RESEARCH ARTICLE

Assessment of Arsenic Levels in Body Samples and Chronic Exposure in People Using Water with a High Concentration of Arsenic: a Field Study in Kutahya

Inci Arikan[1]*, Nazli Dizen Namdar[2], Cuneyt Kahraman[3], Merve Dagci[4], Ezgi Ece[5]

Abstract

Objective: This study aimed to evaluate the prevalence of skin lesions, which is a health effect of chronic arsenic (As) exposure, and determine the hair/blood arsenic concentrations of people living in Kutahya villages who are using and drinking tap water with a high concentration of arsenic. Materials and Methods: A total of 303 people were included in the present cross-sectional study. A prepared questionnaire form was used to collect the participants' information and environmental history. Skin examination was performed on all participants. Hair, blood and water samples were analyzed using atomic absorption spectroscopy. The cumulative arsenic index (CAI) was calculated for all participants. Results: Villages were divided into two groups according to the arsenic level (<20 μg/L, Group I; >20 μg/L, Group II) in their water. The prevalence of skin lesions, hair and blood arsenic level, and CAI were found to be higher in the Group II participants. There was a positive association between body arsenic levels and CAI in the participants of each group. Conclusions: The number of skin lesions and arsenic concentrations in body samples were found to increase with the water arsenic level and exposure time. We hope that sharing this study's results with local administrators will help accelerate the rehabilitation of water sources in Kutahya.

Keywords: Arsenic in water - arsenic in body samples - environmental exposure - field study - Turkey

Asian Pac J Cancer Prev, **16 (8)**, 3183-3188

Introduction

Today, because environmental pollution and exposure to heavy metals are major public health problems in developing and underdeveloped countries, several relevant epidemiological studies have been conducted (Samanta et al., 2004; Anwar et al., 2005; Fasinu et al., 2013).

Some of the heavy metals found intensely in the environment can easily be detected in the human tissues and have clear toxic effects (Chhabra et al., 2012). The update amount, entry route into the body and time of exposure to some heavy metals such as As determine the effects of heavy metals on human health (Jarup, 2004; Anwar et al., 2005).

High levels of As exposure from drinking tap water causes a variety of skin lesions, neurological effects and various diseases, including cancer and hypertension. Toxic doses of exposure are evaluated using samples that are obtained from people, and every country determines its own toxic values (Rodrigues et al., 2008; Smith et al., 2009; Sela et al., 2013). Great importance is placed on these values in terms of planning and management of regional health services, establishing public health policy, and developing primary prevention programs (Rodrigues et al., 2008).

Because of its current geological structure, our country is among those with a high potential presence of inorganic arsenic in natural underground waters. Therefore, it is possible for inorganic arsenic to diffuse from geothermal resources and arsenic-rich rocks into underground water. In our country, the Western and Central Anatolia regions are at the highest risk of exposure. The province of Kutahya is located close to the Aegean and central Anatolia regions with a similar climate and geological nature and has been reported to have rich concentrations of minerals and heavy metals in its soil and water (Dogan et al., 2007; Gunduz et al., 2010). Several studies in certain regions of the province have found high levels of arsenic in the underground water and have investigated the health effects of arsenic exposure using various questionnaire forms (Dogan et al., 2005; Gunduz et al., 2014). However, there are a limited number of small studies in our country, and no population-based field studies exist that have evaluated the arsenic concentration in human body tissues.

This study aimed to evaluate to prevalence of skin lesions, a health effect due to chronic arsenic exposure

*[1]Department of Public Health, [2]Department of Dermatology, [3]Department of Internal Medicine, Medical Faculty, [4]Department of Chemistry, [5]Department of Biology, Faculty of Arts and Science , Dumlupinar University, Kutahya, Turkey *For correspondence: iciarikan@hotmail.com*

and to determine the hair/blood arsenic concentration in people living in Kutahya villages who are using and drinking tap water with a high concentration of arsenic.

Materials and Methods

Study population

Forested land comprises 47.7% of the total area of the Kutahya province, and agricultural activities use 34% of this forested land. There are 13 towns and 511 villages throughout the province. The total population is 573 421, and of these, 248 054 are living in city centers. The remaining 198 154 (34.6%) are living in villages. Tap water in the villages is provided from underground sources.

In the "Regulation for the Water for Human Consumption" in our country, the maximum permissible limit of arsenic in the drinking water has been specified to be 10 μg/L.

The regions with water containing a high level of arsenic comprised the study area. To obtain the list of the villages and the results of water analyses in Kutahya in the last year, information was requested from the Provincial Directorate of Health. A total of 5 villages were randomly selected from the list. In these villages, Igdekoy, Kirgil, Kayaarasi, Gumuskoy and Kepez, there are a total of 1102 people aged 18 years or older. The prevalence of skin symptoms due to contact with arsenic has been reported to vary between 5% and 30% (Smith et al., 2009; Naujokas et al., 2013). Therefore, we targeted at least 285 people to obtain a prevalence of skin lesions of 10%, a 3% margin of error and 95% confidence interval. The field study was conducted in May-September 2014, and a total of 303 people were included in the study. The inclusion criteria were being aged 18 years or over, living in those villages for at least 5 years and agreeing to participate in the study. Pregnant women and those not meeting the inclusion criteria were excluded from the study.

All stages of the study were conducted in accordance with the Declaration of Helsinki and were approved by the Eskisehir Osmangazi University Clinical Research Ethics Committee (Number: 2014-80558721/170).

Field study/ sample collection

In the field study, the pre-determined villages and the leaders of the villages were visited. The people in the villages were informed about how to protect themselves from environmental exposure

A prepared questionnaire form was used to collect the data about sociodemographic variables, employment status, drinking and tap water sources, nutritional characteristics, smoking status, chronic diseases and deceased family members. Moreover, body height, body weight, and waist and hip diameters were measured. After 10 min of rest, blood pressure was measured in the sitting position using an ACURA AC-443 blood pressure monitor followed by a skin examination. In the skin examinations performed by a dermatologist, arsenic keratosis was defined as a large number of hard yellowish keratosic lesions with a symmetric localization in the palmoplantar region.

Hair/blood samples from the participants and samples from the water sources used in the villages were obtained to determine the arsenic level. Hair samples of approximately 1 cm were obtained from the suboccipital region. Blood samples of 4 ml were taken using a sterile disposable needle (Vacutainer Systems) and were collected according to international standards into vacuum EDTA-containing tubes. On the same day, samples were transferred to the Dumlupinar University Advanced Technology Research Center with a maintained cold chain.

Sample analysis

The samples were analyzed using the microwave oven (CEM Corporation, MARS 6, Matthews, USA) burning system and hydride system atomic absorption spectroscopy (Analytik Jena, ZEEnit 650P, Germany). Hair samples and blood samples were stored at +4 ºC and -80 ºC until analysis, respectively. Hair samples were washed in acetone-water-acetone. Hair samples of 0.1 g and blood samples of 1 ml were obtained, and solutions containing 2 ml H_2O_2 (Merck, 35%) and 4 ml HNO3 (Merck, 65%) were prepared. After incubating for 30 min, solutions were collected in teflon tubes and burned in the microwave oven. After cooling for 30 min, the burned samples were transferred into pivoted cap polypropylene tubes of 15 ml. To minimize the loss of samples, teflon tubes were washed with ultra-pure water and added to the polypropylene tube to yield a total volume of 15 ml. For the determination of arsenic concentration, the wavelength of the device was set at 193.696 nm. The stock solution used for the analysis was 1000 ppm arsenic standard (containing 4% HNO3, SCP Science). Standard concentrations for hair and water samples were 1.00, 2.00, 3.00, 4.00 and 5.00 ppb (μg/L), and those for blood samples were 1.00, 5.00, 10.00, 15.00 and 20.00 ppb (μg/L). These standards were used to derive a calibration curve, which was used to determine the arsenic concentration in each sample.

Chronic exposure was calculated in each participant according to the following formula: CAI=arsenic level in the water (μg/L)a x daily drinking water intake (L/day) x duration of exposure (year)b x 365.25

(where a is the mean water arsenic concentration measured in the last year and b is the duration of water use)

Statistical analysis

Data were analyzed using SPSS version 20 statistical package (SPSS, Inc., Chicago, IL, USA). A one-sample Kolmogorov-Smirnov test was used to assess whether the data were normally distributed. The Mann-Whitney U test was used to compare data that were not normally distributed and a t test was used to compare the remaining data. A Chi-square analysis was used to compare the frequencies.

The dependent variables were the hair and blood arsenic levels, and the associated factors were determined using univariate analysis. For the multivariable linear model, the logarithm of the dependent variables were calculated according to the Neperian base to convert the data to a normal distribution; the variables with a p-value of <0.10 in the univariate regression were included in the model. Values of p<0.05 were considered to be statistically significant.

Results

The study was carried out on 303 total people comprising 93 men (30.7%) and 210 women (69.3%). Of the participants, 13.9% were less than 35 years of age, and 23.8% were greater than 65 years of age with a mean age of 53.71±15.18 (min:20-max:81).

According to analyses of the water samples from the village fountain, the villages were divided into two groups as follows: Group I with an arsenic level of 10-20 μg/L (Kayaarasi-Kepez-Gumuskoy: mean water arsenic level: 10.15±0.05 μg/L) and Group II with an arsenic level of >20 μg/L (Igdekoy-Kirgil mean water arsenic level: 44.94±26.17 μg/L). There were no significant differences between these two groups in terms of age, gender, educational status, duration of residence or smoking status (p>0.05).

The villagers in Group II were found to use the village fountain for drinking water more frequently than those in Group I (p=0.028) (Table 1). Moreover, cancer-related deaths in the family (in the 1st degree relatives) and the presence of a chronic disease was higher in the participants living in Group II villages (p≤0.05). In total, 15.5% (n=47) had an arsenic exposure-related skin lesion; those living in Group II villages had a higher lesion prevalence than those living in Group I villages (Figure 1). The positive correlation between skin lesions and CAI was significant (spearman correlation r=0.198; p=0.001).

There were no significant differences between the two group of villages in terms of BMI or blood pressure (p>0.05). Hair and blood arsenic levels and CAI were found to be significantly higher in the participants living in Group II villages (p≤0.05) (Table 2).

The multivariate linear model of the variables associated with hair and blood arsenic levels found a positive association between body arsenic level and CAI in the participants of each group (Figure 2) (Table 3). Moreover, in the participants living in Group II villages, hair arsenic concentration was positively associated with age (p≤0.05) (Table 3).

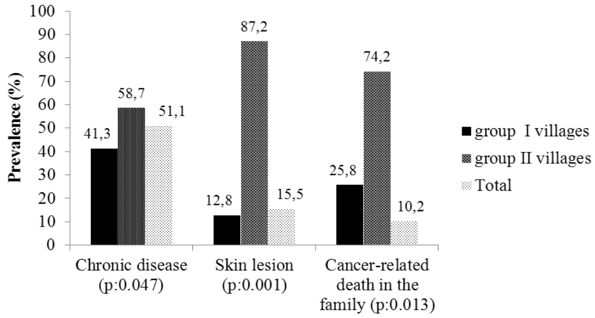

Figure 1. The Prevalence of Diseases in the Participants

Table 1. Sociodemographic and Several Clinical Characteristics of Participants Living in Group I or II Villages

	Group I villages (N=142) n (%)	Group II villages (N=161) n (%)	Total* N(%)	p
Sex				
Male	47 (50.5)	46 (49.5)	93 (30.7)	0.394
Female	95 (45.2)	115 (54.8)	210 (69.3)	
Age				
≤35	20 (48.8)	21 (51.2)	41 (13.5)	0.684
35-55	53 (43.8)	68 (56.2)	121 (39.9)	
≥55	69 (48.9)	72 (51.1)	141 (46.5)	
Level of education				
Illiterate	39 (44.8)	48 (55.2)	87 (28.7)	0.332
Primary	91 (46.2)	106 (53.8)	197 (65.0)	
Secondary	12 (63.2)	7 (36.8)	19 (6.3)	
Time of residing				
<10 year	11 (42.3)	15 (57.7)	26 (8.6)	0.626
≥10 year	131 (47.3)	146 (52.7)	277 (91.4)	
Drinking water sources				
Other	96 (51.9)	89 (48.1)	185 (61.1)	0.028
Village fountain	46 (39.0)	72 (61.0)	118 (38.9)	
Smoking status				
No	107 (45.3)	129 (54.7)	236 (77.9)	0.354
Yes	35 (52.2)	32 (47.8)	67 (22.1)	

*Column percent

Table 2. Comparison of Several Measurable Values between Participants from Group I and II

	Group I villages (mean±SH)	Group II villages (mean±SH)	p
BMI (kg/m^2)	28.50±5.70	27.94±5.20	0.373
Sistol blood pressure (mm/Hg)	128.37±19.08	132.01±19.46	0.103
Diastol blood pressure (mm/Hg)	77.23±12.75	79.64±11.88	0.091
Hair As (μg/g)	0.10±0.46	0.19±0.62	0.036
Blood As (μg/L)	3.04±8.79	4.22±9.42	0.010
CAI	257.53±249.57	819.59±552.56	0.001

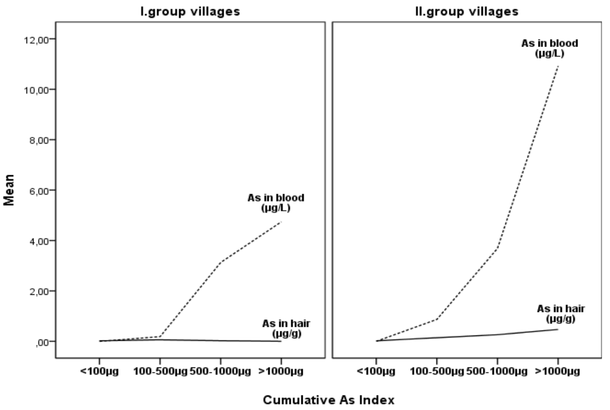

Figure 2. The Distribution of CAI by Hair and Blood Arsenic Levels in the Participants

Table 3. The Results of Multivariate Linear Regression Analysis Showing the Variables Associated with the hair and Blood Arsenic Levels in Participants from Group I and II

Log_{10} Hair As (μg/g)	Adj R^2	β	p
1.group villages	0.115		
CAI		0.336	<0.0001
2.group villages	0.185		
Age		0.200	0.028
CAI		0.390	<0.0001
Log_{10} Blood As (μg/L)			
1.group villages	0.152		
CAI		0.186	0.027
2.group villages	0.299		
CAI		0.431	<0.0001

Discussion

Exposure to deleterious and toxic elements such as arsenic continues to constitute a great risk for public health and environmental health in different regions of the world (Naujokas et al., 2013; Khan et al., 2003). This exposure occurs due to the human- or environment-related factors. Environment-related factors include volcanic activities and the nature of underground waters, whereas human-related factors are occupational exposure, wood protection, pesticides, smoking and use of contaminated food and fuels. Of the endemic regions for chronic arsenic exposure, geological structure has been found to be related to chronic exposure in countries including Bangladesh, Argentina, China, India and West Bengal, whereas mining or industrial activities were related to chronic exposure in Japan, Ghana and Thailand (Rim, 2013; Huang et al., 2014).

The main route of ingestion of inorganic exposure by adults is via the gastrointestinal system and mostly through water products (Sinha et al., 2003, Anetor et al., 2007; Jin-Yong et al., 2014). WHO has estimated that more than 200 million people are exposed to a high concentration of arsenic in drinking water (Argos et al., 2012).

As is in other regions of our country, Kutahya also includes some regions with rocks rich in arsenic due to its geological structure, resulting in a high concentration of arsenic in underground water sources. Unfortunately, in recent years, people living in these villages with high water arsenic concentrations continue to use these water sources, resulting in related environmental health problems and associated human health problems (Dogan et al., 2005; Gunduz et al., 2014).

The present study aimed to evaluate the status of water sources in the villages and health status in people living in these villages. The villages included in this study were divided into two groups according to the arsenic concentration in the water. The participants from these two groups had similar sociodemographic characteristics. The analysis of samples obtained from these water sources demonstrated concentrations higher than the acceptable upper limits set by the WHO (10 μg/L), although the concentrations were lower than those of previous measurements. This finding was attributed to the fact that the previous study was carried out in the summer when the rainfall rate is low, potentially resulting in high water concentrations of arsenic.

Previous studies have shown that chronic exposure to arsenic accumulates in keratinized tissues and results in typical symptoms including nail-skin disorders, hyperkeratosis, hyper pigmentation and dermatitis (Shankar et al., 2014).

The dermal effects due to arsenic exposure vary in various regions of the world. Water arsenic concentration has been found to be significantly associated with skin cancers in Argentina, Chile, US, China and Taiwan (Rodriguez-Lado et al., 2013). In countries with an arsenic concentration of <50 μg/L in drinking and tap water, the prevalence of arsenic-related skin lesions (hyperkeratosis/hyperpigmentation/melanosis) has been reported to be 21.6% in a cross-sectional study from Bangladesh (Ahsan et al., 2000) and 44% in Inner Mongolia, which found no significant correlation with the arsenic concentration in the water (Guo et al., 2006). In an Iranian study by Mosaferi et al, the prevalence of skin lesions was high despite decreasing concentrations of arsenic in the water sources (Moseferi et al., 2008). However, many previous studies on this topic lack data about the effects of previous exposures, leading to inadequate data about exact exposure levels (Ahsan et al., 2000; Guo et al., 2006; Moseferi et al., 2008; Smith et al., 2009; Udensi et al., 2011). In addition, some studies have also reported an increased prevalence of skin lesions even with exposure to water containing 5-10 μg/L arsenic (Yoshida et al., 2004).

Of the participants, 15.5% had arsenic-induced skin lesions, and this prevalence was higher in the participants from Group II villages. Because a latent period is required for skin lesions to develop, the effects and duration of arsenic exposure may be higher in these villages. Moreover, increased CAI value with increasing lesion prevalence also supports this presumption. In addition, the skin lesions included in the prevalence analysis in the present study were limited to arsenic keratosis and pigmentation disorders. Skin lesions were evaluated during field observations, and those with suspicious lesions were invited to the hospital outpatient clinic. Because further examinations of these patients are ongoing, these data were not included in the study.

Because the sample, methodology and units used for the calculation of arsenic concentration differed between the countries, numerous studies have reported that the result may be variable from country to country (Yoshida et al., 2004; Guo et al., 2006; Hall et al., 2006; Moseferi et al., 2008; Smith et al., 2009; Udensi et al., 2011). Hair arsenic concentration has been suggested to be a good indicator of chronic exposure, reflect total body arsenic concentration, and be beneficial in evaluating ongoing exposure (Cohen et al., 2006; Hall et al., 2006; Marchiset-Ferlay et al., 2012). A study from the Ballia region of India reported that blood arsenic levels increased proportionally with the exposure duration and water arsenic concentration (Katiyar et al., 2014). Accordingly, Mazumder et al. have suggested that although low, prolonged water and food arsenic concentration is correlated with urinary arsenic concentration (Mazumder et al., 2014). In a field study in Pakistan, hair and blood arsenic levels were found to be 0.034-0.319 μg/g and <0.5-4.2 μg/L, respectively (Kazi et al., 2009). Several previous studies have suggested that after drinking water with an arsenic concentration of 5-410 μg/L, blood arsenic levels increase to 2-41 μg/L, and normal hair and blood arsenic levels are <1 μg/g and <2 μg/L in those with no arsenic exposure (Marchiset-Ferlay et al., 2012). In addition, body arsenic concentration is affected by several biological factors including gender and age as well as from behavioral factors such as excess use of sea products and smoking/alcohol use. Because of prolonged exposure as well as decreased metabolism and increased susceptibility, arsenic concentrations may be higher in advanced age groups than in younger groups (Calderon et al., 2013).

In parallel to the above-mentioned results, we also found near-normal results for mean hair and blood arsenic levels. However, the positive relationship found with CAI also supports the presumption that arsenic concentration in the body increases with the increasing exposure time and dose. However, there was no significant exposure in the participants in terms of nutritional or agricultural activities. Because the major source of exposure in our region is underground water, we focused on the water sources for the environmental exposure. Many of the villagers were found to be aware of the contaminated water and have reported that their local administration had searched for new water sources in the past 2-3 years. All the villagers reported that they are using the available water sources for cleaning, cooking and other purposes. However, only 39% were using these sources for drinking. In Group II villages, the percentage of people using these available water sources to drink and the level of blood arsenic level were higher, suggesting that exposure is still ongoing.

In addition, epidemiological studies have found that the duration of low-moderate concentration of arsenic exposure correlates with blood pressure and chronic diseases (Li et al., 2013; Zhang et al., 2013).

Interestingly, the prevalence of chronic disease and rate of cancer-related death in the family were higher in the Group II villages. To accurately evaluate the exposure, at least a 10 year follow-up period is necessary from the first exposure time. Moreover, medical records are lacking for retrospective follow-up studies. In light of all this information, researchers plan to carry out a future cohort study including a follow-up and further evaluation of the participants.

There are several limitations in the study. Firstly; the main limitation of our study is that it was a cross-sectional design, data are provided about only the current situation. Follow-up studies are needed to explain the causality. Secondly; as is in all field studies, the number of female participants was higher than that of males. Thirdly; inexact recalls of the participants about their drinking water history may lead to inaccuracies in calculating the CAI.

To our knowledge, this is the first study determining the arsenic concentration in the body samples of people living in the villages with arsenic-rich underground water in our region.

In conclusion, chronic exposure to arsenic in water has resulted in skin lesions in one of every 6 people living in these villages. These lesions and arsenic concentrations in the body samples were found to increase with the water arsenic level and exposure time.

We hope that sharing the results of the present study with local administrators will contribute to accelerate the rehabilitation of water sources. It is very important to provide health education programs related to environmental exposures and protection from toxic elements.

Acknowledgements

Funding: This work was supported by a research grant funded by the Research Foundation of Dumlupinar University, Kutahya, Turkey (Ref.No: 2014/19). The authors thanks to staff at Dumlupinar University Advanced Technology Research Center for help. Conflict of interest: None

References

Ahsan H, Perrin M, Rahman A, et al (2000). Associations between drinking water and urinary arsenic levels and skin lesions in Bangladesh. *J Occup Environ Med*, **42**, 1195-201.

Anetor JI, Wanibuchi V, Fukushima S (2007). Arsenic exposure and its health effects and risk of cancer in developing countries: micronutrients as host defence. *Asian Pac J Cancer Prev*, **8**, 13-23.

Anwar M (2005). Arsenic, cadmium and lead levels in hair and toenail samples in pakistan. *Environ Sci*, **12**, 71-86.

Argos M, Ahsan H, Graziano JH (2012). Arsenic and human health: epidemiologic progress and public health implications. *Rev Environ Health*, **27**, 191-5.

Calderon RL, Hudgens EE, Carty C, et al (2013). Biological and behavioral factors modify biomarkers of arsenic exposure in a U.S. population. *Environ Res*, **126**, 134-44.

Chhabra D, Oda K, Jagannath P (2012). Chronic heavy metal exposure and gallbladder cancer risk in India, a comparative study with Japan. *Asian Pac J Cancer Prev*, **13**, 187-90.

Cohen SM, Arnold LL, Eldan M, Lewis AS, Beck BD (2006). Methylated arsenicals: the implications of metabolism and carcinogenicity studies in rodents to human risk assessment. *Crit Rev Toxicol*, **36**, 99-133.

Dogan M, Dogan A (2007). Arsenic mineralization, source, distribution, and abundance in the Kutahya region of the western anatolia, Turkey. *Environ Geochem Health*, **29**, 119-29.

Dogan M, Dogan AU, Celebi C, Baris YI (2005). Geogenic arsenic and a survey of skin lesions in Emet Region of Kutahya, Turkey. *Indoor-Built Environment*, **14**, 533-6.

Fasinu PS, Orisakwe OE (2013). Heavy metal pollution in sub-saharan africa and possible implications in cancer epidemiology. *Asian Pac J Cancer Prev*, **14**, 3393-402.

Gunduz O, Simsek C, Hasozbek A (2010). Arsenic pollution in the groundwater of simav plain, Turkey: Its impact on water quality and human health. *Water Air Soil Pollution*, **205**, 43-62.

Gunduz O, Bakar C, Simsek C, et al (2014). Statistical analysis of death causes (2005-2010) in villages with high arsenic levels in drinking water supplies of simav plain, Turkey. *Arch Environ Occup Health*, **70**, 35-46.

Guo X, Liu Z, Huang C, et al (2006). Levels of arsenic in drinking water and cutaneous lesions in Inner Mongolia. *J Health Popul Nutr*, **24**, 214-20.

Hall M, Chen Y, Ahsan H, et al (2006). Blood arsenic as a biomarker of arsenic exposure: results from a prospective study. *Toxicol*, **225**, 225-33.

Huang L, Wu H, van der Kuijp TJ (2014). The health effects of exposure to arsenic-contaminated drinking water: a review by global geographical distribution. *Int J Environ Health Res*, **3**, 1-21.

Jarup L (2003). Hazards of heavy metal contamination. *Br Med Bull*, **68**, 167-82.

Jin-Yong Chung, Seung-Do Yu, Young-Seoub Hong (2014). Environmental source of arsenic exposure. *J Prev Med Public Health*, **47**, 253-57.

Katiyar S, Singh D (2014). Prevalence of arsenic exposure in population of Ballia district from drinking water and its correlation with blood arsenic level. *J Environ Biol*, **35**, 589-94.

Kazi TG, Arain MB, Baig JA, et al (2009). The correlation of arsenic levels in drinking water with the biological samples of skin disorders. *Sci Total Environ*, **407**, 1019-26.

Khan MMH, Sakauchi F, Sonoda T, Washio M, Mori M (2003). Magnitude of arsenic toxicity in tube-well drinking water in bangladesh and its adverse effects on human health including cancer: evidence from a review of the literature. *Asian Pac J Cancer Prev*, **4**, 7-14.

Li X, Li B, Xi S, et al (2013). Prolonged environmental exposure of arsenic through drinking water on the risk of hypertension and type 2 diabetes. *Environ Sci Pollut Res*, **20**, 8151-61.

Marchiset-Ferlay N, Savanovitch C, Sauvant-Rochat MP (2012). What is the best biomarker to assess arsenic exposure via drinking water? *Environ Int*, **39**, 150-71.

Mazumder DN, Deb D, Biswas A, et al (2014). Dietary arsenic exposure with low level of arsenic in drinking water and biomarker: a study in West Bengal. *J Environ Sci Health A Tox Hazard Subst Environ Eng*, **49**, 555-64.

Moseferi M. Yunesian M, Dastgiri S, Mesdaghinia A, Esmailnasab N (2008). Prevalence of skin lesions and exposure to arsenic in drinking water in Iran. *Sci Total Environ*, **390**, 69-76.

Naujokas MF, Anderson B, Ahsan H, et al (2013). The broad scope of health effects from chronic arsenic exposure: update on a worldwide public health problem. *Environ Health Perspect*, **121**, 295-302.

Rim KT (2013). Occupational cancers with chemical exposure and their prevention in Korea: a literature review. *Asian Pac J Cancer Prev*, **14**, 3379-91.

Rodrigues JL, Batista BL, Nunes JA, et al (2008). Evaluation of the use of human hair for biomonitoring the deficiency of essential and exposure to toxic elements. *Sci Total Environ*, **405**, 370-6.

Rodríguez-Lado L, Sun G, Berg M, et al (2013). Groundwater arsenic contamination throughout China. *Science*, **341**, 866-68.

Samanta G, Sharma R, Roychowdhury T, Chakraborti D (2004). Arsenic and other elements in hair, nails, and skin-scales of arsenic victims in West Bengal, India. *Sci Total Environ*, **326**, 33-47.

Sela H, Karpas Z, Cohen H, Tal A, Zeiri Y (2013). Trace element concentration in hair samples as an indicator of exposure of population in the Negev, Israel. *Biol Trace Elem Res*, **155**, 209-20.

Sinha D, Roy M, Dey S, Siddiqi M, Bhattacharya RK (2003). Modulation of arsenic induced cytotoxicity by tea. *Asian Pac J Cancer Prev*, **4**, 233-7.

Smith AH, Steinmaus CM (2009). Health effects of arsenic and chromium in drinking water: recent human findings. *Annu Rev Public Health*, **30**, 107-22.

Shankar S, Shanker U, Shikha (2014). Arsenic contamination of groundwater: a review of sources, prevalence, health risks, and strategies for mitigation. *Sci World J*, **2014**, 304524.

Udensi UK, Graham-Evans BE, Rogers CS, Isokpehi RD (2011). Cytotoxicity patterns of arsenic trioxide exposure on HaCaT keratinocytes. *Clin Cosmet Investig Dermatol*, **4**, 183-90.

Yoshida T, Yamauchi H, Fan Sun G (2004). Chronic health effects in people exposed to arsenic via the drinking water: dose-response relationships in review. *Toxicol Appl Pharmacol*, **198**, 243-52.

Zhang C, Mao G, He S, et al (2013). Relationship between long-term exposure to low-level arsenic in drinking water and the prevalence of abnormal blood pressure. *J Hazard Mater*, **262**, 1154-58.