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ORIGINAL ARTICLE

Evaluation of groundwater quality for drinking purposes: a case study from the Beheshtabad Basin, Chaharmahal and Bakhtiari Province, Iran

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Abstract
Groundwater quality monitoring is of great importance in Iran's arid and semi-arid regions where water scarcity exists. This study assessed background information on groundwater quality and heavy metals concentration in the spring water of the Beheshtabad Basin, located in Chaharmahal and Bakhtiari Province, Iran, to examine the suitability of the groundwater for drinking. Groundwater samples were collected from five springs in the basin during the time frame of February 2014 and September 2015 and analyzed in terms of physicochemical characteristics such as pH, electrical conductivity (EC), total dissolved solids (TDS), cations, anions, and heavy metal concentration. These parameters were used to determine the groundwater's suitability for domestic purposes by comparing their measured values to the maximum permissible limits according to recommendations of the World Health Organization. The results revealed that most groundwater samples are suitable for drinking. During the rainy season, however, spring waters are bacteriologically contaminated and unsuitable for human consumption. As important parameters for determining drinking water quality, water quality index (WQI) values in the present study indicated very poor quality water for some groundwater samples in the area dominated by weathering of rocks and dissolution of salts from the bedrock into the water resources, which can be a serious threat to the ecological habitat.

Keywords Groundwater quality · Heavy metal pollution index · Drinking suitability · Beheshtabad basin · Iran

Introduction

Groundwater resources are considered valuable water sources around the globe and they are an increasingly important water supply source in regions with frequent water stress (Richey et al. 2015; Yaghobi et al. 2017). Investigating groundwater quality, as one of the most important and most vulnerable water supply sources, is of high priority (Prasanth et al. 2012). With increasing population and water demand for various purposes including agriculture, drinking, and industry, the need for investment in the water sector is inevitable. These developments have put a great deal of pressure on Iran's groundwater resources. One of the important responsibilities of water decision makers is to assess water quality parameters. Iran, as a vast country with extensive agricultural land, is always faced with water shortages because of high water demand, low rainfall, high evaporation, and uneven rainfall distribution (Khosravi et al. 2017; Abbasnia et al. 2018). At present, agriculture plays a vital role in the national economy and food production in Iran and consumes more than 90% of the available water. In addition to reducing crop yields and creating problems for irrigation systems, poor groundwater quality in agriculture degrades the soil's physical properties and consequently results in land degradation. Therefore, it is necessary to consider the qualitative aspects of water and heavy metal pollution in groundwater (Krishna et al. 2009). In general, groundwater movement along underground pathways increases the concentration of chemical compounds in the water. Groundwater contains varying amounts of nutrients, such as carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), calcium (Ca^{2+}), magnesium (Mg^{+2}), and sodium (Na^+), which affect the suitability of

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groundwater for human consumption, irrigation, and other uses (Bear and Cheng 2010). Water quality assessment for drinking-water purposes involves the determination of the groundwater's chemical composition and remedial measures for restoration of the water quality (Annapoorna and Janardhana 2015; Neisi et al. 2018). Several tools such as water quality indices are implemented (Lermontov et al. 2009) to determine water quality conditions. Water quality index (WQI) is a practical and comparatively simple approach for evaluating the composite influence of the overall quality. It also reflects the composite influence of the different water quality parameters (Singh et al. 2016).

To date, many research studies and projects have been conducted on surface water, and groundwater quality measurements for the domestic, irrigation, and industrial activities in different regions of the world. Some of these studies include the reports in Spain of Valenzuela et al. (2006); in Portugal, by Stigter et al. (2006a, b); in India, by Edmunds and Shand (2008), Hakim et al. (2009), Vasanthavigar et al. (2010), Gurunadha et al. (2011), Nag (2014), Mahendra and Patode (2014), and Ravikumar and Somashekar (2015); in Ghana, by Yidana et al. (2011); in Malaysia, by Prasanna et al. (2012); in Ghana, by Ewusi et al. (2013); in Libya, by Oişte (2014); in Romania, by Abd El-Aziz (2017); in Nigeria, by Majolagbe et al. (2017); in the UAE, by Zhang et al. (2017); in Egypt, by Masoud et al. (2017); in China, by Zhang et al. (2017); in the USA, by Law et al. (2017); and in Iran, by Khosravi et al. (2017).

Given the importance of groundwater quality monitoring, the present study characterized groundwater quality by testing spring water samples in Iran and comparing them with the guidelines stated by the World Health Organization (WHO). To this aim, the quality of spring water from aquifers in the Beheshtabad Basin, located in Chaharmahal and Bakhtiari Province, was evaluated to assess the groundwater suitability for the purpose of drinking. The present achievements can provide decision makers with useful information.

Material and methods

Study area and sampling location

The Beheshtabad Basin, with a total area of 3822 square meters, is in northeastern Chaharmahal and Bakhtiari Province. This watershed is situated between latitudes of 31° 28′ N, 32° 56′ N, longitudes of 50° 36′ E and 51° 45′ E. The basin accounts for about 12.9% of the central Zagros Mountains area, where nearly 44% of the area is mountainous and 56% is plain. It is characterized as a rural setting in which most of the people work in agriculture.

The average annual precipitation is around 419 mm and its climate is essentially semi-arid. The springs are recharged by direct precipitation infiltration, as the main source of groundwater recharge. The average annual temperature is 10.25 °C. Figure 1 depicts the location of the study area together with its five sampling stations.

The sampling method along with the physicochemical and elemental analyses

Water samples from Beheshtabad Basin springs were collected in the months of February (rainy season) and September (dry season) 2014. Groundwater samples from five springs in the study area were collected in triplicate in new, pre-cleaned polypropylene bottles (1 l capacity). After the sample collection, the samples were held at 4 °C in a laboratory refrigerator to avoid microbial degradation. All samples pertinent to the physiochemical parameters were analyzed within 24 h. The parameters of pH and electrical conductivity (EC) were measured with a Hach HQ40d portable meter (USA). Other physiochemical parameters such as soluble cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and soluble anions (CO_3^{2-}, SO_4^{2-}, Cl^{-}, HCO_3^{-} and NO_3^{-}) were analyzed within 24 h after transferring the water samples to the laboratory, according to methods described in the American Public Health Association manual (APHA 2012). Ca^{2+}, Mg^{2+}, CO_3^{2-}, Cl^{-}, and HCO_3^{-} were analyzed by volumetric titration methods. Na^{+} and K^{+} were measured using a flame photometer, and SO_4^{2-} and NO_3^{-} were determined with the spectrophotometric technique.

To analyze the heavy metals (Ag, As, B, Ba, Cd, Co, Cr, Cs, Cu, In, Mn, Ni, Pb, Rb, Se, Sr, U, and Zn), water samples were preserved with ultrapure nitric acid and then transferred to the laboratory. Water samples were analyzed using an ICP mass spectrometer (Agilent 7500, USA). The bacteriological component as total coliform was measured using the most probable number (MPN) method (APHA 2012).

Analytical process precision was evaluated by the relative standard deviation (RSD). To this aim, one sample was analyzed in five replicates. RSD values were obtained for heavy metals during the rainy and dry seasons.

Water quality assessment

In the first step, the proportion of groundwater for domestic purposes was assessed by comparing the values of various water quality parameters to those of the WHO guidelines for drinking water (WHO 2004).

In general, the suitability of water sources for human consumption has been described in terms of WQI, which is one of the most effective ways for describing water quality. The unique feature of WQI is the use of several key parameters of groundwater chemistry for investigating the influence of natural and anthropogenic activities. This index has been

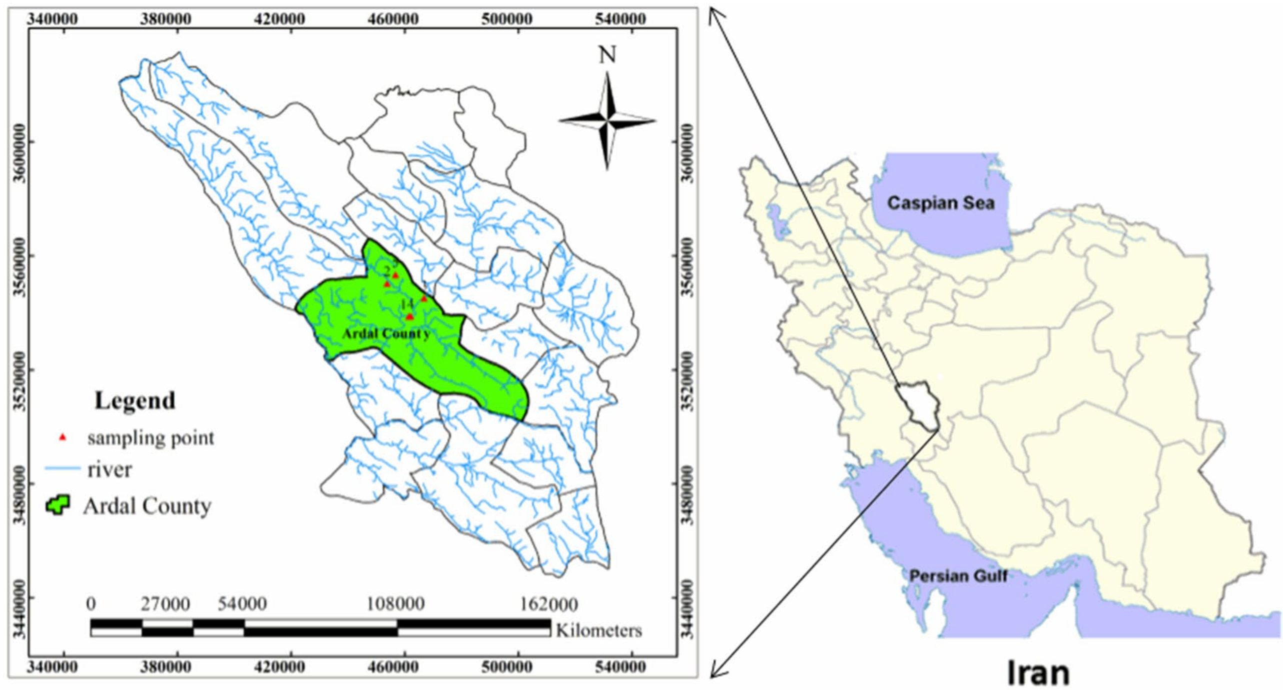

Fig. 1 Location of the study area and five sampling stations in the study area

widely used by various scientists (Zhang et al. 2017; Law et al. 2017; Khosravi et al. 2017) and is defined as:

$$WQI = \sum_{n=1}^{n} QiWi/wi, \quad (1)$$

where

Q_i is the quality rating scale for each parameter, and

W_i is the unit weight for each water quality parameter.

The quality rating scale for each parameter is determined as follows:

$$Q_i = \left[\left(P_i - P_0 \right) / \left(S_i - P_0 \right) \right] \times 100,$$

in which P_i stands for the estimated concentration of the ith parameter in the analyzed water and P_0 is the ideal value of this parameter in the pure water. S_i is the recommended standard value of the ith parameter and W_i is calculated using the following formula:

$$Wi = \frac{1/\sum\left(\frac{1}{Si}\right)}{\mathrm{Si}}.$$

Iran's groundwater resource quality index (IRWQI) creates a score to evaluate the general water quality of Iran's water resources for conventional and toxic pollutants, via combining ten water quality variables into a single number (Hashemi et al. 2011). The parameters covered in this method for conventional pollutants include electrical conductivity (EC), dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), pH, sodium adsorption ratio (SAR), nitrate-nitrogen, total phosphorus, total dissolved solids (TDS), and fecal coliform bacteria.

Those covered in this method for the toxic heavy metal pollutants are arsenic (As), mercury (Hg), cadmium (Cd), lead (Pb), chromium (Cr), cyanide (CN), iron (Fe), manganese (Mn), phenol, and detergent. Table 1 gives the water quality rating according to this WQI for conventional and toxic pollutants.

Table 1 Iran groundwater (GW) resource quality index (IRWQI) classification for the conventional and toxic pollutants

No	IRWQI for GW	Water quality
1	< 15	Water unsuitable for drinking purpose
2	15–29.9	Very poor water
3	30–44.9	Poor water
4	45–55	Good water
5	55.1–70	Very good water
6	70.1–85	Excellent water
7	> 85	Very excellent water

Results and discussion

Physicochemical characteristics of the investigated groundwater samples

The five examined groundwater samples from springs in February and September 2014 samplings indicated that EC is significantly higher in spring No. 1 compared to the other four ones (more than 100 times higher), according to the springs' physical and chemical parameters. Therefore, this salt spring was eliminated from Table 2 calculation of the mean and standard analysis.

pH

pH is an acidic or basic indicator associated with water and is an important indicator of water quality in the present study. According to WHO guidelines, the appropriate pH range for drinking water purposes is 6.5–8.5 (Table 2) and the potability of drinking water is significantly impaired by pH less than 6.5 or greater than 8.5. pH values of the samples were in the range of 7.95–8.38 and 8.14–8.52 for dry and rainy seasons, respectively. Therefore, the pH values associated with all water samples from the springs, for both periods of sampling in the study area are within the permissible limits prescribed by the WHO.

EC

The EC value of water defines the amount of soluble salts (concentration of ionized substances) in the water samples. The maximum permissible limit of EC is 1500 µs/cm for drinking water. In this basin, the EC values of the samples, except that of spring No. 1, were in the range of 331–841 µs/cm, and 312–1000 µs/cm for dry and rainy seasons, respectively, indicating suitable values for the drinking water. However, the EC values associated with spring No. 1 in the northeastern part of the basin were estimated at 104,700 and 130,800 µs/cm for dry and rainy seasons, respectively, which indicate very high EC values beyond the prescribed limit for drinking water. The most important reason for the high EC in spring No. 1 is salt water intrusion from the parent rock, characterized as a fine grained, micaceous, sandy shale and salt (Table 3).

Total dissolved solid (TDS)

According to the WHO (2004), total dissolved solids (TDS) are a measure of all dissolved substances in water (such as calcium, magnesium, potassium, sodium, bicarbonate, chloride, and sulfate) and the small amounts of organic matter dissolved in it. High concentrations of TDS could have adverse effects on taste. As suggested by the WHO, TDS > 1500 mg/l (Table 2) significantly impairs water potability and it is considered to be the maximum permissible limit for drinking water. TDS values of the samples were in the range of 185.4–471 mg/l and 158–560 mg/l for dry and rainy seasons, respectively. Generally, in the study area, the TDS values of samples were below 560 mg/l and the low TDS values of these groundwaters clearly indicate their suitability for drinking with regard to this parameter. Only the TDS value for spring No. 1, for both periods of sampling, exceeded the maximum permissible limit, indicating that it is not suitable for drinking.

Cations and anions

Calcium was the major cation in the groundwater during the rainy season (Table 1). It contributes to water hardness. Higher Ca^{2+} concentrations cause abdominal ailments, are undesirable for domestic uses, and cause encrustation and scaling. Calcium sources in groundwater are calcite, aragonite, gypsum, and anhydrite minerals. The maximum permissible limit of calcium concentration for drinking water is reported as 200 mg/l and the desirable limit for this cation is 75 mg/l (WHO 2004). No investigated water samples except that of spring No. 1, for both periods of sampling, exceeded the permissible limit of Ca^{2+}. According to the WHO (2004), the maximum permissible limit of Mg^{2+} concentration in drinking water is 150 mg/l. Once again, only the water samples from spring No. 1, for both periods of sampling, exceeded this limit.

The maximum permissible limits of Na^+ and K^+ in drinking water are reported as 200 mg/l and 12 mg/l, respectively. In the studied basin, both Na^+ and K^+ values of the water samples (except for spring No. 1) were in the standard range prescribed by the WHO. Na^+ and K^+ values of the samples from spring No. 1 for the dry season were 28,000 and 15 mg/l, respectively, and for the rainy season were 23,300 mg/l for Na^+ and 18 mg/l for K^+. Water samples from spring No. 1 indicated higher Na^+ and K^+ values than the standards outlined by the WHO. The intake of high levels of Na can cause increased blood pressure, arteriosclerosis, and hyperosmolarity. Potassium concentrations in all groundwater samples were lower compared to Na^+, which could be due to the fact that potassium minerals are more resistant to the weathering in the study area.

Overall, the cations and anions of the spring water (except for HCO_3^- and Cl^-) were higher during the rainy season and lower in the dry season, as shown on Fig. 2.

Chloride in groundwater is likely from a variety of sources such as the climate, saturation of sedimentary rocks and soils, salt water influx, household waste, industrial waste, and urban sewage. Obviously, Cl affects the taste of

Table 2 Physicochemical characteristics of the investigated groundwater samples together with the desirable and maximum permissible limits of groundwater quality for drinking purposes (WHO 2004), spring No. 1 (Salt Spring), 2 (Sardab Spring), 3 (Bagh-e-Rostom), 4 (Spring 19) and 5 (Khadrzaneh)

Spring no	pH	EC μs/cm	TDS mg/l	Soluble cations				Soluble anions					Bacteria MPN/100
				Ca^{2+} mg/l	Mg^{2+} mg/l	Na^{+} mg/l	K^{+} mg/l	CO_3^{2-}mg/l	HCO_3^{-} mg/l	Cl^{-} mg/l	SO_4^{-2} mg/l	NO_3^{-} mg/l	
Groundwater sampling, February 2014													
1	8.12	130,800	73,248	1083	388.8	28,000	15	0	197.6	45,000	2100	1.59	0
2	8.38	331	185.4	50.52	8.262	10.6	1.02	6	175.7	10	9	5.7	290
3	8.07	566	317	70.57	10.69	33.5	0.85	0	222.5	60	9	7.86	9.1
4	8.03	841	471	71.85	36.64	52.5	0.68	0	236.7	150	17	8.5	43
5	7.95	815	452.4	74.74	27.6	50.32	0.78	0	214.7	145	18	8	23
Mean	8.1	638.3	356.5	66.9	20.8	36.7	0.8	1.5	212.4	91.3	13.3	7.5	91.3
SD	0.2	239.4	133.1	11.1	13.6	19.4	0.1	3	26.1	68.1	4.9	1.2	133.2
Groundwater sampling, September 2015													
1	8.21	104,700	58,632	100	330.48	23,300	18	6	244	37,500	1800	4.56	0
2	8.52	312	158	5.52	7.43	8.5	0.78	6	146.4	12.5	7.4	5.08	0
3	8.14	1000	560	12	36.45	66	2.8	12	248.9	200	25	6.2	0
4	8.25	823	460.9	7.58	43.35	48.5	0.32	6	268.4	137	13	7	0
5	8.34	803	449.7	7.12	33.43	61	0.24	12	232.3	130	19	7.52	3.6
Mean	8.3	734.5	407.2	8.1	30.2	46	1	9	324	119.9	16.1	6.5	0.9
SD	0.2	295.3	173.3	2.8	15.7	26.1	1.2	3.5	53.8	78.2	7.6	1.1	1.8
Desirable limit													
WHO	6.5	500	500	75	50	200	–	–	244	200	200	5	1
Maximum permissible limits													
WHO	8.5	1500	1500	200	150	200	12	–	240	600	400	100	4

Table 3 Details of water quality classification and index rate of the analyzed samples

Spring no	Index rate	Water quality	Parent material
Groundwater sampling in February 2014			
1. Salt Spring	$20.1 \pm 0.01^{a*}$	Very poor water	Micaceous, sandstone, sandy shale, and salt
2. Sardab Spring	$49.3 \pm 0.05^{b*}$	Good water	Thin- to thick-bedded limestone containing chert
3. Bagh-e-Rostom	$50.3 \pm 0.4^{c*}$	Good water	Thin to massive limestone
4. Spring 19	48.1 ± 0.7^{d}	Good water	High-level terraces
5. Khadrzaneh	$48.6 \pm 0.1^{c*}$	Good water	High-level terraces
Groundwater sampling in September 2015			
1. Salt Spring	17.20 ± 0.01^{a}	Very poor water	Micaceous, sandstone, sandy shale, and salt
2. Sardab Spring	72.70 ± 0.36^{b}	Excellent	Thin- to thick-bedded limestone containing chert
3. Bagh-e-Rostom	40.80 ± 1.5^{c}	Poor water	Thin to massive limestone
4. Spring 19	49.40 ± 2.8^{d}	Good water	High-level terraces
5. Khadrzaneh	40.56 ± 1.6^{c}	Poor water	High-level terraces

One-way ANOVA was performed for the difference between springs and seasons. The same letters indicate no significant difference ($p > 0.05$) between springs in each season

*Indicates a significant difference ($p < 0.05$) between rainy and dry seasons for each spring, separately

water. Sulfate is found in water as sulfate (SO_4^{2-}) presence in drinking water can cause a bitter taste at concentrations greater than 200 mg/l. Soluble anions were dominated by Cl^- and SO_4^{2-} and no groundwater samples (except that of spring No. 1), for both periods of sampling, exceeded the maximum permissible limit for drinking water as recommended by the WHO (2004). The high SO_4^{-2} concentration in spring No. 1 is most likely, from gypsum dissolution. The maximum allowable limits of Cl^-, SO_4^{-2}, HCO_3^-, and NO_3^- in drinking water are 600, 400, 240, and 100 mg/l, respectively. During the dry season, the concentrations of HCO_3^- in springs 1, 3, and 4 exceeded the maximum permissible limit, which is 240 mg/l for drinking water.

Nitrate is likely to enter groundwater from fertilizer, food preservatives, and human and animal waste. It is highly soluble in water and easily transported to drinking water through soil. All samples showed a NO_3^- concentration below the maximum allowable concentration of 100 mg/l (WHO 2004).

Bacterial content

In general, the bacterial content of drinking water is one of the most important aspects of water quality. Drinking bacterial contamination in water is one of the most common and widespread health hazards, caused either directly or indirectly by human or animal excrement. In this study, all four groundwater samples collected in the rainy season were found to be contaminated. The permissible limit of bacterial fecal coliform in drinking water is 4/100 ml (MPN/100 ml). The obtained results indicate that the groundwater from springs is bacterially contaminated and, therefore, unsuitable for human consumption.

Iran water quality index calculation (IRWQI)

The results of IRWQI classification (Table 3) indicate that out of the five spring samples in the rainy season, only one sample was in the second category (very poor quality) and the others were in the fourth category (good water). There was a significant difference in WQI among the four springs, Nos. 2, 3, 4 and 5, but all were found to be in the fourth category and were desirable for drinking.

IRWQI values associated with spring No. 1 were 17.2 ± 0.01 and 20.1 ± 0.01 for rainy and dry seasons, respectively, and were significantly ($p < 0.05$) lower compared to the other four springs (very poor water). The very poor water quality in spring No. 1 for both sampling periods can be attributed to the process of rocks weathering and dissolution of salts from bedrock into the water. The bedrock or mother rock material in this region is fine grained, micaceous, sandy shale and salt.

Moreover, two sampled springs, Nos. 3 and 5, in the dry season were found to be in the third category (poor water) compared to the excellent quality in spring No. 2. The significantly ($p < 0.05$) low water quality in these two springs compared to the excellent quality in spring No. 2 and the good quality in spring No. 4 could result from some high values of physicochemical characteristics of the groundwater samples associated with these springs (Table 2). This is also attributable to the low rainfall infiltration into the groundwater of these regions, leading to a decline in groundwater quality.

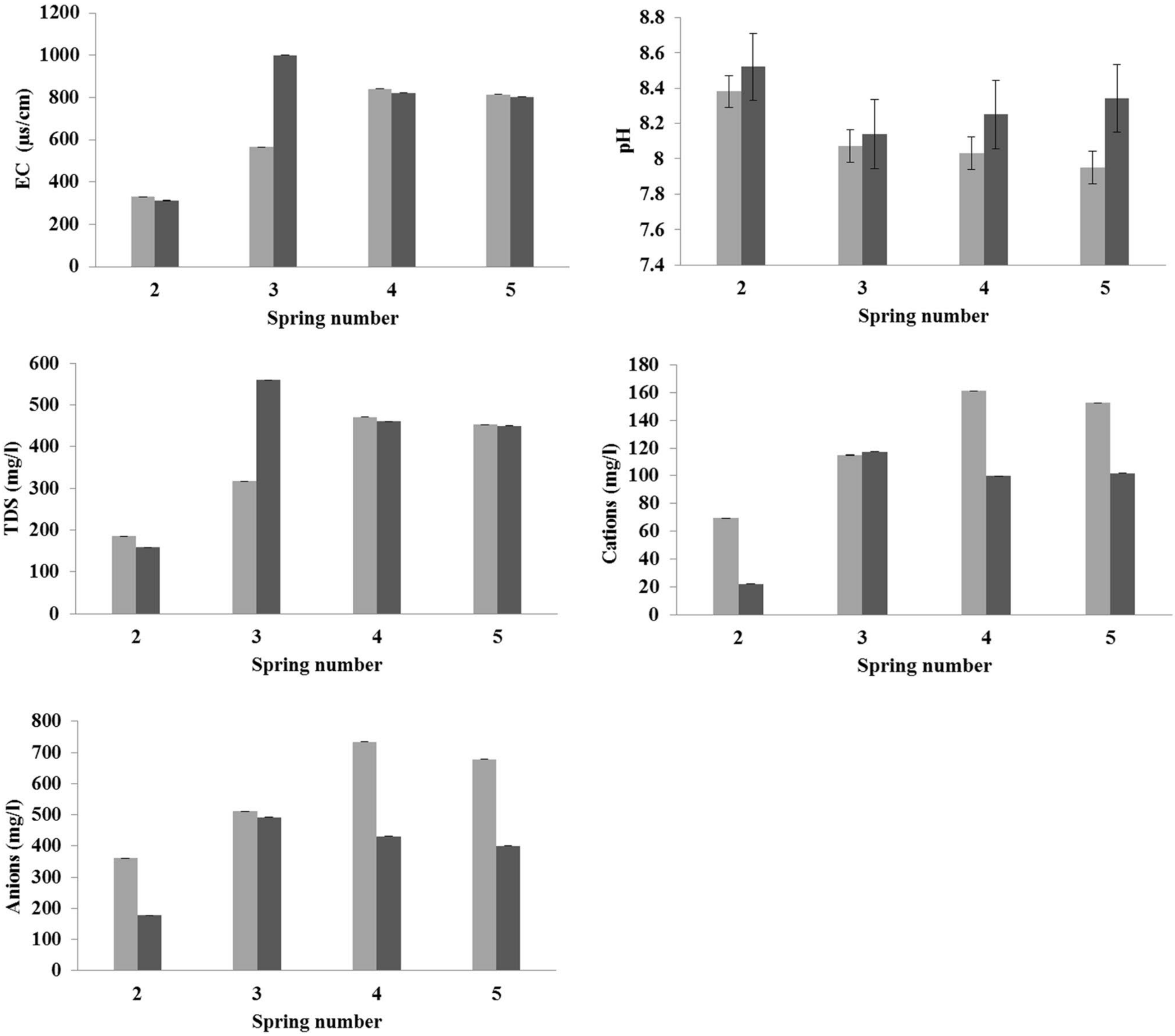

Fig. 2 The average concentrations of electrical conductivity (EC), pH, total dissolved solids (TDS), and sum of cations and anions in groundwater samples in Beheshtabad Basin in the rainy season (dark columns) and the dry season (grey columns). Error bars indicated standard deviation. Spring number indicated; 2 (Sardab Spring), 3 (Bagh-e-Rostom), 4 (Spring 19), and 5 (Khadrzaneh). Spring number 1 was eliminated from the analysis for reasons explained in the text

In general, the results indicate a significant decrease in WQI in the dry season compared to the rainy season; however, for spring Nos. 2 and 4, a significant increase and insignificant increase in WQI, respectively was observed compared to the rainy season.

Table 4 compares the available groundwater quality data with the drinking water of selected areas around the world.

Saeedi et al. (2010) developed a simple process of determining the WQI in Iran's Qazvin plateau and reported that the groundwater quality in this region is closely related to mineral water quality. Jamshidzadeh and Mirbagheri (2011) estimated the groundwater quality in most parts of the Kashan basin in central Iran. They found that the groundwater was undesirable for drinking and could be harmful to human health. However, these authors pointed out that the groundwater quality in this basin is affected by the intrusion of Salt Lake, in Kashan Province's Dasht-e Kavir-Salt Desert National Park.

A few years later, considering the newly published data, Khosravi et al. (2017) indicated that the WQI for the groundwater quality in Birjand, Iran, was not in the range recommended by the WHO and thus the water was unsuitable for drinking.

Table 4 Comparison of selected groundwater quality data for the drinking water of various areas in the world

	pH	EC (µs/cm)	TDS (mg/l)	K^+ (mg/l)	Na^+ (mg/l)	Mg^{2+} (mg/l)	Ca^{2+} (mg/l)	HCO_3^- (mg/l)	Cl^- (mg/l)	SO_4^{-2} (mg/l)	$NO3^-$ (mg/l)
Abdelaziz (2017), in Libya	7.17	469	3175	433	114	413	17		851	1096	14.7
Saeedi et al. (2010), Iran	7.76–8.22		202–1667	0.01–0.17	0.85–18.3	0.55–4.71	1.05–4.26		0.33–13.98	0.68–8.31	
Jamshidzadeh and Mirbagheri (2011), Iran	7.55–8.35	1553–12,300	903–7527	0.02–0.57	7.6–82.5	4–20.12	4–33.5	1–5.4	4.55–91.5	5.5–39.57	
Khosravi et al. (2017), Iran	7.25–8-32	1000–7445	586–4980	1.74–13	110–1042	7–120.64	29.5–511	105–443	75.29–1668	123.86–1487	
Krishna et al. (2015), India	6–8.2	580–7250	373–4669	3.0–36	71–1200	1.2–141.6	26–130	18.3–359.9	115.2–2511	22.2–98.6	
Majolagbe et al, (2017)s, Nigeria	4.6–6.9	100–2690	30.7–1535	6.29–44.3	21.1–424	4.11–19	8.57–178		17.2–371	2.92–228	0.15–3.91
Zhang et al. (2017), China	6.62–8.47		174–2091	0.64–24.26	8.78–171.7	10.31–102.4	27.2–367.2	109–565	11.85–378	7.69–395	0.24–440
The present study	7.95–8.38	331–815	185–471	0.68–1.02	10.6–52.5	8.2–36.6	50.5–74.7	175–236	10–150	9.0–18.0	5.7–8.5

Abdelaziz (2017) reported that the groundwater samples in northwestern Libya were unsuitable for drinking and household uses and illustrated that the examined parameter levels exceeded the WHO's permissible limits. The geochemical characteristics of the groundwater and drinking water quality for Chennai, Tamil Nadu, India were reported to be of excellent and good categories and suitable for drinking water purposes (Krishna et al. 2015).

According to a report by Majolagbe et al. (2017), the groundwater vulnerability to pollution from the Solus dumpsite in Lagos, Nigeria, ranged between moderate and high groundwater pollution potential. Zhang et al. (2017) evaluated the groundwater chemistry in the Hutuo River in China to be of poor quality, which could be the result of anthropogenic activities as well as the river's vulnerability to contamination.

Compared to the published groundwater quality data for other basin regions in the world (Table 4), the calculated groundwater quality in the Beheshtabad Basin with regard to the permissible limits of the WHO is between low and moderate groundwater pollution potential.

As mentioned earlier, the very poor groundwater quality of spring No. 1, for both periods of sampling in the northeastern of the study area can be attributed to the process of rock weathering and dissolution of salts from the bedrock into the water resources.

As shown in Table 2, the total viable bacteria in each of the four water samples during the rainy season were too numerous to count. Excessively high colony numbers of total viable bacteria indicate that the water is highly contaminated with microorganisms and unsuitable for drinking because its consumption could lead to waterborne diseases such as nausea, vomiting, diarrhea, and gastroenteritis. High colony numbers of total viable bacteria in rainy season compared to dry season, are mostly likely from greater infiltration of rainwater into the groundwater, pointing to contamination from agriculture and wastewater runoff in these regions, resulting in a decline of groundwater quality.

Metal concentrations of the investigated groundwater samples

The results for the concentrations of trace metals in the groundwater samples collected from the Beheshtabad Basin are listed in Table 5. RSD values were obtained for heavy metals during the rainy and dry seasons, ranging from 0.0 to 7.0% and 2.0 to 9.8%, respectively (Table 5).

The heavy metal indices (IRWQI) are shown in Table 6. As can be observed from Table 5, almost all measured metal concentrations of spring No. 1, for both periods of sampling, were higher than in the other four.

Table 6 illustrates that all heavy metal indices except those of spring No. 1 in the rainy season were below the

Table 5 Chemical composition and descriptive statistics for the groundwater elements collected in the study area (all values in μg/l) and WHO permissible limits of drinking water quality; Spring Nos. 1 (Salt Spring), 2 (Sardab Spring), 3 (Bagh-e-Rostom), 4 (Spring 19) and 5 (Khadrzaneh)

Spring number	1	2	3	4	5	Mean	SD	RSD%	1	2	3	4	5	Mean	SD	RSD%	WHO
	Groundwater sampling, February 2014								Groundwater sampling, September 2015								
Ag	0.2	0.08	0.09	0.07	0.06	0.1	0.0	0	2.96	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01		8	1
As	142.6	33.3	15.9	0.5	0.6	12.6	15.6	2	4.2	2.8	2.9	< 0.1	1.5	2.4	0.8		50
B	372.4	15.9	62.1	34.6	31.1	35.9	19.2	1	41.7	1.9	45.2	13.1	9.13	17.3	19.1	6	
Ba	20.1	11.1	28.2	33.4	29.7	25.6	9.9	1	28.6	8.8	25.9	8.5	17.4	15.2	8.3	6	700
Cd	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1			< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.01			5
Co	0.5	0.3	0.3	0.4	0.3	0.3	0.1	7	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.01			–
Cr	10.8	12.8	2.2	2.2	2.3	4.9	5.3	7	0.8	1.5	< 0.1	< 0.1	1.1	1.3	0.3	4.6	–
Cs	2.3	< 0.1	9.4	< 0.1	< 0.1	9.4		6	1.3	< 0.1	17.6	1.5	1.3	6.8	9.4	2	1000
Cu	4.4	1.3	1.2	1.1	1	1.2	0.1	3	1.2	8.4	10	< 1	7.2	8.5	1.4	7	1000
In	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1			< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.01			n/a
Mn	21.8	2.6	3.2	1.6	2.2	2.4	0.7	3	39.8	20.4	43.3	2.8	50.9	29.4	21.9	9.8	50
Ni	5.6	1.4	1.3	2.2	2.1	1.8	0.5	7	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.01			20
Pb	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2			< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2			50
Rb	24.0	< 0.5	15.2	< 0.5	< 0.5				17.1	< 1	30.2	2.4	2.7	11.8	16.0	3.5	–
Se	< 1	< 1	< 1	< 1	< 1	< 0.1			< 1	< 1	< 1	< 1	< 1	< 1			10
Sr	17.16	0.58	0.74	0.47	0.43	0.6	0.1	4	8.84	0.1	1.36	0.34	0.33	0.5	0.6	1.66	–
U	< 1	< 1	< 1	< 1	< 1	< 1			< 1	< 1	< 1	< 1	< 1	< 1			2
Zn	99.0	6.6	4.0	4.0	4.0	4.6	1.3	1	0	11.1	4.6	0.7	3.2	4.9	4.4	2	5000

SD standard deviation, *RSD* relative standard deviation

Table 6 IRWQI classification for the heavy metals of the individual samples

Spring number	Index rate	Water quality
Groundwater sampling in February 2014		
1. Salt Spring	34.1	Poor water
2. Sardab Spring	65.5	Very good water
3. Bagh-e-Rostom	78	Excellent water
4. Spring 19	97	Very excellent water
5. Khadrzaneh	97	Very excellent water
Groundwater sampling in September 2015		
1. Salt Spring	67.2	Very good water
2. Sardab Spring	93.2	Very excellent water
3. Bagh-e-Rostom	92.6	Very excellent water
4. Spring 19	93.6	Very excellent water
5. Khadrzaneh	94.9	Very excellent water

detectable values. Therefore, for both periods of sampling, all springs except spring No.1 were in the categories of very good water, very excellent water, and suitable water for drinking purposes categories in regard to dissolved metals (Table 5).

All toxic metals (Ag, As, B, Ba, Cd, Co, Cr, Cs, Cu, In, Mn, Ni, Pb, Rb, Se, Sr, U, and Zn) were below their respective WHO limits except that of spring No. 1 for rainy season. The five examined groundwater samples from springs in February indicated that As and B are significantly higher in spring No. 1 compared to the other four (more than ten times higher). The spatial variations revealed that only samples collected from spring No. 1 in the rainy season had poor water quality and would require measures for mitigation. The other data revealed that IRWQI values for all investigated metals were within safe limits. Therefore, these groundwater springs can be used for drinking without any health risk with regard to dissolved metals.

Given the mean concentrations of trace metals reported in Table 5, the Beheshtabad Basin's groundwater from springs was comparable to and even lower than these elements' concentrations as reported by Shuhaimi-Othman et al. (2008) for Chini Lake, Malaysia; by Kazi et al. (2009) for Manchar Lake, Pakistan; by Singanan et al. (2008) for Wenchi Crater Lake, Ethiopia; by Masresha Alemayehu et al. (2011) for Lake Awassa, Ethiopia; and by Prasanna et al. (2012) for Curtin Lake, Malaysia (Table 7).

Table 7 gives the concentrations of Se and Pb, which were significantly lower in this study compared to other waters worldwide. Thus, the studied basin was in the normal range in terms of its heavy metal concentrations.

Conclusion

The present work provides background information for the groundwater quality of springs in the Beheshtabad Basin to be utilized in future research. The research presents initial results for the identification of groundwater quality and heavy metal concentrations, provides baseline data for future studies, identifies possible sources, and determines the degree of metals pollution in the spring waters from the Beheshtabad Basin.

The electrical conductivity, total dissolved solids, cations, and anions of the water samples did not exceed the maximum permissible limits of the WHO. However, some of the water samples were not bacteriologically suitable for human consumption.

Table 7 Comparison of the heavy metals in the present groundwater samples with other parts of the world (all values in µg/l)

	Al	Ba	Cu	Mn	Ni	Pb	Se	Sr	Zn
Shuhaimi-Othman et al. (2008)	86.79		1.19			3.43			6.55
Kazi et al. (2009)	1.98		18.9	72.56	34.96	82.42	52.76		730.4
Singanan et al. (2008)			0.83	0.3	0.64	0.42			0.93
Masresha Alemayehu et al. (2011)			3		18.1				
Prasanna et al. (2012)	109–151.97	30.23–197.87	0.04–6.95	8.14–13.59	0.05–3.57	0.08–4	0.13–16.15	47.91–54.1	1.49–9.55
This study		9.5–33.4		1.6–50.9	< 0.1–5.6	< 0.2	< 0.1	0.33–17.16	0–99

The water quality analysis clearly shows that trace elements have not been released from natural hydrogeochemical processes and do not have high potential to contaminate the groundwaters. Finally, based on the WHO classification, the spring waters of the Beheshtabad Basin generally are suitable for drinking purposes, although the weathering of rocks and dissolution of salts from bedrock into spring No. 1 poses a severe threat to this habitat and requires serious attention.

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