Arsenic in the Water-Soil-Crop Systems: PETRRA-BRRI-BAU-AAS Study

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Introduction

Groundwater contamination by arsenic (As) is a severe problem in Bangladesh. About 20 million people are at risk of As contamination (WHO, 2001). Most attention has been given to the arsenic contamination of drinking water. Besides domestic use (drinking, cooking, washing, etc.), significant quantities of water from shallow aquifers are being used in the dry season especially for irrigating Boro rice. In Bangladesh, both shallow tube-wells (STW) and deep tube-wells (DTW) are used in large numbers (approximately 2.6 million) to irrigate about 2.5 million ha of land, which contributes significantly to the country's food grain production. About 86% of the total groundwater withdrawn is utilized in the agricultural sector (WRI, 2000). Long-term use of As-contaminated water for irrigation may result in elevated As concentration in soils and plants (Ullah, 1998; Jahiruddin *et al*., 2000; Huq *et al*., 2003; Panaullah *et al*., 2003; Islam *et al*., 2004). Arsenate and phosphate are analogues, and addition of one of the elements to soil may affect the uptake and availability of the other. The objective of this study was to assess the arsenic status in the irrigation water-soil-rice plant system.

Methodology

Levels of As in the irrigation waters, soils, and boro rice (grain and straw) from 100 shallow tubewell (STW) areas of Chapai Nawabganj sadar upazila were measured. Similarly, the As concentration in 230 STW water samples from Charghat upazila were determined. Again, water As concentrations of 171 DTWs and STWs in the PETRRA sub-project areas were analyzed. Besides these, fluctuation of water-As concentration in the observation wells in Charghat and Chapai Nawabganj was monitored over the year. Further investigation was undertaken during the 2002 & 2003 boro seasons to examine the variation of water As concentration, if any, due to well depth, well age, and distance of wells from rivers.

The effects of As contamination on yield and As accumulation in rice were investigated. Two sets of pot experiments, one with soil-added As and the other with irrigation-water As, were conducted in the net-house at BAU, Mymensingh. The levels of soil added arsenic were 0, 5, 10, 15, 20, 30, 40 and 50 ppm, and those of irrigation-water As were 0, 0.1, 0.25, 0.5, 0.75, 1.0, 1.5 and 2 ppm. The effect of added As (plus 2.6 ppm initial soil As) was tested directly on Boro rice (cv. BRRI dhan 29) and its residual effect on T. Aman rice (cv. BRRI dhan 33). Further pot experiments were carried out to evaluate the effect of As in the presence of P on Boro rice. The effects of added As on rice, Indian spinach and red amaranth were also investigated in the green-house at BRRI (3.0 ppm background-soil As).

Results and Discussion

The As concentrations varied widely between locations. The STW-water As concentrations ranged from 0.015 to 0.352 $\mu g\ mL^{-1}$ (Fig. 1), and the soil As contents ranged from 5.8 to 17.7 $\mu g\ g^{-1}$ over the locations. There was a good correlation between water As and soil As (Fig. 3), indicating a possibility of As build up in soil with time. The rice-grain As concentration was in the range of 0.24 to 1.30 $\mu g\ g^{-1}$; 11% of the samples had As levels < 0.5 $\mu g\ g^{-1}$, and the remaining 89 % were in the range of 0.50 to 1.0 $\mu g\ g^{-1}$ (Fig. 2). The grain-As concentration was poorly correlated with soil-As concentration as well as irrigation-water As concentration. Thus, the availability of soil As for plant uptake indicates a complex system. The rice straw-As concentrations ranged from 1.48 to 17.6 $\mu g\ g^{-1}$ and were strongly associated with grain As concentration (Fig. 4). High concentration of As in rice straw fed to cattle may be a threat to cattle health. About 89% of the rice grain grown in Chapai Nawabganj irrigated with As-contaminated water may lead to an intake of more than 100% of the potential maximum tolerable daily intake (PMTDI) for an adult of 70 kg body weight.

From another study it appeared that 8% of the STWs in Charghat (n=230), 56% in Chapai Nawabganj (n = 100) and 29% in the other districts (n = 171) had As concentrations above 0.05 mg L^{-1} (the maximum permissible limit). Further it was observed that As concentration tended to increase in the beginning of the dry months, peaked in May, and then declined with the start of the monsoon. Comparing types of wells, water-As concentration was found to be the highest with HTWs (27%), followed by STWs (21%) and DTWs (7%). Well depth between 40 and 160 ft had the highest level of water As. There was no correlation between water As and well age. The water As level in wells decreased with increasing distance from the rivers.

The results of pot experiments demonstrate that there was a significant yield reduction above 10 ppm soil-applied As or above 1 ppm irrigation-water added As (Figs. 5 & 6). The As concentration in rice grain increased with increasing application of As added either through irrigation water or direct addition to the soil; however, all concentrations were below 1 ppm. The maximum permissible limit of As is 1 ppm for seafoods where organic As comprises above 90 % of the total As. This limit could be less for rice since about 80 % of As in rice grain is inorganic. Again, the straw-As concentrations in all cases were much greater than 1 ppm. There was a residual effect of both soil- and water-added As on the second crop (T. Aman rice). The As-P interaction study indicated that the adverse effect of As was further aggravated by P addition to soil. The leaf size of Indian spinach was reduced and the leaves turned yellowish green color when As was applied at 20 mg kg^{-1} soil. Such negative effect of added As was not observed in case of red amaranth. The highest As content was recorded in roots followed by leaves and stems.

Acknowledgement

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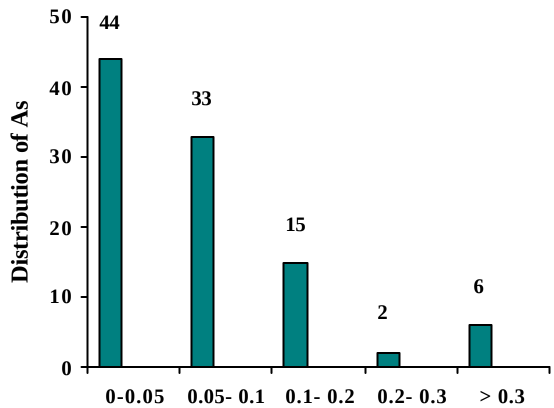

Fig. 1 Frequency distribution of water As (n = 100)

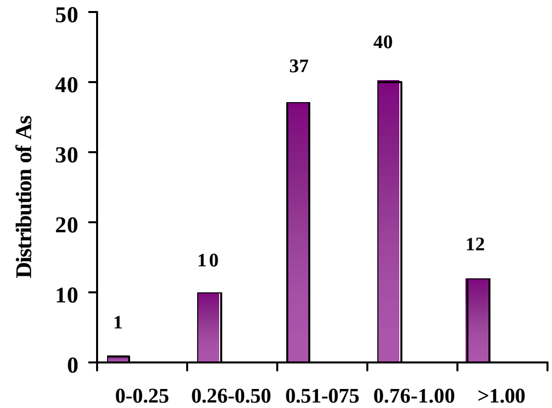

Fig. 2 Frequency distribution of grain As (n = 100)

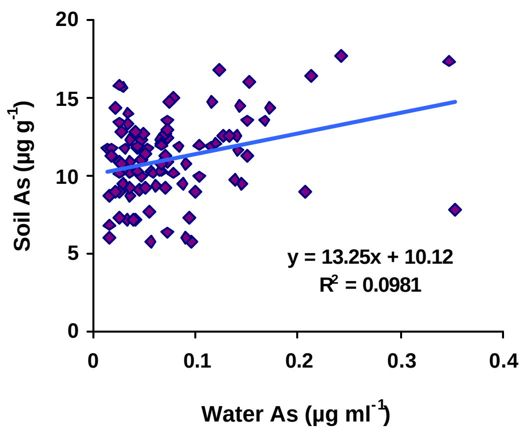

Fig. 3 Relationship between soil As and water As (n = 100)

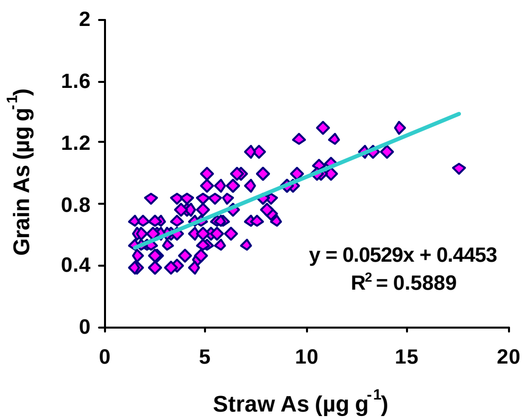

Fig. 4 Relationship between grain As and straw As (n = 100)

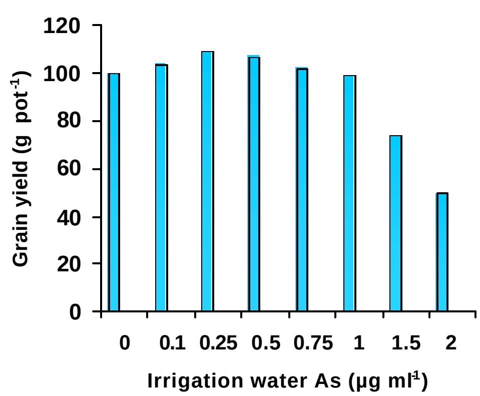

Fig. 5 Effect of irrigation water As on grain yield of rice (Pot expt.)

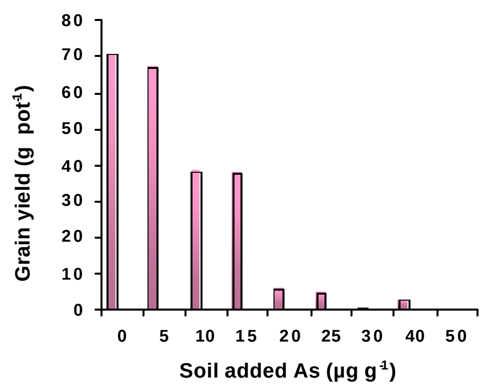

Fig. 6 Effect of soil added As on grain yield of rice (Pot expt.)