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Risk from Winter Vegetables and Pulses Produced in Arsenic Endemic Areas of Nadia District: Field Study Comparison With Market Basket Survey

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Abstract Arsenic contaminated groundwater uses for irrigation potentially lead the incidence of arsenic into food chain. In present study we examined total arsenic concentrations in 32 types of vegetables and 7 types of pulses. Range of total arsenic concentration in edible parts of vegetables collected from grown fields was 0.114–0.910 mg/kg. Highest arsenic values were in spinach 0.910 mg/kg. Vegetable samples were grouped into leafy, non-leafy-fruity, root-tubers. 18 common types of vegetables and pulses were collected through market basket survey, total arsenic were approximately 100 mg lower than those observed for the vegetables collected from the fields.

Keywords Arsenic · Soil · Vegetables · Water

Severe arsenic contaminated areas include parts of West Bengal, India (Das et al. 1996; Chakraborti et al. 2002), and Bangladesh (Nickson et al. 1998; Ohno et al. 2005). From a recent past research has been directed to studies on the transfer of arsenic from groundwater to soil to crops and the subsequent risk posed to human health from ingestion. In arsenic-affected areas, high concentrations of arsenic are consumed not only by humans but also by animals and plants (Roychowdhury et al. 2003; Huq and Naidu 2003; Das et al. 2004). Besides drinking water food has been identified as one of the major sources of arsenic exposure where exposure can occur not only when food is cooked with arsenic contaminated water but also when the food itself is found to contain significant concentrations of arsenic (Dabeka et al. 1993; Tsuda et al. 1995; Sapunar-Postruznik et al. 1996; Roychowdhury et al. 2002, 2003; Meharg and Mazibur 2003; Alam et al. 2003; Abernathy et al. 2003; Watanabe et al. 2004; Das et al. 2004; Patel et al. 2005). For this reason As distribution and dynamics in the food chain has been identified as one of the major research areas for quantifying arsenic exposure and consequential risk for human. Under certain environmental conditions arsenic can be both bioavailable and mobile and can accumulate in edible crops and fodder. Relatively high concentration of arsenic has also been detected in vegetables grown in the arsenic-affected region of Bangladesh (Schoof et al. 1999; Alam et al. 2003; Das et al. 2004) and in parts of Nadia and Murshidabad District of West Bengal (Roychowdhury et al. 2002). Consequent ingestion of arsenic affected crops and vegetables, meat from animals ingesting contaminated fodder, and drinking of contaminated water potentially poses serious threat to human health. Epidemiological study shows that high intake of fruits and vegetables decreases the incidence of some chronic diseases such as cancer, coronary heart disease, hypertension, cataract and diabetes mellitus type 2 (Block et al. 1992; Steinmetz and Potter 1996; Ness and Powles 1997; Krichevsky 1999; Landrum and Bone 2001). The observed clinical symptoms of arsenic toxicity vary greatly, which poses a considerable challenge in relating the potential pathways of transfer of arsenic from groundwater to human metabolic system through food-chain.

It is essential to consider arsenic accumulation in crops to prevent ingestion through contaminated yields. If agricultural products contain excessive levels of arsenic, these

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and their derivative should not be consumed. Intake of low arsenic containing foodstuffs cannot be ensured in an arsenic endemic area without extensive studies. In addition, the total daily amount of arsenic through food is to be considered. Foodstuffs grown in arsenic contaminated soil not only consumed by the people of arsenic exposed areas but also by the people of arsenic non-exposed areas. Present study concentrates on arsenic accumulation data of extensively cultivated winter vegetables, where irrigated water and soil contained high arsenic content. For comparison purposes, market basket survey samples were also analyzed for their arsenic content to disclose the reality about arsenic migration through marketing system in arsenic affected rural areas of West Bengal. The findings are likely to help plan remedial measures to combat arsenic contamination in the food chain through water-soil-vegetables and marketing transfer.

Materials and Methods

In present study, 14 different sample sites were selected which were previously documented (Chakraborti et al. 2002; Roychowdhury et al. 2002) high arsenic prone areas of Nadia District, West Bengal, India. At random irrigation water, respective field soil and vegetables were collected only for winter season from December 2010 to March 2011. Sampling sites, sample sizes and GPS locations are shown in the Table 1.

To monitor the load of arsenic from water samples (100 mL) along with replica (n = 3 minimum), from irrigation-pumps were collected in mid-stream by initially pumping water for five minutes. Immediately after sampling, 1 mL of concentrated HCl (MERCK, GR) was added to the 100 mL vials containing water and transported to laboratory for further analysis. Water sample total arsenic analysis was made with FI-HG-AAS coupled with FIAS 100 system (Perkin Elmer A Analyst 400).

Composite soil samples consisting of five sub-samples were collected from upper layer (0–30 cm) of agricultural lands, from where water and vegetables were collected. Grid sampling was adopted, and the number of samples collected from each site ranged from 15 to 20 per acre. On returning to the laboratory, soil samples were spread on the plastic trays, air dried for 8 days at room temperature, ground, screened to pass through a 0.5-mm non-metal sieve and stored in plastic zip packets till further analysis. Total arsenic of soil was assessed following wet-acid digestion by aqua-regia (3 HCl: 1HNO3; MERCK, GR) and heated until they were colorless. The procedure was repeated. Filtered supernatant was analyzed for total arsenic with FI-HG-AAS coupled with FIAS 100 system (Perkin Elmer A Analyst 400).

Replicate samples (3) of edible vegetable parts commonly grown in the sampling areas were collected directly from the grown fields. Vegetable samples were also collected from local nearby market places of the sampling sites. All plant samples were cleared of adhering soil particles, by washing three times with normal laboratory water followed by de-ionized water (three times) to ensure dislodging and removal of dust particles. Samples were dried in hot air oven at 60 ± 5°C for 48 h, ground using a

Table 1 Sampling sites with GPS location and corresponding irrigation water and soil arsenic content

Sampling sites	GPS locations		As in water mg/kg			As in soil mg/kg		
	Latitude	Longitude	Min.	Max.	Mean	Min.	Max.	Mean
Chakdaha (n = 5)	N23°09′9.5″	E88°25′53.5″	0.13	0.81	0.47	3.87	14.37	9.19
Ranaghat (n = 5)	N23°11′6.0″	E88°15′45.6″	0.21	0.7	0.45	7.05	13.14	9.09
Haringhata (n = 5)	N23°34′9.0″	E88°37′24.4″	0.22	0.53	0.38	3.59	9.32	6.45
Krishnanagar (n = 5)	N23°21′24.4″	E88°44′24.6″	0.91	0.33	0.62	4.21	8.44	6.36
Karimpur (n = 5)	N23°31′15.1″	E88°32′3.05″	0.07	0.39	0.23	3.54	7.93	5.74
Shantipur (n = 5)	N23°48′8.7″	E88°22′35.8″	0.09	0.19	0.14	2.33	4.95	3.66
Hanskhali (n = 5)	N23°57′9.2″	E88°35′35.8″	0.15	0.33	0.24	6.10	11.39	8.70
Dasdia (n = 5)	N23°26′59.6″	E88°34′54.1″	0.06	0.47	0.27	2.35	5.77	4.17
Nonaghata (n = 5)	N23°21′7.6″	E88°31′37.6″	0.14	0.61	0.38	9.71	12.31	10.51
Tehatta (n = 5)	N22°50′10.4″	E88°45′40.1″	0.09	0.39	0.24	3.22	3.66	5.44
Haringhata (n = 5)	N22°29′8.9″	E88°27′42.2″	0.15	0.41	0.28	4.38	11.23	8.25
Bagula (n = 5)	N22°32′11.3″	E88°35′40.7″	0.07	0.33	0.2	3.23	10.21	6.73
Hanskhali (n = 5)	N22°37′33.6″	E88°36′11.8″	0.13	0.61	0.37	7.44	13.05	10.25
Jagulia (n = 5)	N22°01′33.6″	E88°16′11.8″	0.05	0.48	0.27	3.52	8.53	6.48

stainless steel grinder, sifted through a 0.2-mm non-metal sieve, and stored under the room temperature (18°–27°) in polyethylene zip-packets for further analysis.

Mostly used edible parts of plant samples were weighed (1.0 gm) into 100 mL block digestion tubes; conc.HNO_3 (10 mL; MERCK, GR) added and allowed to stand overnight. Next day, these were heated for 3 h at 60°C followed by 6 h at 110°C. After cooling, the digests were passed through filter (Whatman No. 42); the digestion tubes were rinsed three times, passing washings through the filter. Deionized water was used for all washing operations and making to working volume. Total arsenic contents were measured in duplicate by hydride generation AA spectrometry (Perkin Elmer A Analyst 400) with a commercial stock standard (MERK-GERMANY) with calibration curve fit (of five laboratory standard concentrations) of $R^2 > 0.98$ in (lower level of detection 3.0 μg/L) all cases.

Quality control of the analysis was done by analyzing NIST SRM 1568a, the standard reference material of rice flour during each batch of sample run. The recovery percentages varied from 93% to 97%. Again after every 25 samples run in one sample batch, internal laboratory working standards were run for AAS performance checking.

Result and Discussion

Total arsenic content analysis revealed 100% of the irrigated water with up to a 50 times high arsenic content than WHO limit of 10 ppb arsenic for drinking water (WHO 2004), as there are still not any standards or recommended limit of arsenic content of irrigation ground water (Table 1). Soil sample arsenic content were elevated (Table 1) and nearly all samples were with bare minimum 50 spells greater arsenic content than global average.

Apart from drinking water, another concern was vegetable crops grown in arsenic prone areas and irrigated with arsenic-contaminated ground water irrigation. In order to determine arsenic content in food crops, 32 vegetable samples along with 7 types of widely cultivated samples of pulses were collected directly from fields and from immediate local area markets, for comparison purpose. Local farmers trade their harvests in various local markets to district markets for want of desired market price. So there happen a vague demonstration of arsenic concentration of grown crops and vegetables and actual intake of these vegetables by local people because farmers like to sell 100%. Therefore chances of arsenic migration into the non-affected areas are evident.

Results of total arsenic content of all foodstuff samples are summarized in Tables 2, 3 and 4. All levels of arsenic are reported as milligrams of total arsenic per kilogram of samples in wet weight. Mean value was achieved using three replicates measurements of the same sample taking into account the correction by the recovery value. Total arsenic content including all types of vegetables of sample sites ranged from 0.114 (±0.021) mg/kg in green chili (n = 12) to 0.910 (±0.059) mg/kg in spinach (n = 18; Table 2). Total arsenic content of pulses ranged from 0.314 mg/kg in moong (*Vigna* sp., n = 9) to 1.30 mg/kg in pea (*Pisum* sp., n = 8).

Among leafy vegetables basile (*Basella* sp., n = 20) leaf contain 0.201(±0.119) mg/kg arsenic and Bengal gram (*Cicer* sp., n = 18) contain 0.891 (±0.044) mg/kg of total arsenic (Table 2). Present results are quite similar as reported earlier by Das et al. 2004, in case of samples from Bangladesh (Table 5). In some previous studies (Das et al. 2004) arum plant was reported to contain high levels of arsenic, but the literature reports have been rather hazy as it was not reported clearly in which part of plant arsenic level was elevated. In our study arum plant (leaf and stem parts together, n = 11) and tuber (n = 17) showed total arsenic content of 0.373(±0.068) mg/kg and 0.558 (±0.073) mg/kg respectively (Table 2). Arum tuber was examined after pilling of the outer skin. In case of all samples only the dietary parts as used were examined likely for spinach all part together, but for potato, pointed gourd, pumpkin etc. after pilling of the skin.

Among non-leafy and fruity vegetables chili (*Capsicum* sp.) was found to contain lowest arsenic value of 0.114 (±0.021) mg/kg and bitter gourd (n = 7) contained 0.529 mg/kg (±0.044) of arsenic. Some widely cultivated fruits used as vegetables like cucumber (*Cucumis* sp., n = 17) 0.181 (±0.038) mg/kg, ladies finger (*Abelmoschus* sp., n = 20) 0.447 (±0.055) mg/kg, papaya (*Carica* sp., n = 10) 0.446 (±0.048) mg/kg and banana (*Musa* sp., n = 8) 0.319 (±0.092) mg/kg and tomato (*Lycopersicon* sp., n = 19) 0.551 (±0.262) mg/kg also showed high arsenic level (Table 2).

In study areas the main grown oil seed type is mustard seed (*Brassica* sp.), in which analysis showed total arsenic content (n = 5) range from 0.339 mg/kg to 0.373 mg/kg with mean value of 0.351 (±0.068) mg/kg (Table 2). Therefore it can be inferred that only through mustard oil people may be affected of high amount of arsenic (Table 2).

We examined number of vegetable samples which are basically roots and tubers of plants viz. radish, amaranth tuber, elephant foot yam, onion bulb, carrot, potato and curcuma. Among these vegetables arum tuber (n = 17) showed highest total arsenic content of 0.558 (±0.073) mg/kg, compared to 0.187 (±0.077) mg/kg of onion bulb (n = 13) which was lowest of roots and tuber group vegetables (Table 2). Along with rice, potato is one of the

Table 2 Arsenic content of widely cultivated vegetables in winter season

Edible vegetables	Local name	Scientific name	Arsenic content mg/kg wet weight			
			Min.	Max.	Mean	SD
Leafy vegetables						
Spinach [leaf + stem] (n = 18)	Palak	*Spinacia* sp.	0.641	1.39	0.910	0.259
Coriander leaves (n = 11)	Dhone	*Coriender* sp.	0.284	0.411	0.291	0.194
Arum [leaf + stem] (n = 11)	Kochu shak	*Alocasia* sp.	0.132	0.465	0.373	0.068
Amaranthus (leafy parts) (n = 9)	Note shak	*Amaranthus* sp.	0.373	0.576	0.462	0.103
Basile [leaf + stem] (n = 20)	Puin shak	*Basella* sp.	0.182	0.225	0.201	0.119
Bengal gram[leafy parts] (n = 18)	Chola	*Cicer* sp.	0.434	0.573	0.491	0.144
Knolkhol (n = 13)	Ol gobi	*Brassica* sp.	0.333	0.421	0.371	0.890
Cabbage (n = 18)	Bandha kopi	*Brassica* sp.	0.463	0.572	0.482	0.111
Non leafy vegetables basically fruits used as vegetables						
Pumpkin (n = 17)	Kumro	*Cucurbita* sp.	0.225	0.337	0.271	0.057
Cow pea (n = 8)	Borboti	*Vigna* sp.	0.154	0.316	0.263	0.089
Ridge gourd (n = 17)	Jhinga	*Luffa* sp.	0.181	0.351	0.226	0.112
Squash (n = 11)	Lao	*Legenaria* sp.	0.173	0.247	0.187	0.072
Cauliflower (n = 30)	Fulgobi	*Brassica* sp.	0.421	0.544	0.459	0.079
Chili (green) (n = 12)	Lanka	*Capsicum* sp.	0.037	0.125	0.114	0.081
Bitter gourd (n = 7)	Ucche	*Momordica* sp.	0.218	0.631	0.529	0.044
Pointed gourd (n = 9)	Potol	*Trichosanthes* sp.	0.365	0.397	0.383	0.012
Common bean (n = 18)	Seem	*Dolichos* sp.	0.392	0.488	0.412	0.017
Brinjal (n = 22)	Begun	*Solanum* sp.	0.207	0.283	0.261	0.028
Sajina (n = 6)	Sajina	*Moringa* sp.	0.121	0.420	0.337	0.082
Cucumber (n = 17)	Sosa	*Cucumis* sp.	0.152	0.232	0.181	0.038
Ladies finger (n = 20)	Bhindi	*Abelmoschus* sp.	0.314	0.562	0.447	0.155
Papaya (n = 10)	Pepe	*Carica* sp.	0.355	0.561	0.446	0.068
Banana (n = 8)	Kola	*Musa* sp.	0.141	0.480	0.319	0.192
Tomato (n = 19)	Tomato	*Lycopersicon* sp.	0.387	0.877	0.551	0.262
Oil seed						
Mastered seed (n = 5)	*Sorisa*	*Brassica* sp.	0.339	0.373	0.351	0.068
Roots and tubers						
Radish (n = 12)	Mulo	*Raphanus* sp.	0.333	0.649	0.491	0.122
Arum tuber (n = 17)	Mukhi kochu	*Alocasia* sp.	0.437	0.681	0.558	0.073
Elephant foot yam (n = 8)	Ol	*Amorphallus* sp.	0.233	0.569	0.482	0.133
Onion bulb (n = 13)	Piaz	*Allium* sp.	0.182	0.227	0.187	0.047
Carrot (n = 12)	Gajor	*Daucus* sp.	0.303	0.565	0.441	0.053
Potato (n = 14)	Aloo	*Solanum* sp.	0.212	0.591	0.431	0.055
Curcuma (n = 3)	Holud	*Curcuma* sp.	0.312	0.512	0.461	0.128

n sample number

staple among vegetables in study areas, which contained total arsenic in the range of 0.212 mg/kg to 0.591 mg/kg with a mean value of 0.431 (±0.058) mg/kg of 14 collected samples (Table 2).

Level of arsenic reported in literatures for foodstuff from, Japan (Tsuda et al. 1995), and Bangladesh has been compared with present study (Table 5). Mean arsenic concentrations of vegetables (from Nadia) in our study are approximately threefold higher than minimum values. However, the levels of arsenic concentrations found in our study are similar to results obtained by others for arsenic affected regions of Bangladesh. But still no study has been published taking into account of each and every vegetables and pulses separately which are cultivated in the study areas during winter season.

Among pulses group (Table 3), pea (*Pisum* sp., n = 8) showed highest arsenic content of 1.30 (±0.048) mg/kg and moong (*Vigna* sp., n = 9) showed lowest value of

Table 3 Arsenic content of widely cultivated pulses in winter season

Pulses	Local name	Scientific name	Arsenic content (mg/kg wet weight)			
			Min.	Max.	Mean	SD
Lentil (n = 7)	Musur	*Lens* sp.	1.241	2.38	1.12	0.144
Bengal gram (n = 18)	Chola	Cicer sp.	0.734	1.73	0.891	0.102
Moong (n = 9)	Mug	*Vigna* sp.	0.212	0.362	0.314	0.047
Red gram (n = 3)	Arahor	*Cajanas* sp.	0.778	1.39	0.812	0.099
Pea (n = 8)	Motor	*Pisum* sp.	1.482	2.18	1.3	0.048
Green gram (n = 13)	Kalai	*Vigna* sp.	0.773	0.937	0.809	0.022
Kidney bean (n = 9)	Rajma	*Phaseolus* sp.	0.457	0.482	0.462	0.036

Table 4 Arsenic content of vegetables and pulses collected from market

Samples	Local name	Scientific name	Arsenic content (mg/kg wet weight)			
			Min.	Max.	Mean	SD
Vegetables						
Pointed gourd (n = 9)	Potol	*Trichosanthes* sp.	0.072	0.132	0.084	0.101
Brinjal (n = 7)	Begun	*Solanum* sp.	0.223	0.262	0.250	0.023
Ladies finger (n = 9)	Bhindi	*Abelmoschus* sp.	0.031	0.086	0.076	0.046
Arum (n = 7)	Kochu	*Alocasia* sp.	0.082	0.351	0.152	0.133
Cow pea (n = 4)	Borboti	*Vigna* sp.	0.227	0.371	0.252	0.027
Cabbage (n = 22)	Bandha kopi	*Brassica* sp.	0.211	0.338	0.270	0.037
Cauliflower (n = 22)	Fulgobi	*Brassica* sp.	0.190	0.271	0.231	0.028
Spinach [leaf + stem] (n = 32)	Palak	*Spinacia* sp.	0.041	0.139	0.091	0.059
Papaya (n = 7)	Pepe	*Carica* sp.	BDL	BDL	–	–
Beet (n = 6)	Beet	*Beta* sp.	0.107	0.291	0.182	0.066
Carrot (n = 4)	Gajor	*Daucus* sp.	BDL	BDL	–	–
Potato (n = 12)	Aloo	*Solanum* sp.	0.082	0.382	0.210	0.048
Cucumber (n = 12)	Sosa	*Cucumis* sp.	0.102	0.249	0.153	0.083
Tomato (n = 16)	Tomato	*Lycopersicon* sp.	0.117	0.212	0.184	0.064
Pulses						
Lentil (n = 9)	Musur	*Lens* sp.	BDL	BDL	–	–
Bengal gram (n = 10)	Chola	*Cicer* sp.	0.027	0.034	0.031	0.029
Moong (n = 4)	Mug	*Vigna* sp.	BDL	BDL	–	–
Red gram (n = 3)	Arahor	*Cajanas* sp.	BDL	BDL	–	–
Pea (n = 9)	Motor	*Pisum* sp.	BDL	BDL	–	–

0.314 (±0.047) mg/kg of arsenic in it. Interestingly the total arsenic content of the pulses group showed higher end compared to the vegetable groups where highest values was in spinach (Table 2). The common practices of making pulses and vegetables in the study areas of Nadia district is to prepare with excess amount of water (also used for drinking water) and to retain the excess water into preparations. So the cumulative total arsenic is some way higher than in pulses itself as already reported by Roychowdhury et al. (2003).

Main objective of study was to agree on whether there were any difference of total arsenic contents among common type of samples in markets and fields. It is obvious that vegetables are money earning materials for farmers so they do not take it home or use for cooking at all. They sell it to nearby or far away markets depending upon communication. So for the arsenic affected areas there occur a vague reporting about the arsenic availability by vegetables and transfer to the human. In our study out of 32 types of vegetables and 7 types of pulses, we collected 18 (nearly 50%) common products (Table 4) from immediate local market places of the study areas. Comparative study revealed that there were huge differences in the total arsenic values of the market basket survey samples and in many cases the difference is of 100 mg/kg of total arsenic (Table 4). These differences were due to import of

Table 5 Comparison of results from our study with those published by others for foodstuff from arsenic contaminated areas

Reference foodstuffs	Range of arsenic (mg/kg)	References
Bangladesh (vegetables)	0.070–3.990	Das et al. (2004)
Bangladesh	0.019–0.489	Alam et al. (2003)
West Bengal, India	0.040–690	Roychowdhury et al. (2002)
West Bengal, India	0.040–605	Roychowdhury et al. (2003)
Vegetables from fields	0.114–0.910	Present study
Pulses from fields	0.314–1.300	Present study
Vegetables from markets	0.076–0.270	Present study
Pulses from markets	BDL-0.031	Present study

nonlocal vegetables, were also supported by answers of shopkeepers when detailed questionnaire was made.

Hence only market basket survey or only field survey might not give the actual picture of arsenic contaminated food stuffs. From the current study it has been clear that there occur some wrong representation about the arsenic flow through vegetables into the bionetwork of arsenic affected areas. This is the strong back bone of the present work to establish the relationship of field grown vegetables and market basket surveys for the same region.

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References

Abernathy CO, Thomas DJ, Calderon RL (2003) Health and risk assessment of arsenic. J Nutr 133:1536–1538

Alam MGM, Snow ET, Tanaka A (2003) Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. Sci Total Environ 308:83–96

Block G, Patterson B, Subar A (1992) Fruit, vegetables, and cancer prevention: a review of the epidemiological evidence. Nutr Cancer 18:1–29

Chakraborti D, Rahman MM, Paul K, Chowdhury UK, Sengupta MK, Lodh D et al (2002) Arsenic calamity in the Indian subcontinent—what lessons have been learned? Talanta 58:3–22

Dabeka RW, Mckenzie AD, Lacroix GMA, Cleroux C, Bowe S, Graham RA et al (1993) Survey of arsenic in total diet food composites and estimation of the dietary intake of arsenic by Canadian adults and children. J AOAC Int 76:14–25

Das D, Samanta G, Mandal BK, Chowdhury TR, Chanda CR, Chowdhury PP et al (1996) Arsenic in groundwater in six districts of West Bengal, India. Environ Geochem Health 18:5–15

Das HK, Mitra AK, Sengupta PK, Hossain A, Islam F, Rabbani GH (2004) Arsenic concentrations in rice, vegetables, and fish in Bangladesh: a preliminary study. Environ Int 30(3):383–387

Huq SMI, Naidu R (2003) Arsenic in groundwater of Bangladesh: contamination in the food chain. In: Ahmed MF (ed) Arsenic contamination: Bangladesh perspective. ITN-Bangladesh, Dhaka, pp 203–226

Krichevsky SB (1999) β-Carotene, Carotenoids and the prevention of coronary heart disease. J Nutr 129:5–8

Landrum JT, Bone RA (2001) Lutein, zea xanthin and the macula pigment. Arch Biochem Biophy 385:28–40

Meharg AA, Mazibur MD (2003) Arsenic contamination of Bangladesh paddy field soils: implications for rice contribution to arsenic consumption. Environ Sci Technol 37:229–234

Ness AR, Powles JW (1997) Fruit and vegetables, and cardiovascular diseases: a review. Inter J Epidemiol 26:1–13

Nickson R, McArthur J, Burgess W, Ahmed KM, Ravenscroft P, Rahman M (1998) Arsenic poisoning of Bangladesh groundwater. Nature 395:338

Ohno K, Furukawa A, Hayashi K, Kamei T, Magara Y (2005) Arsenic contamination of groundwater in Nawabganj, Bangladesh, focusing on the relationship with other metals and ions. Water Sci Technol 52:87–94

Patel KS, Shrivas K, Brandt R, Jakubowski N, Corns W, Hoffmann P (2005) Arsenic contamination in water, soil, sediment and rice of central India. Environ Geochem Health 27:131–145

Roychowdhury T, Uchino T, Tokunaga H, Ando M (2002) Survey of arsenic in food composites from an arsenic-affected area of West Bengal, India. Food Chem Toxicol 40:1611–1621

Roychowdhury T, Tokunaga H, Ando M (2003) Survey of arsenic and other heavy metals in food composites and drinking water and estimation of dietary intake by the villagers from an arsenic affected area of West Bengal, India. Sci Total Environ 308:15–35

Sapunar-Postruznik J, Bazulic D, Kubola H (1996) Estimation of dietary intake of arsenic in the general population of the Republic of Croatia. Sci Total Environ 191:119–123

Schoof RA, Yost LJ, Eickhoff J, Crecelius EA, Cragin DW, Meacher DM et al (1999) A market basket survey of inorganic arsenic in food. Food Chem Toxicol 37:839–846

Steinmetz K, Potter JD (1996) Vegetables, fruits and cancer prevention: a review. J Am Diet Assoc 96:1027–1039

Tsuda T, Inoue T, Kojima M, Akoi S (1995) Market basket and duplicate portion estimation of dietary intake of cadmium, mercury, arsenic, copper, manganese, and zinc by Japanese adults. JAOAC Int 78(6):1363–1368

Watanabe C, Kawata A, Sudo N, Sekiyama M, Inaoka T, Bae M et al (2004) Water intake in an Asian population living in arsenic-contaminated area. Toxicol Appl Pharmacol 198:272–282

WHO (2004) Guidelines for drinking-water quality, 3rd edn. WHO, Geneva