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Dietary Intake of Arsenic by Households in Marua Village in Jessore

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Abstract

Arsenic (As) consumption through foods by adults and children in the As contaminated Marua village of Chowgacha upazila under Jessore district was studied. The Asian Arsenic Network (AAN) and the Japanese International Cooperation Agency (JICA) have provided some interventions such as installation of deep tube-wells and As-Fe removal plants and awareness program to reduce drinking water As exposure of people living in the village. But scope exists for food crops grown in this area to accumulate As from As contaminated irrigation water. With these points in view, a household food survey was made to investigate As intake by the people living in Marua village. For it, cooked meals and uncooked foods were collected from households and local market. The study revealed that an adult consumed 220 µg As per day from food source and rice alone contributed 86% of it. Considering 80% inorganic As in rice, 220 µg total As is equivalent to 176 µg As which exceeds the WHO's provisional maximum tolerable daily intake of As which is 2 µg/kg body weight i.e. 120 µg As for a 60 kg person. This result suggests that next to drinking water, food (mainly rice) is the principal source of As entry into human body in Bangladesh.

Key words: Arsenic, Daily intake, Food

Introduction

Groundwater contamination by arsenic has caused adverse health effects in Bangladesh (Ahmed, 2003). In 1970s, a huge number of tubewells have been installed in the rural areas in order to provide microbiologically safe drinking water to the people in this country. That time it was not known that the tubewell water may contain a high level of toxic heavy metals like arsenic. By now the tubewell water has affected many people with the symptoms of arsenicosis. For this reason, arsenic entering the human body through drinking water has been a great focus of investigation in arsenic-related studies. Nevertheless, food could be another way of arsenic entry into human body through water-soil-plant transfer (Meharg *et al*., 2003; Duxbury *et al*., 2003; Kurosawa *et al*., 2008). Arsenic-contaminated water used in irrigation contaminates soils, and then uptake by plants causes arsenic contamination of the edible portions of plants, such as vegetables and rice grains. Arsenic in these contaminated foods is then consumed by humans.

The analysis presented in this article is a contribution to the growing body of research evaluating the significance of food consumption as a pathway for environmental arsenic entering into the human body. Among the previous studies which calculated arsenic intake from food, the characterization of food consumption used in these studies was not household-specific. Roychowdhury *et al*. (2003) used fixed figures for rice and vegetables consumption for all households based on the realization that the consumption of these types of food "is almost the same for the villagers" in the study area. Smith et al. (2006) incorporated only the mean value of a self-reported daily serving of rice without that of vegetables in their calculation of arsenic intake.

The purpose of this study was to derive quantitative estimates of the amount of arsenic taken in via food in an arsenic-contaminated rural village in Bangladesh. To that end, a meal survey was conducted to quantitatively record all food ingredients used in cooking for three days in four households, and food samples including both uncooked and cooked materials were collected from these households as well as local markets.

Materials and Methods

This study was conducted in Marua village of Chowgacha upazila under Jessore district. This is predominantly an agriculture oriented village which consists of two settlements - western and eastern ones. Arsenic contamination in the west settlement is serious where 82% tubewells are contaminated by more than 50 ppb arsenic (MPL) and there are about 150 arsenicosis suspected patients, which stands second to Samta village of Jessore where 300 some suspected patients have been recorded (Ahmad *et al*., 1999). Due to the severity of arsenic problem, this village has received a series of arsenic mitigation activities through Asia Arsenic Network (AAN) and Japanese International Cooperation Agency (JICA) to provide As free drinking water. Of the currently used tubewells, only 16% of them were contaminated by As at the level of more than 0.05 mg/L, compared to the contamination rate of 64% in 2000 when the intervention started. Despite the availability of alternate safe water facilities, about 48% households do not use this water facility mainly because that the location of safe water facilities is far, they use shallow tubewell water (Tani and Begum, 2004).

The present food survey in this village recorded all food ingredients (by weight basis) used in cooking over three days at four households. It also recorded the number of adults and children who consumed each meal. From these households, samples of food ingredients and cooked meals were collected for arsenic analysis. Among these samples, a total of 10 samples of several types of arum leaves were collected. Arum leaves are reported to contain high levels of arsenic (Das *et al*., 2004; Huq *et al*., 2006). Food ingredients which were not available from the households were also collected from a local market. Food sample collection was carried out in March and July, 2007. A total of 72 food samples were collected and analyzed.

The food samples (vegetable and meal samples) were collected in polyethylene bags and were brought to the Asia Arsenic Network (AAN) laboratory in Jessore, 20 km away from the sampling site. The vegetables were washed with deionized water, dried at room temperature, cut into pieces and placed in new polyethylene bags. Both the vegetable and meal samples were then dried in an oven at 65°C to record the percentage moisture. The samples (1 g each) were digested with HNO_3-H_2O_2 at 95 ± 3°C in a digestion block. Arsenic concentration in the digest was determined by hydride generation-flame atomic absorption spectroscopy (HG-AAS, model Shimadzu AA-660, Japan). The Arsenic Reference Standard solution of 1000 ± 10 mg L^{-1} as As^{+3} from As_2O_3 (HACH Co., USA) was used in the measurement of arsenic. Five standard solutions ranging from 0-10 µg As L^{-1} were prepared using the reference standard for the preparation of a calibration curve. The calibration curves always showed a strong linear function (r = 0.999). The detection limit of this measurement was 1µg/kg, and when the dilution factor was taken into account, the actual detection limit was about 100 µg/kg.

Results and Discussion

Arsenic level in food

Among the vegetables analyzed for arsenic contamination, leafy vegetables had elevated levels of arsenic (Table 1). Of these leafy vegetables, higher concentrations were found in amaranthus leaves (1900 µg/kg dry weight, n = 1), moringa leaves (1100 µg/kg dry weight, n = 2), and in a variety of arum leaves (1000 µg/kg dry weight, highest concentration = 2000 µg/kg, n = 10). Compared with leafy vegetables (n = 26, mean = 910 µg/kg, SD = 520 µg/kg), fruit vegetables, such as eggplant, pointed gourd, white gourd, tomato, banana, and pumpkin were significantly lower in arsenic (n = 21, mean = 240 µg/kg, SD = 200, t = 1.69, $p < 0.01$). These results are in general agreement with other published concentrations of arsenic in vegetables (Schoof *et al*., 1999; Das *et al.*, 2004; Huq *et al*., 2006). The mean concentration of arsenic in T. Aman rice grain samples (n = 4) was 380 µg/kg (SD = 170 µg/kg). According to the data compiled by Williams *et al.* (2005), the mean range of arsenic in rice grains in Bangladesh lies within 0.10 mg/kg in Rajshahi (Hironaka and Ahmad, 2003) and 0.95 mg/kg in Faridpur (Islam *et al.*, 2004). The arsenic levels of foods recorded in the current study are comparable to the values reported in the previous studies.

Arsenic intake from food

Based on the food survey, daily food consumption by weight per person at the four sample households was calculated (Table 2). The weight values indicate the sum of each food item cooked and consumed in a household in a day, divided by the number of adult-equivalents eating meals. A child was calculated as one-half of the adult equivalent, and no distinction was made between males and females. This table contains three-day records for each household and a total of 12-day records. Because the diet in the studied area was rice-centered, the importance of the arsenic level in rice to humans via the food chain is obvious. The mean total daily energy intake per person was 2300 kcal (SD = 470 kcal). Rice alone comprised 1800 kcal (SD = 400 kcal), or 78% of all energy intake, and the average daily rice consumption was 470 g per person (SD = 90 g).

Table 1. Arsenic concentration (μg/kg) in food item

Food items[1]	n	Mean (dry wt)[2]	Range	S.D.[3]	Moisture %	Mean (wet wt)[4]	S.D.[3]
Leafy vegetables							
Amaranthus (data) leaf	1	1900	1900 -1900	N/A	85	280	N/A
Arum (kochu) leaf	10	1000	300-2000	560	90	92	67
Red leaf (lalshak)	1	690	690-690	N/A	88	85	N/A
Indian spinach (pui) leaf	4	570	200-1000	400	94	34	30
Moringa (sajna) leaf	2	1300	1000-1700	500	76	320	120
Subuj leaves	1	1200	1200-1200	N/A	89	130	N/A
White gourd (chal kumra) leaf	2	600	100-1100	700	92	45	50
Wild aroid (ghat kol) leaf	2	400	300-500	140	94	25	8
subtotal	23	910	100-2000	520	90	100	95
Fruit vegetables							
White gourd	1	100	100-100	N/A	96	4	N/A
Bitter gourd (karela)	4	150	100-300	100	89	17	10
Teasle gourd (kakrol)	1	700	700-700	N/A	89	78	N/A
Pointed gourd (potol)	4	150	100-200	60	91	12	4
Eggplant (begun)	3	170	100-200	60	93	12	3
Okra (dherosh)	2	500	200-800	420	92	37	30
Pumpkin (misty kumra)	3	200	100-400	170	93	12	7
Tomato	1	200	200-200	N/A	96	8	N/A
Banana (kola)	2	350	300-400	70	81	65	15
subtotal	21	240	100-800	200	91	23	23
Other vegetables							
Amaranth stem	1	100	100-100	N/A	84	16	N/A
Elephant foot yam (ol) stem	1	130	130-130	N/A	95	6	N/A
Arum corm	1	890	890-890	N/A	87	120	N/A
Elephant foot yam corm	1	300	300-300	N/A	85	45	N/A
Turmeric (holud) corm	1	400	400-400	N/A	90	40	N/A
Green chili (morich)	1	200	200-200	N/A	87	27	N/A
Onion (piyaj)	2	110	100-120	15	85	17	2
Potato (alu)	1	300	300-300	N/A	84	46	N/A
Rice							
Uncooked rice (chaul)	4	430	230-690	200	13	380	170
Cooked rice (bhat)	4	550	200-790	170	67	180	80
Water-soaked cooked rice (panta bhat)	4	770	400-1000	280	77	160	40
Other foods							
Lentil (dal)	3	110	110-110	0	10	100	0
bori (dried pulse cake)	1	---	---	---	No data	500	N/A
Rui carp	1	100	100-100	N/A	80	20	N/A
Silver carp	1	300	300-300	N/A	77	68	N/A
Date palm jaggery (gur)	1	---	---	---	No data	100	N/A

[1] Food names in Bengali as called in the study village, (English names are given in parentheses).
[2] Mean arsenic content in food on dry weight basis
[3] Standard deviation
[4] Mean arsenic content in food when collected

Table 2. Daily consumption of food per person, and daily arsenic intake based on total food intake and rice alone

HH		A			B			C			D			Mean
Day		1	2	3	1	2	3	1	2	3	1	2	3	
Food ingredients	As content (µg)[a]	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)
Rice	380	367	462	400	625	375	375	485	500	628	409	429	553	467
Lentil	100	0	46	100	125	0	0	26	0	63	27	43	55	40
Drumstick leaf	320	0	0	0	125	0	0	0	0	0	0	0	0	10
Pumpkin leaf	ND[b]	0	0	0	0	0	0	35	0	0	0	0	0	3
Red leaf	85	0	0	0	0	0	0	0	108	0	0	0	63	14
Arum leaf	97	0	0	0	0	0	0	71	0	70	91	0	0	19
Indian spinach leaf	34	0	0	0	0	0	0	0	0	0	0	43	0	4
Eggplant	12	200	0	0	0	125	0	0	0	0	0	17	0	29
Pointed gourd	12	0	162	0	0	0	0	0	0	0	0	0	0	13
Tomato	8	0	0	0	0	0	250	176	0	0	0	0	0	36
Pumpkin	12	0	0	0	0	0	0	0	115	0	73	0	158	29
Banana	65	0	0	0	0	0	0	0	0	0	91	0	0	8
Potato	46	0	208	80	125	50	125	0	100	35	0	0	0	60
Onion	17	0	0	0	0	0	0	44	38	35	0	34	0	13
Rui carp	20	167	92	0	0	0	0	26	31	14	0	0	39	31
Silver carp	68	0	0	0	0	0	63	0	0	0	0	0	0	5
Egg	ND[b]	0	0	0	25	0	0	0	0	49	0	0	0	6
Bori	500	100	46	20	75	0	0	0	23	21	0	51	0	28
Milk	ND[b]	0	0	0	0	0	0	176	308	105	0	43	39	56
Date palm jaggery	100	0	0	0	0	0	125	0	0	0	0	0	0	10
Rice flour bread	230[c]	0	0	0	0	250	250	0	0	0	0	0	0	42
Total As (µg)		200	220	180	330	200	220	200	220	260	170	200	220	220
Rice As (µg)[d]		140	180	150	240	200	200	180	190	240	160	160	210	190

a The arsenic content of food ingredients when sampled

b No data for arsenic content. Arsenic intake from these foods was not included in the total arsenic intake.

c Calculated by the arsenic content of rice and the moisture content of the bread (40%)

d Arsenic intake from rice and rice flour.

Table 2 also shows the daily arsenic intake in the four study households (“A,” “B,” “C,” and “D”) over 3 days. Arsenic intake was calculated using measured arsenic concentrations in food samples taken from the study households (“mean wet weight” in Table 1). For a food item which was not sampled from the study households, the mean arsenic concentration in the item sampled from a local market was used. Daily intake of arsenic per person ranged from 170 µg to 330 µg (mean = 220 µg, SD = 40 µg). The arsenic load from rice (mean = 190 µg, SD = 30 µg) was 86% of all arsenic from the food consumed.

The maximum tolerable daily intake (MTDI) of arsenic provisionally set by the World Health Organization (WHO) is 2 µg per kg body weight per day (WHO, 1996). For a Bangladeshi weighing 60 kg, the MTDI would be 120 µg As. When this standard was used, the daily arsenic intake in all the study households on the recorded days was nearly double the MTDI.

The above calculation is based on total arsenic, regardless of arsenic speciation. Inorganic forms of arsenic are believed to be more toxic to the human body than organic forms (Cullen and Reimer, 1989). Inorganic As content in rice grains varies. Williams et al. (2005) who analyzed samples of rice grains from 9 countries including Bangladesh, detected As^{III}, DMA^{V}, and As^{V} as the main arsenic species in rice. They found that “80 ± 3% (n = 11)” of the total arsenic contained in rice grains in Bangladesh was inorganic. In our calculation, the mean daily arsenic intake from rice was 190 µg based on the arsenic concentration of uncooked rice grains (Table 2). Using the figure of 80% inorganic arsenic (Williams et al., 2005), the daily intake of inorganic arsenic from rice alone was 150 µg, still higher than the MTDI.

Conclusions

This study examined arsenic intake via ingestion of contaminated food using actual records of household food consumption and analysis of the arsenic content in foods consumed in these households in Marua village of Jessore district. The results are alarming, in that both total and inorganic arsenic intake exceeded the MTDI of arsenic provisionally proposed by the WHO, mostly through the consumption of rice. Where tubewells for drinking water were highly contaminated, the main cause of arsenicosis was drinking water. As this study shows, when considering the rice-centered diet in Bangladesh and the possibility of water-soil-plant transfer of arsenic, this toxic metal in the food chain may have a significant impact on the health of rural people.

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