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Project Title

Usage of Water-Filled Trench in Improving Groundwater Quality

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Second Progress Report

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1. Introduction

The water-filled trench method is a simple and cost effective in situ groundwater remediation technique. The mechanisms of water-filled trenches in cleaning up contaminated groundwater include biological degradation, volatilization, and chemical or biological oxidation and precipitation (1, 3). Water-filled trenches make use of these mechanisms to clean up contaminated groundwater, thereby reducing levels of risk to human health and the environment. In Florida, groundwater is vulnerable to different kinds of contamination, in part because of the shallow depth to groundwater in most Florida regions. At Patrick Air Force Base, soil and groundwater contamination caused by benzene, toluene, ethylbenzene, and xylene (BTEX) has been known to occur near the BX Service Station (Site ST-29). At other locations in Florida, groundwater is also easily to be contaminated by contaminants associated with petroleum hydrocarbon releases, which include BTEX. At Hurlburt Air Force Base, perchloroethylene (PCE) and trichloroethylene (TCE) were the major contaminants released over a long period of time. On the other hand, groundwater in Northwest Florida is easily to be contaminated by heavy metals such as iron.

2. Objectives

This research will explore the possibility of the usage of water-filled trenches in removing the organic and inorganic contaminants from the groundwater. During water-filled trench processes, the contaminants may be removed by one or more mechanisms, with certain mechanisms dominating over the others. Therefore, knowledge of the physicochemical and biological processes that are responsible for groundwater decontamination in water-filled trenches is required in order to promote field applications. Three major contaminants in the groundwater are the focus of this research, i.e., BTEX, PCE/TCE and iron. Our objective for this section of the project is to investigate biological BTEX decomposition.

3. Project Progress

Culturing BTEX Reducing Bacteria

In an attempt to isolate a BTEX degrading culture, microorganisms were isolated from leachate samples collected from Santa Rosa Holley Landfill in Santa Rosa County, FL. Continuous cultivation and enrichment of the BTEX degrading culture were carried out in a 250 ml serum bottle containing 100 ml sterilized minimal salt medium amended with approximately 25 mg/l benzene, 25 mg/l toluene and 25 mg/l xylene. The mineral salts medium used in this study had the following composition: KH_2PO_4, 160 mg/l; K_2HPO_4, 420 mg/l; Na_2HPO_4, 50 mg/l; NH_4Cl, 40 mg/l; $MgSO_4 \cdot 7H2O$, 50 mg/l; $CaCl_2$, 50 mg/l; $FeC_{l3} \cdot 6H2O$, 0.5 mg/l; $MnSO_4 \cdot 4H2O$, 0.05 mg/l; H_3BO_3, 0.1 mg/l; $ZnSO_4 \cdot 7H_2O$, 0.05 mg/l; $(NH_4)_6Mo_7O_{24}$, 0.03 mg/l. The medium pH was adjusted to 7.0 with 0.1 M HCl or 0.1 M NaOH. The inoculated serum bottles was put into a rotary-shaker (150 rpm at 25 ℃) in the dark for at least 1 week until the formation of black precipitate at the bottom and on the wall of the serum bottles can be observed. Then 10 ml enriched culture was transferred into 100 ml fresh culture medium amended with approximately 25 mg/l benzene, 25 mg/l toluene and 25 mg/l xylene for the second phase culture enrichment. After the fourth phase enrichment was completed, bacterial cells were harvested and used for the BTEX degradation experiments.

BTEX Degradation Experiments

Batch biodegradation experiments were carried out at room temperature in 250-mL sidearm reactors, and microbial growth and substrate depletion were monitored over time. Biomass concentration was measured by monitoring the optical density at a wavelength of 660 nm, whereas BTEX concentrations were measured in a gas chromatograph (GC). Samples were periodically withdrawn from the reactors and analyzed for biomass and BTEX concentrations. The temperature of the reactors was maintained at 25^{o}C using a water bath.

BTEX Degradation Modeling

If bacterial growth is coupled with substrate depletion and Monod-type kinetics are assumed to describe bacterial growth, substrate and biomass concentrations over time can be described by following equations (2):

$$\frac{dS}{dt} = -\frac{1}{Y}\frac{\mu_m SX}{K_s + S} \quad (1)$$

$$\frac{dX}{dt} = \frac{\mu_m SX}{K_s + S} - \frac{bX}{K_s + S} \quad (2)$$

where S is the substrate concentration (g/l); μ_m maximum specific growth rate (hr^{-1}); X biomass concentration (g/l); t elapsed time (hr); Y growth yield coefficient (g biomass per g substrate); K_s half-saturation coefficient (g/l); and b microbial decay coefficient (hr^{-1}). Ignoring microbial decay, Y can be estimated based on substrate depletion:

$$Y = -\frac{X_0 - X}{S_0 - S} \quad (3)$$

Consequently,

$$S = S_0 - \frac{1}{Y}(X - X_0) \quad (4)$$

By substituting equation (4) into equation (2), bacterial growth can be expressed as:

$$\frac{dX}{dt} = \frac{\mu_m[S_0 - \frac{1}{Y}(X - X_0)]X}{K_s + [S_0 - \frac{1}{Y}(X - X_0)]} - \frac{bX}{K_s + [S_0 - \frac{1}{Y}(X - X_0)]} \quad (5)$$

Experimental Results

64% to 68% of BTEX was degraded within 8 days (Figure 1). The mineralization of toluene occurred at a greater rate than those of benzene and xylene owing to its greater initial concentration.

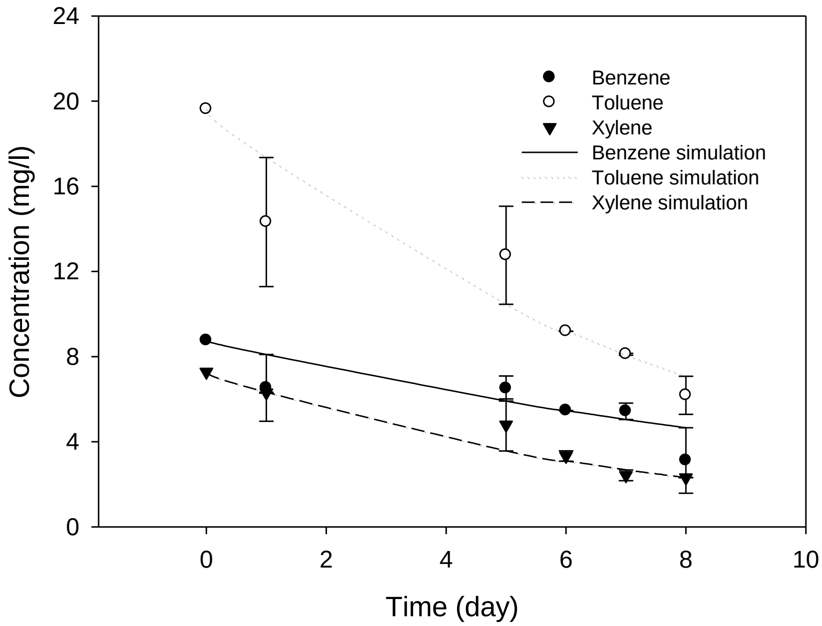

Figure 1. BTEX Degradation Curves

The simulated half-saturation coefficient K_s (mg/l), growth yield coefficient Y (g biomass per g substrate), and maximum specific growth rate μ_m (day^{-1}) are listed in Table 1. Both benzene, toluene, and xylene have similar K_s values, indicating that the culture has similar affinity to these BTEX components. In addition, the Y and μ_m values are also similar. As compared to toluene and xylene, benzene has a slightly greater Y and smaller μ_m.

Table 1. BTEX Degradation Parameters

	K_S	Y	μ_{max}
Benzene	203.6	0.0758	0.00837
Toluene	174.4	0.0673	0.0107
Xylene	169.8	0.0663	0.0110

4. Future work

We will continue to study the anaerobic degradation of PCE and TCE. We will also investigate whether, and if it is yes, to what extent, filtering processes can be utilized in removal BTEX, PCE/TCE and iron. The effect of dissolved oxygen and alkalinity on groundwater decontamination will also be investigated.

5. Miscellaneous

We have updated our website (www.eng.fsu.edu/~gchen) to include this project to facilitate the dissemination of our research discovery. Our prior research regarding iron reduction and release to the groundwater has been accepted and will soon appear in the International

Journal of Environment and Waste Management. We had our first TAG meeting on February 6, 2009 and the minute has been posted on the website.

6. References

1. Field JP, Farrell-Poe KL, Walworth JL. 2007. Comparative treatment effectiveness of conventional trench and seepage pit systems. *Water Environment Research* 79: 310-9
2. Monod J. 1949. The Growth of Bacterial Cultures. *Annual Review of Microbiology* 3: 371-94
3. Pankow JF, Johnson RL, Cherry JA. 1993. Air Sparging in Gate Wells in Cutoff Walls and Trenches for Control of Plumes of Volatile Organic-Compounds (Vocs). *Ground Water* 31: 654-63

7. Publications

Williams, M., Subramaniam, P.K., Tawfiq, K. and Chen, G. (2009) ‘Soil and Microbial Characterization and Microbial Mediated Iron Release nearby Landfills in Northwest Florida, U.S.’, Int. J. Environment and Waste Management, Vol. X, No. Y., pp.000 000.