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***Research Paper***

# Potential Arsenic Enrichment Problems of Rice and Vegetable Crops

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***Abstract*** *- Elevated arsenic level in ground water has emerged as extreme calamity exposing a large population in to the risk of arsenic toxicity from drinking water sources and agricultural products, especially through ground water irrigation. Arsenic concentration of irrigated groundwater, soil, crops and vegetables were assessed in high arsenic affected blocks of Nadia district. Consumption of arsenic contaminated drinking water is the primary route of exposure, along with food as additional source. Arsenic concentrations in irrigation water, field soil and in different parts of grown crops have been assessed to show the bioaccumulation level of arsenic in food chain. Arsenic in irrigated water ranges from 0.23 to 0.73 mg $L^{-1}$and 3.58 to 8.50 mg $Kg^{-1}$ of dry weight in irrigated soil. Inorganic arsenic concentration in various edible and useful parts of rice plants in our experiment are in the order of 2.52 1 to 5.97 mg $Kg^{-1}$ of dry weight in straw; 0.71 to 1.79 mg $Kg^{-1}$ of dry weight in husk and 0.10 to 0.81mg $Kg^{-1}$ of dry weight in rice grain. Higher range of arsenic is assessed in the rabi season vegetables like in spinach 0.96 to 1.63 mg $Kg^{-1}$ of dry weight, 0.051 to 1.14 mg $Kg^{-1}$ of dry weight in tomato fruit, and 1.45 to 3.24 mg $Kg^{-1}$ of dry weight in Bengal gram. Relationships among ground water arsenic content, soil arsenic and edible parts of crops and vegetables have been assessed. Concentration factor and enrichment factor indicates towards the potential risk of human health due to dietary arsenic transfer in to the crops and vegetables.*

**Key words:** Arsenic, Concentration factor, Enrichment factor, Ground water, Rice, Vegetables etc.

## Introduction

Ground water arsenic contamination is crucial water quality problem in gangetic delta plane of Bangladesh and West Bengal, India [1, 2, 3, 12, 26]. Several other countries like Argentina, Chile, China, Japan, Mexico, Mongolia, Nepal, Poland, Taiwan, Vietnam and some parts of the united states[4,5,25] also facing the same problems, with acute situation for the people of some of the villages in different blocks of Nadia District of the state West Bengal [3,6,7,8,9,10] . In these blocks arsenic affected patients are there with major health problems including cancer, melanosis, hyperkeratosis, restrictive lung disease, peripheral vascular diseases, gangrene, diabetes mellitus, hypertension, and ischaemic heart disease[11,12] with increasing evidences among population exposed to arsenic in Bangladesh and West Bengal[13,14,15,16] . Besides drinking water total useable ground water in these areas are arsenic affected and in cases the arsenic concentration is much higher than WHO permissible limit of 10 µg/L [3, 12, 30]. Consumption of arsenic contaminated drinking water is the primary route of exposure; food can provide additional exposure since agricultural produced can accumulate arsenic from contaminated soil and water [17]. Arsenic accumulation through rice is the major disaster in South-East Asian countries [18]. Dietary exposure to arsenic, especially from rice, has drawn increasing attention [19,20,21] . The reason for concern is because inorganic forms of arsenic (arsenite and arsenate) were found to be dominant species in many rice samples examined around the world [21, 22]. Among all the edibles, rice grain plays major role for accumulation of arsenic in the gangetic delta because it is the staple here and accumulates highest amount of arsenic among all crops [20]. A number of studies have been reported on the major impact of irrigation with arsenic containing ground water in case of rice [24].

Ground water irrigation shows increasing trend over the years. One of the consequences of which, is the increasing arsenic level in the irrigated soil. Therefore people are at a risk from exposure of arsenic due to irrigation with contaminated ground water. Uplifted arsenic through irrigation water is bioaccumulated in different parts of plants in different degrees through phytoextraction process. So high amount of arsenic is obvious in rice and vegetables where arsenic content is high in soil and irrigated water. Hence the food chain is a significant pathway of arsenic ingestion in the highly irrigated zones. In our study the trend of arsenic concentration was analyzed in the rice root, rice grain, straw and vegetables commonly cultivated adjacent to the rice fields during rabi season when irrigation is highly ground water fed. Our experimental results will help to take measure especially in rabi season which is suitable for food chain survival of the inorganic arsenic content, the rice cultivation or the vegetable production from which potential risk is higher to us.

## Material and Methods

### Study area

The study area is well known arsenic prone zone in Nadia district, West Bengal. In the present study, some highly irrigated blocks, Ranaghat, Karimpur, Chakdaha, Krishnanagar, Tehatta, Haringhata and Hanskhali have been selected for sampling (Fig.1.). In these blocks during dry season extensive ground water is used for agriirrigation purposes and arsenic concentration is frequently high in both irrigated water and drinking water.

### Sample collection

Irrigated water samples (N=105) were collected (50 ml) randomly during the uniform rate of discharge from shallow tube wells (depth 90 to 150 m). The water samples were collected in polyethylene bottle and were acidified with few drops concentrated nitric acid ($HNO_3$). Soil samples (N=105) were collected from field surface (0-15 cm depth); five replicas were collected from each of seven sampling blocks to make composite sample. Accordingly random composite sampling of rice root (N=105), straw (N=105), husk (N=105), rice grain (N=105) and vegetables (N=105) were done from the field of irrigated block of Nadia, West Bengal during irrigated rabi crops (February to May).

### Sample treatment and analysis

The irrigated water samples were filtered through 0.45 µm filter and were kept in 4°C for total arsenic content analysis. The soil samples were immediately sun dried followed by hot air oven drying at 60°C until constant weight. Rice plant parts and other vegetable samples were washed properly with tap water and then with de-ionized water and were dried in hot air oven at 60°C for 72 hours. The oven dried soil and plant parts samples were made fine homogenized powder by grinding with firm precaution to keep uncontaminated followed by further analysis.

Soil, rice root, straw, husk, rice grain and edible parts of collected vegetables were digested following heating block digestion method [27,31]. 0.5 gm of dried fine powdered samples was mixed with 5 ml of concentrated nitric acid ($HNO_3$) and was left over night as pre-digestion. In the following day tubes were placed on the heating block at 60°C for 3 hours. After cooling at room temperature, 2 ml of concentrated perchloric acid ($HClO_4$) was added for plant samples and 2 ml of concentrated sulphuric acid ($H_2SO_4$) for soil samples in addition to perchloric acid ($HClO_4$). Again the tubes were placed for digestion at 160°C for 3 hours until the clear solution was obtained. The digested samples were cooled down to room temperature and filtered with Whatman No.42 filter paper, the filtrate was used for analysis against own laboratory arsenic standards. For total inorganic arsenic content analysis in all types of samples flow injection hydride generation atomic absorption spectrophotometer (FI-HG-AAS; Perkin Elmer A Analyst -400) was used. Precision and accuracy level of analysis was evaluated by analyzing a standardized reference Rice Flour SRM-1568a (National Institute of Standard and Technology-USA) following same treatment procedure as the samples. In our cases there was 97.91 % recovery of the certified value of SRM.

### Assessment of concentration factor and enrichment factor of arsenic by various crops

Arsenic concentration factor (CF) and enrichment factor (EF) for the rice and vegetables were calculated. For each sampling site (especially irrigated field) the total arsenic is the sum total of water and soil available arsenic content rice and vegetables bioaccumulate arsenic through phytoextraction process from this available arsenic content of water and soil.

Concentration factor (CF) of a plant was calculated using the following equation

$$CF = \frac{\text{As conc in plant grown on contaminated soil} \times (\text{As conc. in contaminated soil})^{-1}}{\text{As conc in plant grown on control soil} \times (\text{As conc. in control soil})^{-1}}$$

Enrichment factor (EF) of a vegetable was calculated using the following equation

$$EF = \frac{\text{As concentration in edible part grown on contaminated soil}}{\text{As concentration in edible part grown on control soil}}$$

### Computation and statistical analysis

After gathering the available data, the statistical data analysis was done using Microsoft Excel and SPSS 15.

## Result and Discussion

### Arsenic in water and soil

Agricultural practices in study area are mostly irrigation dependent. Rice is the main agricultural product which are cultivated in mainly two seasons; amon rice (during July to October), specially rain fed and boro rice (during January to April) solely dependent on ground water irrigation. In this study, sampling was done only for the boro rice along with some vegetable samples grown side by side in this season. The results shows (Table:2) that in rabi season the arsenic content in the irrigated water ranges from 0.23 to 0.73 mg $L^{-1}$ , mean 0.43 (SD ± 0.17),much more higher than WHO permissible limit of arsenic in drinking water [23,33]. So irrigated water arsenic content is high enough from any uncontaminated area irrigated water 0.006 mg $L^{-1}$ and also as reported less as 0.003 mg $L^{-1}$ [28]. In the rice field soil arsenic concentration ranges from 3.58 mg $Kg^{-1}$ to 8.50 mg $Kg^{-1}$ of dry weight, mean 6.67±1.56 which is higher than any uncontaminated site1.03±0.011 and also reported as 1.264 to 2.264 mg $Kg^{-1}$ of dry weight[28] and in another case 0.17± 0.065[29]. In our cases soil arsenic content is positively correlated (P value < 0.05) with the irrigated water (Table. 3).

So it can be said that the soil is good enough loaded with inorganic arsenic to transfer or be accumulated into the crops and vegetables. Though irrigated water does not contain high amount of arsenic at the moment but it is fact that for long time arsenic is being mined on to irrigated soil through irrigated water.

## Arsenic in rice

As a consequence of irrigation with arsenic contaminated water, rice grain contains elevated level of arsenic. The inorganic arsenic concentration in various edible and useful parts of rice plants in our experiment are found to be in the order of 2.52 to 5.97 mg $Kg^{-1}$ (mean 4.48±1.30) of dry weight in straw; 0.71 to 1.79 mg $Kg^{-1}$ (mean 1.14±0.43) of dry weight in husk and 0.10 to 0.81 mg $Kg^{-1}$ (mean 0.49±0.21) of dry weight in rice grain. Arsenic concentration is in the range of 9.79 to 17.61 mg $Kg^{-1}$ (mean 13.15±2.61) of dry weight in the rice root. Whereas arsenic concentration boro rice plant parts ranges from 0.031 to 0.084 mg $Kg^{-1}$ in grain[28] ; 0.44 ± 0.060 mg $Kg^{-1}$ in rice root ; 0.08 ± 0.019 mg $Kg^{-1}$ in straw and 0.07 ± 0.016 mg $Kg^{-1}$ in husk in dry weight basis[29] of uncontaminated site. So the arsenic concentration in rice root, straw, husk and especially rice grains of our study areas is high enough to be a problem for human health.

Graphical representation of arsenic concentration in different useful and edible parts of rice plants are given in Fig. 2. The results shows that among the edible and useful parts of rice plants the straw part contains higher amount of total arsenic 2.52 to 5.97 mg $Kg^{-1}$ of dry weight, then husk and lastly the rice grain 0.10 to 0.81 mg $Kg^{-1}$ of dry weight. These data are in a good agreement with the previous works of Abedin et al. (2002); Rahman et al. (2007); Roychoudhury (2002) and Bhattacharya et al. (2009).

The result shows (Table. 3) positive correlation among irrigated water-soil ( $P$ value $< 0.05$ ); irrigated water-rice root( $P$ value $< 0.05$ ); irrigated water-straw( $P$ value $< 0.05$ ); and irrigated water-rice grain ( $P$ value $< 0.05$ )where as arsenic content of husk is negatively correlated with irrigated water. Concentration Factor (CF) and Enrichment Factor (EF) are calculated (Table.3.) for rice plant parts. In terms of CF rice plant parts may be placed as husk > rice grain > rice root > straw. So enrichment factor also stand likewise husk > rice grain > rice root > straw (Fig.4).

## Arsenic in vegetables

Arsenic content in the edible parts of various vegetables grown adjacent to the rice fields where the main irrigated water source is same in dry season given in Table.2. Arsenic content in Bengal gram depicts the presence of higher inorganic arsenic content that ranges from 1.45 to 3.24 mg $Kg^{-1}$ of dry weight (mean 2.36±0.67).Arsenic content in spinach (0.96 to 1.63 mg $Kg^{-1}$ of dry weight) is comparatively high than that of tomato fruit (0.049 to 1.28 mg $Kg^{-1}$ of dry weight). These results are quite contradictory to the study carried out by Das et al. (2004) which shows arsenic content in spinach is within maximum acceptable limit.

Soil arsenic concentration is much higher than respective irrigated water (Table.2.). In the regions there are common practices to leave the remaining straw part after harvesting of rice and to mix it with in soil during the following plaughing. So year after year there are increasing arsenic level. Rice grain part though contain much low level of arsenic than other parts of the paddy plant, there are risk of arsenic poisoning in human through cooked rice and other diets because total arsenic load is the cumulative arsenic content of rice grain and drinking water or total usable water, as drinking water and irrigated water source are same aquifer region up to the same depth. Among vegetables examined Bengal gram shows highest arsenic content (Table.2.).Arsenic enrichment factor and arsenic concentration factors are depicted (Fig. 4.) to provide scientific prove about most toxic harvested among samples, which prove there are high arsenic poisoning risk due to ingestion of vegetables than rice. In terms of concentration factor (CF) rice plant parts may be placed as Bengal gram >spinach > tomato. So enrichment factor (EF) also stand likewise Bengal gram >spinach > tomato. The experimental data are high enough and adhere with good agreement with the previous data of Roychowdhury et al. The arsenic content in vegetables indicates (Table. 2, Fig. 3) that in dry season higher arsenic concentration prevails in vegetables apart from rice plant grown in adjacent fields of rice where the soil character and irrigation water sources are same.

## Conclusion

Arsenic occurs and survives in ecosystem but now its contamination is a global problem due to biogeochemical and anthropogenic activities. High amount of arsenic content in respective samples is due to the fact that the study was carried over the arsenic prone zone of Nadia District, West Bengal. In these areas, drinking water is the main source of arsenic exposure to the people along with their dietary intake as starting from the rice grain to vegetables arsenic content is increased. Arsenic enrichment factor and relative concentration factor is important to describe the risk of arsenic bioaccumulation. The higher accumulation of arsenic in parts of the rice and vegetables imply not only the risk from arsenic alone but there lies some other factor for total risk like the exposure time and the dietary intake amount and more over the population and individual health criteria. This documentation will help to optimize or reduce the toxicity of arsenic by adopting suitable management strategies.

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**Table 1. Soil characteristics of the arsenic contaminated fields**

| Soil parameters | Values |
|---|---|
| Clay (%) | 71.6 - 81.1 |
| Sand (%) | 5.6 - 6.8 |
| Silt (%) | 12.3 - 24.3 |
| Texture | Clay loam |
| pH | 7.76 ± 0.03 |
| Organic carbon (%) | 0.78 ± 0.09 |

**Table 2. Arsenic content (±SD) of irrigation water, soil, rice root, straw, husk, rice grain, spinach, tomato and chick pea of different blocks.**
**N= Number of sample analyzed.**
**SD= Standard deviation**

| Sampling sites | Irrigated water (N=105) | Soil (N=105) | Rice root (N=105) | Straw (N=105) | Husk (N=105) | Rice grain (N=105) | Spinach (N=105) | Tomato (N=105) | Bengal gram (N=105) |
|---|---|---|---|---|---|---|---|---|---|
| Chakdah | 0.52±0.005 | 6.03±0.013 | 11.07±0.027 | 5.24±0.005 | 0.96±0.012 | 0.59±0.006 | 1.63±0.035 | 0.08± 0.002 | 2.97±0.021 |
| Haringhata | 0.39±0.002 | 7.61± 0.102 | 15.01±0.012 | 3.82±0.054 | 1.67±0.052 | 0.81±0.025 | 1.49±0.021 | 0.049±0.003 | 3.24±0.033 |
| Ranaghat | 0.73±0.003 | 6.97±0.039 | 17.61±0.018 | 4.24±0.041 | 0.71±0.031 | 0.49±0.019 | 1.13±0.039 | 0.063±0.002 | 1.99±0.057 |
| Tehatta | 0.33±0.012 | 8.5±0.099 | 13.01±0.004 | 5.98±0.069 | 1.13±0.067 | 0.40±0.016 | 1.17±0.086 | 1.14±0.051 | 1.75±0.008 |
| Karimpur | 0.23±0.003 | 7.3±0.059 | 11.92±0.087 | 3.57±0.063 | 1.79±0.092 | 0.52±0.038 | 1.34±0.071 | 1.28±0.016 | 2.33±0.008 |
| Krisnanagar | 0.29±0.002 | 3.58±0.011 | 9.79±0.003 | 2.52±0.081 | 0.97±0.009 | 0.1±0.029 | 1.01±0.033 | 0.051±0.001 | 1.45±0.007 |
| Hanskhali | 0.5±0.017 | 6.73±0.028 | 13.67±0.016 | 5.97±0.062 | 0.72±0.002 | 0.51±0.011 | 0.96±0.007 | 0.36±0.007 | 2.82±0.008 |
| Mean | 0.43±0.17 | 6.67±1.56 | 13.15±2.61 | 4.48±1.30 | 1.14±0.43 | 0.49±0.21 | 1.25±0.25 | 0.43±0.54 | 2.36±0.67 |
| Control | 0.006±0.002 | 1.03±0.011 | 2.39±0.021 | 1.91±0.010 | 0.02±0.021 | 0.032±0.003 | 0.023±0.003 | 0.02±0.002 | 0.038±0.021 |

**Table 3. Correlation coefficients among arsenic content of irrigation water, soil and different parts of rice plant.**

| | **Irrigation water** | **Soil** |
|---|---|---|
| Irrigation water | 1 | |
| Soil | 0.0767 | 1 |
| Rice root | 0.6917* | 0.5641 |
| Straw | 0.3251 | 0.5831 |
| Husk | -0.6799* | 0.3384 |
| Rice grain | 0.2526 | 0.6470 |
| *Correlation is significant at the 0.05 level (1-tailed). | | |

**Table 4. Distribution of concentration factors (CF) enrichment factors (EF) for rice plant parts and vegetables.**

| | Rice root | Straw | Husk | Rice grain | Spinach | Tomato | Bengal gram |
|---|---|---|---|---|---|---|---|
| CF | 0.85 | 0.36 | 8.76 | 2.36 | 8.37 | 6.66 | 9.60 |
| | | | | | | | |
| EF | 5.50 | 2.34 | 56.79 | 15.27 | 54.22 | 43.19 | 62.22 |
| | | | | | | | |

**Figure 1. Study sites (•) marked.**

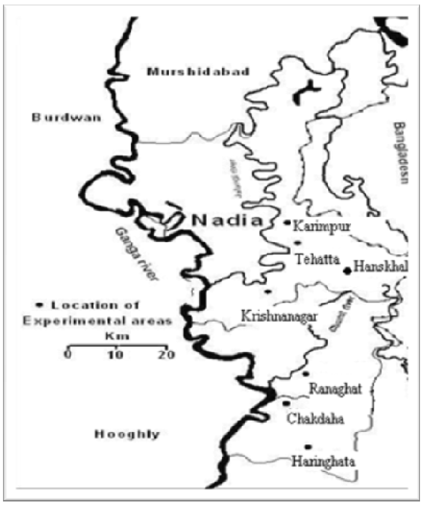


**Figure 2. Arsenic content of different parts of rice plants.**

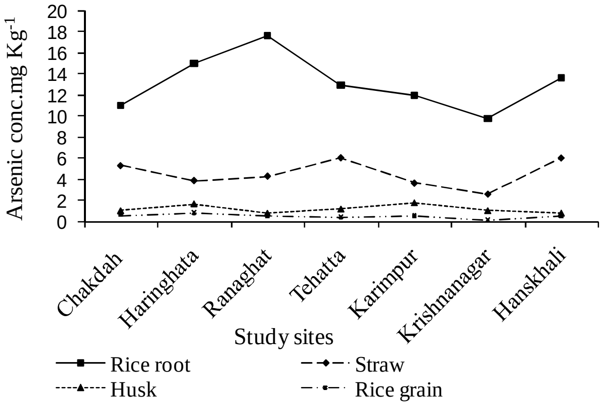


**Figure 3. Arsenic content of irrigation water, soil and various vegetables of the study sites**

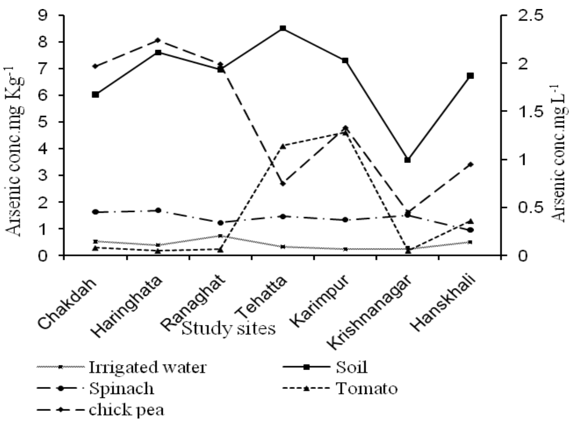


**Figure 4. Relation of mean arsenic concentration and related concentration factor (CF) of experimental samples.**