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Hazardous Effect of Arsenic and its Removal from Contaminated Water
by Alumina – An experimental study**

P. Rout^{1*}, H. M. Jena², S. Anand³ and R. P. Das³

^{1*}KMIPS, Chhend, Roukela,

²Deapt. of Chem. Engg., NIT, Rourkela.

³Regional Research Laboratory, Bhubaneswar-751 013, Orissa, India

ABSTRACT

Arsenic is a commonly occurring toxic metal in natural systems and the root cause of many diseases and disorders. In India arsenic is found in ground water primarily in West Bengal. In the present work adsorption studies of As(V) have also been carried out on alumina. During adsorption the effect of various parameters such as contact time, initial concentration, pH and adsorbent dose has been studied. Kinetics of adsorption showed that the uptake of arsenic is very rapid during first thirty minutes and equilibrium time is independent of initial arsenic concentration. The standard adsorption isotherms were fitted to the data.

Keywords: *Arsenic; Toxicity; Adsorption; Alumina*

1. INTRODUCTION

1.1 Occurrence and Prescribed Limit in Potable Water

Arsenic is a commonly occurring toxic metal in natural ecosystem. It is one of the most toxic elements in the environment and is of great interest in environmental studies [Siegeal (2002); Smedley (2002)]. In India, arsenic is found in groundwater in West Bengal, Orissa and Andhra Pradesh. Arsenic-enriched groundwater is also found in other parts of world, e.g. Bangladesh, USA (Arizona), Korea, Taiwan, Chile, Argentina, Mexico and Thailand [PHED, UNICEF (1999)]. The occurrence of geogenic As(III) and As(V) in ground water is a major problem in West Bengal and Bangladesh. The main anthropogenic sources are industrial waste, fossil fuel power plants, phosphate, fertilizers, coal, oil, cement, mine tailing, smelting, ore processing, metal extraction, metal purification, chemicals, glass, leather, textiles, alkali, petroleum refineries, acid mines, alloys, pigments, insecticides,

herbicides and catalysts. Organic forms of arsenic compounds occur primarily in seafood obtained from several marine organisms that extract arsenic from water and methylene the same to organic compound. The World Health Organization (WHO), the European Union, the United States, and many other countries have established 0.05 mg/L arsenic as the maximum contaminant level for total arsenic in potable water. However there is evidence of adverse health effects at lower exposure levels, and WHO promoted 0.01 mg/L arsenic as the new guideline value for arsenic in potable water. Arsenic enters the aquatic system in the dissolved form through industrial discharge such as metallurgical, glass and ceramic, pesticide manufacturing and petroleum refining industries etc.

1.2 Toxicity

Although arsenic is not the most toxic element especially in pentavalent state yet the same has drawn attention because of its notoriety as a poison both in history and popular literature. Important factors to be considered for a water source to be used for drinking purposes are its bacteriology quality and presence of certain inorganic constituent like fluoride and arsenic. The toxicity of arsenic varies greatly with its oxidation states as As(+3) is much more toxic and mobile than As(+5). Numerous recent investigations indicated that arsenic constitutes a serious health risk at different places and it was also confirmed by medical studies [Saha (1999)]. Ingestion via food or water is the main pathway of this metalloid in the organism, where its absorption takes place in the stomach and intestines, followed by its release into the blood stream. It gets deposited on or bound to tissues. Arsenic is converted by the liver to less toxic form, which is eventually largely excreted in the urine [Carroli (1996)]. It was estimated that more than two lakh people in West Bengal have arsenic skin lesions. Arsenic toxicity develops insidiously after six to twenty months of drinking arsenic contaminated water. In the initial period the skin of the body or palm becomes dark (diffuse melanosis) followed by spotted melanosis usually on chest, back or limbs. Leucomelanosis is common in persons who stopped arsenic contaminated water, but had spotted melanosis earlier. The other symptoms are conjunctival congestion, non-pitting swelling of feet, complications like liver and spleen enlargement and fluid in abdomen. Prolonged use of arsenic contaminated water results in carcinoma affecting lungs, bladder and other sites.

1.3 Treatment methods

A variety of methods have been used in the past for arsenic removal from drinking water and waste water. Existing methods of arsenic removal include precipitation [Chow

(1997), Harper *et. al.* (1992), Raman *et. al.* (1992)], adsorption [Elizalde *et. al.* (2001); Gregor (2001); Gupta *et. al.* (1978), Huang *et. al.* (1984),], ion exchange [Clifford *et.al.*(1991)] and ultra filtration [Bellack (1971)]. Arsenic adsorption reactions are influenced by changes in pH, occurrence of redox (reduction/oxidation) reactions, presence of competing anions, and solid phase structural changes at the atomic level. As a result, arsenic may be present in a variety of redox states. Arsenic and arsenite are the two forms of arsenic commonly found in ground water. Currently, Al or Fe hydroxides are commonly used as adsorption agents in water treatment systems [Hering *et.al.*(1996)]. Activated alumina is another such adsorbent, which has a great affinity for various organic and inorganic pollutants. It has been reported that activated alumina has been effective for arsenic removal [Lin *et.al.*(2001), Singh *et.al.*(2001)]. The aim of this work is to evaluate the effectiveness of alumina for the removal of arsenic from water and to investigate the parameters affecting arsenic removal.

2. MATERIAL AND METHODS

2.1 Chemicals

All the chemicals used in this study were of analytical grade. Alumina (Grade Sialca DF-1) was used for the adsorption studies. The properties of this material are given in Table 1. Stock As(V) solution was prepared from sodium arsenate ($\text{Na}_2\text{HAs}_2\text{O}_7 \cdot 7\text{H}_2\text{O}$) supplied by E. Merck, Germany. Synthetic As(V) solutions of different concentrations were prepared by diluting the stock arsenic solution.

Table 1 Data on alumina

Grade Sialca DF-1 Alumina: Ram Krishna Mission, Kolkota, India.

| Elements | Quantitative Value |
|--|--------------------|
| Surface Area , m^2/g (BET) | 268 |
| Particle size, mm | 0.5 – 2.0 |
| Pore volume, cc/g | 0.38 |
| Bulk density, g/cc | 0.75 to 0.85 |
| Al_2O_3 | 93.0 % min |

2.2 Adsorption

Batch adsorption experiments were carried out by taking different doses of alumina (0.1 – 1.0 g) with 50 ml of arsenic spiked distilled water. The arsenic concentration in water was varied from 7.5 to 150 ppm. All the adsorption studies were carried out in 250 ml

conical flasks at ambient temperature ($\sim 30^{\circ}\text{C}$). The solution volume used in each experiment was 50 ml. The solutions with adsorbent were stirred at a constant rate by a horizontal water bath shaker. A suitable volume of hydrochloric acid or sodium hydroxide solution was added to adjust pH that was measured with a digital pH meter (Systronic - pH System 361). After removal of the adsorbent by filtration, the concentration of the anion remaining was determined by UV – Visible spectrophotometer (UV – 2101 PC UV – Vis Scanning Spectrophotometer) using molybdate method at 840 nm wavelength. The adsorption isotherms were studied with varying doses of adsorbent at a fixed initial concentration of As(V).

3. RESULTS AND DISCUSSION

3.1 Adsorption Studies

3.1.1 Effect of time: The kinetics study of adsorption of arsenic from synthetic solutions at pH 7.0 and adsorbent concentration of 10 g/L was carried out and the results are shown in Fig.1. Adsorption kinetics is very fast and within 30 min maximum adsorption takes place and becomes almost constant after 1 h. The time data up to 1h was used for kinetic purpose.

3.1.2 Effect of As(V) concentration: The effect of initial arsenic concentration on adsorption is given in Fig.2. With an increase in arsenic concentration, the amount of arsenic adsorbed also increased upto arsenic concentration of 40 mg/L and beyond this concentration there was no significant change in adsorption indicating that the adsorption sites are saturated. The adsorption capacity was found to be in the order of 3.4 – 3.5 mg/g of adsorbent.

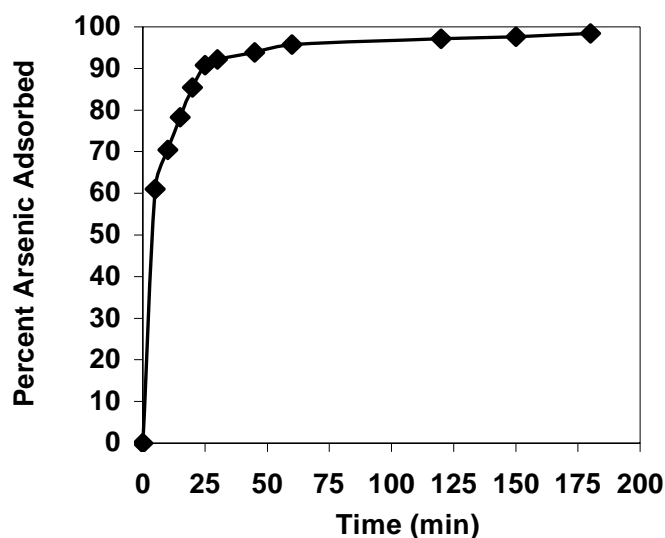


Fig. 1 Effect of time on adsorption of As(V) on activated alumina

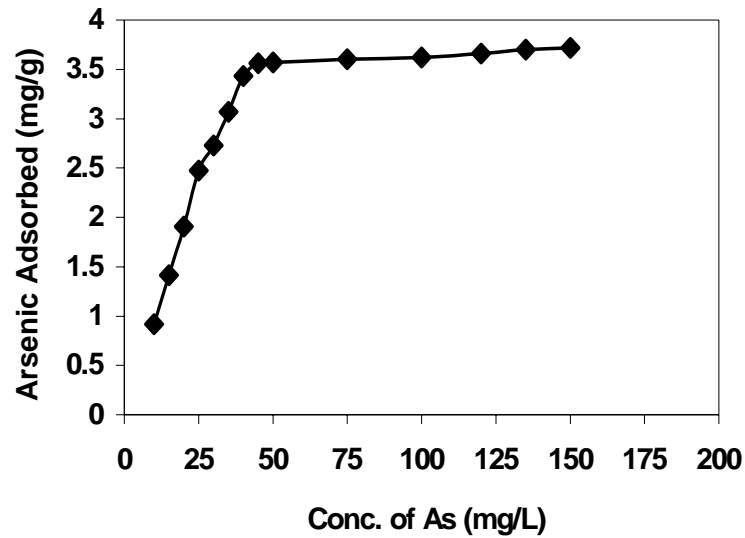


Fig.2 Effect of variation of As(V) concentration on its adsorption

3.1.3 Effect of adsorbent concentration: The effect of adsorbent dosage at pH 7.0 and arsenic concentration of 10 mg/L is shown in Fig.3. The contact time was maintained at 60 min. The amount of arsenic adsorbed increased with an increase in adsorbent dose and nearly 96.97 % of arsenic was adsorbed with 12 g/L of adsorbent. However, it can be seen that after 10 g/L there is only a small change in arsenic adsorption. Therefore, the value of 10 g/L has been used in further studies. Change in adsorbent dose did not affect the initial or the final pH.

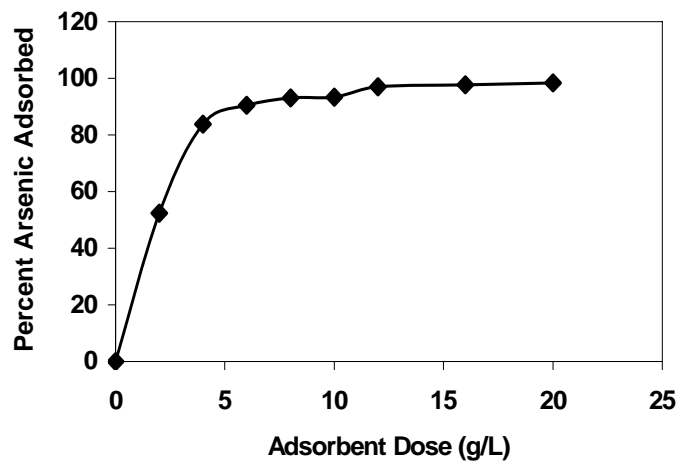


Fig. 3 Effect of adsorbent dose on the amount of arsenic adsorbed

3.1.4 Adsorption Isotherm (Langmuir plot) :Langmuir equation has the following form:

$$C_e/(x/m) = 1/ab + C_e/a$$

Where C_e is the equilibrium concentration (mg/L), x is the amount of arsenic adsorbed in mg and a and b are Langmuir constants and m is the mass of the adsorbent in g, (x/m is the amount adsorbed at equilibrium, mg/g),

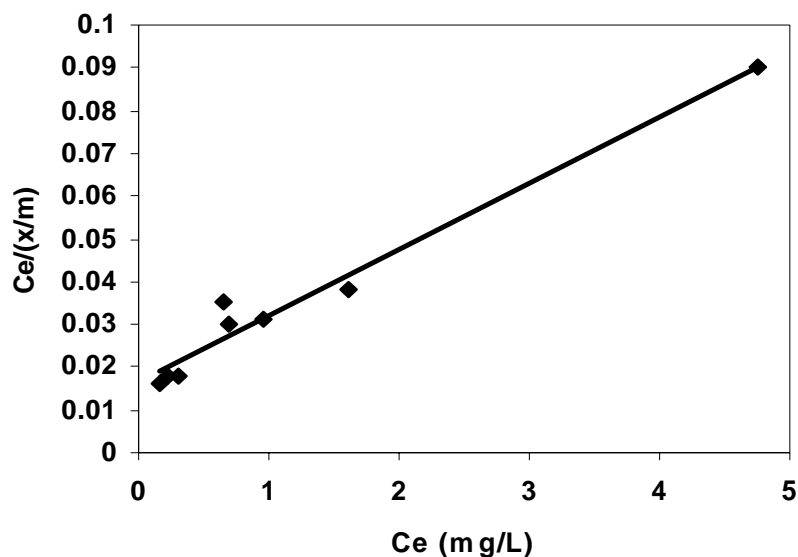


Fig. 4 Langmuir plot for adsorption of arsenic on activated alumina

4. CONCLUSION

- I. Optimum adsorption time is found to be 30 min at 10 g/L initial arsenic concentration at pH 7.
- II. Alumina can absorb more than 96.97% of arsenic at 12 g/L initial arsenic concentration in one hour at pH 7.
- III. Maximum loading capacity of alumina was found to be 3.5 mg/g.
- IV. The adsorption kinetics found to obey the Langmuir equation.
- V. Alumina can be effectively use to remove arsenic from drinking water.

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