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JEB
Journal of Environmental Biology

ISSN: 0254-8704
CODEN: JEBIDP

Prevalence of arsenic exposure in population of Ballia district from drinking water and its correlation with blood arsenic level

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Abstract

An investigation was carried out to ascertain the effect of arsenic in the blocks of Ballia district in Uttar Pradesh in the upper and middle Ganga plain, India. Analysis of 100 drinking water samples revealed that arsenic concentration was below 10 µg l^{-1} in 60% samples, 10-50 µg l^{-1} in 6%, 100 µg l^{-1} in 24% and 200 µg l^{-1} in 10% samples, respectively. The arsenic concentration in drinking water ranged from 12.8 to 132.2 µg l^{-1}. The depth of source of drinking water (10-60 m) was also found with a mean of 36.12±13.61 µg l^{-1} arsenic concentration. Observations revealed that at depth ranging from 10 to 20m, the mean level of arsenic concentration was 17.398±21.796 µg l^{-1}, while at 21 to 40m depth As level was 39.685±40.832 µg l^{-1} and at 41 to 60m As level was 46.89±52.80 µg l^{-1}, respectively. These observations revealed a significant positive correlation (r=0.716, t=4.215, P<0.05) between depth and arsenic concentration in drinking water. The age of water sources were ranged from zero to 30 years. The study indicates that the older sources of drinking water showed higher chance of contamination. Results showed that group 21–30 years having maximum arsenic concentration with mean value of 52.57±53.79 µg l^{-1}. Correlation analysis also showed a significant positive correlation (r =0.801, t = 5.66, P<0.05) between age of drinking water sources and their respective arsenic concentration(µg l^{-1}). Arsenic concentration in blood with mean value 0.226±0.177 µg dl^{-1} significantly increased as compared to control. The blood arsenic content correlated significantly (r=0.6823, t=3.93, P<0.05) with drinking water arsenic level and exposure time (r = 0.545, t = 3.101 & *P<0.05) for populations residing in Ballia districts. Observations and correlation analysis revealed that individuals having depth of drinking water sources 20-30 m were less affected with arsenic exposure.

Publication Info

Paper received:
03 September 2012

Revised received:
20March 2013

Re-revised received:
24 October 2013

Accepted:
30 October 2013

Key words

Arsenic, Blood, Depth, Drinking water, Environmental toxicology, Exposure time, Pollution

Introduction

Arsenic concentration in lakes are often less than rivers, due to adsorption by iron oxides, although changes in water levels (Nimick et al. 1998; Smedley and Kinniburgh 2002) and geothermal activity can enhance concentrations in some cases (Duker *et al.,* 2005). Groundwater from alluvial and deltaic watersheds generally has high arsenic concentration due to predominantly reducing conditions (Smedley and Kiniburgh, 2002).

Human activities such as fossil fuel combustion and metal smelting, as well as the semiconductor and glass industries, have intensified arsenic accumulation in the environment (Bell 1998). Although, arsenic contamination in drinking water is derived from parent rock distribution, mining activities that may result in high levels of arsenic contamination in soil, surface water, groundwater and vegetation (Smedley *et al.,* 1996). Additionally, human modifications to the natural hydrograph, including the construction of dams (Armah *et al.* 1998), wastewater recycling and irrigation practices (Siegel 2002), can potentiate arsenic accumulation in soil and water supplies.

According to sources (WHO, 2004 and UP Jal Nigam, 2004) high concentration of arsenic has been detected in drinking water of 16 districts of Uttar Pradesh, India. The Arsenic Task Force (ATF) has found that the presence of poisonous metalloid in these areas is as high as 50 $\mu g\ l^{-1}$. According to WHO (2001) the safe level of arsenic in the ground-water is > 10 $\mu g\ l^{-1}$. Sources revealed that arsenic was first reported in drinking water of Ballia in 2003. Survey carried out by U P Jal Nigam (2004), in Ballia, revealed the concentration of As was found above prescribed threshold level. The Task Force revealed that approximately 1.20 lakh people could be affected by arsenic in 55 villages of three blocks of Ballia. Arsenic poisoning in humans causes arsenicosis, alteration in cytokines profile and disease like skin lesions.

Now it is clear that there are many countries in the world where arsenic in drinking-water has been detected at concentration greater than the standard value of 0.01 mg l^{-1} or the prevailing national standard (Tudorache *et al.,* 2011). Countries where adverse health effects have been documented include Bangladesh and India. Contaminated drinking water is the major problem for human health in many cities of India (Suthar 2011; Chakrabarty 2011). It is clear that arsenic exposure alters normal biological functions resulting in direct initiation or predisposition of an organism to disease. However, the impact of arsenic on exposed populations has not been extensively researched. In an effort to understand the overall effect of arsenic on the health of humans, the present study characterizes the correlation of arsenic occurrence with depth and age of drinking water sources as well as with blood arsenic level found in the exposed individuals.

Materials and Methods

Sampling sites : Ballia is an eastern district of the state of Uttar Pradesh, India covering an area of 3000 sq.km. and having a total population of about 27 lakh (density of 925 per sq.km). The district

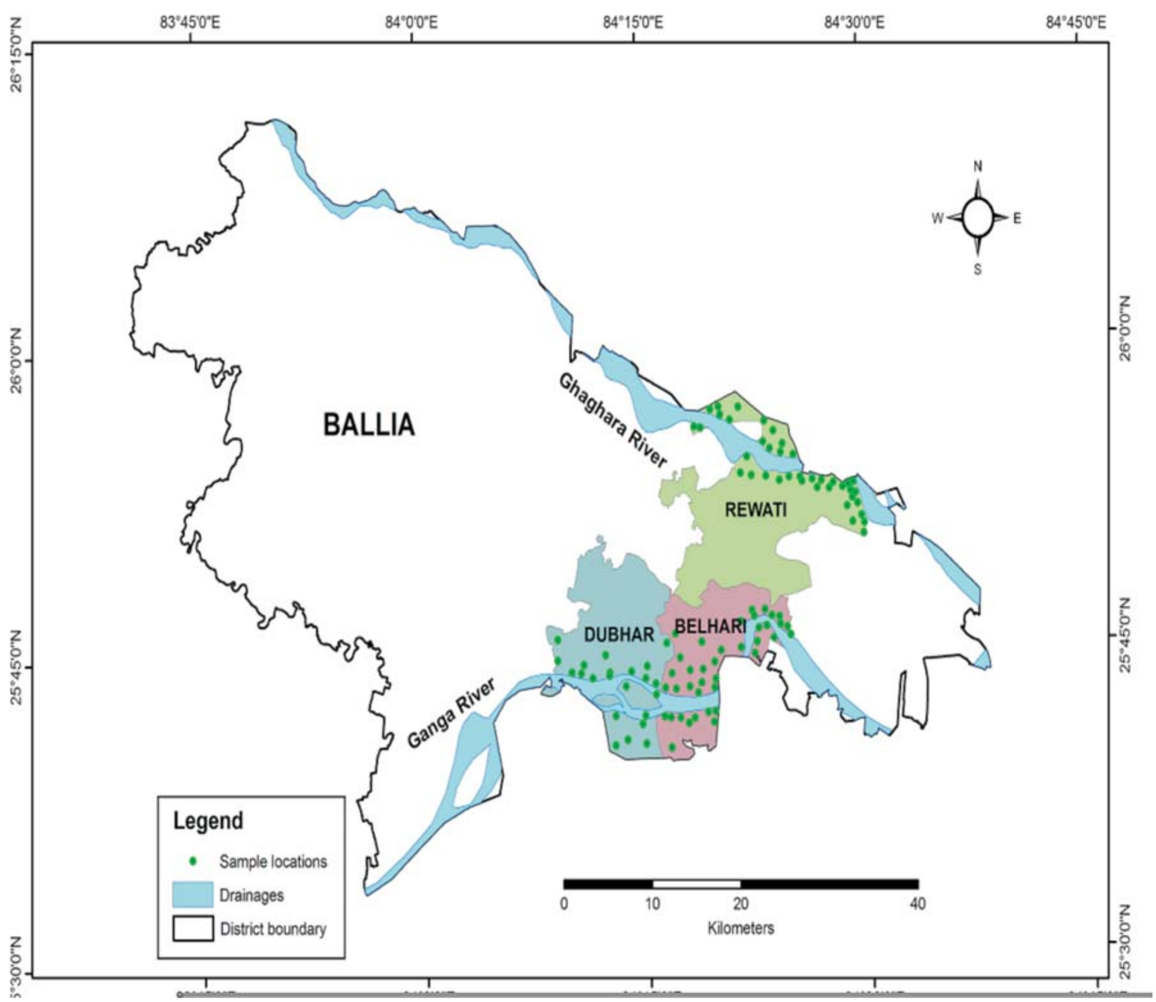

Fig. 1: Sampling location map of Ballia district along with rivers

is bounded on two sides by river Ganga and Ghagra (Fig. 1). Drinking water in the district occurs under unconfined and semi confined conditions. Study focused and undertook a detailed survey of villages in Belhari block along with two other blocks, Dubhar and Rewati with a (population 0.1 million during the year 2012).

Drinking water and blood samples collection : 100 water samples were collected from drinking water sources and handpump at different depth. All these sources of drinking water from the sampling area were cemented. The depth of sources ranged between 10-60m, drawing water from different alluvial aquifers. For 100 wells, information regarding the age and depth of wells were collected from the users. The depth of drinking water sources varied according to distribution and requirement of villagers. Human blood samples (100 no) were collected from both arsenic affected area or from site where arsenic concentration in drinking water greater than standard value (10 $\mu g\ l^{-1}$). The polypropylene tubes for blood sample collection were previously decontaminated with nitric acid (10%) and then kept in deionized water. A 5 ml of blood was collected into decontaminated sample tubes for determining arsenic level (APHA, 2005) .

Determination of arsenic in drinking water : All the water samples were digested with HNO_3**.** Determination of arsenic was made directly on each final solution using AAS as described by Floyed and Hezekiah (1997).

Estimation of blood arsenic content : Total arsenic in blood samples of individuals exposed to arsenic was estimated as per the protocol of National Institute for Occupational Safety and Health (2005) using AAS after digesting the sample with 5% HCl:HNO_3 solution.

Statistical analysis : Results were expressed as mean value. Comparison between the two groups of control and arsenic contamination were performed using the Pearson's correlation coefficient, student's t test, analysis of variance (ANOVA). All analysis was conducted using SPSS 12 software. A value of $P<0.05$ was considered statistically significant.

Results and Discussion

Arsenic contamination in drinking water of Ballia districts and the incidence of its toxicity in people living in these zones is reported in the present study. Arsenic enters in to food chain via water, irrigated vegetables and animal feed (Huq *et al.,* 2006). Based on the analysis of 100 drinking water samples in Belhari block, 60% had arsenic level below 10 $\mu g\ l^{-1}$, 6% between 10-50 $\mu g\ l^{-1}$, 24% above the critical level 50-100 $\mu g\ l^{-1}$ (Indian standard for arsenic contamination in drinking water) and 10% above 100 $\mu g\ l^{-1}$ of arsenic concentration, respectively (Fig. 2). The mean range of arsenic concentration in different drinking water was 0.579 $\mu g\ l^{-1}$ to 135 $\mu g\ l^{-1}$. This gives the information about depth and arsenic concentration in drinking water samples. Observations revealed that at 10m to 20m depth, the mean arsenic concentration was 17.398±21.796 $\mu g\ l^{-1}$, while at 20m to 40m depth it was 39.685±40.832 $\mu g\ l^{-1}$. These evidences also suggested that highest mean value (46.89±52.80 $\mu g\ l^{-1}$) of arsenic contamination was found at 41-60 m depth of drinking water. For the study of age effect (or exposure time) of drinking water on concentration of arsenic, all the samples divided in to four groups (0-40) with 10 years intervals. Observations shows that group 20-30 years having maximum arsenic concentration with mean value of 52.57±53.79 $\mu g\ l^{-1}$. Although group 30-40 years having lowest mean arsenic value (4.44±1.6 $\mu g\ l^{-1}$) due to reduced water quantity. The presence of arsenic contamination in drinking water might be due to release of arsenopyrite in shallow aquifers oxidation and oxyhydroxide reduction. (Mandal *et al.,* 1998).

Correlation analysis showed a significant positive correlation between arsenic level and depth (in meter) of drinking water sources (correlation coefficient; r=0.7161, t=4.2159 & *P<0.05) (Fig. 3). However, another significant positive correlation was found between age of drinking water source or exposure time (in years) with arsenic level (correlation coefficient; r = 0.8017, t = 5.6698 & *P < 0.05) (Fig. 4). Arsenic above permissible limit in shallow aquifer was found in many zones of Ballia districts and it might be possible that this was due to geogenic origin. All these zones were located in flood plains. Efforts are being taken towards ensuring safe drinking-water either through mitigation techniques or through exploring alternative source of drinking water (Ali *et al.,* 2012).

Contamination of drinking water by arsenic, particularly in Gangetic alluvium has been the most dangerous natural calamities and anthropogenic influences (Singh and Singh, 2007). The highest arsenic contamination depth zone has maximum exposure, although water sources having age more than thirty years decrease in water level. Correlation analysis showed significant evidences that arsenic contamination increases with depth and exposure time of drinking water.

Now there is need to reduce the utilization of arsenic contaminated drinking water because it posing a significant risk of this toxic element entering into the food-chain through crop/plant uptake and consumption by animals and humans (Huq *et al.* 2006). In Ballia district thirty to forty percent net cultivable land is under irrigation, and more than 60% of this irrigation is met from drinking water (Huq and Naidu 2005); thus, the risk from arsenic-contaminated water being used is high. Arsenic is widely distributed in surface water and measured values below 10 $\mu g\ l^{-1}$ are common in these blocks of Ballia district (Aktar *et al.,* 2010; Smith *et al*., 2002). During investigation, it was found that some areas were arsenic-contaminated while few were safe. This study marked a correlation between arsenic concentration and depth of water sources, however it supports the evidence of arsenic

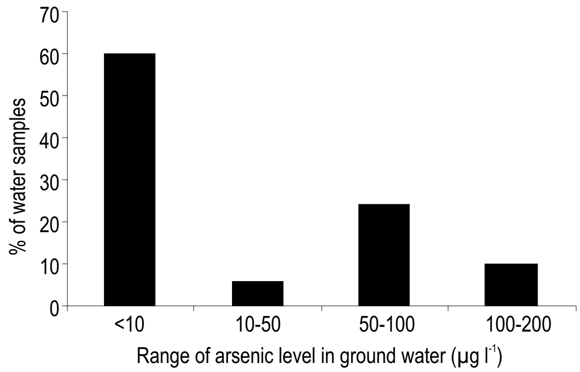

Fig. 2 : Distribution of Arsenic contamination in drinking water

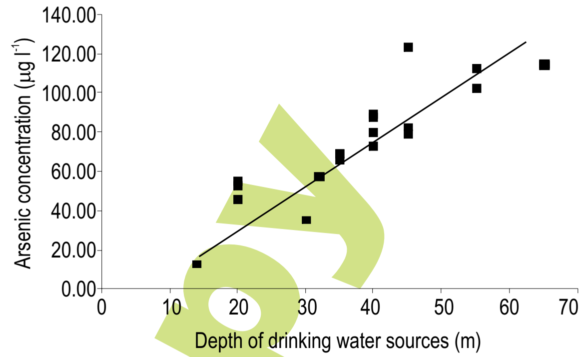

Fig. 3 : The correlation coefficient between arsenic level and depth of drinking water resources (in meter) (r = 0.7161, t = 4.2159 & *P<0.05)

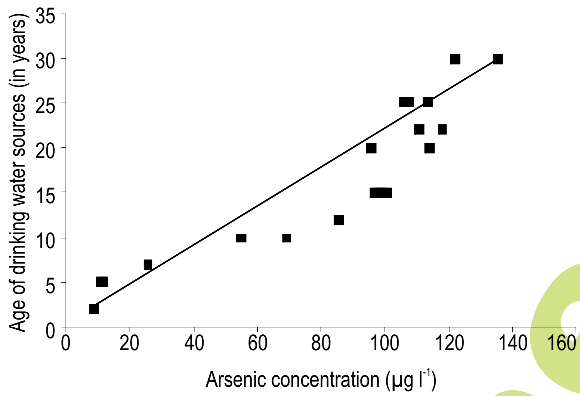

Fig. 4 : A significant positive correlation between age of drinking water sources or exposure time (in years) with arsenic level (r = 0.8017, t = 5.6698 and *P<0.05)

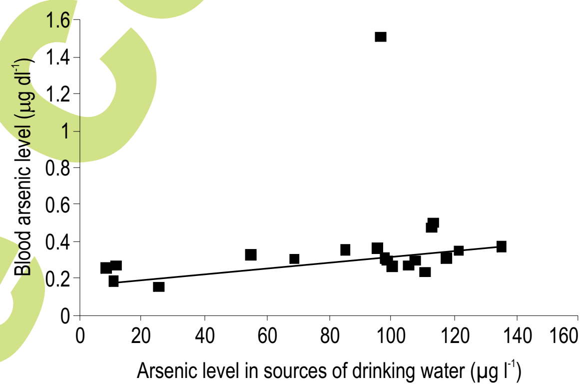

Fig. 5 : The correlation coefficient between blood arsenic level and drinking water contamination (r = 0.6823, t = 3.9395, *P<0.05)

contamination in Ballia district (Rahman *et al.,* 2005a; 2005b; 2005c; 2005d; Ahmad *et al.,* 2006).

In Belhari block, blood arsenic concentration in human was found to be higher than 50 µg l^{-1}(Table 1). Out of 100 individuals, 65 showed blood arsenic level above 0.1 µg dl^{-1}. The mean blood arsenic level of these 65 arsenic exposed individuals was 0.2264±0.1772 µg dl^{-1} (range 0.109 - 1.51 µg dl^{-1}) as compared to control (<0.1 µg dl^{-1}). This study indicate a significant higher blood arsenic level in the drinking water exposed individual $P<0.05$ as compared to unexposed healthy volunteers. Correlation analysis showed, significant positive correlation between As level in blood and arsenic level in drinking water (correlation coefficient; r = 0.638, $P<0.05$) (Fig. 5).

It is also possible that incidental ingestion and inhalation of dust containing arsenic may also be a significant pathway of exposure. Some observations provide significant information on contamination through arsenic-contaminated irrigation-water and the subsequent transfer of arsenic via water to crops (Huq *et al.,* 2006). However, animal studies have shown that arsenic deficiency may be detrimental and has been linked with increased mortality, reduced fertility, increased spontaneous abortion rate, low birth weight in offspring and damage to red blood cells (Ratnaike, 2006). Elevated level of arsenic in biological samples and drinking water causes many type of arsenical skin lesions (Rahman *et al.,* 2001; Galer *et al.,* 1998). Chronic arsenic exposure causes a characteristic pattern of dermal effects that might start with melanosis (pigmentation) to keratosis and hyperkeratosis (Mandal *et al.,* 1996). Drinking water with As level greater than 300 µg l^{-1} for several years may cause skin lesions (Chakraborti *et al.,* 2002).

Chronic arsenic toxicity due to drinking arsenic contaminated water has been on one of the worst environmental health hazards affecting many villages of Ballia districts. Detailed clinical examination and investigation of such patients revealed clinical manifestation of such toxicity. Over and above hyperpigmentation and keratosis, weakness, anaemia, burning sensation of eyes, solid swelling of legs, liver fibrosis, chronic lung disease, gangrene of toes, neuropathy and skin cancer are some of the other manifestations (Buschmann *et al.,* 2008; Nayak *et al.,*

Table 1 : The levels of arsenic in drinking water and human blood sample

Types of samples	No. of samples	Values
Borewell water	100	0.579 – 135 (μg l^{-1})
Human blood samples	100	0.16 – 1.51 (μg dl^{-1})

2007; Lage *et al.,* 2006).

The ingestion of arsenic-contaminated drinking water is the major cause of arsenic poisoning in these areas. According to observations, drinking water in the majority of Belhari block has concentration As exceeding the WHO limit. This study also indicated that increase level of arsenic found in higher depth.

Acknowledgment

The authors would like to acknowledge DMLT trained staff of CSJM University, Kanpur for collection of human blood samples.

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