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The Removal of Arsenate in Waste Water with an Adsorbent Prepared by Binding Hydrous Iron(III) Oxide with Polyacrylamide

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Synopsis. Studies have been made to remove arsenate in waste water with an adsorbent prepared by binding hydrous iron(III) oxide with polyacrylamide. Arsenate anions were thus adsorbed over the pH range of 5—8; the adsorption capacity of arsenate was 43 mg per gram of the adsorbent.

The reaction of hydrous iron(III) oxide with several anions has been studied by several workers,[1-3] but the study of the reverse reaction, that is, the desorption or the decomposition, has been seen in only a few papers. It was observed that hydrous iron(III) oxide is a good anion exchanger and that such adsorbed anions as phosphate and fluoride are desorbed by treating them with a dilute solution of sodium hydroxide.[4]

On the other hand, our attempts to avoid the intricate filtration and precipitation of hydrous metal oxides, which detract from its utility for industrial application, have led us to make a proposal for utilizing a composite adsorbent, such a combination of polyacrylamide and hydrous metal oxides.[5] The present paper will report on fundamental work to remove arsenate in waste water by using a composite adsorbent prepared by binding hydrous iron(III) oxide with polyacrylamide.

Experimental

All the chemicals used were of an analytical grade. A stock solution of sodium arsenate was prepared by dissolving 4.1675 g of sodium arsenate in 100 cm^3 of water (1.33×10^{-1} mol dm^{-3} as As).

The most efficient adsorbent was prepared by the following procedure; to 100 cm^3 of water in which are dissolved 5.406 g of iron(III) chloride, we add a concentrated ammonia solution until the pH becomes 7. The precipitate is then separated from mother liquor by centrifuging, and, to the precipitate, 14 g of acrylamide, 4 g of *N,N′*-methylenediacrylamide, and 2 g of ammonium peroxodisulfate as a polymerization initiator, dissolved in 100 cm^3 of water, are added, after which the mixture is stirred vigorously at 70 °C on a water bath. The brown product thus obtained is ground to 50—80 mesh powder in water by using an electric mixer.

All the experiments for the adsorption were carried out by the following procedure, unless otherwise stated: place 50 cm^3 of a solution of sodium arsenate and 0.2 g of the adsorbent in a 100 cm^3 flask. Adjust the pH with an acetate buffer solution. When equilibrium is reached after shaking for 3 h, separate the adsorbent from the solution, determine spectrophotometrically the concentration of arsenate remaining in the solution by means of the molybdenum blue method, and then calculate the percentage of the adsorption from the difference between the initial and the remaining concentrations. In the experiment using a column ($\phi 1.7\times2.5$ cm) loaded with 2.5 g of the adsorbent, the 1.33×10^{-3} mol dm^{-3} arsenate solution was passed through the column at a constant and known flow rate, 0.8 cm^3/min. Collect the effluent in a graduated cylinder, testing the outlet continually for the ions to be exchanged.

Results and Discussion

Figure 1 shows the percentage of the adsorption of arsenate as a function of the pH in the solution. Arsenate anions were collected with the adsorbent in amounts greater than 95% over the pH range of 5—6. It seems that the percentage tends to decrease at pH values lower than 4, because arsenic acid is too weak to dissociate.

Figure 2 shows a breakthrough curve when the 1.33×10^{-3} mol dm^{-3} arsenate solution was passed through the column. The breakthrough capacity, as calculated from the curve, is 43 mg per gram of the adsorbent.

The minimal volume of the 0.5 mol dm^{-3} sodium

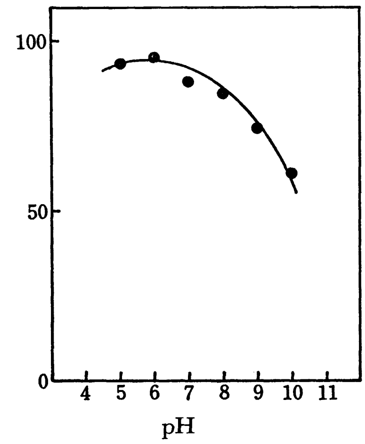

Fig. 1. Relation between pH and the adsorption of As(V).

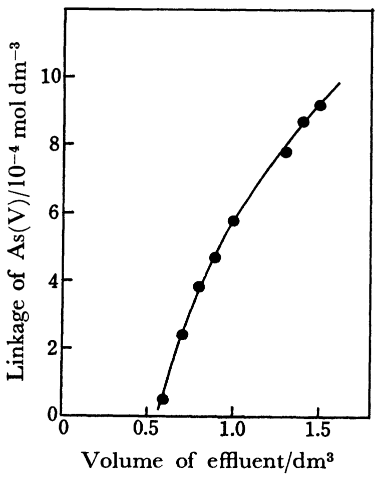

Fig. 2. Breakthrough curve of As(V).
Column: ϕ 1.7×26 cm; adsorbent: 2.5 g; flow rate: 0.83 cm^3/min; As(V): 1.33×10^{-3} mol dm^{-3}.

hydroxide solution required for the elution of arsenate anions can be determined as follows. Collect the effluent in fractions, determine the concentration of arsenate present in a fraction, and then plot the concentration against the volume of the effluent. The volume of the sodium hydroxide solution required for the generation can be determined from the elution curves; fifty cm^3 was sufficient to elute. Further, we examined how the capacity of the adsorption varied when the adsorbent was employed repeatedly. The results are shown in Fig. 3. The capacity was reduced to four-fifth its initial value by ten repetitions. That decrease is attributable to the contamination of the surface. However, if the 0.01 mol dm^{-3} hydrochloric acid is passed through and the adsorbent is washed, the capacity is restored to its original value. Also, we examined how the temperature in the solution affected the adsorption. Arsenate anions were adsorbed from the solution more easily and in greater quantities at a high temperature rather than at room temperature. Last, the adsorption capacities of the adsorbent for several anions were examined by a batch method using 2.67—5.34 mol dm^{-3} solutions of these anions. Table 1 show that the adsorbent can catch fluoride, phosphate, and molybdate, while it does not catch chloride and sulfate. Juging from these results, we can expect that the adsorbent can well be applied to the treatment of waste containing arsenate, such as geothermal waste water after the generation of electricity.

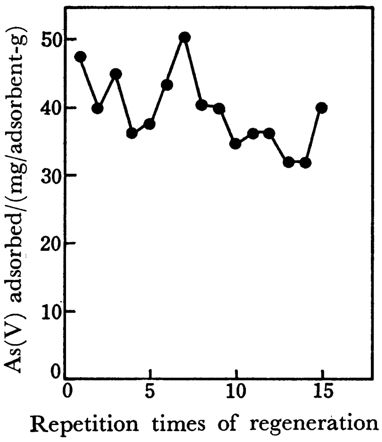

Fig. 3. Relation between repetition times of regeneration and the adsorption capacity of our efficient adsorbed for As(V).

Table 1. The adsorption capacity of our efficient adsorbent for various anions

Anions	Adspt. capacity of adsorbent for anions /mg g^{-1}	Initial concn. of anions/mol m^{-3}
AsO_4^{3-}	43 (as As)	2.67×10^{-3}
AsO_3^{3-}	46 (as As)	2.67×10^{-3}
$P_3O_{10}^{5-}$	26 (as P)	6.46×10^{-3}
F^-	24	2.10×10^{-2}
MoO_4^{2-}	12 (as Mo)	4.17×10^{-3}

The experiments were carried out at pH 4.

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