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# Metal Concentrations in Rice and Pulses of Samta Village, Bangladesh

M. G. M. Alam,[1] G. Allinson,[2] F. Stagnitti,[2] A. Tanaka,[3] M. Westbrooke[1]

[1] School of Science, University of Ballarat, Post Office Box 663, Ballarat Victoria 3353, Australia
[2] School of Ecology and Environment, Deakin University, Post Office Box 423, Warrnambool, Victoria 3280, Australia
[3] Environmental Chemistry Division, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-0053, Japan

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Rice (*Oryza sativa* indica) is by far the most important cereal grown in Bangladesh, accounting for nearly two-thirds of total domestic cereal production. Depending on local climate and soil conditions, typically three crops are grown: *aus* (planted in March-April and harvested in June-July); *aman* (planted in June-July and harvested in November-December); and *boro* (planted in December-January and harvested in April). Both *aus* and *aman* are largely rainfed, while *boro* is mostly irrigated. With a per capita consumption of about 150 kg/year, rice is the major staple food of Bangladesh, accounting for roughly 73% of caloric intake. Other important food crops include pulses such as beans, lentils and peas (known locally as *kheshari, masur* and *mung*). The grass pea (*Lathyrus sativus* L.; *khesari*) is cultivated over 33% of Bangladesh, accounting for 34% of pulse production (Malek *et al*., 1996).

Drinking of arsenic contaminated well water has become a serious threat to the health of many millions in Bangladesh (Paul and De, 2000). However, the implications of contamination of agricultural soils from long-term irrigation with arsenic contaminated groundwater for phyto-accumulation in food crops, and thence dietary exposure to arsenic, and other metals, has not been assessed previously in Bangladesh. In this study, cereal and pulses were collected from the arsenic affected area of Samta village in the Jessore district, and screened for As, Cd, Cu, Pb and Zn by inductively coupled plasma emmison spectrometry (ICP-AES) and inductively coupled plasma mass spectrometry (ICP-MS).

## MATERIALS AND METHODS

The study was conducted in Samta village of Jessore district, approximately 12 km from the border with West Bengal, India (Fig.1). The population is 89% Muslim, 21% Hindu. The average annual income is Taka 32000 (about US $ 660). The total area of the village is 3.2 km2, with approximately 3600 living in residential Samta village. The small Betna river bounds the village to the east, but the main source of water for the villagers are 284 mainly shallow tubewells.

*Correspondence to:* G. Allinson

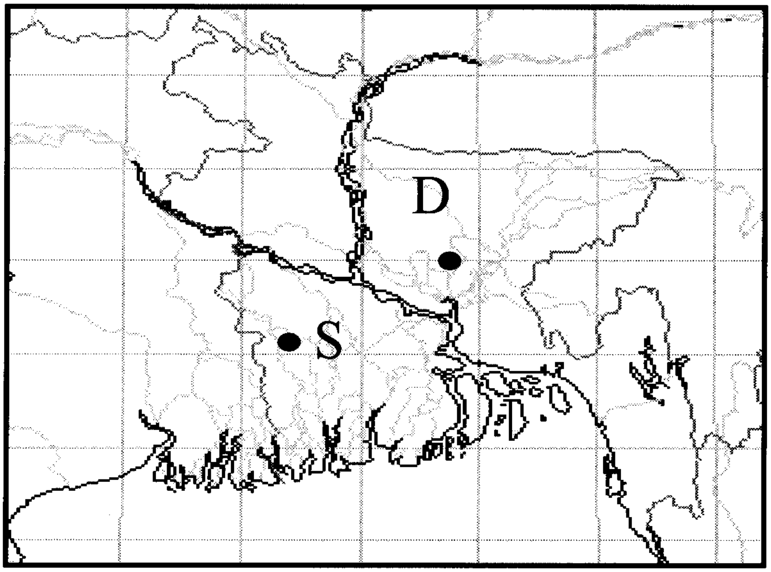


Figure 1. Location of Samta village (S) relative to the Bangladesh capital, Dhaka (D).

Cereals and pulses were collected in 1999. Samples were taken from stocks to be consumed locally and were very probably also harvested locally, but in most cases the sites of production could not be identified. The samples were weighed, washed with distilled water to eliminate air-borne pollutants, dried in an oven at 105°C for 24 hours, and then re-weighed to determine water content. After homogenisation of the bulk sample, a small portion, typically 50 mg, was transferred to a 7 ml Teflon PFA (perfluoroalkoxy) vial. An aliquot of ultrapure $HNO_3$ (1 ml) was added and then the cap of the vial closed tightly. The sample was kept at room temperature for 2-3 hours. Thereafter, the caps were briefly opened to vent gases, resealed, and inserted into a stainless steel jacket. Ater sealing, the bomb was heated at 140°C for 4 h. After cooling the bomb overnight,the vial was opened slowly and carefully to allow gases to vent. Then, 0.1 ml HF was adeded to dissolve siliceous materials, and the sample heated at 120°C to evaporate the HF. After cooling, 0.1 ml $HNO_3$ was added, and the sample heated to near drynes. This process was repeated twice more, then the residue was dissolved with 0.5 ml HNO3, and made up to the final volume (50 mL) with deionised water. This digestion method is suitable for the determination of volatile elements because the digestion is completed in a doubly closed system. All samples were analyzed three times for Ca, Fe, Mg, Na, P, and Si and the trace elements As, B, Ba, Be, Cd, Co, Cr, Cu, Mn, Mo, Pb, and Zn by ICP-AES (Model ICAP-750, Nippon Jarrel Ash, Tokyo, Japan) and ICP-MS (Model HP 4500, Yokogawa Analytical Systems Inc., Tokyo, Japan). Standard solutions were prepared from SPEX Certi Prep stock solutions. Sample blanks were analyzed after every 7 to 10 samples. Detection limits were set at three times the standard deviations of the blanks. Three standard reference materials ( Rice Flour-unpolished, CRMs 10-a, 10-b, and 10-c, National

**Table 1**. Summary of certified and reference (*) metal concentrations in NIES CRMs 10-a, 10-b and 10-c.

| Element | CRM 10-a | | CRM 10-b | | CRM 10-c | |
|---|---|---|---|---|---|---|
| | Certified | Observed | Certified | Observed | Certified | Observed |
| | | | ( mg kg$^{-1}$) | | | |
| Al | 3.0 | 2.89 ± 0.006 | 2.0 | 1.93 ± 0.007 | 1.5 | 1.46 ±0.003 |
| As | 0.17 * | 0.17 ± 0.004 | 0.11 * | 0.13 ± 0.004 | 0.15 * | 0.15 ± 0.006 |
| Ca | 93 ± 3 | 92.54± 0.28 | 78 ± 3 | 77.83 ± 0.04 | 95 ± 2 | 95.06 ± 0.32 |
| Cd | 0.023 ± 0.003 | 0.025 ± 0.002 | 0.32 ± 0.02 | 0.32 ± 0.002 | 1.82 ±0.06 | 1.78 ± 0.05 |
| Cr | 0.07 * | 0.08 ± 0.001 | 0.22 * | 0.21 ± 0.002 | 0.08 | 0.10 ± 0.003 |
| Cu | 3.5 ± 0.3 | 3.14 ± 0.4 | 3.3 ± 0.2 | 3.10 ± 0.3 | 4.1 ± 0.3 | 3.9 ± 0.4 |
| Co | 0.02 * | 0.02 ± 0.002 | 0.02 * | 0.02 ± 0.001 | 0.007 * | 0.007 ± 0.001 |
| Fe | 12.7 ± 0.7 | 12.56± 0.12 | 13.4 ± 0.9 | 12.94 ±0.31 | 11.4 ± 0.8 | 10.69 ± 0.23 |
| Mn | 34.7 ± 0.008 | 31.73± 0.006 | 31.5 ± 1.6 | 29.72 ± 1.02 | 40.1 ± 2.0 | 38.14 ± 1.76 |
| Mo | 0.35 ± 0.05 | 0.43 ± 0.003 | 0.42 ± 0.05 | 0.45 ± 0.02 | 1.6 ± 0.1 | 1.62 ± 0.01 |
| Na | 10.2 ± 0.3 | 10.32± 0.12 | 17.8 ± 0.4 | 17.54 ± 0.21 | 14.0 ± 0.4 | 13.93 ±0.14 |
| Se | 0.06 * | 0.07 ± 0.007 | 0.02 * | 0.02 ± 0.004 | 0.07 * | 0.07 ± 0.004 |
| Sr | 0.3 * | 0.42 ± 0.0.05 | 0.3 * | 0.02 ± 0.03 | 0.2 * | 0.03 ± 0.004 |
| Rb | 4.5 ± 0.3 | 4.14 ± 0.002 | 3.3 ± 0.3 | 3.14 ± 0.003 | 5.7 ± 0.3 | 5.46 ± 0.02 |
| Zn | 25.2 ± 0.8 | 22.38 ± 0.6 | 22.3 ± 0.9 | 21.71±0.04 | 23.1 ± 0.8 | 24.22 ± 0.03 |
| | | | **Wt.%** | | | |
| P | 0.340± 0.007 | 0.339 ± 0.008 | 0.315±0.006 | 0.316±0.003 | 0.335±0.008 | 0.334±0.007 |
| K | 0.280± 0.008 | 0.280 ±0.004 | 0.245± 0.010 | 0.242±0.006 | 0.275±0.010 | 0.275± 0.008 |
| Mg | 0.134±0.008 | 0.132 ±0.003 | 0.131±0.006 | 0.130±0.007 | 0.125±0.008 | 0.124± 0.006 |

Values quoted on a dry weight basis. The minimum determinable limits (MDL) indicated are based on mean – 10 standard deviations for the digested blanks (American Public Health Association, 1995).

Institute for Environmental Studies, Japan) were analysed for each trace element, one per set. For matrix correction and the development of a refined metal correction, two internal standards, In and Bi, were chosen to produce accurate ICP-MS results. The concentration were calculated on a dry weight basis.

## RESULTS AND DISCUSSION

Analysis of the CRMs found all certified and reference elements to be within 5-15% of expected values (85-110% recovery; Table 1). Based on this analysis, quantitative results were expected for seventen elements (Al, As, Ca, Cd, Cr, Cu, Co, Fe, K, Mg, Mn, Mo, Na, Se, Sr, Rb and Zn), all of which were detected in rice and pulses but only five metals (As, Cd, Cu, Pb and Zn) are discussed in this paper. The concentrations of these elements in the Samta Village rice and pulses are summarised in Table 2. Values quoted have not been corrected for analyte recoveries from certified reference materials.

Samta village was chosen as the model village in our study because we knew 90% of the tube wells in this village had arsenic concentrations above the Bangladesh standard of 0.05 mg $l^{-1}$ (Yokota *et al.,* 2001). Tube wells with arsenic concentrations of over 0.50 mg $l^{-1}$ were distributed across a belt-like east-west zone in the southern part of the village. The high concentrations of arsenic in surface water in the Samta village is presumably derived from agricultural use of contaminated irrigation water. Soil pH in the study area (4.9-8.8) suggests that arsenic will be immobile in local soil profiles. Indeed, Matsumoto and Hosoda (2000) found that arsenic content in sediments in Samta village were highest in the first upper muddy layer (3.0 to 261.5 mg $kg^{-1}$), decreasing with depth.

In some ways, the situation in Bangladesh may be compared to regions of Japan where irrigation of paddy fields with water contaminated by mining wastes or waste water from geothermal power stations has frequently produced growth depression of rice (Takamatsu *et al.,* 1982). Our study indicate that As concentration in rice in Samta village was higher than the American brown easy cook rice (0.12 mg $kg^{-1}$), Supreme Basmati Rice (<0.04 mg $kg^{-1}$), Minnesota quick wild rice (<0.04 mg $kg^{-1}$), and Arborio risotto rice (<0.04 mg $kg^{-1}$; Ministry of Agriculture, Fisheries and Food, 1999). The average per capita consumption of polished rice in Bangladesh is about 260 g $d^{-1}$ (Masironi *et al.,* 1977), resulting in an average intake of As from rice was estimated to be 91 μg $d^{-1}$. This is below the Joint Expert Committee on Food Additives (JECFA) Provisional Tolerable Weekly Intake (PWTI) of 15 μg $kg^{-1}$ body weight (equivalent to 130 μg $d^{-1}$ for a 60 kg adult) for inorganic arsenic (World Health Organization, 1989). The average Cd concentration in Samta rice is the same as that of rice worldwide (0.02 mg $kg^{-1}$;

**Table 2**. Mean concentrations (range) of As, Cd, Cu, Pb, and Zn in rice and pulses from Samta village, Jessore District, Bangladesh.

| Crop | Elemental concentration (mg $kg^{-1}$ dry weight) | | | | |
|---|---|---|---|---|---|
| | As | Cd | Cu | Pb | Zn |
| Rice | 0.35 (0.16-0.58) | 0.02 (0.01-0.04) | 2.94 (2.27-3.39) | 7.71 (2.60-15.89) | 12.7 (10.4-15.3) |
| Red Split Lentil | 0.04 (0.01-0.07) | 0.01 (0.00-0.03) | 12.8 (11.2-13.9) | 0.59 (0.58-0.86) | 56.7 (47.5-65.0) |
| Grasspea | 0.03 (0.01-0.06) | 0.003 (0.00-0.01) | 9.8 (8.3-10.5) | 1.48 (1.06-2.65) | 45.6 (39.6-54.4) |
| Pea | 0.03 (0.01-0.06) | 0.03 (0.02-0.04) | 14.1 (12.2-16.9) | 0.64 (0.38-0.76) | 34.1 (29.9-44.9) |

Watanabe *et al.*, 1989). Not surprisingly, therefore, the average daily intake of Cd (5.2 μg), does not exceed the recommended 60 μg $d^{-1}$ (60 kg adult World Health Organization, 1993). Copper concentrations are comparable with Japanese values (2.81 mg $kg^{-1}$; Ohmomo and Sumiya, 1981), but lower than rice from China, Philippines and Taiwan (4.21, 3.9 mg $kg^{-1}$, and 4.4 mg $kg^{-1}$; Suzuki et al, 1980; Masironi et al, 1977). Dietary exposure to copper for Samta population is below the Provisional Maximum Tolerable Daily Intake (PMTDI) of 30 mg $d^{-1}$ for a 60 kg person (World Health Organization, 1982 a). Pb concentrations in rice are higher than Australia, Italy, Japan and the United States (2.07, 6.97, 5.06, and 3.41 μg $kg^{-1}$, respectively; Zhang *et al.,* 1996). The average weekly intake of Pb from Shamta rice is estimated to be 14 mg, which greatly exceeds the PTWI for Pb of 1.5 mg $wk^{-1}$ for a 60 kg adult (World Health Organization, 1993). Zinc concentrations in the Samta rice are lower than in Japan, Indonesia and China (23.38, 23.51 and 21.47 mg $kg^{-1}$, respectively; Herawati et al., 1998). The average weekly intake of Zn from Shamta rice is estimated to be 21 mg, which is less than the recommended a PMTDI of 60 mg $d^{-1}$ (World Health Organization, 1982b). Highest concentrations of zinc were found in samples of dry pulses (red split lentil, grasspea and pea), possibly correlated to the higher protein content of pulses compared with rich. The concentration of Cu, Zn and Cd in pulses compare well with those reported by Tripathi *et al.,* (1997), but the concentration of all elements in pulses, especially red split lentil, were higher than in UK Total Diet studies (Ysart et al., 1999b).

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## REFERENCES

Herawati N, Rivai IF, Koyama H, Suzuki S, Lee, Y (1998) Copper in rice and in soils according to soil type in Japan, Indonesia and China:: A baseline study. Bull Environ Contam Toxicol 60:266-272.

MacIntosh DL, Spengler JD, Ozkaynak H, Tsai L, Ryan B (1996) Dietary exposures to selected metals and pesticides. Environ Health Perspec 104:202-209.

Malek MA, Sarwar CDM, Sarker A, Hassan MS (1996) Status of grass pea research and future strategy in Bangladesh. In Arora RK, Mathur PN, Riley KW, Adham Y, (ed) Lathyrus Genetic Resources in Asia: Proceedings of a Regional Workshop, 27-29 December 1995, Indira Gandhi Agricultural University, Raipur, India. IPGRI Ofiice for South Asia, New Delhi. p 7-12

Masironi R, Koirtyohann SR, Pierce JO (1977) Zinc, copper, cadmium and chromium in polished and unpolished rice. Sci Total Environ 7:27-43.

Matsumoto T, Hosoda, T (2000) Arsenic contamination and hydrogeological background in Samta village, western Bangladesh. Abstract, Pre-Congress Workshop (Bwo 10), Arsenic in Groundwater of Sedimentary Aquifers. 31st International Geological Congress, Rio de Janeiro, Brazil, August 3-5.

Minstry of Agricuulture, Fisheries and Food (MAFF) (1999) 1997 Total Diet Study: Aluminium, Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Tin and Zinc. Food Surveillance Information Sheet, No. 191 (London: HMSO).

Ohmomo Y, Sumiya M (1981) Estimation of heavy metal intake from agricultural products. In: Kitagishi K, Yamane I (ed) Heavy metal pollution in soils of Japan. Japan Scientific Societies Press, Tokyo. p 235-244.

Suzuki S, Djuangshi N, Hyodo K, Soemarwoto O (1980) Cadmium, copper, and zinc in rice produced in Java. Arch Environ Contam Toxicol 9: 437-449.

Takamatsu T, Aoki H, Yoshida T (1982) Determination of arsenic, nomethylarsinate and dimethylarsinate in soil polluted with arsenic. Soil Science, 133:239-246.

Tripathi RM, Raghunath R, Krishnamoorthy TM (1997) Dietary intake of heavy metals in Bombay city, India. SciTotal Environ 208:149-159.

Watanabe T, Nakatsuka H, Ikeda M (1989) Cadmium and lead in rice available in various areas of Asia. Sci Total Environ 80:175-184.

World Health Organization,WHO. 1982a. Toxicological evaluation of certain food additive. Joint FAO/WHO expert committee on food additives. WHO Food Additives Series, Number 17 (Geneva: World Health Organisation).

World Health Organization,WHO. 1982b. Evaluation of certain food additives and contaminants. Technical Report Series, Number 683 (Geneva: World Health Organisation).

World Health Organization,WHO. 1989. Toxicological evaluation of certain food additive and contaminants. Thirty-third meeting of the Joint FAO/WHO Expert Committee on Food Additives. WHO Food Additives Series, Number 24 ( Cambridge: Cambridge University Press).

World Health Organization,WHO. 1993. Evaluation of certain food additives and contaminants.WHO Technical Report Series, Number 837 ( Geneva: World Health Organization).

Yokota H, Tanabe K, Sezaki M, Akiyoshi Y, Miyata T, Kawahara K, Tsushima S, Hironaka H, Takafuji H. Rahman M, Ahmad SA, Sayed MHSU, Faruquee MH (2001) Arsenic contamination of groundwater and pond water and water purification system using pond water in Bangladesh. Eng Geol 60:323-331

Ysart GE, Miller PF, Crews H, Robb P, Baxter M, Delargy C, Lofthouse S, Sargent C, Harrison N (1996) Dietary exposure estimates of 30 metals and other elements from the UK Total Diet Study. Food Add Contam 16:391-403.

Zhang ZW, Moon CS, Watanabe T, Shimbo S, Ikeda M (1996) Lead content of rice collected from various areas in the world. Sci Total Environ 191:169-175.