

Adsorptive Removal of Arsenic from Aquatic Environment

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Abstract

According to the World Health Organization, arsenic is one of the most toxic elements for human health and the concentration limits of this pollutant are hardly attained in drinking water. Removal of arsenic from aquatic environment is an active issue all over the world. Adsorption process receives major attention due to its low cost, simplicity, high efficiency, easy regeneration of sorbents and easy handling. In the present work, adsorptive removal of As(III) and As(V) was investigated using three kinds of adsorbents, Diaion-CRB05 with *N*-methylglucamine group as a functional group, Lewatit-FO36, and AMAs (Goethite) with FeO(OH) group. Batch adsorption of arsenic indicates that adsorption is affected by pH, and the optimal pH range is 3.0 – 4.5 for As(V) and 7.0 – 9.0 for As(III). Adsorption isotherms of both As(III) and As(V) are of Langmuir mechanism, and LewatitFO36 is revealed to possess the highest adsorption capacities for both As(V) (122 mg/g) and As(III) (98.0 mg/g). Desorption of the loaded arsenic from all of adsorbents could be performed by either diluted HCl or NaOH solution. Column studies for the arsenic removal indicated that Lewatit FO36 was effectively performed to remove As(V) until bed volume of 820.

Keywords: Arsenic, Lewatit FO36, CRB05, AMAs, Adsorption

1. Introduction

In nature, arsenic (As) exists in over 200 ores including elements type arsenua, sunphides, sulphosalt, oxide, arsenate, and arsenite. Arsenic is dispersed into the environment by natural weathering process, geological activity, volcanoes, or biological dissolving of minerals and ores. The transformation of arsenic from the solid phase to the liquid phase is determined by the pH, the redox potential, dissolved oxygen, atmospheric temperature, and water temperature [1,2]. The toxicity of arsenic relates to its absorption and retention time in the body. At low concentrations, arsenic is an essential microelement for life and has an important role in nucleic metabolism, profit and hemoglobin synthesis. However, in high concentration, it would be an extremely toxic substance, its concentrations of 1 – 4 mg/kg of body weight is enough to kill a person (lethal dose LD₅₀) [3,4].

Therefore, the World Health Organization (WHO) has thus classified inorganic As as a toxin and carcinogen. WHO also defines the maximum contaminated level of arsenic in drinking water is 10 µg/L. Removal of As from drinking water is thus mandatory.

Adsorptive removal of arsenic was considered to be more convenient than chemical precipitation or coagulation methods, and less expensive than ion-exchange resins or membrane filtration.

This study is elucidated to removal properties of arsenic using two organic materials (DIAION CRB05 from Mitsubishi Chemicals, with *N*-methylglucoamine group, Lewatit FO36 from Lanxess with FeO(OH)) and an inorganic material (AMAs from Toda Kogyo with FeO(OH)) as adsorbents.

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2. Experiments

CRB05 was treated by 2 mol/L HCl before adsorption experiments. Aqueous feed solutions were prepared by dissolving NaAsO₂ for As(III) and Na₂HAsO₄·7H₂O for As(V) solution. In the case of batchwise adsorption, adsorption was conducted by shaking aqueous feed solution and adsorbent. Elution was carried out by either HCl or NaOH solutions. Adsorption amount, q (mg/g), was determined by $q = ((C_0 - C) \cdot L) / m$, where C_0 and C are initial and equilibrium concentrations of As (mg/L), L is the volume of solution (L), and m is weight of adsorbent (g).

In the case of column experiments, the adsorbent was packed into a column to be sandwiched by glass wool. The feed solution, As(V), As(III), or As(III+V) solution at neutral pH, was fed into the column at flow rate of 0.2 mL/min (S.V. = 2.7 h⁻¹). Elution process was conducted with NaOH for AMAs and Lewatit FO36 or HCl for CRB05. Concentration of As was measured by ICP-AES. Bed volume (B.V.) was calculated by $B.V. = v \cdot t / V$, where v is flow rate (mL/min), t is time (min), and V is wet volume of the adsorbent (mL).

3. Result and discussion

3.1 Batch experiment

Figure 1 shows the effect of pH on removal percentage of arsenic with the three adsorbents. The pH of the solution is the most important parameters affecting adsorption of As, because the species distribution is strongly affected by pH. In the case of As(V), removal percentage with all of adsorbents were sharply dependent on the pH and high removal efficiencies were obtained at pH = 3.0 – 4.5. In the case of As(III), pH dependencies of the removal with all adsorbents investigated were similar and high removal efficiencies were obtained in pH range 7.0 – 9.0.

Adsorption isotherms of As(III) and As(V) were investigated at optimal pH values for each adsorption system with initial concentration from 10 to 2000 mg/L, as shown in Figure 2. The initial arsenic concentration in the solution plays a key role as a driving force to overcome the mass transfer resistance between the solution and solid phases [5]. All adsorption isotherms were of Langmuir mechanism [6], and the maximum adsorption amounts, and the adsorption constants were calculated and summarized in Table 1. Since Lewatit FO36 shows the high adsorption capacities for both As(III) and As(V), it is expected as suitable adsorbent for the removal of arsenic in the water environment.

Figure 3 shows desorption percentage of the As from the adsorbents with HCl or NaOH of different concentration (0 – 3 mol/L). Effective desorption was carried out with HCl from CRB05 and with NaOH from AMAs and Lewatit FO36.

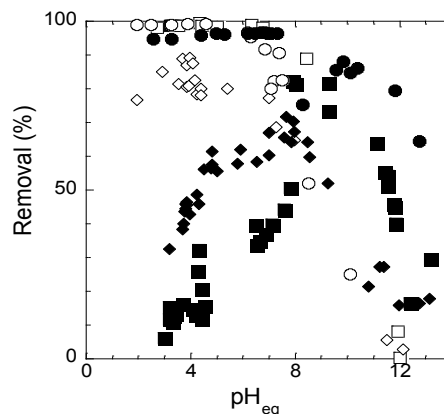


Figure 1. Effect of pH on removal percentage of As(III) and As(V)

■□: CRB05; ◆◇: Lewatit FO36; ●○: AMAs.
Closed keys: As(III); open keys: As(V).

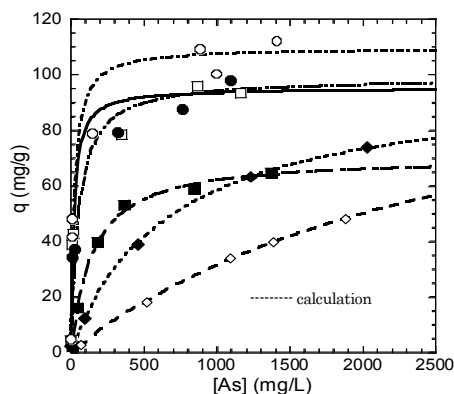


Figure 2. Adsorption Isotherm fit with Langmuir model.

Keys are same as Figure 1.

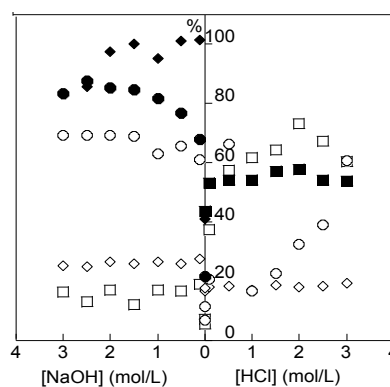


Figure 3. Effect of [H⁺] and [OH⁻] on desorption percentage of As(III) and As(V).

Keys are same as Figure 1.

Table 1. Maximum adsorption amounts and adsorption constants for As(III) and As(V).

Constant	As(V)			As(III)		
	CRB05	Lewatit FO36	AMAs	CRB05	Lewatit FO36	AMAs
pH_{eq}	3.49 ± 0.05	4.06 ± 0.04	3.24 ± 0.06	7.76 ± 0.05	6.54 ± 0.04	6.22 ± 0.06
q_m (mg/g)	95.23	121.95	109.89	70.9	98.04	99.01
K_a (L/mg)	0.429	0.0004	0.0483	0.0071	0.0149	0.0205
R^2	0.997	0.995	0.995	0.999	0.994	0.994

3.2 Column experiment

The breakthrough curve for adsorption of As by Lewatit FO36 was performed with flowrate 0.2 mL/min (S.V. = 2.7 h⁻¹), feed solution was prepared by As(V), As(III) and As(III+V) with concentration 3.5 mg/L. Figure 4 shows the breakthrough and elution curves of As(V), As(III), and As(III+V) with LeFO36. Result indicates that Lewatit FO36 was selective for As(V), because it could be adsorbed until B.V. 820, while As(III) was completed at B.V. 240.

In the case of mixed solution As(III+V), containing 1 : 1 of As(III) and As(V), the Lewatit FO36 could adsorb all As until B.V. 400. In the range of B.V. from 500 to 1100, As(III) was oxidized to As(V) by FeO(OH) in Lewatit FO36.

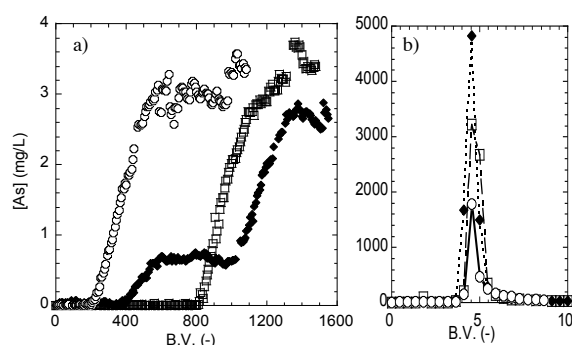


Figure 4. Breakthrough curve (a) and Elution curve (b) of arsenic with Lewatit FO36

○: As(III), □: As(V), ◆: As(III+V)

Loaded As(V) was almost completely eluted from Lewatit FO36 by 2 ml/L NaOH with elution yield of 97.3%, while As(III) and As(III+V) were completely elutes with elution yield reach to 116% and 100%, respectively.

4. Conclusion

In batch adsorption study, Langmuir isotherm model indicate that Lewatit FO36 is the best adsorbent with high maximum adsorption capacity for both of As(III) and As(V). The desorption behaviors of arsenic from adsorbents are dependent on acid and alkali concentrations.

In the case of column experiment, Lewatit FO36 was selective for adsorb As(V), some other factors as velocity, wet volume are investigating.

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