Contamination by arsenic and other trace elements in drinking water and residents in Vietnam

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Abstract In the present study, contamination levels of As and other trace elements and their association were examined for groundwater and human hair collected at Gia Lam District and Thanh Tri District, suburban areas of Hanoi, Vietnam in September 2001. Concentrations of As in groundwater ranged from <0.10 to 330 μg/l, about 40 % of these exceeding WHO drinking water guideline of 10 μg/l. Interestingly, some groundwater samples also had higher concentrations of Mn and Ba than WHO drinking water guidelines. A significant positive correlation was observed between As and Fe levels in groundwater, which may indicate that As is released into groundwater by reductive dissolution of Fe oxyhydroxides adsorbed with As. Arsenic concentrations in hair of residents in Hanoi ranged from 0.088 to 2.77 μg/g. These levels were lower than those in other As-contaminated areas, but higher than those of normal people. Arsenic concentrations in hair of some individuals from suburban Hanoi were higher than the level associated with skin pathology, suggesting potential health risk for people consuming As-contaminated water in this area. Significant positive correlations were observed between concentrations in groundwater and in human hair for As, Mn and Ba. The manifestations of chronic As poisoning and arsenicosis have not been observed in residents in these areas, which might be due to the fact that cumulative As ingestions from contaminated water are still lower than the threshold levels. To our knowledge, this is the first study on the human exposure to not only As but also Mn and Ba from the As-contaminated areas in Vietnam.

Keywords: Arsenic; barium; groundwater; human hair; manganese; Vietnam

Introduction

Arsenic is a naturally occurring element and ubiquitous in the environment, but can cause

carcinogenesis at low levels (WHO, 2001). Arsenic pollution in groundwater has been a serious environmental problem over the world during the last decade, particularly in Asian countries such as Bangladesh, India (Nickson *et al.*, 1998; Acharyya *et al.*, 1999; Chowdhury *et al.*, 1999; Chowdhury *et al.*, 2000), and Taiwan (Wu *et al.*, 1989). An estimated 36 million people in the Bengal Delta are at risk from As-contaminated water (Nordstrom, 2002). Recently, elevated As concentrations (up to 3050 ng/ml) have been reported in the groundwater of sub-urban areas of Hanoi, the capital city of Vietnam, suggesting a health risk to the people consuming As-contaminated water in Red River delta (Berg *et al.*, 2001). However, no investigation has been made on the human exposure to As in Vietnam and therefore, the possible toxic impacts of the As contamination on Vietnamese residents are still obscure.

In the present study, As concentrations were determined for groundwater and human hair collected at Gia Lam District and Thanh Tri District, suburban areas of Hanoi, Vietnam in September 2001. In addition, contamination levels of other trace elements and their association with As level were also examined in groundwater and human hair.

Materials and Methods

Groundwater and human hair samples were collected from households from Gia Lam and Thanh Tri districts in the suburban areas of Hanoi during September 2001. Rainwater and pond water, which are the two other sources of drinking water to residents in these districts, were also collected. All samples were kept at –20 °C until chemical analysis.

The water samples were acidified with H_2SO_4 for As and with HNO_3 for other elements. Human hair was washed with 0.3 % polyoxyethylene lauryl ether (Okamoto *et al.*, 1985) and subsequently dried for 12 h at 80 °C. Then they were digested with a mixture of HNO_3-H_2SO_4-$HClO_4$ (Agusa *et al.*, 2002) for As and with a microwave using HNO_3 for other elements. Analysis of As was performed using a hydride generation atomic absorption spectrometer (Agusa *et al.*, 2002). Concentrations of 20 elements (V, Cr, Mn, Co, Cu, Zn, Ga, Rb, Sr, Mo, Ag, Cd, In, Sn, Sb, Cs, Ba, Tl, Pb and Bi) and Hg were determined by ICP-MS and CV-AAS, respectively (Agusa *et al.*, 2003).

Results and Discussion

Concentrations of As in the groundwater ranged from <0.01 to 330 μg/l (Fig. 1). Median As concentration in groundwater in Gia Lam (5.04 μg/l) was higher than that in Thanh Tri (1.47 μg/l). About 40 % of these samples contained As concentrations exceeding WHO drinking water guideline of 10 μg/l (WHO, 1996). In contrast, low concentrations of As were found in pond water and not detected in rainwater.

Interestingly, about 76 % of the samples exceeded the WHO drinking water guideline for Mn (500 μg/l) (Fig. 1). Our study also indicates that Ba concentrations were higher than WHO drinking water guideline (700 μg/l) in 3 samples of groundwater (Fig. 1). These findings indicate that people in Red River Delta are exposed not only to As but also to Mn and Ba from groundwater and that synergistic toxic effects of these elements should be evaluated in this population.

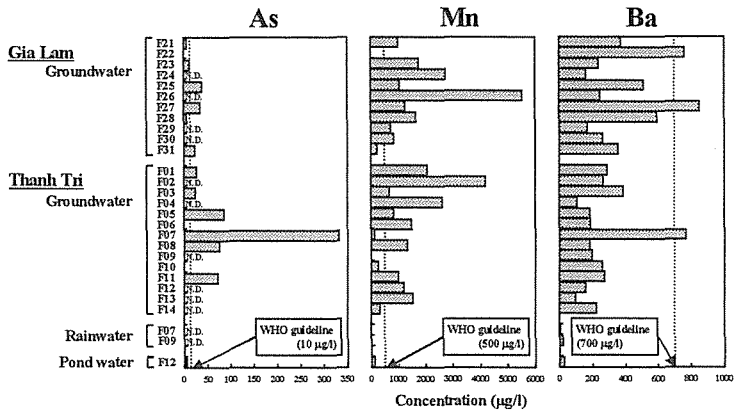

Fig. 1. Arsenic, Mn and Ba concentrations in groundwater, rainwater and pond water in the suburban areas of Hanoi. Sample number (F01-14, F21-31) indicates well in each home.

To understand the magnitude of contamination, concentrations of As in groundwater in the present study were compared with those in water from other As-contaminated areas. Median values in groundwater in this study were lower than those in other contaminated areas. However, maximum values were comparable to those levels.

A significant positive correlation between As and Fe concentrations was found in groundwater. This relationship is consistent with the hypothesis of Berg *et al.* (2001). Berg *et al.* (2001) reported that As may be associated with Fe oxyhydroxides and As levels may be influenced by reductive dissolution of Fe oxyhydroxides in Red River alluvial tract in Vietnam.

Arsenic levels in hair of residents in Hanoi ranged from 0.088 to 2.77 μg/g dry wt. (Fig. 2) and the values from both sites were comparable, which was consistent with the results of groundwater. These levels were lower than those from other As contaminated areas, but higher than those in normal people. Arsenic levels in hair of some individuals exceeded the level that may cause skin pathology (Arnold *et al.*, 1990) (Fig. 2), suggesting potential health effects to populations living in the areas investigated. No significant differences in As concentrations in hair were found among the family members (father, mother, son, and daughter) (Fig. 2), which might imply that degree of As exposure is similar within the family.

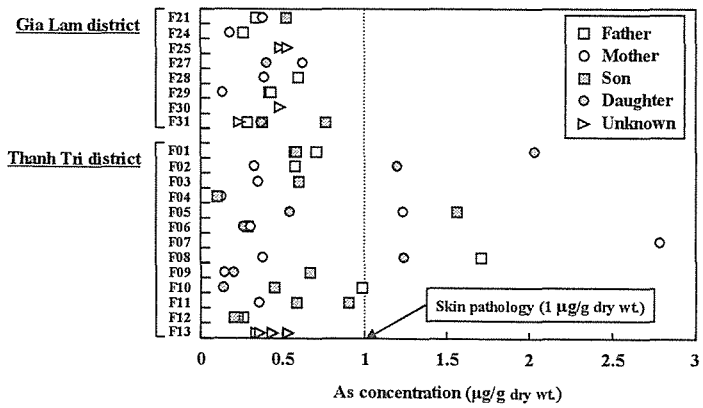

Fig. 2. Arsenic concentrations in hair of residents in the suburban areas of Hanoi. Sample number (F01-13, F21, F24, F25, F27-31) indicates well in each home.

A significant positive correlation was observed between the As concentrations in groundwater and human hair (Fig. 3). Manganese and Ba concentrations in hair of residents were also correlated with those in groundwater. These results suggest that residents in the suburban areas of Hanoi are chronically exposed to As, Mn and Ba from groundwater.

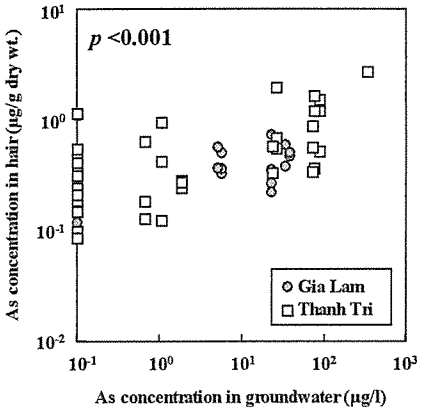

Fig. 3. Relationship between As concentrations in groundwater and hair of residents in the suburban areas of Hanoi.

Manifestations of chronic As poisoning have not been observed in residents in the investigated areas. This might be due to the fact that private wells in the study areas were installed only 1-10 years ago. Cumulative As exposure was estimated from As level in groundwater, year of tube-well usage, annual ingestion rate of groundwater and daily water consumption, using the equation: [Cumulative As intake (mg)] = [As level in groundwater (mg/l)] x [Age of well (year)] x [Ingestion rate of groundwater (182.5 day/year)] x [Water consumption (2 l/day)]. The cumulative As ingestion by the residents of suburb of Hanoi was 0.04-241 mg, which was much lower than the level that may cause internal cancers (min. 672 mg) (Bates *et al.*, 1992). Although exact information on water consumption rate and period of well usage by each person was not available in this estimation, this relatively small cumulative intake may explain the apparent absence of As-related toxic effects in the residents. Further studies are needed to evaluate the possible toxic effects of arsenic on the population of these areas.

References

Acharyya, S.K., Chakraborty, P., Lahiri, S., Raymahashay, B.C., Guha, S. and Bhowmik, A. (1999). Arsenic poisoning in the Ganges delta. *Nature*, **401**(6753) 546-547.

Agusa, T., Kunito, T., Kubota, R., Monirith, I., Tanabe, S. and Tana, T.S. (2002) Arsenic pollution in Cambodia. *Biomedical Research on Trace Elements*, **13**, 254-255 (in Japanese).

Agusa, T., Kunito, T., Nakashima, E., Minh, T.B., Tanabe, S., Subramanian, A., and Viet, P.H. (2003) Preliminary studies on trace element contamination in dumping sites of municipal wastes in India and Vietnam. *Journal de Physique IV*, **107**, 21-24.

Arnold, H.L., Jr., Odom, R.B. and James, W.D. (1990) *Andrew's Diseases of the Skin: Clinical Dermatology*, 8th ed., W.B. Saunders Company, Philadelphia.

Bates, M.N., Smith, A.H. and Hopenhayn-Rich, C. (1992). Arsenic ingestion and internal cancers: a review. *American Journal of Epidemiology*, **135**(5) 462-476.

Berg, M., Tran, H.C., Nguyen, T.C., Pham, H.V., Schertenleib, R. and Giger, W. (2001). Arsenic contamination of groundwater and drinking water in Vietnam: a human health threat. *Environmental Science and Technology*, **35**(13) 2621-2626.

Chowdhury, T.R., Basu, G.K., Mandal, B.K., Biswas, B.K., Samanta, G., Chowdhury, U.K., Chanda, C.R., Lodh, D., Roy, S.L., Saha, K.C., Roy, S., Kabir, S., Quamruzzaman, Q. and Chakraborti, D. (1999). Arsenic poisoning in the Ganges delta. *Nature*, **401**(6753) 545-546.

Chowdhury, U.K., Biswas, B.K., Chowdhury, T.R., Samanta, G., Mandal, B.K., Basu, G.C., Chanda, C.R., Lodh, D., Saha, K.C., Mukherjee, S.K., Roy, S., Kabir, S., Quamruzzaman, Q. and Chakraborti, D. (2000). Groundwater arsenic contamination in Bangladesh and West Bengal, India. *Environmental Health Perspectives*, **108**(5) 393-397.

Nickson, R., McArthur, J., Burgess, W., Ahmed, K.M., Ravenscroft, P. and Rahman, M. (1998). Arsenic poisoning of Bangladesh groundwater. *Nature*, **395**(6700) 338.

Nordstrom, D.K. (2002). Public health. Worldwide occurrences of arsenic in ground water. *Science*, **296**(5576) 2143-2145.

Okamoto, K., Morita, M., Uehiro, T., Fuwa, K., and Zhen, K. (1985) About environmental standard materials NIES No. 5 Hair. *Kankyo Kenkyu*, **55**, 109-117 (in Japanese).

WHO (1996) Guidelines for Drinking Water Quality. 2nd edition., Geneva: World Health Organization International Program on Chemical Safety, 156-167.

WHO (2001) Environmental Health Criteria 224: Arsenic and Arsenic Compounds. 2nd edition., Geneva, World Health Organization.

Wu, M.M., Kuo, T.L., Hwang, Y.H. and Chen, C.J. (1989). Dose-response relation between arsenic concentration in well water and mortality from cancers and vascular diseases. *American Journal of Epidemiology*, **130**(6) 1123-1132.