Vertical Distribution of Soil Arsenic and some Selected Parameters in a Rice-Field Irrigated with As-Contaminated Water

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INTRODUCTION

Most of the shallow groundwater in Bangladesh is heavily contaminated with arsenic. Groundwater is used extensively in irrigation of rice, and the As it contains is suspected to contaminate soil and may enter the food crops. The behaviour and mobility of As in soil, particularly in the rice fields, is now a major concern. Soil pH, redox potential, contents of oxides and hydroxides of iron and manganese, clay and soil organic matter (SOM) are among the important factors affecting the mobility and adsorption of As (Smedely and Kinniburgh, 2002). Little information is available on the vertical movement of As in the rice fields in Bangladesh. Hence research on this aspect deserves special attention. Considering this point, a study was conducted to determine the vertical distribution of soil As and the pertinent soil properties in different depths of soil in an irrigated rice field.

METHODS

The experiment was conducted in Tala thana of Satkhira district in the south-western Bangladesh. Sampling was done in December 2002 when there was standing boro (dry season) rice which was being irrigated with As contaminated groundwater (250 µg As/l). Soil samples were collected from 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm depths from 22 locations representing the entire field with an area of 1.1 ha. Samples were analysed for pH, clay contents, total and acidified oxalate extractable As (FeOx-bound As), Fe and Mn (Wasay et al. 2000). Soil samples were digested in tri-acid mixture ($HClO_4$+HNO_3+H_2SO_4). The As in the digest or in the oxalate-extract was determined using an atomic absorption spectrophotometer equipped with hydride generation system (HG-AAS). The SOM was determined by the wet oxidation method (Nelson and Sommers, 1982). The Fe and Mn concentrations were determined according to the method of Olson and Ellis (1982).

RESULTS AND DISCUSSION

The soil of the experimental site was moderately alkaline (Table 1). Mean concentration of soil As was higher in the top soil (0-15 cm) than in lower depths. Total As concentration decreased in the subsurface soil (15-30 cm) and then increased with soil depth (Fig. 1a). The vertical distribution pattern of FeOx-bound As was similar to that of total As (Fig. 1a). An average of 76% of the total As was found in FeOx-bound form. This fraction dominates over other As fractions in soils (Miah et al. 2003). The vertical distributions of oxalate-extractable Fe and clay contents exhibited similar distribution patterns to that of total As (Fig. 1b and c). Total Fe content increased gradually from topsoil to the lower layers (Table 1).

Table 1. Selected properties of the four depths of soils in the study area (mean±standard error) (n=22).

Depth (cm)	pH	SOM (%)	Total Fe (%)	Total Mn (mg/kg)
0-15	8.10±0.04	2.08±0.051	4.01±0.15	533.6±12.8
15-30	8.15±0.04	1.25±0.053	4.23±0.12	537.1±19.1
30-45	8.14±0.02	1.12±0.039	4.28±0.14	549.8±19.7
45-60	8.14±0.02	1.14±0.063	4.33±0.12	539.1±18.41

Soil organic matter (SOM) in the top layer was higher than in the lower layers. The higher level of SOM in the flooded topsoil may enhance the adsorption of As (Smedley and Kinniburgh 2002). The dissolution of As from the Fe oxides and hydroxides may also increase the topsoil As, as evidenced by Takahashi et al. (2004). Arsenic concentration in the topsoil was further increased by the high As concentration of the irrigation water itself.

The similarity in the vertical distribution of As to oxalate extractable Fe and clay contents suggests that the mobility of As in soil is closely related to these properties. Adsorption of As was found to be higher in soils with higher clay content by Huq et al. (2003). Takahashi et al. (2004) found that As is principally hosted by Fe and Mn hydroxides.

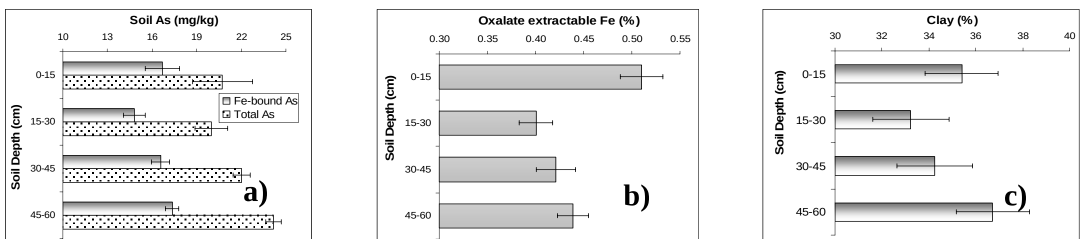

Fig. 1. Concentration of a) total and Fe-bound As, b) oxalate extractable Fe and c) clay in four depths of the soils in the study area (error bars indicate ±).

CONCLUSION

The study revealed that in high pH soil, in flooded and therefore reduced conditions, As is mobile and can be leached from surface to the deeper layers. The mobility is closely related to the clay and oxalate extractable iron content of the soil. Mobile As in the rice field soils may contaminate the groundwater considerably.

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