Report for 2003DE30B: Graduate Fellowship: Removal And Inactivation Of Water-Borne Viruses Using Elemental Iron

- Water Resources Research Institute Reports:
    - Jin, Yan, Pei Chiu and Liping Zhang, 2005, Removal and Inactivation of Water-borne Viruses Using Permeable Iron Barriers, Fellowship Progress Report to the Delaware Water Resources Center, Newark, Delaware, 5 pages.
- Other Publications:
    - Boyd, Amy, Ed., Spring 2004, Delaware Water Resources Center WATER NEWS Vol. 5 Issue 1, "Removal and Inactivation of Water-borne Viruses Using Elemental Iron", http://ag.udel.edu/dwrc/newsletters/Spring2004.pdf, pp. 6-7.
    - Boyd, Amy, Ed., Fall 2003 Delaware Water Resources Center WATER NEWS Vol. 4 Issue 2, "DWRC Awards Two New Graduate Fellowships", http://ag.udel.edu/dwrc/newsletters/fall2003.pdf p.6.

Report Follows

Delaware Water Resources Center (DWRC) Fellowship Project 2003-2005
"Removal and Inactivation of Water-borne Viruses Using Elemental Iron"
Liping Zhang, DWRC 2003-2005 fellow
Advisors at the University of Delaware (UD):
Dr. Yan Jin, Plant & Soil Sciences
Dr. Pei Chiu, Civil & Environmental Engineering

Drinking water safety and the growing demand for potable water are two critical water resource issues facing Delaware. The mission of **DWRC** includes supporting research, education, and outreach programs that focus on water supply, water management, and water quality. The research of **DWRC** fellow Liping Zhang, advised by Dr. Yan Jin of the **UD** Department of Plant and Soil Sciences and Dr. Pei Chiu of the **UD** Department of Civil and Environmental Engineering, will evaluate the feasibility of using elemental iron to remove and inactivate waterborne viruses. The purpose of this research is to ultimately develop an effective and economical technology that can be used to remove pathogens from water.

Ms. Zhang received her M.S. in environmental science and engineering and has two and half years of experience in water quality research. She has a keen interest in her Ph.D. project, stating, "Dr. Jin and Dr. Chiu are creative persons and have extensive experience in virus fate and transport in porous media and using elemental iron to treat environmental pollutants. Under their direction, I hope to provide a scientific understanding of the interactions between viruses and elemental iron and iron oxides and the factors that influence these interactions." Liping is very excited about her research, which she hopes to yield an innovative, effective, robust, and low-cost technology that can be used to remove viruses (and potentially other pathogens) in drinking water, wastewater, and groundwater, and ultimately contribute to Delaware's water quality. Other potential benefits of the iron technology may include lower disinfectant dosage and cost and reduction in disinfection by-product formation.

Abstract

Microbiological contamination of drinking water continues to be one of the greatest challenges in public health risk management in the 21st century. Among the different classes of microbial pathogens, viruses are of particular importance as they are smaller than bacteria and protozoa, far more mobile in subsurface environments, and also more resistant to the currently available water treatment technologies. The United States Environmental Protection Agency (USEPA) in the proposed Ground Water Rule (GWR) identifies viruses as the target organisms because they are responsible for approximately 80% of water-borne disease outbreaks for which infectious agents were identified.

The proposed research will evaluate the feasibility of using elemental iron in a continuous-flow treatment barrier to remove and inactivate waterborne viruses. ***We hypothesize that iron can be used to remove viruses from water because elemental iron can continuously generate and renew the surface iron oxides and oxyhydroxides through corrosion in water, and iron oxides and oxyhydroxides have been shown to inactivate viruses***. A preliminary column test we conducted recently shows that a very thin layer (3 mm) of iron filings in the flow path of virus-contaminated groundwater (8.8 min residence time) resulted in approximately 2-log (99%) removal of two viruses over 40 pore volumes, and 90% of the removal was due to inactivation rather than reversible sorption. We propose to conduct a series of column experiments to further evaluate the effectiveness of iron to remove two bacteriophages and an avian virus and to investigate the effects of the variables and medium conditions that are relevant to water treatment, including iron type and age, pH, and dissolved oxygen.

The specific objectives are:

1. To test the effectiveness of elemental iron to continuously remove and inactivate viruses from contaminated water,
2. To investigate the effects of important parameters (e.g., residence time, iron type and age, virus type) and medium conditions (pH, dissolved oxygen) on the efficacy of virus removal, and
3. To identify the types of Fe oxides/oxyhydroxides involved in virus removal and inactivation.

The proposed study represents the first attempt to evaluate elemental iron for removing pathogens from water. Although elemental iron has been used in permeable reactive barriers (PRBs) to remove chemical contaminants in groundwater for almost a decade, it has never been shown to remove viruses. The proposed study will help determine whether iron PRBs can potentially be a feasible technology for removing waterborne viruses. The research will also provide information regarding the interactions between virus particles and iron mineral surfaces involved in virus removal. This information will form the basis for elucidating, in our subsequent studies, the mechanisms for virus inactivation and sorption by iron oxides - a process that is important in both natural and treatment systems.

Upon successful completion of the proposed project, we will seek longer-term funding to (1) study the mechanisms via which virus sorption and inactivation by iron oxides occur and (2) establish partnerships with water and wastewater treatment companies and organizations to conduct pilot-scale studies. The proposed research and subsequent studies are expected to yield innovative, effective, robust, and low-cost technologies that can be used to remove viruses (and potentially other pathogens) in drinking water, wastewater, and groundwater. Other potential benefits of the iron technology may include lower disinfectant dosage and cost and reduction in disinfection by-product formation. Such technologies are urgently needed to alleviate increasing public concerns about drinking water safety and to meet the growing demand for potable water – two critical water resource issues facing Delaware.

Significance and Potential Impact of the Proposed Study:

It has been estimated that 76 million cases of acute gastrointestinal illnesses per year in the U.S. is foodborne (Mead et al., 1999) and 10-40% of these cases may be associated with drinking water (Payment et al., 1991, 1997). Groundwater contaminated with pathogenic microorganisms has been implied in more than 80% of all waterborne disease outbreaks in the U.S. (Ryan et al., 2002). These outbreaks continue to occur despite improvements in water treatment practices and regulations. Among the different classes of pathogens, viruses pose a particular threat to public health due to its high mobility in groundwater. If our hypothesis is proven, iron can perceivably be used in subsurface barriers or above-ground treatment systems to remove and inactivate waterborne viruses. Such iron-based "virus filters" can be either a stand-alone process or added onto an existing water and/or wastewater treatment system to enhance the overall removal efficiency of viruses and possibly other pathogens. Iron filings are relatively inexpensive and have been used in groundwater PRBs for the past decade. The proposed iron treatment process is passive, continuous, and long-lasting, and involves minimal startup, maintenance, and operation costs. The iron treatment can also potentially decrease the disinfectant dosage required, minimize the formation of toxic disinfection by- products, while achieving reduction of the numbers of pathogens in treated water.