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Arsenic contamination in groundwater and its toxic effects on human health in Vietnam

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Abstract Chronic arsenic poisoning due to consumption of arsenic-contaminated water has been reported in many countries. In Vietnam, Berg et al. (2001) reported that extremely high level of arsenic (up to 3050 μg/L) was detected in groundwater from the region around Red River, Hanoi City. However, detailed survey on arsenic contamination of groundwater has not been conducted and also no information is available on the toxic effects of arsenic on human health in Vietnam. We investigated the concentrations of total arsenic and individual arsenicals in groundwater, human hair, and urine and urinary 8-OHdG levels at Thanh Tri in Vietnam. Total arsenic concentrations in groundwater from Thanh Tri ranged from <1 to 94.0 μg/L, and 95.2% of these values exceeded the WHO guideline value for arsenic in drinking-water. These results suggest that groundwater at Thanh Tri is relatively highly polluted by arsenic. Mean total arsenic concentration in hair of Thanh Tri residents was 1.9±1.9 μg/g dry wt and the highest value (7.55 μg/g dry wt) was comparable to those of Bangladesh and West Bengal, India, where the serious arsenic contamination problems occurred. These results suggest that residents of Thanh Tri are chronically exposed to arsenic from dinking water and might be at high risk of toxic effects of arsenic.
Keywords Arsenic; Groundwater; Human health; Pollution; Toxic effects; 8-OHdG

Introduction

Recently, chronic arsenic poisoning due to consumption of arsenic-contaminated water has been reported in many countries, such as Bangladesh, India, Thailand, China, Argentina, and Chile (Nordstrom, 2002). Hence, worldwide concern on arsenic contamination of groundwater and its toxic influence on human health have increased markedly (Mandal et al., 1998; Chowdhury et al., 2000). In case of Vietnam, Berg et al. (2001) reported that total arsenic concentration in groundwater from the region around Red River, Hanoi City was extremely high (up to 3050 μg/L). However, detailed survey has not been conducted on the arsenic contamination in groundwater and also no information is available on the toxic effects of arsenic on human health in Vietnam.

In the present study, we determined the concentrations of total arsenic and individual arsenic compounds in groundwater, human hair, and urine collected from Thanh Tri, Vietnam. We also investigated urinary 8-hydroxy-2'-deoxyguanosine (8-OHdG) levels to make clear the association of DNA oxidative damage by arsenic contamination in the residents of Thanh tri.

Materials and Methods

Samples

Arsenic pollution survey was conducted on 25 families at Thanh Tri, Hanoi City, Vietnam in September, 2002. Human hair (*n*=82) and urine (*n*=82) samples were collected from each participant and kept frozen at −20°C until analyses. Prior to analysis, human hair samples were washed ultrasonically with 0.3% polyoxyethylene lauryl ether and rinsed with MilliQ water to remove exogenous contaminants. To remove particles and minimize matrix effects, all human urine samples were diluted 5-fold using MilliQ water and filtered with a 0.20 μm cellulose filter before use. Raw groundwater samples (*n*=21) and sand-filtrated groundwater samples (*n*=12) were collected from the well of each household at Thanh Tri, Vietnam.

Chemical analysis

Analysis of total arsenic was conducted as described previously (Kubota et al., 2001). Human hair samples were treated with acid mixture (HNO_3:$HClO_4$:H_2SO_4 = 1:2:1) and digested by heating until the perchloric acid was removed. Total arsenic concentrations in human hair and groundwater were determined by hydride generation atomic absorption spectrometry (HG–AAS).

Chemical speciation of arsenic in urine sample was performed according to the method of Kubota et al. (2002) and Mandal et al. (2000). Arsenic compounds were identified and quantified by high performance liquid chromatography/ inductively coupled plasma–mass spectrometry (HPLC/ ICP–MS). Hamilton PRP–X100 anion–exchange column (6.7 mM $NH_4H_2PO_4$ buffer (pH = 6.0)) and Shodex Asahipak ES-502N 7C anion–exchange column (15 mM citric acid buffer(pH= 2.0)) were used for the separation of each arsenic compounds in urine sample. Rubidium was added to both mobile phases as an internal standard to achieve a concentration of 50 ng/g. Eight arsenic species (arsenite (As (III)), arsenate (As (V)), methylarsonic acid (MMA), dimethylarsinic acid (DMA), arsenobetaine (AB), arsenocholine (AC), trimethylarsine oxide (TMAO), and tetramethylarsonium iodide (TeMA)) were used as standard substances in this study. The ion intensities at m/z 75 (^{75}As), 77 (^{40}Ar^{37}Cl and ^{77}Se), and 87 (^{87}Rb) were monitored.

Determination of urinary 8–OHdG by ELISA

The amounts of 8-OHdG in urine samples were determined using competitive ELISA method with an ELISA kit "8-OHdG Check" (Japan Institute for the Control of Aging, Shizuoka). Data were corrected by urinary creatinine and 'urinary 8-OHdG (ng/ml)/ creatinine (mg/ml) ratio' is abbreviated to 'urinary 8-OHdG (ng/mg.Cr.)' in this study.

Results and Discussion

Groundwater

Total arsenic concentrations in raw groundwater from Thanh Tri were 247 ± 126 μg/L and the values were widely different among sampling locations (<1-474 μg/L) (Fig. 1A). Although these values were comparable to or lower than those of other arsenic polluted areas, such as Bangladesh and India (Mandal et al., 1998; Chowdhury et al., 2000), 95.2% of the raw groundwater from Thanh Tri exceeded the WHO and Vietnamese guideline value for arsenic in drinking-water of 10 μg/L. These results suggest that groundwater in Thanh Tri is relatively highly polluted by arsenic. Total arsenic concentration in sand-filtrated groundwater from Thanh Tri was 22.0 ± 18.0 μg/L and the values were also different between sampling locations (<1-52.7 μg/L) (Fig. 1B). 75.0% of the sand-filtrated groundwater from Thanh Tri exceeded 10 μg/L (WHO and Vietnamese guideline), suggesting that arsenic is not effectively removed by this sand-filtration method used in Thanh Tri. Thus, it is necessary to improve the method of removal for arsenic in groundwater.

Human hair and urine

Mean total arsenic concentration in human hair of Thanh Tri residents was 1.1 ± 1.2 μg/g dry wt and the highest value (7.5 μg/g dry wt) (Fig. 2) was comparable to those of Bangladesh and India (Mandal et al., 1998). Moreover, 32.9% of human hair sample from the residents at Thanh Tri exceeded the threshold arsenic level in human hair (1 μg/g dry wt) (Arnold et al., 1990) which can cause toxic effects. These results suggest that residents of Thanh Tri are chronically exposed to arsenic from groundwater and might be at high risk of toxic effects of arsenic, such as carcinogenicity.

Chemical speciation of arsenic revealed that dimethylarsinic acid was the major arsenic compound in almost all the urine samples of the residents at Thanh Tri. Moreover, methylarsonic acid and inorganic arsenic were also detected in the urine samples. The concentrations of 8-OHdG in urine samples from the residents of Thanh Tri were 7.4 ± 4.4 ng/mg Cr. (range, 0.8–29.0 ng/mg Cr.).

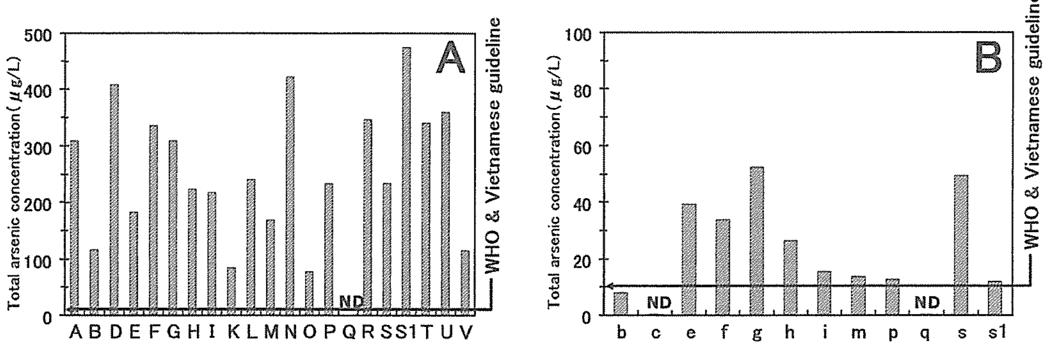

Figure 1 Total arsenic concentrations in raw groundwater (A) and sand-filtrated groundwater (B) from Thanh Tri, Hanoi City, Vietnam

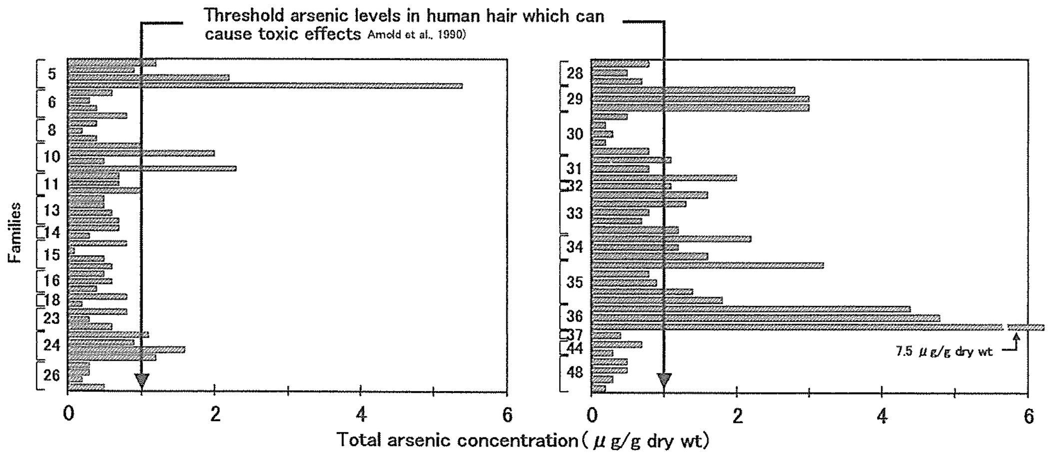

Figure 2 Total arsenic concentration in human hair of Thanh Tri residents

Conclusion

We investigated the concentrations of total arsenic and individual arsenicals in groundwater, human hair, and urine and urinary 8-OHdG levels at Thanh Tri, Vietnam. High arsenic levels were detected in raw groundwater samples from Thanh Tri and the values were comparable to or lower than those of other arsenic polluted areas. 90.9% of total groundwater (raw and sand-filtrated) from Thanh Tri exceeded the WHO guideline value for arsenic in drinking-water. Total arsenic concentration in hair of Thanh Tri residents was 1.9±1.9 μg/g dry wt and the highest value was comparable to those of Bangladesh and West Bengal, India. These results suggest that groundwater in Thanh Tri is highly polluted by arsenic and the residents of Thanh Tri are chronically exposed to arsenic from dinking water and might be at high risk of toxic effects of arsenic.

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