Correlation between Arsenic Concentration in Drinking Water and Human Hair

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ABSTRACT

Exposure to inorganic arsenic mainly occurs via drinking water, however because of potential changing of water sources during time, there is not consensus over the best route for assessment of past exposures to arsenic. At present study, we compared three potential sources of data in this regard. Thirty nine human hair samples were taken from persons residing in three villages of Bijar city in Kurdistan province of Iran with different drinking water sources and different levels of arsenic. All the subjects were female and at least one gram of scalp hair was gathered from the distal part of participants' hair. Samples were analyzed using Neutron Activation Analysis method. Arsenic concentration of water samples were measured using Silver Diethyl Ditiocarbomate Method (SDDC) and the total intake of arsenic through drinking water were calculated for each participant. According to results, arsenic content of drinking water ranged from 0 to 0.455 mg/l (average: 0.18). The figures for arsenic concentration in hair were from 0.012 to 3.41 mg/kg (average: of 0.53) and for calculated total intake from 0 to 8.9g (average: 2.02). A close relationship between calculated total intake via drinking water and arsenic concentration in hair (R=0.711, $P<0.001$) was obtained and also relationship between current arsenic content of drinking water and arsenic concentration in hair (R= 0.662, $p<0.001$). Using age as a covariate did not alter the results.

Keywords: *Arsenic, Hair, Drinking water, Neutron activation analysis*

INTRODUCTION

Arsenic is a common contaminant in natural water resource and a challenge for the scientists. Its presence in water has been reported in recent years from several parts of the world, like USA, China, Chile, Bangladesh, Taiwan, Mexico, Argentina, Poland, Canada, Hungary, Japan, India, Vietnam, Nepal (Jain et al., 2000; and Jack et al., 2003) and more recently from Iran (Mosaferi et al., 2003).Inorganic arsenicals have been classified as group I carcinogens based on human epidemiological data (IARC, 1987). The general features of chronic arsenic poisoning include malaise, weakness, general debility, decreased appetite, and often substantial weight loss up to 10 or 15 kg, also peripheral neuropathy. More specific features include the typical raindrop pigmentation of the skin

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and hyperkratosis of the palms of the hands and the soles of the feet, including the typical arsenic corns (Hindmarsh, 2002). For many years, scientists have used blood, urine, hair and nail samples as biomarkers for detection of arsenic in human. Hair has a long history in human studies of revealing chronic exposure to arsenic and can provide useful information in chronic arsenic poisoning. Because hair is biologically stable, accurate assays can be performed on hair with hundreds of years old (Pangborn, 2004). However external contamination of the hair by arsenic must be excluded for this diagnosis to be made and this often is not possible (Hindmarsh, 2002). In comparison with other parts of the body, arsenic is normally found in higher concentrations in human hair and also nails. This has been explained by the high content of keratin in these tissues (Shapiro, 1967). Although human nails and hair have similar affinities for arsenic, but hair is more convenient to sample analysis than nails, and can identify chronic arsenic poisoning (Hindmarsh et al., 1999). Several problems confront the toxicologist when using this test: there is only a very approximate relationship between hair arsenic concentration and arsenic toxicity. Thus, patients with chronic arsenic poisoning may have hair, concentrations varying, from 10-100 mg arsenic/kg hair whereas levels of around 45 have been reported in arsenic related fatalities (Hindmarsh, 2002).

Our past studies showed that the water sources of some villages of Bijar were naturally contaminated with arsenic and inhabitants of these villages had been exposed to arsenic via consumption of unsafe drinking water for a long period of time. We wondered if in hair arsenic could be used as a good proxy for total life arsenic intake (via drinking water) and thus we conducted this study.

MATERIALS AND METHODS

Thirty nine human hair samples were taken from persons residing in three villages of Bijar city in Kurdistan province of Iran with different drinking water sources and different levels of exposure to arsenic via drinking water, 13 samples from each village. The first village had not arsenic in its drinking water and was considered as not exposed. The second was exposed to low level of arsenic, and the third one had high levels of arsenic in its drinking water sources for many years but the exposure was eliminated since 4 years ago. The samples were collected randomly from female inhabitants of the selected villages and at least one gram of scalp hair was gathered from the distal parts of participant's hairs. Neutron Activation Analysis (NAA) was employed to determine arsenic content in samples using irradiation facility of Isfahan Minyator Reactor.

Drinking water samples were analyzed through Silver Diethyldithiocarbomate Method (SDDC) for arsenic levels. Total lifetime intake of arsenic from drinking water sources (g) for each person was calculated using formula: $\Sigma \alpha_i d_i$ with assuming 2 liters per capita per day (LPCD), where:

a_i = arsenic content of the i_{th} water source that has been used by any given participant;

and d_i = duration of usage of the i_{th} water source by any given participant.

RESULTS

Thirty nine female participants were involved in this study. The age of the participants ranged from 11 to 74 years (mean 32± 17) and the residence duration varied from 2 to 74 years. There was not any statistically significant difference between age (P= 0.49) and residence duration (P= 0.29) of different villages. Table 1 shows arsenic mean concentrations of drinking water sources of the three villages. Each number is the annual average of arsenic concentration in drinking water. As shown in this table the, values ranged from 0 to 0.455 mg/l. Table 2 shows the arsenic content in hair samples and total life intake in each participant. Table 3 shows more details about arsenic concentration of hair and water samples in each exposure level.

Fig.1 shows the consistency between the arsenic concentration in hair and total life intake. There was a close relationship between hair arsenic and total arsenic intake via drinking water (pearson correlation coefficient=0.711,$P<0.001$ Fig. 2). Also the relationship between current arsenic content of drinking water and arsenic concentration in hair ($P<0.001$, Fig. 3) was statistically significant.

Total arsenic intake via drinking water increased by 2.69g and its 95% confidence interval (95% CI) ranged from 1.80-3.59 for each mg increase in hair arsenic, and this was not affected by the age of participants (Tables 4 and 5).

Table 1: Mean concentration of arsenic in water resources of studied villages (Each concentration is equal to annually average concentration of water resource)

Village	Concentration (mg/L)
Najaf- Abad	0.0
Gheshlaghnoruz	0.085
Gavandak	0.455
Mean	0.180

Table 2: Age, residence time, total life time intake and concentration of arsenic in hair samples

Case No.	Age (Y)	Residence time in village (Y)	Total life time intake* (g)	Hair arsenic conc. (mg/kg)	±Erorr
1	58	58	0.0000	<0.012	0.000
2	14	14	0.0000	0.039	0.004
3	34	18	0.0000	0.044	0.004
4	22	22	0.0000	0.021	0.002
5	50	50	0.0000	0.055	0.006
6	74	74	0.0000	0.042	0.008
7	50	50	0.0000	0.090	0.007
8	12	12	0.0000	0.230	0.010
9	13	13	0.0000	0.051	0.004
10	45	45	0.0000	<0.026	0.000
11	50	30	0.0000	0.120	0.010
12	21	21	0.0000	0.030	0.004
13	32	32	0.0000	0.066	0.004
14	11	11	0.6205	0.300	0.020
15	62	62	0.3103	0.160	0.020
16	11	11	0.6205	0.061	0.004
17	13	13	0.6205	0.440	0.020
18	21	21	0.6205	0.560	0.030
19	32	32	0.3103	0.023	0.004
20	29	29	0.3103	1.090	0.080
21	50	50	0.6205	0.310	0.050
22	15	15	0.6205	0.280	0.030
23	18	18	0.6205	0.032	0.003
24	14	14	0.6205	0.230	0.010
25	61	61	0.6205	0.170	0.010
26	35	35	0.6205	0.280	0.020
27	30	30	6.7420	1.680	0.070
28	47	47	8.9000	1.510	0.070
29	16	16	4.3180	0.680	0.040
30	22	3	2.2240	0.570	0.030

Table 2: Continued…

31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32	29	2	0.0000	1.210	0.070
33	16	16	4.3180	0.130	0.010
34	50	30	6.8870	0.480	0.020
35	34	34	7.1800	0.580	0.030
36	23	23	5.7560	0.910	0.070
37	39	39	7.7300	3.410	0.030
38	54	22	5.8700	1.450	0.060
39	18	18	4.9820	1.120	0.030
Mean	31.9	28.4	1.9700	0.540	0.030

* Calculated from drinking water only

Table 3: Age, residence time, and concentrations of arsenic in samples (water supplies, hair samples; and total arsenic intake via drinking water)

Exposure status	Mean age	Mean residence time	Water arsenic conc.(mg/l)	Total arsenic intake via drinking water (g)				Hair arsenic (mg/kg)			
				Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
No exposure (0 mg/l)	36.5	33.8	0.00	0.00	0.00	0.00	0.00	0.06	0.057938	0.01	0.23
Low level chronic exposure (0.085 mg/l)	28.6	28.6	0.09	0.55	0.14	0.31	0.62	0.30	0.28	0.02	1.09
High level interrupted exposure (0.455 mg/l)	30.5	22.9	0.46	5.38	2.37	.00	8.90	1.24	0.89	0.13	3.41

Table 4: Regression of total arsenic intake from drinking water and hair arsenic content

	Unstandardized Coefficients B	Sig.	95% Confidence Interval for B	
			Lower Bound	Upper Bound
(Constant)	0.270	0.712	-1.201	1.742
Hair arsenic content (mg arsenic/kg hair)	2.693	0.000	1.797	3.589
Age in year	0.008	0.667	-0.030	0.046

R square = 0.51

Table 5: Arsenic content of hair by age different groups

Age group	No.	Mean	S. D	*P* value
≤15 years	9	0.30567	0.333383	
16-25 years	9	0.59478	0.760002	
26-45 years	10	0.84090	1.077748	0.41
46-55 years	7	0.57357	0.636623	
≥56 years	4	0.09600	0.080713	
Total	39	0.53621	0.736950	3.410

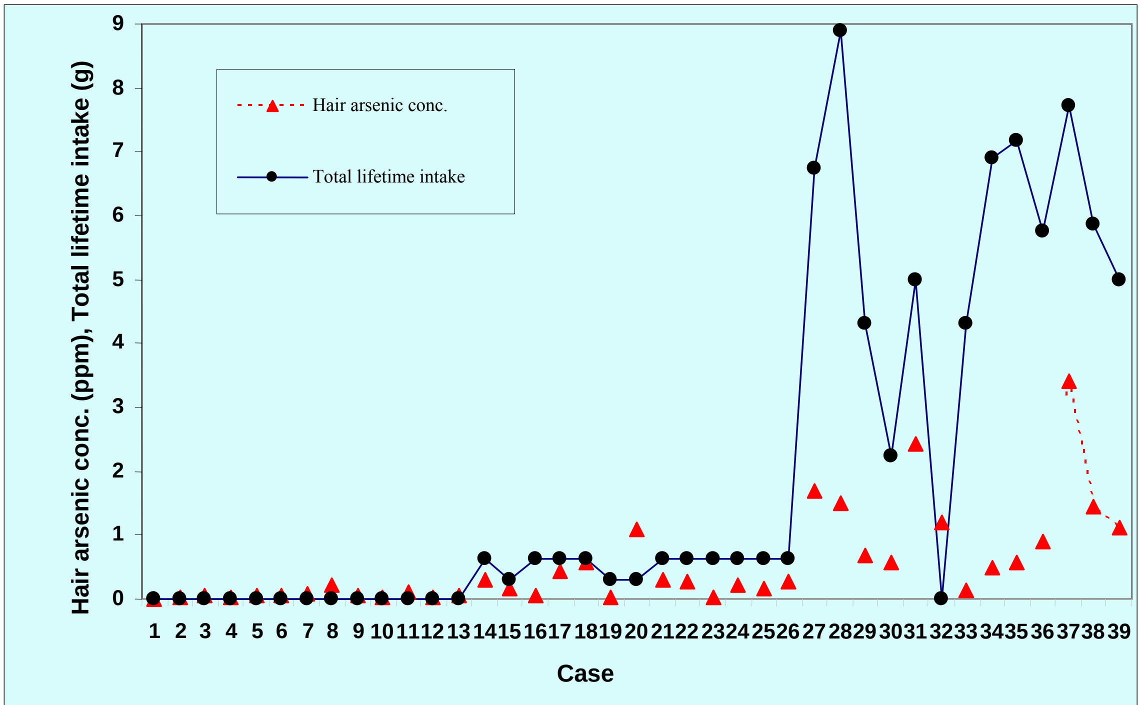

Fig. 1: Consistency of arsenic concentration in hair samples and total life intake in each participant

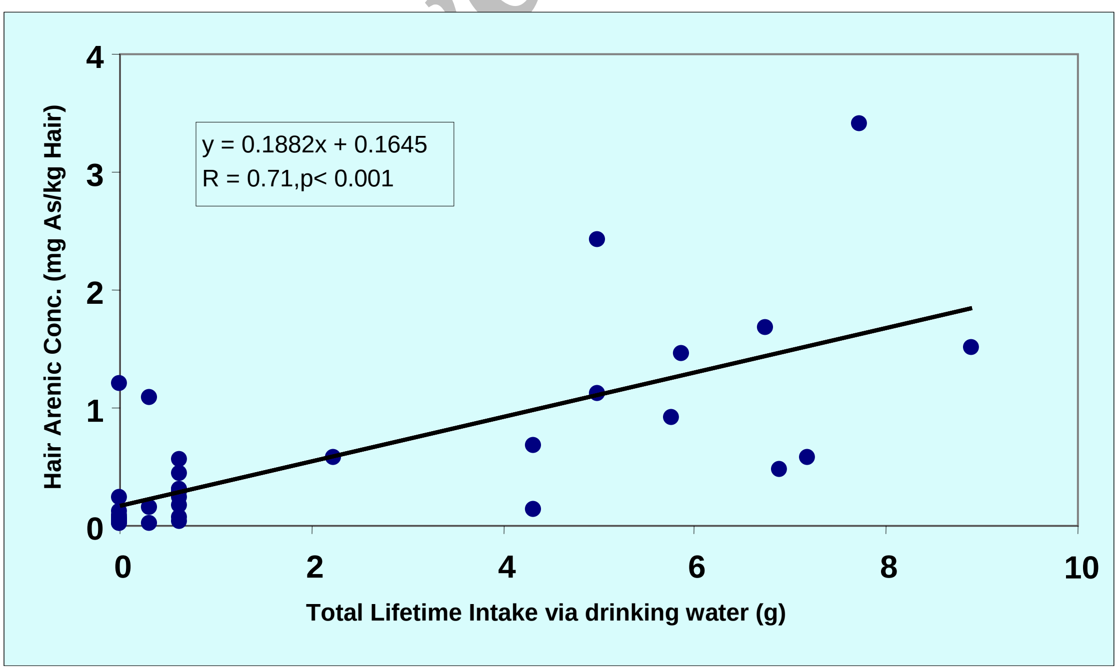

Fig. 2: Arsenic concentration in hair vs. total arsenic intake via drinking water

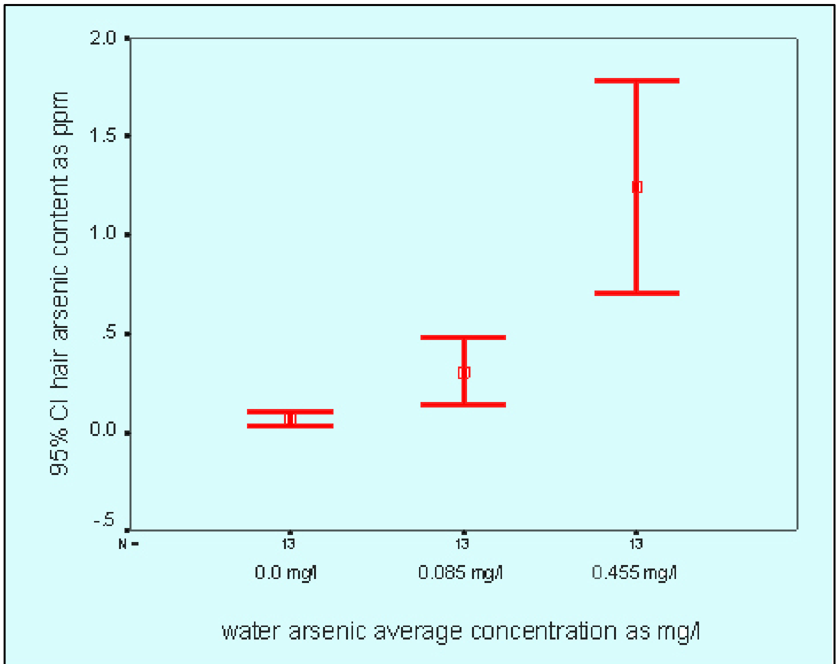

Fig. 3: Distribution of arsenic concentration of hair samples in different exposure groups

DISCUSSION

In a clean environment, the normal level for hair arsenic concentration is, not surprisingly, often less than in a contaminated location. In people with no known exposure to arsenic the concentration of arsenic in hair is generally 0.02-0.2 mg/kg (Valentine et al., 1979; Olguin et al., 1983; Narang et al., 1987; Takagi et al., 1988; Koons and Peters 1994; Wang et al., 1994; Wolfsperger et al., 1994; Vienna et al., 1995; Paulsen et al., 1996; Raie 1996; Rogers et al., 1997; Kurttio et al., 1998). The concentrations of arsenic in hair are clearly increased in people consuming drinking water with high arsenic concentration. Our study showed a close relationship between arsenic concentration in hair and total lifetime intake (via ingestion of contaminated water). Also the correlation between arsenic concentration of drinking water and arsenic concentration in hair was statistically significant. There are many studies that support our findings. For example, concentrations ranging from 3 to 10 mg/kg were reported commonly in people in areas in West Bengal that had high arsenic concentrations in drinking water (Das et al., 1995). On a group basis, a few reports indicated that the correlation between the concentration of arsenic in drinking water and the concentration in hair is fairly good, although it is not known how much of the arsenic in hair originates from arsenic in blood and how much is bound due to external contact with the water, as discussed above. Whatever the explanation, our findings showed that hair arsenic concentration can be used as a good proxy for chronic arsenic ingestion via drinking water. However in some cases, there is no accordance between hair arsenic content and total life intake (e.g. case No. 32). The most probable explanation of this finding is that of external contamination due to using contaminated water for washing purposes.

In studies carried out in California and Nevada, a concentration of 400 µg/l in drinking water corresponded to about 1.2 mg arsenic/kg of hair and 100 µg/l in water corresponded to about 0.5 mg arsenic/kg in hair (Valentine et al., 1979). In Alaska, an average of 400 µg/l in drinking water corresponded to 3.3 mg/kg in hair (Harrington et al., 1978). In Hungary, people with drinking-water concentrations ranging from 50 to 100 µg/l, had an average hair concentration of 3 mg/kg (Borzsonyi et al., 1992). In this study we found that each 100 µg/l increase in water content of arsenic corresponded to 0.26 mg arsenic/kg of hair as an average. Grantham and Jones (1977) found the highest hair arsenic concentrations in children while we did not see any significant relation between age and hair arsenic. Goldsmith et al (1972) in a study of 98 subjects drinking water with arsenic content varying from 10µg/l to 1.4 mg/l, concluded that hair arsenic elevated above 0.4 mg/kg dry weight when drinking water arsenic exceeded 50 µg/l, and this has been supported by other studies(Valentine et al., 1979). Our findings (0.3 mg arsenic/kg hair in people exposed to 0.085 mg/l water arsenic) are concordant with these results. Hindmarsh (1977) in the relatively pristine environment of Nova Scotia, Canada, found normal hair arsenic levels to be less than 1 mg/kg. Saad et al. (2001), showed that arsenic level of hair samples of apparently healthy Egyptian ranged between 0.04 and 1.04 mg As/kg hair, and about 55% of the analyzed samples were within the range of allowable values (0.08- 0.25 mg As/kg hair). However, Liebscher and Smith (1968) reported a range of 0.02 to 8.17 mg/kg in 1250 hair samples from persons living in the industrial city of Glasgow, Scotland. Sky-Peck (1990) obtained similar results when he analyzed 987 hair samples from residents of Chicago in 1980s. Levels of up to 10 mg/kg have been found in the hair of children living downwind from an electric power plant burning arsenic contaminated soft coal (Hindmarsh, 2002). Pazirandeh et al. (1998) in a study conducted in the west of Iran (our study region but in a different polluted village) analyzed 60 hair samples collected from three groups of people (the first group not exposed, the second exposed but healthy and the third exposed with signs of chronic arsenic poisoning from the same village) by using Neutron Activation Analysis (NAA).

According the results of this study, arsenic concentration of hair can be used as a good measure of past exposure to arsenic via drinking water. As the same water source is used for both drinking and hygienic purposes, extrinsic contamination of hair with arsenic is not a major concern in our communities.

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