (dehalogenation of TCP), and pH changes of Bio-beads column decreased where applied loading increased. To obtain mass balances, measured chloride releases were compared to those calculated from GC measurements (of TCP) for Bio-beads column. Measured chloride releases by Bio-beads column agreed well with those calculated from GC measurements. Evolution of $H^+$ by acid production (HCl) in the effluents of the Bio-beads column indicated by pHs gave further evidence of TCP dehalogenation.

The immobilized cells system biodegraded TCP to harmless end-products with removal efficiencies of 91% to 100% at applied loading of 600 mg/L-d to 300 mg/L-d, respectively (Shirazi, F., 2000). The results from three years of bench-scale studies/evaluation (Shirazi, F., 1997) suggest that immobilization is key to the ability of this process to concentrate and protect active bacteria mass in small diameter media. The Bio-beads were protected against toxic shock loads of TCP (> 550 mg/L), and low dissolved oxygen required by immobilized bacteria to degrade TCP under aerobic conditions.

In general, the largest market for this type of technology is clearly the Department of Energy and the Department of Defense for remediation of federal sites affected by past / historical activities. Additional markets include the commercial U.S. market including applications to problems identified under legislation such as CERCLA (Superfund), RCRA, Underground Storage Tanks, and additional environmental laws. There are many federal agencies (e.g., DOD, DOE, USEPA, USACE) and private sector clients who will find this technology useful for a variety of site conditions and contaminants

Overall advantages with respect to the above applications are:

- Cost effective-low capital and O&M costs.
- Variety of contaminants treated.
- High quality effluent produced by combined physical and biological treatments.
- Capable of complete biotransformation of organic compounds without formation of any by-products
- Capable of handling both environmental stresses and toxic shock conditions.
- Easy to manufacture, maintain, and replace media.
- Capable to operate at a wide range of organic compounds concentration and loading rates (HRT).
- Produce little or no sludge; remain permeable over long period of time.

References:

Shirazi, F. 1997. "Development of Biological Permeable Barriers for Removal of Chlorophenols (2,4,6-Trichlorophenol) in Contaminated Groundwater." PhD Dissertation, Oklahoma State Univ., Stillwater, OK.

Shirazi, F. 2000. "Biological Permeable Barrier to Treat Contaminated Groundwater Using Immobilized Cells". U.S. Patent No. 60/106687.