

Arsenic removal from drinking water using granular ferric hydroxide

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Abstract

This paper examines the use of granular ferric hydroxide (GFH) to remove both arsenate [As(V)] and arsenite [As(III)] present in drinking water by conducting batch and column studies. The kinetic studies were conducted as a function of pH, and less than 5 µg/l was achieved from an initial concentration of 100 µg/l for both As(III) and As(V) with GFH at a pH of 7.6, which is in the pH range typically encountered in drinking water supplies. In the isotherm studies, the observed data fitted well with both the Freundlich and the Langmuir models. In continuous column tests (five cycles) with tap water using GFH, consistently less than 5 µg/l of arsenic was achieved in the finished water for 38 to 42 hours of column operation, where the influent had a spiked arsenic concentration of 500 µg/l. High bed volumes (1260 and 1140) up to a breakthrough concentration of 5 µg/l were achieved in the column studies. The adsorptive capacities for GFH estimated from the column studies were higher than that of activated alumina reported in the previous studies. Speciation of a natural water sample with arsenic showed the dominance of As(III) species over As(V). Batch and column studies showed that granular ferric hydroxide (GFH) can be effectively used in small water utilities to achieve less than 5 µg As/l in drinking water.

Keywords: adsorption, drinking water, arsenic removal, granular ferric hydroxide, arsenic speciation

Nomenclature

C	equilibrium concentration (µg/l)
C_e	effluent adsorbate concentration (µg/l)
C_o	influent adsorbate concentration (µg/l)
k	Thomas rate constant (ml/min.µg)
x	mass of solute adsorbed (µg)
m	mass of adsorbent (g)
b	a constant related to the energy or net enthalpy of adsorption (l/µg)
Q^o	mass of adsorbed solute completely required to saturate a unit mass of adsorbent (µg/g)
K	the Freundlich constant indicative of the adsorption capacity of the adsorbent (l/µg)
k	rate constant for adsorption (g/h.µg)
n	experimental constant indicative of the extent of adsorption of the adsorbent
Q	volumetric flow rate (ml/min)
q_o	maximum solid phase concentration (µg/g)
V	throughput volume (ml)
R	separation factor estimated from the Langmuir constant
r	regression coefficient.

Introduction

Arsenic contamination of surface and subsurface waters is reported in many parts of the world and is considered a global issue. As a naturally occurring toxic substance in the earth's crust, arsenic

enters into aquifers and wells through natural processes, and to the water cycle as a result of anthropogenic activities. Arsenic contamination of subsurface waters is believed to be geological. High arsenic concentrations may result from dissolution of, or desorption from iron oxide, and oxidation of arsenic pyrites (Welch et al., 1999). The severity of arsenic pollution of groundwater is reported in Bangladesh, where most of the people rely on tube wells as a source of drinking water. It is estimated that 30 to 70 million people in Bangladesh are at risk due to the exposure of arsenic contaminated water (Chowdhury et al., 1999; Ward, 2000). Until recently, occurrence of arsenic in Bangladesh water supplies was believed to be caused by pyrite oxidation; however, recent studies showed that the causative mechanism of arsenic release to groundwater was reductive dissolution of As-rich Fe oxyhydroxide. The reduction was driven by microbial degradation of organic matter, which was present in concentrations as high as 6% C in water (Nickson et al., 2000; McArthur et al., 2001).

Ingestion of inorganic arsenic can result in both cancer (skin, lung and urinary bladder) and non-cancer effects (NRC, 1999). The acute and chronic toxicity effects of the ingestion of arsenic-contaminated water have been well documented. Population-based studies showed that arsenite [As(III)] and arsenate [As(V)] may adversely affect several organs in the human body (Tseng et al., 1968; Smith et al., 1998; Mazumder et al., 1998; Subramanian and Kosnett, 1998; Ma et al., 1999; Chowdhury et al., 1999; Karim, 2000). Since the majority of the people affected world-wide live in small communities, it makes sense to develop a treatment technology tailored for small communities. Furthermore, a reduction in acceptable consumption levels of arsenic by the regulatory agencies is forcing water utilities to identify and implement cost-effective arsenic removal technologies.

Treatment technologies that have been tested to remove arsenic from drinking water under both laboratory and pilot-scale studies were summarised by Viraraghavan et al. (1994). Iron-based salts

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