



INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Arsenic Contamination In Pulses

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Abstract

Ganga-Meghna-Brahmaputra basin is one of the major arsenic-contaminated hotspot in the world. To assess the level of severity of arsenic contamination, concentrations of arsenic in irrigation water, soil, rice, wheat, common vegetables, and pulses, intensively cultivated and consumed by the people of highly arsenic affected Nadia district, West Bengal, India, were investigated. Results revealed that the arsenic-contaminated irrigation water (0.318–0.643 mg l⁻¹) and soil (5.70–9.71 mg kg⁻¹) considerably influenced in the accumulation of arsenic in rice, pulses, and vegetables in the study area. Arsenic concentrations of irrigation water samples were many folds higher than the WHO recommended permissible limit for drinking water (0.01 mg l⁻¹) and FAO permissible limit for irrigation water (0.10 mg l⁻¹). But, the levels of arsenic in soil were lower than the reported global average of 10.0 mg kg⁻¹ and was much below the EU recommended maximum acceptable limit for agricultural soil (20.0 mg kg⁻¹). The present study reveals that pulses grown in the study area are safe for consumption, for now. But, the arsenic accumulation in the crops should be monitored periodically as the level of arsenic toxicity in the study area is increasing day by day.

Keywords: Arsenic, Irrigation water, Crop, Vegetable, Pulses, West Bengal

Introduction

Arsenic is one of the major global environmental pollutants because of its highly toxic and carcinogenic properties. The intake of arsenic by humans occurs through contaminated water and food. The epidemiological studies show that the chronic arsenic poisoning can cause serious health effects including cancers, melanosis (hyper-pigmentation or dark spots and hypo-pigmentation or white spots), hyperkeratosis (skin hardening), restrictive lung disease, peripheral vascular disease (black foot disease), gangrene, diabetes mellitus, hypertension, and ischemic heart disease (Guha-Mazumder et al. 2000; Morales et al. 2000; Srivastava et al. 2001; Rahman 2002). Arsenic seems to be a cancer promoter rather than a cancer initiator (Lee-Feldstein 1986). The World Health Organization (WHO) ranked this calamity as “the largest poisoning of a population in history” (Smith et al. 2000).

Studies on the impact of the arsenic-contaminated groundwater irrigation on crops has attracted attention only during the last couple of years (Roychowdhury et al. 2002; Duxbury et al. 2003; Ghosh et al. 2004; Samal 2005; Norra et al. 2005; Huang et al. 2006; Rahman et al. 2007; Dahal et al. 2008; Bhattacharya et al. 2009). These works document the enrichment of arsenic in soil and a limited uptake by different plants, including rice, cereals,

and vegetables. The reported arsenic concentrations in agricultural plants varied from 0.007 to about 7.50 mg kg⁻¹ (Mandal and Suzuki 2002; Roychowdhury et al. 2002; Liao et al. 2005; Dahal et al. 2008). Mandal and Suzuki (2002), on their study on arsenic around the world, reported that the arsenic concentration in plants varied from less than 0.01 to about 5.0 mg kg⁻¹. Roychowdhury et al. (2002), studying arsenic affected areas of Murshidabad, West Bengal, India, found that the accumulation of arsenic in various food composites.

People in West Bengal, India, have been reported to be suffering from groundwater arsenic toxicity for long (Chowdhury et al. 2000, 2001). Over 50 million people living in the Ganga-Meghna-Brahmaputra plain are at the risk through severe arsenic toxicity (Chakraborty et al. 2004; Pal et al. 2007). Nine out of total 19 districts of West Bengal have groundwater arsenic contamination (Nickson et al. 2000; Chakraborty et al. 2002). Among the contaminated districts, the severely affected Murshidabad district deserves special mention in terms of level of arsenic contamination and area coverage (Samal 2005; Bhattacharya et al. 2009). In rural West Bengal, farmers are generally not aware of the Food and Agricultural Organization (FAO) guideline value of arsenic in irrigation water (0.10 mg l⁻¹; FAO 1985), and as the irrigation system in these areas is mostly dependent on groundwater, there is a high possibility of transfer of arsenic from contaminated irrigation water and soil to crops. Thus, the objectives of the present study were to find the distribution of arsenic in irrigation water, soil, and crops and to assess the influence of arsenic-contaminated irrigation water. This study would help to evaluate the severity of human health risk from arsenic toxicity through water–soil–plant system.

Materials and Methods

a. Study Area

The study area (Murshidabad district of West Bengal, India) is highly contaminated with arsenic (Samal 2005; Bhattacharya et al. 2009). Five blocks of Murshidabad district have been chosen for the present study. In all these areas, the level of arsenic in groundwater is frequently exceeding WHO permissible limit for drinking water (0.01 mg l⁻¹; WHO, 2001) and Food and Agricultural Organization permissible limit for irrigation water (0.10 mg l⁻¹; FAO 1985).

b. Sample Collection

Ground water samples have been collected from the shallow tube well pumps of large diameters, used for irrigation in the study area. Prior to sample collection, the pumps were kept running for about 10–15 min in order to get a uniform rate of discharging water. Then, the water samples were collected in polyethylene bottles and preserved with concentrated HNO₃. Soil samples were collected from 10–15 cm depth in a 2 m² area by composite sampling from the fields irrigated with the arsenic- contaminated water and transferred to airtight poly- ethylene bags. Similarly, pulse samples were collected freshly from a selected plot (2 m² areas) from the same site or, at least, as close as possible to the point where soil samples were collected. At each sampling site, five sub-samples of pulses were collected, and then, those were aggregated into one sample for further treatment. Crop samples were collected during their harvesting time and in their respective harvesting periods (Boro crops in March, pre-monsoon crops in June and Aman crops in December).

c. Sample Analysis

The total arsenic of samples was analyzed by flow injection hydride generation atomic absorption spectrophotometer (FI-HG-AAS, Perkin Elmer A Analyst 400) using external calibration (Welsch et al. 1990). The optimum HCl concentration was 10% v/v and 0.4% NaBH₄ produced the maximum sensitivity. For each sample of the digested soil, pulse and irrigation water, three replicates were taken and the mean values were obtained on the basis of calculation of those three replicates. Standard reference materials (SRM) from National

Institute of Standards and Technology (NIST), USA, were analyzed in the same procedure at the start, during, and at the end of the measurements to ensure continued accuracy.

Results and Discussion

a. Analytical Quality Control Data

The observed arsenic concentrations (milligrams per kilogram dry weight) of SRM from NIST, USA, were as follows: San Joaquin soil (SRM 2709A) 16.2 ± 0.9 (certified value, 17.7 ± 0.8), rice flour (SRM 1568A) 0.27 ± 0.08 (certified value 0.29 ± 0.03), and spinach leaves (SRM 1570) 0.062 ± 0.009 (certified value 0.068 ± 0.012), respectively. The certified and the observed values were thus in good agreement.

b. Arsenic Content in Irrigation Water

Usually shallow tube well pumps are used for irrigation in the study area (running about 8 h day^{-1} , 8 months year^{-1}). In our investigation, arsenic concentrations in irrigation water samples ranged from 0.318 to 0.643 mg l^{-1} (Fig. 2a), which is many folds higher than the recommended WHO permissible limit of 0.01 mg l^{-1} for drinking water (Das et al. 2004; Rahman et al. 2007) and FAO permissible limit for irrigation water (0.10 mg l^{-1} ; FAO 1985). Arsenic adsorbed on Fe-/Mn- oxides/hydroxides is released into the groundwater due to a decrease of the redox state in the aquifer (Nickson et al. 2000; Smedley and Kinniburgh 2001; Stüben et al. 2003). McArthur et al. (2001) and Ravenscroft et al. (2001) related the change in redox conditions to layers enriched in organic matter (e.g., peat), which promoted intensive microbial activity. Arsenic-rich pyrite has been identified in the sediments of the Ganges delta of West Bengal (Roy Chowdhury et al. 1999). The heavy withdrawal of groundwater may be the reason why iron pyrites decompose (Das et al. 1996; Chowdhury et al., 1999) and release arsenic into water.

c. Accumulation of Arsenic in Soil

Soil arsenic is the major source for the arsenic uptake of crops (Huang et al. 2006). Besides its natural origin, various anthropogenic activities like mining, smelting, coal burning, irrigation with arsenic- contaminated water, and application of wastes, animal manures, and arsenic-containing pesticides and herbicides may also contribute arsenic to soil (Dutr e et al. 1998; Flynn et al. 2002; Mandal and Suzuki 2002; Alam et al. 2003; Warren et al. 2003; Baroni et al. 2004; Camm et al. 2004).

The levels of arsenic in the investigated soil samples are given in Fig. 2b. The total arsenic concentrations in the soil ranged from 5.70 to 9.71 mg kg^{-1} dry weight. The results clearly show that the extensive withdrawal of arsenic-contaminated groundwater for the last 15–20 years for irrigation has resulted in elevated concentration of arsenic in agricultural field soil of the study area as compared with the background value of arsenic (2.31 – 3.07 mg kg^{-1}) in the non-irrigated land of the study area. Several reports have been published about arsenic accumulation of soil due to the irrigation with arsenic-contaminated ground water in West Bengal (Chakraborty et al. 2002; Samal 2005; Bhattacharya et al. 2009). The highest content of arsenic in soil of West Bengal (19.4 mg kg^{-1}) was reported by Roychowdhury et al. (2005). But, the accumulation of arsenic in soil in the study area was lower than the reported global average of 10.0 mg kg^{-1} (Das et al. 2002) and was much below the maximum acceptable limit for agricultural soil of 20.0 mg kg^{-1} as recommended by the European Community (Rahman et al. 2007). The comparatively lower content of arsenic in soil is due to the loss of arsenic by microbial bio- methylation process from soil to air, uptake by the plants, infiltration, and surface run off during precipitation. In addition, the study area is a flood plain of the river Ganges, thus due to the high solubility of arsenic in reduced condition (Fitz and Wenzel 2002), it can be carried away downstream. But, the arsenic content of the soil was found to be significantly correlated with the arsenic content of the irrigation water ($r=0.522$; Fig. 3), thus, there is a high possibility of increase of arsenic concentration in the soil in near future, if the trend of using large amount of arsenic-contaminated ground water for irrigation continues. Similar prediction was earlier given by Das et al. (2004).

Conclusion

Groundwater is the major source of irrigation in the study area. For the past 15–20 years, higher exploitation of groundwater has been done for the extensive cultivation of rice, pulses, and vegetables to ensure food security. Thus, the potential of arsenic contamination is increasing day by day in the groundwater of the study area and enhancing the human health risk from arsenic toxicity via water–soil–plant system. Results from the present investigation reinforced the severity of arsenic toxicity of the irrigation water and soil in West Bengal, India, and their influence in contaminating rice, pulses, and vegetables, commonly consumed by the people living in and around the study area. Also, a significant amount of the crops and vegetables are transported to the various markets of West Bengal. Thus, probable indirect arsenic toxicity in the people living in the non-arsenic- contaminated areas is also a concern. Other than a few samples of potato, all the studied samples of rice, pulses, and vegetables showed arsenic content below the food hygiene concentration limit of 1.0 mg kg^{-1} . Thus, the study does not indicate an immediate danger, but the uptake of arsenic by agricultural plants should be monitored periodically as there is high possibility of increase of arsenic in the crops in near future, if the common trend of using arsenic- contaminated groundwater for irrigation continues.

Proper watershed managements by minimizing the excessive withdrawal of groundwater and by using available sources of surface water (river, pond, etc.) for irrigation are to be done in an urgent basis. In addition, crops requiring high irrigation should be replaced by the crops requiring low irrigation in the arsenic-prone areas.

Acknowledgement

The authors are thankful to Prof. P K Pal, Department of Botany, University of Burdwan for his valuable suggestion and comments on the present investigation.

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