

Arsenic in Bangladesh Soils and Its Relationship with Water Soluble Soil Organic Carbon

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Abstract

An experiment was done to see the effect of water soluble organic carbon in soil on the release of arsenic (As). Fifty soil samples, rich in organic carbon were collected from five districts of Bangladesh namely Comilla, Jessore, Satkhira, Gopalganj and Bagerhat. Water soluble organic carbon (WSOC) of the analyzed samples ranged between 15 to 466 mg/L with an average of about 155 mg/L whereas the arsenic concentrations varies between 1.4 to 5.9 mg/L with an average of 4.2 mg/L. The arsenic contents were much higher in soils where peat deposits are prominent (Gopalganj). There has been a log-log relationship between WSOC and soil, as for all the soils, the R^2 ranging from 0.355 to 0.811. Correlation between water soluble organic carbon and soil arsenic showed a positive and significant relation between the two parameters indicating the fact that organic or peat deposits contributes to the release of arsenic in Bangladesh environments.

Keywords

Arsenic Hot Spots, Contaminated Groundwater, Release of Arsenic, Peat Deposits

1. Introduction

The widespread use of arsenic contaminated groundwater for irrigation has been reported to pose the risk of soil build-up of arsenic and its subsequent transfer to plants [1] [2] [3] [4]. Arsenic contamination of ground water is instrumental in creating not only health problems; it is also aggravating crop production systems in arsenic hot spots too in the country. The Bengal Delta Plain has become one of the most severely contaminated parts in the world [5]. In Bangladesh,

groundwater is the primary source of drinking water for up to 90% of the total population [6]. In some areas of Bangladesh, groundwater arsenic concentrations reach 2 mg L^{-1} [7] [8], where the WHO provisional guideline value for drinking water is only 0.01 mg L^{-1} . In tube-wells from 41 of the total 64 districts in Bangladesh, 51% of the samples were above 0.01 mg L^{-1} (WHO-permissible limit for drinking water), 35% were above 0.05 mg L^{-1} , 25% were above 0.10 mg L^{-1} , 8.4% were above 0.3 mg L^{-1} , and 0.1% were above 1.0 mg L^{-1} [8]. An estimated population of 25 million are exposed to arsenic concentrations of more than 0.05 mg L^{-1} (Bangladesh permissible limit), and the number would be approximately doubled if WHO limit of 0.01 mg L^{-1} were adopted [9]. In Bangladesh, irrigation is mostly dependent on groundwater. Background levels of arsenic in soils are $4 \text{ to } 8 \text{ mg As kg}^{-1}$. In areas irrigated with contaminated water, the soil level can reach up to 83 mg As kg^{-1} and report recorded elevated As concentrations of up to 57 mg As kg^{-1} in soils collected from four districts of Bangladesh [10].

The biogeochemical cycle of naturally occurring arsenic in the terrestrial as well as aquatic environment has been extensively studied in recent years due to increased awareness of arsenic contamination and toxicity [11]. Under natural conditions, the highest concentration of arsenic are found in groundwater as a result of water-rock interactions and the greater tendency in aquifers for the physical and geochemical conditions seem to be favorable for arsenic mobilization and accumulation. It is opined that the distributions of organic matter, particularly peat deposits, in the aquifer sediment primarily control the arsenic release mechanism [12]. Water soluble organic carbon is considered to have an effect on origin of groundwater arsenic. The aim of this research is to investigate the effect of water soluble organic carbon fractions on arsenic and to derive hypotheses for possible future trends.

2. Materials and Methods

Fifty sites in five districts of Bangladesh were selected for collecting the samples for the experiment. Fourteen soil samples were collected from Comilla district, five from Jessore district, eight from Satkhira, eighteen from Gopalganj and five from Bagerhat district.

The bulk of soil samples representing 0 - 15 cm depth from the surface were collected by random soil sampling method as suggested by the Soil Survey Staff of the [13]. The samples were collected with spade and put into polythene bags, tagged with rubber band and labeled.

Once the soil samples were transported to the laboratory, these were dried in the air for 4 days (at 40°C) by spreading them in a thin layer on a clean piece of paper. Visible roots and debris were removed from the soil samples and discarded. For hastening the drying process, the soil samples were exposed to sunlight. After air-drying, a portion of larger and massive aggregates were broken down by gently crushing them using a wooden hammer. Ground samples were screened to pass through a 2 mm stainless still sieve. These soil samples were

used for the determination of water soluble organic carbon content of soils. A portion of the soil samples (2 mm sieved) were further ground and screened to pass through a 0.5 mm sieve. These soils were used for arsenic determination of the soils.

The content of the water soluble carbon compound was determined by Tyurin method and by determination of the dichromatic oxidation rate of the water. A flask with 1 gram of soil with 25 cm³ of distilled water was shaken using a rotation for 15 minutes; then the suspension obtained was left for 24 hour. Next, it was shaken for 15 minutes again. The suspension was filtered using a dense filter, and, after the filtration, the volume was measured using a measuring cylinder. Aliquots (10 cm³) of the water extracts were taken for the analysis [14].

Arsenic in soil was extracted by digestion with aqua-regia. For determination of aqua-regia extractable arsenic, 2.5 gm soil was digested in 20 ml aqua-regia for approximately 3 - 4 hours using a sand bath as a heating source (app. 150°C). The sample and acid were placed in 100 ml Pyrex glass beaker. After dissolution, samples were diluted up to a volume of 100 ml, mixed and filtered prior to analysis [15].

The arsenic content of the soil samples were determined from the extract by Hydride Generation Atomic Absorption Spectrophotometry (HGAAS) with the help of 50 % KI and 10 % Urea in acid medium. Standard solutions were prepared from sodium meta-arsenite. Standard solutions were prepared freshly from the dilution of 10.0 mg As (III) L⁻¹ stock solutions. Concentration of arsenic were determined using the solutions containing 10.0 ml of sample (or standard), 10.0 ml of concentrated HCl and 0.50 ml of Urea reagent (80% W/V) that were reduced by adding 0.50 ml KI reagent (40% W/V), 30 to 60 minutes prior to analyses [16]. Standard concentration of 5, 10, 15, 20 and 30 µg As (III) L⁻¹ were used. The hydride was generated using 6N HCl and 1.2% NaBH₄ and 1% NaOH in deionized water (Portman and Riley, 1964). After completion of all these preparations, sample reading was taken using Hydride Generation Atomic Absorption Spectrophotometry (HGAAS).

All extractions and analyses were done in triplicates. Correlations among various pairs were calculated to determine significant differences between the groups at $P < 0.05$. MINITAB (version 15) Packages and Microsoft Excel were used for the statistical and graphical evaluations.

3. Results and Discussion

3.1. Water Soluble Organic Carbon

The maximum and minimum values of water soluble organic carbon of the 50 soil samples are 466 mg/L and 15 mg/L respectively. The average value of water soluble organic carbon of 50 soil samples is 154.66 mg/L (standard deviation \pm 78.23). The water soluble organic carbon of the soil samples from different districts showed that those from Comilla district ranged from 15 mg/L to 191 mg/L and the average value is 117.5 mg/L (standard deviation \pm 53.19); those from Jessore district ranged from 46 mg/L to 173 mg/L and the average value is 138

mg/L (standard deviation \pm 54.49); those from Satkhira district ranged from 87 mg/L to 392 mg/L with an average value of 168.75 mg/L (standard deviation \pm 106.09); those from Gopalganj district ranged from 78 mg/L to 466 mg/L and the average value is 174.22 mg/L (standard deviation \pm 89.17) while water soluble organic carbon of the soil samples of Bagerhat district ranged from 147 mg/L to 221 mg/L and the average value is 182.4 mg/L (standard deviation \pm 32.49) (Tables 1(a)-(e)).

3.2. Arsenic (As)

The maximum and minimum concentrations of arsenic in the 50 soil samples have been found to be 5.94 mg/L and 1.41 mg/L respectively. The average value of arsenic is 4.21 mg/L (standard deviation \pm 1.27). Arsenic of the soil samples from different districts showed that arsenic in the soil samples of Comilla district ranged from 1.84 mg/L to 5.94 mg/L with an average concentration of 4.28 mg/L (standard deviation \pm 1.26); those from Jessore district ranged from 1.41 mg/L to 3.92 mg/L and the average concentration is 2.75 mg/L (standard deviation \pm 1.08); those from Satkhira district ranged from 3.48 mg/L to 5.71 mg/L and the average concentration is 4.62 mg/L (standard deviation \pm 0.92); those from Gopalganj district ranged from 2.2 mg/L to 5.98 mg/L and the average concentration is 4.40 mg/L (standard deviation \pm 1.39) while arsenic concentration of the soil samples of Bagerhat district ranged from 3.26 mg/L to 5.36 mg/L and the average concentration is 4.11 mg/L (standard deviation \pm 0.80) (Tables 1(a)-(e)).

3.3. Relation between Water Soluble Organic Carbon and Arsenic

Correlation between soluble organic carbon and the corresponding arsenic in

Table 1. (a) Concentration of Arsenic and Water soluble organic carbon of the soil samples of Comilla district; (b) Concentration of Arsenic and Water soluble organic carbon of the soil samples of Jessore district; (c) Concentration of Arsenic and Water soluble organic carbon of the soil samples of Satkhira district; (d) Concentration of Arsenic and Water soluble organic carbon of the soil samples of Gopalganj district; (e) Concentration of Arsenic and Water soluble organic carbon of the soil samples of Bagerhat district.

(a)							
Sample Name	S(C1)	S(C2)	S(C3)	S(C4)	S(C5)	S(C6)	S(C7)
Arsenic (mg/L)	4.24	3.35	4.75	5.13	3.22	4.93	4.55
WSOC (mg/L)	93	135	90	173	90	69	122
Sample Name	S(C8)	S(C9)	S(C10)	S(C11)	S(C12)	S(C13)	S(C14)
Arsenic (mg/L)	4.80	5.94	4.63	4.91	1.84	1.93	5.75
WSOC (mg/L)	107	163	153	191	15	53	191

(b)					
Sample Name	S(J1)	S(J2)	S(J3)	S(J4)	S(J5)
Arsenic (mg/L)	3.1	1.84	3.5	1.41	3.92
WSOC (mg/L)	173	130	168	46	173

(c)

Sample Name	S(S1)	S(S2)	S(S3)	S(S4)	S(S5)	S(S6)	S(S7)	S(S8)
Arsenic (mg/L)	4.94	3.56	5.3	4.42	5.7	3.89	3.48	5.71
WSOC (mg/L)	95	87	392	90	208	107	137	234

(d)

Sample Name	S(G1)	S(G2)	S(G3)	S(G4)	S(G5)	S(G6)
Arsenic (mg/L)	5.81	4.80	2.20	3.81	2.70	5.89
WSOC (mg/L)	176	155	78	115	98	262
Sample Name	S(G7)	S(G8)	S(G9)	S(G10)	S(G11)	S(G12)
Arsenic (mg/L)	2.51	3.62	5.20	3.55	3.07	5.27
WSOC (mg/L)	199	131	160	137	115	233
Sample Name	S(G13)	S(G14)	S(G15)	S(G16)	S(G17)	S(G18)
Arsenic (mg/L)	5.12	5.70	5.70	2.42	5.77	5.98
WSOC (mg/L)	168	204	128	90	466	221

(e)

Sample Name	S(B1)	S(B2)	S(B3)	S(B4)	S(B5)
Arsenic (mg/L)	4.31	3.94	3.26	3.67	5.36
WSOC (mg/L)	198	196	147	150	221

soils of five districts was calculated to observe any relationship between the two parameters. There exists a significant positive relationship between the two, signifying the fact that arsenic release in Bangladesh environment is related to the organic carbon contents of soil (**Figure 1**). The trend line, $y = 0.009x + 2.755$ and R^2 being 0.334 further confirm this ($P = 0.000$ and Pearson correlation of water soluble organic carbon and arsenic = 0.578).

The arsenic in Comilla, Jessore, Satkhira, Gopalganj and Bagerhat districts were also found to be directly correlated with soluble organic carbon. The P and the Pearson correlation values are 0.002, 0.052, 0.099, 0.009, 0.037 and 0.754, 0.875, 0.623, 0.596, 0.901 respectively. The results are presented in **Figures 2-6**; **Table 1(e)**. The trend line being $y = 0.017x + 2.186$, $y = 0.017x + 0.358$, $y = 0.005x + 3.713$, $y = 0.009x + 2.78$, $y = 0.022x + 0.062$ with R^2 of 0.568, 0.766, 0.388, 0.355, 0.811 for Comilla, Jessore, Satkhira, Gopalganj and Bagerhat respectively.

In soils of Comilla district for S(C12) the arsenic concentration was found to be 1.84 mg/L and the corresponding WSOC was 15 mg/L while in S(C9), the arsenic concentration was 5.94 mg/L where the WSOC was 163 mg/L. In soils of Jessore district S(J4), arsenic concentration was found to be 1.41 mg/L and the corresponding WSOC was 46 mg/L while in soil S(J5), arsenic concentration was 3.92 mg/L where the WSOC was 173 mg/L. In soils of Satkhira district S(S2), arsenic concentration was found to be 3.56 mg/L and the corresponding WSOC was 87 mg/L while in soil S(S8), arsenic concentration was 5.71 mg/L where the

WSOC was 234 mg/L. In soils of Gopalganj S(G3), arsenic concentration was found to be 2.2 mg/L and the corresponding WSOC was 78 mg/L while in soil S(G18), arsenic concentration was 5.98 mg/L where the WSOC was 221 mg/L and in soils of Bagerhat, S(B3), arsenic concentration was 3.26 mg/L where the WSOC was 147 mg/L while in soil S(B5), arsenic concentration was 5.36 mg/L where the WSOC was 221 mg/L.

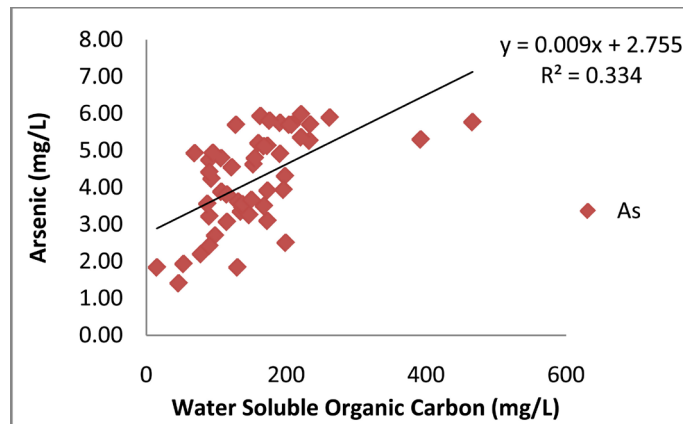


Figure 1. Relation between WSOC and As in five districts.

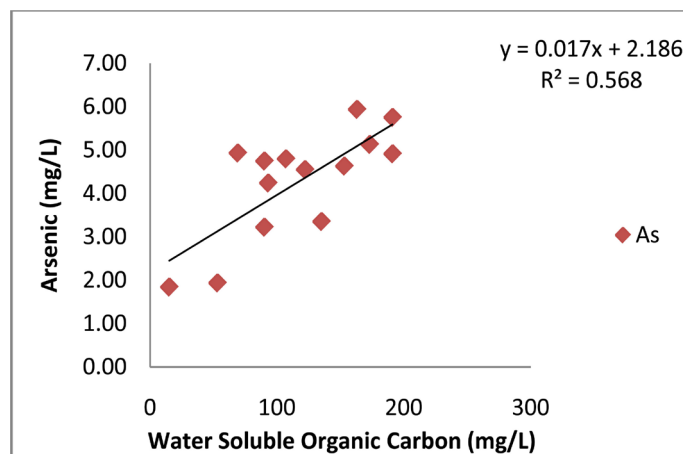


Figure 2. Relation between WSOC and As in Comilla district.

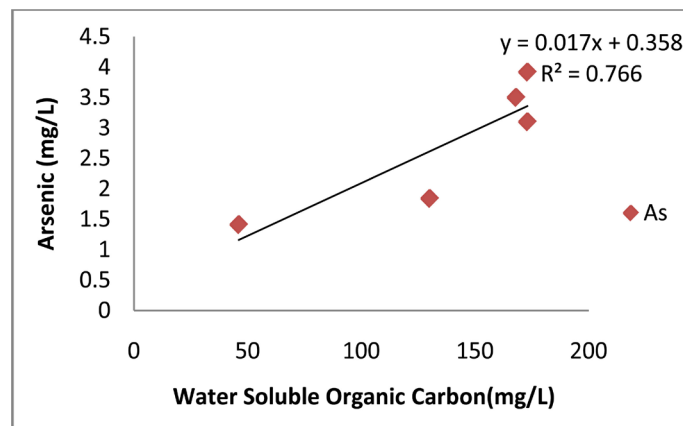


Figure 3. Relation between WSOC and As in Jessore district.

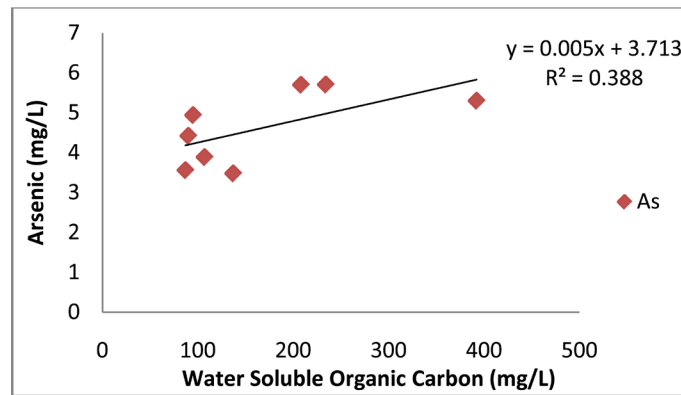


Figure 4. Relation between WSOC and As in Satkhira district.

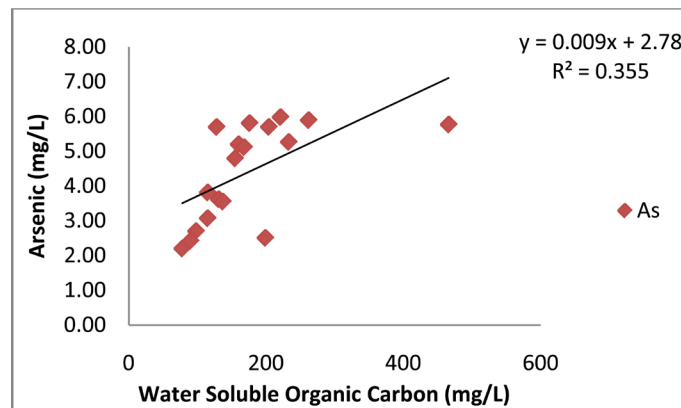


Figure 5. Relation between WSOC and As in Gopalganj district.

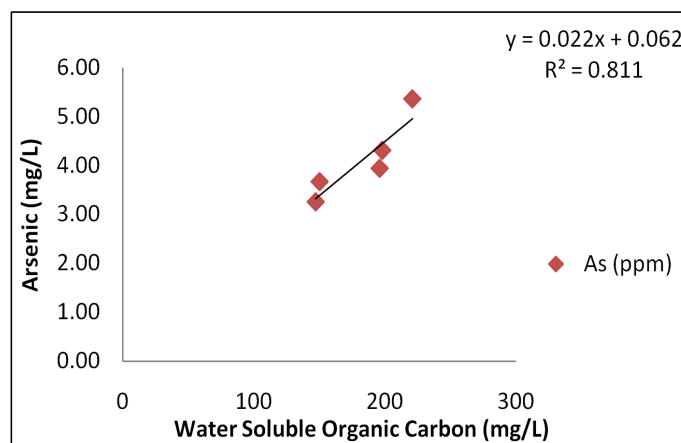


Figure 6. Relation between WSOC and As in Bagerhat district.

The distribution of organic matter, particularly peat deposits, in the aquifer sediments primarily controls the arsenic pollution mechanism. Peat beds are common beneath the old Meghna Estuarine Floodplain and Gopalganj-Khulna Peat Basins [12].

4. Conclusion

There are many debates on the theory of arsenic release in Bangladesh environ-

ment. One important hypothesis is that organic deposits are responsible for its release in Bangladesh environment. It has been observed that there is a positive relationship between water soluble organic carbon and arsenic in the soils. The higher the water soluble organic carbon is, the higher the arsenic content. The present findings justify that organic or peat deposits could contribute in the release of arsenic in our environment.

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