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Arsenic Health Risk Assessment through Groundwater Drinking (Case Study: Qaleeh Shahin Agricultural Region, Kermanshah Province, Iran)

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ABSTRACT: Groundwater resources make up an important portion of potable and irrigation water in Iran, making it important to monitor toxic elements of pollutants in these resources in order to protect the inhabitants' health. The current study has been carried out to assess the health risks, caused by trivalent inorganic arsenic-polluted groundwater in Qaleeh Shahin Plain, an important agricultural region in Kermanshah Province. For this purpose, in total 20 groundwater wells have been chosen randomly. The samples have been filtered (0.45 μm) and preserved with HNO_3 to a pH level lower than 2, then to be taken in acid-washed polyethylene bottles and kept at a temperature of 4 °C for further analysis. Finally, As(III) concentration has been determined, using ICP-OES with three replications. Results have shown that mean content of As (ppb) in groundwater samples were 6.0 ± 3.0 for winter and 9.0 ± 6.0 for summer in 2014. Also, according to the results, the computed values of the hazard quotient (HQ) and target risk (TR) of groundwater samples were below 1 and less than 10E-06, respectively; therefore, non-carcinogenic effect (chronic risk) and carcinogenic exposure are not likely for the inhabitants of this study area. However, due to over and long-term use of agricultural inputs in the study area, it is recommended to have some paramount consideration for better management and care of using agricultural inputs, especially chemical fertilizers, arsenical pesticides, or herbicides, and for treatment of As-polluted groundwater with proper removal methods prior to preparation of drinking water.

Keywords: inorganic arsenic, potable water, health risk, agricultural inputs

INTRODUCTION

Nowadays, contamination of drinking water with different hazardous chemicals, such as pesticides, trace elements (particularly the so-called heavy metals), pharmaceuticals, and polycyclic aromatic hydrocarbons released from different anthropogenic sources (e.g., urbanization, unprecedented population growth, mining, and industrialization) have become a global concern (Chen, 2002; Rapant and Krcmova, 2007; Velea et al., 2009; Nasrabadi et al., 2010). Therefore, contamination of surface and groundwater resources leads to important environmental and human-health-related issues (Emmanuel et al., 2009; Muhammad et al., 2011; Khan et al., 2013).

Arsenic, in both its organic and inorganic species, is hazardous and toxic metalloids in nature, classified under group A of hazardous components by USEPA. It is known as a human carcinogen element. Presence or discharge of As in the drinking water resources from both geo-genic and

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anthropogenic sources (Bissen and Frimmel, 2003; Baig et al., 2009). Arsenate (AsO_4^{-3}) and arsenite (AsO_3^{-3}) is the most common inorganic species of As present in natural water system, considered more toxic than organic species of this element (Hall et al., 1999; Bissen and Frimmel, 2003; Pizarro et al., 2003; Lim et al., 2007).

Long-term exposure to As especially through drinking contaminated water can cause serious health problems, such as increased potentiality for lung, liver, kidney, bladder, and skin cancer, gangrene, hypertension, melanosis, hyperkeratosis, skin lesion, and peripheral vascular disease (Josef et al., 2007; Fatmi et al., 2009; Nguyen et al., 2009; Rahman et al., 2009; Muhammad et al., 2011).

Additionally, through contamination of surface and groundwater resources, Arsenic can also enter food chains, especially agricultural products (Arain et al., 2009; Rahman et al., 2009). Of course, the content of As in drinking water has been used to compute the potential health risk assessment including Daily Intake (DI), HQ, and TR (Nguyen et al., 2009; Kavcar et al., 2009). In the literature review, Liang et al. determined chronic poisoning health risks from drinking As-polluted water in the Pingtung Plain, Taiwan (Liang et al., 2016). Rasool et al. reported the health effects of chronic As exposure through consumption of groundwater resources in Punjab, Pakistan (Rasool et al., 2016). Also, Singh and Ghosh worked on the health risk via consumption of As-contaminated groundwater in Patna district, India (Singh and Ghosh, 2012). In another study, Muhammad et al. computed the health effects of chronic arsenic exposure from drinking groundwater in northern Pakistan (Muhammad et al., 2011).

Nowadays, more than 50% of world population, especially residents in arid regions, are dependent on groundwater for drinking or other usages (e.g., agricultural and industrial activities). Therefore, as human welfare is directly linked to water quality, the health risk assessment from drinking contaminated water is a vital concern for mankind (Rasool et al., 2016).

Groundwater is one of the major sources of drinking water in the study area and thus it is important to assess the quality of groundwater with respect to contaminants. In this regard, the present study has been carried out to assess the health risk of As(III) through drinking groundwater resources of Qaleeh Shahin Plain during winter and summer in 2014, based on the hazard quotient and target risk.

MATERIAL AND METHODS

The study was conducted in southeast Sarpol-e Zahab Township in Kermanshah Province, west of Iran. Qaleeh Shahin aquifer and irrigated farming in this region are 190 km^2 and 25 km^2 vast, respectively (Nazari and Sobhanardakani, 2015; Sobhanardakani and Nazari, 2016; Yari and Sobhanardakani, 2016)

In this study, according to the Cochran's sample size formula, groundwater samples were collected from 20 wells, distributed at different locations of Qaleeh Shahin Plain, based on different land use patterns, like agricultural and residential areas, in winter and summer of 2014. Figure 1 illustrates the sampling stations. The samples were taken in acid-washed 200 ml polyethylene bottles to avoid unpredictable changes in character as per standard procedures. The collected samples were filtered (Whatman no. 42), preserved with 6N of nitric acid (supra pure Merck, Germany), and keep at a temperature of 4 °C for further analysis (Sobhanardakani, 2016; Yari and Sobhanardakani, 2016). The analysis of As(III) content in water samples was performed using ICP-OES (Varian, 710-ES, Australia) with three replications at a wavelength of 188.98 nm. To check the accuracy of the analytical method, arsenic standard solution for ICP (Sigma-Aldrich, Germany) with different contents (0 ppb, 5 ppb, 10 ppb, 15 ppb, and 25 ppb) of this element was used for calibration.

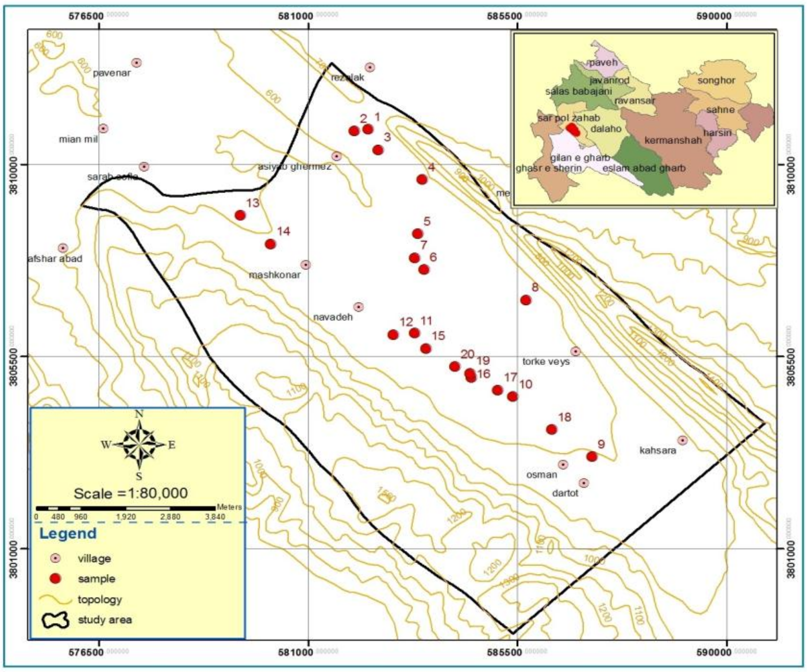

Fig 1. Map of the sampling stations

For calculating the Daily Intake of As(III), according to Equation 1, the model derives by the US EPA was used (Liang et al., 2016):

$$DI = \frac{Cw \times IR}{Bw} \quad (1)$$

Where DI stands for daily intake of As (mg/kg/day), with C_w and IR representing the content of As(III) in the groundwater (ppm) and daily water intake rate of an adult (1.5 l/day), respectively. Also, the B_w is the body weight (70 kg).

The study calculated Hazard Quotient for health risk assessment of non-carcinogenic exposure effects. In other words, HQ refers to the ratio of the potential exposure to a pollutant level at which no adverse health effects are expected according to Equation 2:

$$HQ = \frac{DI}{RfD} \quad (2)$$

Where RfD represents the oral reference dose of As (0.0003 mg/kg/day) (Liang et al., 2015). In this context, if HQ is above 1, a non-carcinogenic effect is considered to be possible. Also, if the calculated HQ is below 1, no adverse health effects are expected as a result of exposure to As.

Health risk from carcinogenic exposure was computed as a Target Risk (TR) that indicated that excess probability of contracting cancer over a lifetime of 70 years. The target risk was computed according to Equation 3:

$$TR = \frac{DI \times EF \times ED \times CSF}{AT} \times 10^{-3} \quad (3)$$

In which EF and ED represent the exposure frequency (365 days) and exposure duration (30 years), respectively. CSF indicates the cancer slope factor (1.5 mg/kg/day); and AT is the average time for carcinogen during 70 years (25,550 days). Also, 10E-03 is a conversion factor. In this regard, if TR is less than 10E-06, the health risk of carcinogenic exposure is accepted (Liang et al., 2016).

The statistical analysis of the obtained results consisted of a first Kolmogorov-Smirnov test for normality, followed by the study of the variance homogeneity, using a One-way ANOVA. The statistical analyses were done using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA) statistical package.

RESULTS AND DISCUSSION

Table 1 gives As(III) contents in the groundwater samples, whose data show that all groundwater samples were contaminated with As(III). Among the analyzed samples, As (ppb) was seen to range from 1.0 to 10.0 for winter and from 2.0 to 23.0 for summer.

Comparing As(III) contents in the analysis of groundwater samples with Maximum Permissible Limits (MPL) (10.0 ppb) has been provided by WHO (Hudson-Edwards et al., 2005; Singh et al., 2014; Sobhanardakani et al., 2014), indicating that the mean content of As(III) in all samples, collected from winter and summer seasons was lower than MPL.

In addition, the HQ values of As(III) in the groundwater samples, collected during both winter and summer seasons, were found less than 1, just as the TR values of this element in all groundwater samples were within the safe limits (TR < 10E-06).

Table 1. Concentration of trivalent As (ppb) in groundwater samples, collected from Qaleeh Shahin Plain in winter and summer seasons

Station	Winter	Summer
1	2.0	4.0
2	10.0	5.0
3	6.0	10.0
4	6.0	4.0
5	9.0	23.0
6	7.0	7.0
7	4.0	20.0
8	4.0	2.0
9	1.0	8.0
10	7.0	10.0
11	2.0	12.0
12	10.0	7.0
13	2.0	5.0
14	8.0	13.0
15	6.0	20.0
16	9.0	5.0
17	6.0	7.0
18	10.0	8.0
19	10.0	2.0
20	4.0	7.0
Mean ± S.D.	6.0 ± 3.0	9.0 ± 6.0

Table 2. Non-carcinogenic and carcinogenic health risk of As(III) from drinking groundwater

Season	DI (mg/kg/day)	TR	HQ
Winter	1.37E-04	8.81E-08	0.46
Summer	1.97E-04	1.27E-07	0.66

As one of the vital natural resources, water has been used for domestic, drinking, industrial, and irrigation purposes. People around the world, especially in dry and semi-dry regions, have used groundwater as a source of drinking water or other purposes such as irrigation and domestic usages. In this regard, it is important to note that almost 90% of the required water of Iran is provided from groundwater resources (Sobhanardakani et al., 2016). Therefore, it is very important to assess the groundwater quality for protection of the consumer health.

The chronic health hazards of As poisoning differs among individuals, populations, and geographic areas. The geographic variations can be attributed to differences in As levels of drinking water, quantities of water consumption, anthropometric characteristics (weight and height), and the starting age and duration of exposure to As-containing resources, including the drinking water, itself. Therefore, for variability of As content in groundwater, daily water intake rate and body weight are important required input parameters in the exposure and risk health models, presented in Equations (1) to (3) (Chen, 2014).

According to computed values of TR, the target risk values of the samples, collected in both winter and summer, were 8.81 E-08 and 1.27 E-07, respectively, being less than safety limits (10E-06); therefore, chronic poisoning health risks from drinking As-polluted water does not threaten residents of study areas. These findings were in opposition to those of Liang et al., who reported that about 48% of the inhabitants of Pingtung Plain in Taiwan were under chronic poisoning health risks from drinking As-polluted water (Liang et al., 2016).

Also, the results of another study showed that the mean values of HQ were greater than 1 and health effects of chronic As exposure occurred through consumption of groundwater resources in Punjab State, Pakistan (Rasool et al., 2016). Similar to previously mentioned studies, Singh and Ghosh reported that health risk occured through consumption of As-polluted groundwater in Patna district, India (Singh and Ghosh, 2012). The study of Singh et al. showed that the calculated Hazard Index (HI) in groundwater resources ranged from 0.9 to 10 and 10.40 to 40.47 for Vaishali and Bhagalpur, India, respectively (Singh et al., 2014). Also, Muhammad et al. found that since HQ value was below 1, there was no health effects of chronic As exposure from drinking the groundwater in Kohistan region, northern Pakistan (Muhammad et al., 2011). In another study Nguyen et al. reported that the 42% and 100% consumers of treated and untreated groundwater were under non-carcinogenic effect in Ha Nam province, Vietnam (Nguyen et al., 2009).

CONCLUSION

This study was conducted to provide information on trivalent inorganic arsenic contents in groundwater resources of the Qaleeh Shahin Plain, Kermanshah Province, Iran, using the ICP-OES. Results confirmed clear accumulation of As(III) in the analyzed groundwater samples. Based on these results, the mean concentration of As(III) in all samples, collected from the study area, was lower than MPL (10.0 ppb). Also, despite the fact that computed values of HQ and TR of groundwater samples from Qaleeh Shahin Plain were below 1 and less than 10E-06 respectively, non-carcinogenic effect (chronic risk) and carcinogenic exposure were crossed out for the inhabitants of this study area; however, due to overuse of agricultural inputs in the study area, it is recommended to have paramount consideration for managing the use of agricultural inputs, especially chemical fertilizers, arsenical pesticides, or herbicides, and for treatment of As-polluted groundwater with some proper removal methods prior to drinking the water.

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