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# Health Risk Assessment of Inorganic Arsenic Through Groundwater Drinking Pathway in some Agricultural Districts of Hamedan, West of Iran

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**Abstract**

Groundwater resources are an important portion of potable water in Hamedan Province, Iran. Therefore, monitoring the pollutants especially heavy metals in these resources are vital to protect the residents' health. This study aimed to assess the health risks caused by inorganic arsenic pollution through groundwater drinking pathway in four important agricultural areas of Hamedan Province, Iran. In so doing, a total of 180 groundwater wells were chosen randomly for sampling during the spring and summer seasons in 2015. The samples were filtered (0.45 µm), preserved with HNO3 at a pH level lower than 2, and stored in acid-washed polyethylene bottles at 4°C for further analysis. Finally, arsenic content was determined using inductively coupled plasma- optical emission spectrometry (ICP-OES). The results showed that the mean contents of arsenic (mg/L) in groundwater samples taken during the spring were 0.052 for Asadabad plain, 0.007 for Ghahavand plain, 0.006 for Razan plain, and 0.004 for Toyserkan Plain; whereas, the mean content in groundwater samples taken during the summer from Asadabad, Ghahavand, Razan, and Toyserkan plains were 0.058, 0.009, 0.007, and 0.004, respectively. Moreover, based on the computed values of the non-carcinogenic risk of groundwater samples from Asadabad plain, the hazard quotient (HQ) was greater than 1. Therefore, a non-carcinogenic effect is considered to be possible for the inhabitants of this study area. Accordingly, serious considerations including managing the use of agricultural inputs especially arsenical pesticides or herbicides and treatment of arsenic-contaminated groundwater with some proper methods before water ingestion are recommended.

**Keywords:** Arsenic, Water quality, Health risk, Agricultural areas

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## 1. Introduction

Although arsenic is a naturally and widely distributed metalloid occurring in environment (rocks, soil, air, and water), it is generally known as a toxicant and carcinogen (1-3). The pollution of water resources by some persistent organic pollutants especially heavy metals released from various sources as a consequence of industrialization and urbanization have been an increasing worldwide concern during the last few decades (4).

Arsenic levels in the subsurface environment result from both natural processes such as weathering of minerals, geothermal processes, and microbiological activities, and anthropogenic activities including non-ferrous metal smelting, mining activities, production of energy from fossil fuel, and use of arsenical pesticides in agriculture and wood preservation (1, 2, 5, 6). The presence of arsenic in groundwater resources was identified as a widespread fundamental issue (1). A review of the literature represents that exposure to arsenic can cause various types of adverse health effects including an endemic peripheral vascular disease known as blackfoot disease, cancers of the kidney, liver, prostate, bladder, lung, lymphoid tissue, colon, skin, and nasal cavity, ischemic heart disease, hyperkeratosis, hyperpigmentation, diabetes, and meningioma (3,7,8).

Water is a major ingredient required for every living organism on the Earth planet. In other words, life is not possible on the Earth planet without water. The world's 3% fresh water has been sufficient for meeting the requirements of human since the beginning of life on the Earth (4,9). Nowadays, the increase of contamination of the groundwater resources with heavy metals due to rapid urbanization, unplanned industrialization, mining and agricultural activities is one of the serious eventualities. Thus, determination of heavy metal levels in groundwater, taken for drinking purpose, is of great importance from the human health point of view (10-12).

Hamedan is basically known as an agricultural province. Groundwater exploitation has risen in the last

2 decades in this area due to climate change and hence extended drought. It is proven that in the regions with intensive agricultural activities, water quality degradation occurs due to the use of agricultural inputs such as chemical fertilizers and metal-containing pesticides, organic fertilizers, reuse of sewage sludge, and wastewater irrigation (13).

Considering the fact that the groundwater is the major reservoir for drinking and for general household use in the areas under this study, and owing to the geologic structure and characteristics of aquifers in the study areas especially the presence of minerals containing arsenic and fine grained deposits such as clay and silt, aquifer thickness, and extensive use of arsenical pesticides in agriculture (14-16), assessment of health risks of groundwater arsenic contamination is required for protecting the health of the residents. Therefore, the current study aimed to evaluate the health risks of drinking groundwater for residents of four important agricultural areas of Hamedan Province (Asadabad, Ghahavand, Razan, and Toyserkan plains), Iran, based on the hazard quotient (HQ) and target risk (TR).

## 2. Methods

### 2.1. Study Areas

All study areas are located in Hamedan, west of Iran. Asadabad plain with aquifer area about 962 $km^2$ and 1650 m above the sea level is located in southwest of Hamedan township. Water requirements including drinking water for residents of this area are supplied by 1148 wells, 416 springs, and 57 aqueducts. Razan-Ghahavand plain with aquifer area about 3084 $km^2$ is located in northeast of Hamedan Province. Water requirements for residents of this area are supplied by 1788 wells, 104 springs, and 96 aqueducts. Moreover, Toyserkan plain with an aquifer area about 805 $km^2$ is located in south of Hamedan township And water requirements of this area are supplied by 1610 wells, 280 springs, and 154 aqueducts (4,14,15).

### 2.2. Sampling and Sample Analysis

In this study, groundwater samples were collected from 30, 20, 20, and 20 wells which were distributed in different locations of Asadabad, Ghahavand, Razan, and Toyserkan plains, respectively, based on different land use patterns, including agricultural and residential areas during the spring and summer seasons in 2015, with three internal replicates. The sampling stations in the study areas are shown in Figure 1. The samples were taken in acid washed 200-mL polyethylene bottles to avoid unpredicted changes in characteristics as per standard procedures. The collected samples were filtered (Whatman no. 42), preserved with 6N of $HNO_3$ (Suprapur Merck, Germany), and kept at 4°C for further analysis (12, 17). The analysis of arsenic species in water samples was performed by

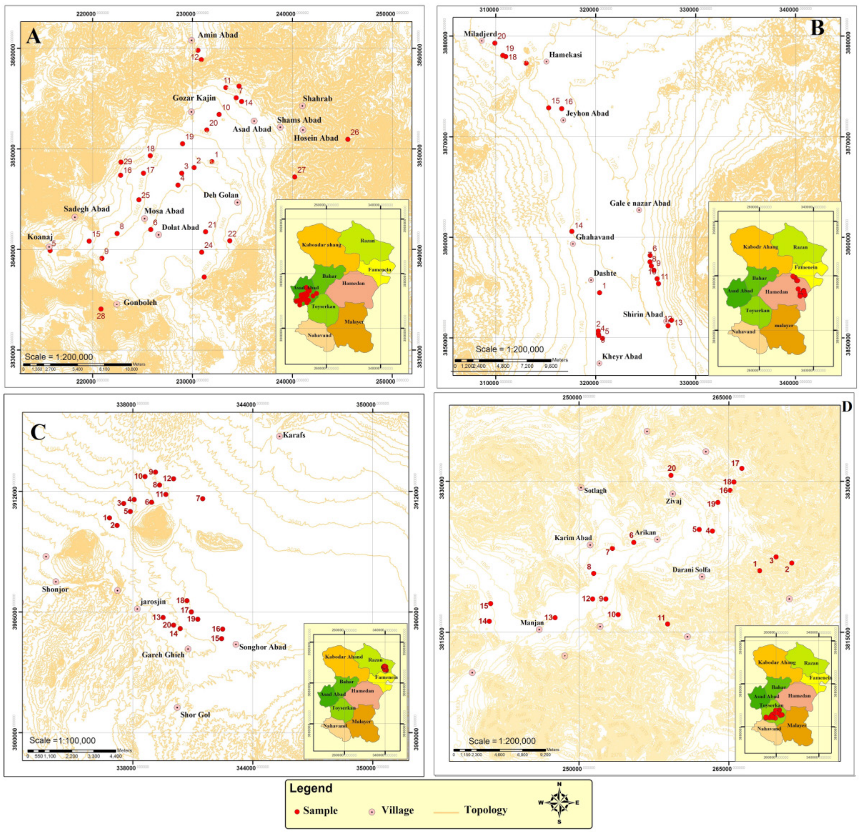


**Figure 1.** Map of Sampling Stations: (a) Asadabad Plain; b) Ghahavand Plain; (c) Razan Plain; (d) Toyserkan Plain

inductively coupled plasma mass spectrometry (Varian, 710-ES, Australia) in three replicates. The ICP-OES equipped with megapixel charge coupled device (CCD) detector arrays, providing the capability of simultaneous monitoring of arsenic emission, lies in the wavelength range between 177 and 260 nm. To check the accuracy of the analytical method, a multi-element standard solution (Merck, Germany) with different contents of arsenic (0, 5, 10, 15, 25 ppb) was used for the calibration.

## 2.3. Carcinogenic and Non-carcinogenic Health Risk Assessment

### 2.3.1. Calculation of Daily Intake of Arsenic

The daily intake of arsenic is computed based on the presented model derived from the US EPA using the equation 1 (3):

$$DI = \frac{C_w.IR}{B_w} \quad (1)$$

where DI and $C_w$ are the daily intake of arsenic (mg/kg/day) and arsenic level in groundwater (mg/L), respectively. IR is the daily water intake of an adult (1.5 L/day); and $B_w$ is body weight (70 kg).

### 2.3.2. Target Risk Model

Health risk for carcinogenic exposure was computed as a target risk which means excess probability of developing cancer over a lifetime of 70 years. The TR was calculated using the equation 2:

$$TR = \frac{DI.EF.ED.CSF}{AT} \times 10^{-3} \quad (2)$$

where EF and ED are the exposure frequency (day/year) and exposure duration (year), respectively. CSF represents the cancer slope factor (1.5 mg/kg/d); and AT is the average time of exposure to carcinogens during 70 years (25,550 day). In addition, $10^{-3}$ is a conversion factor and ED refers to the exposure frequency for 365 days per year over 30 years (i.e., EF × ED = 10950 day). In this regard, if TR < $10^{-6}$, the health risk for carcinogenic exposure is accepted (3).

### 2.3.3. Hazard Quotient Model:

The health risk for non-carcinogenic exposure was computed as a hazard quotient. HQ refers to the ratio of the potential exposure to a level at which no adverse health effect is expected. It is mathematically calculated using the equation 3:

$$HQ = \frac{DI}{RfD} \quad (3)$$

where RfD is the oral reference dose (0.0003 mg/kg/d) (18-20). In this regard, if the HQ >1, a non-carcinogenic effect is considered to be possible. Moreover, if the calculated HQ < 1, then no adverse health effect is expected as a result of exposure to arsenic.

### 2.4. Statistical Analysis

The obtained data were analyzed using Shapiro-Wilk test for normality, followed by ANOVA parametric test for the study of the variance homogeneity, a DMS post hoc test, and Duncan multiple range test. The statistical calculations were done using SPSS (SPSS Inc., Chicago, IL, USA) statistical package version 20.0.

## 3. Results and Discussion

The arsenic concentrations in the analyzed groundwater samples are presented in Table 1. According to Table 1, the percentage of contamination of groundwater samples with arsenic reached 100%. Based on the results, among the groundwater samples taken during the spring, arsenic (mg/L) was detected in the levels ranging from 0.02 to 0.076 with a mean level of 0.052 for Asadabad plain, 0.003 to 0.014 with a mean level of 0.0075 for Ghahavand plain, 0.001 to 0.012 with a mean level of 0.0059 for Razan plain, and 0.00008 to 0.0075 with a mean level of 0.0037 for Toyserkan plain. Whereas, among the analyzed groundwater samples taken during the summer, arsenic

**Table 1.** Arsenic Concentration (mg/L) in Groundwater Samples Collected From Asadabad, Ghahavand, Razan, and Toyserkan Plains

| Sampling Site | No. of Samples | Min. | Max. | Mean | S.D. |
|---|---|---|---|---|---|
| | | | Spring | | |
| Asadabad plain | 30 | 2.00E0-2 | 7.60E0-2 | 5.20E0-2b | 1.30E0-2 |
| Ghahavand plain | 20 | 3.00E0-3 | 1.37E0-2 | 7.50E0-3c | 1.20E0-3 |
| Razan plain | 20 | 1.10E0-3 | 1.20E0-2 | 5.90E0-3b | 7.00E0-4 |
| Toyserkan plain | 20 | 8.00E0-5 | 7.50E0-3 | 3.70E0-3a* | 2.23E0-3 |
| | | | Summer | | |
| Asadabad plain | 30 | 2.30E0-2 | 8.90E0-2 | 5.80E0-2c | 2.00E0-2 |
| Ghahavand plain | 20 | 2.25E0-3 | 1.72E0-2 | 9.00E0-3b | 4.00E0-3 |
| Razan plain | 20 | 2.83E0-3 | 1.00E0-2 | 7.00E0-3b | 2.00E0-3 |
| Toyserkan plain | 20 | 5.70E0-4 | 7.21E0-3 | 4.00E0-3a | 2.00E0-3 |

* The letters (a, b, c) represent the statistical difference between mean concentration of arsenic in groundwater samples based on the results of One-way ANOVA (*P* = 0.05).

(mg/L) was detected in the levels ranging from 0.023 to 0.089 with a mean level of 0.058 for Asadabad plain, 0.002 to 0.017 with a mean level of 0.009 for Ghahavand plain, 0.003 to 0.010 with a mean level of 0.007 for Razan Plain, and 0.0006 to 0.007 with a mean level of 0.004 for Toyserkan plain.

Comparing the arsenic concentrations in the studied groundwater samples with the maximum permissible limits (MPL) (0.01 mg/L), recommended by the WHO (21-23), indicated that except for the groundwater resources in Asadabad plain, the mean content of arsenic in all other samples was lower than the MPL.

In addition, all the calculated TR values of arsenic were within the safe limits (TR < $10^{-6}$). However, the values of HQ were found over 1 in the groundwater samples collected from Asadabad plain, while HQ values were less than 1 in other samples (Table 2).

Water as a natural resource has been used for different purposes, namely for domestic, drinking, industrial, and irrigation purposes. People around the world especially in arid and semi-arid regions have used groundwater as a source of drinking water, and even today more than 50% of the world's population depend on groundwater resources for survival. Regarding the fact that Iran is located in the arid regions, groundwater is an ideal supply of drinking water and thus almost 90% of the required water is secured through the use of groundwater resources (4). Therefore, assessment of the groundwater quality for protecting the consumers' health is of great importance.

It has been proved that the health hazards of chronic arsenic poisoning differ among populations, individuals, and geographical areas. The geographical variation can be attributed to differences in contents of arsenic in drinking water, differences in quantities of water consumption, differences in anthropometric characteristics including weight and height, as well as differences in the initial exposure and duration of exposure to arsenic-containing foodstuffs especially drinking water. Therefore, the variability of arsenic in groundwater, daily water intake, and body weight are the important required input parameters in the exposure and health risk models of equations (1) to (3) (24).

**Table 2.** Carcinogenic and Non-carcinogenic Health Risk of Arsenic From Ingestion of Groundwater

| Sampling Site | DI | TR | HQ |
|---|---|---|---|
| **Spring** | | | |
| Asadabad Plain | 1.11E-03 | 7.13E-06 | 3.70 |
| Ghahavand Plain | 1.61E-04 | 1.03E-06 | 0.54 |
| Razan Plain | 1.26E-04 | 8.10E-07 | 0.42 |
| Toyserkan Plain | 7.93E-05 | 5.10E-07 | 0.26 |
| **Summer** | | | |
| Asadabad Plain | 1.24E-03 | 7.97E-07 | 4.13 |
| Ghahavand Plain | 1.93E-04 | 1.24E-07 | 0.64 |
| Razan Plain | 1.50E-04 | 9.64E-08 | 0.50 |
| Toyserkan Plain | 8.57E-05 | 5.51E-08 | 0.28 |

Based on the computed values of TR, regarding TR < $10^{-6}$ (Table 2) for both spring and summer seasons, inhabitants in none of the study areas were therefore under health risks from chronic poisoning for drinking arsenic-contaminated water. These results disagreed the findings of Liang et al who reported that about 48% of the inhabitants of Pingtung Plain, Taiwan, were under health risks from chronic poisoning because of drinking arsenic-contaminated water (3). In another study, Rasool et al reported that since mean values of HQ were greater than 1, health effects of chronic arsenic exposure occurred through consumption of groundwater resources in Mailsi and Punjab, Pakistan (25). Likewise, Singh and Ghosh reported that health risk occurred due to the consumption of arsenic-contaminated groundwater in Patna district, India (26). Moreover, Singh et al revealed that the calculated ranges of the hazard index (HI) in groundwater resources of Bihar, India, were 0.9 to 10 and 10.40 to 40.47 for Vaishali and Bhagalpur, respectively (22). Furthermore, the results of the study of Muhammad et al showed that since HQ was less than 1, no health effects from chronic arsenic exposure was seen due to the drinking of groundwater in Kohistan region, northern Pakistan (27). Nguyen et al assessed the risk of arsenic exposure through the consumption of groundwater in Ha Nam province, Vietnam, and showed that 42% and 100% of treated and untreated groundwater consumers were under non-carcinogenic effect (28).

## 4. Conclusions

To sum up, the current study was conducted to analyze the inorganic arsenic content as well as carcinogenic and non-carcinogenic exposure to arsenic through ingestion of groundwater collected from four important agricultural districts of Hamedan Province, west of Iran. Based on the results of the current study, since the computed values of HQ of groundwater samples from Asadabad plain was greater than 1 for both spring and summer seasons, a non-carcinogenic effect (chronic risk) is considered to be possible for the inhabitants of this study area. Therefore, serious considerations including managing the use of agricultural inputs especially chemical fertilizers, arsenical pesticides or herbicides, and treatment of arsenic-contaminated groundwater with some proper methods before water ingestion are recommended.

### Conflict of Interest Disclosures

The author declares that he has no conflict of interest.

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