

# Remediation of Arsenic from Contaminated Water Using Tata's Granular Blast Furnace Slag (TGBFS)

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In the arena of eco-toxicological world, arsenic pollution is a matter of alarming concern. The intake of arsenic contaminated water having concentration above the permissible limit causes arsenic poisoning in living beings. In present study, batch mode laboratory experiments were carried out using adsorption technology for remediation of arsenic from contaminated water making use of Tata's Granular Blast Furnace Slag (TGBFS). A significant amount of arsenic is removed by adsorption onto TGBFS. The parameters like pH, contact time, temperature etc. were studied to find out the adsorption capacity of the adsorbent – TGBFS.

**Keywords:** Arsenic, Remediation, Tata's Granular Blast Furnace Slag (TGBFS), Contaminated Water.

## Introduction

In the arena of eco-toxicological world, arsenic pollution is a matter of alarming concern. Arsenic, one of the ecotoxic metals, causes 'Arsenic poisoning' in different parts of the world. Its increasing level in different parts of the world has caused alarming concern. It is emitted into the environment from both natural and anthropogenic sources. Now-a-days, the entire arsenic of the world is obtained as a byproduct of the smelting of copper, lead, cobalt and gold ore. The quantity of arsenic generally associated with lead and copper ores may range from trace to 2-3%, whereas that with gold ores around 11% arsenic was recovered as arsenic trioxide in about 20 countries from the smelting and roasting of non-ferrous metal ores or concentrates.<sup>[1]</sup> Shrivastava A.K. <sup>[2]</sup> reviewed that Jharkhand is the hot spot for arsenic pollution. Acharyya et.al. <sup>[3]</sup> suggested that the potential sources of arsenic in the Ganges basin could be Gondwana Coal Seams in the Rajmahal basin (contains upto 200ppm arsenic), isolated sulphide outcrops in the Darjeeling Himalayas (contains upto 0.8% arsenic) along with the coal basins of the Damodar Valley.

Arsenic emissions from different sources contaminate drinking water, waste water and industrial effluents. It is used in many medicines in low doses. Arsenic in water above its threshold limit

value (TLV) causes toxic effects on living organisms. The high concentration of arsenic in water and arsenic poisoning is reported in Japan, New Zealand, Bangladesh, West Bengal, Chennai and some other parts of India also including Jharkhand <sup>[4]</sup>. Arsenic contamination of ground water was reported in Chennai, Bangladesh etc. Chronic poisoning by arsenic leads to loss of appetite and weight, diarrhoea, constipation, gastro-intestinal disturbances, skin cancer etc <sup>[5]</sup>.

Arsenic occurs naturally in surface and ground water. It is found in natural soil, rock and aquifers. Arsenic is associated with ores of Cu, Fe and Au. Its compounds had been used in insecticides e.g. lead arsenates. Its compounds, both-inorganics like arsenic trioxide, sodium, arsenate and calcium arsenate and organics like monosodium methane arsenate and disodium methane arsenate are used as herbicides. Arsenic is generated from fossil fuel burning also. In fertiliser plants, liquid effluents are reported to contain the element ranging from 0.27-3.2mg/l<sup>[6]</sup>. In Latin America, high concentrations (0.6-0.8 mg/l) of arsenic have been reported in drinking water and these were associated with endemic poisoning and the 'black foot' disease.<sup>[7]</sup> The pollution level of arsenic was estimated in the Mahi river in Baroda<sup>[9]</sup>. Anand estimated arsenic in fish specimens obtained from Bombay region<sup>[9]</sup>. Arsenic is a metabolic inhibitor and causes iron deficiency. It causes carcinogenesis in man<sup>[10-12]</sup>. Excessive amount of arsenic in irrigation water reduces the yield of crops. The toxicity of arsenic in +3 state (As<sup>+3</sup>) is higher than that of arsenic in the +5 state (As<sup>+5</sup>) since arsenite reacts with sulfhydryl group. Various adsorbents have been used for remediation of arsenic from water/waste water<sup>[13-14]</sup>.

## Experimental Chemicals

Analytical grade chemicals were used during experiments and

arsenic solution was prepared by dissolving the required quantity of arsenic salt.

**Characteristics of TGBFS**

The TATA's Granular Blast Furnace Slag was washed with tap water and distilled water to remove impurities and dried in an oven at 103°C temperature. The chemical characterisation of Tata's Granular Blast Furnace Slag (TGBFS) shows the major components as follows:

- SiO<sub>2</sub>=30.7%
- Fe<sub>2</sub>O<sub>3</sub>=3.20%
- Al<sub>2</sub>O<sub>3</sub>=20.81%
- CaO=33.90%
- MgO=8.42% etc.

**Adsorption Experiments**

The batch sorption experiments were conducted at room temperature at 20±0.5°C in a rotatory shaker. One gm of Tata's Granular Blast Furnace Slag (TGBFS) was agitated with 100ml of aqueous solution of arsenic at desired concentration, pH and temperature, using the shaking machine for different retention time. At the end of predetermined time intervals, the adsorbents were centrifuged at 10,000 rpm for 2 minutes, then filtered. The supernatant liquid was analysed for the remaining arsenic concentration using Atomic Absorption Spectrophotometer (AAS).

**Results**

The results of experimental studies are given in Tables 1, 2 & 3 showing the percentage removal of arsenic in different environmental conditions namely pH, contact time and temperature.

**Table-1: Effect of pH**  
Initial Concentration of As = 50mg/l

| Sl. No. | pH  | Arsenic in Filtrate (mg) | Arsenic Sorbed (mg) | % Removal of As |
|---------|-----|--------------------------|---------------------|-----------------|
| 1       | 2.0 | 4.7                      | 0.3                 | 6               |
| 2       | 3.0 | 4.4                      | 0.6                 | 12              |
| 3       | 4.0 | 4.1                      | 0.9                 | 18              |
| 4       | 5.0 | 3.2                      | 1.8                 | 36              |
| 5       | 6.0 | 2.2                      | 2.8                 | 62              |
| 6       | 6.5 | 1.4                      | 3.6                 | 72              |
| 7       | 7.0 | 0.45                     | 3.55                | 71              |

**Table-2 : Effect of Contact Time**  
Initial Concentration of As = 50mg/l  
pH = 6.5

| Sl. No. | Time in Minutes | Arsenic in Filtrate (mg) | Arsenic Sorbed (mg) | % Removal of As |
|---------|-----------------|--------------------------|---------------------|-----------------|
| 1       | 5               | 4.65                     | 0.35                | 7               |
| 2       | 15              | 4.1                      | 0.90                | 18              |
| 3       | 30              | 3.15                     | 1.85                | 37              |
| 4       | 60              | 2.15                     | 2.85                | 57              |
| 5       | 2x60            | 1.15                     | 3.85                | 77              |
| 6       | 3x60            | 1.05                     | 3.95                | 79              |

**Table-3 : Effect of Temperature**  
Initial pH = 6.5  
Concentration of Arsenic Solution = 50 mg/l  
Contact Time = 2 hours

| Sl. No. | Temp °C | Initial Conc of As in mg | As Sorbed in mg | % Removal of As |
|---------|---------|--------------------------|-----------------|-----------------|
| 1       | 20°C    | 1.15                     | 3.85            | 77              |
| 2       | 30°C    | 0.9                      | 4.1             | 82              |
| 3       | 40°C    | 1.0                      | 4.0             | 80              |

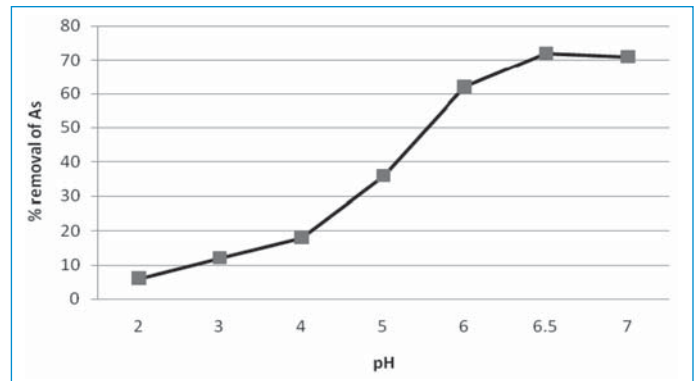


Fig.1: Effect of pH on Remediation of As by TGBFS.

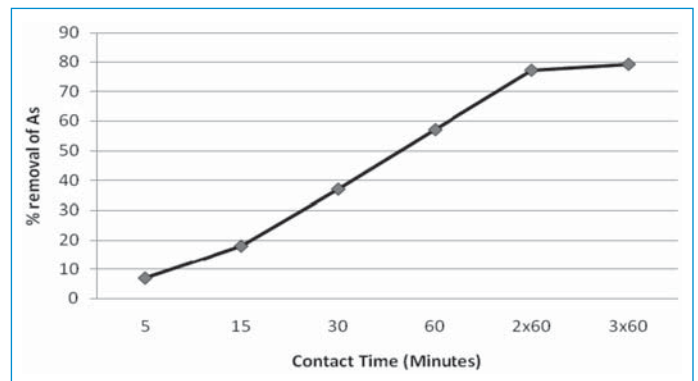


Fig. 2: Effect of Contact Time on Remediation of As by TGBFS.

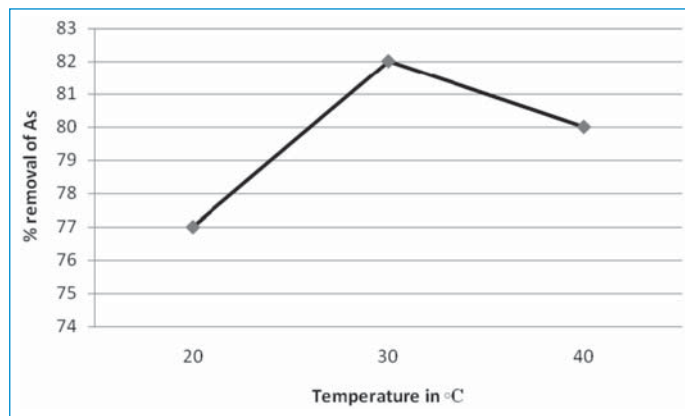


Fig. 3: Effect of Temperature on Remediation of As by TGBFS.

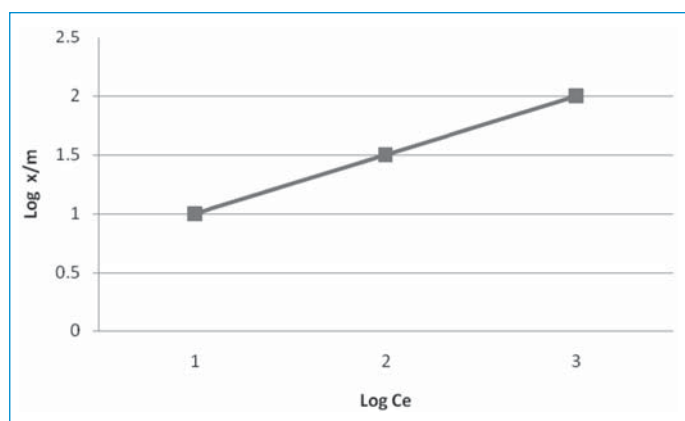


Fig. 4: Freundlich Adsorption Isotherm for As on TGBFS.

## Discussion

The effect of pH, contact time and temperature on remediation of arsenic using TGBFS based adsorption technology is discussed as follows :

### Effect of pH on the Remediation of Arsenic

One gm of Tata's Granular Blast Furnace Slag (TGBFS) was gently agitated with 100ml of aqueous solution of arsenic for 2 hours. The pH of the initial solution was varied between 2.0 to 7.5. It can be seen from Table-1 that pH increases with the increase in the sorption of arsenic. There is a steep rise in the sorption of arsenic with the increase in pH upto 6.5, thereafter there is little decrease as shown in Fig. 1. Therefore, the pH of the solution was maintained at 6.5 in all future experiments.

### Effect of Contact Time on the Remediation of Arsenic

The concentration of arsenic solution was maintained 50mg/l and the pH of the solution was fixed at 6.5. Hundred ml of 50 mg/l solution at 6.5 pH was agitated with 1gm. of Tata's Granular Blast Furnace Slag (TGBFS) for different periods of contact time. The results are tabulated in Table-2. It is observed from Fig. 2 that the percentage removal of arsenic reaches to 77% for contact time of 2 hours.

### Effect of Temperature on the Remediation of As

The effect of temperature on remediation of arsenic by Tata's Granular Blast Furnace Slag (TGBFS) is shown in Table-3. The increase in the temperature from 20°C to 40°C increased the sorption of arsenic from 77 to 82% as shown in Fig. 3. The increase in the uptake of arsenic with temperature may be due to the dissolution of the adsorbing species.

### Adsorption Model

The adsorption process can be explained by Freundlich and Longmuir models. These models are most frequently employed.

The Freundlich equation can be written in the linearised form

$$\log \frac{x}{m} = \log K + \frac{1}{n} (\log C_e)$$

Where  $x/m$  is the amount of metal ion adsorbed at equilibrium concentration  $C_e$  and  $K$  and  $n$  are Freundlich constants concerning the multilayer adsorption capacity.

The adsorption data follow Freundlich model of adsorption as shown in Fig. 4.

### Conclusions

- A good amount of arsenic is removed by adsorption onto Tata's Granular Blast Furnace Slag (TGBFS) at pH=6.5 and contact time of 2 hours.
- It is most promising technology because of its economic viability.
- It may be useful in remediation of arsenic by column studies and helpful in controlling the threatened sustainability due to menace of arsenic pollution at the global level.
- It may also be useful in the development of Continuous Mixed Batch Reactor (CMBR) for the treatment of arsenic rich water/waste water.

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### References

1. Minerals Yearbook Metals and Minerals, US Department of the Interior, Bureau of Mines, Washington DC, 1923-1990.
2. A.K. Shrivastava, Ground Water Pollution in Jharkhand, Proceedings of Symposium on Contemporary Science & Technology : Scientific Foresight, Patna, 2008, 20-22 December.
3. S. K. Acharyya, P.Chakraborty; S. Lahri; B. C. Raymahashay, S. Guha A. Bhowmik, Arsenic Poisoning in the Ganges Delta (Brief Communication) Nature, 1999, 401: 545.

4. V. Subramaniam, N. Madhavan and S.A.S. Naqvi, Arsenic in our Environment: A Critical Review, Book Entitled "Environmental Hazards in South Asia", V. Subramanian, Capital Publishing Company, New Delhi, 2002, 189.
5. K. C. Pillai, 'Heavy Metals in Aquatic Environment, Book Entitled "Water Pollution and Management", C. K. Varshney, Wiley Eastern Limited, New Delhi, 1991, 83.
6. S. R. Alggarswamy, B. B. Bhalerao, and S. Rajagopalan, Treatment of Wastes from Fertilizer Plants, Ind. J. Env. Health, 1973, 15, 52.
7. World Health Organization, Health Hazards of Human Environment, W.H.O., Geneva, 1972.
8. S. Rajagopalan, I. A. Jayangounder, S. G. Shekh, and C. S. Mehta, Water Pollution Problems in Gujarat, Environment Health Seminar, Ahmedabad, March, 1972.
9. S. J. S. Anand, Determination of Mercury, Arsenic and Cadmium in Fish by Neutron Activation, J. Radio, Anal. Chem, 1978, 44, 101-107.
10. Mukherjee et.al., Geol. Soc. India, 1991, 37, 132-135.
11. R. T. Nickson, J. M. Mc Arthur, W.G Burgess, K. M. Ahmed, P. Ravencraft, Rahman, M., Arsenic Poisoning of Bangladesh Ground Water, Nature, 1998, 395-338.
12. S. R. Aston, I. Thornton, J. S. Webb, B. L. Milford and J. B. Purves. Arsenic in Stream Sediments and Wastes of South West England. The Science of Total Environment, 1975, 4(4), 347-358.
13. A. K. Shrivastava, Removal of Arsenic from Water/Waste Water by Treated Saw Dust (TSD), Proceedings of National Seminar on EIGMI-2008, BIT, Sindri, Dhanbad, 2008, 4-5 April, 67-71.
14. Jang Min, Min Hong Soo, Kim Tak Hyun and Park Lae Kwang, Removal of Arsenite and Arsenate Using Hydrous Ferric Oxide Incorporated into Naturally Occurring Porous Diatomite Environ. Sci & Technol., 2006, 14(5), 1636-1643.