Julianna G. Camacho

Department of Civil Engineering

Nature of the Problem

Two of the most toxic environmentally mobile compounds found in water are arsenic (As) and chromium (Cr). The United Nations reported that arsenic pollution of drinking water extracted from groundwater aquifers has become a problem of tremendous dimensions throughout Asia. The effects of drinking arsenic-contaminated water include skin lesions and cancers, gangrene, and internal cancers of the bladder, kidney and lungs. Arsenic is classified by the International Agency of Research on Cancer and the US EPA as a human carcinogen. The toxicity of arsenic can be altered by a change in oxidation state, chemical composition, solubility and pH. The toxicity of arsenic decreases according to the reverse order of oxidation state.

The Department of Health and Human Services has determined that chromium compounds are known carcinogens causing lung and gastrointestinal tract cancers. There are many industries using chromium that are possible sources of Cr (VI) pollution in water. One industry that contributes harmful levels of Cr (VI) to the environment is the metal-plating industry. Chromic acid is used in the electroplating process and can be present in industrial wastewaters. Cr (VI) can also enter water supplies from industrial cooling towers where chromic acid is added to the water to inhibit metal corrosion. Other products that contain Cr (VI) are paints, pigments, tanning agents, inks, fungicides and wood preservatives. The wood treatment industry produces a notable amount of arsenic and chromium contamination, specifically by chromate copper arsenate (CCA). CCA is an inorganic, waterborne preservative that protects wood from rotting due to insects and microbial agents. It has been used to pressure treat lumber used for decks, playgrounds and other outdoor uses since the 1930's. Also, since the 1970's the majority of the wood used in residential settings was CCA-treated wood. According to the report of American Wood Preserves Institute in 1996 79% of the wood preserve in the United States was treated with water porn preservatives. As of January 1, 2004, EPA will not allow CCA products to be used to treat wood intended for any residential uses.

Chromium concentrations in unpolluted fresh water have been found to be less than 12 ppb. In contrast, the value of contaminated water can be as high as 100 ppb, which exceeds the recommended MCL's established by the US EPA. The major species of chromium found in contaminated waters are trivalent chromium Cr (III) and hexavalent chromium Cr (VI). The presence of Cr (VI) is of great importance as Cr (VI) is more water soluble and extremely toxic, in comparison to Cr (III).

Sorption of the toxic metals onto a metal oxy-hydroxide is the most popular and practical removal method from contaminated water. Adding salts of metals such as iron and aluminum forms the oxy-hydroxide sorbents. These oxy-hydroxides are strong adsorbents for As (V) and chromium (III) in pH neutral water. However, arsenic and chromium sorption processes frequently fail to meet the maximum contamination levels of 10 ppb and 100 ppb respectively in drinking water when they are present at the oxidation states of As (III) and Cr (VI). Further, the stability of the treatment process residuals in leaching environments is also influenced by As and Cr speciation. This is due to the low binding capacity of the metal oxy-hydroxides. To enhance removal, it is beneficial to oxidize As (III) to As (V) and reduce Cr (VI) to Cr (III) prior to sorption and coagulation. The proposed research is to investigate the simultaneous oxidation of arsenic and reduction of chromium to improve the efficiencies of their respective removal processes and produce stable non-leaching treatment residuals.

Heterogeneous photo catalytic reactions have been extensively studied in recent years, especially using TiO2 as the catalyst. The majority of these investigations have focused on modifying organic matter. When UV irradiates the TiO2 it undergoes either a conduction band (CB) or a valence band (VB) mediated photoreaction pathway. The pathway is dependent on the solution pH, scavengers, and other variables. Cr (VI) photo reduction occurs via both direct reduction by the photogenerated electrons in TiO2 CB, and the radical-mediated indirect route. Simultaneously, Ar (III) is directly oxidized by the photogenerated electron holes located in TiO2 VB or indirectly by the oOH radicals from the photo catalytic reactions. Thus, one can expect the simultaneous reduction and oxidation reactions using the TiO2/UV process. Besides the simultaneous reduction oxidation capacity, sorption of the resulting ions on to TiO2 is possible (with specific area of ~60 m2/g and pHzpc of 6.0). Further, the combined process of UV/TiO2 with pre coagulation and membrane filtration could be one of the most effective methods for simultaneous arsenic and chromium removal.

Most of the past investigations concerning arsenic oxidation and chromium reduction have been focused on empirical kinetic studies and not on simultaneous reduction/oxidation in mixed material systems. These past results are difficult to compare to simultaneous oxidation/reduction processes due to difference in reaction conditions.

Research Objectives

The objectives of my research will be the development of a process for the simultaneous arsenic oxidation and chromium reduction and a unified predictive model for the combined operations of arsenic oxidation, chromium reduction, sorption, and coagulation/ flocculation. TiO2/UV process may be the best approach however the Fenton reagent system will also be examined. Other methods may be discovered and found to be vastly superior to either the photocatalytic or iron systems. The research proposed seeks to obtain practical applicability and predictive capability that will allow for the selection of proper oxidation and reduction operating techniques and conditions for contaminated water containing arsenic (III) and chromium (VI). This research will include development and verification of predictive models for the combined operations of arsenic oxidation, chromium reduction, sorption, and coagulation/flocculation. This work will comprise the following: determination of the optimum arsenic oxidation and chromium reduction processes based on prior literature and laboratory experiment; experimental investigation of the simultaneous arsenic oxidation and chromium reduction; kinetic modeling for arsenic oxidation and chromium reduction, based on not only the reaction order and rate constant but also radical and electron reactions; and verification of the simultaneous oxidation/reduction kinetic model derived.

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Academic Qualifications

At Texas A&M University I have As a graduate research assistant, I recently conducted a study of the Texas A&M Brayton Fire School's wastewater treatment system. The data collected through this project will be used in the future to optimize treatment of the wastewater, allowing the fire school to improve water quality and reduce cost. At project completion, a report was presented to Brayton Fire School's personnel and the Texas A&M University faculty.

As a National Science Foundation intern at the Center for Advanced Engineering Fiber and Films (CAEFF), I worked within a multi-disciplinary research team. My role within the project was to analyze filter samples acquired from DuPont corporation using optical microscopy and image analysis software to develop a particle size distribution function for computer modeling of polymer flow through rigid filtration media. At the completion of the project, an abstract and poster were presented to industrial personnel and the CAEFF's faulty and staff.

As an undergraduate research assistant at the University of Puerto Rico at Mayagüez, I had the opportunity to conduct research with three distinguished members of the faculty. The first research experience allowed me to work with a professor in organic chemistry. My responsibility was to create a Fourier Transform Infrared spectroscopy library of the variety of substances the graduate students were using in their research. My second research experience consisted of the oxidation optimization of an alcohol with a relatively new catalyst, Magtrive. Samples were taken at different time intervals and analyzed using Nuclear Magnetic Resonance. My third research experience was with a professor in chemical engineering with whom I worked on two separate projects. First, I worked with a graduate student conducting research on biomass steam explosion. The project objective was to determine the viability of altering the structural features of the biomass by steam explosion. At the end of the project an oral report of the work was presented to the research team. The second project involved the optimization of proton exchange membrane fuel cell's performance by humidification control. The objective of the project was to identify the optimal operating conditions of a Hydrogen-Fuel Cell. Critical parameters such as membrane humidification, water balance, cell pressure and humidification temperature were evaluated using Nafion®-117 as the electrolyte. I conducted experiments by changing resistance to the flow through the fuel cell and measuring key parameters. I was pleased to have placed first at the 2000 AIChE National Student Poster Paper Competition in Los Angeles.

All of my research experiences have taught me essential professional skills such as good communication, social interactions needed for teamwork, and the importance of building a network of peers. Research is hard work that requires commitment and time. Also, it is important to note that by conducting research under a faculty advisor one becomes a junior research colleague of the faculty. I hope to establish a form mentoring relationship with my academic advisor and contribute in a positive manner to the body of knowledge. Further, I hope to improve the ability to remove toxic metals from contaminated water to improve human health.

Intended Career Path Statement

My career goals are to attain a professional occupation that is challenging and rewarding in any number of fields like industry, consulting, management, academia, and others. To achieve this I must initiate a self-directed program of research. My research experiences have taught me essential professional skills such as good communication, the social ability needed for teamwork, and the importance of building a network of peers. Research is hard work that requires commitment and time. Also, it is important to note that by conducting research under a faculty advisor one becomes a junior research colleague of the faculty. With this position comes responsibilities and thus accountability. Further I desire a research topic that utilizes my skills in engineering and chemistry. Thus, I wish to focus my research in an area that directly impacts human health. One such area is the removal of toxic metals from contaminated drinking water.