

Physicochemical Properties and Surface Complexation Modeling of Nano-Scale Hydrrous Ferric Oxide Incorporated Natural Aluminumsilicate: Implication of Arsenic-Contaminated Groundwater Remediation

Min Jang^{1*} · Jae Kwang Park¹ · Jai-Young Lee² · Sang Il Choi³

¹Department of Civil and Environmental Engineering, University of Wisconsin-Madison

²Department of Environmental Engineering, The University of Seoul

³Department of Environmental Engineering, Kwangwoon University

e-mail: jang@cae.wisc.edu

ABSTRACT

Arsenic contaminations in groundwaters are creating potentially serious environmental problems for humans and other living organisms. Due to this recognition, a new arsenic limit of $10 \mu\text{g L}^{-1}$, lowered from the current $50 \mu\text{g L}^{-1}$, will become effective in 2006 for the United States water treatment systems, resulting in that small public water utilities will face heavy financial burdens to comply with this regulation. In the world, arsenic contamination of groundwater is remarkably problematic in Bangladesh, where most people rely on tube wells as a source of drinking water. About 40~60 % of the population (125 million people) in Bangladesh have been estimated to be adversely affected by arsenic contamination. Thus, there is an urgent demand for an economic, highly effective, and reliable technique that is capable of removing arsenic species to this new level. In this study, a simplified and highly-effective method was tried to immobilize iron oxide onto a natural-occurring porous aluminum silicate (diatomite). Experimental results of several physicochemical properties (XRD and nitrogen sorption isotherm) and arsenic edges showed that iron oxide incorporated into diatomite was homogeneously dispersed amorphous hydrrous ferric oxide (HFO). Amorphous HFO has been widely studied as a promising adsorptive material for removing both arsenate and arsenite from aqueous phase due to its high isoelectric points (IEPs, 8.1) and selectivities for arsenic species. Sorption trends of iron 25% (based on the mass of

supporting material) impregnated diatomite [designated as Fe (25%)-diatomite] for both arsenite and arsenate were similar to those of HFO, reported by Dixit and Hering (2003). The pH at which arsenite and arsenate are equally sorbed was pH 7.5, which also corresponds to the value reported for HFO. Based on the mole of iron incorporated into diatomite, arsenic sorption capacities of Fe (25%)-diatomite were comparable to or higher than those of the referenced HFO. Surface complexation modeling revealed that large differences in constants of arsenate surface species between Fe (25%)-diatomite and reference media (HFO or goethite) might be attributed to aluminum hydroxyl groups in the diatomite. Modified differential column batch reactor (DCBR) and small-scale column tests demonstrated that Fe (25%)-diatomite had rapid sorption speeds and high sorption capacities compared to a conventional sorbent (AAFS-50) that has been known as the first preference in removing arsenic in Bangladesh. Column tests were conducted to determine arsenic removal efficiencies for both AAFS-50 and Fe (25%)-diatomite. For arsenite case, Fe (25%)-diatomite treated about 1,100 or 2,200 BVs based on $10 \mu\text{g L}^{-1}$ (new regulation) or $50 \mu\text{g L}^{-1}$ (current regulation) of arsenic concentration, respectively, showing much better performance than AAFS-50. AAFS-50 treated only about 150 BV below $50 \mu\text{g L}^{-1}$. In the column results of arsenate, AAFS-50 had higher removal capacity of arsenate (350 BVs below $50 \mu\text{g L}^{-1}$) than arsenite. As shown in arsenite case, Fe (25%)-diatomite had much better performances than AAFS-50. About 1,100 or 2,100 BVs of arsenate solution were treated below 10 or $50 \mu\text{g L}^{-1}$ for Fe (25%)-diatomite. Accordingly, Fe (25%)-diatomite had similar performances for both arsenite and arsenate in column tests, as shown in batch kinetics or edge tests. These results could be explained from the fact that Fe (25%)-diatomite contained highly-dispersed HFO having a great affinity for arsenic species and well-developed macropore structure as shown by SEM and PSD analysis. HFO-diatomite developed in this study is thought to be better than conventional media due to its high arsenic removal efficiencies, as well as simple and environmentally-friendly preparation method.

Key words: groundwater, arsenic, diatomite, amorphous hydrous ferric oxide, surface complexation modeling