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## Arsenic Removal Properties of Laterite Soil by Adsorption Filtration Method

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**Abstract:** Laterite soil samples were studied to monitor their efficiency in removing arsenic from contaminated water by adsorption filtration method in laboratory condition. Prepared 10 mg L<sup>-1</sup> solution of As<sup>3+</sup>/As<sup>5+</sup> was passed through the six soil samples. At room temperature, a batch of three different samples adsorbs 1010, 925 and 932.5 mg kg<sup>-1</sup> of arsenic and their removal efficiency were found to be 58.74, 65.32 and 65.39%, respectively. At 100°C temperature, the three specimens studied show the adsorptivity of 54.40, 63.47 and 58.69%, while the respective amount adsorbed was calculated 848, 694 and 760 mg kg<sup>-1</sup>, respectively. Studied IR spectra of the sample of different temperature gradients revealed that the efficiency of a particular composite is high temperature sensitive and the most important and noticeable performance of soil samples is observed when the samples are treated at room temperature, this is the optimum temperature for these soil samples. Above this temperature the efficiency decline gradually.

**Key words:** Arsenic contamination, removal efficiency, soil composite, optimum temperature

### INTRODUCTION

Arsenic contamination of groundwater resources poses the greatest threat on the health of millions of people worldwide, particularly in the densely populated river deltas of Southeast Asia (Lenny *et al.*, 2008). Another study also mentioned that an estimated 100 million people in Bangladesh and in the eastern part of India are currently affected by widespread arsenic poisoning caused by drinking water drawn from the underground (Ng *et al.*, 2003). For Bangladesh, the limit set for arsenic contaminated drinking water is 0.005 mg L<sup>-1</sup> though the recommendation by World Health Organization is 0.001 mg L<sup>-1</sup>. Also, the US Environmental Protection Agency (USEPA) has adopted an arsenic maximum contaminant level of 0.001 mg L<sup>-1</sup>, which was enforced in January 23, 2006.

It is now revealed that most of the international drinking water standards are in the range of 0.004-0.005 mg L<sup>-1</sup> arsenic (Elizade-González *et al.*, 2001a). For this reason, there is growing interest in using low-cost materials to remove arsenic from water. One of the promising methods appears to be adsorption of inorganic arsenic compounds from solution using both natural and synthetic sorbents. Some low-cost natural matters, e.g., activated red mud (Altundogan *et al.*, 2002) and natural

zeolites (Elizade-González *et al.*, 2001b), were tested as potential sorbents of As species. Furthermore, removal of arsenic using granular adsorptive media is currently the most widely used option for small community systems and individual homes (USEPA, 2003).

Since, arsenic is typically present in natural water at low concentration (micromolar to nanomolar), its adsorption and desorption behavior on mineral surfaces plays an important role in regulating its aqueous concentration in groundwater and surface water. It is established that under oxidized condition, arsenate has strong affinity to bind with Fe<sup>+3</sup> oxide minerals as an inner-sphere complex, probably predominately as a bidentate, binuclear surface complex (Foster, 2003). In recent past, the application of iron oxide studied to remove metals from water and wastewater (Benjamin *et al.*, 1996) and arsenic removal with iron oxides has been investigated (Raven *et al.*, 1998; Driehaus *et al.*, 1998; Joshi and Chaudhuri, 1996; Wilkie and Hering, 1996).

The groundwater's in aquifers of Lower Pleistocene and older age, beneath the Madhupur Tract and the Barind Tract, are free from arsenic pollution and iron because these aquifers are oxic and particularly where iron has been recrystallized as more stable phases such as hematite and reductive dissolution of iron oxyhydroxides

does not occur in them (Ravenscroft *et al.*, 2001). In addition, the fine iron-manganese concretions recorded in Madhupur's soil (Brammer, 1996). The present research investigated the performance of laterite soil a potential source of iron oxide collected from Madhupur Tract on removing arsenic.

## MATERIALS AND METHODS

**Soil sample collection:** In 20th August 2006, soil samples were collected from shibpur Sub-District (Upazila) in different levels at 10, 20 and 30 m from the surface and they labeled SS1, SS2 and SS3, respectively. Shibpur is one among the Sub-District (Upazila) of Norshindi and it is located at the middle west of Norshindi District. This Sub-District is located at 23°56' (north) and 24°07' (north) longitude at the north and the south, respectively and 29°39' (east) and 90°50' (east) latitude at the east and the west, respectively. The distance of Shibpur from Dhaka city and Norshindi District is 56 and 7 km, respectively. About 2/3 land area located at the south and west of Shibpur is formed by the sediment of the river Brahmaputra, but the remaining one third land area is formed by ancient Madhupur Tract.

**Column preparation:** Six columns were made with 5 g uniformly grained soil. Among them three columns were made with untreated soil samples of SS1, SS2, SS3 and another three columns were made with soil samples SS1 (100°), SS2 (100°), SS3 (100°) (particle size 0.1 cm) that treated with 100°C temperature. The prepared 10 mg L<sup>-1</sup> As<sup>3+</sup>/As<sup>5+</sup> solution was passed through the columns until the saturation volume of the six soil samples were reached. Water sample that passed through the columns was collected on the sample bottles after several time intervals. The absorbance of the samples was measured in the spectrophotometer. The flow rates of the columns were measured and it was range of 2-2.5 mL min<sup>-1</sup>.

**Arsenic detection method:** The silver diethyldithiocarbamate (SDDC) colorimetric method is based on the evolution of arsine gas in which inorganic arsenic is reduced to arsine, AsH<sub>3</sub>, by zinc in acid milieu, the arsine is bubbled through a solution of silver diethyldithiocarbamate, AgS.CS.N(C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>, in pyridine or chloroform; a red soluble complex is formed that can be measured photometrically at a specific wavelength of 535 nm (Eaton *et al.*, 2005).

**Arsine generation:** Ten milliliter collected water sample was taken into the generator flask followed by the addition of 5 mL concentrated hydrochloric acid, 2 mL

15% potassium iodide and 10 drops of stannous chloride solution. It was allowed to stand, with random agitation for about 15 min to ensure complete reduction of As (V) to As (III). The absorption tube was charged with 4.00 mL of SDDC solution. Cotton wool impregnated with lead acetate solution was placed in the scrubber to absorb any hydrogen sulphide, which may be subsequently evolved. After adding 3.0 pure granulated zinc to the solution in the generating flask, the scrubber-absorber was connected immediately. The evolution of arsine is 99% complete in 30 min and virtually complete in about 45 min. The volume of the solution was readjusted, if necessary, to the original volume and then poured into a 1 cm cell and the absorbance was recorded at 535 nm using the reagent (SDDC solution) as the reference.

### Preparation of standard curve for arsenic measurement:

To measure the arsenic content in the collected water sample, it was essential to prepare standard curves. For this purpose, a mother solution of 10 mg L<sup>-1</sup> (As<sup>3+</sup>/As<sup>5+</sup> at 1:1 ratio) was prepared and this solution was diluted to many other intermediate solutions of different concentrations. After preparing all these solutions, their absorbance was measured in spectrophotometer (M-390). Then, standard curve was generated for total arsenic (As) in various concentrations.

## RESULTS AND DISCUSSION

To establish suitable arsenic removal technique by column adsorption filtration, some arsenic removing materials were prepared from easily available chemicals and in this study, the value of the raw material and production cost is considered. Different types of adsorbing materials such as Activated Alumina (AA), Modified Activated Alumina (MAA), Granular Ferric Hydroxide (GFH), Granular Ferric Oxide (GFO) and granular titanium dioxide (TiO<sub>2</sub>) have been developed and implemented in recent years (Bang *et al.*, 2005; Jing *et al.*, 2005; Westerhoff *et al.*, 2006). Compared to the number of reports on removal of arsenic by iron oxide, only limited studies have been conducted by laterite soil. One recent study revealed that laterite soil is very effective for arsenic adsorption as the pH of the raw water did not change after arsenic removal and iron was not leached (Maji *et al.*, 2007). In the present study, 10 mg L<sup>-1</sup> arsenic solution is passed through the soil samples until the saturation volume to calculate the adsorption capacity and establish the suitable state of the sample on temperature sensitivity.

At room temperature, comparative study on the three different soil samples showed that the amount of arsenic adsorption in SS1 is higher than that of SS2 and SS3. The amount of arsenic passed through the column SS1 is 2470 mg kg<sup>-1</sup> and the amount of arsenic absorbed 1010 mg kg<sup>-1</sup> in Table 1. So, the average arsenic adsorbing capacity of SS1 which is collected from 10 m deep is 58.74% (5 g of the adsorbent). It is also found that the amount of arsenic passed through the columns SS2 and SS3 are 2667 and 2695 mg kg<sup>-1</sup> and the amount of arsenic absorbed 925 and 932.5 mg kg<sup>-1</sup>, respectively (Table 1). So, the average arsenic adsorbing capacity of SS2 and SS3 are 65.32 and 65.39%, respectively (5 g of the adsorbent).

At 100°C temperature, the amount of arsenic passed through the three columns is 1860, 1900, 1840 mg kg<sup>-1</sup> and the amount of arsenic absorbed 848, 694, 760 mg kg<sup>-1</sup>, respectively in Table 2. Among these three soil samples SS1 (100°) which collected from 10 m deep showed better performance on arsenic adsorption than that of the other two collected from 20 and 30 m.

The average arsenic adsorbing capacity of SS1 (100°), which treated at 100°C temperature, is decreased by 4.34% than that of SS1 at room temperature whereas the arsenic adsorbing capacity of SS2 (100°) and SS3 (100°) are

declined by 1.85 and 6.70% than that of SS2 and SS3. The result of the column studies showed that the removal efficiencies of the soil sample SS1, SS2 and SS3 are at their best as obtained and the removal efficiency of the soil sample SS1 (100°), SS2 (100°), SS3 (100°) is lowest, when they heated to 100°C in Fig. 1.

At elevated temperature hydrated ferric oxide losses its chemical hydration bond tended to move towards the stoichiometric composition Fe<sub>2</sub>O<sub>3</sub>. The IR spectrums of the soil samples SS1, SS2 and SS3 exhibits sharp peak above 3500 cm<sup>-1</sup>, which indicates the presence of trace

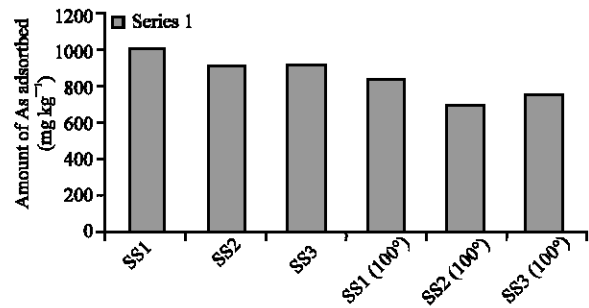


Fig. 1: The comparison of the amount of As adsorbed by all the soil samples

Table 1: Arsenic (As<sup>3+</sup>/As<sup>5+</sup> at 1:1 ratio) removing performance at room temperature

Amount of adsorbent (g)	Initial As conc. (mg L <sup>-1</sup> )	Volume passed (mL)	SS1		SS2		SS3	
			As conc. (mg L <sup>-1</sup> )	As adsorbed (mg)	As conc. (mg L <sup>-1</sup> )	As adsorbed (mg)	As conc. (mg L <sup>-1</sup> )	As adsorbed (mg)
5	10	50	0.10	0.495	3.0	0.35	2.8	0.36
		150	1.70	1.325	3.5	1.00	3.3	1.03
		250	2.80	2.045	4.2	1.58	3.8	1.65
		350	4.00	2.645	4.8	2.10	4.4	2.21
		450	5.00	3.145	5.6	2.54	5.5	2.66
		550	5.75	3.570	6.3	2.91	6.2	3.04
		650	6.35	3.935	7.0	3.21	7.5	3.29
		750	6.80	4.255	7.7	3.44	7.8	3.51
		850	7.00	4.555	8.5	3.59	8.4	3.67
		950	7.80	4.775	9.2	3.67	9.6	3.71
		1050	8.40	4.935	9.7	3.70	9.8	3.73
		1150	8.90	5.045	-	-	-	-
		1250	9.50	5.095	-	-	-	-

Table 2: Arsenic (As<sup>3+</sup>/As<sup>5+</sup> at 1: 1 ratio) removing performance at 100°C

Amount of adsorbent (g)	Initial As conc. (mg L <sup>-1</sup> )	Volume passed (mL)	SS1		SS2		SS3	
			As conc. (mg L <sup>-1</sup> )	As adsorbed (mg)	As conc. (mg L <sup>-1</sup> )	As adsorbed (mg)	As conc. (mg L <sup>-1</sup> )	As adsorbed (mg)
5	10	50	1.0	0.45	3.2	0.34	1.0	0.45
		150	1.9	1.26	3.7	0.97	2.5	1.20
		250	3.0	1.96	4.5	1.52	4.5	1.75
		350	4.5	2.51	5.1	2.01	5.8	2.17
		450	5.2	2.99	5.8	2.43	6.4	2.53
		550	5.8	3.41	6.5	2.78	7.2	2.81
		650	6.7	3.74	7.2	3.06	8.5	2.96
		750	7.5	3.99	7.8	3.28	9.2	3.04
		850	8.2	4.17	8.6	3.42	-	-
		950	9.3	4.24	9.5	3.47	-	-

amount of free hydroxyl group in the soil sample whereas there are no such peak is found for other three samples that treated at 100°C temperature. Therefore, the present study suggests that laterite soils that contain hydrated ferric oxide have better performance in removing arsenic from contaminated water. Although, this type of finding is completely absent on the other study, the present study also supports the previous study by Maji *et al.* (2007), that natural laterite soil is very effective for removing arsenic in small scale. In addition, as the present study investigated the soil samples performance for 10 mg L<sup>-1</sup> arsenic contaminated water, it can be undoubtedly used to achieve better performance for low level arsenic contamination.

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