# ADSORPTION OF ARSENIC (III) BY IRON OXIDES IN DRINKING Water

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## Abstract

The aim of this work is to characterize a material that consists of native Fe-oxide and evaluate its potential in the removal of Arsenic ($As^{3\pm}$) from the water through adsorption mechanisms. The surface area of the adsorbent was 3.10 $m^2/g$. X-ray diffraction indicates that the material contains 56% $Fe_2O_3$, 25.20% $Fe_3O_4$, 14.80% FeO, and 3.50% metallic Fe. The experimental analysis was conducted with a solution containing 100 µg/L of $As^{3\pm}$. The amount of Fe-oxide in the solution varied from 0.5 to 30 g/L (followed by a constant agitation of 150 rpm). The results indicate 100% efficiency in the removal of $As^{3\pm}$ was achieved in 3 hours using Fe-oxide at concentrations of 20 to 30 g/L. 85.2% of the $As^{3\pm}$ was removed in 4 hours and 99% in 6 hours, both using a solution with 10 g/L of Fe-oxide. The maximum adsorption capacity of the material was 164 µg/g whereas 89% of the $As^{3\pm}$ was removed in 2 hours using a solution of 20 g/L of Fe-oxide. These results are in agreement with the recommended international requirements for human water consumption.

## Introduction

Arsenic ($As^{3\pm}$) is found in low quantities as part of the geological background of several aquifers. However, these $As^{3\pm}$ levels are enough to cause harmful effects on humans (i.e., 50 µg/L (Argentina), 135 µg/L (México-Chihuahua), > 1000 µg/L (Bangladesh)). The Environmental Protection Agency (EPA, 1999) and the World Health Organization (OMS, 1996) established a concentration of 0.01 mg/L total As in the water as a recommendable limit. The maximum concentration of total As in water destined for human consumption is 0.025 mg/L (NOM-127); authorities are trying to decrease this concentration to 0.010 mg/L. The use of Fe-oxides in the removal of $As^{3\pm}$ proves to be a good option due to its natural occurrence in nature, easy availability and low cost.

## Methods and Materials

The adsorbent is from natural origin (distributed by Quimicos, Reactivos y Minerales S.A.) An arsenic ($As^{3\pm}$) solution (100 µg/L) was prepared using sodium arsenite ($NaAsO_2$, 100%) (Fisher laboratories). This salt was diluted in water, which comes from underground water wells in Chihuahua City. The total As concentration from this water was 20 µg/L.

Different amounts of (adsorbent) were mixed with the $As^{3\pm}$ solution using jar test equipment. The Fe-oxides amounts were from 0.5 to 30 g/L and were constantly agitated at 150 rpm (Maiti et al., 2007) for 1 to 12 hours. The solution was filtered and digested, and then the As was quantified. The analysis was conducted under room temperature and neutral water pH.

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

## Results and Discussion

The calculated surface area was 3.10 $m^2/g$ and the pore diameter of the material ranged from 3.50 and 6.20 nm. According to the BET isotherm classification (Gregg et al., 1967), this material is classified as a slightly porous material (isotherm type IV), and the adsorption mechanism was forming a multilayer.

Using the Scanning Electron Microscope (SEM), the inorganic composition of the material was: Fe (69.20%), O (21.51%), Ca (3.73%), Si (3.78%), Mg (0.73%), and Al (1.05%) as shown in Figure 1a. The micrographs show particles with different sizes and little porosity.

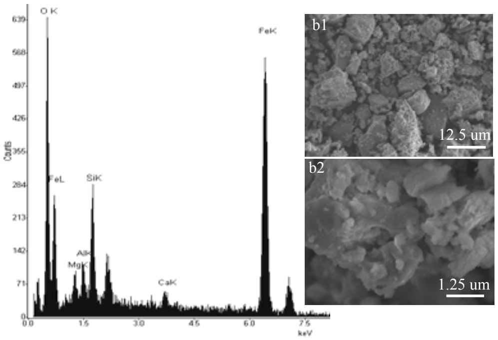

Fig. 1: a: Fe-oxides EDS (scale: 5000x); b: micrographs (scale 1000x and 10000x, respectively).

X-Ray diffraction analysis indicated that the material contains $Fe_2O_3$ (56.50%), $Fe_3O_4$ (25.20%), FeO (14.80%), and Fe (3.50%). Figure 2 shows the X-ray diffractogram.

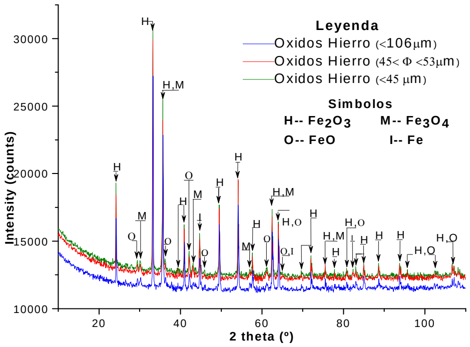

Fig.2: X-Ray diffractogram of Fe-oxides

Arsenic Removal Efficiency: Higher amounts of the absorbent (20 to 30 g/L) allowed a very fast removal (100%) of the As in 4 hours. 89% of As was removed during the first two hours using amounts of 20 g/L and this result is in agreement with the Mexican standards (NOM-127, 1994). Using 10 g/L, 85.2% of arsenic was removed in 4 hours and 99% in 6 hours. With 5 g/L, total As was removed after 9 hours of agitation. The efficiency of arsenic removal using small amounts of Fe-oxides (2 -3 g/L) is low and the total time of the reactions are over 12 hours. Similar results are reported by Maiti et al., 2007 and Singh et al., 1996.

The optimum conditions of operation are 20 g/l of iron oxides and 2 hours of agitation time. However, the amount of generated solids is high, therefore, it is important to consider lower amounts of Fe-oxides. This would imply longer reaction and retention times. Another option is to consider amounts of 10 g/L and 4 hours of retention. The energy consumption and the size of the equipment are two parameters to be considered.

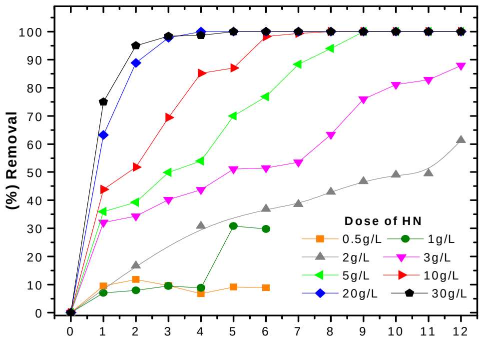

Fig. 3. Removal of $As^{3\pm}$ with different amounts of Fe-oxide (C: 12-µg/L, pH:8, time: 12 h, agitation: 150 rpm).

## Conclusions

This study indicates that Fe-oxide is a highly effective absorbent in the removal of $As^{3\pm}$. The optimum removal (100%) time ranges from 2 to 4 hours using amounts of 10 to 20 g/L, which allows to get a treated water quality in agreement with the international standards (10 µg/L). The maximum adsorption capacity of the material was 164 µg/g. The material consists mainly of $Fe_2O_3$ (56.50%), $Fe_3O_4$ (25.20%), FeO (14.80%), and Fe (3.50%). The surface area was 3.10 $m^2$/g.

## References

Maiti, A., Gupta, S.D., Basu, J.K., and De, S. 2007. Adsorption of arsenite using natural laterite as adsorbent. *Separation and Purification Technology* 55: 350–359

Singh,,D.B., Prasad, G. and Rupainwar, D.C.. 1996. Adsorption technique for the treatment of As(V)-rich effluents. *Colloids and Surfaces* 111: 49-56.

Gregg, S.J. and Sing, K.S.W. 1967. Introduction and physical adsorption of gases by non-porous solids. *Adsorption, Surface Area and Porosity*. Academic Press Inc. London Inglaterra and N.Y., USA. Pp. 1-8 y 93-108.

Official Mexican Standard NOM-127-SSA1-1994. Environmental Health, water for human use and consumption – permissible limits of quality and treatments to which water must be submitted for its drinkability.

World Health Organization, 1996. Guidelines for Drinking-water Quality, Health Criteria and Other Supporting Information, second ed., vol. 2. WHO, Geneva, Switzerland, pp. 940–949.

US EPA, 1999. Toxicity characteristics leaching procedure. US Environmental Protection Agency, Fed. Reg. 55, 11798–11877.