Novel Carbon Porous Material with Nanostructural for Separation of Arsenic(III) from Water with Highest Adsorption Capacity

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Abstract: Arsenic is a heavy metal and exists in an oxidation state of -3, 0, +3 or +5 which the As (III) is more toxic than other. Due to the extreme toxicity of As(III) in drinking water many research was done to find natural and economical adsorber for removing it from the water. Porous carbonaceous nanostructural materials have been widely used in the adsorption of contaminated water, gas storage, separation, and purification. By special experimental method were produced in Beshel Activated Carbon Industry (BACI) a new carbon adsorber material (BACI-2017) with nano pores, for removal of As (III) in contaminated water. Because of existing an appropriate pores and surface area, the new adsorber has shown a high tendency for adsorption of Arsenic (III) from water. Experiment: Two different particle sizes, mesh 4x8 and mesh 100 and greater than 100 mesh, were used. The separation of As(III) were done with 0.5 gram of BACI-2017 with mesh 4x8 and 0.1 gram of BACI-2017 with 100 mesh and greater than 100 mesh and six different concentrations of As(III) solution, 5, 10, 20, 30, 50, 100 and 100, 200, 300, 400, 500, 1000 ppm respectively. In all experiments the pH was about 8.5. The results showed that the maximum adsorption capacity of As(III) calculated from Langmuir isotherm was found 41.48 mg/g for 0.5 gram of GRG-2017 and 455 mg/g for 100 mesh and greater than 100 mesh. The contact time in all experiments was 15 minutes. The study showed that the adsorption capacity of arsenic is strongly depending on the particle size of adsorber. The results: The BACI-2017 nanopores adsorber for removal of As (III) from aqueous solution shown that the As (III) can be separated from water with a high capacity of 455 mg/g or 455 g of As (III) per kg of adsorber BACI-2017. This is a world record with highest adsorption capacity in comparison with other studies till now, March 2017.

Keywords: Nano Adsorber, Carbon with Nano Pores, Arsenic (III), Separation, Water, Beshel Activated Carbon

1. Introduction

Arsenic can be presented in water in an oxidation state of -3, 0, +3 or +5, depending on the pH and redox potential of the water occurs arsenic often in trivalent. The presence of arsenic in water is due to natural weathering process or other industrial and anthropogenic activities [1-5]. As (III) is more toxic than arsenic (V), because arsenic (III) binds to single but with higher affinity to vicinal sulfhydril groups that reacts with a variety of proteins and inhibits their activity [6]. Arsenic(III) is more stable than As(V) because of electronic configuration. Long term ingestion of arsenic contaminated drinking water causes skin, lungs and kidney cancer, gastrointestinal disease, bone marrow disorder, cardiovascular diseases and other diseases [7]. Due to the extreme toxicity of arsenic in drinking water, World, Health, Environmental Protection Agency has set 0.01 mg/L and 0.05 mg/L (10-50 ppb) as the maximum permissible limit of arsenic in drinking water [8-11]. Many conventional processes for separation of arsenic like adsorption [12] and [13], coagulation [12], co-precipitation [14], ion-exchange [15], [16], [17] and [18] and oxidation-reduction process have been reported. Among all the process, the adsorption is one of the promising methods
2. Materials and Methods

2.1. Reagents and Chemicals

All chemicals were used of analytical grade and are obtained from Merck. All solutions are prepared in distilled water. 1 Liter stock solution of arsenic(III) was prepared by dissolving 1.73 g sodium arsenic oxide (AsNaO$_2$) and diluted to 1 L, 1.00 ml=1.00 mg arsenic(III), standard arsenic(III) solution were prepared for analysis by dilution of stock solution. The new Nano Adsorber with the name of BACI-2017 obtained from Beshel Activated Carbon Industry.

2.2. Adsorption Experiments

The experiment was carried out by mixing of 0.5 or 0.1 gram of adsorbent with 50 ml of arsenic (III) solution with different concentrations in 500 ml Erlenmeyer glass with stopper. The mixture was shaken for one minute vigorously by hand and then after 15 minutes retention time arsenic solution was filtrate. In all experiments the pH was about 8.5 and contact time was 15 minutes. The concentration of As (III) measured with an atomic absorption spectrophotometer (AAS) which were calibrated before measurement of sample (Figure 1).

![Figure 1. Calibration Curve for As (III) using atomic absorption spectrophotometer.](image)

Arsenic uptake by the adsorbing material was calculated using the following equation:

$$Q_e = \frac{(C_0 - C_e)V}{W}$$

where:
- $Q_e$: Equilibrium uptake (mg/g)
- $C_0$: As(III) initial concentration (mg/g)
- $C_e$: As(III) Equilibrium concentration (mg/g)
- $V$: Volume of solution (L)
- $W$: Mass of adsorbent material (g)

2.3. Adsorption Isotherm

The relationship between the equilibrium of arsenic(III) adsorbed and the solute concentration was verified using various isotherms. In this study the isotherm models Langmuir and Freundlich were used to find the best fitted model.

3. Results and Discussion

3.1. Effect of As (III) Concentration in Adsorption Process

3.1.1. Mesh Size: 4x8

The experiment was made with 50 ml of arsenic(III) solution with 6 different concentrations, 5, 10, 20, 30, 50 and 100 mg/L and every sample was mixed with 0.5 gram of BACI-2017 with mesh 4x8 and contact time 15 minutes.

The result in table1 and figure 2 shown that with increasing of concentration of As(III) will be the percentage of adsorption increased from 86 to 99%.

![Figure 2. The percentage removal of different concentration of arsenic (III) by BACI-2017 (0.5g) with Mesh 4x8.](image)

<table>
<thead>
<tr>
<th>Sample</th>
<th>$C_0$ (mg/l)</th>
<th>BACI-2017 (g)</th>
<th>Time Contact (Minute)</th>
<th>$C_e$ (mg/l)</th>
<th>%Removal of As(III)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>0.5</td>
<td>15</td>
<td>0.700</td>
<td>86</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>0.5</td>
<td>15</td>
<td>0.765</td>
<td>92.35</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>0.5</td>
<td>15</td>
<td>0.802</td>
<td>95.99</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
<td>0.5</td>
<td>15</td>
<td>0.854</td>
<td>97.15</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>0.5</td>
<td>15</td>
<td>0.898</td>
<td>98.20</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>0.5</td>
<td>15</td>
<td>0.930</td>
<td>99.07</td>
</tr>
</tbody>
</table>

3.1.2. Mesh Size: 100 and Greater than 100 Mesh

The experiment was done with mesh size of 100 and > 100 mesh and 50 ml of arsenic(III) solution with 5 different concentrations, 100, 200, 300, 400, 500 and 1000 mg/L and every sample was mixed with 0.1 gram of BACI-2017 with mesh 100 and greater than 100 mesh and contact time 15 Minutes.

The result in Table2 and figure3 shown that with increasing of concentration of As(III) the adsorption capacity increased.
3.2. Adsorption Capacity of As(III) with BACI-2017

3.2.1. GRG-2017 with Mesh Size 4x8

The maximum As(III) adsorption capacity in batch experiment calculated by Langmuir adsorption isotherm was 4.91 mg/g [Table 3 and Figure 4].

Table 3. The test results related in order to determine Isotherm Langmuir for BACI-2017 (0.5g) with Mesh 4x8.

<table>
<thead>
<tr>
<th>No.</th>
<th>$q_e$ (mg/g)</th>
<th>$C_e$ (mg/L)</th>
<th>L$q_q$</th>
<th>L$nC_e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.18</td>
<td>0.700</td>
<td>-1.71</td>
<td>-0.36</td>
</tr>
<tr>
<td>2</td>
<td>0.42</td>
<td>0.765</td>
<td>-0.86</td>
<td>-0.27</td>
</tr>
<tr>
<td>3</td>
<td>0.92</td>
<td>0.802</td>
<td>-0.08</td>
<td>-0.22</td>
</tr>
<tr>
<td>4</td>
<td>1.41</td>
<td>0.854</td>
<td>0.35</td>
<td>-0.16</td>
</tr>
<tr>
<td>5</td>
<td>2.41</td>
<td>0.898</td>
<td>0.88</td>
<td>-0.11</td>
</tr>
<tr>
<td>6</td>
<td>4.91</td>
<td>0.930</td>
<td>1.59</td>
<td>-0.07</td>
</tr>
</tbody>
</table>

Figure 4. Langmuir adsorption isotherm study for the arsenic (III) removal for BACI-2017 (0.5g) with Mesh 4x8.

3.2.2. BACI-2017 with Mesh Size 100 and Greater than 100 Mesh

The maximum As (III) adsorption capacity in batch experiment calculated by Freundlich adsorption isotherm was 455 mg/g [Table 4 and Figure 5].

Table 4. The test results related in order to determine Isotherm Freundlich for BACI-2017 with 100 mesh and greater than 100 mesh (0.1g).

<table>
<thead>
<tr>
<th>No.</th>
<th>$q_e$ (mg/g)</th>
<th>$C_e$ (mg/L)</th>
<th>L$q_q$</th>
<th>L$nC_e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49.50</td>
<td>1</td>
<td>3.90</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>98.00</td>
<td>4</td>
<td>4.58</td>
<td>1.39</td>
</tr>
<tr>
<td>3</td>
<td>145.50</td>
<td>9</td>
<td>4.98</td>
<td>220</td>
</tr>
<tr>
<td>4</td>
<td>190.00</td>
<td>20</td>
<td>5.25</td>
<td>3.00</td>
</tr>
<tr>
<td>5</td>
<td>230.00</td>
<td>40</td>
<td>5.44</td>
<td>3.69</td>
</tr>
<tr>
<td>6</td>
<td>455.00</td>
<td>90</td>
<td>6.12</td>
<td>4.50</td>
</tr>
</tbody>
</table>

Figure 5. Freundlich adsorption isotherm study for the arsenic (III) removal for BACI-2017 (0.1g).

4. Conclusion

In this study a new carbonaceous nano structural material BACI-2017 were produced in laboratory scale in R&D and industrial scale in Beshel Activated Carbon Industry, using electrical furnace and rotary furnace for the removal of As(III) from water. The maximum removal efficiency of As(III) was 91% of 0.1 g of adsorbent and with As(III) concentration of 1000 mg/L with pH 8.5, contact time of 15 min and mesh size of 100 and greater than 100 mesh. The adsorption data are best supported in the Freundlich model with maximum adsorption capacity of 455 mg/g, which is the highest adsorption capacity till now March 2017. The study showed, as expected, with decreasing of particle size the adsorption capacity was dramatically increased from 4.91 mg/g to 455 mg/g. From the above study it is clearly concluded that the material can be suitably used for removal of arsenic with highest adsorption capacity. The present adsorber material BACI-2017 is prepared in laboratory and industrial scale for removal of arsenic (III) from water with highest adsorption capacity which is not reported anywhere in the literature.

This is a novel environment friendly natural material which can be utilized in small scale to large scale water treatment for arsenic removal.

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References


[21] Jianying Zhang, et al., Enhanced Adsorption of Trivalent Arsenic from water by functionalized diatom silica shells, April 2. 2015, PLOS ONE.
