

Removal of Arsenic from Aqueous Solution Using Both Fly Ash and Bottom Ash as Adsorbents by Column Studies

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Abstract – Environmental pollution is currently one of the most important issues facing humanity. It is undesirable side effects of industrialization, urbanization, population growth and unconscious attitude towards the environment. Mainly contamination of arsenic in drinking water has adverse effects on human health. Contamination of arsenic in drinking water is a serious problem affecting many countries with guideline value exceeding 10µg/L as recommended by World Health Organization. Continuous experiments were conducted using adsorbents such as Fly Ash and Bottom Ash. These adsorbents were modified by using Ferrous Sulphate (FeSO₄). Breakthrough curves were developed by conducting column studies for modified bottom ash with flow rates of 3 ml/min and 6 ml/min. For 3 ml/min, a breakthrough point was obtained at 76.67 hours and for a flow rate of 6 ml/min, the breakthrough point was achieved at 26 hours respectively.

Key Words: Contamination, Pollution, Adsorbent, Arsenic, Continuous experiments.

1. INTRODUCTION

In India, environmental pollution has become a cause of concern at various levels. Due to lack of sewage treatment plants, generally untreated sewage effluents are released either on agricultural land for irrigation or disposed of in nearby water bodies. Arsenic contamination in groundwater is the major threat to the worldwide drinking water resources [1].

Toxicity of Arsenic (III) in drinking water is more compared to that of arsenic (V). Estimated acute minimal lethal dose of arsenic is about 70 to 200 mg or 1 mg/kg/day for adults [3]. The occurrence of arsenic in the environment is usually of many forms and found in rocks, soil, natural waters, air, and food. But, arsenite (III) and arsenate (V) are usually present in natural waters [1].

Major source of arsenic emitted to the environment is mainly due to the anthropogenic activities such as release of industrial effluents, smelting of non-ferrous metals, mining of ores, burning of fossil fuels, pesticides usage containing arsenic and contamination by the use of arsenic in preservation of timber and drilling of geological deposits mobilizes the arsenic into drinking water sources [6]. The occurrence of arsenic in the water through various

environmental conditions along with the range of concentrations is given in Table 1.

Table 1: Occurrence of Arsenic

Source of Arsenic	Arsenic Conc. (µg/L)
Arsenic-rich sediments (eg: Bangladesh, Vietnam, China)	10-5000
Groundwater contaminated by mining activities (eg: Ghana)	50-5000
Geo-thermal influenced water (eg: USA, Argentina)	<10-50,000

Arsenic (III) is more dominant than arsenic (V) in terms of toxicity and mobility [1]. Intake of elevated levels of inorganic arsenic through drinking water causes ill effects and long-term exposure leads to serious health problems. Ingestion of ground water containing high concentrations of arsenic has been reported to be the acute arsenic intoxication of a concentration of about 21.0 mg/L [6].

2. MATERIALS AND METHODOLOGY

A. Preparation and analysis of Synthetic Arsenic (III) Solution

Arsenic Trichloride (As₂O₃) is used for the preparation of arsenic(III) standard solution. A stock solution of 1000 mg/L of As(III) is prepared by dissolving 1.320 gm of arsenic trioxide in 1000 ml distilled water.

The solution is diluted as per required concentrations of standard arsenic(III) solution [8]. Initial and residual concentrations of arsenic samples were analyzed using Perkin Elmer Atomic Absorption Spectrophotometer (AAS). Using hydrochloric acid and sodium hydroxide, sample pH adjustments were made as required.

B. Determination of Removal Efficiency of Arsenic(III) by trial studies

For the adsorption of arsenic (III) from synthetic arsenic solution, both bottom ash and fly ash were used as adsorbents. Trial studies were carried out to know the arsenic(III) removal efficiency from synthetic solution.

Bottom ash is a coal-fired residue obtained from thermal power plants which are collected at the bottom of the furnace and was procured from Raichur Thermal Power Station (RTPS), Raichur and it is shown in figure 1. The chemical composition of bottom ash includes oxides of silica, iron, and aluminium which are the main mineral compounds, present in maximum percentage than that of magnesium, calcium, and sulfur. It also contains heavy metals like arsenic, selenium, boron, cadmium, and lead.

Fly ash is captured from the flue gas produced during combustion of coal by electrostatic precipitators or bag filters near the chimney. Fly ash was procured from Raichur Thermal Power Station (RTPS) and it is shown in figure1. Fly ash is usually of particle size in the range of 10 to 100 microns.



Fig.1: Bottom ash and Fly ash.

Table 2: Physical characteristics of Fly Ash and Bottom Ash

PROPERTIES	FLY ASH (Class F)	BOTTOM ASH
Color	Whitish Grey	Grey
Form	Powder	Crystalline
Bulk density	1047 Kg/cum	2350 Kg/cum
Specific gravity	2.2	1.3-3
Fineness	0.4-0.04 mm	>0.1 mm
Moisture content	<0.3%	Slurry

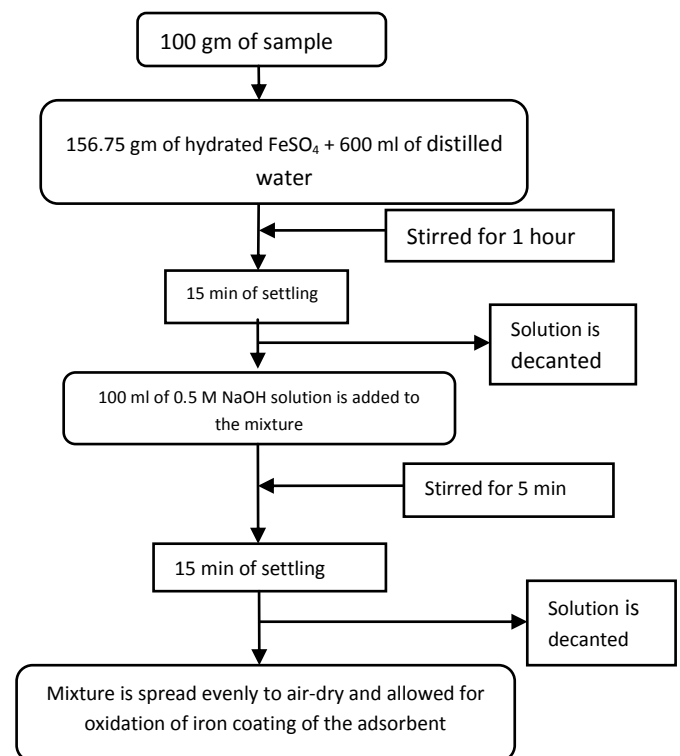
Trial studies conducted using raw fly ash and bottom ash as adsorbents which resulted with the rise in arsenic concentrations of synthetic arsenic solution. Due to the presence of high concentrations of arsenic content in both fly ash and bottom ash, an arsenic reduction was not observed. Hence, both the adsorbents were modified as follows.

Table 3: Chemical Composition of Fly Ash and Bottom Ash

COMPONENTS	FLY ASH	BOTTOM ASH
Silica	55-65%	55-65%
Ferric oxide	5-7%	5-9%
Alumina	22-25%	15-20%
Calcium	5-6%	5-7%
Magnesium	<1%	0.1-5%
Titanium	Traceable	1-2%
Manganese	<1%	1-1.5%
Phosphorus	<1%	1-1.5%
Sulphates	0.1%	0.1%
Potassium	0.09%	>0.1%
Unburnt Carbon	1-1.5%	2-3%

C. Modification of Adsorbents

Coating of adsorbents by using Ferrous Sulphate (FeSO₄): Methodology for coating of adsorbents using Ferrous Sulphate (FeSO₄) is shown below,



Iron coated adsorbents were used for the trial studies to know arsenic (III). Iron coated bottom ash and iron coated fly ash are shown in fig.2.



Fig.2: Iron coated bottom ash and iron coated fly ash.

D. Developing the break through curve by conducting column studies

The column studies were carried out to develop the break through curve by setting the optimum parameters. The columns used were of diameter 2.5 cm and height of 25 cm for both modified bottom ash and modified fly ash and are represented in figure 3. The studies were carried out to the depth of 15 cm, and flow rates of 3 ml/min and 6 ml/min using bottom ash and flow rate of 2 ml/min using fly ash respectively.

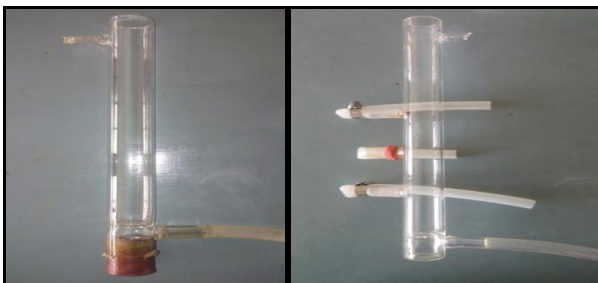


Fig.3: Columns used for the Continuous study.

E. Atomic Absorption Spectrophotometer (AAS)

It was used to determine the arsenic concentrations of the samples. The analysis was carried out by Perkin Elmer Atomic Absorption Spectrometer. It works on the furnace method and at a temperature of 2000°C and it is represented in figure 4.



Fig.4: Atomic Absorption Spectrophotometer (AAS)

3. RESULTS AND DISCUSSIONS

Trial studies were conducted to evaluate the removal efficiency of arsenic using fly ash and bottom ash for the present study. Due to the presence of arsenic content in both the adsorbents, there was an increase in arsenic concentrations. An attempt was made to remove arsenic from adsorbents by acid washing process, which resulted in less percentage removal of arsenic. Hence, the iron coating of adsorbents was made using Ferrous Sulphate (FeSO₄).

COLUMN STUDIES

Objective: To determine break through curve by conducting column studies.

To determine the 100% breakthrough time of modified bottom ash and modified fly ash for arsenic (III), the operational parameters obtained from the batch study are considered and Ce/Co is plotted against time. The effect of flow rate on both the modified adsorbents is checked for arsenic(III) removal. Flow rates of 3 ml/min and 6 ml/min were maintained for a uniform depth of 15 cm for iron coated bottom ash. The obtained breakthrough curves of modified bottom ash are represented in figure 5 and figure 6.

The initial concentration of 46.92 µg/L, at pH 7 and flow rate of 3 ml/min continuous flow was maintained and from the figure 5 it is observed that modified bottom ash can remove 100% As(III) for the time period of 31.33 hours and bed was saturated by the time period of 156 hours or 6.50 days, the volume of synthetic solution treated is 28 litres. The initial concentration of 47.85 µg/L, at pH 7 and flow rate of 6 ml/min was maintained and from the figure 6, it is observed that modified bottom ash can remove 100% As(III) for the time period of 2.66 hours and bed was saturated by time period of 80.67 hours or 3.36 days and the volume of solution treated is 29 litres. Removal performance of modified bottom ash is represented in Table 4.

The experiment was conducted to know the effect of flow rate on modified fly ash for arsenic (III) removal with the depth of 15 cm and flow rate of 2 ml/min. The technical problem arises during the process, as the sample was not passing through the bed due to the fineness of modified fly ash. Hence sand was mixed with modified fly ash so that sample could flow easily, but the same problem arised and removal efficiency was very low due to the discontinuous flow. Column studies carried using both the modified adsorbents.

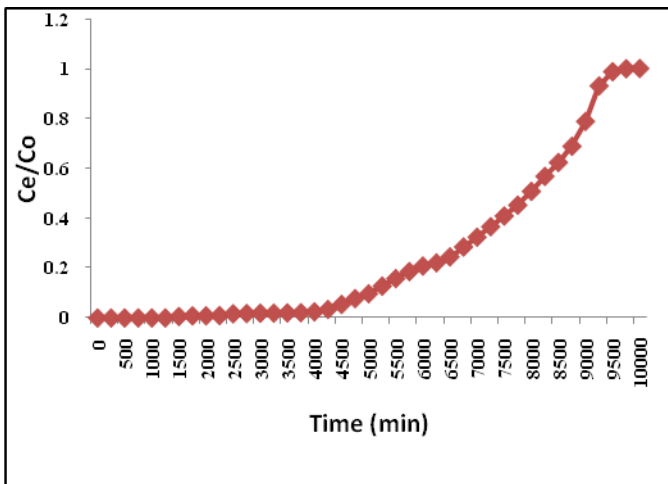


Fig.5: Break through curve for arsenic binding under flow conditions, solution of 50 µg/L at pH 7 and flow rate of 3 ml/min

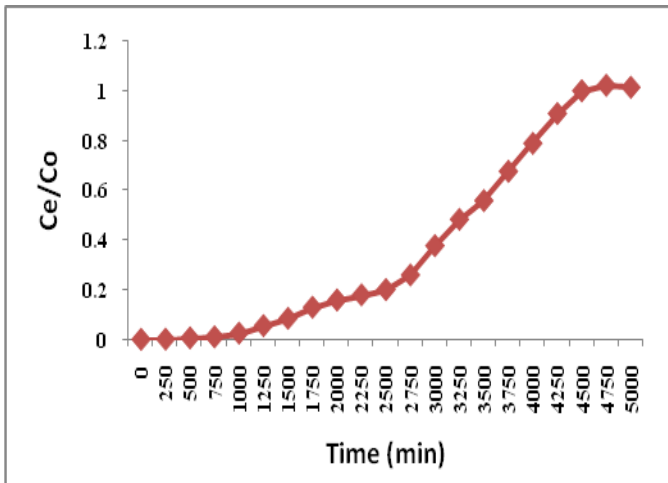


Fig.6: Break through curve for arsenic binding under flow conditions, the solution of 47.85 µg/L, at pH 7 and flow rate of 6 ml/min.

Table 4: Performance representation of Column Studies of flow rate 3 ml/min

Time (min)	Initial Concentration (µg/L)	Final Concentration (µg/L)	Efficiency (%)
40	46.92	0.001599	99.996
80	46.92	0.002796	99.994
120	46.92	0.003899	99.9916
160	46.92	0.004297	99.9908
200	46.92	0.005897	99.987

240	46.92	0.007296	99.984
1560	46.92	0.289027	99.38
1720	46.92	0.40304	99.14
1760	46.92	0.41383	99.118
1880	46.92	0.4589	99.02
3080	46.92	0.7929	98.31
3160	46.92	0.83517	98.22
3200	46.92	0.89898	98.08
3240	46.92	0.9177	98.04
3280	46.92	0.9609	97.95
3320	46.92	1.0003	97.86
3360	46.92	1.1533	97.54
3400	46.92	1.6051	96.58
4600	46.92	2.5665	94.53
4640	46.92	3.6738	92.17
4680	46.92	4.579	90.24
4720	46.92	6.0104	87.19
4760	46.92	7.432	84.16
4800	46.92	8.7458	81.36
4840	46.92	9.7875	79.14
4920	46.92	10.3927	77.85
6120	46.92	11.509	75.47
6160	46.92	13.381	71.48
6200	46.92	15.225	67.55
6240	46.92	17.2079	63.325
6280	46.92	19.223	59.03
7800	46.92	21.264	54.68
7840	46.92	23.856	49.156
7880	46.92	26.68	43.137

7920	46.92	29.30	37.55
7960	46.92	32.356	31.04
9320	46.92	37.04	21.057
9360	46.92	43.73	6.798
9400	46.92	46.417	1.072
9440	46.92	46.976	-
9480	46.92	47.013	-

4840	47.85	43.424	9.249
4920	47.85	47.797	-
4960	47.85	48.85	-
5000	47.85	48.47	-

Table 5: Performance representation of column studies of flow rate 6 ml/min

Time (min)	Initial Concentration (µg/L)	Final Concentration (µg/L)	Efficiency (%)
40	47.85	0.00469	99.990
80	47.85	0.04135	99.913
120	47.85	0.28097	99.412
160	47.85	0.47108	99.015
200	47.85	1.1900	97.51
240	47.85	2.6269	94.51
280	47.85	4.03806	91.56
320	47.85	6.1745	87.096
360	47.85	7.5646	84.19
400	47.85	8.5632	82.109
1560	47.85	9.5626	80.01
1680	47.85	12.378	74.13
1720	47.85	18.017	62.34
3080	47.85	23.078	51.77
3440	47.85	26.68	44.24
4680	47.85	32.317	32.46
4760	47.85	37.696	21.22



Modified Bottom Ash

Modified Fly Ash

Fig.6: Column studies carried out using both the adsorbents for depth of 15 cm

4. CONCLUSION AND FUTURE SCOPE OF WORK

Based on the results obtained for arsenic removal using both fly ash and bottom ash as adsorbents, as discussed above, the following conclusions are made.

- The trial studies using raw bottom ash and raw fly ash showed that the arsenic removal from synthetic solution was not efficient due to the presence of arsenic in the adsorbents.
- Trial studies using modified adsorbents showed the better removal efficiency of arsenic from aqueous solution.
- The optimization of the various operating parameters towards arsenic removal using both modified bottom ash and modified fly ash,
 - As the concentration of arsenic(III) increases the removal efficiency of the arsenic from synthetic solution decreases.

- Initially the rate of adsorption increases with the rise in the dosage and agitation time later decreases for the same.
 - Arsenic(III) removal efficiency using both the adsorbents increases as the pH of the aqueous solution increases.
- Using modified bottom ash, for the flow rate of 3 ml/min, concentration of 50 µg/L and at neutral pH, the bed was saturated by the time period of 158 hours or 6.58 days, the volume of synthetic solution treated is 28 litres and for the flow rate of 6 ml/min, concentration of 50 µg/L and at neutral pH, the bed was saturated by time period of 80.67 hours or 3.36 days and the volume of solution treated is 29 litres.
- Saturation time of the modified bottom ash bed decreases with the increase in the flow rate of the solution to be treated.

Future scope of work:

- Regeneration studies should be carried out for both the modified adsorbents.
- Column studies using modified fly ash are to be carried out.
- Kinetics studies for the arsenic(III) removal using adsorption data should be carried out.

REFERENCES

[1] Lokendra Singh Thakur and Pradeep Semil (2013), "Removal of Arsenic in Aqueous Solution by Low-Cost Adsorbent: A Short Review", International Journal of Chem Tech Research (IJCTR), ISSN: 0974-4290, Vol.5, No.3, pp 1299-1308.

[2] Dinesh Mohan, Charles U. Pittman (2007) "Arsenic removal from water/waste water using adsorbents", Journal of Hazardous Materials, 142(2007) 1-53.

[3] WHO (2001), United Nations Synthesis Report on "Arsenic in Drinking Water", Geneva.

[4] M.K. Singh and Anil Kumar (2012), "A Global Problem of Arsenic in Drinking Water and Its Mitigation –A Review", International Journal of Advanced Engineering Technology (IJAET), Vol.III, pp 196-203, E-ISSN 0976-3945.

[5] D. VanHalem et al., (2009), "Arsenic in drinking water: a worldwide water quality concern for water supply

companies". Drinking Water Engineering and Science", 2, pp 29-34.

[6] IPCS (2002), "Exposure to Arsenic: A Major Public Health Concern", Environmental Health Perspectives, 112(11):1172-1177.

[7] S. Lakshmi Narayan et al., (2014), "A batch study on the removal of nickel (II) using low-cost adsorbent fly ash", International Journal of Chemical and Petrochemical Technology (IJCPT), ISSN(P):2277-4807; ISSN(E): 2319-4464 Vol.4, Issue 1, February 2014, 31-36.

[8] Standard methods for the examination of water and wastewater, American Public Health Association (APHA), the American Water Work Association (AWWA) and the Water Environment Federation (WEF) publication (2006).

[9] Ajay K. Agarwal et al., (2014), "Langmuir, Freundlich and BET Adsorption Isotherm Studies for Zinc ions onto coal fly ash", International Journal of Application or Innovation in Engineering & Management (IJAIEM), Vol.3, ISSN: 2319-4847.

[10] V.T. Nguyen et al., (2009), "Arsenic removal by a membrane hybrid filtration system", Desalination 236, pp. 363-369.

[11] Trina Dutta et al., (2012), "Removal of Arsenic Using Membrane Technology- A Review", International Journal of Engineering Research and Technology (IJERT), ISSN:2278-0181, Vol.1

[12] P.Xu et al., (2013), "Selective removal of arsenic and monovalent ions from Brackish Water Reverse Osmosis Concentrate", Journal of Hazardous Materials 260, pp.885-891.

[13] F. Prieto Garcia et al., (2012), "Study of Arsenic Removal with Ionic Exchange Resins in Drinking Water from Zimapan, Hidalgo State, Mexico", International Journal of Applied Science and Technology, Vol.2, No.6. www.ijastnet.com

[14] Imran Ali et al., (2012), "Removal of Arsenate from Aqueous Solution by Electro-Coagulation Method Using Al-Fe Electrodes", International Journal of Electrochemical Science, Vol.7, pp.1898-1907.

[15] P.D. Nemade et al., (2012), "Comparison of Arsenic Adsorption by Electrocoagulation and Chemically Generated Hydrous Ferric Oxide (HFO) from Water", International Journal of Engineering Research and Technology (IJERT), ISSN: 2278-0181, Vol.1.

[16] M.Shruthi et al., (2013), "Removal of Arsenic from Groundwater using Electrochemical Coagulation Process", International Journal of Current Engineering and Technology, ISSN 2277-4106.

[17] A.M. Garcia-Lara et al.(2014), "Arsenic Removal from Natural Groundwater by Electrocoagulation Using Response Surface Methodology", Journal of Chemistry.<http://dx.doi.org/10.1155/2014/857625>.

[18] Omar J. Flores et al. (2014), "Arsenic Removal from Groundwater by Electrocoagulation Process in a Filter-Press-Type FM01-LC Reactor", International Journal of Electrochemical Science, Vol.9, pp.6658-6667.

[19] G.G. Kleiman and Uzi Landman (1973), "Theory of Physisorption: He on Metals", Physical review, Vol.8, No. 12.

[20] A.Dabrowski (2001), "Adsorption From Theory To Practice", Advances in Colloid and Interface Science. Vol.93, pp.135-224.

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