

## ARSENIC IN RICE GRAINS AT SONARGAON, BANGLADESH

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### Abstract

Rice plants absorb substantial amount of arsenic when grown in rice field soil containing 3.21 mg/kg arsenic and irrigated with contaminated groundwater from a shallow tube-well having  $476 \pm 3$   $\mu\text{g}$  arsenic/l at Sonargaon, Bangladesh. It is revealed that highest total arsenic accumulation occurred in roots ( $5.790 \pm 0.337$  mg/kg) followed by shoots ( $3.766 \pm 0.370$  mg/kg) and brown-rice grains ( $2.552 \pm 0.507$  mg/kg). The concentration of total arsenic in rice grains was beyond permissible limit (1.00 mg/kg) for human consumption. At the time of harvest  $4.90 \pm 1.11 - 8.27 \pm 1.35$  mg As/kg soil remained in the rice field soil. However, majority of the soil arsenic is washed out by rain and flood water leaving more than 3.00 mg As/kg soil after flood period which along with high level of As contaminated groundwater for irrigation, elevated the level (up to  $8.27 \pm 1.35$  mg As/kg soil) beyond permissible limit of e.g. in USA it is 5 mg/kg soils for agriculture use. To keep the environment clean, surface water for irrigation has been suggested.

### Introduction

In the major part of Bangladesh, high concentration of arsenic in the groundwater from hand tube-well and shallow tube-well (STW) used for drinking and irrigation, respectively has been observed (BGS 1999). This has been polluting the environment alarmingly and local people have been suffering from arsenicosis (melanosis, gangrene, chronic ulcer, skin cancer, etc.) (Dey 2002). Studies in home and abroad confirmed that a substantial amount of this heavy metal is absorbed by plants (Anderson *et al.* 1980, Aziz 2000, Jain *et al.* 1989, Wauchope 1983) including rice (Juhasz *et al.* 2006, Meharg and Rahman 2003, Xu *et al.* 2008). It has been observed that in presence of arsenic,  $\text{PO}_4\text{-P}$  absorption is affected (Aziz 2000), where phosphate may be replaced by arsenates and prevents ATP generation (Walsh and Keeney 1975, Wauchope 1983, Zingaro and Bottino 1983). Islam and Ullah (2003) also found that As in plants antagonize the uptake of nutrients like N, P, K, S, Ca, Mn and Zn. Jahan *et al.* (2003) have shown in a pot experiment that As toxicity symptoms in rice (var. BR 26) started from 20 mg As kg/ soil. Importance value index ( $\geq 20$ ) indicated that out of 14 weeds four were very sensitive to arsenic (Aziz and Ahmed 2010). Rice is particularly susceptible to As accumulation compared to other cereals as it is generally grown under flooded conditions where As mobility is very high (Heikens 2006, Xu *et al.* 2008). Rice is by far the largest food dietary source of inorganic-As for populations not drinking water with elevated As (Meacher *et al.* 2002). An attempt was therefore taken to determine total As accumulation in rice grain grown in fields irrigated with arsenic contaminated groundwater.

### Materials and Methods

High yielding *boro*-rice variety BR-28 was grown during lean period in a farmer's field at village Sanmandi ( $23^\circ 40' 35''$  N,  $90^\circ 35' 14''$  E), Nilkanda Union under P. S. Sonargaon in Narayanganj district, Bangladesh.

The experiment was conducted in  $19 \times 19$  m plots of five replicates arranged in a complete randomized block design. Recommended doses of NPK fertilizers at the rate of 45, 15 and 40 kg/ha, respectively were applied to all plots at the time of land preparation except N which was

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applied in two splits- 25 kg/ha at 15 DAT and 20 kg/ha before flowering. The *boro*-rice crop was irrigated once in a week with pond water (as control) and As contaminated (476  $\mu\text{g/l}$ ) groundwater from a STW. The quality of irrigation water is given in Fig. 1.

The soil textural class- silt clay, and contained 4.31% sand, 45.56% silt, 50.13% clay; having 6.35 pH, 200  $\mu\text{S/cm}$  EC, 0.87% iron, 3.21 mg/kg arsenic, 1.85% organic matter, at Meghna Floodplain in Silmondi and Narailbag soil series. Soil particle size analysis was carried out by hydrometer method (Day 1965) while organic carbon by wet oxidation method of Wakley and Black modified by Jackson (1973) and soil pH from a solution of 1 : 2.5 of soil and water. Total As was determined by Atomic Absorption Spectrophotometer (AAS) after digestion with  $\text{HNO}_3$ -HCl at 5 : 1 in a closed system. Plant samples as roots, shoots and paddy grains were collected separately and dried at 70°C for three days, grounded and kept in poly-bags till analysis. Arsenic concentration in brown-rice grains was cross checked by Neutron Activation Analysis (NAA) using the 3 MW Research Reactor at Atomic Energy Research Establishment, Saver, Dhaka.

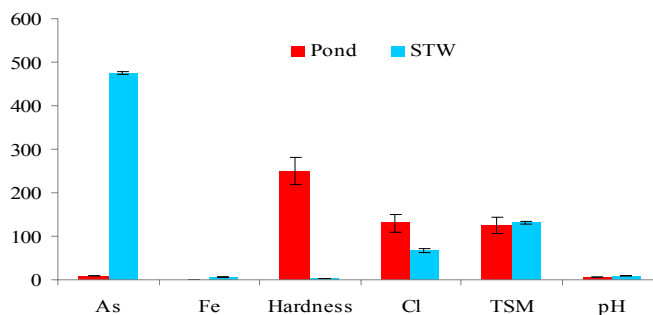


Fig. 1. Water quality of pond and ground-waters (STW) used in irrigating BR-28 rice. Unit for As is  $\mu\text{g/l}$  and for others is mg/l. n = 5; bars, standard deviations.

## Results and Discussion

Arsenic concentration in soils of the experimental plots during rice cultivation is shown in Fig. 2. It is revealed that irrigation with  $476 \pm 3$   $\mu\text{g/l}$  As contaminated STW water increased soil arsenic due to coagulation and sedimentation as indicated by 7.51 mg/kg soil after 7 days of irrigation against initial value of 3.21 mg/kg soil. However, As concentration in the soil irrigated with the groundwater during the cultivation cycle of rice ranged from 4.90 to 8.27 mg/kg soil, where the permissible limit for USA is 5 mg/kg and 10 - 20 mg/kg in Canada, Uk, Australia for agriculture use of soils (Duxbury and Zavala 2010). Bangladesh do not have defined permissible limit for As. Total As in soils of control plots decreased to almost steady level of 1.91 to 2.60 mg/kg from its initial value, though irrigated every seven days interval with pond water having about 9.5  $\mu\text{g/l}$  As. Xu *et al.* (2008) reported bioavailability of As under flooded condition but in the present study rice plants appeared not to absorb As (only insignificant amount by roots) at a concentration of (on an average) 2.50 mg As/kg soil or less. The presence of 3.21 mg/kg soil arsenic at the time of plantation of rice seedling compared to  $8.27 \pm 1.35$  at the time of harvest, indicates that during monsoon the rain and floodwater washed out the arsenic from the previous year's rice-field soil to the surrounding environment.

Arsenic concentration in the *boro*-rice plant parts at the time of harvest is shown in Fig. 3. It is revealed that As was accumulated mostly in roots followed by shoots and brown-rice grains. The brown-rice grain contained 2.552 mg/kg total As, determined by AAS. The total As in rice grains collected from an adjacent farmer's field irrigated with the same groundwater was cross

checked by NAA and was found to be  $2.56 \pm 0.20$  mg/kg. Meharg and Rahman (2003) reported total brown-rice grain As of 1.7 - 1.8 mg/kg when grown in soils containing 15 - 27 mg/kg total As in Bangladesh soil. The high As accumulation in rice grains in the present study was perhaps due to high As content in irrigation water used in flooding the soil which was already contaminated with As. The presence of 1.91 to 2.60 mg As/kg soil after rice harvest against 3.21 mg As/kg initial soil indicates that most of the arsenic absorptions take place from water. The high As content in straws might affect cattle due to bioaccumulation.

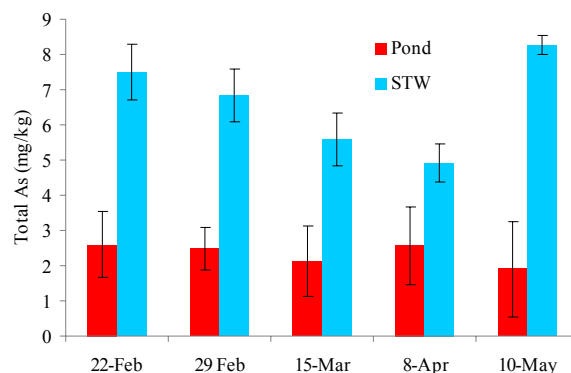


Fig. 2. Arsenic concentration in soils of the experimental plots during rice cultivation, irrigated with pond and STW waters. Initial soil arsenic was 3.21 mg/kg, while pond water contained  $9.50 \pm 0.50$   $\mu$ g/l; STW water contained  $476 \pm 3$   $\mu$ g/l arsenic. Seedlings were transplanted on 15 Feb. and the rice crop was harvested on 10 May.  $n = 5$ ; bars, standard deviations.

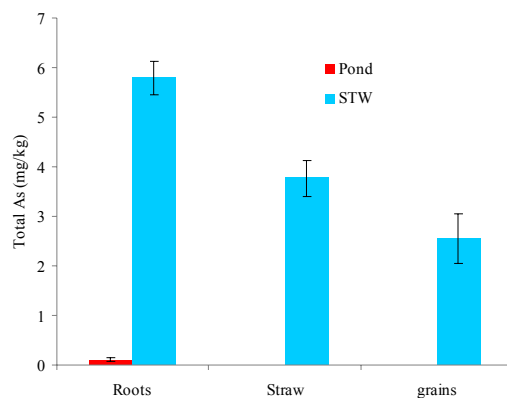


Fig. 3. Arsenic concentration in roots, straw and brown-rice grains of rice plants at the time of harvest. Initial soil arsenic was 3.21 mg/kg, while pond and STW waters contained  $9.50 \pm 0.50$   $\mu$ g/l and  $476 \pm 3$   $\mu$ g/l arsenic, respectively.  $n = 5$ ; bars, standard deviations.

The concentration of absorbed As in rice grains was much above the permissible limit of 1.00 mg/kg (Das *et al.* 2004) for human consumption. Heikens (2006) indicated that elevated As in rice significantly contribute to dietary As intake and estimated that around 50% of total As in the grain is inorganic-As, rest is dimethylarsinic acid (DMA). Bioavailability of inorganic-As from rice has been shown to be high (Juhasz *et al.* 2006). Zhu *et al.* (2008) estimated that As concentration in rice would have to be as low as 0.050 mg/kg if consumed at 200 g/d to equate to

similar exposure from drinking water at 10 µg/l. Bangladesh rice has  $2.552 \pm 0.507$  mg total As/kg which means that 0.85 to 1.276 mg inorganic-As (assuming about 33 to 50% of total As: Meharg *et al.* 2008) is present per kg rice. But Xu *et al.* (2008) reported that in rice grains from flooded conditions DMA accounted for a majority of the total-As, and inorganic As varies from 22 to 42% which in quantity ranged from 0.561 to 1.072 mg/kg for Bangladesh rice. If the lowest amount 0.561 mg inorg.-As per kg rice grain is considered and equate to permissible limit of 0.050 mg/l water (which would be 0.250 mg inorganic-As/kg is consumed at 200 g/day by a person) then a person in the study area is consuming double the amount of permissible As. China has a food standard limit of 0.15 mg inorganic-As/kg (USDA 2006). There is currently no Bangladesh regulation regarding As levels in foods but for drinking water which is 50 µg/l. Thus high inorganic-As (compared to Chinese permissible limit) in the rice grain at Sonargaon can lead to greatly increased exposure to chronic carcinogen.

In the present study it was revealed that a substantial amount of arsenic remained in the soil after harvesting the rice crop which will be absorbed by other subsequent crops causing health hazard. The washed out arsenic (by rain and flood waters) is being carried to the estuaries at the end and is being accumulated year after year. This would affect the marine flora and fauna in near future (Aziz 2002). Ahmed *et al.* (2010) recorded 0.86 (SE 0.057; CV 34.66) mg As/kg leaves of *Sonneratia apetala*, a mangrove plant with insignificant variation in three coastal islands of Bangladesh indicating that groundwater As is being accumulated in the biotic and abiotic components of the environment. Thus digging out groundwater for irrigation should be immediately stopped. Attempt has been taken to store river water twice a day by rubber dam (e. g. at Sonargaon, in the Old Brahmaputra River) in areas with tidal effect for irrigation of *boro* crops and has been successful. In areas having no tidal water in rivers, Bangladesh should have surface water reservoirs for irrigation of all types of crops during lean period. Surface water (undisturbed) contains all elements in a relatively constant proportion necessary for the growth and development of all organisms. The best solution, to be relieved from the arsenic hazard, would thus be to use surface water with proper care for all purposes (Aziz 2002).

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