

# Removal of arsenic (III) from groundwater by nature iron oxides adsorbent

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## 1 ABSTRACT

The aim of this study is to evaluate the potential for removal of arsenic (III) from groundwater through adsorption mechanisms, using naturally-occurring and low-cost iron oxides. The surface area of the used adsorbent was 3.10 m<sup>2</sup>/g. Batch experiments were conducted with different amounts of adsorbent (0.5 to 30 g/L). The arsenic solution was prepared using underground water and an As<sup>3+</sup> concentration of 100 µg/L. The system was constantly stirred at 150 rpm for 12 hours.

The results indicate 100% As<sup>3+</sup> removal after 3 hours using a dose of 20 g/L of iron oxides. A dosage of 20 g/L of iron oxides and 2.25 hours or 10 g/L and 5.5 hours of retention time produced water quality in agreement with the international standards (10 µg/L). The maximum adsorption capacity of the material was 164 µg As/g. The concentration of iron ions in the effluent was an average of 0.03 mg/L.

## 2 INTRODUCTION

Arsenic (As) is found in most bodies of groundwater as part of the geological background or anthropogenic contamination. It is usually found in low quantities that are nevertheless high enough to cause adverse health effects. The cases of millions of affected people have been studied and documented in many parts of the world such as Bangladesh (0.25-1600 µg/L), India (50-23800 µg/L), Taiwan (10-1800 µg/L), Mexico (1-160 µg/L), USA (2600 µg/L) (Lillo J., 2000). The US Environmental Protection Agency (EPA, 1999) and the World Health Organization (OMS, 1996) established a concentration of 10 µg/L total As in water as the maximum permissible limit. In Mexico, the maximum concentration of total As in water destined for human consumption is 25 µg/L (NOM-127, 1994). The removal of As through adsorption processes using iron oxides has been widely documented and shown to be highly efficient.

## 3 MATERIALS AND METHODS

Arsenic (III) solution (100 µg/L) was prepared using sodium arsenite (NaAsO<sub>2</sub> 100%) from Fisher Scientific laboratories. This salt was diluted in water, which comes from underground water wells in Chihuahua City. The adsorbent (Fe-oxide) was from natural origin, distributed by Quimicos, Reactivos y Minerales S.A. de C.V. (QRM). Batch experiments were conducted for different amounts of adsorbent (0.5 to 30 g/L). The Fe-oxides were mixed with the As<sup>3+</sup> solution using jar test equipment. The system was constantly stirred at 150 rpm (Maiti et al. 2007) for 1 to 12 hours. The influence of stirring on the adsorption processes was determined for 100, 150 and 200 rpm. The analysis was conducted under room temperature and the pH of natural water.

The characterization of the adsorbent was performed with the Brunauer-Teller (BET) method using Quantachrome Corporation equipment for determining the surface area and Phillips X-Ray diffraction equipment (model X'Pert) for determining the adsorbent crystal structure. The elemental analysis was conducted using a JEOL scanning electron microscope (SEM), model JSM 5800-LV. As and Fe concentrations were determined using a GBC atomic absorption spectrophotometer with Hydride generation (model Avanta Sigma).

## 4 RESULTS AND DISCUSSION

### 4.1 Characterization of adsorbent

The specific surface area was 3.10 m<sup>2</sup>/g, and the pore diameter of the Fe-oxide ranged between 3.50 and 6.20 nm. It was a mesoporous material according to the IUPAC (International Union of Pure and Applied Chemistry), and was classified as a slightly porous material with a multilayer adsorption mechanism according to the BET isotherm classification. The X-Ray diffraction analysis shows that the adsorbent contains 56.52% hematite (Fe<sub>2</sub>O<sub>3</sub>), 25.20% magnet-

ite ( $\text{Fe}_3\text{O}_4$ ), 14.80% ferrous oxide ( $\text{FeO}$ ) and 3.50% iron (Fig. 1). The Scanning Electron Microscope (SEM) shows the inorganic composition of the material: Fe (70.27%), O (19.50%), Ca (4.78%), Si (3.55%), Al (1.27%) and Mg (0.64%) (Fig. 2c). The micrographs were taken at  $\times 550$  (Fig. 2a) and  $\times 4300$  (Fig. 2b) magnification. In both cases, the micrographs show particles with different sizes and low porosity.

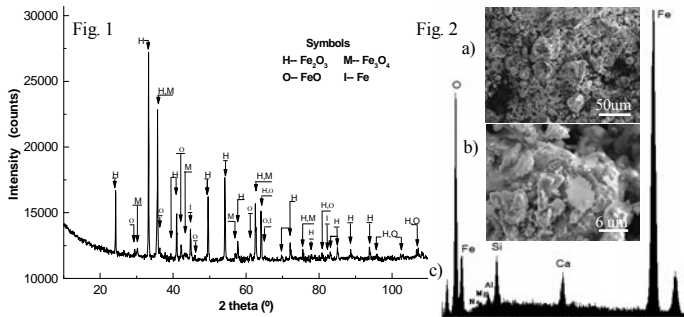


Figure 1: X-Ray diffractogram of Fe-oxides. Figure 2: a) Fe-oxides EDS ( $\times 4300$ ). b) Micrographs at  $\times 550$  and c)  $\times 4300$

#### 4.2 Arsenic removal efficiency

Higher amounts of the adsorbent (20 to 30 g/L) allowed a very fast removal (100%) of  $\text{As}^{+3}$  in 3 hours. 89% of As was removed during the first two hours using concentrations of 20 g/L, a result in agreement with the Mexican standards (NOM-127, 1994). Using 12.0 g/L and 4 hours, 15.0 g/L and 3.5 hours or 17.0 g/L and 3.0 hours, water with concentrations lower than 10  $\mu\text{g/L}$  were also obtained (EPA-OMS). The arsenic removal efficiency using small amounts of Fe-oxides (2-3 g/L) is low, and the total reaction times are over 12 hours. Similar results are reported by Singh et al. 1996. The optimum conditions of operation were 20 g/l of Fe-oxides and 2.25 hours or 10 g/L and 5.5 hours of retention (Fig. 3).

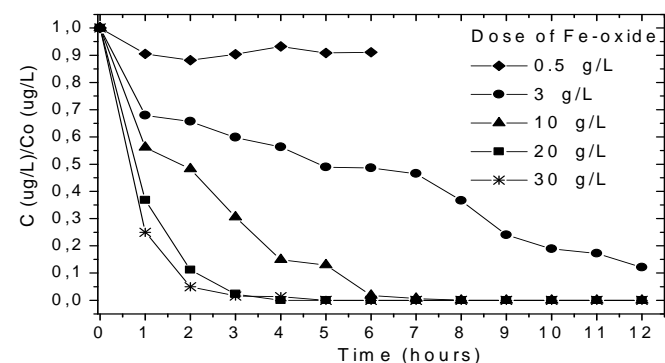


Figure 3: Arsenic removal efficiency (Co: 120  $\mu\text{g/L}$ , pH: 8.0; time: 12h; agitation: 150 rpm)

#### 4.3 Effect of stirring speed

The effects of stirrer rpm on the arsenic adsorption are presented in Figure 4. It was observed during the experiment that 100 rpm is not enough to keep 100% of the iron particles in suspension; larger particles

(diameter  $> 106 \mu\text{m}$ ) precipitate. Similarly, the efficiencies achieved with 150 and 200 rpm are quite similar; arsenic removal is almost invariant at higher rpm, so the use of extra energy was not justified. The optimum stirring was 150 rpm a value consistent with A. Maiti et al., 2007. The results indicate that further increases in stirrer speed will only yield to incremental enhancement in mass transfer.

#### 4.4 Iron concentration in treated water

The variation of iron concentration in treat water is independent of the added adsorbent dose. The NOM-127, 1994 set the maximum allowable concentration for iron in drinking water at 0.30 mg/L. The treated water meets the limits of the norm, with an average effluent iron concentration of 0.03mg/L (Fig. 5).

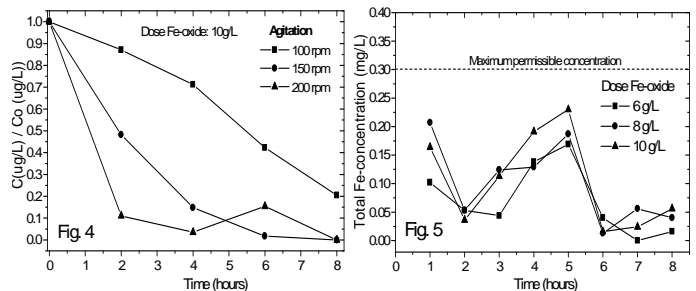


Figure 4: Effect of RPM on adsorption of  $\text{As}^{+3}$  ions (Co: 120  $\mu\text{g/L}$ ; time: 8h; Dose: 10 g/L). Figure 5: Variation of total iron concentration in the effluent.

### 5 CONCLUSIONS

This study indicates that the Fe-oxides are a highly effective adsorbent for the removal of  $\text{As}^{+3}$ . The conditions for optimum removal (100%) were 2.25 hours and 20 g/l or to 5.5 hours and 10 g/l, which produce a treated water quality (international standards). The maximum adsorption capacity of the material was 164  $\mu\text{g/g}$ . The material consists mainly of different species of Fe- oxides. The optimum stirring speed was 150 rpm. The pH of the system was between 8.02 and 8.55. The concentration of iron ions in the effluent was averaged 0.03 mg/L.

### 6 REFERENCES

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