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Accumulation, Distribution and Source Analysis of Arsenic in Rice in Different Growing Areas of Bangladesh

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Abstract

Background: Being a leading dietary source of arsenic, the importance of exposure to arsenic through rice must be considerable. This study aimed to assess the accumulation, distribution and source analysis of arsenic in rice in different growing areas of Bangladesh. **Methods:** The cross-sectional analytical study was carried out in the Department of Biochemistry and Molecular Biology, Bangabandhu Sheikh Mujib Medical University, Shahbag, Dhaka. Total sample 260, among them 100 water samples from the arsenic-contaminated deep tube-well (Used for irrigation), 100 rice samples produced here off and 60 (0–20 cm depth) soil samples were collected. No major Ethical Implication was required. Statistical analysis was done by SPSS 24 version. **Result:** The present study revealed the mean value of arsenic concentration found in soil at the selected plot was ranging from 8-14 mg kg−1. In the study, the highest value of arsenic concentration in irrigation water was found in Sirajdikhan was 70 ± 47 (μg L−1) and the utmost value of arsenic concentration in rice was 173 ± 236 μg kg−1 found in Shariyatpur. Inferential statistics was done at a 95% confidence interval and 5% level of significance. An independent T-test was found significant ($p<0.01$) and results showed the arsenic concentration was more in rice than in water and soil. **Conclusion:** Rice exposure can contribute to the total daily intake of arsenic. Rice and water consumption patterns and arsenic levels in rice is needed to refine human exposure assessment.

Keywords:- Arsenic, Accumulation, Distribution, Source analysis, Typical growing area.

INTRODUCTION

The Greek word "arsenikon" means yellow orpiment, arsenic is derived from the word "arsenikon". Being a metalloid, arsenic has both metallic as well as non-metallic characteristics and the corresponding chemical process.[1] In Bangladesh, national growth relies mainly on the agricultural sector with its gross domestic product. For maintenance of livelihood, more than 80%of the population depends on the agriculture.[2] The United State along with the European food surveys showed on the basis of daily arsenic intake, rice is a major dietary source of arsenic second to fish products. In countries that have a rice subsistence diet, the importance of dietary exposure to arsenic through rice could be considerable.[3] Rice production has always a big challenging issue for our country due to the high population growth rate and the increasing demand of food grain production. Bangladesh government emphasized on increasing rice production in order to ensure food security. As a sequence of it, Bangladesh government has encouraged production of heavy yield variety rice to become self-sufficient in food grain that require a large volume of irrigation water. So, over the last couple of decades, the use of ground water for irrigation has increased gradually in which about 86% of total baseline water withdrawn was utilized in agricultural sector.[4] In Bangladesh, ground water is used extensively to irrigate rice crops as well as used as drinking particularly.[5] Rice is the predominant source of inorganic arsenic from foods. Boro rice is most commonly contributed at least 50 percent to the provisional maximum tolerable daily intake in our country which provides 73% of regular calorie intake. The amount of arsenic ingested by the local peoples of arsenic contaminated region could be considerably more than before if arsenic in paddy soils leads to raise arsenic in the rice grain.[6] As drinking water is the primary known source of arsenic calamity whereasit could be far worse if rice is added with the toxic elements. Alternative safe drinking water can lessen the arsenic exposure from drinking at a certain limit where dealing with rice arsenic in that regards would be impossible to manage. In this way, food arsenic contamination become in worse condition then drinking water contamination.[7]

Several epidemiological studies in Bangladesh has considered in the investigation into drinking water contamination. Very few studies have been published which consider other potential arsenic exposure routes to the populations.[8] In arsenic contaminated areas of Bangladesh, the concentration of arsenic in rice produced was about 0.3 mg/l which is 2-3 times higher than the arsenic content of rice produced in non-contaminated areas.[9] World Health Organization revealed provisional tolerable weakly intake of arsenic was established at 0.015 mg/kg bodyweight, whereas provisional maximum tolerable daily intake (PMTDI) were set at 0.002 mg/kg body weight, which is equivalent to 0.12 mg/day for a 60 kg person. For risk assessment, in case of this epidemiological data refers to inorganic arsenic. But due to inappropriate toxicological data it's not possible for World Health Organization to establish a similar recommendation for organic arsenic species in rice.[10] This study aimed to assess the accumulation, distribution and source analysis of arsenic in rice in different growing areas of Bangladesh.

MATERIAL AND METHODS

The cross-sectional analytical study was carried out in the Department of Biochemistry and Molecular Biology, Bangabandhu Sheikh Mujib Medical University, Shahbag, Dhaka. The duration of this study was approximately 1 year. This study was conducted in maximally cultivated varieties of rice and water collected from a deep tube well used for the cultivation of those types of rice. Total sample 260, among them 100 water samples from the deep tube-well (Used for irrigation) and 100 rice samples produced here off and different 60 soil samples (0–20 cm depth) were collected from the selected areas. Both rice and water samples were collected from five upstairs of Bangladesh (Bajitpur, Arihazar, Bancharampur, Shariyatpur, Sirajdikhan). Due to nil potential risks, no informed consent from the subjects was taken. No major Ethical Implication was required. Statistical analysis

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was done by SPSS 24 version. Rice and irrigation water was collected from the arsenic-contaminated areas and locally along with the maximally cultivated type of rice was included. Rice and irrigation water was collected from any arsenic-free areas and imported as well as the minimally cultivated type of rice was excluded from the study.

The freeze-dried sample was at first thawed, then kept under the sun for three consecutive days to remove the moisture. After sundry. The samples were homogenized using a commercial home vegetable grinder. After grinding each sample, the grinder was cleaned with detergent and de-ionized water, so that no arsenic could transfer from one sample to another. A sub-sample of 0.5 gm was weighed from the homogenized sample and transferred to a test tube in order to use later on for digestion purposes.

All the samples were digested in a water bath at 95c, using nitric acid ($HNO3$) and hydrogen peroxide. Nitric acid and hydrogen peroxide were added at the time of interval as per schedule. The digestion was thought to be completed when the final digestant was cleared or straw-coloured. Following digestion, each digestant was cooled and diluted with de-ionized water to a final volume of 25 ml.

Rice digestant was analyzed for total arsenic, using Graphic furnace Atomic absorption spectrophotometer-6650 of Shimadzu using WizArd software and a 60 sample capacity autosampler. The WizArd software recommended optics parameters was followed, as well as a built-in furnace program of the software for arsenic measurement. Three replicate readings were taken for each sample and the mean value was considered as sample concentration. The value for the maximum allowable RSD 7.0 was adapted for this study. Before each analytical run, the GFAAS was freshly calibrated for arsenic measurement. The calibration curves were performed using calibration standard, preparation by diluting the stock Arsenic Standard Solution of Wako. Arsenic in Nitric acid solution dropped on the platform in the graphite tube was thermally stable up to 600c. Addition of matrix modifier extends the range of arsenic stability to 1100c. Numerous modifiers were used to stabilize arsenic in high furnace temperature, here 5% magnesium nitrate was used in this study as a modifier.

RESULTS

Arsenic concentration in paddy soil was showed in [Table 1]. Arsenic concentration in irrigation water the rice samples produced here off was showed in [Table 2] and graphical presentation of maximum values of arsenic-contaminated irrigation water showed in [Figure 1]. Arsenic concentration in rice produced in the arsenic-contaminated areas of Bangladesh was shown in [Table 3] and a graphical representation of maximum and minimum values of arsenic-contaminated rice showed in [Figure 1,2] respectively. Co-relation between arsenic concentration in water and arsenic concentration in rice, the result was found statistically significant showed in [Table 4] ($p<0.05$).

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Table 1: Arsenic concentration in paddy soil (mg kg−1), n= (60)

Area name	Mean	Maximum	Minimum
Bajitpur	11.4	17.5	9.7
Arihajar	14.3	16.2	10.9
Bancharampur	12.1	14.6	9.8
Shariyatpur	8	10.4	6.8
Sirajdikhan	13.9	16	9.3

Table 2: Arsenic concentration in irrigation water (µg L−1), n= (100)

Area name	Mean±SD	Maximum	Minimum
Bajitpur	47.83±15.529	84	23
Arihajar	63.56±23.603	91	13
Bancharampur	46.72±35.155	132	6
Shariyatpur	43.01±28.320	108	9
Sirajdikhan	70.49±47.246	122	4

Table 3: Arsenic concentration in rice (µg kg−1), n= (100)

Area name	Mean±SD	Maximum	Minimum
Bajitpur	117.5190± 104.066	410	17
Arihajar	125.11±137.246	452	34
Bancharampur	82.82±107.412	440	9
Shariyatpur	173.20±235.714	805	16
Sirajdikhan	53.67±46.822	240	5

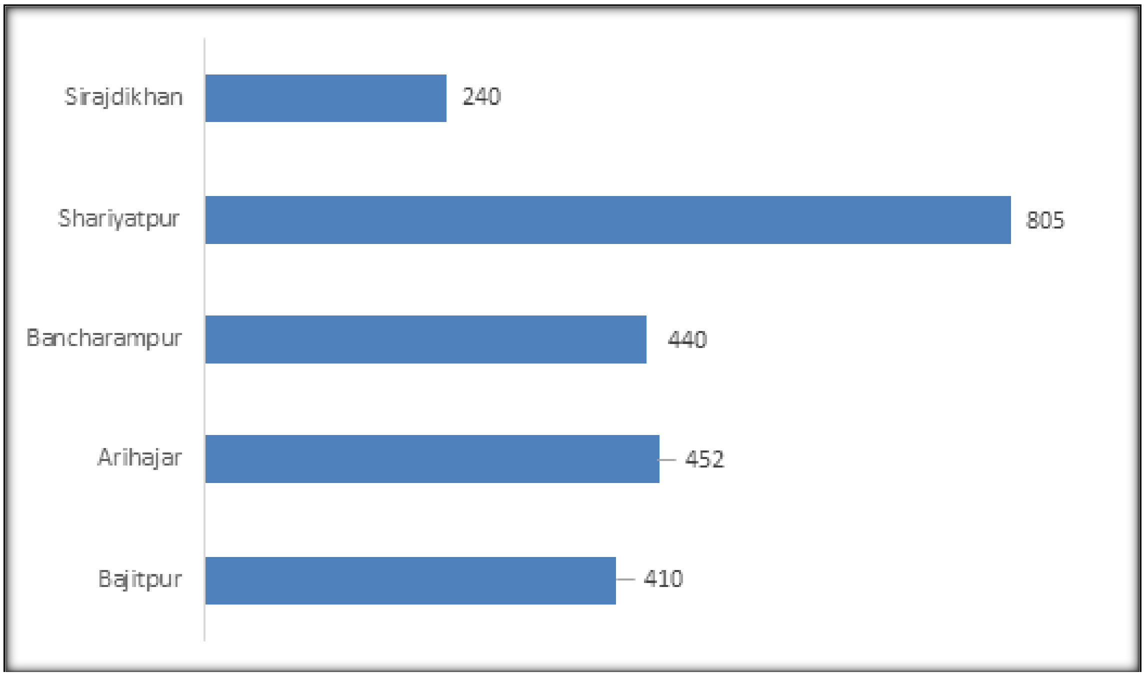

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Figure 1: Maximum arsenic concentration in rice (µg kg−1), n= (100)

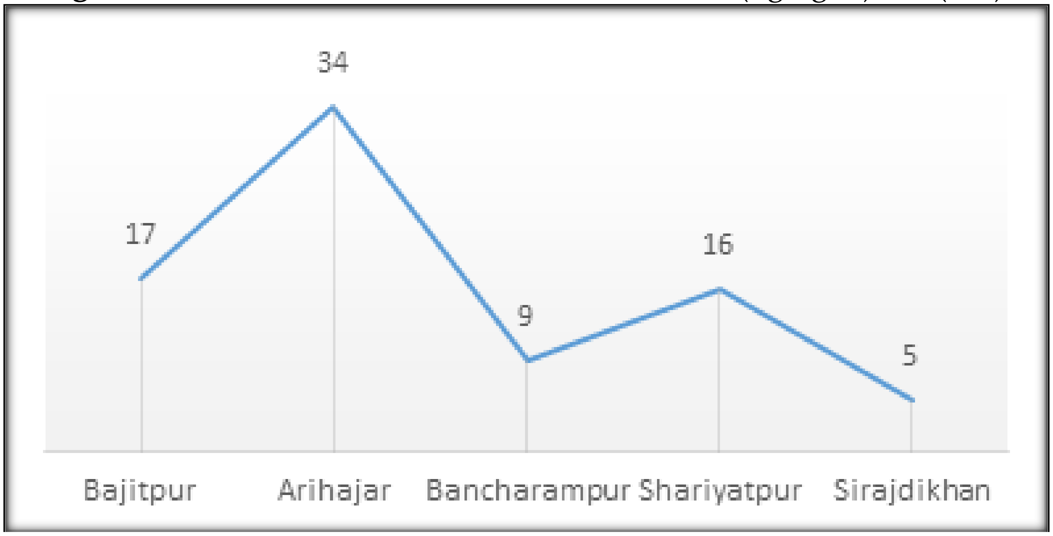

Figure 2: Minimum arsenic concentration in rice (µg kg−1), n= (100)

Table 4: Co-relation between arsenic concentration in water and arsenic concentration in rice

Substance	Arsenic concentration	P value
Mean±SD		
Water	54.32 ± 32.9	P<0.01
Rice	110.5± 143.7	P<0.01

*P value was determined by Independent T test, it was significant at 95% confidence interval & 5% level of significance

Table 5: Co-relation between arsenic concentration in soil and arsenic concentration in rice

Substance	Arsenic concentration	P value
Mean±SD		
Soil	12.6± 2.8	P<0.01
Rice	110.5± 143.7	P<0.01

*P value was determined by Independent T test, it was significant at 95% confidence interval & 5% level of significance

DISCUSSION

Many studies have been conducted on arsenic content in water. A few studies have been done on arsenic content in rice. But so far our knowledge very limited studies have done where arsenic concentration (organic and inorganic) has estimated both in water and in rice produced by that water simultaneously. In the present study, arsenic concentrations from soil samples across the five-place [Table 1] recorded a maximum grade of 17.5 mg kg−1 in Bajitpur and a minimum grade of 6.8 mg kg−1 in Shariyatpur, range value of mean was 8-14.3 mg kg−1, where a maximum grade of arsenic in soil was 16.6 mg kg−1 in SZ, and a minimum grade of arsenic was 3.7 mg kg−1 in WS respectively along with the mean arsenic value in that study was ranging from 6.3 to 13.6 mg kg−1, 9 to 12mg\kg, 1.34 to 14.09mg/kg, 10 to 70mg/kg, 2.07 to 12mg/kg, which were below the national soil environmental quality standard of China

(Class I, 15 mg kg−1).[11,12,13,14,15,16,17] In this study, the arsenic concentration of water from the selected spot [Table 2] recorded a maximum value of 132 (mg kg−1) in Bancharampur and a minimum value of 4 (mg kg−1) in Sirajdikhan where arsenic concentration in natural water was revealed by as 10–5000 (μg l−1) in baseline groundwater.[13] Arsenic concentrations in water being significantly below the Class III water national standard for surface water (0.05 μg L−1) had a mean range of 5.5–9.9 μg L−1 and the highest concentration was up to 38.8mg/l wherein present study the mean range of arsenic in water was 43.01-70.49 μg L−1.[14,15,16,17,18] There were no signs of arsenic concentration level between market rice of northern and southern China. Arsenic concentrations in rice [Table 3] indicated that the maximum concentration was 173.20 mg kg−1 in present study where maximum concentration was 1.8mg/kg,[19] different study showed that arsenic concentration in rice was 0.0235±0.014ppm,[20] 0.11-0.28mg/kg and up to 11.1 mg kg−1.[11,21,22] The total arsenic concentration of the most consumed food of Bangladesh (rice) was moderate (199.76 μg/kg) in relation to the concentration found in samta village (300 μg/kg) of jessore. But another study found similar concentration of rice arsenic from Rajshahi and Dhaka.[9] Arsenic concentration in rice also varies globally where a different study found a similar concentration (210 μg/kg) in Taiwan.[3] Another study found slightly higher values (245 μg/kg) in west Bengal.[15] An independent sample T test was highlighted the correlations between arsenic concentration in water and arsenic concentration in rice [Table 4] as well as concentration of arsenic in soil and rice [Table 5] and both were found significant ($p<0.01$). In this study the results suggested that arsenic was found more in rice rather than water. A different finding was indicated in the study where there was no significant correlation between arsenic concentration in water and arsenic concentration in rice which might be due to the production process.[23,24,25]

Limitations of the study:

This study was conducted in some selected areas. The results were not reflected all the areas of Bangladesh.

CONCLUSIONS

The magnitude of groundwater contamination in Bangladesh is well recognized. But arsenic from food is still not well address in any standard. The outcome of this study might shed some light on bringing this issue to the surface which needs proper advertising. Thus to protect our community from chronic arsenic exposure as well.

Recommendation

Develop proper management options so that the policy makers may take some necessary steps for arsenic contamination in water along with rice according to need.

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