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Human exposure to arsenic in groundwater from Lahore district, Pakistan

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ABSTRACT

In the present study we determined As concentrations in healthy volunteers from three different age groups (children, adults and old age) residing in Lahore, Pakistan to gain insight into arsenic exposure to humans via drinking water. The results revealed that the concentrations of As were significantly ($p < 0.05$) different among different sites, while non significant trends were observed among different age classes. As concentrations in blood and nails samples showed a significant ($p < 0.05$) positive correlation. The mean concentrations of As were higher in nails samples (1.43 μg/g) followed by blood samples (1.15 μg/L); urine samples (0.82 μg/l) and hair samples (0.74 μg/g) based on all sites. The antioxidants enzyme activities in blood samples showed a significant ($p < 0.01$) decrease with the increase in As concentrations. The result suggests that urgent action is needed to prevent further human exposure to As.

1. Introduction

Arsenic (As) is a metalloid, which exists naturally in the environment in inorganic as well as organic forms (Flora et al., 2009). Arsenic in surface water mainly exists as As^{+5} while As^{+3} is more ubiquitous in deep anoxic wells and known to be more toxic than the pentavalent form as it reacts with thiol groups of proteins (Basu et al., 2001). World Health Organization (WHO) standard for arsenic is 10 ppb in drinking water. Long-term consumption of water containing arsenic is a major health risk, and in some countries, the effects on health are well documented. About 130 million people in developing countries are being poisoned by As via drinking water with levels higher 10 μg/l (Mandal and Suzuki, 2002). People living in many developing and some developed countries suffer from high arsenic exposure (Mandal and Suzuki, 2002) and are at risk of arsenic exposure. Many studies on As poisoning due to consumption of As-contaminated water have been reported worldwide (Kazi et al., 2009; Mandal and Suzuki, 2002; Ng et al., 2003). The release of soluble arsenic species into groundwater is a major problem in many parts of the world (Nickson et al., 2005; Tian et al., 2001). Arsenic poisoning through drinking water became a widespread public health concern, especially in West Bengal of India and China (Parvez et al., 2006; Yu et al., 2007).

In Pakistan, drinking water comes from groundwater and surface water including rivers, lakes and reservoirs. The

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present way of disposing agricultural, industrial and domestic effluents into natural water-bodies results in serious surface and groundwater contamination. Natural ground water As-poisoning in Pakistan in soils is being related to weathering of parent rocks and pedogenesis. Pakistan has low levels of arsenic in groundwater as compared to China, Bangladesh and India (Ahmad et al., 2003). United Nations Children's Fund (UNICEF) in collaboration with government of Pakistan conducted a national survey in 2004 on arsenic concentrations in groundwater, From one-third of the total districts of the country (35/104), 8712 drinking water samples were collected. Of them 9% contained arsenic 410 mg/L and 0.7% were 450 mg/L. Most of these groundwater sources were affected in the range of 0–500 mg/L (Ahmad et al., 2003). Ground water As-contamination in Pakistan have also been reported by Local Government and Rural development Department (LGRDD) of Pakistan in collaboration with UNICEF took a survey of As concentration in groundwater from drinking water supply wells in Pakistan, survey revealed hot spots of As enrichment in some parts of Indus basin.

Arsenic contamination in drinking water has been reported by several past studies in many areas of Pakistan. Muzaffargarh area south western edge of Punjab, Pakistan (Nickson et al., 2005), Kalalanwala (Punjab, Pakistan) and surrounding areas (Farooqi et al., 2007; Naseem et al., 2001), Jamshoro, sub district-Sehwan (Kazi et al., 2009), Manchar Lake, One of the Asia's and Pakistan's largest freshwater lake, located west of river Indus, Jamshoro (Arain et al., 2009), Southern part of Sindh, Pakistan (Kazi et al., 2009) and district Khairpur, situated in northeast of Sindh (Fatmi et al., 2009) are contaminated with elevated levels of arsenic and human are exposed via consumption of arsenic contaminated water. To date, no comprehensive study so far conducted in Pakistan to evaluate the As toxicity in human due to consumption of arsenic enriched groundwater. Moreover the influence of age and severity of the exposure status of arsenic is still unclear in these residents. It was the matter of concern to quantify arsenic in human to insight the severity of exposure.

This study was conducted to evaluate the arsenic exposure to individuals, living in the natural Arsenic (As) contaminated areas by using biological samples (blood, urine, nails and hair) via consumption of As-contaminated water. The purpose of the present study was to find the inter-specific variation of arsenic among age classes and to compare the arsenic level in different risk areas. The goal was to unravel the correlation between arsenic concentrations and antioxidant enzymes activities in human.

2. Materials and methods

2.1. Study area

The study area forms part of district Lahore in the Punjab Province, Pakistan (Fig. 1a) bounded by 73.22°–74.45°E, 31.20°–31.60°N covering an area of approximately 4000 km^2. The area is a part of the Punjab alluvial plain which display similarities to the arsenic (As) affected aquifers of West Bengal and Bangladesh. Mineral ore is a source of arsenite (As^{+3}), releases into water and contaminates drinking water wells; and arsenate (As^{+5}) releases from erosion of natural land sources and industrial contamination of soil that is carried by rain runoff into surface water and used as a drinking water source.

Three sites Chung, Manga-Mandi and Kalalanwala were selected and further subdivided into Low (As 4 μg/L in drinking water), medium (As 672 μg/L in drinking water) and high (As 2400 μg/L in drinking water); (Farooqi et al., 2007) risk areas respectively, along Lahore-Multan road (Fig. 1c) exceeding the WHO limit 10 μg/L arsenic in drinking water. Lahore cantt was selected as control far away from arsenic contaminated areas.

2.2. Recruitment of human subjects and selection criteria

A total of 48 human subjects 12 from each site consisting of adults (aged 25–35), children (aged 10–15) and old age people (aged 40–50) were selected for collection of blood, urine, nails and hair samples, who were using ground water for drinking. Inorganic arsenic can be bioaccumulated in the human body through seafood consumption for a long period of time. So, for collection of samples those places were selected where no sea food was available, and 3 days before sampling the recruited subject were also asked not to take sea food. As study participants the arsenic exposed subjects were chosen regardless the presence or absence of arsenic induced skin lesions. Control samples were collected from a group of people who never drank As-contaminated water and lived at a place far from As-contaminated regions of Lahore.

2.3. Collection of samples and storage

Biological samples (blood, urine, hair and nails) $n = 48$ each, from the selected human groups were collected from study sites as reported previously (Afridi et al., 2011). Collected hair and nail samples were stored at room temperature individually in clean polyethylene bags and sealed tightly. The 5 mL of fresh venous whole blood samples were collected by using sterile syringes and stored in 5 mL EDTA tubes at 4 °C till further analysis. Spot urine samples were collected in pre-washed ($1HNO_3$:$1H_2O_2$) polyethylene bottles. Immediately after collection, the urine samples stored in salt ice mixture and later, on return to the laboratory kept at −20 °C until analysis were carried out.

2.4. Pretreatment/washing of nail and hair samples

To remove surface dust the nail samples were scrubbed using nylon brush. The hair and nail samples were cleaned following the procedure outline by the International Atomic Energy Agency (IAEA, 1985). The washed samples were placed in glass beakers and allowed to dry at 50 °C overnight in a drying oven.

2.5. Samples digestion and arsenic analysis

Hair and nail samples were digested by the procedure outlined previously (Samanta et al., 2004). A microwave digestion system MARS 5 (CEM Corporation, version 194A02, Matthews, USA) was used for hair and nail samples digestion. The frozen urine samples were thawed and prepared according to the