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Modified Hematite Iron for Removing Arsenic(V) from Water

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Abstract: The need for effective and cheap adsorbents will rise due to the extensive acknowledgement of the lethal health effects of arsenic exposure through drinking water. Natural iron ores was chemically modified with nitric acid for use as adsorbent. The modified ore was used for removing arsenic from water. Adsorbent dose, pH and contact time were the important parameters which were optimized using 1 mg/L of arsenic solution. Hematite a cheap indigenous iron ore was found very efficient for the adsorption of arsenic .Nearly 95 % As (V) was adsorbed using 4 g/L adsorbent dose optimum pH range 5–6.5. The column study was also conducted which showed adsorption capacity of 3.5mg/gm of arsenic adsorbed.

Keywords: Adsorption, Iron Ore, Arsenic

1. INTRODUCTION

Arsenic is extremely fata and leads to toxic and carcinogenic effects on human health. This metalloid is the cause of skin diseases, kidney and lung cancer and also is the source of neurological and cardiovascular damage. Due to these situations WHO has provided an intervening drinking water standard of 10 ppb, however many countries because of lack of treatment technology are still using 50 ppb as their drinking water standard (Toshishige, and Suzuki, 2000).

Arsenic in drinking water till today is a global issue and needs immediate attention. Recently Arsenic contamination has been testified in Bangladesh, USA, Chile,China,Mexico,Taiwan,Poland,Canada,Japan,New Zealand,Argentina, Pakistan, and India. In south-east Asia arsenic pollution has aroused responsiveness to the environmental activity and providence of Arsenic. The responsible activities for arsenic are mining, smelting of non-ferrous metals and burning of fossil fuels and wide use of fertilizers on crops, and fungicides (Xu, *et al.,* 1991 Anawar *et al.,* 2003) We are having Arsenic in water in many zones of Pakistan therefore it has become tremendously significant to identify the quality of drinking water for Arsenic. According to the report of Pakistan Council of Research in Water Resources (PCRWR) and UNICEF regarding monitoring of groundwater quality, in many areas of province Punjab 10–200 ppb) as was identified. In Sindh province, 10–50 ppb of arsenic has been found effecting nearly 16–36% of the population (Ahmad, *et al.,* 2004)

Worldwide thorough research is conducted to develop new treatment technologies for the treatment of drinking water to make it safe from arsenic. Technologies like membrane separation, precipitation-coagulation, lime softening, activated alumina, ion exchange, and adsorption are the widely used method (Kartinen, *et al.,* 1995) (Goldberg. *et al.,* 2001) (Han, *et al.,* 2002).

Among all these methods the adsorption technique has received much consideration using different materials like oxisol (Ladeira, *et al.,* 2004), manganese ore (Chakravarty, *et al.,* 2002) zeolite and volcanic stone (Elizalde-Gonz´alez, *et al.,* 2001) natural iron ore (Zhang, *et al.,* (2004) (hematite Ona-nguema, *et al.,* 2005).

Iron ores are present in abundance and are cheaper than synthetic materials for the removal of arsenic from water. In the present study Hematite ore is used as adsorbents for arsenic removal. This work therefore focused on important factors and their effect on arsenic adsorption.

2. MATERIALS AND METHOD

Materials:

Iron ore was kindly provided by Geological department, Sindh University Jamshoro. The main iron minerals in the samples was magnetite, hametite and limonite and its composition is given in **(Table 1)**. Hematite had the highest iron content, hence it was ground on the ball mill to reduce the size to 1.68 mm and finally sieved to obtain particle of 380 µm size. The samples were thoroughly washed with distilled water , and was then soaked in 0.001M HCl solution. The

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sample contained traces of HCL so it was rinsed several times with the distilled water. The sample was oven-dried at 50◦C overnight and then was chemically modified by 1N HNO_3 for 6h.

Table1: Composition of Magnetite

S. No	Elements	Hematite (%)	Siderite (%)	Limonite
1	Fe	45	36	31.3
2	SiO2	19.46	26	19.8
3	Al2O3	6.58	13	5.5
4	P	0.06	0.3	8.4
5	S	0.04	0.5	0.6
6	Ca	0.05	0.05	0.006
7	Mg	0.007	0.007	0.008
8	Others	1.0	1.0	1.2

The surface structure of Hematite was determined by Jeol JSM-6380 LV Scanning Electron Microscope equipped with an electron dispersive spectrometer (SEMEDS). All the reagents were of analytical grade. Stock solution of 1000 mg/L As(V) was prepared by dissolving of $Na_2HAsO_4.7H_2O$ in double distilled water. The stock solution was further diluted to prepare different concentrations of arsenic. The buffers of pH (2-3) (4-6) and (7-10) were prepared by mixing an appropriate volume of 0.1M solution of HCl- KCl, CH_3COOH-CH_3COONa and H_3BO_3-NaOH respectively.

Batch Experiments:

The sorption capacity was determined by shaking100 ml of 1mg/l As (V) with 0-10gm iron ore and mined with the magnetic stirrer for 30-180 mins. Arsenic solution of different pH 1-10 were used Samples were collected at fixed intermissions and filtered through 0.2lm membrane filter. The supernatant was analyzed for As, on inductively coupled plasma spectrometer (ICP), the result are an average of triplicate experiments. The following equations were used to calculate the sorption efficiency (%) amount of adsorption at equilibrium (qe mg/g).

$$qe\left({}^{mg}\!/\!{}_{g}\right) = \frac{(C_O - C)v}{m}$$

$$Sorption\ efficiency\ \% = \frac{C_o - C}{C_o} \times 100$$

Where Co and Ce represent the initial concentration and equilibrium concentration (mg/l) respectively. The volume of solution is v, the weight of ore is m (g) and C is the final concentration at the termination of the sorption process (mg/l).

Column study:

Glass filter column having internal diameter 8 mm and length 85 mm is used. The column is filled with 0.5 gm adsorbent up to 2mm bed volume and supported with both ends with glass wool. The column was supplied continuously with feed 600ppb of As(V) and of 8pH.. The adjusted flow-rate was 1ml/min, which relates to empty bed contact time of 2min.At different time intervals samples were collected and analyzed on ICP for the residual arsenic concentrations.

3. RESULT AND DISCUSSION

Batch adsorption study:

Effect of adsorbent dose and contact time

The Batch experiments were performed to find out the optimum contact time and the amount of adsorbent dose for maximum sorption of arsenic. 100 ml of 1 ppm arsenic sample were shaked on the magnetic stirrer with different dose of adsorbent 0–10 g/l. It was found that as the quantity of ore increased the removal efficiency also improved and highest sorption of 95 % was achieved when 4 g/l of iron ore was used **(Fig. 1).** Consequently4 g/l of adsorbent was used for further experiments. Kinetic study was performed using 4 g/l of adsorbate, the sample along with the adsorbate was shaked from 30 min to 180 min . Upto 99 % of arsenic removal was achieved within 90 min time hence a shaking time of 90-min is assumed as the equilibrium time.

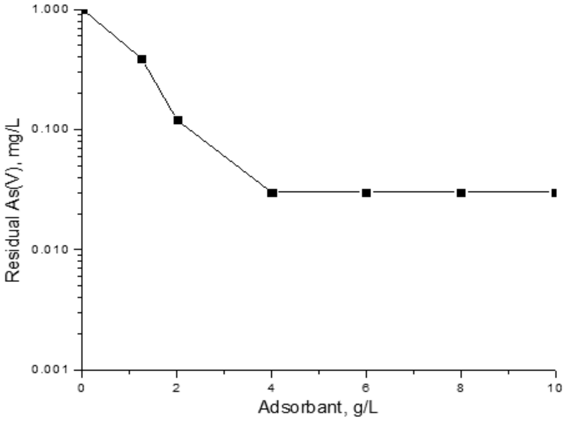

Fig 1.**Effect of adsorbent dose on As(V) adsorption**

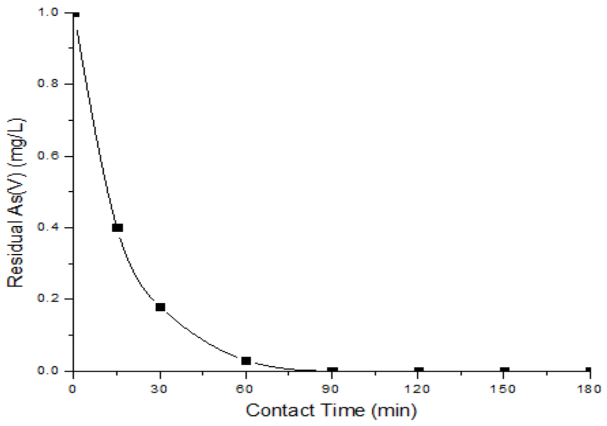

Fig 2. **Effect of Contact time As(V) adsorption on iron ore**

Effect of pH

4 g/l of iron ore was used for the sorption of 1 ppm arsenic samples of different pH 2-10. Maximum sorption was achieved in samples having5–6.5 which is very close the work reported by Zang (2004). At this pH minimum amount of iron ore is dissolved hence maximum sorption is achieved at this condition.

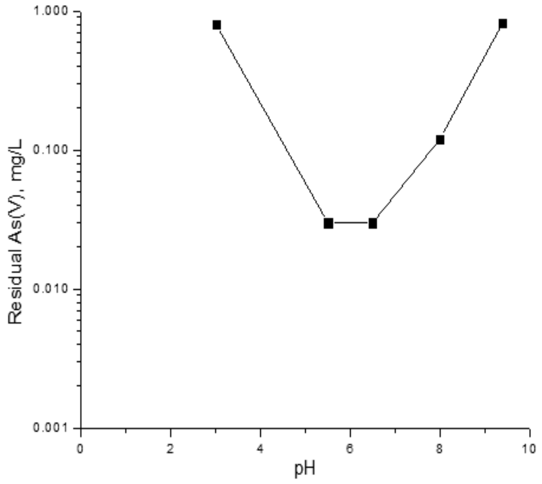

Fig. 3. **Effect of pH on As(V) adsorption on iron ore**

Column breakthrough test

The ore displayed a strong recollection of As(V) at pH 8in the column study. The feed solution of 600 ppb was constantly passed through the glass column packed with 0.5 g of the Hematite at 1ml/min flow rate. Where is fig (Fig. 4) shows the typical column water break through curve. As(V) was retained on the column to allow the passage of the feed solution for more than 1500 times of the bed volume. Almost3.5 mg of As was retained on 0.5 g of the ore.

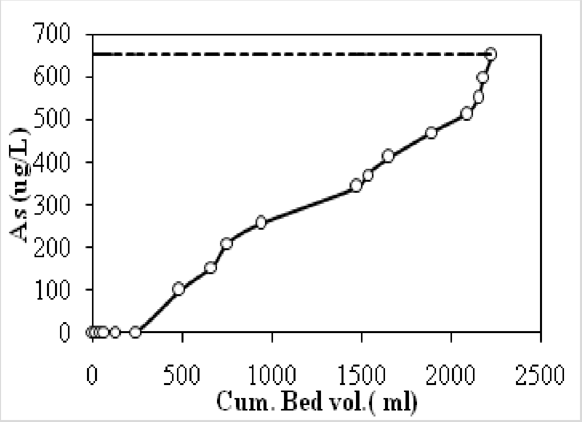

Fig. 4 Column breakthrough profile for the adsorption of As(V) by the Hematite iron ore in bed: 0.5 g (I.D. 8mm),1 As(V) feed: 600 ppm, pH8, flow-rate: 1 ml min .

SEM of the adsorbents

Surface images of the virgin Hematite iron ore, modified Hematite iron ore and the arsenic adsorbed hematite iron ore were analyzed by scanning electron microscopy (XL Series: XL30ESEM,Holland), as shown in **(5(a)–(c). Fig. 5(a))** shows SEM macrographs of the rough areas of the virgin ore at 500×magnification.

The structure look like that of a complex material with fibers regularly interspaced in the matrix. The fiber is silica and the matrix consists largely of cellulose, hemicelluloses and lignin (Anshu *et al.*, 2004) **(Fig. 5(b))** shows SEM micrographs of the surface areas of modified ore (500×magnification) comprising of open pores. (**Fig.5(c)** shows SEM micrographs (500×magnification)of modified ore when used as adsorbent to remove arsenic from the aqueous solution.

The blockage of the pores showed that arsenic has occupied the space favoring the phenomenon of sorption.

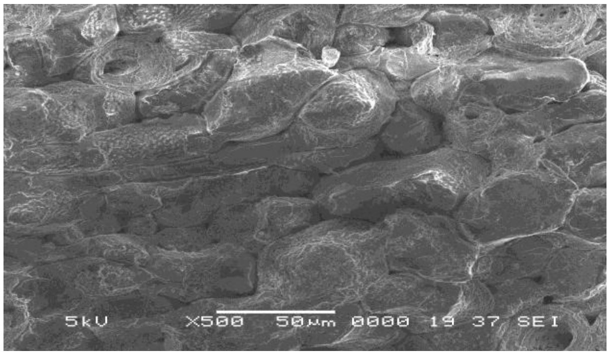

Fig. 5(a) Virgin Hematite iron ore

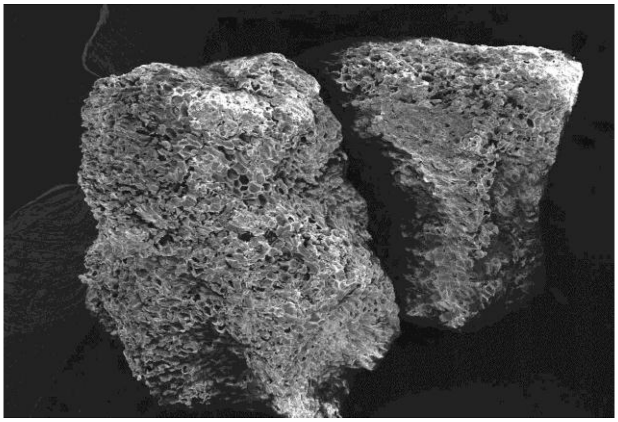

Fig. 5(b)–Modified Hematite iron ore

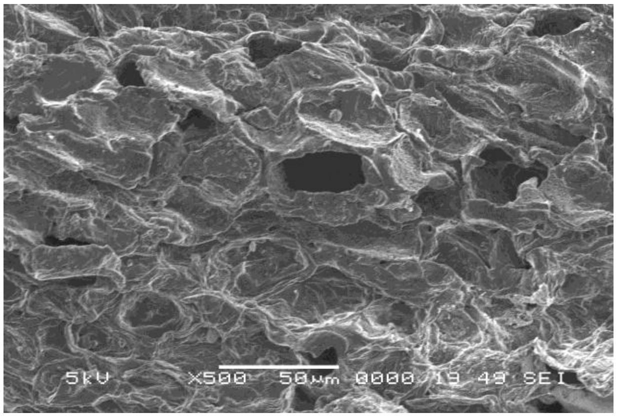

Fig. 5(c) Arsenic adsorbed hematite iron ore

4. CONCLUSION

The Hematite iron ores are effective in removing arsenic from water. Nearly 95 % of arsenic was adsorbed from water using 4 g/L adsorbent dose at the optimum pH range 5.–6.5. mg/L. . The results achieved in this experiments worthwhile for future studies on field scale for the treatment of groundwater for the removal of arsenic making the water safe for drinking purpose.

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