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Assessment of toxic metals in groundwater and saliva in an arsenic affected area of West Bengal, India: A pilot scale study

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Communities in many parts of the world are unintentionally exposed to arsenic (As) and other toxic metals through ingestion of local drinking water and foods. The concentrations of individual toxic metals often exceed their guidelines in drinking water but the health risks associated with such multiple-metal exposures have yet to receive much attention. This study examines the co-occurrence of toxic metals in groundwater samples collected from As-rich areas of Nadia district, West Bengal, India. Arsenic in groundwater (range: 12–1064 $\mu g\ L^{-1}$; mean ± S.D: 329 ± 294 $\mu g\ L^{-1}$) was the most important contaminant with concentrations well above the WHO guideline of 10 $\mu g\ L^{-1}$. Another important toxic metal in the study area was manganese (Mn) with average concentration of 202 ± 153 $\mu g\ L^{-1}$, range of 18–604 $\mu g\ L^{-1}$. The average concentrations ($\mu g\ L^{-1}$) of other elements in groundwater were: Cr (5.6 ± 5.9), Mo (3.5 ± 2.1), Ni (8.3 ± 8.7), Pb (2.9 ± 1.3), Ba (119 ± 43), Zn (56 ± 40), Se (0.60 ± 0.33), U (0.50 ± 0.74). Saliva collected from the male participants of the area had mean concentrations of 6.3 ± 7.0 μg As L^{-1} (0.70–29 $\mu g\ L^{-1}$), 5.4 ± 5.5 μg Mn L^{-1} (0.69–22 $\mu g\ L^{-1}$), 2.6 ± 3.1 μg Ni L^{-1} (0.15–13 $\mu g\ L^{-1}$), 0.78 ± 1.0 μg Cr L^{-1} (< DL–5.9 $\mu g\ L^{-1}$), 0.94 ± 0.90 μg Pb L^{-1} (< DL–4.2 $\mu g\ L^{-1}$), 0.56 ± 0.37 μg Se L^{-1} (0.11–1.5 $\mu g\ L^{-1}$) and 194 ± 54 μg Zn L^{-1} (112–369 $\mu g\ L^{-1}$). The high concentrations of salivary As and Mn are believed to be indicative of intake from the groundwater. The clustering of salivary As and Mn in principal component analysis further indicated influence of the common exposure source. Zinc and selenium comprised a separate component presumably reflecting the local deficiencies in intakes of these essential elements from drinking water and foodstuff. Thus the study reveals that the concentration of other metals beside As must be monitored in drinking water before implementation of any policies to provide safe water to the affected communities.

1. Introduction

The groundwater of Bengal delta plain comprising of Bangladesh and West Bengal, India has drawn the attention of the scientific community all over the World due to the presence of arsenic (As) in groundwater at levels much above the WHO permissible limit of 10 $\mu g\ L^{-1}$ (Bhattacharyya et al., 2003; Bhowmick et al., 2013b). The crisis in health of local communities stemming from the switch from surface water to groundwater for drinking, cooking and irrigation purposes has been well documented (Chowdhury et al., 2000; Guha Mazumder et al., 2010). The chronic intake of As is associated with a range of dermal, neural, cardiovascular, hematological, renal, endocrine and hepatic diseases along with increased risk of cancer of various organs (Rahman et al., 2001; Ahsan et al., 2006; Kapaj et al., 2006; Guha Mazumder et al., 2010). Among the health effects, skin lesions are the most common identifiable health outcomes in human (Haque

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et al., 2003; Ahsan et al., 2006). Under continued exposure, the skin-identifiable manifestations are generally characterized by changes in pigmentation (melanosis including diffuse and spotted) and/or keratosis (with thickening of skin) of varying severity (Ahsan et al., 2006; Rahman et al., 2006).

Groundwater in West Bengal is a complex mixture of various dissolved metals of different concentrations, and as a result, there is unintentional co-exposure of several contaminants to individuals (Frisbie et al., 2009; Bacquart et al., 2012). Friesbie et al. (2002) found elevated levels of manganese, lead, nickel and chromium along with arsenic in the groundwater of Bangladesh and stated that strategies should be implemented not only to provide As free water but also to eliminate other toxic elements that may accompany As poisoning. Thus the exposure from groundwater source is commonly in the form of multiple metals and considering the single-As exposure does not appropriately represent the health risk of a community (Berglund et al., 2011). Upon exposure, the combined effect of the metals may be different from the sum of the individual effects and can be synergistic or antagonistic of each other. As example, while dietary supplement of selenium has been shown to reduce the toxicity of arsenic (Wang et al., 2002; Christian et al., 2006), nickel acts synergistically with As to exaggerate lung cancer (Denkhaus and Salnikow, 2002). Thus while assessing the health risk of a community, apart from the individual contaminants, attention should also be paid to the combination of contaminants.

Human biomonitoring involves the study of biological fluids, tissues or other accessible structures as biomarkers of exposure to and effects of contaminants (Manno et al., 2010). There are numerous reports in the literature, where As in blood, urine, hair and nail has been used as a biomarker so as to assess the exposure of a community to As (Rahman et al., 2001; Shraim et. al. 2003; Marchiset–Ferlay et al., 2012, references therein). Recently, saliva has been shown to be a competent biological matrix that can be used as a biomarker of As toxicity in local communities (Yuan et al., 2008; Bhowmick et al., 2013a). The non-invasive and easy sample collection procedure along with unsophisticated requirement for sample storage are among the advantages of saliva especially for screening large populations, involving children and patients with limited coping abilities. Therefore, although there is increasing evidence that support the use of saliva for biological monitoring, until now, we have limited understanding of the concentration of various metals in saliva of a population that are exposed to a range of toxic metals (Gil et al., 2011).

The primary aim of the present study was to monitor a suite of toxic metals in ground water with respect to the WHO standard and examine saliva as a representative biological matrix for assessing multiple metal exposures in a rural population of West Bengal, India. To achieve this, we measured the As concentration along with other metals (Mn, Cr, Mo, Ni, Pb, Ba, Zn, Se, U) in groundwater of the area and also analyzed the saliva samples for the metals that were important from the exposure point-of-view. The present study is designed to provide baseline value for future work, where saliva will be used as an easily available biological fluid to monitor the multi-metal exposure for a community.

2. Materials and methods

2.1. Study area and sample collection

Nadia is one of the districts of West Bengal, India where the arsenic concentration in groundwater is above the WHO guideline (10 μg L^{-1}) (Guha Mazumder et al., 2010). The study areas, Debagram and Chhoto-Itna are neighboring villages which are located in the northern part of the district (Fig. 1). The details of the study

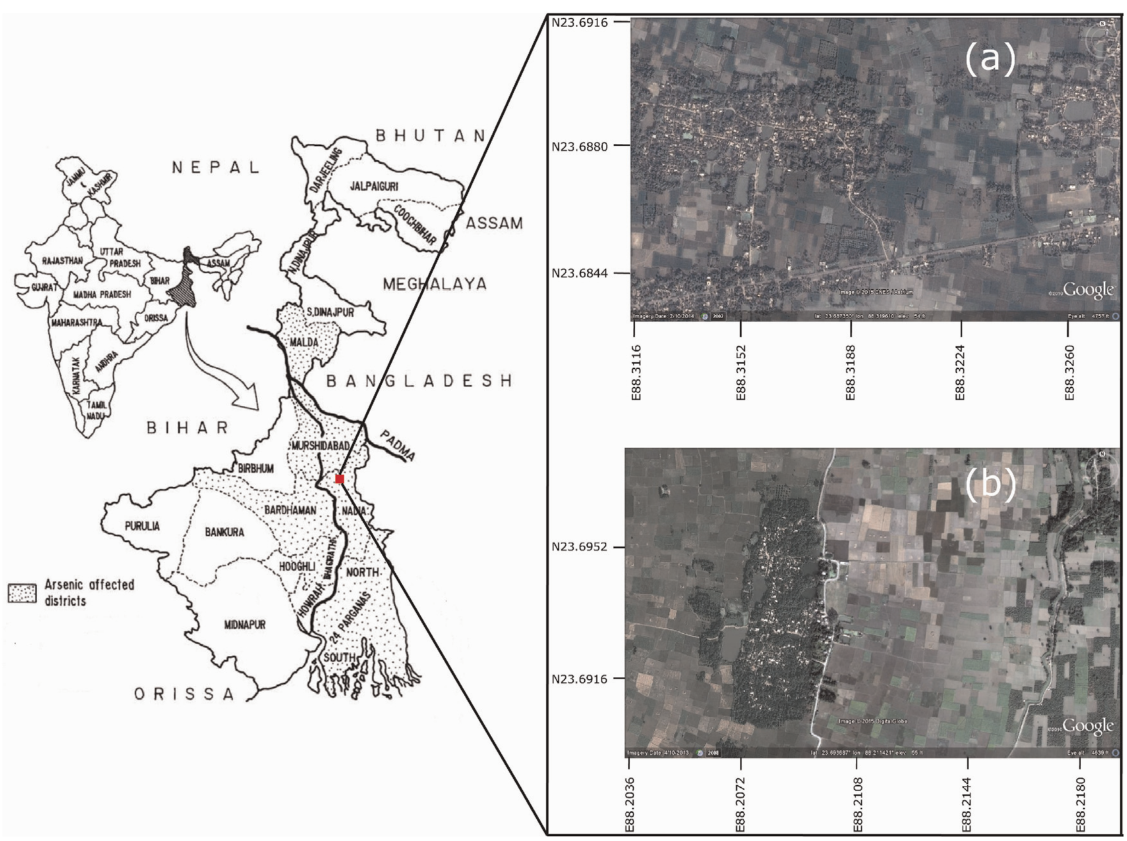

Fig. 1. Map of the study area. The sampling areas are marked with the red circle. The map also shows the Google Earth image of the study areas; (a) Debagram and (b) Chhoto-Itna. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)