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Innovative Remediation of Arsenic in Groundwater by Nano Scale Zero-Valent Iron

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Abstract

This research examines the feasibility of using laboratory-synthesized nano scale zero-valent iron particles to remove arsenic from aqueous phase. Batch experiments were performed to determine arsenic sorption rates as a function of the nano scale zero-valent iron solution concentration. Rapid adsorption of arsenic was achieved with the nano scale zero-valent iron. Typically 1 mgL^{-1} arsenic (III) was adsorbed by 5 gL^{-1} nano scale zero-valent iron below the 0.01 gL^{-1} concentration within 7 min. The kinetics of the arsenic sorption followed pseudo-first-order reaction kinetics. Observed reaction rate constants (K_{obs}) varied between 11.4 to 129.0 h^{-1} with respect to different concentrations of nano scale zero-valent iron. A variety of analytical techniques were used to study the reaction products including HGAAS (hydride generator atomic adsorption spectrophotometer), SEM (scanning electron microscopy) and TEM (transmission electron microscopy). Our experimental results suggest novel method for efficient removal of arsenic from groundwater.

key-words: nano scale zero-valent iron, pseudo-first-order reaction, sorption.

1. Introduction

Arsenic compounds are toxic and carcinogenic (1,2,3).The world health organization (4) has set a guideline concentration of 0.01 mgL^{-1} for arsenic in drinking water. Adsorption is one of the many methods to remove As from ground water. Attention has recently focused on zero-valent iron (Fe^0) for immobilizing arsenic. The mechanism of As (III) and As (V) removal involves adsorption of As (III) and As (V) on iron oxide formed in-situ as a result of the Fe^0 corrosion reaction (5,6,7). Nano scale zero-valent has been applied extensively in the remediation of Cr (VI) and Pb (II) (8), nitrate (9) but there are less research in the remediation of arsenic. We present here the application of laboratory synthesized nano scale zero-valent iron for the remediation of arsenic. The main objective of our research is to investigate the removal of As (III) from aqueous solutions by the adsorbent developed from nano scale zero-valent iron.

2 . Materials and Method

Nano scale zero valent iron was synthesized by using already reported method (10). All the chemicals used were of analytical grade unless otherwise specified. Stock solutions of As (III) were prepared from reagent grade $NaAsO_2$ (Aldrich). Required amount of nano scale zero-valent iron was added to 50 mL polypropylene copolymer centrifuge tube (Corning, USA) containing 20 mL solution of desired concentration of As (III). The samples were placed on a water bath shaker (185 rpm) at 25 °C temperature. After completion of reaction, the suspensions were filtered through 0.22 μm membranes and determined by HGAAS.

3. Results and Discussion

3.1 Effect of dosases of adsorbent

The influence of nano scale zero-valent iron concentrations (0.5, 2.5, 5, 7.5, 10 gL^{-1}) on the rate of adsorption of the As (III) was investigated using 1 mgL^{-1} of the As (III) and initial solution pH; results are shown in Figure 1. From the Figure 1, it is evident that there is an initial faster rate of disappearance of As (III) from aqueous solution. The adsorption of arsenic took place within 7 min. It was found that As (III) adsorption increased upon increasing the adsorbent concentration, because as the number of active sites of iron particles for As (III) adsorption increases, the adsorption rate of the arsenic increases (9). The lower adsorbent concentration decreases active sites, which reduces the As (III) adsorption. The fact that this initial high rate of removal suggest that the mechanism is physical rather than chemical (8).

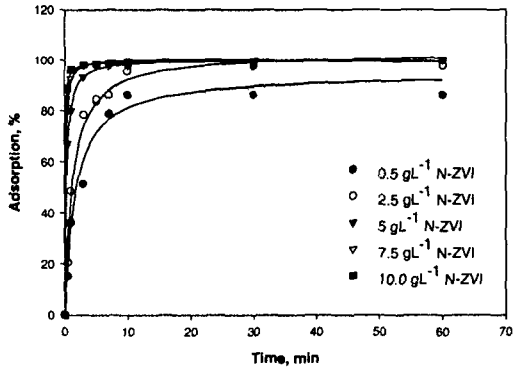

Figure 1. The effect of NZVI content on the adsorption of arsenic of 1ppm solution with different concentration of NZVI.

3.2 Kinetics of Arsenic adsorption by nanoscale zero-valent iron

The adsorption of arsenic was examined using 0.5 gL^{-1} to 10.0 gL^{-1} of nano scale zero-valent iron in a 50 mL vial without controlling pH of the solution (Figure 2). The rate of removal of arsenic fitted to pseudo-first-order reaction kinetics:

$$Ln(\frac{[As]t}{[As]_o}) = -k_{obs}\, t \qquad (1)$$

where [As]t and [As]o are the concentrations of As(III) at time t and 0, respectively, and k_{obs} is the pseudo-first-order rate constant (h^{-1}). The rate constant of the adsorption of the As (III) was calculated from the slope of the plot of As (III) concentration, on a logarithmic scale, versus time (Figure 2). For 20 mL of arsenic solution and 0.5 gL^{-1} to 10.0 gL^{-1} nano scale zero-valent iron, the initial As(III) adsorption rates were 11.4 to 129.0 h^{-1}, respectively (Table 1). It was found that there was an initial faster rate of disappearance of arsenic from aqueous solution. The adsorption of arsenic took place within 7 min. This sequence of reactivity was consistent with the results of remediation of chromium (VI) and lead (II) by nano scale zero-valent iron (11).

Table 1. Pseudo-First-Order Rate Constants (kobs) for arsenic removal by nano scale zero-valent iron.

Nanoscale zero-valent iron, gL^{-1}	k_{obs}, min^{-1}	R^2
0.5	11.4	0.85
2.5	16.2	0.94
5.0	33.6	0.99
7.5	49.8	0.94
10.0	129.0	0.99

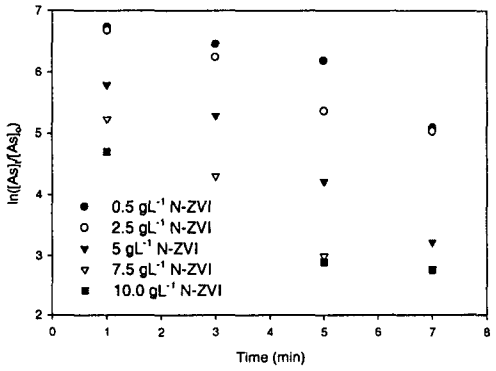

Figure 2. Comparision of first order kinetic remediation of arsenic : 1g/L of As(III), initial solution pH.

3.3 Morphological study of adsorbent

The morphological appearance of the nano scale zero-valent irons using SEM is shown in the Figure3 below. It shows surface texture and different pore sizes of the material. More than 90% of synthesized nano scale zero-valent irons were in the size of 1-100 nm, which is confirmed by SEM and TEM study. The BET specific surface area of nano scale zero-valent iron was 30 m^2/g. TEM bright images of nano scale zero-valent iron samples are presented in Figure 4 below, which shows existence of nano particles.

Figure 3. SEM photomicrographs of zero-valent iron general appearance

Figure 4. TEM micrographs of nano nano scale scale zero valent

4. Conclusion

The results show that nano scale zero-valent iron can be used for the effective removal of As(III) under the defined optimized condition. The removal of As (III) is 99% at 1 mgL^{-1} initial arsenic concentration at 5 gL^{-1} nano scale zero valent iron concentration and at the initial pH of the solution. The adsorption reaction was very fast (within minutes). The nano scale zero-valent iron (1-100 nm size) is one of the adsorbent to remove arsenic from ground water effectively, reliably and cost effectively. Further studies such as effect of temperature, anions, dissolved organic matter and inorganic constituents is going on in our laboratory for its *in-situ* and *ex-situ* application.

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