SciencePG
Science Publishing Group

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

Hossein Ghafourian, Mohammad Rabbani, Zahra Ghazanfari

Department of Environmental Engineering, Islamic Azad University, Tehran North Branch, Tehran, Iran

Email address:

h_ghafourian@iau-tnb.ac.ir (H. Ghafourian)

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 than100 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 with mesh 4x8 and 0.1 gram of BACI-2017 calculated from Freundlich isotherm was 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 sulfhydryl 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

[12]. The aim of this work is to prepare an environment friendly natural carbonaceous material in laboratory and industrial scale for removal of As (III) with high efficiency and adsorption capacityofwater. The highest adsorption capacity for As (III) are reported to vary from 3.5 mg/g till 41.48 mg/g [19-23].

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).
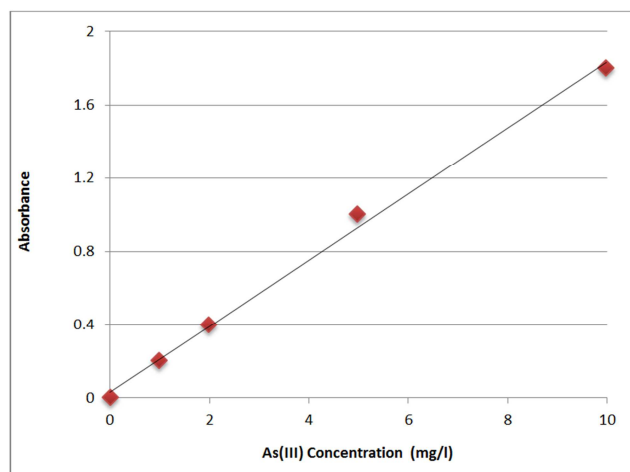

Figure 1. *Calibration Curve for As (III) using atomic absorption spectrophotometer.*

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

$$Qe= (C0-Ce)V/W \qquad (1)$$

Q_e: Equilibrium uptake (mg/g)
V: Volume of solution (L)

C_0: As(III) initial concentration (mg/g)
C_e: As(III) Equilibrium concentration (mg/g)
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 table1and figure 2 shown that with increasing of concentration of As(III) will be the percentage of adsorption increased from 86 to 99%.

Table 1. *The Effect of As(III) concentration with BACI-2017 with 4x8 Mesh (0.5g).*

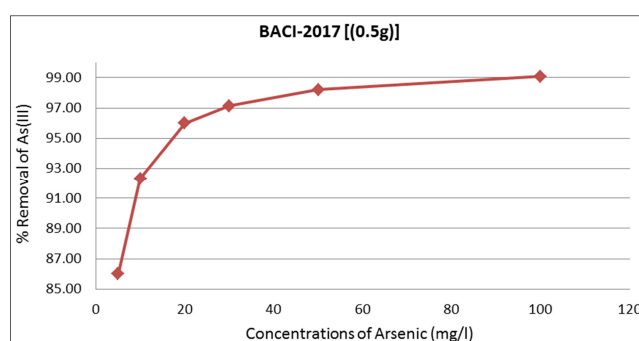| Sample	C_o (mg/l)	BACI-2017 (g)	Time Contact (Minute)	C_e (mg/l)	%Removal of As(III)
1	5	0.5	15	0.700	86
2	10	0.5	15	0.765	92.35
3	20	0.5	15	0.802	95.99
4	30	0.5	15	0.854	97.15
5	50	0.5	15	0.898	98.20
6	100	0.5	15	0.930	99.07

Figure 2. *The percentage removal of different concentration of arsenic (III) by BACI-2017 (0.5g) with Mesh 4x8.*
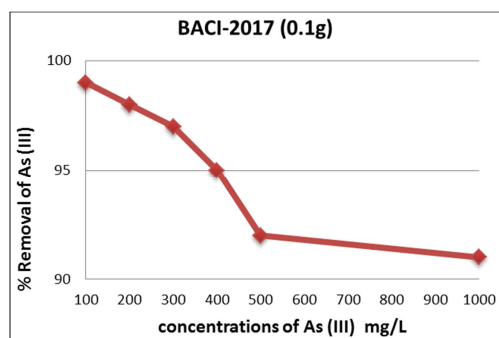
3.1.2. Mesh Size: 100 and Greater than 100 Mesh

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 inTable2and figure3 shown that with increasing of concentration of As(III) the adsorption capacity increased.

Table 2. *Arsenic adsorption by BACI-2007 with 100 mesh and greater than 100 mesh in different concentrations.*

Sample	C_o	BACI-2017 (g)	Time Contact (Minute)	C_e	Adsorption (%)
1	100	0.1	15	1	99
2	200	0.1	15	4	98
3	300	0.1	15	9	97
4	400	0.1	15	20	95
5	500	0.1	15	40	92
6	1000	0.1	15	90	91

Figure 3. *The percentage removal of different concentration of arsenic (III) by BACI-2017 (0.1g) with 100 mesh and greater than 100 mesh.*
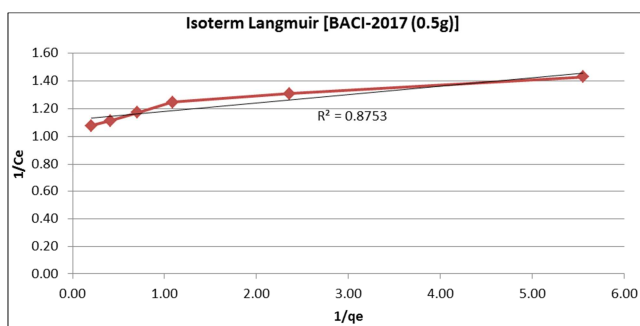
3.2. Adsorption Capacity of As(III) with BACI-2017

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 [Table3 and Figure 4].

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

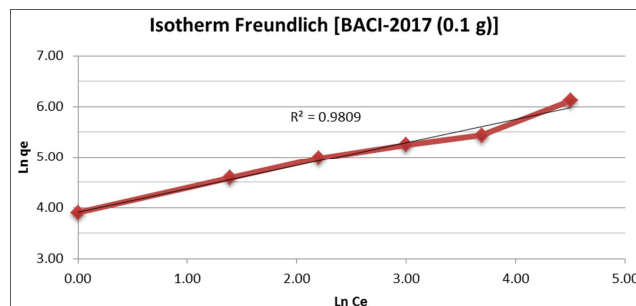| No.	qe (mg/g)	C_e (mg/L)	Lnq_e	LnC_e
1	0.18	0.700	-1.71	-0.36
2	0.42	0.765	-0.86	-0.27
3	0.92	0.802	-0.08	-0.22
4	1.41	0.854	0.35	-0.16
5	2.41	0.898	0.88	-0.11
6	4.91	0.930	1.59	-0.07

Figure 4. *Langmuir adsorption isotherm study for the arsenic (III) removal for BACI-2017 (0/1g) with Mesh 4x8 (0.5g).*

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 Freunlich adsorption isotherm was 455 mg/g [Table 4 and Figure 5].

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

No.	q_e (mg/g)	C_e(mg/L)	Lnq_e	LnC_e
1	49.50	1	3.90	0
2	98.00	4	4.58	1.39
3	145.50	9	4.98	220
4	190.00	20	5.25	3.00
5	230.00	40	5.44	3.69
6	455.00	90	6.12	4.50

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-2017were 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.

Acknowledgements

References

[1]   D. Mohan, P. Charle Arsenic removal from water/wastewater using adsorbents– a critical review,Journal of Hazardous Materials, 142 (1–2) (2007), pp. 1–53.

[2]   Y. S. T. Choong, G. T. Chuah, H. Y Robia, L. F. G. Koay, I. Azni Arsenic toxicity, health hazards and removal techniques from water: an overview,Desalination, 217 (2007), pp. 139–166.

[3]   S. Shevade, R. Ford Use of synthetic zeolites for arsenate removal from pollutant water,Water Research, 38 (2004), pp. 3197–3204.

[4]   L. Lorenzen, J. S. J. Van Deventer, M. W. Landi Factors affecting the mechanism of the adsorption of arsenic species on activated carbon Minerals Engineering, 8 (4) (1995), pp. 557–.

[5]   F. Di. Natale, A. Erto, A. Lancia, D. Musmarra Experimental and modelling analysis of As(V) ions adsorption on granular activated carbon Water Research, 42 (2008), pp. 2007–2016.

[6]   H. V. Aposhian, R. M. Maiorino, R. C. Dart, D. F Perry Urinary excretion of meso-dimercaptosuccinic acid in human subjects Clinical Pharmacology & Therapeutics, 45 (5) (1989), pp. 520–526.

[7]   IARC, Overall evaluation of carcinogenicity to humans. As evaluated in IARC monographs vol. 1–73, 1998, (http://www.iarc.htm) (updated November 30, 1998).

[8]   Exposure to arsenic: a major public health concern WHO Document Production Services, Geneva, Switzerland (2010).

[9]   EPA, Environmental Protection Agency, Environmental Pollution Control Alternatives, EPA/625/5-90/025, EPA/625/4-89/023, Cincinnati, US, 1990.

[10] M. J. Maushkar, Guidelines for water quality monitoring, Central pollution control board (A Government of India organisation), Delhi, India, 2007.

[11] BIS, (Bureau of Indian Standards) 10500 Indian Standard Drinking Water Specification; First revision, vol. 1–8, Bureau of Indian Standard Publication, New Delhi, India (1991).

[12] S. W. Wan Ngah, C. L. Ten, M. K. A. M. Hanafiah Adsorption of dyes and heavy metal ions by Chitosan composites a review Carbohydrate Polymers, 83 (2011), pp. 1446–1456.

[13] A. Afkhami, M. Saber-Tehrani, H. Bagheri Simultaneous removal of heavy-metal ions in wastewater samples using nano-alumina modified with 2,4-dinitrophenylhydrazineJournal of Hazardous Materials, 181 (2010), pp. 836–844.

[14] Z. Wu, M. He, X. Guo, R. Zhou Removal of antimony(III) and antimony(V) from drinking water by ferric chloride coagulation: competing ion effect and the mechanism analysis Separation and Purification Technology, 76 (2010), pp. 184–190.

[15] R. K. Misra, S. K. Jain, P. K. Khatri Iminodiacetic acid functionalized cation exchange resin for adsorptive removal of Cr(VI), Cd(II), Ni(II) and Pb(II) from their aqueous solutions, Journal ofHazardous Materials, 185 (2011), pp. 1508–1512.

[16] F. Fernane, M. O. Mecherri, P. Sharrock, M. Hadioui, H. Lounici, M. Fedoroff Sorption of cadmium and copper ions on natural and synthetic hydroxylapatite particles Materials Characterization, 59 (2008), pp. 554–559.

[17] A. Dabrowski, Z. Hubicki, P. Podkościelny, E. Robens Selective removal of the heavy metal ions from waters and industrial wastewaters by ion-exchange method Chemosphere, 56 (2004), pp. 91–106.

[18] S. K. Nataraj, K. M. Hosamani, T. M. Aminabhavi Nanofiltration and reverse osmosis thin film composite membrane module for the removal of dye and salts from the simulated mixtures Desalination, 249 (2009), pp. 12–17.

[19] Kanel SR,etal, Removal of As(III) from Grounwater by nanoscale zero-vallent Iron, Environ SciTechol,2005 Mar 1, 39(5): 1291-8.

[20] Yuttasake Chammmin, et. al., Removal arsenic from aqueous solution br adsorption Leonardite, Elsevier Volume 240, 15 March 2014, Pages 202-210.

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

[22] Zhu H.,et. al.,Removal of arsenic from water by supported nano zero valent Iron on activated carbon, J. Hazard Mater. 2009 De 30, 172(2-3).

[23] Sandip Mandal, et. al.,Adsorption capacity of arsenic(III) removal from water, water resource and industry, volume 4, December 2013 Pages 51-67, Elsevier.