Impact of Soil Fe Oxide on Retention of Arsenic in Bangladesh Rice-Producing Soils

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INTRODUCTION

In a companion paper in this session (Panaullah *et al.*, 2003), the arsenic concentrations of the surface agricultural soils of five *thanas* of Bangladesh were evaluated. Concentrations were variable between *thanas*. For example, Senbag exhibited uniformly low arsenic concentrations, compared to Faridpur and Tala which exhibited considerably higher concentrations and wider distributions of soil arsenic. In all cases, there was a relatively poor correlation between soil arsenic concentration and irrigation-water arsenic concentration, indicating that soil factors (e.g., mineralogy, texture, drainage patterns, etc.) as well as irrigation water arsenic concentration strongly contributed to the total soil arsenic concentration. The object of the current study was to evaluate the possible influence of several soil parameters (principally Fe and Mn form and concentration) on observed soil arsenic concentrations.

MATERIAL AND METHODS

The five specific *thanas* (Senbag, Brahmanbaria sadar, Faridpur sadar, Tala, and Paba) were selected based on previously observed high arsenic levels in drinking water, the prevalence of shallow tube wells for irrigated rice production, and to represent diverse geographic regions of Bangladesh. One-hundred soil samples (0-15 cm depth) were collected from rice fields in each *thana*, with each sample representing a separate STW command area. Samples were collected in an approximate grid pattern to represent the major STW-irrigated, boro rice producing areas in the *thana*. Soils were air-dried, and soil pH, texture, organic matter, and clay content were determined. Total free Fe oxide and poorly crystalline Fe oxide were determined by citrate dithionite extraction and pH 3.0 ammonium oxalate (in the dark) extraction, respectively. Three arsenic parameters were utilized: (i) total soil arsenic by HNO_3/H_2O_2 digestion, (ii) pH 4.0, 0.1 M Na phosphate extraction, and (iii) pH 3.0, 0.2 M NH_4 oxalate extraction (in the dark). Arsenic, Fe and Mn concentrations of soil extracts were determined by FI-HG-AAS and FAAS. Soil mineralogy was also studied by XRD, SEM, and TEM. Data was evaluated by multivariate statistical procedures.

RESULTS AND DISCUSSION

Each of the various arsenic assays showed a positive correlation with each other, though the degree of correlation differed between *thanas* (Fig. 1). The amount of arsenic extracted by the three arsenic assays decreased in the following order: total arsenic > oxalate-extractable arsenic >> phosphate-extractable arsenic. The oxalate-extractable arsenic represented an average of approximately 70 % of the total arsenic, which indicates the relative importance of the poorly crystalline Fe oxides compared to the well-crystalline oxides in the retention of arsenic in the rice-producing soils of the current study. Arsenic is readily extracted from the poorly crystalline Fe oxides by ammonium oxalate, due to the ligand enhanced dissolution of the oxide, but is not readily extracted from the well-crystalline oxides. The arsenic extraction behavior from the rice-producing soils of Bangladesh has especially important implications to arsenic solubility and potential arsenic bioavailability in flooded rice culture, since the poorly crystalline Fe oxides are much more readily dissolved than the crystalline oxides under the conditions of flooded rice culture.

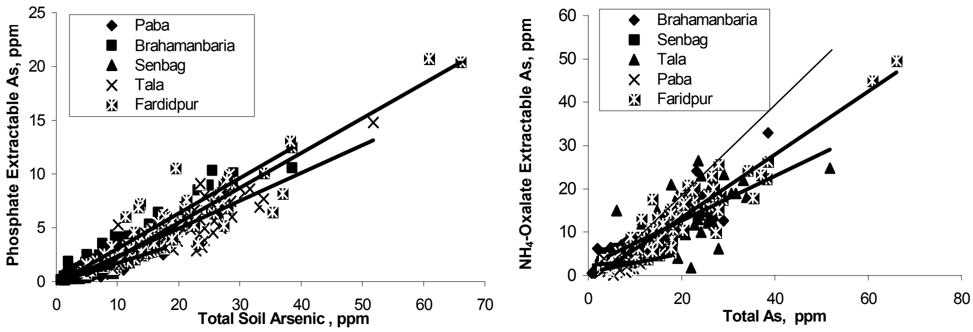

Fig. 1. The relationships of (i) phosphate-extractable arsenic and (ii) oxalate-extractable arsenic, with total soil arsenic for the five thanas.

The total free Fe-oxide contents of the soils differed both within and between *thanas* (Fig. 2). These results indicate the strong influence of local soil environmental conditions (deposition of new alluvial sediments, mineralogy, pH, irrigation patterns, drainage patterns, pH) on soil Fe-oxide concentration. Weak positive correlations between soil arsenic concentration and several iron parameters were observed. These relationships suggest the probable role of soil Fe oxides in arsenic retention and mobility, though the relatively poor correlations also indicate that the soil and environmental factors that contribute to arsenic retention are quite complex. Mineralogical analysis has indicated the occurrence of trioctahedral mica and Fe^{2+}-chlorite in the plow layer of Bangladesh rice-producing soils, though the concentrations are variable. Edge sites of these minerals would also contribute to arsenic adsorption.

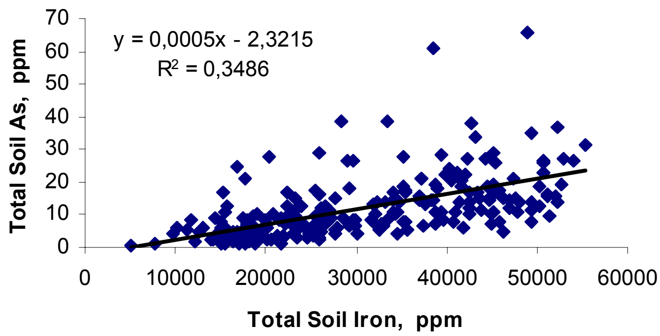

Fig. 2. The relationship between total soil arsenic and total soil Fe oxide for the five *thanas*.

The amount of arsenic extracted by each of the three assays decreased in the following order among thanas: Faridpur>Tala>Brahmanbria>Paba>Senbag, though the previously observed highest arsenic levels in drinking water were in Senbag. There was a wide variation of arsenic contents in soils both between and within thanas. The low arsenic levels in Senbag soils samples might be influenced by higher sand and lower clay concentrations and higher hydraulic conductivities. Conversely, the higher levels of arsenic in Faridpur sadar, Tala and Brahmanbaria soils might be due to the higher phyllosilicate and Fe oxide contents.

The Fe-oxide reactions, content and forms must be considered in the optimized management and mitigation of arsenic in flooded rice culture.