Chemosphere 152 (2016) 520–529

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Arsenic groundwater contamination and its health effects in Patna district (capital of Bihar) in the middle Ganga plain, India

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HIGHLIGHTS

- 61% and 44% of the tube-wells had arsenic above 10 and 50 µg/l, respectively in Patna, Bihar, India.
- Arsenical skin lesions were noted in 69 people out of 712 screened.
- All biological samples had arsenic above the normal levels.
- Arsenic neuropathy was observed in 40.5% arsenicosis patients.
- Obstetric outcome was also noted in women exposed to high arsenic.

ARTICLE INFO

Article history:
Received 7 July 2015
Received in revised form
20 February 2016
Accepted 28 February 2016

Handling Editor: X. Cao

Keywords:
Groundwater
Arsenic
Biological samples
Arsenical skin lesions
Arsenical neuropathy
Pregnancy outcome

ABSTRACT

We investigated the extent and severity of groundwater arsenic (As) contamination in five blocks in Patna district, Bihar, India along with As in biological samples and its health effects such as dermatological, neurological and obstetric outcome in some villages. We collected 1365 hand tube-well water samples and analyzed for As by the flow injection hydride generation atomic absorption spectrometer (FI-HG-AAS). We found 61% and 44% of the tube-wells had As above 10 and 50 µg/l, respectively, with maximum concentration of 1466 µg/l. Our medical team examined 712 villagers and registered 69 (9.7%) with arsenical skin lesions. Arsenical skin lesions were also observed in 9 children of 312 screened. We analyzed 176 biological samples (hair, nail and urine). Out of these, 69 people had arsenical skin lesions and rest without skin lesions. We found 100% of the biological samples had As above the normal levels (concentrations of As in hair, nail and urine of unexposed individuals usually ranges from 20 to 200 µg/kg, 20–500 µg/kg and <100 µg/l, respectively), indicating many people are sub-clinically affected. Arsenical neuropathy was observed in 40.5% of 37 arsenicosis patients with 73.3% prevalence for predominant sensory neuropathy and 26.7% for sensor-motor. Among patients, different clinical and electrophysiological neurological features and abnormal quantitative sensory perception thresholds were also noted. The study also found that As exposed women with severe skin lesions had adversely affected their pregnancies. People including children in the affected areas are in danger. To combat As situation in affected areas, villagers urgently need (a) provision of As-safe water for drinking and cooking, (b) awareness about the danger of As toxicity, and (c) nutritious food.

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1. Introduction

Arsenic contamination in groundwater is a major public health concern in different parts of the world for the last few decades. Arsenic has been identified in 105 countries in the world with an

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http://dx.doi.org/10.1016/j.chemosphere.2016.02.119
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estimate of the exposed population of >200 million worldwide at concentration greater than the World Health Organization (WHO) guideline value of As of 10 μg/l (Murcott, 2012; Naujokas et al., 2013). Asian countries, especially the Ganga–Meghna–Brahmaputra (GMB) plain of India and Bangladesh, are the worst affected among the world As scenario (Chakraborti et al., 2013). In GMB-plain alone, currently >100 million people are at risk from groundwater As contamination above 10 μg/l (Chakraborti et al., 2013).

Groundwater As contamination and its health effects in the lower Ganga plain of West Bengal, India was first reported in 1984 (Garai et al., 1984). Contamination and future danger of As in groundwater and its health effects in the Bhojpur district at middle Ganga plain of Bihar was first reported in 2003 (Chakraborti et al., 2003). Several articles have already been published on the various aspects of groundwater As contamination in the Bihar state, India including the extent and magnitude of contamination, human health effects from As toxicity, source and mechanism of contamination, contamination of As in food chain etc. (Ghosh et al., 2009; Kumar et al., 2010a, 2010b; Singh, 2011; Singh and Ghosh, 2011, 2012; Singh et al., 2014; Singh, 2015; Singh and Vedwan, 2015; Chakraborti et al., 2016; Kumar et al., 2016). It was reported that 50 blocks in 11 districts of Bihar are As-affected based on the field testing kit results supported by UNICEF (Nickson et al., 2007). In 2009, a study reported that 57 blocks in 15 districts of Bihar are As-affected (Saha, 2009). Another study analyzed 1050 tube-well samples from Patna district and reported that Maner block of this district is worst As-affected where maximum concentration of As was 724 μg/l (Bhattacharya et al., 2011). A study estimated high cancer risk in the As-contaminated areas in Maner block of the Patna district (Singh and Ghosh, 2012). It was also reported that all 23 blocks of Patna district are As-affected (>10 μg/l) and high incidence of cancers of skin, liver, breast and gall bladder was observed in blocks of Patna district (Nath et al., 2013). In a recent article, it was reported that approximately 46% of the geographical regions, 72 of 352 community blocks are As-contaminated and >10 million people in rural Bihar are exposed to elevated levels of naturally occurring As (Singh, 2015). It was also reported that River Ghaghara and Gandak, are potential sources of As and Katihar was the most vulnerable district because of the socioeconomic and biophysical conditions, followed by Vaishali, Samastipur, Khagaria, and Purnia (Singh, 2015). Recently, we published a paper on As exposure and outcomes of antimonial treatment in visceral leishmaniasis patients in Bihar, India (Perry et al., 2015). Recently we have also reported the magnitude of groundwater As contamination in Shahpur block of Bhojpur district in Bihar and it health effects including dermal, neurological and obstetric effects along with carcinogenic and non-carcinogenic risks (Chakraborti et al., 2016).

The present study describes the groundwater As-contamination scenario of 5 blocks in Patna district in the middle Ganga plain of Bihar, India and the prevalence of As toxicity such as arsenical dermatitis, arsenical neuropathy and obstetric outcome. To the best of our knowledge, after our Bhojpur, Bihar report (Chakraborti et al., 2003), this is the first report describing the arsenical dermatitis, arsenical neuropathy, pregnancy outcome of a group of patients in Patna district, Bihar.

2. Methods

2.1. Study area

Patna district is situated in the southern part of the Ganga River and is surrounded by the district Bhojpur in west, Begusarai in east and the river Ganga separates it from Vaishali district, Samastipur and Saran districts in north. The district consists of 23 blocks. Each block has several Gram panchayets (GP, cluster of villages) and each GP has several villages. Out of total 23 blocks of Patna district, this study covers 5 blocks (Maner, Fatua, Patna urban, Danapur and Bakhtiyarpur).

2.2. Sample collection and As analysis

Groundwater extracted by the tube-well is the primary source of drinking water in the study area. In this fact finding random survey, we collected 1365 hand tube-well water samples from 48 villages in 21 GPs of Patna between 2004 and 2015, based on our ongoing research surveys in Bihar. Depth of tube-wells information was obtained for 1049 (77%) of the 1365 tube-wells analyzed. Depth information was obtained from tube-well owners. The owners were unable to provide us the depth of remaining tube-wells. We also collected 176 biological samples (60 hairs, 62 nail, and 54 urine samples), of which 69 samples were from patients with arsenical skin lesions and rest from those living in the As-contaminated villages, but having no skin lesions, based on the analysis of As in tube-well waters. Collecting biological samples from both As-affected and non-affected people from As-contaminated villages will provide information on population exposed to As as well as individuals who are sub-clinically affected from As exposure but not having arsenical skin lesions. This is well accepted method based on our previous works from several states (West Bengal, Uttar Pradesh, Manipur, Jharkhand and Bihar also) of India and Bangladesh (Chatterjee et al., 1995; Samanta et al., 1999; Chakraborti et al., 2004, 2008; Ahamed et al., 2006a; Nayak et al., 2008; Chakraborti et al., 2013; Rahman et al., 2014). The protocols of groundwater, urine and biological sampling, the digestion procedures for hair and nail, analytical procedures were reported earlier (Chatterjee et al., 1995; Samanta et al., 1999; Rahman et al., 2014). Briefly, water samples were collected in prewashed with nitric acid (1:1) polyethylene bottles and one drop of nitric acid (1:1) was added for 10 ml of collected sample as preservative. Spot urine samples were also collected in pre-washed polyethylene bottles and immediately after collection, the samples were stored in salt ice mixture and later on return to the laboratory kept at −20 °C until analyzed. Hair and nail samples were cut using stainless steel blade and stored in zip lock bag until analyzed. About 10% water samples, randomly selected from 1365 samples collected for As analysis, were also analyzed for iron (Fe) concentrations by spectrophotometry (Shimadzu double beam spectrophotometer Model UV-150-02). For urine samples, only inorganic As and its metabolites [(As(III), As(V), MMA(V) and DMA(V)] were measured with no chemical treatment. Under the experimental condition of FI-HG-AAS, arsenobetaine and arsenocholine do not produce a signal (Chatterjee et al., 1995). Hair, nail and skin scale samples were analyzed for total As after digestion using a simple digestion method (Samanta et al., 1999). Briefly, 0.02–0.05 g of sample was taken in a 25-ml beaker and then 4 ml concentrated HNO_3 and 2 ml (30% v/v) H_2O_2 were added. The beaker was placed on a hot plate at 80–90 °C. Heating was continued with time to time addition of a known volume of concentrated HNO_3 until the colour turned from deep brown to pale yellow. On reaching a final volume of about 1 ml, heating was discontinued. After cooling, 2–3 ml of water was added, and the solution was filtered through a Millipore filter and finally made up to 5 ml and then analyzed. Arsenic in water, urine and biological samples (hair and nail) after acid digestion were analyzed by the FI-HG-AAS. Details of the instrumentations have been described in our earlier publications (Chatterjee et al., 1995; Das et al., 1995). The 1, 10-phenanthroline method with UV-visible spectrophotometer was used for iron analysis of water samples (Fries et al., 1977). Accuracy of our analytical method using

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