

Assessment of Arsenic Contamination in Relation to Soil Properties of Kustia and Rangpur Districts

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Abstract- The total arsenic (As) contents of collected soil series were determined using FI-HG-AAS (Flow Injection Hybrid Generation Atomic Absorption Spectrometry) method to find out whether the soils are contaminated or not in soil of different series in Kushtia and Rangpur, Bangladesh. Besides arsenic, the other elements vizs. soil properties like soil pH, organic carbon, total nitrogen content and exchangeable cations like Ca, K and Na were also estimated in the Soil Science laboratory at Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Results showed that the As level of Kushtia district ranged from 11.03 mg/kg - 21.06 mg/kg. The lowest As contaminated soil series in Kushtia district was Gopalpur 1 (11.03 mg/kg) and the highest contaminated soil series in Kushtia district was Ishurdi (21.06 mg/kg). In Rangpur district, the As level ranged from 1.80 mg/kg - 6.57 mg/kg, where all the soil series were non-contaminated. Kaunia 2 (6.57 mg/kg) and Belabo 1 (5.10 mg/kg) soil series were slightly contaminated with refers a level of 6 mg/kg and Belabo 2 (4.72 mg/kg) soil series were also slightly contaminated with refers a level of 5 mg/kg. The total As contents in the different surface soils were varied mainly due to local differences in the soil types, biogeochemical activities and farm management practices

50,000 have so far been brought under investigation by different Government and non-Government agencies. The rest are still beyond the survey. The actual picture of the severity of arsenic pollution is yet to be revealed as the entire country could not be surveyed till now.

The reasons for arsenic contamination of ground water in Bangladesh are yet to be identified. The source of arsenic contamination in the seven districts of West Bengal is noted to be geological. Bore-hole sediment analysis at several arsenic contaminated areas showed high arsenic concentration in soil layers where it was found to be associated with iron pyrites. The reason why arsenic is leaching out from the sources is not yet clear. Several studies have indicated that due to heavy extraction of groundwater, there is marked fluctuation of water level (Ali, 2009). As a result there is aeration of soil leading to decomposition of the pyrites that causes leaching of arsenic. Bangladesh is geographically adjacent to west Bengal having similar aquifers and socio-economic background.

Environmental pollution has become a major problem along with increase of the world population. Many reports (Ali, 2009) indicate the large variability of groundwater arsenic problem on both local and regional scales. After 1995, the crisis has emerged into broad public awareness. It has been estimated that water poisoning is affecting as many as 85 million people, nearly 13 million of which is contaminated with arsenic. The scale of disaster in the country is beyond that of the accidents in Bhopal and Chernobyl. It is likely that irrigation with this ground water may increase the As level in soil and this toxic element may consequently be health hazard after entering into the food chain through crop uptake.

Ground water is the source of drinking water for more than 97 percent of rural population who do not have access to public water supply system. These groups of people are at risk by exposed to arsenic pollution. So it is necessary to find out arsenic problem in the different soils of Bangladesh. Therefore, this study was undertaken with a view to assess the As concentration of Kushtia and Rangpur district's soil.

The main objectives of the study are:

- to find out the arsenic status of the soil in the studied areas; and
- to assess the arsenic contamination in soils of Kushtia and Rangpur districts in Bangladesh.

I. INTRODUCTION

Groundwater arsenic contamination is a severe problem in Bangladesh. Presently, above 50 million people in 60 districts are affected by arsenic contamination. The severely arsenic affected areas are in the southeast and southwest parts of the country. Besides domestic use (drinking, cooking, washing, etc.), a significant quantity of groundwater is utilized in agricultural sector, especially for irrigation. This toxic element may enter into the food chain (Huq *et al.*, 2006), thus posing a significant threat to human health.

Arsenic problem has emerged as a fresh blow to Bangladesh, a country of 140 million populations, known as a land of frequent natural calamities. Recent surveys showed that about 90 million people of the country are living under the risk of arsenic problem as the groundwater of a vast region contaminated with arsenic and the arsenic pollution is not only causing serious health hazard to the people, but also affecting the environment and creating social problems.

More than 2 million tube-wells are presently being used as the source of drinking water in Bangladesh. Out of those, only

II. MATERIALS AND METHODS

It deserves very careful consideration in scientific research. The methods and procedures followed in conducting this study have been presented in this chapter with a conceptual framework. A study was initiated for the assessment of arsenic status of Kushtia and Rangpur districts whether the soils have undergone any contamination or not.

3.1 Sample preparation and laboratory analysis

Air-dried soil samples were ground and passed through 100 mesh sieve and stored in a plastic bottle for laboratory analysis. Approximately 0.5 grams of air-dried soil samples were taken in a glass bottle for oven drying. After oven drying at 50^o C for 24 hours, all the samples were crushed and made into a fine homogenous powder within approximately 12 minutes using an agate mortar and a pestle. The agate mortar and pestle were cleaned with ethanol to ensure that the trace metal contamination did not originate from the grinding process.

3.2 Methods of analysis

3.2.1 Soil pH

Soil pH was determined by glass electrode pH meter as described by Jackson (1962). Twenty gram air-dry soil was taken in a beaker and 50 ml distilled water was added to it. The suspension was stirred well for several times during the next 30 minutes and allowed to stand for about an hour. Then the electrode was immersed into the partly settled soil suspension and pH was measured. The result was reported as "Soil pH measured in water" (Soil-water ratio being 1: 2.5)

3.2.2 Organic carbon

Organic carbon was determined titrimetrically by Walkely and Black's (1935) wet Oxidation method with oxidation of organic carbon with potassium dichromate (K₂Cr₂O₇). According to procedure 2 g soil along with 10 ml 1 N K₂Cr₂O₇ solution and 20 ml of conc. H₂SO₄ was taken in a 500 ml conical flask. After 30 minutes rest, about 200 ml distilled water and 10 ml conc. H₃PO₄ were added. Then 40 drops of diphenylamine indicator (C₁₂H₁₁N) was added and titrated against XN ferrous sulphate solution until purplish blue color was turned to fresh green color. The organic matter content of each sample was calculated by multiplying the content of organic carbon by Van Bemmelen factor, 1.73 (Page *et al.*, 1982).

3.2.3 Total nitrogen content

Total nitrogen content was determined by micro-Kjeldahl method. The soil was digested with H₂O₂ and conc. H₂SO₄ in presence of a catalyst mixture (K₂SO₄: CuSO₄. 5H₂O: Se in the ratio of 10: 1: 0.1) and the nitrogen in the digest was determined by distillation with 40% NaOH followed by filtration of distillate trapped in H₃BO₃ with 0.01 N H₂SO₄ (Bremmer and Mulvaney, 1982).

3.2.4 Exchangeable Ca, K and Na content

Exchangeable calcium, potassium and Sodium were determined by ammonium acetate extraction method. In this method, soil sample was saturated with NH₄Oac solution and the supernatant clear solution was separated and collected. The NH₄Oac solution was added again to make the final volume up to

100 ml for each sample. For the cation of Ca⁺⁺, K⁺ and Na⁺ the flame photometer was separately adjusted and different standard curves were prepared to find out the concentration of the cation but the extracting solution used for each sample was same. From each reading the concentration of each ion was obtained from their respective standard curves and was expressed as me%.

3.3 Analysis of arsenic

3.3.1 Reagents

All reagents were of analytical reagent grade. Distilled deionized water was used throughout. Standard solutions were prepared by dissolving appropriate amounts of As₂O₃ (Merck, Germany), standard arsenic (V) Titrisol (Merck, Germany), CH₃AsO₃Na₂.6H₂O (Carlo-Erba, Italy) and (CH₃)₂AsO₂Na.3H₂O (Sigma, USA). Standard stock solutions were stored in glass bottles and kept refrigerated. Dilute arsenic solutions for analysis were prepared daily. Cation [Dowex X-50w (H⁺ form)] and anion [Dowex-1 (Cl⁻ form)] exchange resins (Sigma, USA) were used. Sodium diethyldithiocarbamate (Merck, Germany) was used as a 0.5% (w/v) solution and purified shaking with chloroform. Ashing acid suspension was prepared by stirring 10% (w/v) Mg(NO₃)₂.6H₂O and 1% (w/v) MgO in water until homogenous.

The reducing solution was sodium tetrahydroborate (Merck, Germany) 1.25% (m/v) in 0.5% (m/v) sodium hydroxide. The HCl concentration was 5 M. Sodium acetate-acetic acid buffer at pH 5.5 was prepared by mixing acetic acid (0.2 M) until the pH was 5.5; citric acid-citrate buffer at pH 3.0 was prepared by using 40% (w/v) citric acid and adjusting the pH with NaOH solution. The buffers were purified by extraction with Na-DDTC and chloroform.

3.3.2 Speciation of arsenic content

A 250-ml aliquot of filtered preserved water sample adjusted to a pH of about 5.5 by adding dilute NaOH was transferred into a 500-ml separating funnel; 10 ml of sodium acetate-acetic acid buffer at pH 5.5 was added and the funnel was shaken; 5 ml of 0.5% Na-DDTC and 5 ml of chloroform were then added. The solution was shaken for 3 min. The procedure was repeated twice. All three chloroform extracts were combined and placed into a 50 ml round-bottom flask; chloroform was then removed by a rotary evaporator kept at 30^oC on a water bath. The dry residue was decomposed by warming with nitric acid (0.1 ml), cooled and then transferred quantitatively into a known volume (5-10 ml) with water. Then FI-HG-AAS was used for the determination of arsenic against arsenate standard. After arsenite was removed from the water by chelate extraction, the remaining arsenic was determined directly by FI-HG-AAS against an Arsenate standard or total arsenic was measured directly by injecting the aliquot into FI-HG-AAS against arsenate standard and arsenate was determined by subtracting arsenite from total arsenic. Blanks were determined under identical conditions (Gautam *et al.*, 1992).

III. RESULTS AND DISCUSSION

In this chapter, the research results with regards to evaluate the soil physical and chemical characters e.g. particle size

distribution (sand, silt and clay contents), soil pH, organic matter, total N and exchangeable cations (Ca⁺⁺, K⁺ and Na⁺) contents for the assessment of arsenic status in Kushtia and Rangpur districts.

4.1.1 Soil pH, organic carbon and total N contents in different surface soil series in Kushtia and Rangpur districts

The pH value, organic carbon and total N contents of the selected soil series are described in the study (Table 4). In Kushtia district, all the soil series were observed nearby in neutral condition and the range of pH values in Kushtia district are 6.69 to 7.49. Only Garuri 1 series were slightly acidic (pH value 6.69). In Rangpur district, all the soil series were observed in acidic in nature and the range of pH value in Rangpur district were 4.3 to 5.4. The organic carbon content in the soils of Kushtia district ranged from 0.58% to 1.76%. The highest value of organic carbon content in soil was found in Ghior soil series (1.76%). The organic carbon content in the soils of Rangpur district ranged from 0.59% to 1.25%. The highest value of organic carbon content was found in Chandra 2 soil series (1.25%). It was observed that the total nitrogen content in the soils of Kushtia district ranged from 0.084% to 0.140%. The highest value was found in Garuri 1 soil series (0.140%). In Rangpur district, the total nitrogen content ranged from 0.04% to 0.1%. The highest value was found in Kaunia 2 soil series (0.1%).

Soil pH, organic carbon and total N contents showed variations in the soils of different soil series in Kushtia and Rangpur districts. The variations in pH values might be due to the differences of the farm management practices in the studied areas. The process that can contribute to these variations might be due to the redistributions of soil pH, organic carbon and total N contents in the different sampling areas. The variations in organic carbon and total N contents were mainly due to the use of organic manures during the farming activities (e.g. different farm manures and fertilizers, etc.). The variations in the studied soils also might be due to the local differences in soil characteristics, changes in cropping systems (e.g. crop types, fertilization, irrigation, etc.) and other management practices in the farming communities.

Table 1. Soil pH, organic carbon and total N contents in different surface soil series in Kushtia and Rangpur districts

Soil series	Physiographic unit	pH	Organic C (%)	Total N (%)
Garuri 1	Ganges River Floodplain	6.69	1.25	0.140
Garuri 2	"	7.28	1.20	0.105
Sara	"	7.38	0.58	0.084
Gopalpur 1	"	7.51	1.04	0.091
Gopalpur 2	"	7.40	0.81	0.119
Ishurdi	"	7.49	1.21	0.088

Ghior	"	7.47	1.76	0.125
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4.1.2 Exchangeable cation (Ca, K and Na) contents in different surface soil series in Kushtia and Rangpur districts

The exchangeable Ca, K and Na contents in the soils of Kushtia and Rangpur districts are described in the study (Table 5). The exchangeable Ca content in the soils of Kushtia district ranged from 15.00me% to 20.00me%. The highest value was found in Ghior soil series (20.00me%). In Rangpur district, the exchangeable Ca content ranged from 0.48me% to 1.98me%. The highest value was found in Kaunia 1 soil series (1.98me%). The exchangeable K content in the soils of Kushtia district ranged from 0.41me% to 0.53me%. The highest value was found in Garuri 1 soil series (0.53me%). In Rangpur district, the exchangeable K content ranged from 0.07me% to 0.24me%. The highest value was found in Pirgacha 1 soil series (0.24me%). The exchangeable Na content in the soils of Kushtia district ranged from 1.33me% to 1.49me%. The highest value was found in Gopalpur and Ghior soil series (1.49me%). In Rangpur district, the exchangeable Na content ranged from 0.06me% to 0.20me%. The highest value was found in Kaunia 1 soil series (0.20me%). The exchangeable Ca, K and Na contents showed variations in the soils of different soil series in Kushtia and Rangpur districts. The process that can contribute to these variations might be due to the redistributions of exchangeable Ca, K and Na contents in the different sampling areas. The variations in the exchangeable cation contents in different soils might be due to the differences in the farm management activities (e.g. fertilizations, etc.). The soils of Kushtia and Rangpur districts are represented the intensity of various actions of different processes under the tropical environment and the intensification of the overwhelming human activities. The variations in the studied soils also might be due to the local differences in soil characteristics, changes in cropping systems (e.g. crop types, fertilization, irrigation, etc.) and other management practices in the farming communities. The findings of this study revealed that the natural biochemical activities played important roles in the soil texture (sand, silt and clay), soil pH, and contents of organic carbon, total N and exchangeable cations (Ca, K and Na). The study showed a wide variation in soil texture, organic carbon, total nitrogen and exchangeable cations (Ca, K and Na) within Kushtia and Rangpur districts. The soil characters might be due to the variations in the soil characteristics and management practices at the farm level.

Table 2. Exchangeable cation (Ca, K and Na) contents in different surface soil series in Kushtia and Rangpur districts

Soil series	Physiographic unit	Exch. Ca(me%)	Exch. K (me%)	Exch. Na (me %)
Garuri 1	Ganges River Floodplain	17.50	0.53	1.33
Garuri 2	"	16.25	0.44	1.43
Gopalpur	"	15.00	0.44	1.49
Ghior	"	20.00	0.41	1.49

4.2 Assessment of arsenic contents

4.2.1 General Arsenic contents in soil

The natural content of arsenic in soils is 5 mg/kg (Backer and Chesnin, 1975) or 6 mg/kg (Bowen 1979). Smith *et al.* (1998) reported a background arsenic level of 8 mg/kg for non-contaminated agricultural soils. The safe levels of arsenic in irrigation water, soils and foods are yet to be established for Bangladesh.

4.2.2 Arsenic contents of Kushtia and Rangpur districts

The arsenic contents of Kushtia district ranged from 12.03 mg/kg - 20.06 mg/kg, where all the soil series were highly contaminated (Table 6). The highest contaminated soil series in Kushtia district was Ishurdi (20.06 mg/kg). The lowest contaminated soil series in Kushtia district was Gopalpur 1 (12.03 mg/kg). In Rangpur district, the arsenic contents ranged from 1.81 mg/kg - 6.97 mg/kg, where all the soil series were non-contaminated. But according to Bowen (1979), Kaunia 2 (6.97 mg/kg) and Belabo 1 (5.15 mg/kg) soil series were slightly contaminated and Belabo 2 (4.72 mg/kg) soil series were also slightly contaminated according to Backer and Chesnin, 1975.

Comparison of total arsenic contents among the different soil series showed variations in Kushtia and Rangpur districts. The variations of the arsenic contents in the soils of different soil series might be associated with the local differences in parent materials (e.g. as-bearing minerals), farm management practices (e.g. use of arsenical pesticides), continental inputs (e.g. dry and wet deposition) and other biogeochemical activities.

Table 3. As contents of Kushtia and Rangpur districts

Kushtia district		Rangpur district	
Soil series	As level (mg/kg)	Soil series	As level (mg/kg)

Garuri 1	16.50	Pirgacha 1	3.43
Garuri 2	13.27	Pirgacha 2	4.44
Sara	16.31	Kaunia 1	3.17
Gopalpur 1	11.03	Kaunia 2	6.97
Gopalpur 2	18.28	Gangachara	3.55
Ishurdi	21.06	Belabo 1	5.10
Ghior	16.25	Belabo 2	4.72

4.2.3 Relationship between As distribution and soil properties

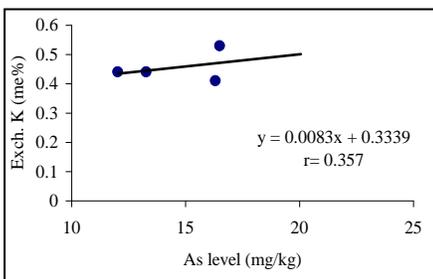
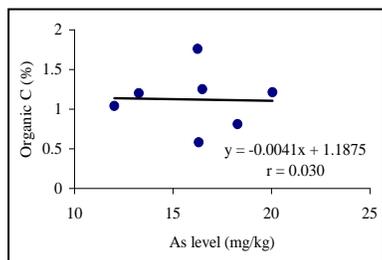
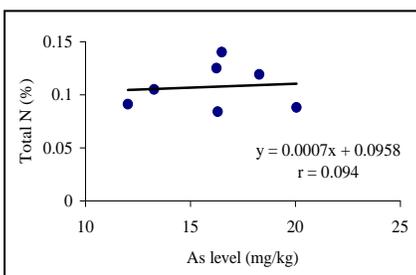
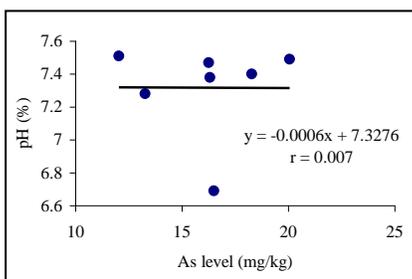
It has been reported that the soil composition such as sand, silt, clay contents, soil pH, organic carbon, total N and exchangeable cations (Ca, K, Na) are the major factors controlling trace elements in soils (Chen *et al.*, 1999). The variation in the As contents recorded in this study was, therefore, expected since the soils also varied considerably in the sand, silt, clay contents, soil pH, organic carbon, total N and exchangeable cations (Ca, K, Na) contents.

Table 4. Correlation coefficient (r) among the total As contents and the selected soil properties

Soil properties	r values	
	Kushtia	Rangpur
pH	0.007 ^{NS}	0.338 ^{NS}
Organic C (%)	0.030 ^{NS}	0.294 ^{NS}
Total N (%)	0.094 ^{NS}	0.076 ^{NS}
Exch. Ca (me %)	0.860*	0.513 ^{NS}
Exch. K (me %)	0.357 ^{NS}	0.121 ^{NS}
Exch. Na (me %)	0.476 ^{NS}	0.179 ^{NS}

* = Significant at 5% level of probability
NS = Not significant.

From the Table 7 it is found that, in Kushtia district, exchangeable Ca (r= 0.860*) was significant at 5% level of probability and other soil properties were not significant.



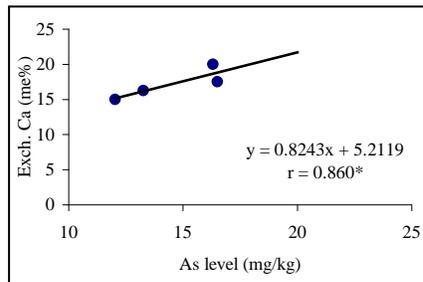


Fig.1. Relationship between As distribution and selected soil properties in Kushtia district.

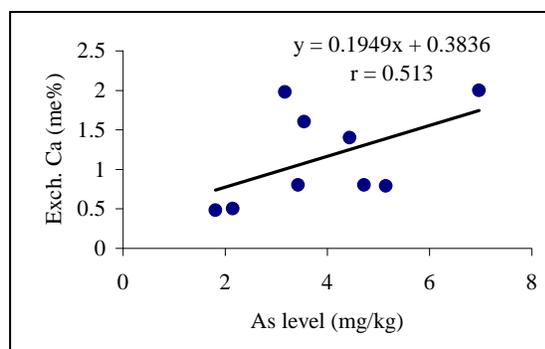
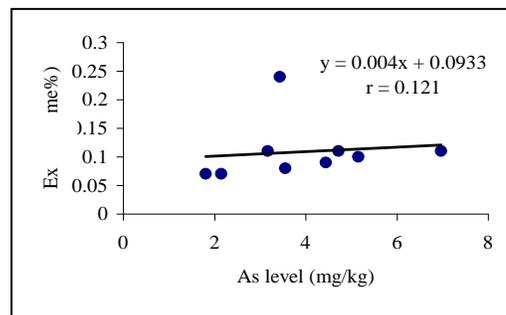
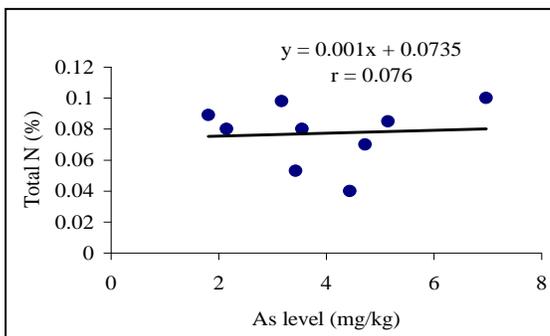
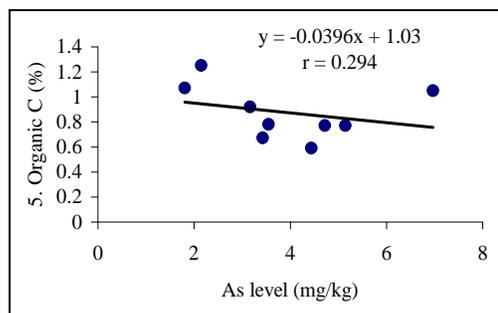
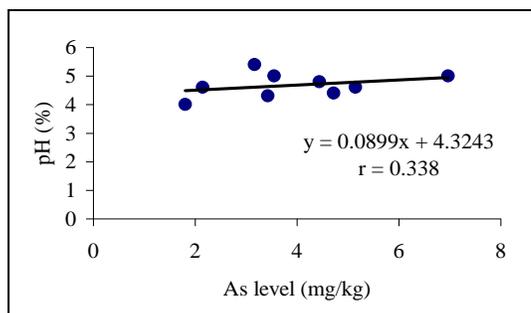


Fig.2. Relationship between As distribution and selected soil properties in Rangpur district.

IV. SUMMARY AND CONCLUSION

It can be concluded that in terms of the distribution of As in the soils of this study hold a clear benefit for the country. A clear

difference in the As contents was observed in the soils of Kushtia and Rangpur districts probably due to the differences in the soil types, biogeochemical and farm management practices. The difference in the As contents of different soil series might be due

to the variations in the landscape characteristics. In considering the present catastrophic ground water As contamination under the results of the soils of these two areas will play a significant role in Bangladesh. Routine research with wide public awareness, government participation and government regulations are essential for developing of safe and sound environment for the future.

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