



Florida A&M University – Florida State University

College of Engineering

Gang Chen, Ph.D.

Department of Civil & Environmental Engineering

2525 Pottsdamer Street, Tallahassee, FL 32310-6046

Tel (850) 410-6303 Fax (850) 410-6142

E-mail: gchen@eng.fsu.edu



Project Title

Usage of Water-Filled Trench in Improving Groundwater Quality

Tag Members

Lee Martin, Peter Grasel, Casey Taylor, Jim Langenbach, Subramanian Ramakrishnan, Michael Watts, and Clayton Clark

First Progress Report

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John D. Schert

Executive Director

Hinkley Center for Solid and Hazardous Waste Management

4635 NW 53rd Avenue, Suite 205

Gainesville, FL 32606-4367

by

Gang Chen, Amy Chan Hilton, and Kamal Tawfiq

Department of Civil and Environmental Engineering

FAMU-FSU College of Engineering

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, 2). 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 the first section of the project is to continue to investigate iron related groundwater contamination following our prior research sponsored by the Hinkley Center. From our prior research, we have demonstrated that ferrous iron can be released to the groundwater when landfill leachate reacts with iron rich soil in the presence of iron reducing bacteria. However, we suspect that some of the reduced iron may not be released directly to the groundwater; instead, they are adsorbed to the iron reducing bacteria. We need to quantify the amount of reduced iron that can be adsorbed to the bacteria in order to accurately to predict ferrous iron release to the groundwater.

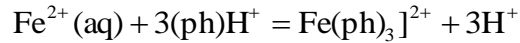
3. Project Progress

Culturing Iron Reducing Bacteria

The iron reducing bacteria were cultured in minimal salt media with the sampled soil from Jackson County (Spring Hill Landfill) as the base consortia. The media had a composition (mg/l) of KH_2PO_4 , 160; K_2HPO_4 , 420; Na_2HPO_4 , 50; NH_4Cl , 40; $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 50; CaCl_2 , 50; $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, 0.5; $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$, 0.05; H_3BO_3 , 0.1; $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, 0.05; $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24}$, 0.03; glucose, 200; and ammonia chloride, 60. The pH of the media was adjusted to 7.4 with 1 M HCl or 1 M NaOH, after which the media were sterilized by autoclaving (121°C and 1 atm) for 20 min. Glucose was filter-sterilized and aseptically added to the autoclaved media. Five grams of soil was then added to 100 ml of the culturing media. Culturing was performed in a reactor equipped with appropriate CO_2 entrapping devices. For this research, 1 M KOH was used to entrap CO_2 and iron reducing bacteria culturing was proceeded under anaerobic conditions in an anaerobic chamber.

Iron Adsorption Experiments

Iron adsorption on iron reducing bacteria was conducted following standard adsorption techniques. The batch adsorption experiments were carried out in autoclaved (121 °C and 1 atm for 20 mins) high-density polyethylene reaction vessels. Bacterial strains were first harvested by centrifugation at 12,000 × g for 15 mins after growth in minimal salt media. The cell pellets were then washed and re-suspended in an electrolyte solution to make a bacterial solution. The electrolyte solution was prepared using analytical reagent-grade NaCl and nano-pure de-ionized water (NPDI, Barnstead, Dubuque, IA) at a concentration of 10⁻⁵ M and adjusted to pH 7. To determine the adsorption of ferrous iron on bacterial cells, a series of 15ml vials containing ferrous iron chloride solutions (15 ml) at the concentrations of 0.25, 2.0, 3.5, 10.0, 15.0, and 30.0 mg/l as Fe²⁺ and 0.1 g bacterial cells (including blank controls) (sealed with Teflon-lined screw caps) were agitated on a Wrist Action Shaker (Burrel Scientific, Model 75) for 24 hrs to reach equilibrium. In separate experiments, a series of kinetic batch experiments were performed to investigate the dependence of iron adsorption on adsorption time. The suspensions were then centrifuged at 12,000 × g for 15 mins, after which ferrous iron concentrations in the supernatant were measured by reacting with 0.0125 M 1,10-phenanthroline.



After reacting with 1,10-phenanthroline (C₁₂H₈N₂·H₂O), a stable, high colored complex was formed, which was quantified using a spectrophotometer at a wavelength of 520 nm (Shimadzu UV-1650 PC). The amount of ferrous iron adsorbed per bacterial mass was obtained by using the following equation:

$$q = (C_i - C_e) \times V/M = K_s \cdot C_e$$

where q is the amount of ferrous iron adsorbed onto bacterial cells (mg/g), C_i and C_e are the ferrous iron initial and equilibrium ferrous iron concentrations (mg/l), V is the volume of the aqueous phase (l), M is the mass of bacterial cells (g), and K_s is the partition coefficients of ferrous iron with iron reducing bacteria.

Experimental Results

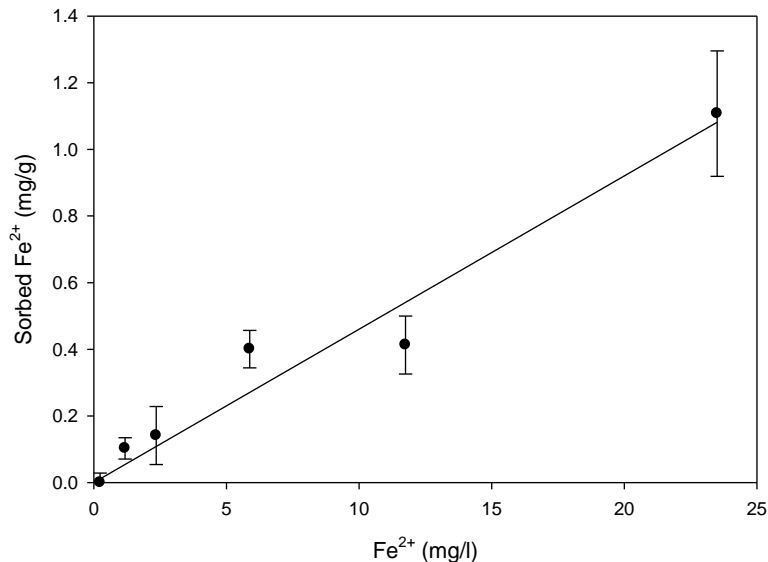


Figure 1. Adsorption Isotherms of Ferrous Iron on Iron Reducing Bacteria

Ferrous iron had a linear isotherm on iron reducing bacteria (Figure 1). From isotherm experiments, the average partition coefficient was found to be 0.046 l/g. These data were obtained based on the assumption that equilibrium of ferrous iron adsorption on iron reducing bacteria can be reached within 24 hours. In order to provide evidence of this assumption, ferrous iron kinetic adsorption experiments were conducted for each of ferrous iron concentrations investigated in this study, i.e., 0.25, 2.0, 3.5, 10.0, 15.0, and 30.0 mg/l.

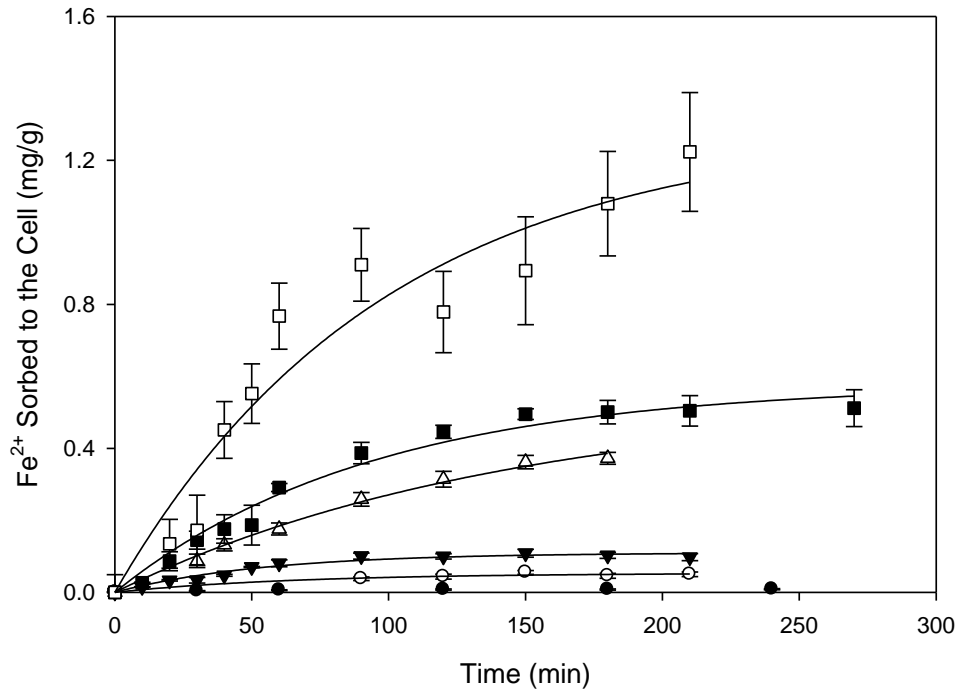


Figure 2. Kinetic Adsorption Experiments of Ferrous Iron on Iron Reducing Bacteria

The results demonstrated that equilibrium was reached after two hours' of adsorption reaction for most cases (Figure 2). The kinetic adsorption of ferrous iron on iron reducing bacteria was further simulated by:

$$q = a(1 - b^C)$$

Table 1. Adsorption Parameters of Ferrous Iron Kinetic Adsorption Experiments

| | a | b | R ² |
|------|-----------------|-----------------|----------------|
| 0.25 | 0.0085 ± 0.0002 | 0.9796 ± 0.0013 | 0.9970 |
| 2.00 | 0.0533 ± 0.0058 | 0.9850 ± 0.0056 | 0.9606 |
| 3.50 | 0.1099 ± 0.0058 | 0.9818 ± 0.0025 | 0.9609 |
| 10.0 | 0.5424 ± 0.0473 | 0.9931 ± 0.0010 | 0.9945 |
| 15.0 | 0.5779 ± 0.0317 | 0.9894 ± 0.0013 | 0.9788 |
| 30.0 | 1.2890 ± 0.1837 | 0.9898 ± 0.0029 | 0.9214 |

The “b” values simulated from all the cases were very consistent, which were in the range from 0.97 to 0.99; however, the “a” vales were dependent upon the initial ferrous iron concentrations (Table 1). By further analysis, it was found that “a” corresponded to the equilibrium concentration, C_e (Figure 3).

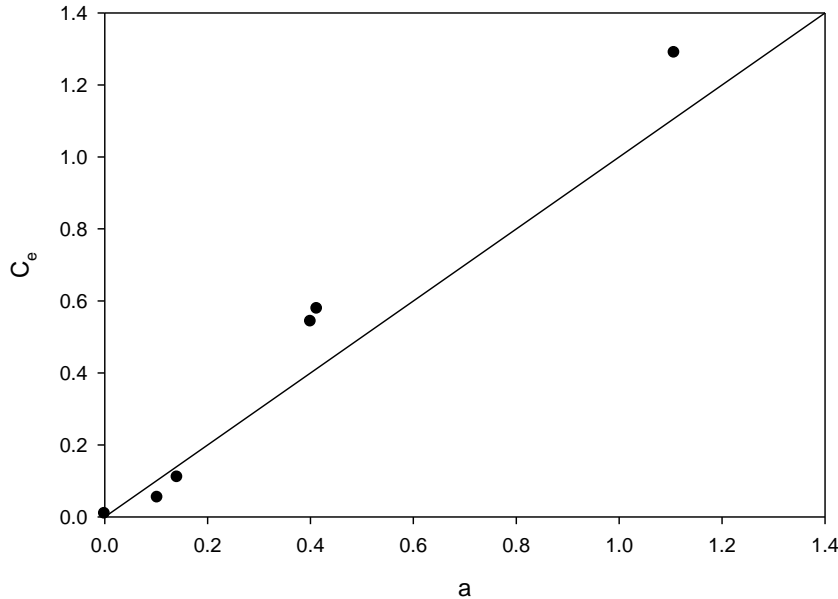


Figure 3. C_q as a Function of “a”

4. Future work

We will investigate whether, and if it is yes, to what extent, water-filled trenches can be utilized in removal BTEX, PCE/TCE and iron. We will simulate water-filled trench processes in the laboratory to investigate the possible decontamination of BTEX, PCE and TCE as well as ferrous iron. We expect to observe organic decomposition, volatile organic compound vaporization, and metal oxidation and precipitation in these experiments. The decontamination rate will be quantified. 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 will have our first TAG meeting in January, 2009. We will notify the Hinkley Center when the meeting is scheduled.

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. 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.