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ABSTRACT

Access to drinking water is one of the most important indicators determined by the World Health Organization (WHO). This investigation surveyed the concentration of various pollutants in drinking water and its health risk attribute to Arsenic in Sistan and Baluchistan province, Iran. Water samples were collected from ground water and analyzed for physical parameters, anions, and heavy metals using the standard procedures. The concentrations of sulfate (269 ± 127 mg/l) in five sites exceeded the permissible limit (250 mg/l), while chlorine concentrations (223 ± 100 mg/l) in four sites exceeded the permissible limit (250 mg/l) set by WHO. Similarly, the concentrations of Mg (30 ± 11 mg/l) in four sites exceeded the permissible limit (30 mg/l), while Na concentrations (222 ± 99 mg/l) in five sites exceeded the permissible limit (200 mg/l) set by Institute of Standards and Industrial Research of Iran (ISIRI). In addition, arsenic was in acceptable levels recommended by WHO and local regulations. Based on the calculated indices of hazard qutient (HR) and excess lifetime cancer risk (ELCR), the in-use drinking water has no adverse effects on the consumer's health. Excessive use of fertilizers and pesticides, unsuitable sewerage systems, and inappropriate sludge and solid waste disposal in this province can lead to drinking water pollution. Also, excessive pumping of ground water should be managed as an effective method for supply of safe drinking water.

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hazard quotient; excess lifetime cancer risk; metalloid; drinking water; ground water

Introduction

Safe drinking water availability is one of the most important indicators determined by the World Health Organization (WHO 2004). Nowadays population growth, development of societies as well as municipal and agricultural water requirements, industrial use, and generating

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/bher energy from water are gradually increasing (Bazrafshan *et al.* 2016). In addition, microbial and chemical contamination of water is also an important issue in health topics. In recent decades, water body resources polluted due to heavy metals has become one of the serious environmental problems. Also, environmental pollution with heavy metals is considered a result of urbanization and industrial growth (Wang *et al.* 2012; Das *et al.* 2009; Farkas *et al.* 2007) High levels of heavy metals in water also have adverse impact on human health, which makes water impotable (Jafari *et al.* 2018; Zhang *et al.* 2007). Water contaminated via heavy metals, various anion and cations such as Cd, Pb, Cr, As, Hg, Ni, Zn, $So4^{2+}$, $No3^{-}$, $No2^{-}$, Cl^{-}, F^{-}, $Ca^{2\,+}$, Na^{+}, $Mg^{2\,+}$, K^{+}, and other elements, can have harmful effects on human health due to excessive intake of contaminated water by human beings (Steenland and Boffetta 2000; Muhammad *et al.* 2010). High or low concentration of physical and chemical parameters in drinking water can directly or indirectly be associated with public health (Muhammad *et al.* 2011). There is no direct relation between human health and pH of drinking water, while this parameter can indirectly effect some water quality characteristics, such as ion solubility, the survival of pathogens, and other contaminants. Acidic and alkaline water can lead to corrosive water and bitter taste of water, respectively (Shah *et al.* 2012; Khan *et al.* 2013). Furthermore, potassium is considered as one of the trace elements in the human body, and its deficiency leads heart problems, high blood pressure, inflammation of the bladder, and kidney disease. Also, high levels of potassium can cause abnormal protein metabolism, ovarian cysts, high heart rate, and decreased renal function (Kumar *et al.* 2016; Brahman *et al.* 2016; Chakraborti *et al.* 2016). The main source of sodium required for human body is mineral water. Lack of sodium in the body can lead to low blood pressure, depression, fatigue, mental apathy, and dehydration of the body. Excessive intake of sodium causes high blood pressure, stroke, edema, kidney damage and stomachache, headache, and nausea (Asghari *et al.* 2018; Goyer *et al.* 2004; Rubenowitz *et al.* 2000). Lack of some cations such as calcium and magnesium in drinking water is associated with cardiovascular diseases. Nitrates and nitrites are the main contaminants of groundwater resources. Average concentration of nitrate and nitrite has been increasing due to the urbanization growth, industrial and agriculture sewage as well as overexploitation of aquifers and the groundwater resources. High concentration of nitrate and nitrite causes health problems such as Methemoglobinomia (Yang *et al.* 2006; Van Leeuwen 2000). In addition, high level of nitrate can increase the risk of abortion in maternal as well as it also can influence reduction of oxygen transfer to fetus through the mother's blood (Chetty and Prasad 2016; Gamao *et al.* 2015). Fluoride is a micro-essential element for humans that protects teeth against microbial attack, especially in childhood (KazemiMoghadam *et al.* 2018; Yousefi *et al.* 2018; Mohammadi *et al.* 2017; Neisi *et al.* 2018; Mirzabeygi *et al.* 2018). Exposure to high concentration of fluoride, in long term, can lead to chronic adverse effects such as dental and skeletal fluorosis, neurological, and Alzheimer problems (Mohammadi *et al.* 2017; Yousefi *et al.* 2017; Asghari *et al.* 2017). Drinking water containing high sulfate and calcium carbonate leads to indigestion and severe diarrhea in consumers (Chien*et al.* 1968; Jacobsen *et al.* 2005). Quality of water is one of the main concerns of the people, which is directly linked to the human welfare (Rapant and Krčmová 2007; Soleimani *et al.* 2018; Mirzabeygi *et al.* 2017). Therefore, water quality monitoring is an effective approach for water resources protection. There are many programs for monitoring water budgets in Iran and other countries (Yousefi *et al.* 2018; Biglari*et al.* 2016; Takdastana *et al.* 2018; Mirzabeygi *et al.* 2016; Yousefi *et al.* 2018; Abbasnia*et al.* 2018; Yousefi *et al.* 2018; Asghari *et al.* 2018). The presence of heavy metals in drinking water can be associated to anthropological activity such as discharging effluent of industry, agriculture, mining activity as well as geological activities such as soil erosion, weathering of rocks, deposits in minerals, and volcanic activity (Bazrafshan *et al.* 2016; Jafari *et al.* 2018; Muhammad *et al.* 2011; Khan *et al.* 2013). Heavy metals are dangerous for humans due to some characteristics such as stability, toxicity, and bio-accumulation. Excessive intake of heavy metals such as Cd, Cr, Pp., As, Hg, Ni, Co, and Zn are carcinogenic to humans (Jordao *et al.* 2002). Physical, chemical, and biological properties of various forms of arsenic are similar, but toxicity grade of these properties is different. Organic and inorganic forms of arsenic are common in nature. Both forms of arsenic are toxic, but the semimetallic inorganic compounds are more toxic than the organic forms (Zhang *et al.* 2007; Muhammad *et al.* 2010; Chakraborti *et al.* 2016). Among inorganic compounds, toxicity of As^{3+} is higher than As^{5+}(Alimohammadi *et al.* 2017; Hall 1999). Receiving arsenic through the water causes severe health problems such as cancer, gangrene, melanosis, hyperkeratosis, high blood pressure, skin lesions, peripheral vascular disease, and carcinogens effects in lungs and skin (Thundiyil *et al.* 2007; Rahman *et al.* 2009; Fatmi *et al.* 2009; Humans IWGotEoCRt, Organization WH, Cancer IAfRo 2004). High concentrations of arsenic and other chemical parameters in the groundwater in different parts of the world especially in South Asia have been reported (Muhammad *et al.* 2010; Muhammad *et al.* 2011; Khan *et al.* 2013). The permissible concentration of arsenic has been reported to be 10 μg/l by the World Health Organization (WHO) and Institute of Standards and Industrial Research of Iran(ISIRI) (WHO 2004; Association APH, Association AWW, Federation WPC, Federation WE 1915). The aim of this study was to determine the level of anions, cations, and metalloid arsenic in drinking waters. In addition, the contamination of drinking water with arsenic and its harmful effects on human health were evaluated to determine the carcinogenic and noncarcinogenic effects of arsenic contamination in ground waters with emphasize on physical and chemical characteristics of drinking water.

Methods and materials

Study area

Sistan and Baluchistan province is located between 58° 55′- 63°20′ E longitude and 25° 4′-31°25′ N latitude (southeastern of Iran), which includes eight cities (Zabol, Zahedan, Khash, Iranshahr, Nikshahr, Saravan, Chabahar, and Sarbaz) as illustrated in Figure 1. The area of this province is 18,175 square kilometers. The region is almost flat and has a warm climate. The average annual temperature in this area is 25 °C degrees. The highest and lowest temperatures in the region are 50 ° C and −7 ° C, respectively, and the evaporation is 4000 mm per year (four times more than the average evaporation rate in Iran). The average rainfall in the region is 70–130 mm per year (Biglari *et al.* 2016).

Sampling

Water samples were collected from 493 wells of drinking water supply system in the eight cities in Sistan and Baluchestan province (Figure 1). At each sampling point, two water samples were separately collected in polyethylene containers with 2 liters of volume. Along with sampling, the water was allowed to flow for two minutes and then sampling bottles were slowly filled. Samples were separately collected for chemical and heavy metals analysis. At each point, one bottle without adding acid and bubbles was

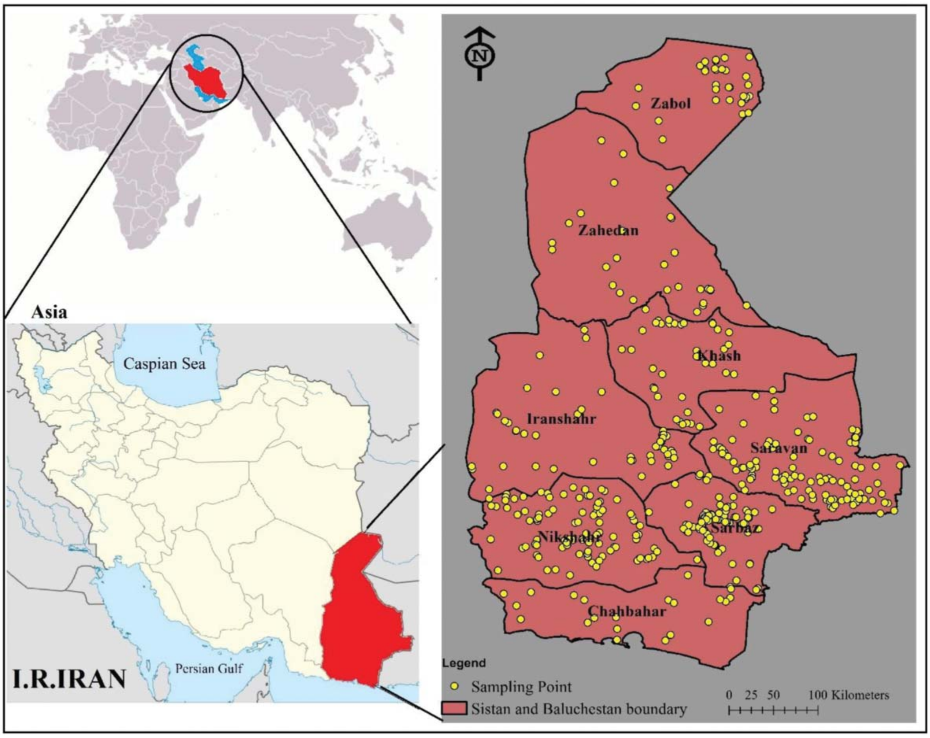

Figure 1. Location map of the studied area and sampling site. (Source: Department of Geography, University of Birjand, Birjand, Iran.).

filled up. Another bottle was rinsed with double-distilled water and nitric acid with 1:1 ratio. pH of samples was adjusted to less than 2 with pure nitric acid (E. Merck, Darmstadt, Germany) in order to reduce the absorption of heavy metals in the lining of containers and staticize the microbial activity. After transferring the samples to the laboratory, acidified water samples were tested for heavy metals, and nonacidic samples were tested for analysis of physical and chemical parameters. All water samples were transferred to the laboratory at 4 °C.

Analysis

All samples were analyzed based on the standard methods (Way 2012). The main parameters, such as pH, electrical conductivity (EC), and temperature at sampling point were measured by Water Checker u-10. Sulfate, fluoride, and nitrate were measured using a spectrophotometer (HACH DR 5000). Chloride (Cl) was measured by the standard titration with $AgNO_3$. Total dissolved solids (TDS) was calculated using equation: TDS = 0.55−0.75 (EC). Bicarbonate was measured by titration with HCl. Calcium was estimated by titration with EDTA. Sodium and potassium were determined by a flame photometer. Heavy metal concentrations were analyzed by an atomic absorption spectrophotometer paired with a graphite furnace (Perkin Elmer AA-Analyst 200 model). The laboratory temperature was 25 °C. All chemicals used in this study were of analytical of grade, and double-distilled water was used for experimental analysis.

Statistical analysis

All data were statistically analyzed by SPSS V.21, and map of the area was generated using Arc GIS. V 10.3.

Arsenic risk assessment

Exposure assessment

Arsenic metalloid enters human body through several pathways including oral intake, inhalation, and dermal contact, but the most common intake occurs through oral intake and other ways have negligible contribution (Muhammad *et al.* 2010; Roychowdhury *et al.* 2003). The average daily dose (ADD) was calculated according to the following equation:

$$ADD = \frac{CIREDEF}{BWAT}$$

where ADD is the average daily dose during the exposure (mg/kg-day) and C represent the arsenic concentration in water (μg/l), IR is water ingestion rate (2 liters for adults and one for children's), ED is exposure duration (70 years for adults and ten for children), EF is exposure frequency (365 days' years^{-1}), BW is body weight (72 kg for adults and 32.7 kg for children), and AT is average life time (25,550 days for adults and 3650 days for children) (Muhammad *et al.* 2010; Khan *et al.* 2013; Ebrahimi *et al.* 2013, Moya *et al.* 2011).

Human health risk assessment

In this study, carcinogenic and noncarcinogenic risk levels were assessed. Generally, the hazard quotient (HQ) indices can be calculated by the following equation:

$$HQ = ADD\ /\ RFD$$

where the As reference dose (RFD) is 0.0003 mg kg^{-1} day^{-1}. Occurrence of noncarcinogenic effects is possible when HQ values are more than unity. The excess lifetime cancer risk (ELCR) was calculated using following equation (Muhammad *et al.* 2010; Moya *et al.* 2011):

$$ELCR = ADD \times CSF$$

where the cancer slope factor (CSF) for As was considered 1.5 mg kg^{-1} day^{-1}(Muhammad *et al.* 2010; Muhammad *et al.* 2011; Rasool *et al.* 2016; Adamu *et al.* 2015).

Results

Physical parameters

Table 1 summarizes the temperature, pH, TDS, and EC values in the drinking water of the study area. The pH values of groundwater were in the following order: Iranshahr > Saravan > Sarbaz

Table 1. Mean concentrations of physical parameters in drinking water collected from different parts of Sistan and Baluchestan province.

Counties	Statistics	pH	TDS (mg/l)	EC (μs/cm)	Temperature (°C)
Iranshahr N[a] = 65	Range	7.3-8.32	276–3130	432–4890	20–24
	Mean	7.9	1164	1818	21.9
	Stdd[b]	0.27	666	1041	1
Chabahar N = 28	Range	7.1–8.2	349–5485	546–8570	19–24
	Mean	7.7	1323	2068	20.7
	Std d	0.26	1043	1630	1.1
Khash N = 34	Range	7.02–8.2	439–2573	686–4020	20–24
	Mean	7.75	1097	1713	21.5
	Std d	0.24	500	781	1.3
Zabol N = 31	Range	6.9–8.26	425–2016	665–3250	20–23
	Mean	7.8	580	906	21.8
	Std d	0.32	367	574	0.9
Zahedan N = 35	Range	6.8–8.2	299–6310	468–9860	20–23
	Mean	7.7	1887	2947	22
	Std d	0.37	1455	2274	0.9
Saravan N = 135	Range	7.08–8.3	353–2362	551–3690	18–24
	Mean	7.86	968	1513	21.6
	Std d	0.25	470	734	1.2
Sarbaz N = 77	Range	7.3–8.2	274–1965	428–3070	20–24
	Mean	7.8	568	888	21.5
	Std d	0.22	268	419	1.1
Nikshahr N = 89	Range	7.2–8.3	339–1542	529–2410	19–24
	Mean	7.74	742	1160	21.8
	Std d	0.31	292	456	1.3

> Zabol > Khash > Nikshahr > Chabahar > Zahedan area (Figure 2). In Iranshahr area, the highest pH (8.32) of groundwater may be attributed to underground sulfide mineralization. The low pH (6.9) was observed in the collected groundwaters of Zahedan area. The results showed that both groundwaters have been presented from slightly acidic to slightly alkaline. However,

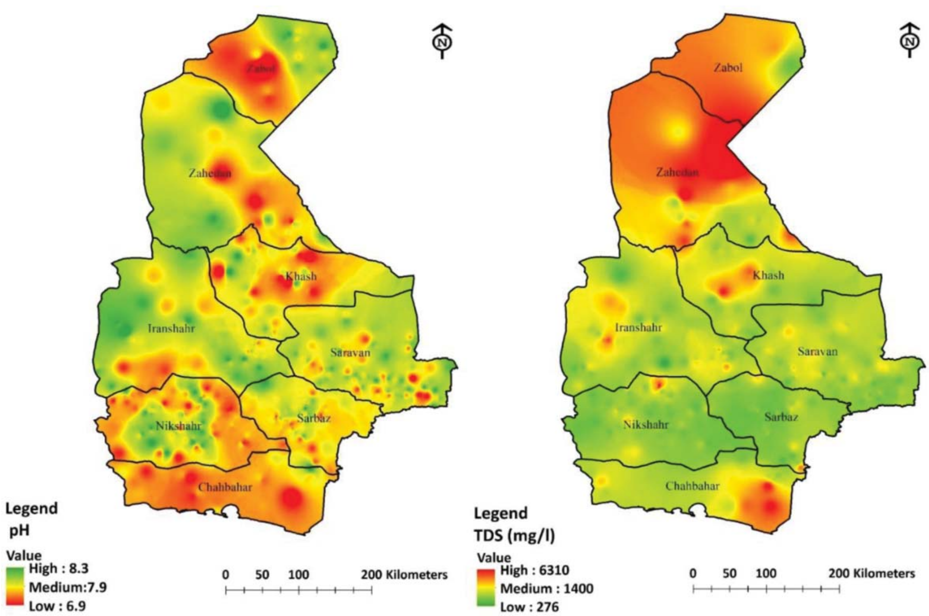

Figure 2. pH and concentration TDS (mg/l) in drinking water of Sistan and Blouchestan.

pH values of groundwater were within the permissible limits of ISIRI and WHO (Table 2). (WHO 2004; Institute of Standards and Industrial Research of Iran 2011).

Also, the EC values of groundwater were similar to following pH order: Zahedan > Chabahar > Iranshahr > Khash > Saravan > Nikshahr > Zabol >Sarbaz area (Figure 2). The highest observed value for EC was 2947 μs/cm and was within permissible limits. The lowest EC (888 μs/cm) were found in the groundwater samples collected from Sarbaz area. Similarly, the TDS values of groundwater were: Zahedan > Chabahar > Iranshahr > Khash > Saravan > Nikshahr > Zabol > Sarbaz area (Table 1). The highest observed value for TDS was 1887 mg/l for groundwater of Zahedan and the lowest TDS (568 mg/l) was found in the groundwater samples collected from Sarbaz area (Figure 2). Some of these sources exceeded the permissible limit set by ISIRI (1500 mg/l) and WHO (1000 mg/l) as given in Table 2.

Anions and cations

Table 3 presents the mean concentration of cations and anions in the drinking water samples collected from study area. The SO_4^{2-} values were in the following order: Zahedan > Chabahar > Saravan > Iranshahr > Khash > Sarbaz > Zabol >Nikshahr. Some of these sources exceeded the permissible limit set by ISIRI (250 mg/l) and WHO (250 mg/l) as given in Table 2. The highest SO_4^{2-} (506 mg/l) was observed in the water sample collected from Zahedan area. The lowest SO_4^{2-} (20 mg/l) was found in the groundwater samples collected from Nikshahr area (Figure 3).

Similarly, the NO_3^- values of groundwater were in the following order: Zahedan > Sarbaz > Khash > Iranshahr > Nikshahr > Saravan > Chabahar > Zabol. The highest NO_3^- (17.5 mg/l as NO_3) was observed in the water sample collected from Zahedan area. The lowest NO_3^- (12 mg/l as NO_3) was found in the groundwater samples collected from Zabol area (Figure 3) which was within the permissible limits set by ISIRI (50 mg/l as NO_3) and WHO (50 mg/l as NO_3) as given in (Table 2). The F^- values of groundwater were in the following order: Zahedan > Khash > Iranshahr > Saravan > Chabahar > Zabol > Nikshahr > Sarbaz. The highest F^- value (0.92 mg/l) was observed in the water samples collected from Zahedan area (Figure 3). The lowest F^- value (0.4 mg/l) were found in the groundwater

Table 2. Drinking water quality guidelines given by different organizations.

Contaminant	ISIRI[a] (mg/l)	WHO limits[b] (mg/l)
As	0.01	0.01
NO_3	50	50
SO_4	400	250
Cl	400	250
F	1.5	1.5
Ca	300	—
Mg	30	—
K	—	—
Na[f]	200	—
PO4	—	—
HCO_3	—	—
TDS	1500	1000
pH	6.5–8.5	6.5–8.5

A dash indicates that there is no information available regarding possible limits.
[a]Institute of Standards and Industrial Research of Iran.
[b]As per the WHO (2004) Guidelines for drinking water quality, 2nd edition. Geneva, World Health Organization.

Table 3. Mean values (mg/l) of anions and cations in groundwater samples collected from Sistan and Blouchestan.

Counties	Statistics	K^+	Na^+	Mg^{2+}	Ca^{2+}	HCO_3^-	NO_3^-	SO_4^{2-}	Cl^-	F^-
Iranshahr N[a] = 65	Range	2–30	50–1065	5–62	16–178	85–693	6–49	40–1000	40–954	0.2-1.7
	Mean	6	309	19	69	246	15	307	284	0.61
	Stdd[b]	4	224	11	33	100	6	227	205	0.31
Chabahar N = 28	Range	3–13	71–698	11–273	31–400	117–427	2.5–72	70–1150	64–1210	0.05–1.4
	Mean	8	283	46	98	252	12	404	297	0.51
	Std d	2.5	194	52	83	76	17	317	291	0.31
Khash N = 34	Range	2–30	27–707	8–97	32–1524	156–729	6–37	60–750	57–905	0.2–1.7
	Mean	7	218	35	132	312	16	273	253	0.71
	Std d	4.6	152	21	200	129	8	178	165	0.31
Zabol N = 31	Range	3–6	60–558	14–53	32–92	166–256	8–19.5	100–690	62–545	0.2–0.9
	Mean	5	107	32	45	188	12	155	106	0.51
	Std d	0.8	114	11	14	23	6	138	111	0.21
Zahedan N = 35	Range	3–13	60–1236	14–118	18–448	37–541	5.5–67	19–1500	50–1305	0.2–1.5
	Mean	7.5	406	48	128	308	17.5	506	409	0.92
	Std d	3	295	27	112	111	12	397	333	0.38
Saravan N = 135	Range	2–30	4–625	3–76	31–808	22–549	1.7–56	30–1050	35–773	0.1–1.8
	Mean	4.7	206	24	73	288	14	255	190	0.53
	Std d	2.8	129	14	67	84	9	199	125	0.2
Sarbaz N = 77	Range	2–10	31–360	9–44	6–146	134–490	5–54	30–740	40–641	0.15–0.95
	Mean	4.6	101	16	64	234	16	104	98	0.4
	Std d	1.5	65	5	21	57	9	106	75	0.2
Nikshahr N = 89	Range	1–10	18–386	10–51	26–162	141–630	5–68	30–540	41–415	0.1–1.4
	Mean	4.5	151	21	73	265	14.5	152	153	0.46
	Std d	2.3	86	9	27	72	9	105	85	0.2

samples collected from Sarbaz area, which was within the permissible limits set by ISIRI (1.5 mg/l) and WHO (0.4 mg/l) as given in (Table 2).

The Cl^- values of groundwater were in the following order: of Zahedan > Chabahar > Iranshahr > Khash > Saravan > Nikshahr > Zabol > Sarbaz, area. The highest Cl^- value (408 mg/l) was observed in the water sample collected from Zahedan area (Figure 3). The lowest Cl^- value (98 mg/l) was found in the groundwater samples collected from Sarbaz area. Some of these sources exceeded the permissible limit set by ISIRI (400 mg/l) and WHO (250 mg/l) as given in Table 2.

The Mg^{2+} values of groundwater were in the following order: Zahedan > Chabahar > Khash > Zabol > Saravan > Nikshahr > Iranshahr >Sarbaz. The highest Mg^{2+} (48 mg/l) was observed in the water sample collected from Zahedan area. The lowest Mg^{2+} (16 mg/l) was found in the groundwater samples collected from Sarbaz area. Some of these sources exceeded the permissible limit set by ISIRI (30 mg/l) and WHO as given in (Table 2).

The Ca^{2+} values of groundwater were in the following order: Zahedan > Chabahar > Iranshahr > Khash > Saravan > Nikshahr > Zabol > Sarbaz. The highest Ca^{2+} (128 mg/l) was observed in the water sample collected from Zahedan area. The lowest Ca^{2+} (45 mg/l) was found in the groundwater samples collected from Sarbaz area (Figure 4) within the permissible limits set by ISIRI and World Health Organization (WHO) as given in (Table 2). The Na^+ values of groundwater were in the following order: Zahedan > Iranshahr > Chabahar > Khash > Saravan > Nikshahr > Zabol >Sarbaz. The highest Na^+ (406 mg/l) was observed in the water sample collected from Zahedan area. The lowest Na^+ (101 mg/l) was found in the groundwater samples collected from Sarbaz area. Some of these sources exceeded the permissible limit ISIRI (200 mg/l) and WHO as given in Table 2.

Similarly, the K^+ values of groundwater were in the following order: Chabahar > Zahedan > Khash > Iranshahr > Zabol > Saravan > Sarbaz >Nikshahr area. The highest K^+

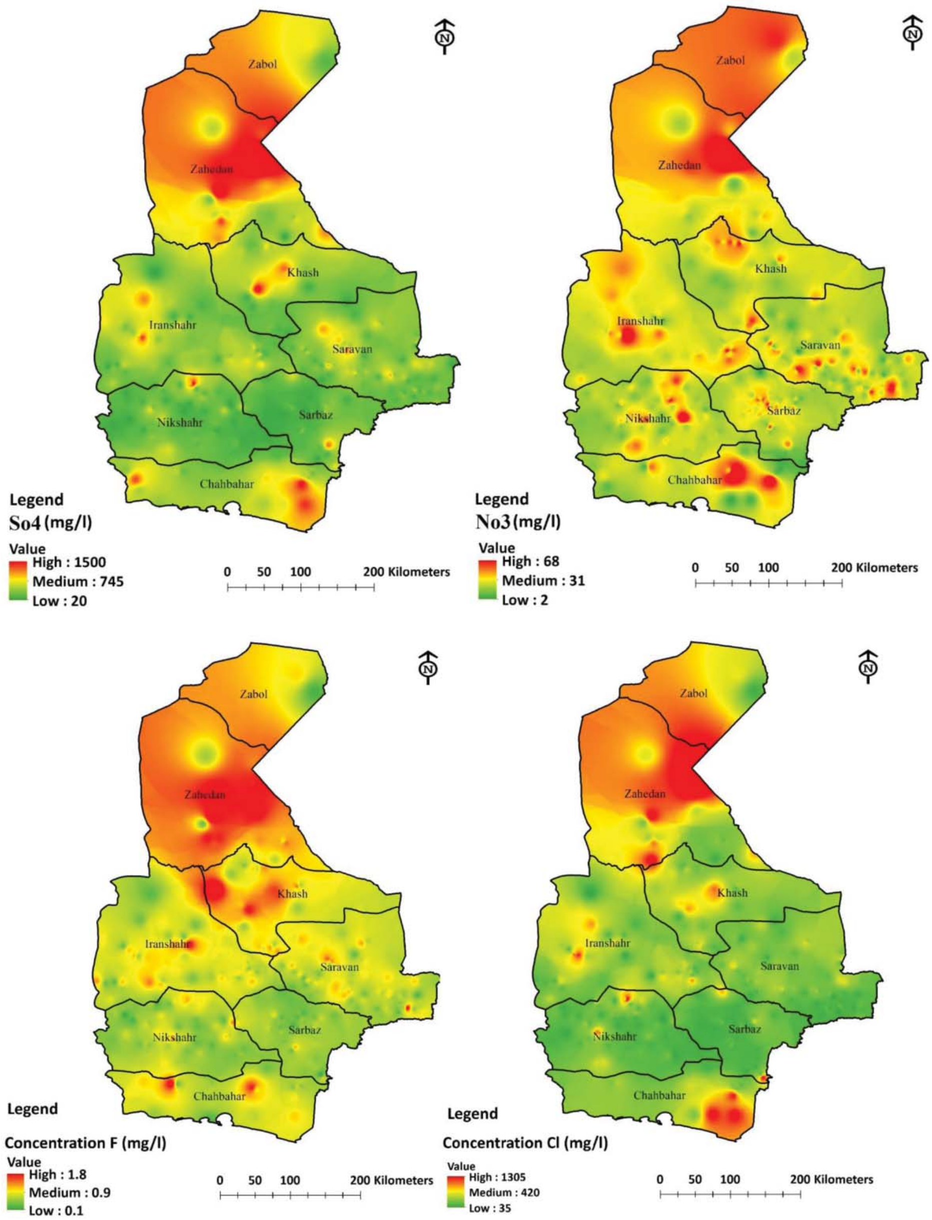

Figure 3. So_4^{-2}, $No3^-$, F^-, and Cl^- concentration (mg/l) in drinking water of Sistan and Baluchestan.

(8 mg/l) was observed in the water sample collected from Chabahar area. The lowest K value (4.5 mg/l) was found in the groundwater samples collected from Nikshahr area (Table 2).

Heavy metal

Table 4 represents the As concentrations, HQ, and carcinogenic risk in the drinking water of the study area. The As values were in the following order: Zabol > Khash >

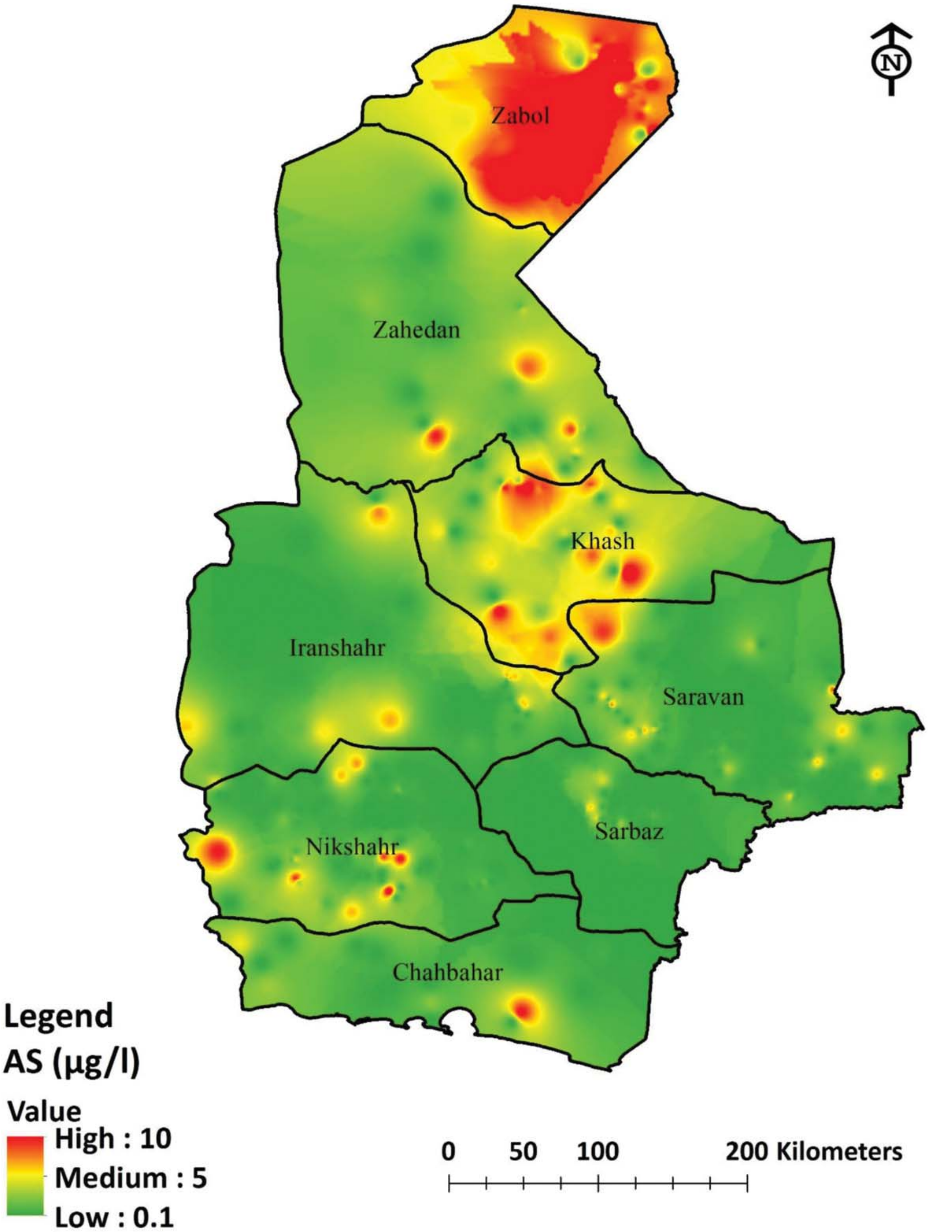

Figure 4. Arsenic concentration (μg/l) in drinking water of Sistan and Baluchestan.

Zahedan >Iranshahr > Nikshahr > Chabahar > Saravan > Sarbaz area. The highest As (5.8 μg/l) was found in the water sample collected from Zabol area. The lowest As (0.42 μg/l) was found in the groundwater samples collected from Sarbaz area (Figure 4), which was within the permissible limits set by Iran Environmental Protection Agency (Iran-EPA, 2008,), World Health Organization (WHO), and United States Environmental Protection Agency (US-EPA) (Table 4). The HQ values of groundwater were in the

Table 4. Concentrations as (μg/l), HQ and cancer risk in water sample collected from the study area.

Counties	Statistics	Concentration Arsenic	Hazard quotient of As		Carcinogenic risk of As	
			Adults	Children	Adults	Children
Iranshahr N[a] = 65	Range	0.01–7.4	0.001–1.26	0.019–1.39	1.54E-6-1.1E-04	1.69E-6-1.2E-04
	Mean	1.5	0.01	0.29	2.26E-5	2.65E-5
	Std d	2.25	0.011	0.41	3.47E-5	3.74E-5
Chabahar N = 28	Range	0.1–9	0.017–1.55	0.038–1.74	1.54E-6-1.4E-04	4.80E-7-2.2E-05
	Mean	0.9	0.155	0.21	1.41E-5	2.70E-6
	Std d	2	0.348	0.37	3.13E-5	4.70E-6
Khash N = 34	Range	0.1–11	0.017–1.87	0.019–2.06	1.54E-6-1.6E-04	2.42E-7-2.6E-05
	Mean	4.3	0.73	0.83	6.60E-5	1.06E-5
	Std d	3.5	0.60	0.64	5.50E-5	8.30E-6
Zabol N = 31	Range	0.1–12.5	0.017–2.14	0.038–2.35	1.54E-6-1.9E-04	4.80E-7-3.0E-05
	Mean	5.8	1	1.09	8.90E-5	1.40E-5
	Std d	3.8	0.65	0.72	5.80E-5	9.20E-6
Zahedan N = 35	Range	0.1–8.6	0.017–1.48	0.019–1.63	1.54E-6-1.3E-04	2.42E-7-2.1E-05
	Mean	2	0.35	0.39	3.18E-5	5.05E-6
	Std d	2.5	0.43	0.47	3.87E-5	6.06E-6
Saravan N = 135	Range	0.1–9	0.017–1.54	0.038–1.71	1.54E-6-1.3E-04	4.80E-7-2.2E-05
	Mean	0.72	0.12	0.17	1.11E-5	2.20E-6
	Std d	1.84	0.31	0.33	2.84E-5	4.30E-6
Sarbaz N = 77	Range	0.1–9.5	0.017–1.63	0.038–1.44	1.54E-6-1.4E-04	4.80E-7-1.9E-05
	Mean	0.42	0.07	0.11	6.40E-5	1.49E-6
	Std d	1.5	0.25	0.23	2.20E-5	2.95E-6
Nikshahr N = 89	Range	0.1–11	0.017–1.90	0.038–2.06	1.54E-6-1.7E-04	4.80E-7-2.6E-05
	Mean	1	0.17	0.22	1.55E-5	2.87E-6
	Std d	2.3	0.39	0.42	3.51E-5	5.46E-6

following order: Zabol > Khash > Zahedan > Iranshahr > Nikshahr > Chabahar > Saravan > Sarbaz area. The highest As (5.8 μg/l) was observed in the water sample collected from Zabol area. The lowest As (0.42 μg/l) was found in the groundwater samples collected from Sarbaz area (Figure 4).

Table 4 also shows the average HQ indices for adults and children in the study area. The estimated HQ index for studied areas were in the following order: Zabol > Khash > Zahedan > Iranshahr > Nikshahr > Chabahar > Saravan > Sarbaz. The highest HQ value for adults (1) was observed in the water samples collected from Zabol area. About 12% of houses in Zabol area are consuming the groundwater for drinking purpose and therefore can be considered as low risk from As. However, no risk was noticed for remaining (88%) populations in Zabol and Khash, Zahedan, Iranshar, Nikshahr, Chabahar, Saravan, and Sarbaz. The highest HQ value for children (1.09) was observed in the water sample collected from Zabol.

Table 4 also illustrates the potential cancer risk values for adults and children in the study area. The average ELCR value of in the drinking water were in the following order: Zabol > Khash > Zahedan > Iranshahr > Nikshahr > Chabahar > Saravan > Sarbaz. The highest ELCR value for adults (8.90×10^{-5}) and for children (1.4×10^{-5}) was observed in the water samples collected from Zabol area. The CR value greater than one in million (10^{-6}) was generally considered significant by USEPA. The results indicated that drinking water generally has low ELCR values except for the 12% of houses of Zabol area that showed medium risk based on USEPA approach (Agency, U.E.P. 1999). The cancer risk index of study area was lower than those reported for drinking water in Pakistan and Vietnam (Muhammad *et al.* 2010; Nguyen *et al.* 2009).

The results from Khash, Zahedan, Iranshahr, Nikshahr, Chabahar, Saravan, and Sarbaz areas showed that water has medium level of contamination and is suitable for drinking and other domestic purposes (Table 4).

Statistical techniques

The correlation matrices among average physiochemical parameters of groundwater are given in Table 5. Correlation coefficients showed that various physiochemical parameter pairs have significant positive correlation such as TDS–EC (r = 1.000), SO_4–TDS (r = 0.981), SO4–E (r = 0.981), Cl–TDS (r = 0.987), Cl–EC (r = 0.987), F–TDS (r = 0.834), F–EC (r = 0.834), Mg–TDS (r = 0.734), Mg–EC (r = 0.734), Mg–SO_4 (r = 0.794), Ca–TDS (r = 0.765), Ca–EC (r = 0.765), Ca–HCO_3 (r = 0.831), Ca–Cl (r = 0.768), Ca–F (r = 0.801), K–TDS (r = 0.817), K–SO_4 (r = 0.864), K–Cl (r = 0.864), K–Ca (r = 0.786), K–Mg (r = 0.850), Na–EC (r = 0.974), Na–TDS (r = 0.974), Na–SO_4 (r = 0.959), Na–Cl (r = 0.985), Na–F (r = 0.783), and Na–K (r = 0.767). Similarly, some pairs also showed a significant negative correlation such as Mg–pH (r = −0.875) and K–pH(r = −0.747).

Discussion

The previous and present studies indicated that groundwater contaminated with different heavy metals and chemicals is responsible for numerous human health risks. Based on the recent investigations conducted on various hazardous chemical contamination and heavy metals in surface and groundwater, heavy metals play an important role in human health. The exposed population in this study is classified as low-income class. The groundwater resources have been illegally used through installing numerous wells and bore holes by local people due to lack of governmental audits and surveillance and

Table 5. Correlation matrix of selected average physiochemical parameters for surface water in the study area.

Parameter	Aa	pH	TDS	EC	HCO_3	NO_3	SO_4	Cl	F	Mg	Ca	K	Na
As	1												
pH	−.169	1											
TDS	−.144	−.534	1										
EC	−.145	−.534	**1.000****	1									
HCO_3	−.248	−.286	.644	.644	1								
NO_3	−.204	−.099	.413	.412	.643	1							
SO_4	−.106	−.561	**.981****	**.981****	.546	.239	1						
Cl	−.123	−.477	**.987****	**.987****	.629	.391	**.972****	1					
F	.277	−.461	**.834****	**.834***	.668	.610	**.766***	**.824***	1				
Mg	.276	**−.875****	**.734***	**.734***	.328	−.043	**.794***	.695	.631	1			
Ca	.037	−.684	**.765***	**.765***	**.831***	.552	.706	**.768***	**.801***	.674	1		
K	.090	**−.747***	**.817***	**.817***	.424	.111	**.864****	**.846****	.653	**.850****	**.786***	1	
Na	−.191	−.358	**.974****	**.974****	.574	.383	**.959****	**.985****	**.783***	.610	.660	**.767***	1

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). Bold values signify that the level is more correlated water shortages (Bazrafshan *et al.* 2016; Khan *et al.* 2013; Wcisło *et al.* 2002). Groundwater used in the studied area has no contamination because it is placed between underground rocks unlike surface waters. In this point of view, no noticeable water treatment method was considered for drinking water. However, the quality of these water resources may not be acceptable. Previous studies showed that the drinking water quality is associated with many factors that can lead to serious health problems (Ebrahimi *et al.* 2013; Sajadi *et al.* 2015; Demir *et al.* 2015). Although pH of drinking water has no direct effects on human health, but pathogens' survival and metals' solubility can be affected by pH changes that can have significant direct effect on public health (Khan *et al.* 2013; Demir *et al.* 2015). Gastrointestinal discomfort is an unavoidable phenomenon that occurs via pH changes in sensitive people (Muhammad *et al.* 2011; Khan *et al.* 2013). Chemical characteristics of water such as anions and cations are considered as an important part in drinking water quality that can have influence on human health. As an adverse consequence of excessive use of fertilizer in the farms, high concentration of SO_4^{2-} can be observed in drinking water (Mora *et al.* 2009, Tamasi and Cini 2004). Drinking water with high concentration of SO_4^{2-} may cause health problems such as laxative action. Apart from SO_4, fertilizers, manures, and sewages are considered as the significant sources of NO_3^-. Methemoglobinemia or blue baby disease is related to high concentration of nitrate in drinking water. However high concentration of nitrate (more than 10 mg/l) have no serious toxicity effects on adults (WHO 2004; Chowdary *et al.*, 2005; Mohammadi *et al.* 2017). It is reported that there is no association between health risks and heavy metals in drinking water due to the low amount of HRI (less than 1) (Khan *et al.* 2013). According to previous study there is not enough evidence for on differences between inorganic and organic arsenic exposure (Joca *et al.* 2016). Another study in Pakistan conducted on drinking water showed that there is risk potential related to As toxicity for children (Brahman *et al.* 2016). More documents were needed to approve heavy metals and its health effects. Ultimately, it was suggested to improve people and farmers' knowledge in the study area about using organic and inorganic materials as fertilizer for protecting groundwater sources with emphasis on groundwater contamination and human health risks. Furthermore, strict governmental management and administration on effective water treatment as well as monitoring of selected water supply sources far from contaminated sources should be considered.

Conclusion

As per the obtained results, drinking water in the study areas contaminated with SO_4^{2-}, Cl, Mg, and Na was in acceptable levels recommended by WHO and local regulations in the case of heavy metal (As). Based on the calculated indices of HQ and ELCR, drinking water has no adverse effects on the human health. It is important to have knowledge (or being more cautious) about main drinking water polluting factors such as the immoderate use of fertilizers and pesticides as well as unsuitable sewage, sludge, and solid waste disposal that can contaminate drinking water. As a consequence, regarding the excessive use of ground water by local people in Sistan and Baluchestan, applying more audits by governmental offices on water withdrawal and its quality issues is suggested.

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