Removal of As of Aqueous Solution Using Activated Alumina Gel

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***Abstract*—One of the serious subjects of recent discussions of environment problems is pollution of underground water, surface water and river water by toxic heavy metals. The issue is critical in that it destroys the surrounding environment and even affects human beings. There is a recent study that reported that drinking of water polluted with arsenic can cause serious health problem. However, as the arsenic (As) can exist in various shapes according to the environmental characteristics and is highly migratory, it is not easy to purify the water contaminated by arsenic, and there are few studies of it. As such, this study used the adsorption method to remove the arsenic. Based on the fact that the adsorption can quickly remove and strongly adsorb the pollutants, it intended to examine the efficiency of removing arsenic using the activated alumina gel which is one of the adsorption media. The test result indicated that more than 80% of arsenic in an aqueous solution was removed within 24 hours and more than 95% of arsenic was removed when the aqueous solution was continuously observed for about one week. The result confirmed that the activated alumina gel was the outstanding medium to be used as the absorbent.**

***Index Terms*—Removal of arsenic, pH, activated alumina gel, adsorption, media**

I. Introduction

Arsenic's history in science, medicine and technology has been overshadowed by its notoriety as a poison in homicides. Arsenic is viewed as being synonymous with toxicity. Dangerous arsenic concentrations in natural waters in now a worldwide problem and often referred to the USA, China, Chile, Bangladesh, Taiwan, Mexico, Argentina, Poland, Canada, Hungary, Japan and India.

Arsenic is widely distributed in the earth's crust and biotic environment and penetrates into the water and air through natural means through the erosion of rocks, minerals and soil. It also penetrates into the environmental system by human activities such as semiconductor and dye manufacturing, wood preservation media, and agricultural pesticides and thus are detected in wide areas worldwide. [1] The water system generally contain arsenic in the level of 5 ~ 50 ㎍/L. There is a report that it can directly affect the ecosystem and human beings as the high concentration of up to 100 ~ 2,000 ㎍/L can be locally observed according to the pH and contents of aqueous solution. [2] Arsenic has various oxidation states (+5, +3, 0, and -3) according to the environmental nature. Under the natural condition, the inorganic arsenic exists mostly as As(III) and As(V), and the distribution of dissolved As(III) and As(V) in the aqueous solution depends on the potential of the oxidation-reduction. [3] In that case, the arsenic state is mostly affected by pH, and As(V) exists in the form of oxidized anion form such as H2AsO4, HAsO42- and AsO43- according to pH under the oxidation dominated environment. On the other hand, As(III), which is more toxic than As(V), exists thermodynamically stably and in the form of H3AsO3, H2AsO3-, and HAsO32- according to pH under the reduction condition. [4]

Since As (III), which is exposed to nature through the natural and industrial activities, can cause the acute and chronic toxicity to human body if it pollutes the earth surface water and underground water widely used as the source of drinking water, there is a need for the technology to economically and efficiently process the As (III) to use them as the stable water resources. [5]

Different arsenic removal technology is applied according to the water quality of the polluted area. Co-precipitation/precipitation, ion exchange, adsorption using the activated alumina, reverse osmosis, nano-filtration, and electro-dialysis reversal are widely studied as the technologies to remove arsenic. [6]

The precipitation technology is generally effective for large facilities to treat the arsenic polluted underground water while the membrane, icon exchange and adsorption technologies are more effective for smaller facilities. Although the existing arsenic removal technologies can be effective, the arsenic can be eluted into the water again when the surrounding environment changes from oxidized environment to reduced environment since arsenic is sensitive to oxidation-reduction potential. Moreover, removing arsenic with such treatment facilities cannot be the fundamental solution.

Benefits of treating heavy metals with adsorption include quick removal of heavy metals and generating stable compounds by strongly adsorb the pollutants. The leading adsorption method is the removal using activated alumina gel. The active alumina is the commercially available medium. A study reported that 90% of

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pentavalent arsenic in the inlet water can be removed through selective adsorption. [2]

Therefore, this study intended to check the performance of the activated alumina gel as the adsorbent and its efficiency of removing arsenic in the aqueous solution.

II. Material and Methods

A. Materials

The activated alumina gel used in testing is the porous alumina trihydrate obtained by heat treating the hydrated alumina is mostly composed of alumina (Al2O3). Fig. 1 shows an Activated Alumina Gel used in testing. It has the residual moisture content of 7% and high mechanical strength against the impact and friction. The moisture adsorption capacity is around 13 ~ 15%, and the minimum equilibrium dew point can be up to -76 ℃. The spent activated alumina gel can be regenerated by heating to 175 ~ 230 ℃.

Figure 1. Activated alumina gel used in testing

TABLE I. Composition of Activated Alumina Gel

Type		Activated Alumina Gel
Composition	Al2O3	99.8 %
Specific Gravity		2.6
Packaging Density[kg/m3]		800
Specific Heat[Kcal/kg·deg]		0.21
Porosity		0.71
Specific Surface Area[m3/g]		260 ~ 330
Compressive Strength[kg]		85
Heat Resistance[℃]		650
Regeneration Temperature[℃]		175 ~ 250
Equilirium Absorption Rate (%)	Relative Humidity 10%	8.7
	Relative Humidity 40%	16.0
	Relative Humidity 80%	22.8

The activated alumina gel used in testing is F200 from Alcoa in the US, and the composition of Al2O3 is 99.8%. The standard As solution (1,000 mg/L) was manufactured using NaAsO2 (Fluka, USA), and the pH of the solution was adjusted using HNO3. The standard solution used in analysis was manufacturing using 1,000 mg/L standard solution from Inorganic Ventures. ICP (Inductively Coupled Plasma, Thermo) was used to analyze the arsenic and evaluate the arsenic removal efficiency.

B. Methods

It is very difficult to directly compare adsorption capacities due to a lack of consistency in the literature data. Sorption capacities were evaluated at different pH, temperatures, As concentration range, adsorbent doses and As(III)/As(V) ratios. Absorbents were used for treating ground water, drinking water, synthetic industrial wastewater, and actual wastewater, etc. [12]

The principle of adsorption applied in this study is the soluble substance being removed from the water after it comes in contact with solid surface and then being attached to the surface of the adsorbent. The adsorbents are packed as the intermediate medium in a fixed bed column, and the solution polluted with arsenic is adsorbed to the adsorbent. The adsorption capability of the adsorbent is affected by the specific surface area of the adsorbent and pH of the solution. When the adsorption capability of the adsorbent in the column reaches saturation, it is regenerated or replaced with new adsorbent. The effectiveness of adsorbent depends on the treatment water quality and properties. [7]

To check the pH change and arsenic concentration according to the weight of the activated alumina gel, the weight of the activated alumina gel was set to 15g, 20g, 25g, and 30g, and the initial pH range was set to around 7 ~ 8 using HNO3, and the distilled water was added to set the volume of solution to 500 mL. 4 samples were agitated on a stirrer at 25 ℃ and 150 rpm and a sample was collected pH was measured at each time. The test lasted for around 100 hours. After the test, the arsenic concentration of the sample was analyzed with ICP to check the arsenic removal efficiency of the activated alumina gel.

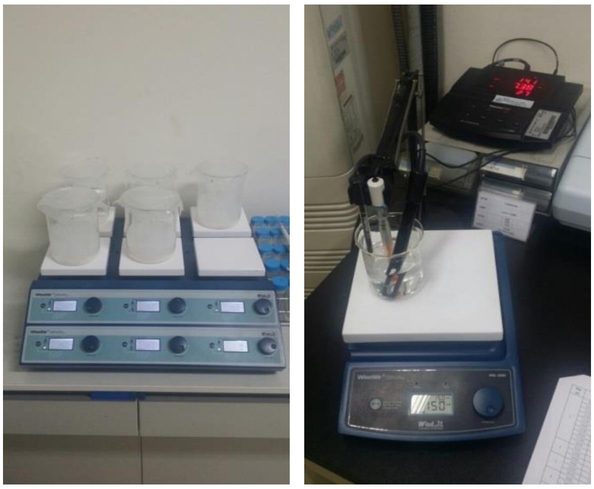

Figure 2. Adsorption test for each arsenic weight

After the first test, the regeneration test was conducted in the same way. Its purpose was to check the regeneration capability of the activated alumina gel based on the result of the first test. The active alumina gel used in the first test (15g, 20g, 25g, and 30g) were washed several time with the triple distilled water and dried in a dry oven at 150 ℃. 4 solutions were made in the same way as the first test and tested under the same condition to check the removal of the arsenic in the aqueous solution. Fig. 2 shows an adsorption test for each arsenic weight.

III. Results and Discussion

A. Change of pH Change with Time

Fig. 3 shows the change of pH with time during the test. pH began at 8 with all arsenic weights (15g, 20g, 25g, and 30g), but the pH increase rate differed as time passed. In the case of A, all samples reached around pH 11 within 1 day for all weights indicating the average pH increase of 2.6 over the initial pH. They remained above pH 10 as more time passed more. In the case of B (test with regenerated adsorbent), the pH increase was more gradual for all samples. In the case of regeneration test, its pH increased by 1.3 in average indicating that the efficiency becomes lower when using the regenerated activated alumina gel. However, Fig. 3 confirms that even the regenerated active alumina gel did sufficiently remove the arsenic in the aqueous solution.

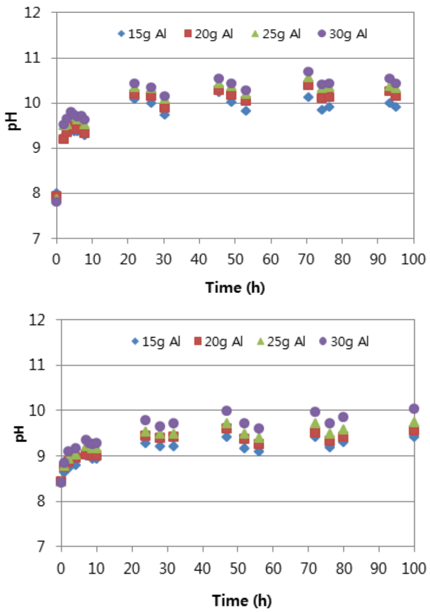

Figure 3. Change of pH per Arsenic Weight with Time (A (Top): First test, B (Bottom): Regeneration test)

B. Change of Arsenic Concentration with Time

In addition to the change of pH with time for different amount of activated alumina gel, the removal rate of arsenic removal from the aqueous solution was analyzed. For that, the arsenic composition of each sample as time passed was checked. Fig. 4 shows the analysis result.

Fig. 4 shows the change of arsenic concentration C/C_0 in the aqueous solution after the arsenic is removed by the activated alumina gel. It began with 1.0 initially and decreased to 0.2 within 10 hours indicating around 80% of arsenic was removed. Moreover, more than 90% was removed within 30 hours. Although B (test with regenerated adsorbent) showed more gradual removal of arsenic than A, the graph confirmed that it still removed around 80% of arsenic within 10 hours and the arsenic continued being removed steadily as time passed.

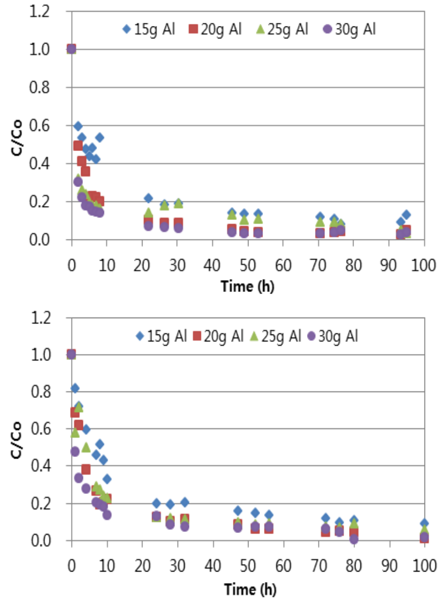

Figure 4. Change of C/C_0 of Arsenic with Time (A (Top): First Test, B (Bottom): Regeneration Test)

The test result indicates that the regenerated activated alumina gel clearly had different speed of removing the arsenic than the fresh activated alumna gel but it was still an effective adsorbent that can efficiently remove the arsenic if it is used continuously for a long time.

Based on the result, we intent to analyze the removal efficiency using the same medium (activate alumina gel) to remove As(III), which can be critically toxic to human body as described in INTRODUCTION, in a future study. Moreover, we also intend to study the performance of activated alumna gel as the adsorbent of other heavy metals in more depth.

IV. Conclusion

The Heavy metal such as lead has been serious polluters of water since perhaps earlier. They have been major water pollutants during the 20th century and continue to create serious problems in the 21st century. As we have documented here, arsenic in drinking water is having a major human impact in several locations. Many treatment technologies are available for arsenic remediation but none of them is found to be completely applicable.

Currently, about 100 million people are consuming water with arsenic concentration up to 100 times the 10 $\mu g/L$ guideline of the World Health Organization. [13] and there are inadequate measures to arsenic pollution in Korea and other countries due to the few studies of arsenic content and arsenic pollution in the water. Therefore, this study intended to check the efficiency of activated alumina gel as the adsorbent to remove arsenic.

AS stated in the introduction, although the hybrid adsorbents aimed at As(III) removal from water, they should also be effective for As(V) removal due to the presence of activated alumina Gel remaining uncovered.

Adsorption was affected by initial pH values, with higher initial pH values decreasing adsorption efficiency. The adsorption isotherms indicate that the unit layer adsorption capacity decreased from 8.01 when initial pH increased from 8.0 to 10.8, with adsorption efficiency dropping. Using the activated alumina gel as the heavy metal (arsenic) adsorbent, more than 80% of arsenic in an aqueous solution was removed within 24 hours and more than 95% was removed in around a week, confirming high efficiency of the activated alumina gel.

Moreover, the regeneration test using the regenerated activated alumina gel in the same test was conducted. Although there was difference of efficiency according to the weight of the medium, 75% in average of arsenic was removed in 24 hours and more than 90% was removed in around a week, also confirming the outstanding adsorption capability of the regenerated activated alumina gel.

Therefore, it was judged that the activated alumina gel was an outstanding medium to remove the arsenic in the aqueous solution. Also, activated alumina gel is very efficient and can be regenerates in situ to extend the useful life.

In some developing countries such as Bangladesh and India, where concentrated arsenic pollution in the water is a problem, the small scale and economic treatment is urgently needed. Application of the adsorption technology will be greatly effective in those regions.

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