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Removal of Arsenic From Wastewater Using Bentonite

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Abstract

Arsenic in water can do harm to human health. High arsenic concentrations have been reported recently from the USA, China, Chile, Bangladesh, Taiwan, Mexico, Argentina, Poland, Canada, Hungary, Japan and India. Conventional techniques used for arsenic removal involves oxidation, precipitation, membrane separation. The present study involves the removal of arsenic from wastewater by batch adsorption technique using bentonite. Bentonite contains montmorillonite which has the quality to adsorb inorganic and organic materials. Relying upon arsenic test strip method, the quantity of arsenic was determined after the treatment of 500 ppb arsenic solution with bentonite. Percentage adsorption was determined for bentonite-arsenic solution system as a function of i) contact time, ii) pH iii) temperature iv) mesh size and v) adsorbate dose. Maximum arsenic adsorption was observed at 20°C at pH 2 and 8. Minimum particle size favors maximum arsenic adsorption. The time taken to maintain equilibrium was 30 minutes. Bentonite is suitable for removal of arsenic from wastewater.

Key words: Arsenic removal, Bentonite, Batch adsorption, Wastewater

Introduction

In some areas of the world, arsenic presence in drinking water systems is a serious human health hazard. Serious adverse health effects, (NRC 1999) including human mortality, from arsenic contamination of drinking water are well documented. Arsenic (III) compounds are primarily non-ionic (Arivar *et al.* 2005) whereas arsenic (V) compounds are primarily ionic at normal drinking water pH levels. A simple and economical domestic arsenic removal kit (Goel *et al.* 2004) has been designed and successfully evaluated in

laboratory using sand-iron scrap mixture as media for the removal of arsenic from water. Removal of arsenic (V) from wastewater (Hong *et al.* 2000) by bentonite and D202 resin was studied. The peak adsorption appears at pH 4 and 7. For treatment of wastewater containing arsenites and arsenates (Velcheva *et al.* 1995) were treated with grey bentonite modified with $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, MgSO_4 or $\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$. The best results were obtained in the range

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pH 6 and 7 with bentonite modified with ferrous salts. Studies on removal of arsenic (III) by adsorption (Nagrnaik *et al.* 2004) on groundnut husk and carbon were carried out at room temperature. Maximum adsorption capacity was observed at pH 7.0. Arsenate adsorption (Ouvard *et al.* 2001) by a natural manganese oxide was studied. The affinity order was determined: arsenates \gg phosphates $>$ hydrogen carbonates \sim sulfate. The effectiveness of the use of special clays for heavy metal removal from waste water was evaluated. The sepiolite and the magnesian bentonite were effective in reducing the (Andrade *et al.* 2005) heavy metal concentration of the industrial wastewater samples. Photocatalytic oxidation of arsenite and simultaneous removal of the generated arsenate (Shen *et al.* 2006) from aqueous solution was investigated. Goethite was synthesized from the oxidation of ferrous carbonate. The optimum pH of adsorption (Lakshmipathiraj *et al.* 2006) was found to be 5.0. Biosorption of arsenic using algae as sorbent was studied. Maximum adsorption (Hansen *et al.* 2006) capacities were estimated to 45.2 mg/g (pH=2.5), 33.3 mg/g (pH=4.5), and 28.2 mg/g (pH=6.5) indicating better adsorption at the lower pH. The removal of arsenic (III) on iron oxide-coated sand in batch studies (Gupta *et al.* 2005) conducted as a function of pH, time, initial, arsenic concentration, and adsorbent dosage. An adsorption process for the removal of as (V) and as (III) was evaluated using zirconium (VI) loaded chelating resin. Arsenate

ions strongly adsorbed in the pH range from 2 to 5, (Balaji *et al.* 2005) while arsenite was adsorbed between pH 7 and 10.5. Contamination of drinking water due to arsenic is a severe health hazard problem. Present investigation aims to remove arsenic in water by using bentonite.

Materials and Methods

Sample

Bentonite sample was collected from Jehlum (Pakistan). The bentonite sample was oven dried at 100°C for 2 hours. The sample was crushed to fine powder and was passed through 25 microns sieve to study temperature, pH, adsorbate does, and time effect. The pH of 1% slurry of bentonite was 8. The time effect, adsorbate does, pH and mesh size effects were studied at 20° (room temperature).

Contamination control

All glass wares were washed carefully, rinsed by distilled water and kept in dust free atmosphere without touching their inside.

Reagents

All the reagents used of analytical grade. Arsenic solution (E. Merck) 1000 ppm was used to make standard i.e., 500 ppb arsenic solution.

Principle

Arsenic strip test method was used for the determination of arsenic quantity after

adsorption of 500 ppb arsenic solution on bentonite clay. When zinc and sulphuric acid were added to compounds of arsenic (III) and arsenic (V), arsine hydride was liberated, which in turn reacted with mercury (II) bromide contained in the reaction zone of the analytical test strip to form yellow brown mixed arsenic mercury halogenides. The concentration of arsenic (III) and arsenic (V) was measured semi quantitatively by visual comparison of the reaction zone of the analytical test strip with the fields of a colour scale.

Method

1. Insert a test strip halfway through the slot in the cap of the reaction vessel, reaction zone first.
2. Use the syringe to transfer 10ml of sample solution to the reaction vessel, add 1 measuring spoon of reagent 1 and shake.
3. Add 10 drops of reagent 2 (hydrochloric acid) and attach the cap immediately to the reaction vessel.
4. Leave to stand for 30 minutes, swirling gently 2 or 3 times during this period .
5. Remove the test strip, dip briefly in water, shake gently and compare the reaction zone with the color scale.

Procedure

50 mL of standard solution were added into beakers containing two grams of bentonite

sample and stirred for various time intervals (15, 30, 45, 60 and 75 minutes) to study the adsorption of arsenic as a function of time room temperature. Solutions were filtered carefully and volume was made upto 50 mL for each solution with distilled water. Quantity of the arsenic adsorbed was determined by arsenic test strip. Results are given in Table I. Adsorption of arsenic as a function of pH was studied using a range of 2, 4, 6, 10, 12, and 14. The pH was maintained using 0.1N HCl and 5M NaOH. Results are given in Table II. Adsorption of arsenic as a function of temperature was studied by stirring and the heating the solutions at temperatures in the range of 20, 40, 60, 80, and 100°C for half an hour. Results are given in Table III. The effect of mesh size and adsorbate does were also studied at room temperature. The results are given in Table IV and V respectively.

Result and Discussion

In this study, the batch adsorption process was used in order to remove arsenic from wastewater. Arsenic kit was used to determine the quantities of arsenic in wastewater after adsorption on bentonite sample.

Adsorption of arsenic on bentonite as a function of time was determined and equilibrium was reached after mixing for 30 minutes, indicates that surface precipitation as well as ion exchange may be the possible adsorption mechanism. (Table I).

Table I. Effect of time on adsorption of arsenic

Time (minutes)	Adsorption (%)
15	90
30	92.5
45	40
60	40
75	40

From Table II it is found that maximum adsorption is observed at pH 2 and 8. At pH 10, no adsorption observed. It was noted that as in reaction vessel, when zinc and sulphuric acid are added to arsenic containing basic solution (pH 12 and 14) no reaction takes place. A pH value of 8 is reasonable for drinking water quality. The characteristic pH values for surface-water and ground-water supplies are within the range of 6 to 8. At lower pH values (i.e. 2) arsenic exists predominately as an anion in the form $H_2AsO_4^-$ and is attracted to the positively charged soil surfaces (e.g., Fe oxides). At high pH values (pH > 8) As (V) exists as an anion in the form $HAsO_4^{2-}$ and the Fe oxide surfaces become increasingly negatively charged. The repelling negative charges between the soil particle and the As (V) ion help to explain the decrease in As (V) adsorption with an increase in pH. Laboratory measurements of decreased adsorption of arsenic with increasing pH are consistent with observations in arsenic contaminated water .

Table II. Effect of pH on adsorption of arsenic

pH	Adsorption (%)
02	92.5
04	80
06	40
08	92.5

Effect of temperature on arsenic adsorption was noted at various temperature ranges (20, 40, 60, 80, 100°C). Maximum adsorption was observed at 20°C room temperature. At higher temperature the percentage adsorption decreases because there may be breakdown of the forces by which arsenic ions were adsorbed on bentonite. (Table III).

Table III. Effect of temperature on adsorption of arsenic

Temperature (°C)	Adsorption (%)
20	95
40	92.5
60	90
80	40
100	80

Effect of mesh size on adsorption of arsenic by bentonite was noted at room temperature at pH 8. The mesh size of bentonite clay used were 25, 40, 50, 60, and 70 microns. The results showed that maximum adsorption was occurred on 25 and 40 microns particle sizes of bentonite. As the particle size increases adsorption decreases due to decrease in surface area of clay. (Table IV)

Table IV. Effect of mesh size on adsorption of arsenic

Mesh size (microns)	Adsorption (%)
25	92.5
40	92.5
50	90.0
60	80.0
70	40.0

Effect of adsorbate dose was noted on adsorption of arsenic on bentonite by varying the solid to liquid ratio. The maximum adsorption was observed when the solid to liquid ratio was 1:12.5, 1:25 and 1:37.5. 92.5 % adsorption occurred at these ratios but as the adsorbate dose increases to 1:50 the adsorption rate decreases due to increase in volume of solution. (Table V).

Table V. Effect of adsorbate dose on adsorption of arsenic

adsorbate dose (mL)	Adsorption (%)
25	92.5
50	92.5
75	92.5
100	80.0

Conclusion

From this study it was concluded that bentonite is a good and cheap adsorbent, it is efficient, cost-effective and environment-friendly for application in arsenic-contaminated wastewater treatment. The batch

adsorption process is the best process for removal of arsenic metal in wastewater because it is simple, time saving and inexpensive. 95% arsenic removal is possible by batch adsorption process using bentonite.

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