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ORIGINAL ARTICLE

ARSENIC ADSORPTION BEHAVIOR OF METAL ACTIVATED CARBON IN COMPARISON OF ACTIVATED CARBON

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Abstract:

In this work, two adsorbents, namely MAC (metal activated carbon) and AC (Activated carbon), have been synthesized and studied for their adsorption behavior towards arsenic. Results of static adsorption studies carried out in the laboratory have shown greater than 99 percent removal of As^{+3} (which is about four times more toxic than As^{+5}) and As^{+5}, individually and as a 1:1 mixture, by MAC. Effect of various parameters such as adsorbent dose, contact time and initial concentration (of arsenic species under investigation) on removal of arsenic from water are presented. A dose of 15 g/L for MAC adsorbent has been optimized for effective removal of As^{+3} (<10 ppb (g/L), WHO drinking water limit) within 4 hours of contact time and with an optimized initial arsenic concentration of 2 ppm (mg/L). Similar studies for removal of As^{+5} and 1:1 mixture of As^{+3}:As^{+5} from water have shown that an optimized dose of 10 g/L of MAC in contact with As+5 contaminated water (initial As^{+5} concentration: 1 ppm) for 6 hours and an optimized dose of 20 g/L of MAC in contact with arsenic contaminated water [initial arsenic (1:1 As^{+3}:As^{+5}) concentration: 1 ppm] for 4 hours is sufficient for almost hundred percent removal of As^{+5} and 1:1 mixture of As^{+3}:As^{+5}, respectively, from water.

KEY WORDS:

Toxic metals, adsorption, drinking water, Arsenic,

INTRODUCTION

Metal ions such as lead, mercury (Kadirvelu *et al*), arsenic (Chakraborti *et al*), chromium, cadmium (Rajkumar *et al*), etc. are highly toxic in nature and pose a great threat to the existence of all life forms, even at trace levels (Katsoyiannis *et al*).

The toxicity of arsenic varies with the species of arsenic present in water. As^{+3} is the most toxic species of all the known forms of arsenic. Arsenic is known to cause acute and chronic toxicity, predominant symptoms being skin manifestations called Arsenicosis. Several other manifestations such as melanosis, keratosis, leukomelanosis, hyperkeratosis, conjunctivitis, bronchitis and skin cancer also result from arsenic toxicity. The problem of arsenic poisoning is widely prevalent in the lower Gangetic plains, more so in Bangladesh and in West Bengal, India (Pearce *et al*).

The foregoing discussion, therefore, enforces the need to develop reliable and economical water remediation technologies. Over the past decade, water remediation, with respect to removal of toxic metal ions, has gained impetus and the present work is an effort in the same direction. Amongst the various water remediation technologies being developed worldwide (Katsoyiannis *et al*, http://web.mit.edu), adsorption

is the most cost-effective and commonly used technique with comparable efficiency (Katsoyiannis et al). This paper discusses development and use of activated carbon-based adsorbents for the removal of all kinds of arsenic species from water.

EXPERIMENTAL

All reagents used are of AR quality and Milli-Q grade water has been used for solution preparation. Metal ion solutions have been prepared using the corresponding salts, $NaAsO_2$ for the preparation of As^{+3} solution and Na_3AsO_4 for the preparation of As^{+5} solution. Merck standard solutions have been used for metal analysis.

Adsorbent Preparation:

The adsorbents, AC and MAC, have been prepared by mixing indigenously available powdered activated carbon (supplied by Active Carbon, Hyderabad), metal (MnO_2 in case of MAC, in case of AC no metal was added), clay (reported to be a very good adsorbent for various metals (Ake *et al*)) and binder in the ratio of 1:1:1:1. After manual mixing, this mixture is fed to a two-roll mixer for efficient mixing, and finally made into granular form by passing it through a granulator.

Adsorbent Characterization:

The adsorbents thus prepared have been characterized for their surface features, composition and surface area by SEM (Scanning Electron Microscope, Model: LEO 1455), EDX (Energy Dispersive X-ray analysis) and Surface Area Analyzer (Model: Micromeritics ASAP 2010), respectively.

Adsorption isotherm studies:

Static adsorption studies have been carried out by shaking 100mL solution of definite concentration of the metal ion with required dose of adsorbent for a stipulated time on a rotary shaker at 30^0C 1^0C.

Metal Analysis:

The analysis of the water samples collected in each of the studies prior to and after adsorption has been carried out using Hydride Generator (Model: HG-3000) attached to AAS (Model: GBC 904AA) (as per ASTM Standards).

RESULTS AND DISCUSSION

Characterization:

SEM micrographs of the two adsorbents, as depicted in Figs. 1 & 2, confirm granular morphology with diameter ranging from 1-2 mm in both the cases, and the comparison of Figs. 3 & 4 clearly confirm the presence of Mn in MAC. The values of surface area and elemental composition, for AC and MAC, are given in Table 1.

Optimization of Dose:

The adsorbent (AC/MAC) dose has been varied from 5 g/L to 40 g/L, keeping the other parameters, viz. adsorption time and initial concentration of metal ion (As^{+3}), constant at 24 hrs. and 1ppm, respectively. The study indicated higher adsorbing efficiency of MAC for both As^{+3} and As^{+5}, individually as well as in a 1:1 mixture, (final concentration <10 ppb). Optimized adsorbent (MAC) doses for effective metal ion removal (Figs. 5, 6 and 7) were found to be:

1. 15.0 g/L for As^{+3},
2. 10 g/L for As^{+5}, and
3. 20 g/L for 1:1 mixture of As^{+3} and As^{+5}

The values of Freundlich constants, K and n (Table 1), as determined from the following equation (Kadirvelu and co-workers, 2002), also confirm that MAC is a better adsorbent for arsenic.

$$\frac{x}{m} = KC_e^{1/n}$$

where, x/m is the amount adsorbed per unit mass of the adsorbent

Ce is the equilibrium concentration of the adsorbate in the solution
K is the adsorption capacity
n is the affinity of the adsorbent for the adsorbate

OPTIMIZATION OF CONTACT TIME:

Results of experiments carried out for contact time optimization, by varying the adsorption time from 2 hours to 24 hours and keeping other parameters constant, show that 4 hours of contact time is sufficient for the effective removal of As^{+3}, 6 hours for As^{+5}, and 4 hours for 1:1 mixture of As^{+3} and As^{+5} (Figs. 8, 9, and 10).

OPTIMIZATION OF INITIAL CONCENTRATION OF METAL ION:

This study involved variation of initial concentration of As^{+3} from 1 ppm to 10 ppm, keeping the other two adsorption parameters constant at their optimized values. From the corresponding adsorption isotherm (Fig. 8) it can be deduced that with an adsorbent dose of 15 g/L and a contact time of 2 hours, desired removal can be achieved only up to 2 ppm initial concentration; the adsorbent efficiency decreasing thereafter for the aforesaid dose and contact time.

CONCLUSION

The novel adsorbents, developed for the present work, have been proved quite efficient for the removal of arsenic from water and, thus, can be successfully utilized in the development of water remediation technologies.

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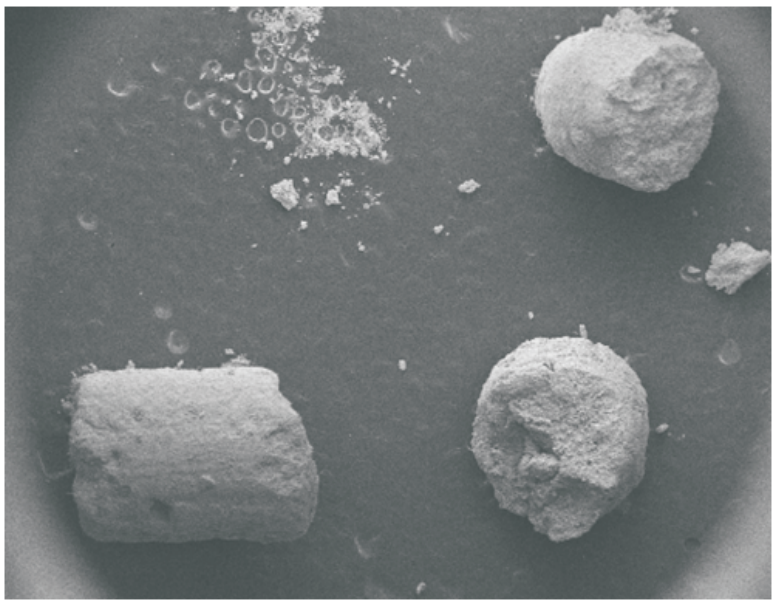

Fig.1: SEM micrograph of MAC showing its granular morphology (Mag: 14X)

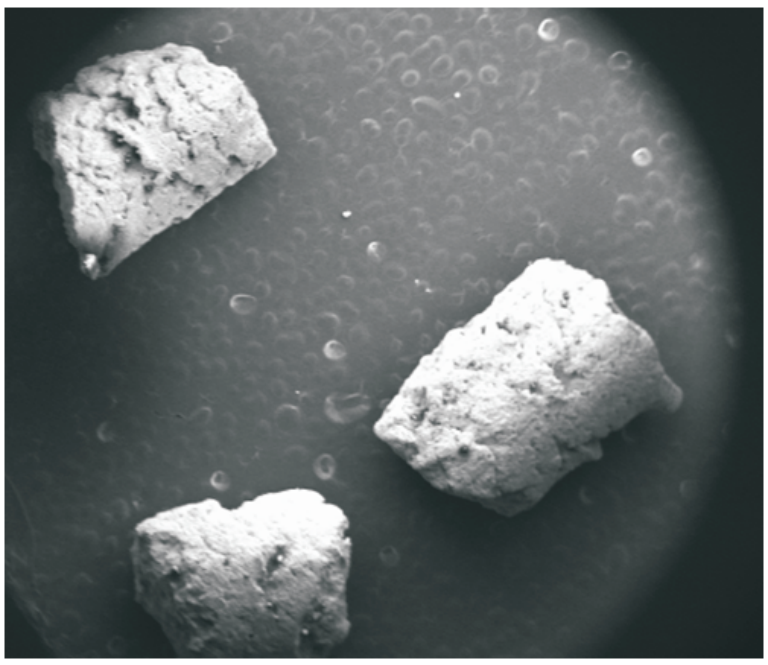

Fig.2: SEM micrograph of AC showing its granular morphology (Mag: 14X)

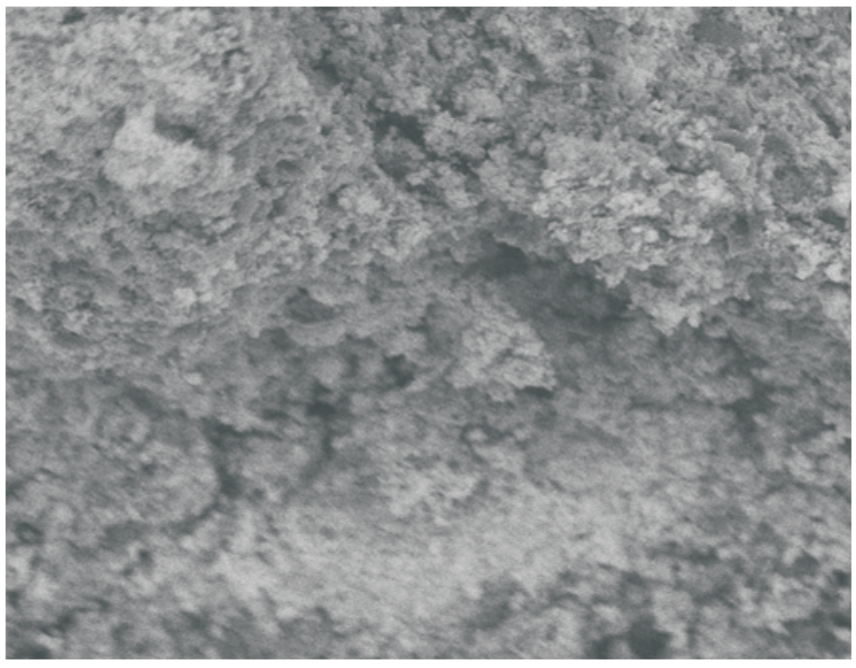

Fig.3: SEM micrograph of MAC showing presence of Mn (Mag: 1.00 KX)

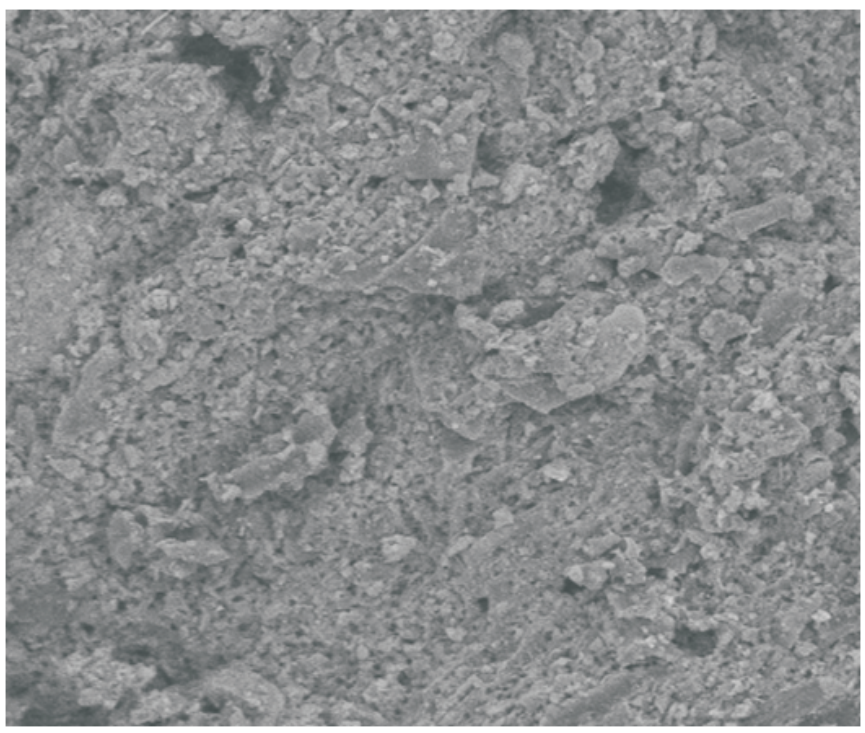

Fig.4: SEM micrograph of AC showing absence of Mn (Mag: 1.00 KX)

Table 1: Characteristics of Adsorbents

Adsorbent	Surface Area (m^2/g)	Composition (weight %)					Freundlich Constants					
							As^{+3}		As^{+5}		1:1 mixture of As^{+3} and As^{+5}	
		C	O	Al	Si	Mn	K	n	K	n	K	n
AC	170	65.63	26.36	3.28	3.27	0.00	0.56	$2.6e^{-4}$	$2.6e^{-4}$	0.56	2.45	2.57
MAC	180	26.11	33.75	3.53	4.01	32.59	1.12	5.8	4.754	0.84	20.38	2.71

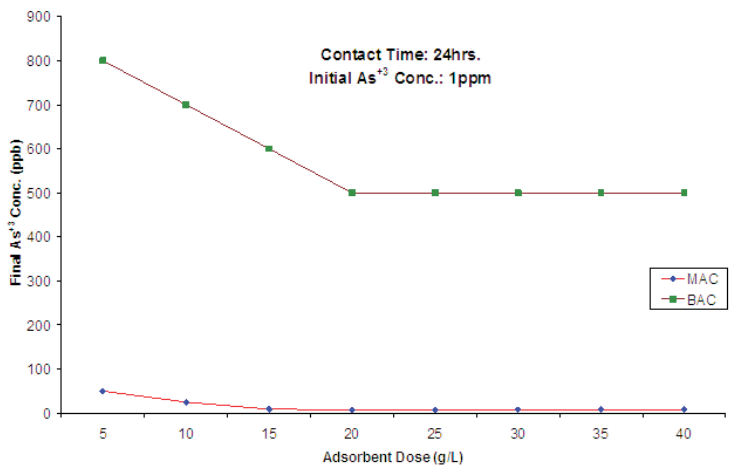

Fig.5: Effect of Adsorbent Dose on As^{+3} adsorption

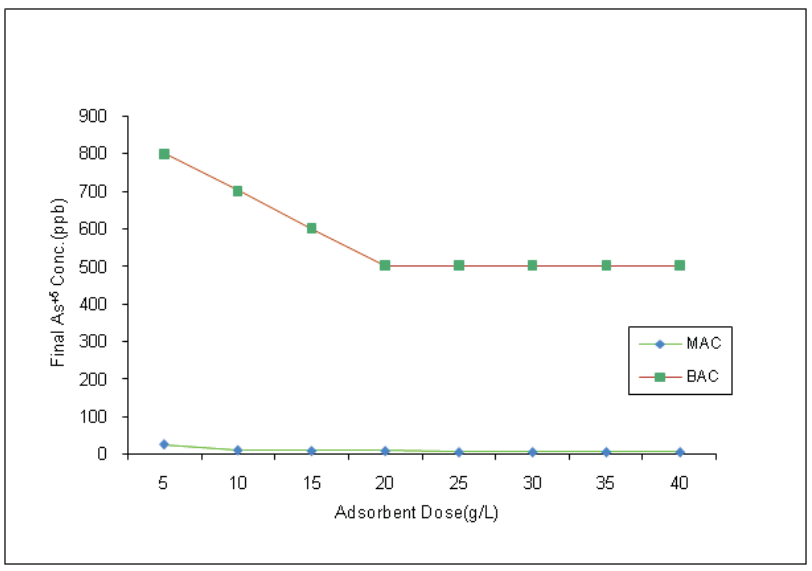

Fig.6: Effect of Adsorbent Dose on As^{+5} adsorption

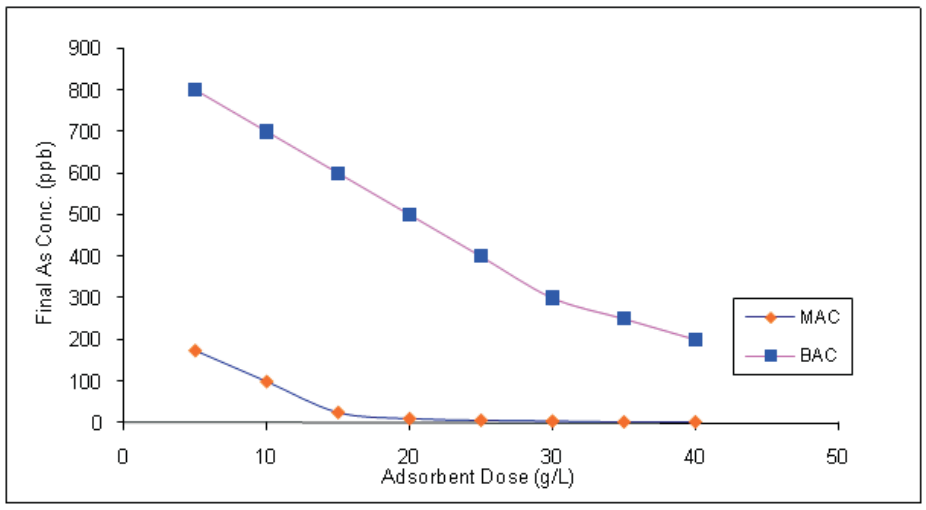

Fig.7: Effect of Adsorbent Dose on adsorption of 1:1 mixture of As^{+3} and As^{+5}

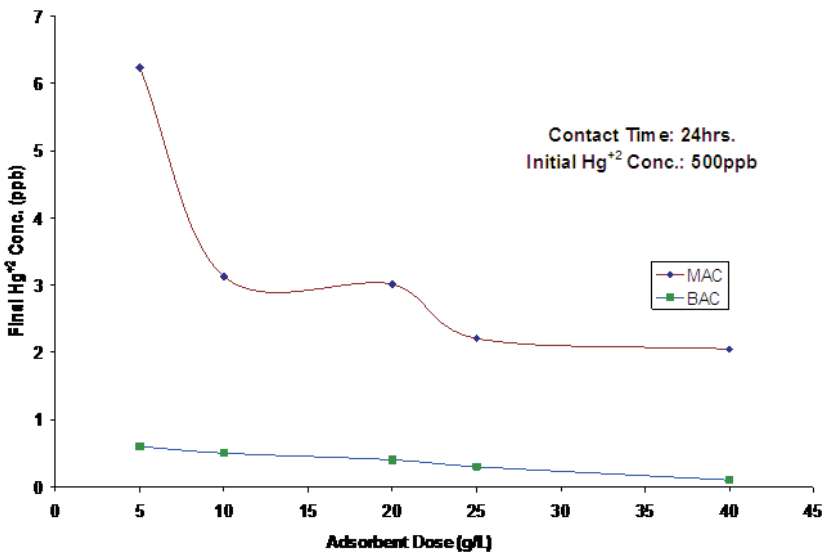

Fig.6: Effect of Adsorbent Dose on Hg^{+2} adsorption

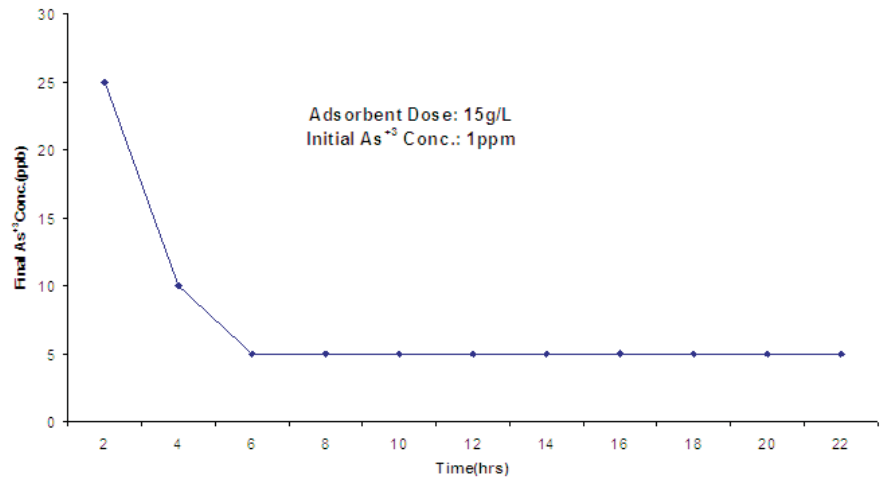

Fig.7: Effect of adsorption time, employing MAC adsorbent, on As^{+3} adsorption

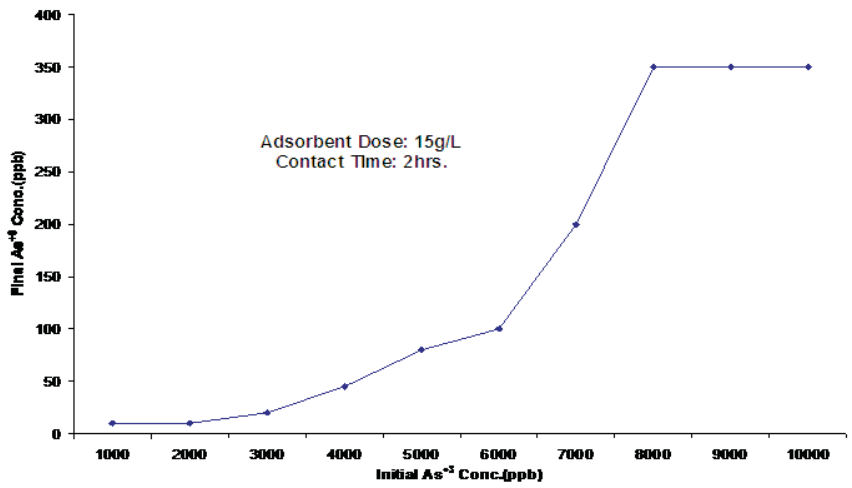

Fig.8: Effect of initial As+3 concentration on adsorptive removal of As^{+3} using MAC