

## Project Summary

**Title:** Removal of As(III) and As(V) in Contaminated Groundwater with Thin-film Microporous Oxide Adsorbents

**Project I.D.:** R/UW-REM-003

**Investigators:** **Marc A. Anderson (Principal Investigator)**  
Professor, Environmental Chemistry and Technology Program  
University of Wisconsin – Madison

**Walter Zeltner**  
Associate Scientist, Water Science and Engineering Laboratory,  
University of Wisconsin – Madison

**Eunhyu Lee**  
Research Assistant, Dept. of Civil and Environmental Engineering  
University of Wisconsin – Madison

**Period of Contract:** July 2000 – June 2002

### Objectives:

The principal objective of this study is to develop and test inexpensive, high-performance photoactive adsorption media for the simultaneous removal of arsenite, As(III), and arsenate, As(V), from groundwater without pH adjustment. This process utilizes UV-irradiated photoactive thin films composed of novel mixed oxides prepared by sol-gel processing. These materials will be employed in a unique photocatalytic process, which simultaneously removes both arsenic species without additional pH adjustment or further chemical addition.

### Methods:

Aluminum oxide ( $\text{Al}_2\text{O}_3$ ), spinel ( $\text{MgAl}_2\text{O}_4$ ), and titanium oxide ( $\text{TiO}_2$ ) sols were synthesized by sol-gel technology and coated on glass beads. The adsorption efficiency of each coated material was determined in a batch reactor.

### Results and Discussions:

The relationship between the adsorption capacity and the pH of the isoelectric point (IEP) of aluminum oxide and spinel was intensively studied. The IEP of pure aluminum oxide was 8.0, but its IEP decreases to 5.4 when it adsorbs arsenic. Pure spinel had a higher IEP of 10.2, which decreased to 6.7 after adsorption of arsenic. The adsorption capacity for arsenic significantly decreased for both materials at pH values higher than their IEP. These results confirm that (1) adsorption of anions shifts the IEP of adsorbents to lower pH values and (2) the IEP of the adsorbent is strongly related to its adsorption capacity.

During this research, we also developed a novel approach for simultaneously removing both As(III) and As(V) without a separate oxidation step. This process involves heterogeneous photocatalytic adsorption. The adsorbent acts as a photocatalyst to oxidize arsenite to arsenate with the latter species being adsorbed by the catalytic adsorbent. Our studies utilized two types of nanoparticles,  $\text{TiO}_2$  and  $\text{AlOOH}$ . These particles were mixed as a stable suspension (sol) that was used to coat glass beads. The thin-films that were deposited on the beads served as both the photocatalyst and the adsorbent. Test solutions at pH 7.0 contained 0.01 M  $\text{NaNO}_3$  as a background electrolyte and initial concentrations of arsenite and arsenate of 3 mg/L in separate studies of adsorption in the presence and absence of UV light. Based on the batch tests, the amount of As (III) adsorbed onto the mixed Al+Ti medium was almost identical to that of As (V). These results suggest that almost 100% of arsenite is oxidized to arsenate with this latter species being adsorbed by the film.

### **Conclusions/Implications/Recommendations:**

Adsorption processes that employ activated alumina require a pH between 5.5 and 6.0 for optimum arsenic removal. Because these pH values are outside the pH range at which most water treatment plants operate (pH = 6.0 ~ 9.0), most plants install a separate pH adjustment unit before the adsorption process. Results of this study indicate that the IEP of pure aluminum oxide, which is the main component of activated alumina, is 8.0. This IEP decreases to 5.4 when the aluminum oxide adsorbs arsenate. This result confirms that the pH effect noted above is likely due to the adsorption of arsenate or other protolyzable anions on the activated alumina, which lowers its IEP from 8.2 to 5.5 ~ 6.0. The spinel material displays the same effect. However, because spinel has a higher intrinsic IEP than aluminum oxide, the adsorption capacity of spinel for arsenate does not decrease significantly over the typical pH range of natural waters. As a result, spinel adsorbs 2.5 times more arsenate than activated alumina at pH 7.0.

Another concern with arsenic removal is treating arsenite, which is uncharged at the pH of drinking water, therefore, difficult to remove by adsorption or ion exchange. Arsenite is typically removed by oxidizing it to arsenate and then adsorbing the arsenate. The use of a  $\text{TiO}_2$  photocatalyst has been shown to significantly accelerate the photooxidation of arsenite. Initial studies demonstrate that both arsenic species can be removed in a photocatalytic adsorption process using a novel thin-film material.

**Related Publications:** None at present.

**Key Words:** Arsenite, Arsenate, Adsorption, Surface Charge, Photooxidation, Arsenic Remediation

**Funding:** University of Wisconsin Water Resources Institute