

*Full Length Research Paper*

# Remediation of arsenic from water/waste water using engineered carbon (EC)

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**In the arena of eco-toxicological world, Arsenic pollution is a matter of alarming concern. Intake of arsenic contaminated water having concentration above the permissible limit causes Arsenic poisoning in living beings. In the present study, a batch mode lab. experiment was done using adsorption technology. Here, engineered carbon (EC) was used for remediation of arsenic from water/waste water. A significant amount of Arsenic is removed by adsorption on to EC. The parameters like pH, contact time, temperatures etc. are studied to find out the adsorption capacity of the adsorbent – engineered carbon (EC).**

**Key words:** Arsenic, engineered carbon, remediation, water/waste water.

## INTRODUCTION

Arsenic is one of the ecotoxic metals which cause 'Arsenic poisoning' in different parts of the world. It is ubiquitous in the environment, ranks 20th in natural abundance, comprising about 0.00005% of the earth's crust, 14th in sea water and 12th in human body (Mondal, 2002). It is introduced in the body through food, drinking water and ambient air (Ulman et al., 1998). The major input of arsenic into the body is by drinking water, which is significant sink for this pollutant. The maximum contamination limit (MCL) for arsenic in drinking water is 0.5 mgL<sup>-1</sup>. The elevated levels of Arsenic in the environment from various sources have posed serious threat to health due to arsenic poisoning in living beings. The various sources of Arsenic include by products of smelting of copper, lead, cobalt and gold ores, coals, arsenic compounds as insecticides (lead arsenate) herbicides (Arsenic trioxide, sodium arsenate, calcium arsenate, monosodium methane arsenate etc.) medicines, fossil fuel burning, fertilizer plants, natural soil, rocks and aquifers etc. (Shrivastava et al., 1992; Shrivastava, 2008). Fertilizer plants, liquid effluents are reported to contain the element ranging from 0.27 – 3.2 mg/l (Alggarswamy et al., 1973). In Latin America, high concentration (0.6 – 0.8 mg/l) of arsenic has been reported in drinking water and these were associated with endemic poisoning and the 'black foot' disease (WHO, 1972).

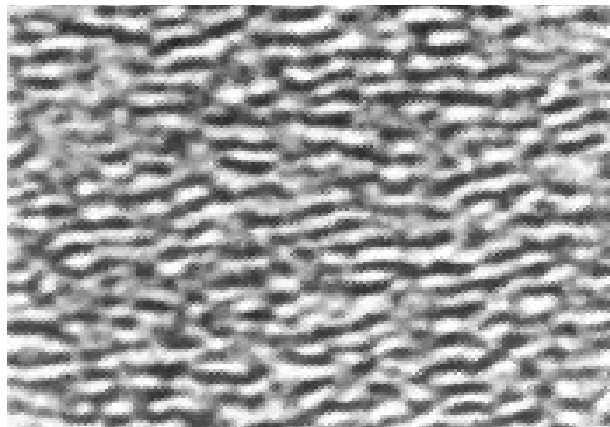
The pollution level of Arsenic was estimated in the Mahi river in Baroda (Rajagopalan et al., 1972). Anand (1978) estimated arsenic in fish specimens obtained from

Bombay region. Acharyya et al. (1999) suggested that the potential sources of Arsenic in the Ganges basin could be Gondwana Coal seams in the Rajmahal basin (contains up to 200 ppm arsenic), isolated sulphide outcrops in the Darjeeling Himalayas (contains up to 0.8% arsenic) along with the coal basins of the Damodar valleys.

Arsenic emitted from different sources contaminate drinking water, waste water and industrial effluents. Arsenic pollution has been reported in various parts of India e.g. Jharkhand, Bihar, U.P., West Bengal, Chennai etc and other countries of the world. (Subramanian et al., 2002; Nickson et al., 1998). Arsenic poisoning leads to loss of appetite and weight, diarrhoea, constipation, gastro-intestinal disturbances, skin cancer etc. (Pillai, 1991). Arsenic is a metabolic inhibitor and causes iron deficiency.

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>). There are different methodologies with varying degrees of success have been developed to manage arsenic pollution and other type of water pollution. These include coagulation, foam-floatation, filtration, ion-exchange, sedimentation, solvent extraction adsorption, electrolysis, chemical oxidation, chemical precipitation and membrane process. (Prasad, 1994; Desesso et al., 1998; Mondal et al., 2006; Sorg et al., 1978; Jeckel, 1994; Jr. Kartinen et al., 1995; Kuhlmeier et al., 1996; Ng et al., 2004; Bates et al., 1998; Meenakshi et al., 2006; Peter, 2005).

Among various available technologies for water



**Figure 1.** TEM image of engineered carbon.

pollution control (especially Arsenic pollution) mentioned above adsorption process is considered to be most promising technologies because it is economical and easy to set up.

Sutherland et al. (2001) reviewed different types of adsorption processes for arsenic removal in Bangladesh, evaluating the performance of nine technologies in terms of removal efficiency, cost, biological contamination, flow rate, reagent use, filtration time and maintenance. Various adsorbents have been used for remediation of arsenic from water e.g. Porous Diatomite (Min et al., 2006) activated alumina with a proprietary additive AAFS-50 (Alcan, 1998).

Some other adsorbents like TSD, (Shrivastava, 2008), Ganga sand (Vaishya et al., 1993), minerals (Singh et al., 2002) bio materials (Hossain et al., 2005) Tata's Granular blast furnace slag - TGBFS (Shrivastava, 2009), different mineral surfaces (Carrilo and Drever, 1998; Bowell, 1994; Vander Hock et al., 1994) and other adsorbents like activated carbon (Huang and Fu, 1984), activated alumina and bauxite (Gupta and Chen, 1978), oxides and clay minerals (Frost and Griffin, 1977; Malotky and Anderson, 1976; Matis et al., 1997) and Metal treated activated carbon (Huang and Vane, 1989; Kobayashi et al., 1994) etc. had been used for remediation of As from water/waste water and from drinking water also (Hathaway et al., 1987).

The objective of this study is the remediation of Arsenic from arsenic containing water/waste water. It is a very important part of environmental studies. Extensive environmental researches are being carried out, in this area, all over the world.

## **MATERIALS AND METHODS**

The batch mode lab. experiment was done using adsorption technology. Here, engineered carbon (EC) was used for the removal of As from water/waste water. It is effective adsorbent because of high degree of porosity and large surface area.

## **Chemicals**

All chemicals used in this experiment were of analytical grade. Arsenic solution was prepared by dissolving the required quantity of Arsenic salt. Stock solution of arsenic having 50 mg/l concentration was prepared.

## **Engineered carbon**

Smart material engineered carbon was prepared by chemical oxidation and degassing processes of Junk carbonaceous material like discarded tyres of vehicles. First of all, junk carbonaceous material; discarded tyre was burnt to ashes. This carbon was used for oxidation with nitric acid. 10 g of the carbon samples was heated with 300 ml of pure nitric acid in borosil beaker of 500 ml capacity in a water bath maintained at about 80 °C. When all but about 20 ml of the acid had evaporated, the contents were cooled diluted with water and transferred over a filter paper. The carbon sample was washed exhaustively with hot distilled water until it was free of nitrate ions. The washed carbon sample was dried first in air and then in an electric oven, out gassed at 120 °C and stored in stoppered borosil glass bottles.

## **Degassing of carbons**

Oxidized carbons were degassed at temperatures of 400, 650 and 950 °C to eliminate gradually varying amounts of the carbon-oxygen surface group. The degassing was carried out by placing 5 g of the carbon sample in a temperature controlled tube furnace. The carbon sample was spread in a thin layer about 5 inches long in the quartz tube furnace. It was kept in position by means of porous copper gauze plugs. The tube furnace was then connected to Hyvac Cenco Vacuum pump. The temperature was allowed to rise gradually in steps of 50 °C. After degassing at each temperature, the sample was allowed to cool in vacuo to avoid reformation of the complexes. Cooled sample was then transferred to a stoppered bottle flushed with nitrogen. The samples were referred to as 'degassed samples of carbon'.

Thus, following above chemical heat treatment and degassing processes smart material engineered carbon is prepared. TEM image of engineered carbon is shown in Figure 1. Characteristics and specification of engineered carbon shows similarity with that of activated carbon of good quality. It has C as major content. It has high degree of porosity and enhanced surface area.

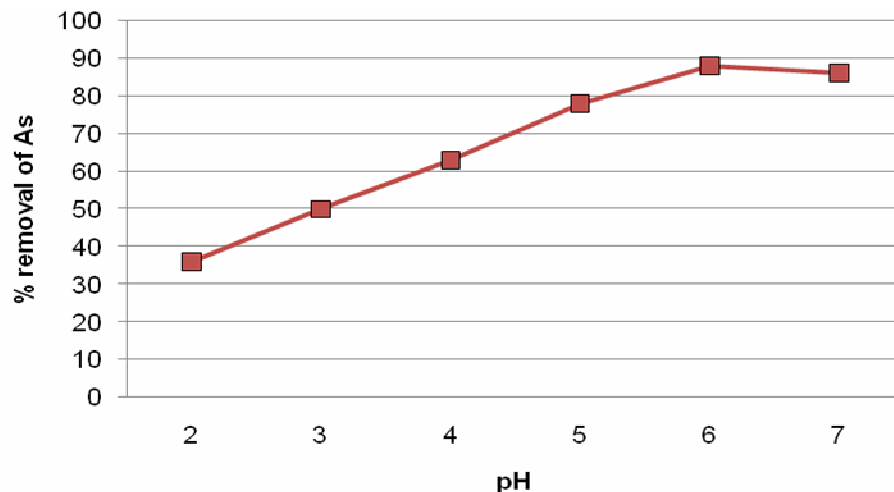


Figure 2. Effect of pH on adsorption of As by EC.

Particle porosity  $\approx 0.91$  ep, enhanced surface area =  $1150 \text{ m}^2/\text{g}$

### Adsorption experiments

The batch adsorption experiments were conducted at room temperature in a rotatory shaker. 0.2 g of engineered carbon was agitated with 20 ml of aqueous solution of Arsenic at desired concentration, pH, contact time, and temperature using the shaking machine for different retention time. Here pH varies from 2 - 7, contact time varies from 15 min to 4 h, temperature varies from 20 to  $35^\circ\text{C}$  and concentration of arsenic solution is 50 mg/l. Adsorption experiments were carried out to know the effect of pH, contact time and temperature on percentage remediation of solution/arsenic containing water / waste water using engineered carbon. At the end of pre-determined time intervals the adsorbent was centrifuged at 10,000 rpm for 2 min then filtered. The supernatant liquid was analyzed for the remaining arsenic solution using atomic absorption spectro photometer (AAS), Model G.B.C. 902 – Double Beam AAS.

### Adsorption isotherm

The adsorption studies follow the key theories of Langmuir and Freundlich.

The adsorption isotherm data may be described by the classical Langmuir equation:

$$\frac{X}{X_m} = \frac{K_c C}{1 + K_c C}$$

Where  $x$  is the amount adsorbed at equilibrium concentration  $C$  and  $X_m$  is the maximum amount adsorbed,  $K$  is the Langmuir equation constant. This equation can be written in the linear form as:

$$\frac{C}{X} = \frac{1}{KX_m} + \frac{C}{X_m}$$

The linear Langmuir plots between  $C/X$  and  $C$  are shown in figure and Langmuir constants  $X_m$  and  $K$  calculated from the linear plots are recorded in Table.

The linear form of the Freundlich equation can be written as:

$$\log x = \log Kt + n \log C$$

When  $n$  is a parameter characterizing quasi-gaussian energetic heterogeneity of the adsorbent surface.

The linear Freundlich plot is shown in Figures 2 - 5. The adsorption isotherms of As (III) ions from aqueous solution of arsenic solution at controlled pH = 6.0 and contact time = 3 h on engineered carbon are presented in Figure 5. The uptake of As (III) ions is significantly rapid a contact time of 3 h.

## RESULTS AND DISCUSSION

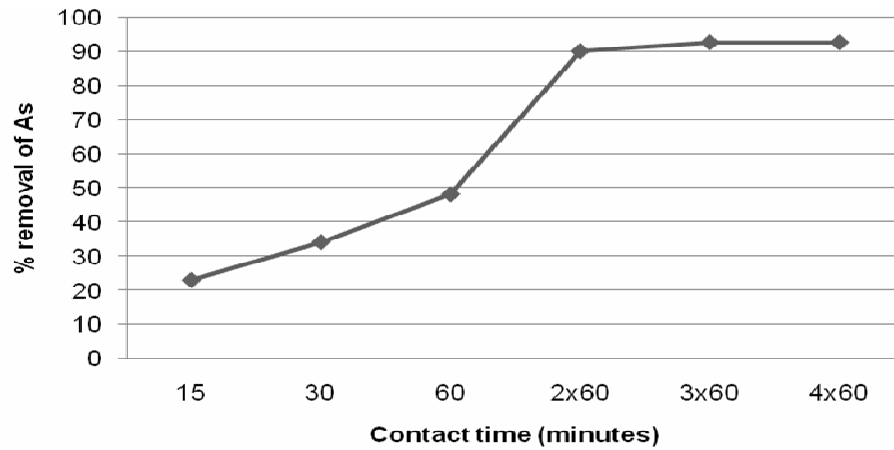
The results of experimental studies were given in different Table e.g. Tables 1, 2 and 3 showing percentage removal of arsenic in different environmental conditions e.g. pH, contact time and temperature. Percentage removal of As was well illustrated by different Figures e.g. Figures 2, 3 and 4. Adsorption isotherm was also shown by Figure 5.

## DISCUSSION

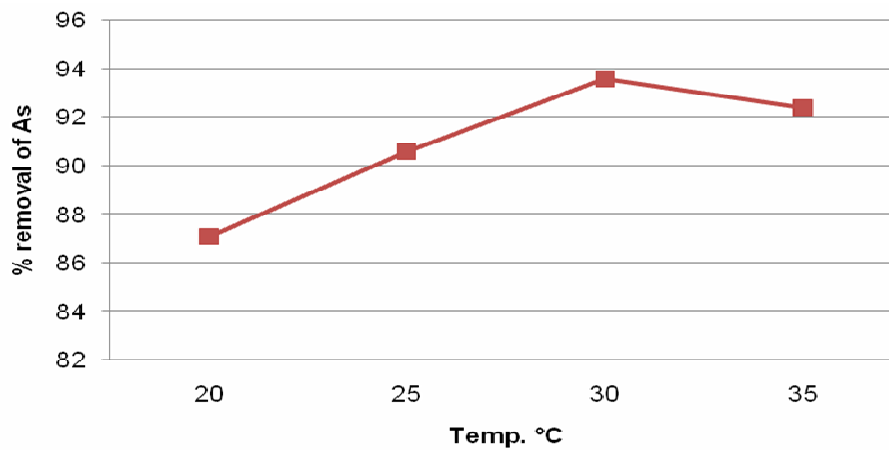
The effect of pH, contact time and temperature on remediation of arsenic using engineered carbon (EC) following adsorption technology is given point wise in the following headings.

### Effect of pH on the remediation of As

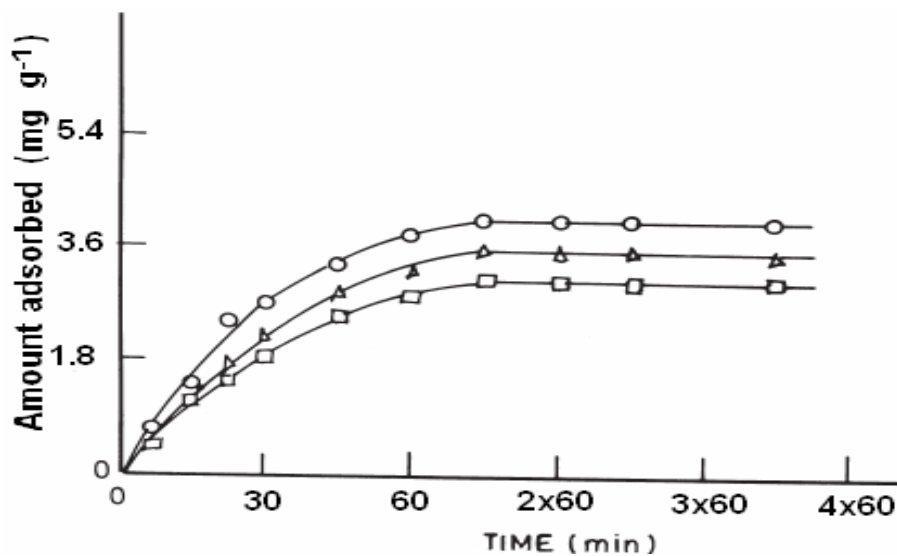
0.2 g of engineered carbon was gently agitated with 20 ml of 50 mg/l of Arsenic solution for 3 h. The pH of the initial solution varied between 2.0 to 7.0. A significant change in the extent of adsorption has been found with



**Figure 3.** Effect of contact time on adsorption of As by EC.



**Figure 4.** Effect of temperature on remediation of As by EC.



**Figure 5.** Remediation of Arsenic by Engineered carbon at temperature 20, 30 and 35°C, conditions; Arsenic concentration 50 mg/l, pH 6.0.

**Table 1.** Effect of pH.

S/No.	pH	As in the filtrate (mg/l)	As adsorbed (mg/l)	Percent removal
1	2	3.2	1.8	36
2	3	2.5	2.5	50
3	4	1.85	3.15	63
4	5	1.1	3.9	78
5	6	0.6	4.4	88
6	7	0.7	4.3	86

Initial concentration of As = 50 mg/l (1 g EC/100 ml of solution), time of shaking = 3 h.

**Table 2.** Effect of contact time.

S/No.	Time (min)	As in the filtrate (mg/l)	As adsorbed (mg/l)	Percent removal of As
1	15	3.845	1.155	23.1
2	30	3.29	1.71	34.2
3	60	2.59	2.41	48.2
4	2x60	0.450	4.550	90.1
5	3x60	0.365	4.635	92.7
6	4x60	0.365	4.635	92.7

Initial concentration of As = 50 mg/l (1 g EC/100 ml of solution) pH = 6.0.

**Table 3.** Effect of temperature.

S/No.	Temp. (°C)	As in the filtrate(mg)	As sorbed (mg)	Percent removal of As
1	20	0.65	4.35	87.0
2	25	0.47	4.53	90.6
3	30	0.32	4.68	93.6
4	35	0.38	4.62	92.4

Initial concentration of As = 50 mg/l (1 g EC/100 ml of solution) pH = 6.0, Contact time = 3 h.

an increase of pH from 2 to 7.

It is obvious from Table 1 and Figure 2 that as pH increased, adsorption of Arsenic increased, which achieved optimum value at pH 6.0. This was followed by a decrease in the adsorption density. Hence, for all further experiments, the pH of the solution is maintained at 6.0, this trend is supported by earlier studies (Gupta and Chen, 1978; Ferguson and Anderson, 1974; Frost and Griffin, 1977) using amorphous hydroxides and other adsorbents for arsenic removal.

#### Effect of contact time on the remediation of As

The concentration of Arsenic solution used for experiment was 50 mg/l. The pH of the solution is fixed that is, 6.0. 20 ml of 50mg/l solution at fixed pH 6.0 was agitated with 0.2 g of engineered carbon (EC) in stoppered bottles kept in shaking machine for different period of contact time. The results are shown in Table 2

and Figure 3. It is observed that percentage removal of As reaches to 92.7% when contact time is 3 h. The adsorption rates were initially rapid because of the readily accessible sites on the adsorbent surface resulting in a decrease in the percentage removal of pollutant species with an increase in initial concentration.

#### Effect of temperature on the remediation of As

The effect of temperature on the percentage removal of Arsenic by engineered carbon (EC) is shown in the Table 3 and Figure 4. Increase in temperature from 20 to 30 °C increased the sorption of As from 87.0 to 93.6%. The increase in percentage remediation of Arsenic with increasing temperature from 20 to 30 °C may be due to increase in adsorption capacity of adsorbent – engineered carbon.

The above discussion was made in the light of three important parameters of adsorption technology used for

remediation of arsenic from contaminated/polluted water. The adsorption isotherms of As from aqueous solutions have been studied on engineered carbon (EC). The generated data from adsorption experiments follows Langmuir adsorption isotherm equation. It is well illustrated by Figures 2 - 5. The adsorption isotherms of As (III) ions from aqueous solution of Arsenic solution at controlled pH = 6.0 and Contact time = 3 h on Engineered carbon are presented in Figure 5.

## Conclusion

It is concluded from the above experimental studies that a good amount of Arsenic that is, = 93.6% is removed by adsorption on engineered carbon, at pH = 6.0 contact time of 3 h and temperature 30°C. It is effective technology for remediation of Arsenic containing water/waste water coming from arsenic compounds manufacturing plants. It may be useful in development of prototype effluent treatment plant (ETP) or periodical and continuous removal batch reactor for treatment of arsenic containing industrial effluents and arsenic contaminated water.

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