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Arsenic, Toxic Heavy Metals, and C–N–P in Peaty Sediments in Samta Village, Southwestern Bangladesh

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Concentration of Arsenic (As), other toxic heavy metals, and C, N, P of the peaty sediments collected from Samta Village, Bangladesh were analyzed. The sediment layers were located in 6.5–9.0 m in depth from ground surface. According to the results, As, N (total), NH_4–N and C (total) concentrations were larger in peat than peaty clay layers. As is, therefore, may be related to N (total), NH_4–N and C (total) in concentrations. There were significant amount of ash, which was inorganic residue (minerals), in the sediments. P_2O_5 in the sediments may be sourced from phosphate fertilizers. The concentration of Fe, Al and Mn were high, while the concentrations of Cr, Cu, Zn, Pb were low. Based on the correlation analysis, the higher As may be related to higher C, N, H in concentrations. Thus, organic substances may be related to the higher As concentration. P_2O_5 and NH_4–N were not closely related to the As concentrations. Positive correlations of As with Cu, Zn, Cd, and Pb in concentrations were observed, while any correlation of As with Fe and Mn was not observed.

Key words: Arsenic, sediment core, nitrogen, carbon, heavy metals

INTRODUCTION

In Bangladesh and West Bengal, shallow groundwater aquifers (mostly <100 m) provide over 90% of drinking water (McArthur *et al*., 2001), however, one million water wells in these areas are contaminated by As with concentrations of $>50\,\mu g.L^{-1}$. Previous reports indicated that a high As concentration in groundwater was associated with a high prevalence of arsenicosis (McDonald *et al*., 2006).

The As concentration varies with the depth of aquifer as well as the hydrological characteristics of the area. The As concentration in the aquifer sediments in Bangladesh was controlled by the dissolution of iron, manganese and aluminium oxy–hydroxides under anoxic conditions (Bhattacharya *et al*., 2009; Kumar *et al*., 2016). In anoxic conditions, As was released when the As–rich iron and manganese oxy–hydroxides were reduced in a process that solubilizes iron and manganese and its absorbed load and increases bicarbonate concentration (Das *et al*., 1996; Nickson *et al*., 1998). In addition, As concentration in groundwater may be affected by phosphate fertilizers (Campos, 2002; Lin *et al*., 2016), and chemical nitrogen fertilizer application (Uddin and Kurosawa, 2011). In the recent study, Whaley–Martin (Whaley–Martin *et al*., 2017) showed that the oxidation of human/livestock waste coupled with reductive dissolution of iron–oxy–hydroxides may enhance the As release to groundwater from sediments.

In many previous studies, As concentration was very high in peat layer than in others in the As contaminated areas in Bangladesh. Therefore, the authors collected peat or peaty sediments in a highly As contaminated area in Bangladesh, and analysed their concentrations of toxic heavy metals, carbon (C), nitrogen (N), phosphorus (P) and some others as well as their As concentrations. Based on these results, the authors clarify the factors relating to high As concentration in the peaty sediments.

MATERIALS AND METHODS

Study area

The study area of Samta Village is situated on the southeastern part of Bangladesh in Jessore District, neighboring to India. Samta Village is a highly As contaminated area (Alam, Snow and Tanaka, 2003). In the area, groundwater is used not only for drinking purposes but also for irrigation purposes in dry season. The driest month in the area is December with 8 mm precipitation. Most precipitation falls in June, with 314 mm in average. In the rainy season, groundwater levels up to 1.5 to 2.0 m compared to the dry season. Hand–dug wells and many tube–wells are shallow (Biswas *et al*., 1998). The total geographical area of Samta Village is 3.2 km^2, where the main portion of the area is used for residential and paddy field purposes.

Sampling methods

Two boreholes in order to collect sediments (Core1 and Core2) were drilled from 0 m (ground surface) to 10 m in depth in Samta Village with hammering method. The horizontal distance between C1 and C2 cores was about 10 m. Sediments collected from the cores were classified as peat, peaty clay, clay and silty clay accord-

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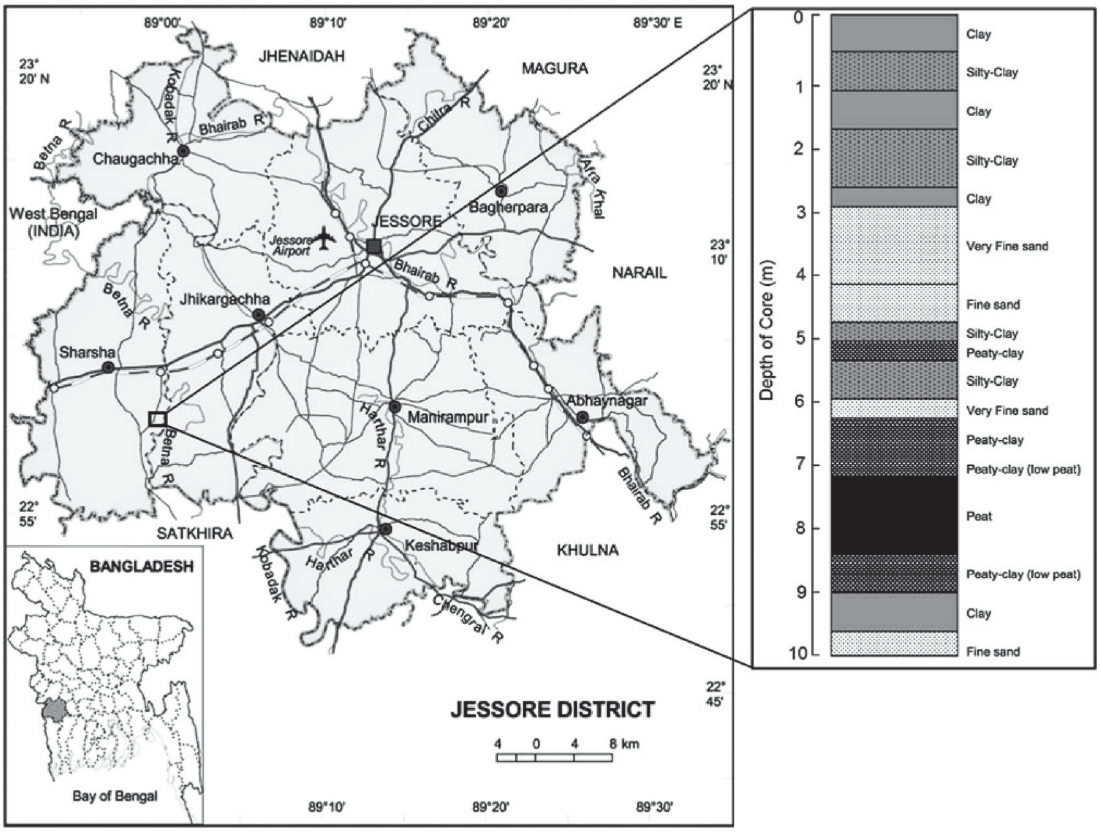

Fig. 1. Samta Village, Jessore District, Bangladesh (study area) and the diagram of the sediment layer from which peat samples were collected.

ing to the criterion given by Roy *et al.* (Roy *et al.*, 2005). The classification results indicated that two cores profiles were nearly the same with each other (Fig. 1). In the layers, three layers of peat/peaty clay in Cores 1 and 2 were targeted, which were the layers of peaty clay (L1 layer: 6.5–7 m), peat (L2 layer: 7.5–8.3 m) and peaty clay (low peat) (L3 layer: 8.5–9 m).

These samples collected were preserved in a plastic bag and then brought to Kyushu University, Japan for analysis with an import permission.

Analytical methods

Sediment samples were air–dried and ground to powder and sieved through a 2 mm sieve for further analysis. In order to determine the total concentration of heavy metals, the digestion method of the United States Environmental Protection Agency 3050B method (USEPA, 1996) was applied. The digested solutions were diluted with pure water and filtered through 0.45 μm syringe filter to analyse the concentrations of arsenic (As), lead (Pb), cooper (Cu), zinc (Zn), cadmium (Cd), chromium (Cr), iron (Fe), aluminum (Al) and manganese (Mn). Analysis was done by using Inductively coupled plasma – Mass spectrometry (ICP–MS, 7500ce, Agilent Tech, Inc., CA, USA). All determinations were repeated two times from digestion to analysis. The concentrations of C, N, H and ash in sediments were determined by using CHN Corder. For analysing NH_4–N, a colorimetric method was applied (Dorich and Nelson, 1983; SSSA, 1996). Available phosphourus (P_2O_5) concentration was analyzed using Olsen method (SSSA, 1996; Iatrou *et al.*, 2014).

Table 1. The main properties of the sediments in the two sediment cores

Core	Layer	Depth (m)	H (%)	C (%)	N (%)	C/N ratio	Ash (%)	P_2O_5 (μg/g)	P_2O_5 (%)	NH_4–N (μg/g)
1	L1	6.5–7.0	1.38	1.71	0.13	13.2	85.1	341.5	0.09	46.2
	L2	7.5–8.0	1.74	5.15	0.37	13.9	79.1	450.1	0.09	386.2
	L3	8.5–9.0	1.02	0.91	0.06	15.2	87.7	485.3	0.08	36.3
2	L1	6.5–7.0	1.36	0.59	0.07	8.4	85.7	444.1	0.09	77.4
	L2	8.0–8.3	2.14	10.24	0.75	13.7	70.0	469.3	0.12	337.1
	L3	8.5–9.0	1.3	1.23	0.11	11.2	83.2	604.4	0.12	262.6

RESULTS

Concentrations of trace toxic elements and soil properties

Table 2. Mean values of the concentration (μg/g) of As, and other toxic heavy metals in the two sediment cores

Core	Layer	Al	Fe	Mn	Cr	Cu	Zn	Cd	Pb	As
1	L1	10,239	17,794	93.3	23.3	13.6	22.3	0.1	15.3	9.4
	L2	9,244	13,470	78.6	20.7	18.3	18.8	0.1	17.2	54.7
	L3	8,643	16,079	117.2	20.6	13.0	22.2	0.1	17.1	9.0
2	L1	10,454	20,505	374.5	24.3	15.4	22.9	0.1	17.4	9.6
	L2	7,873	10,998	71.2	18.7	29.5	14.2	0.3	24.9	79.1
	L3	8,806	18,111	145.6	19.5	13.0	23.6	0.1	16.5	9.0

Correlations between the parameters

Table 3. The Peason's correlation coefficient values between the parameters measured for the peaty sediments

Core	H	C	N	Ash	P_2O_5 (Avail)	P_2O_5 (Total)	NH_4–N	As	Al	Fe	Mn	Cr	Cu	Zn	Cd
C	__0.95**__	1.													
N	__0.95**__	1.**	1.												
Ash	__–0.97**__	__–0.98**__	__–0.98**__	1.											
P_2O_5–Avail.	–0.12	–0.05	–0.04	–0.07	1.										
P_2O_5–Total	0.55	0.53	0.56	–0.68	0.62	1.									
NH_4–N	0.76	0.72	0.73	–.79	0.37	0.59	1.								
As	__0.94**__	__0.98**__	__0.97**__	__–0.95**__	–0.04	0.45	0.79	1.							
Al	–0.41	–0.64	–0.63	0.62	–0.54	–0.58	–0.54	–0.6	1.						
Fe	–0.76	–0.91	–0.89	0.83	0.	–0.32	–0.69	–0.91	0.77	1.					
Mn	–0.34	–0.51	–0.48	0.43	0.04	–0.09	–0.42	–0.47	0.61	0.75	1.				
Cr	–0.41	–0.61	–0.6	0.62	–0.62	–0.64	–0.67	–0.58	0.97	0.74	0.67	1.			
Cu	__0.93**__	__0.97**__	__0.97**__	__–0.96**__	–0.05	0.57	0.62	__0.93**__	–0.58	–0.8	–0.3	–0.5	1.		
Zn	__–0.91*__	__–0.99**__	__–0.98**__	__0.94**__	0.13	–0.42	–0.65	__–0.97**__	0.62	__0.92**__	0.48	0.55	__–0.97**__	1.	
Cd	__0.89*__	__0.97**__	__0.97**__	__–0.92**__	–0.23	0.41	0.55	__0.92**__	–0.58	__–0.88**__	–0.53	–0.51	__0.95**__	__–0.98**__	1.
Pb	0.8	__0.88*__	__0.89*__	__–0.88**__	0.11	0.65	0.50	__0.83*__	–0.69	–0.73	–0.21	–0.57	__0.96**__	__–0.89**__	__0.87*__

(, ** significant at 0.05 and 0.01 levels;* P_2O_5 *(Avail):* P_2O_5 *Available)*

DISCUSSION

According to Table 1, N, NH_4–N and C concentrations were far larger in L2 layer than in the layers. While, according to Table 2, As concentration was also far larger in L2 layer than in the layers. The As concentration in L2 layer was 54.7–79.1 μg/g. Therefore, As may be related to N, NH_4–N and C in concentrations. Concentration of H was also large in L2 layers.

Ash occupied a large portion of 70% or more, showing a lot of inorganic residue (minerals) left in the sediments. P_2O_5 has a possibility to be sourced from phosphate fertilizer, because P_2O_5 is a usual form of phosphate fertilizers. In Table 2, P_2O_5 was always higher than NH_4–N. N concentration was low in L1 and L3 layers (< 0.2) but medium or high in L2 layers. The C/N ratio, an indicator for the degree of decomposition, ranged medium or low of 8.4–15.1.

According to Table 2, Fe concentration was the largest with more than 10,000 μg/g, followed by Al (7,873–10,454 μg/g) and then by Mn (71.2–374.5 μg/g) concentrations. Concentrations of Cr, Cu, Zn and Pb did not differ with each other and ranged from 13.6–29.5 μg/g. Cd concentration was a low of 0.1–0.3 μg/g.

According to Table 3, significant correlations were observed between the concentration of As, C–H–N and ash. The correlation coefficient of As with C–H–N was positive, and that with ash was negative. Thus, the higher As may be related to higher C, N, H in concentrations. Here, organic substances may be related to the higher As concentration. While, neither correlation of P_2O_5 nor NH_4–N with the As concentration was observed. Further examination is necessary.

Significant positive correlations were also observed between As and Cu, Zn, Cd and Pb concentrations. It was not clear why the As was related to other toxic heavy metals of Cu, Zn, Cd and Pb in concentrations. On the other hand, significant correlation was not observed between As and Fe, and between As and Mn. For which, further examination is necessary.

AUTHOR CONTRIBUTIONS

Nguyen Van Thinh performed the chemical analyses and wrote the first draft of the manuscript. Masaru Matsumo and Kiyoshi Kurosawa conducted the data analyses and provided laboratory equipment in Japan. Shamin Uddin sampled the sediment cores in Bangladesh and sent the samples to Japan. Yiping Xie assisted the chemical analysis in laboratory.

REFERENCES

Alam, M. G. M., Snow, E. T. and Tanaka, A. (2003) 'Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh', *Science of The Total Environment*, **308**(1–3), pp. 83–96. doi: https://doi.org/10.1016/S0048-9697(02)00651-4

Bhattacharya, P., Hasan, M. A., Sracek, O., Smith, E., Ahmed, K. M., von Brömssen, M., Huq, S. M. I. and Naidu, R. (2009) 'Groundwater chemistry and arsenic mobilization in the Holocene flood plains in south–central Bangladesh', *Environmental Geochemistry and Health*, **31**(1), pp. 23–43. doi: 10.1007/s10653–008–9230–5

Biswas, B. K., Dhar, R. K., Samanta, G., Mandal, B. K., Chakraborti, D., Faruk, I., Islam, K. S., Chowdhury, M. M., Islam, A. and Roy, S. (1998) 'Detailed study report of Samta, one of the arsenic–affected villages of Jessore District, Bangladesh', *Current Science*. Current Science Association, **74**(2), pp. 134–145. Available at: http://www.jstor.org/stable/24100461

Campos, V. (2002) 'Arsenic in groundwater affected by phosphate fertilizers at São Paulo, Brazil', *Environmental Geology*, **42**(1), pp. 83–87. doi: 10.1007/s00254–002–0540–0

Das, D., Samanta, G., Mandal, B. K., Roy Chowdhury, T., Chanda, C. R., Chowdhury, P. P., Basu, G. K. and Chakraborti, D. (1996) 'Arsenic in groundwater in six districts of West Bengal, India', *Environmental Geochemistry and Health*, **18**(1), pp. 5–15. doi: 10.1007/BF01757214

Dorich, R. A. and Nelson, D. W. (1983) 'Direct Colorimetric Measurement of Ammonium in Potassium Chloride Extracts of Soils1', *Soil Science Society of America Journal*. Madison, WI: Soil Science Society of America, **47**, pp. 833–836. doi: 10.2136/sssaj1983.03615995004700040042x

Iatrou, M., Papadopoulos, A., Papadopoulos, F., Dichala, O., Psoma, P. and Bountla, A. (2014) 'Determination of Soil Available Phosphorus using the Olsen and Mehlich 3 Methods for Greek Soils Having Variable Amounts of Calcium Carbonate', *Communications in Soil Science and Plant Analysis*. Taylor & Francis, **45**(16), pp. 2207–2214. doi: 10.1080/00103624.2014.911304

Kumar, M., Ramanathan, A. L., Rahman, M. M. and Naidu, R. (2016) 'Concentrations of inorganic arsenic in groundwater, agricultural soils and subsurface sediments from the middle Gangetic plain of Bihar, India', *Science of The Total Environment*, **573**, pp. 1103–1114. doi: https://doi.org/10.1016/j.scitotenv.2016.08.109

Lin, T.–Y., Wei, C.–C., Huang, C.–W., Chang, C.–H., Hsu, F.–L. and Liao, V. H.–C. (2016) 'Both Phosphorus Fertilizers and Indigenous Bacteria Enhance Arsenic Release into Groundwater in Arsenic–Contaminated Aquifers', *Journal of Agricultural and Food Chemistry*. American Chemical Society, **64**(11), pp. 2214–2222. doi: 10.1021/acs.jafc.6b00253

McArthur, J. M., Ravenscroft, P., Safiulla, S. and Thirlwall, M. F. (2001) 'Arsenic in groundwater: Testing pollution mechanisms for sedimentary aquifers in Bangladesh', *Water Resources Research*, **37**(1), pp. 109–117. doi: 10.1029/2000WR900270

McDonald, C., Hoque, R., Huda, N. and Cherry, N. (2006) 'Prevalence of Arsenic–related Skin Lesions in 53 Widely–scattered Villages of Bangladesh: An Ecological Survey', *Journal of Health, Population and Nutrition*. icddr,b, **24(2)**, pp. 228–235. Available at: http://www.jstor.org/stable/23499361

Nickson, R., McArthur, J., Burgess, W., Ahmed, K. M., Ravenscroft, P. and Rahman, M. (1998) 'Arsenic poisoning of Bangladesh groundwater.', *Nature*, **395**(6700), p. 338. doi: 10.1038/26387

SSSA (Soil Science Society of America; American Society of Agronomy) (1996) *Methods of Soil Analysis. Part 3 –Chemical Methods*. Edited by D. L. Sparks

Uddin, S. and Kurosawa, K. (2011) 'Effect of chemical nitrogen fertilizer application on the release of arsenic from sediment to groundwater in Bangladesh', **4**, pp. 294–302. doi: 10.1016/j.proenv.2011.03.034

USEPA – United States Environmental ProtectionAgency (1996) *Method 3050B: Acid digenstion of sediments, sludges and soils*