AVAILABILITY OF ARSENIC, PHOSPHORUS, POTASSIUM, CALCIUM, MAGNESIUM AND IRON TO VARIOUS VEGETABLES GROWN IN NORTHWEST BANGLADESH

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INTRODUCTION

Arsenic contamination in ground water extended to the USA, Argentina, China, Myanmar, Taiwan, Nepal, India and Bangladesh. More than 80 million people in Bengal Delta are living in zones with arsenic above 50 ppb arsenic in their ground water (Smedley and Kinniburgh, 2002). Arsenic crisis in Bangladesh is a great concern to environment and bealth issues, because millions of people in Bangladesh are at risk of different degrees of arsenic contamination not only through ground water but also through food growing on arsenic contaminated soil. Meharg and Rahman (2003) reported that irrigation of paddy rice field with arsenic contaminated ground waters has led to arsenic build-up in paddy soil, with subsequent elevation in rice grain arsenic.

Vegetables crops also need irrigation at different stages of growth, if they are grown with arsenic contaminated water may accumulate more arsenic and may be hazardous for human consumption. Vegetables are chief sources for mineral and vitamins for the millions of Bangladeshi people and vegetables are widely grown in the country on medium high to high lands where rice is not suitable or economic. Brown (2001) reported that the vegetables grown on contaminated soils favor arsenic uptake by the vegetables. They found that the arsenic accumulation in the edible parts of carrot, Indian spinach and green beans were different but far lower than arsenic consumption standards set by the U.S. Public Health Service (2,600 parts per billion) and even fell well below the Canadian standards (1,000 parts per billion) (Brown, 2001). Bańuelos (2002) found a greater Se accumulation in broccoli and canola grown with contaminated irrigation water that the plants grown with the normal irrigation water. Arsenic concentration in beans, kohlrabi, marigold, lettuce, carrots and celery ranged from <0.1 to 1.6 ppm when they were grown on control soils, but these values rose from 0.75 to 13 ppm when they were grown on red slag-soil mixture (Bunzl et al., 2001). However, the objective of the present study was to ascertain arsenic accumulation in summer vegetables grown in arsenic hot spot areas with low and high arsenic contaminated irrigation water.

METHODOLOGY

Nine different summer (April-September) vegetables samples were collected from three villages- Ghropakia, Ranihati and Hotathpara of Chapainowabganj district, Bangladesh. The vegetables were amaranth (*Amaranthus gangeticus* L.) eggplant (*Solanum melongena* L.) Chenopodium (*Chenopodium album* L.), Green pepper (*Capsicum annum* L.), Indian Spinach (*Basella alba* L.), Jute (*Corchorus olitorius* L.), Red amaranth (*Amaranthus spp.*), Ridge gourd (*Luffa acutanggula* L.), and Sweet gourd (*Cucurbita moschata*). Soil background arsenic concentration in Ghorapakia, Ranihati and Hotathpara villages were 8.9, 9.3 and 7.8 mg kg^{-1}, respectively and irrigation water arsenic concentration were 0.048, 0.058 and 0.983 mg L^{-1} respectively.

The vegetables were grown under farmers' management. According to the farmers' records vegetables fields received about 5-6 t cowdung application 15-20 days before seedling and 150 kg N, 25 kg P and 100 kg K ha^{-1} during final land preparation. Vegetable were collected from three villages considering the difference in irrigation water arsenic. In each village, vegetable were collected from the command area of the selected irrigation tube well. The vegetables field

received irrigation at every 2-4 days during April-May, however, the amount of irrigation applied was not measured. Farmers flooded the vegetable field but allowed no standing water.

Edible portion of the fresh vegetables samples were digested with HNO_3 and $HClO_4$ mixture (5:2), arsenic was determined by a hydride generation atomic adsorption spectrophotometer (Perkin Elmer, A Analyst 100, fitted with flow injection analysis system, FLAS 100), P, K, Ca. Mg and Fe were also analyzed from the same digest. Phosphorus was determined through vanadomolybdate yellow color method by spectrophotometer and Ca. Mg, K and were determined directly by atomic absorption spectrophotometer (Yoshida et al., 1976). From another portion of the vegetables samples, moisture content was determined by sun drying followed by drying at 68^0C for 72 hours. Duplicate analysis was done for each of the vegetables. The mean and standard error of arsenic concentration was calculated and expressed in dry weight basis.

RESULTS

Arsenic concentration varied in various vegetable species and in the same vegetable collected from different location (Table 1). Arsenic concentration in amaranthus collected from Ghorapakia village (0.048 μg L^{-1} irrigation water As) had 22 mg kg^{-1} arsenic, which was increased to 38 μg kg^{-1} in the sample from Ranihati village (0.058 μg L^{-1} irrigation water As) and the amaranthus collected from Hotathpara village had 174 μg kg^{-1} arsenic. The As concentration in the red amaranthus also was the lowest (26 μg kg^{-1}) in Ghorapakia sample and several fold higher (237 μg kg^{-1}) in Hotathpara sample. Arsenic concentration in chenopodium, green pepper, and Indian spinach samples did not very much between locations. Arsenic in the ridge gourd of Ghorapakia had only 4 μg kg^{-1} which was increased to 37 and 35 μg kg^{-1} in Ranihati and Hotathpara sample. The variation in As in the just leaf collected from three villages was observed, the lowest, the lowest (12 μg kg^{-1}) in Ghorapakia sample and the highest (85 μg kg^{-1}) in Ghorapakia sample and the highest (85 μg kg^{-1}) in Ranihati sample.

Within a village, the variation in arsenic content in vegetables was pronounced. For example, in Hotathpara village (irrigation water As was 0.983 μg L^{-1}) arsenic content in sweet gourd was 12 μg kg^{-1} in chenopodium leaf 19 μg kg^{-1}, in ridge gourd it was 35 μg kg^{-1}, in Indian spinach 42 μg kg^{-1}, while in amaranthus and red amaranthus it was very high.

Phosphorus concentrations in the vegetables dry matter are presented in Table 2. Phosphorus concentration in the vegetables of Ghorapakia ranged from 4.6 to 9.8 g kg^{-1}, in Ranihati it ranged from 3.9 to 11.6 g kg^{-1} and in Hotathpara the range was 2.0-9.4 g kg^{-1}, respectively. In most of the vegetables, phosphorus concentration in the sample of Ghorapakia was greater than other two villages. In case of amranthus and red amranthus phosphorus concentration seemed to decrease with increasing arsenic concentration, however, the effect was not pronounced in other vegetables.

Potassium concentration in amaranthus, eggplant, chenopodium, and Indian spinach was greater in the samples of Ghorapakia than other two villages, while in ridge gourd it was higher in Hotathpara (Table 3). In Ghorapakia, potassium concentration in Indian spinach was the highest (88.2 g kg^{-1}) and the lowest (26.8 g kg^{-1}) in green pepper. Effect of elevated arsenic concentration in amaranthus and red amaranthus was not found in potassium concentration. Potassium concentration in jute leaf varied considerably between two villages being the greater in Ranhati and lower in Ghorapakia.

Variation in calcium concentration between vegetables was large (Table 4). Leafy vegetables, such as amaranthus, chenopodium, India spinach and red amaranthus contained higher

calcium than eggplant, green pepper, ridge gourd and sweet gourd. The highest calcium concentration of 62.5 g kg^{-1} was found in red amaranthus (from Ghorapakia) and the lowest 3.0 g kg^{-1} in green pepper of Ranihati village. Variation in calcium concentration in red amaranthus was also pronounced between villages. In Ranihati and Hotathpara samples of red amranthus contained 28.2 and 33.6 g kg^{-1} arsenic compared to 62.5 g kg^{-1} in Ghorapakia. Effect of irrigation water arsenic on the calcium concentration was not distinct in other vegetables. Calcium concentration in amaranthus samples from Ghorapakia, Ranhati and Hotathpara was 22.8, 18.7 and 32.0 g kg^{-1}, respectively.

Magnesium concentration in leafy vegetables (amaranthus, Indian spinach, red amaranthus) was greater than in the fruit vegetables (eggplant, ridge gourd and sweet gourd), however, variation between locations was not large (table 5).

Iron concentration in vegetables varied largely between species and locations (Table 6). Amaranthus contained 1487 mg kg^{-1} Fe in the sample collected from Ghorapakia, which increased to 2401 mg kg^{-1} in the Ranhati samples and 4294 mg kg^{-1} in Hotathpara samples. In red amaranthus the Fe concentration was 1312, 2853, and 6701 mg kg^{-1} in the samples of Ghorapakia, Ranihati and Hotathpara, respectively. In case of Indian spinach and ridge gourd, Fe concentration in the samples of Ghorapakia was greater than in other two villages. The results suggest that the amaranthus and red amaranthus samples contained higher arsenic also contained higher iron.

DISCUSSION

Irrigation water arsenic produced significant effect on the arsenic concentration in amaranthus, red amaranthus, jute, and ridge gourd. Vegetables are important dietary items in Bangladesh, therefore, arsenic concentrations of all the vegetables were far below the toxic levels of 1000 ppb (Brown, 2001), but the toxicity of arsenic depends on its total intake in the body. Duxbury et al. (2005) mentioned that the FAO and WHO jointly established a provisional tolerable dietary intake of 0.015 mg As/kg body weight/week, or 130 μg/day for a 60 kg adult. In arsenic contaminated zones, this limit is exceeded through intake of water and rice, and consumption of fresh vegetables containing any amount of arsenic would add to the poison. Amaranthus and red amaranthus grown with arsenic contaminated irrigation water contained an elevated amount of arsenic; consumption of these vegetables is crucial in the arsenic hot spot area. Low-income group of people in Bangladesh relies on vegetables as mineral and vitamin source, but vegetables produced with arsenic contaminated irrigation water should be avoided because it would create extra arsenic load to their body.

CONCLUSIONS

Elevated concentration of arsenic in irrigation water increased arsenic concentration in the vegetables, but the effect was pronounced in amaranthus and red amaranthus, the two quick growing vegetables.

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Table 1. Arsenic concentration (μg kg^{-1} dry weight) $\pm$ SE in various summer begetables collected from three villages of different arsenic concentration in irrigation water. Chapanowabganj, Bangladesh.

Vegetables	Ghorapakia[1] (0.048 mg L^{-1})	Ranihati (0.058 mg L^{-1})	Hothapara (0.983 mg L^{-1})
Amaranth (*Amaranthus gangeticus* L.)	22 $\pm$ 1	38 $\pm$ 1	174 $\pm$ 15
Egg plant (*Solanum melongena* L.)	14 $\pm$ 1	35 $\pm$ 5	4 $\pm$ 1
Chenopodium (*Chenopodium album* L.)	19 $\pm$ 5	no sample	19 $\pm$ 8
Green pepper (*Capsicum annum* L.)	9 $\pm$ 1	4 $\pm$ 1	no sample
Jute (*Corchorus olitorius* L.)	12 $\pm$ 1	85 $\pm$ 10	28 $\pm$ 7
Indian spinach (*Basella alba* L.)	64 $\pm$ 6	65 $\pm$ 6	42 $\pm$ 10
Red amaranth (*Amaranthus spp*)	26 $\pm$ 4	39 $\pm$ 3	237 $\pm$ 21
Ridge gourd (*Luffa acutanggula* L.)	8 $\pm$ 1	37 $\pm$ 3	35 $\pm$ 5
Sweet gourd (*Cucurbita moschata*)	no sample	17 $\pm$ 1	12 $\pm$ 2

[1] Figure in parenthesis is irrigation water arsenic in the village. Soil back ground arsenic in Ghorapakia, Ranihati and Hotathpara village were.9, 9.3 and 7.8 mg $kg^{-1,}$ respectively.

Table 2. Phosphorus concentration (g kg^{-1} dry weight) $\pm$ SE in various vegetables collected from three villages of different arsenic concentration in irrigation water. Chapanowabganj, Bangladesh.

Vegetables	Ghorapakia[1] (0.048 mg L^{-1})	Ranihati (0.058 mg L^{-1})	Hothapara (0.983 mg L^{-1})
Amaranth (*Amaranthus gangeticus* L.)	9.8 $\pm$ 1.1	3.6 $\pm$ 0.0	4.7 $\pm$ 1.0
Egg plant (*Solanum melongena* L.)	7.1 $\pm$ 0.2	5.4 $\pm$ 0.8	6.0 $\pm$ 1.6
Chenopodium (*Chenopodium album* L.)	5.8 $\pm$ 1.3	no sample	2.0 $\pm$ 0.1
Green pepper (*Capsicum annum* L.)	7.2 $\pm$ 0.3	4.6 $\pm$ 0.7	no sample
Jute (*Corchorus olitorius* L.)	5.4 $\pm$ 1.1	6.6 $\pm$ 0.3	4.3 $\pm$ 0.6
Indian spinach (*Basella alba* L.)	4.6 $\pm$ 1.2	4.7 $\pm$ 0.1	4.8 $\pm$ 1.0
Red amaranth (*Amaranthus spp*)	9.6 $\pm$ 0.7	6.6 $\pm$ 2.8	3.5 $\pm$ 0.2
Ridge gourd (*Luffa acutanggula* L.)	7.6 $\pm$ 0.3	11.6 $\pm$ 1.4	9.4 $\pm$ 1.2
Sweet gourd (*Cucurbita moschata*)	no sample	3.9 $\pm$ 0.4	4.3 $\pm$ 0.1

Table 3. Potassium concentration (g kg^{-1} dry weight) ± SE in various vegetables collected from three villages of different arsenic concentration in irrigation water. Chapanowabganj, Bangladesh.

Vegetables	Ghorapakia[1] (0.048 mg L^{-1})	Ranihati (0.058 mg L^{-1})	Hothapara (0.983 mg L^{-1})
Amaranth (*Amaranthus gangeticus* L.)	62.7 ± 2.1	28.0 ± 1.2	50.1 ± 13.8
Egg plant (*Solanum melongena* L.)	50.4 ± 0.1	37.1 ± 0.3	39.4 ± 5.3
Chenopodium (*Chenopodium album* L.)	71.2 ± 19.2	no sample	37.2 ± 7.6
Green pepper (*Capsicum annum* L.)	26.8 ± 1.2	21.6 ± 0.4	21.9 ± 0.8
Jute (*Corchorus olitorius* L.)	34.4 ± 7.1	60.1 ± 8.0	no sample
Indian spinach (*Basella alba* L.)	88.2 ± 0.1	54.1 ± 1.9	41.5 ± 0.4
Red amaranth (*Amaranthus spp*)	56.9 ± 6.2	39.7 ± 7.0	51.0 ± 10.1
Ridge gourd (*Luffa acutanggula* L.)	44.1 ± 3.5	47.8 ± 3.9	61.4 ± 14.0
Sweet gourd (*Cucurbita moschata*)	no sample	32.7 ± 2.4	21.1 ± 0.1

[1] Figure in parenthesis is irrigation water arsenic in the village. Soil background arsenic in Ghorapakia, Ranihati and Hotathpara village were.9, 9.3 and 7.8 mg $kg^{-1,}$ respectively.

Table 4. Calcium concentration (g kg^{-1} dry weight) ± SE in various vegetables collected from three villages of different arsenic concentration in irrigation water. Chapanowabganj, Bangladesh.

Vegetables	Ghorapakia[1] (0.048 mg L^{-1})	Ranihati (0.058 mg L^{-1})	Hothapara (0.983 mg L^{-1})
Amaranth (*Amaranthus gangeticus* L.)	22.8 ± 2.4	18.7 ± 1.7	32.0 ± 6.0
Egg plant (*Solanum melongena* L.)	7.1 ± 0.2	6.2 ± 0.3	7.7 ± 1.8
Chenopodium (*Chenopodium album* L.)	20.6 ± 4.1	no sample	20.0 ± 4.8
Green pepper (*Capsicum annum* L.)	4.4 ± 1.0	3.0 ± 0.6	11.4 ± 0.3
Jute (*Corchorus olitorius* L.)	9.3 ± 2.5	15.5 ± 1.4	no sample
Indian spinach (*Basella alba* L.)	23.2 ± 1.6	32.9 ± 10.6	17.6 ± 7.4
Red amaranth (*Amaranthus spp*)	62.5 ± 1.4	28.2 ± 6.0	33.6 ± 6.5
Ridge gourd (*Luffa acutanggula* L.)	11.4 ± 2.2	10.4 ± 0.4	13.2 ± 1.6
Sweet gourd (*Cucurbita moschata*)	no sample	5.8 ± 1.5	4.3 ± 0.1

[1] Figure in parenthesis is irrigation water arsenic in the village. Soil background arsenic in Ghorapakia, Ranihati and Hotathpara village were.9, 9.3 and 7.8 mg $kg^{-1,}$ respectively.

Table 5. Magnesium concentration (g kg^{-1} dry weight) ± SE in various vegetables collected from three villages of different arsenic concentration in irrigation water. Chapanowabganj, Bangladesh.

Vegetables	Ghorapakia[1] (0.048 mg L^{-1})	Ranihati (0.058 mg L^{-1})	Hothapara (0.983 mg L^{-1})
Amaranth (*Amaranthus gangeticus* L.)	28.3 ± 6.6	13.3 ± 3.4	31.0 ± 10.0
Egg plant (*Solanum melongena* L.)	3.5 ± 0.1	4.6 ± 0.2	4.3 ± 1.5
Chenopodium (*Chenopodium album* L.)	14.1 ± 2.6	no sample	8.1 ± 0.6
Green pepper (*Capsicum annum* L.)	2.4 ± 0.3	3.0 ± 0.3	8.6 ± 2.3
Jute (*Corchorus olitorius* L.)	7.6 ± 1.4	12.2 ± 0.6	no sample
Indian spinach (*Basella alba* L.)	34.3 ± 3.4	27.4 ± 0.7	34.0 ± 5.3
Red amaranth (*Amaranthus spp*)	38.8 ± 4.9	27.9 ± 7.7	30.9 ± 9.5
Ridge gourd (*Luffa acutanggula* L.)	15.4 ± 1.4	19.7 ± 1.7	16.3 ± 1.6
Sweet gourd (*Cucurbita moschata*)	no sample	2.6 ± 0.3	2.2 ± 0.1

[1] Figure in parenthesis is irrigation water arsenic in the village. Soil background arsenic in Ghorapakia, Ranihati and Hotathpara village were.9, 9.3 and 7.8 mg $kg^{-1,}$ respectively.

Table 6. Iron concentration (mg kg^{-1} dry weight) ± SE in various vegetables collected from three villages of different arsenic concentration in irrigation water. Chapanowabganj, Bangladesh.

Vegetables	Ghorapakia[1] (0.048 mg L^{-1})	Ranihati (0.058 mg L^{-1})	Hothapara (0.983 mg L^{-1})
Amaranth (*Amaranthus gangeticus* L.)	1487 ± 57	2401 ± 141	4294 ± 249
Egg plant (*Solanum melongena* L.)	165 ± 23	1412 ± 199	1610 ± 227
Chenopodium (*Chenopodium album* L.)	593 ± 30	no sample	1063 ± 195
Green pepper (*Capsicum annum* L.)	255 ± 36	177 ± 25	1098 ± 91
Jute (*Corchorus olitorius* L.)	402 ± 11	2291 ± 60	no sample
Indian spinach (*Basella alba* L.)	3936 ± 129	3365 ± 363	1135 ± 69
Red amaranth (*Amaranthus spp*)	1312 ± 286	2853 ± 300	6701 ± 616
Ridge gourd (*Luffa acutanggula* L.)	2542 ± 156	2133 ± 252	1217 ± 172
Sweet gourd (*Cucurbita moschata*)	no sample	1121 ± 29	1564 ± 85

[1] Figure in parenthesis is irrigation water arsenic in the village. Soil background arsenic in Ghorapakia, Ranihati and Hotathpara village were.9, 9.3 and 7.8 mg $kg^{-1,}$ respectively.