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Assessment of Arsenic in the Water-Soil-Plant Systems in Gangetic Floodplains of Bangladesh

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Abstract: The levels of arsenic in irrigation waters (STW), soils and rice plants (grain and straw) in five districts viz., Pabna, Chapai Nawabganj, Rajbari, Faridpur and Gopalganj of the Gangetic floodplains of Bangladesh were assessed during the year 2001. The arsenic concentrations for all samples (soil, water, grain and straw) varied considerably between locations. Generally, the arsenic levels in soils and waters were higher in Rajbari and Faridpur compared to the other three districts. There was a good correlation between water-As and soil-As over the locations. None of the soils had arsenic level more than 20 $\mu g\ g^{-1}$ (the maximum acceptable limit for agricultural soils). About 16% grain samples had no detectable As and on the other hand 14% grains had As level more than 1 ppm. Comparing varietal effects, the grain As concentration in IR 8 and BRRI dhan 29 rice were higher in comparison with BRRI dhan 28 and Parija. There was no correlation between rice grain As and soil As content. The As concentrations were always lower in grain than in straw.

Key words: Arsenic, STW water, soil, rice grain, rice straw

INTRODUCTION

Arsenic poisoning has become a silent killer in Bangladesh. At present, 59 districts across the country are affected by arsenic contamination. As a result, 80 million people are now at risk and 10,000 people have shown the symptoms of arsenicosis[1]. It is generally agreed that the source of this arsenic contamination is geological[2]. Historically, surface water (pond, river) and earthen wells have been used as a source of drinking water in Bangladesh. During 1970s, the UNICEF installed thousands of tube-wells in the country in order to provide a safe source of drinking water. At the time, arsenic was not thought to be a problem in groundwater. This problem of arsenic contamination in this country has been confirmed in 1993. In addition to the immediate concern of arsenic in drinking water, the arsenic contamination might have a detrimental effect on food quality and a devastating long-term effect on land and agricultural sustainability. Irrigation with arsenic contaminated groundwater to rice and other crops may increase its concentration and eventually arsenic may enter into food chain through crop uptake. About 80% of the soils of Bangladesh are alluvial in origin. These soils have been developed on the sediments brought down by the mighty rivers like Ganges, Brahmaputra and Meghna. The land area under Ganges river floodplain covers 18.5% of the total area of Bangladesh. Most of the hand tube-wells in the Ganges river floodplain are contaminated with arsenic[3]. But reports on arsenic in irrigation water-soil-plant system is lacking in this country. Therefore, this study was planned to assess the arsenic in irrigation water-soil-rice plant systems in Gangetic floodplain of Bangladesh

MATERIALS AND METHODS

Thirty-five samples for each of irrigation water, soil and rice plant (grain and straw) were collected from five districts of Bangladesh viz., Pabna, Chapai Nawabganj, Rajbari, Faridpur and Gopalganj during boro season of 2001. The sampling areas belong to two major AEZs: High Ganges River Floodplain (AEZ11) and Low Ganges River Floodplain (AEZ 12). Water samples were collected from shallow tube-wells exclusively, after 10-15 min of operation. The samples were taken in 100 mL plastic bottles previously washed with acid followed by rinse with respective STW water. Three milliliter of 6 M HCl was added to each bottle to arrest the microbial growth and to prevent precipitation of metals (Fe, Al, etc.). The water samples were brought to the laboratory and kept in the refrigerator until analysis by AAS.

Soil samples at 0-15 cm depth were collected from adjacent rice fields of the STW. Five soil samples were randomly taken to make a composite sample and kept in a polythene bag for each site. Then, the soil samples were

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dried in the air, ground and passed through a 2 mm sieve and finally stored in plastic pots. The soils were analysed for texture, organic matter, pH, available P, S, exchangeable K and Ca contents along with arsenic. Ten rice plants at maturity of the crop were collected at random from each field site. Then, the grain and straw samples were separated and stored in the polythene bags. Plant samples were dried for 72 h at 65°C in oven. Husks were removed from the rice grains. The samples were finely ground and stored for chemical analysis. The As content in soil, rice grain and straw was determined by digesting the sample with di-acid mixture followed by flow injection hydride generation atomic absorption spectrophotometer with Perkin-Elmer model 2380 and MHS-10 hydride generator assembly using matrix-matching standard[4].

RESULTS AND DISCUSSION

Arsenic in STW water: The As levels in STW water varied widely in samples of different districts as well as different locations of a district (Table 1). Generally, the arsenic levels in waters were higher in Rajbari and Faridpur compared to those of Pabna, Chapai Nawabganj and Gopalganj. The STW water As levels in Pabna ranged from 0.008–0.157 ppm, in Chapai Nawabganj from 0.005-0.186 ppm, in Rajbari from 0.007–0.192 ppm, in Faridpur from 0.072-0.128 ppm and in Gopalganj from 0.051-0.142 ppm. The maximum permissible of As level irrigation water is 0.10 ppm[5], hence all the STW water samples collected from Pabna district was within the safe range. Three out of eight water samples collected from Chapai Nawabganj district had As levels beyond 0.10 ppm while only one water sample from Gopalganj district had As level more than 0.10 ppm. Four water samples collected from Rajbari and 2 water samples from Faridpur had As levels higher than the maximum permissible level of As in irrigation water. On an average 37% of the water samples had As level more than the maximum permissible limit for irrigation water.

Arsenic in soils: The collected soil samples were also analyzed for basic soil properties along with total As determination. Texturally the soils were silt loam, silty clay loam, clay loam and silty clay. Soil pH ranged from 7.1-8.1, organic matter from 0.71-6.51%, total N from 0.017-0.174%, available P from 2.4-94.8 ppm, available S from 6.3-36.5 ppm, exchangeable K from 0.12-0.61 me% and the exchangeable Ca from 9.7–17.7 me% (Table 2). The arsenic concentrations in soils from different locations varied widely. The levels of As in soils over five districts ranged from 2.09 –11.37 ppm. Among the five districts, the soils of the Pabna and Gopalganj districts had relatively lower levels of As compared to other three districts. The highest soil-As concentration of 11.37 ppm was found in soil sample from Rajbari followed by 10.44 ppm in soil sample from Faridpur. Soil As content was positively correlated with irrigation water As (Fig. 1). Total As content in soils was also positively correlated with available P, available S and exchangeable K (Fig. 2). This indicated that the As contaminated irrigation water may be a potential danger for building up of As reserve in soil. Although none of the soils had arsenic level more than 20 μg g^{-1}, the maximum acceptable limit for agricultural soils[6] but irrigating the rice with elevated concentration of As may pose a threat on long term agricultural sustainable in Bangladesh. Jahiruddin *et al.*[7] studied the As levels of twenty calcareous and 20 non-calcareous soils of Bangladesh. They reported that the mean As levels of calcareous soils was 17 ppm while for non-calcareous soils was 7.65 ppm. Based on a review on As concentration in soils, American soils seldom contained more than 10 ppm As, while in the Canadian soils the level generally did not exceed 15 ppm and in Australian soils 0.6-3.9 ppm[8].

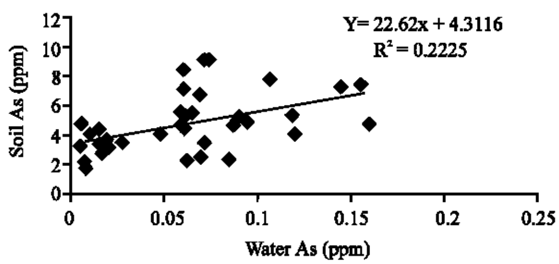

Fig. 1: Relationship between water As and soil As

The variation in soil As levels in different districts of the Gangetic river flood plain may be due to variation of the volume of irrigation water having different levels of As used in different regions and also the time period for irrigation with contaminated waters[9]. The uptake of As by rice grain and straw vary widely depending on the cultivars[10]. season[11,12], soil types and P nutrition of crops[13]. During the monsoon season, the paddy soils remain submerged for few months during which a good amount of arsenic may be lost from the soil with horizontal flow of water and also through volatilisation from the soil[14].The percolation of irrigation water in paddy field is low generally 1-2 cm a day[15] due to the presence of 3-4 cm hard plough plan in most of the soils of Bangladesh developed over the years due to continuous cultivation up to a certain depth. Besides, the upper 1-2 cm of a flooded paddy field is aerobic where As will be

Table 1: Arsenic concentration ranges in water and soil samples from various districts

	Water (ppm)			Soil (ppm)		
District	Range	Mean	S.D	Range	Mean	S.D
Pabna (n = 6)	0.008-0.057	0.025	0.018	2.09-5.42	3.91	1.30
Chapai Nawabganj (n = 8)	0.005-0.186	0.084	0.074	4.02-9.17	5.96	2.03
Rajbari (n = 8)	0.007-0.192	0.088	0.057	2.93-11.37	6.71	3.16
Faridpur (n = 7)	0.072-0.128	0.088	0.023	6.11-10.44	8.13	1.68
Gopalganj (n = 6)	0.051-0.142	0.092	0.029	2.41-6.90	4.92	1.75

Table 2: Range, mean and standard deviation of the chemical properties of soils of the study area (n=35)

Property	Range	Mean	SD
Soil pH	7.1–8.1	7.74	0.194
OM (%)	0.71-6.51	1.86	1.04
Total N (%)	0.017-0.174	0.087	0.035
Available P (ppm)	2.4-94.8	23.50	22.72
Available S (ppm)	6.3-36.5	18.56	7.97
Exchangeable K (me%)	0.12-0.61	0.33	0.108
Exchangeable Ca (me%)	9.7-17.7	13.73	2.15

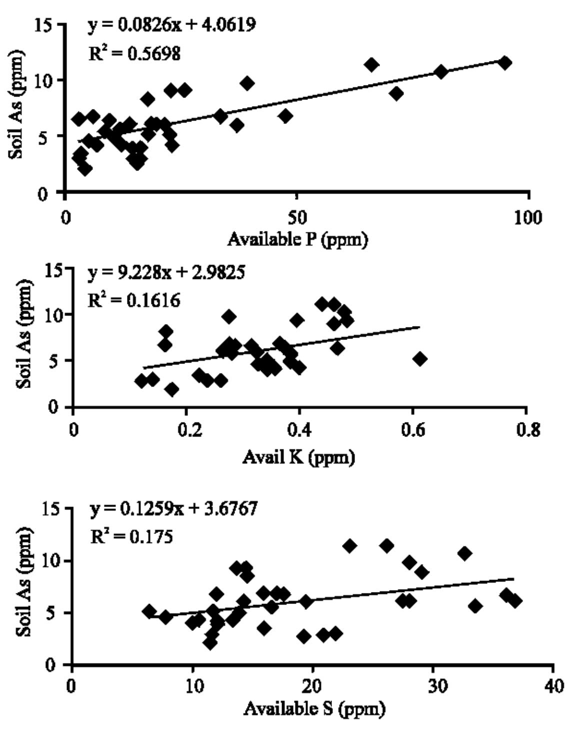

Fig. 2: Relationship between available P, K and S contents and soil As content

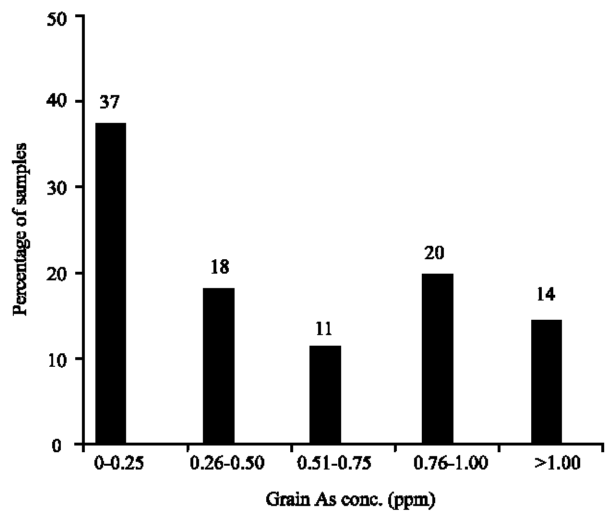

Fig. 3: Frequency distribution of grain-As

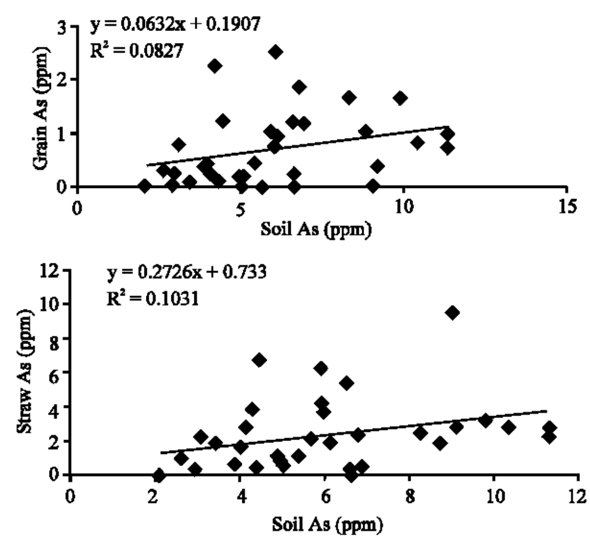

Fig. 4: Relationship between soil As and grain or straw As

adsorbed by the soil particles. Therefore, the leaching loss of As through the rice soil will be minimum. The As accumulated in the top layers may also subject to losses through water erosion due to heavy monsoon rainfall. However, all these need to be quantified before final quantification of building up the arsenic in paddy fields.

Table 3: Arsenic concentration rice grain and straw from different districts

	Rice grain (ppm)			Rice straw (ppm)		
District	Range	Mean	S.D	Range	Mean	S.D
Pabna (n = 6)	0-0.342	0.199	0.137	0-1.05	0.682	0.418
Chapai Nawabganj (n = 8)	0-0.989	0.325	0.338	0.52-9.53	3.87	3.28
Rajbari (n = 8)	0.052-2.05	0.764	0.744	0.42-5.34	2.99	1.69
Faridpur (n = 7)	0.208-1.50	0.953	0.616	0.31-3.34	2.17	1.50
Gopalganj (n = 6)	0-0.182	0.567	0.462	0-3.77	1.48	0.959

Table 4: Arsenic content in different varieties of rice grain and straw

	Grain			Straw		
Varieties	Range	Mean	SD	Range	Mean	SD
IR 8 (n=8)	0.052-2.05	0.790	0.744	0.42-5.34	2.06	1.69
BRRI dhan 28 (n=3)	0.000-0.624	0.312	0.312	2.72-9.53	6.18	3.41
BRRI dhan 29 (n=17)	0.000-1.82	0.644	0.573	0.00-4.09	1.80	1.37
Parija (n=5)	0.156-0.989	0.333	0.389	0.52-6.81	2.49	2.58
Type (n=2)	0.780-0.83	0.805	0.035	1.89-1.99	1.94	0.07

Grain as concentration: The grain As concentration in samples collected from different locations varied widely ranging from 0-2.05 ppm (Table 3). The rice grain samples from Pabna and Gopalganj had the lowest As concentration compared to those collected from other districts. The highest As concentration in rice grain was found in Rajbari samples followed by Faridpur samples. Sixteen per cent of the rice grain samples had no detectable As, 21% of the samples had As level below 0.25 ppm and 14% of the samples had As level more than 1 ppm (Fig. 3) The concentration of As in rice grain varied widely among the varieties of rice (Table 4). The As concentration in grain of IR 8 ranged from 0.052-2.05 ppm with a mean of 0.79 ppm, for BRRI dhan 28 from 0-0.624 ppm with mean of 0.312 ppm, for BRRI dhan 29 from 0-1.82 ppm with a mean of 0.644 ppm, for Parija from 0.156-0.989 ppm with a mean of 0.333 ppm while for Type rice it was 0.78-0.83 ppm with a mean of 0.805 ppm. A comparison on wide rice genotypes is necessary to find out the genotype that accumulate lower amount of As in grain, this option may help the reduced entry of As into the food chain. Meharg and Rahman[10] also reported wide variation in the levels of As in rice grains of different genotypes. They tested grain As levels of nine Bangladesh rice genotypes of rice and found that the As levels ranged from 0.043 to 0.206 $\mu g\ g^{-1}$. Grain-As was poorly correlated with soil As (Fig. 4) indicating that the amount of bio-available As is not only dependent on total As in soils but other factors also regulate the uptake of As by the rice plants and also translocation of As from root to the rice grain. Levels of arsenic in rice grain are typically 0.05-0.4 $\mu g\ g^{-1}$ for North America, Europe and Taiwan[16,17].

Straw as concentration: The As concentrations in rice straw samples showed wide variation depending on the locations and rice variety grown there (Table 3). The straw samples collected from Pabna districts had the lowest range of arsenic from 0-1.05 ppm. The straw samples from Chapai Nawabganj had the highest content of arsenic. Out of the 35 samples, only two samples did not have any detectable As. The straw As concentration was poorly correlated with the irrigation water As and soil As.

The results from the aforesaid discussion and findings, it can be concluded that the arsenic status in all the selected soils were quite low. But irrigating the rice crops with elevated As concentration may lead to the accumulation of As in soils as well as uptake the by the crops. There was no correlation between the soil-As and As concentration in rice grain indicating that future research is needed on the bio-availability of As for rice crops.

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