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Assessment of chemical quality of drinking water in rural areas of Qorveh city, Kurdistan province, Iran

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Original Article

Abstract

Groundwater aquifers as one of the main sources of water supplies are faced with different risks such as level dropping due to lack of precipitation, and natural and non-natural pollutants. Thus, it is extremely necessary to monitor ground water quality. In the present study, the concentration of cations, anions, and some toxic metals was evaluated in 21 rural water supplies in Qorveh plain in two stages. Data were analyzed with Rockwork and Arc GIS software. Results from Hydro chemical analysis showed that all the studied parameters had lower concentrations than the permitted limits, except for arsenic (As) and selenium (Se) in some of water resources. As concentration in 20% of studied resources were higher than recommended standards. There was a significant difference between nitrate (NO_3^-) concentrations in the two low- and high-water seasons ($P < 0.01$). Bicarbonate (HCO_3^-) and calcium (Ca^{2+}) were the prevalent anion and cation, respectively, meaning that samples type was calcium-bicarbonate. Wilcox diagram classified the samples in C2-S1 and C3-S1 classes. Correlation coefficient between chemical parameters showed that HCO_3^- and Ca^{2+} had the highest correlation. Finally, it can be said that except for As and Se, other water characteristics have a good quality for drinking water application. However, current and uncontrolled application of the studied water supplies, especially in agricultural activities, can change and decrease their quality. Therefore, it is important to prevent the health threats of such process.

KEYWORDS: Water Quality Monitoring, Water Resource, Drinking Water, Heavy Metals, Water Quality Standard

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Introduction

Improper operation of groundwater resources change their quality and introduce either direct or indirect destruction in other resources. Arid and semiarid areas are more vulnerable to such destructive effect because of their higher dependency to groundwater resources.[1] Thus, proper management of water resources in such areas needs to study their quality.[2] To proper operation of ground water in every area, it is necessary to precisely recognize its quantity and quality. Hydrological and hydro-chemical studies can be used for such purpose and to decide on the possibility of mixing waters with different resources. Brackish water, as the most prevalent groundwater pollution that decreases its quality, is going to become a very serious problem worldwide.[3] Therefore, considering increasing use of groundwater and its importance in arid areas such as Iran, qualitative

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assessment of such resources is very important part of ground water studies. Physical and chemical qualitative variation of ground water is a function of geological characteristics and human activities in every area.[4] However, some special compounds, such as heavy and toxic metals in drinking water can be serious threat for consumers' health, making its monitoring more important.

Among water chemical pollutants, arsenic (As) can find its way to water resources through solution in soil layers.[5] Thus, As pollution in water resources is one of the most serious threats for natural ecosystems and human health, which become a big health concern in many countries worldwide:[6,7] South Asia, Bangladesh, West Bengal, India, and Tiwan and some South American countries such as Argentina and Mexico; and also some urban and rural areas in Iran such as Kurdistan and Khorasan, are facing this problem.[8,9] As polluted water in Qorveh and Bijar in Kurdistan province of Iran in some local and limited studies has been reported.[10] Therefore, it is necessary to prevent consumer exposure to As, particularly in areas of potential natural pollution, by continuously monitoring of water. Since the main water supply of Qorveh's rural areas is ground water, and considering that agricultural activities in the area use different types of fertilizers and pesticides, and also the possibility of As pollution of groundwater, this study aimed to assess chemical quality and toxic metal contents in ground water supplies of some rural areas of Qorveh city.

Materials and Methods

In this cross-sectional study, concentration of chemical parameters in drinking water in some drinking water supplies of rural areas of Qorveh city (21 villages covered by Kurdistan Rural Water and Wastewater Company) was investigated. Samples were taken in two low- and high-water seasons in the year 2012, according to standard methods for the examination of water and wastewater.[11] Then, they were transferred to the laboratory under standard conditions and kept in the refrigerator until the examination. Turbidity, temperature, electrical conductivity, and pH were measured in sampling site. Sulfate (SO_4^{2-}), phosphate (PO_4^{3-}), nitrate (NO_3^-), chloride (Cl^-), fluoride (F^-), calcium (Ca^{2+}), magnesium (Mg^{2+}) were determined using an ion chromatograph. Sodium (Na^+), lithium (Li^+), and potassium (K^+) were measured by a flame photometer. All examined parameters were determined according to standard methods for the examination of water and wastewater.[11]

In order to compare the results of two phases of the study SPSS for Windows (version 16.0, SPSS Inc., Chicago, IL, USA) and Wilcoxon test were used. To determine the correlation between the anion and the cation Pearson correlation coefficient was used. Rockwork was used to analyze the results of chemical analysis in the studied samples. Using the results obtained from previous step, ground water type was determined and its application for drinking, agricultural and industrial purposes were assessed. Moreover, ArcGIS was used to study the spatial variation of As and nitrate.

Results and Discussion

Table 1 represents the anions and cations' concentration and other water quality parameters in the studied water supplies. Table 2 shows the statistical characteristics of the chemical parameters.

Results showed that majority of anions and cations are within the standard rages. Hardness survey results showed that the water hardness in all the villages is temporary hardness (no permanent hardness was observed), categorizing as completely hard, hard and slightly hard (9.5%, 66.5%, and 23.8%, respectively). Therefore, hardness in the studied water supplies was lower than the recommended standards and did not have adverse effect on the consumers. However, its continuous increase can be a concern for future. It also, limits such supplies application for industrial purposes.

Table 1. Water quality parameters of groundwater in rural areas (high-water season)

Village	pH	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)	NO_3 (mg/l)	SO_4 (mg/l)	F (mg/l)	Cl (mg/l)	TDS (mg/l)	EC (µS/cm)	Alkalinity (mg/L $CaCO_3$)	TH (mg/l $CaCO_3$)
Amir Abad	7.7	69.3	9.7	8.6	36	18.0	16.0	0.40	8.3	460	660	246	210
Chomoghloo	7.3	38.2	8.7	5.6	63	12.9	16.5	0.39	7.6	410	598	216	130
Najaf Abad	7.5	77.5	17.0	1.3	58	7.3	34.6	0.40	5.9	575	847	308	260
Tazeh Abad	7.6	91.0	41.3	8.5	161	1.1	113.0	0.75	50.4	1108	1655	529	393
Bayeh	7.8	59.0	11.0	1.1	58	7.0	51.1	0.38	18.0	465	694	211	190
Zarin Abad	7.4	60.0	13.6	2.6	52	14.6	22.9	0.43	12.0	482	701	250	204
Alahyari	8.0	57.0	3.0	2.5	54	14.5	23.2	0.31	11.9	410	599	201	152
Dirakloo	7.6	49.0	9.2	2.5	53	15.4	26.7	0.25	13.2	406	605	194	158
Muzafarabad	7.7	59.0	11.4	2.5	53	14.4	23.0	0.31	12.0	460	683	235	192
Zivieh	7.5	34.7	5.1	1.1	61	11.7	30.0	0.39	9.7	365	528	175	106
Saeed Abad	7.8	65.3	7.3	0.8	34	20.4	7.7	0.43	6.3	398	583	209	190
Vinsar	7.6	85.7	16.0	2.1	113	38.6	150.0	0.30	28.3	759	1151	255	276
Ghandab Sufla	7.5	79.5	9.5	2.1	114	38.3	165.0	0.31	29.3	711	1061	219	234
Ghandab Olya	7.8	46.9	7.5	4.7	62	38.5	47.2	0.54	27.2	430	627	166	146
Dosar	7.7	79.6	12.2	6.7	95	34.4	64.5	0.49	45.9	682	1021	279	250
Babashaydolla	7.5	75.5	15.8	2.1	110	39.7	167.0	0.26	26.8	700	1078	214	250
Baharloo	7.8	66.0	18.0	2.1	109	36.2	149.0	0.42	32.6	675	1045	225	236
Jodaghyeh	7.8	97.0	23.8	6.8	82	28.3	67.0	0.50	35.7	771	1152	355	336
Miham Olya	7.6	49.0	8.7	0.6	14	16.0	13.9	0.33	11.4	290	407	150	146
Miham Sufla	7.9	34.7	7.3	1.0	34	21.0	13.8	0.39	11.7	310	449	161	115
Gharbelaghkhan	7.9	31.8	11.0	20.0	83	35.0	81.0	0.45	23.2	482	719	164	160
National Standard of Iran[12] (max. permissible)	-	-	-	-	200	50.0	400.0	1.50	400.0	1500	-	-	500

TDS: Total dissolved solids; EC: Electrical conductivity; TH: Total hardness

Table 2. Descriptive statistics of elemental concentration for the studied parameters

Parameter	N	Low-water season				High-water season			
		Mean	Standard deviation	Min	Max	Mean	Standard deviation	Min	Max
EC	21	882.62	335.51	470.0	1820.0	803.00	303.58	407.0	1655.00
TDS	21	585.95	226.86	320.0	1270.0	540.43	196.67	290.0	1108.00
pH	21	7.52	0.22	7.2	7.9	7.65	0.19	7.3	8.00
Ca	21	68.76	18.81	34.0	102.8	62.18	19.14	31.8	97.00
Mg	21	16.23	10.17	2.0	51.5	12.71	8.12	3.0	41.00
Na	21	72.52	37.59	19.0	160.0	71.38	35.08	14.0	161.00
K	21	3.95	4.30	0.6	19.3	4.06	4.44	0.6	20.00
HCO_3	21	315.00	113.80	209.0	744.0	288.20	102.00	183.0	645.00
Cl	21	21.05	17.68	4.2	81.5	20.34	13.05	6.0	50.00
SO_4	21	65.64	59.47	6.6	175.6	61.19	54.72	167.5	7.66

EC: Electrical conductivity; TDS: Total dissolved solids

Ionic frequency, water type and geochemical facies, and the way it developed in the studied villages showed that bicarbonate (HCO_3^-) and Ca^+ are the dominant anion and cation in the studied supplies, respectively, introducing calcic bicarbonate as the water type. Results obtained from Rockwork showed that rock bed in the studied villages, is mainly made up of limestone, dolomite and feldspar. Spread of carbonate rocks in the study area and dissolution of carbonate minerals are the main source of Ca^{2+} and Mg^{2+} ions in the water. The high concentration of HCO_3^- ions in the water is due to erosion and weathering of carbonate and silicate minerals. Table 3 was prepared according to Schuler diagrams (figures not provided), and it was found that the water samples from the studied villages are classified mainly into three groups, ranged from moderate to good. Due to its significant use in agriculture, one of the major issues in the study of water quality in the area is to evaluate its quality criteria for agriculture. To determine the quality of groundwater in agriculture Wilcox diagram was used (figures not presented). Based on its results, 61.9% of samples were in C2-S1 class, classified as slightly salty water for agriculture, and the rest were in C3-S1 class, considering as usable brackish water for agriculture.

Based on sodium percentage, more than 40% of the samples were good and about 50% of them had acceptable qualities. According to the residual sodium carbonate criteria for water quality, more than 90% of the samples had acceptable and the rest had good qualities.

Table 3. Classification of water bodies based on Schuler diagram

Water classification	SO_4	Cl	Na	pH	TH	TDS
Good	80.95	100.00	95.24	85.71	76.19	61.90
Acceptable	19.05	0	4.76	14.29	23.81	33.33
Average	0	0	0	0	0	4.76
Unsuitable	0	0	0	0	0	0
Unpleasant	0	0	0	0	0	0
Non-potable	0	0	0	0	0	0

TH: Total hardness; TDS: Total dissolved solids

Evaluation of water quality for industrial application showed that 4.8% of samples were balanced, 47.6% of them were scale forming and the rest were corrosive waters. Correlation coefficients between the different chemical parameters measured in the studied villages showed the highest correlation exists between HCO_3^- and Ca^{2+} (Table 4). Piper diagram also confirmed that the facies of water was calcic bicarbonate, showing that the main chemical composition of water is $Ca(HCO_3)_2$.

Considering the presence of other cations and anions in the water and existence of the correlation coefficient between them, other chemical compounds are $CaSO_4$, $CaCl_2$, $Mg(HCO_3)_2$, $MgSO_4$, $MgCl_2$, $NaHCO_3$, Na_2SO_4, NaCl, and KCl (depending on the specific terms of the ratio of Ca^{2+} to Mg^{2+} and Na^+ to Ca^{2+} in each of the studied sources).

Table 4. Correlation matrix of studied water quality parameters

	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3	TH	TDS	EC	pH
Ca	1											
Mg	0.661**	1										
Na	0.573**	0.716**	1									
K	−0.081£	0.242£	0.268£	1								
HCO_3	0.738**	0.914**	0.628**	0.188£	1							
Cl	0.634**	0.806**	0.877**	0.354£	0.852**	1						
SO_4	0.518*	0.455*	0.853**	0.090£	0.265£	0.697**	1	1				
NO_3	0.151£	−0.142£	0.322£	0.188£	−0.305£	0.067£	0.615**	0.615**				
TH	0.922**	0.889**	0.724**	0.158£	0.888**	0.867**	0.561**	0.561**	1			
TDS	0.813**	0.875**	0.917**	0.225£	0.841**	0.977**	0.733**	0.733**	0.935**	1		
EC	0.809**	0.868**	0.826**	0.217£	0.823**	0.948**	0.755**	0.755**	0.930**	0.999**	1	
pH	−0.090£	0.152£	−0.152£	0.21£	−0.185£	−0.277£	−0.099£	−0.099£	−0.100£	−0.145£	−0.136£	1

* Correlation is significant at the 0.05 level; £: Non-significant; ** Correlation is significant at the 0.01 level; TH: Total Hardness; TDS: Total Dissolved Solids; EC: Electrical Conductivity

According to table 1, the concentration of fluoride in the most of the water sources (85%) was less than the recommended standard, so this deficiency, especially in children, may lead to health problems.

According to table 1, the mean nitrate concentration in water supplies is 22.06 mg/l with a standard deviation of 12.3 mg/l, and nitrate concentrations in drinking water in all villages were less than the national standard.

However, nitrate concentrations in water supplies of Saeed Abad, Vinsar, Ghandab Sofla, Ghandab Olya, Dosar, Babashaydolla, Baharloo, Jodaghyehand Gharbelaghkhan villages were between 20 and 45 mg/l. Considering the nitrate risks at concentrations higher than 20 mg/l, it is possible that these villages would face with problems caused by nitrates.

The results showed that the nitrate distribution in low-water season, unlike nitrite, had wide variations and in most cases nitrate concentration in the season of high water is higher than the low-water season.

According to the Wilcoxon test and its correlation coefficient, it was found that there is a significant difference between the nitrate ions concentration in samples taken in the two seasons of high and low water ($P < 0.01$). It is due to increased agricultural activities in the high-water season following increased consumption of fertilizers and pesticides, which results in high concentration of nitrate in returned and agricultural drainage waters. Similar results were obtained in Semnan and Kashan.[13,14]

According to the map of nitrate concentrations (Figure 1), the greatest band of the nitrate concentration is in the northern part of the plain's center, which is an agricultural area with a high population. Therefore, the use of nitrate fertilizers in these areas is an important factor in increasing the concentration of nitrate ions in the water. In this regard, high concentrations of nitrate in groundwater of agricultural areas in Bahar (Hamadan) plain (122 mg/l), the agricultural district of Rajasthan, India (70-700 mg/l) and Krishna Delta, India (39% of samples had more than 50 mg/l) confirm the role and impact of agricultural activities on nitrites increase in water.[15-17]

The results of metal concentrations presented in table 5. According to the table, except for the As, concentrations of other metals are in the recommended standard ranges. The mean concentrations of As in water supplies is 16.25 µg/l with a standard deviation of 15.1 µg/l. 66.6% of the villages had the lowest concentration (1 µg/l) and Dosar village had the highest concentration (47 µg/l). According to the Institute of Standards and Industrial Research of

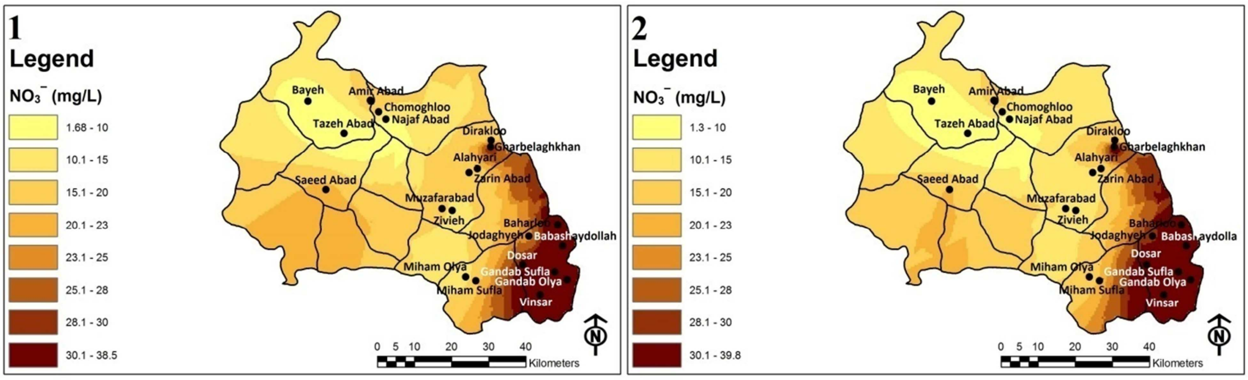

Figure 1. Spatial distribution of nitrate in ground water in low- and high-water seasons

Table 5. Trace metal concentrations (μg/l) in drinking water samples (high-water season)

Village	Cr	Pb	Cu	As	Zn	Se	Fe	Al	Ba
Amir Abad	6.1	0.4	20	10	16	7	2.0	8.6	214
Chomoghloo	7.5	0.4	19	24	65	6	1.3	3.0	93
Najaf Abad	7.0	0.4	20	1<	18	1	6.8	7.3	18
Tazeh Abad	10.0	0.4	22	1<	13	20	6.6	4.5	32
Bayeh	12.4	0.3	17	1<	11	1	34.0	4.2	42
Zarin Abad	9.0	0.4	21	1<	15	5	2.5	1.2	7
Alahyari	8.8	0.4	20	1<	15	8	4.8	2.4	89
Dirakloo	13.0	0.4	17	1<	14	8	54.0	1.3	8
Muzafarabad	8.3	0.4	18	1<	13	1	0.2	0.3	11
Zivieh	9.6	0.4	22	1<	10	1	1.6	2.2	18
Saeed Abad	11.6	0.4	23	1<	25	10	7.0	0.1	11
Vinsar	14.6	0.4	16	1<	17	5	11.4	0.5	6
GhandabSufla	14.6	0.4	18	9	28	10	16.0	53.0	7
GhandabOlya	14.0	0.3	25	12	11	4	4.2	4.0	41
Dosar	13.6	0.4	27	47	50	15	5.3	1.8	13
Babashaydolla	7.5	0.4	25	1<	19	11	246.0	5.5	6
Baharloo	6.0	0.4	27	1<	9	4	96.0	6.3	10
Jodaghyeh	7.0	0.4	20	9	17	1	6.3	4.8	63
MihamOlya	7.6	0.4	21	1<	5	1	3.2	8.5	1
MihamSufla	7.0	0.4	19	1<	21	10	5.7	1.4	9
Gharbelaghkhan	6.7	0.4	23	10	19	1	20.5	5.7	7
National Standard of Iran[12] (Max. Permissible)	50.0	10.0	2000	10	3000	10	300.0	100-200	700

Iran, No. 1053 and also World Health Organization, As concentration in 23.8% of water supplies is higher than recommended concentration and in 9.5% of them As concentration is close to the maximum allowable concentration. Therefore, there is a risk of exposure to As for consumers, and it is essential to determine and monitor its amounts in water.

As and its compounds are great threats to human and other organisms' health, and As-contaminated soils and sediments and water supplies are important sources of food chain contamination. Abundance of As in calcareous soils of the Qorveh basin plain, as the Kurdistan Province's major agricultural region, leads to contamination of agricultural corps and water sources. To obtain sufficient information about the characteristics of As-contaminated regions is a key step to their reform. To assess and manage the risks of As contamination, it is important that the geochemical conditions in the contaminated site be investigated and geochemical data be collected. The stabilization mechanism of As in calcareous soils of the Qorveh basin plain and the effect of soil physicochemical characteristics on more toxic fraction ratios should be considered. Geological formations and soils of Qorveh basin plain, mostly limestone, contain significant amounts of As, resulted from volcanic activity of Tertiary geology, consists of volcanic rocks, hot springs and geothermal activities.

Among the important minerals containing As in soil, arsenopyrite, orpiment, and realgar can be pointed out.[18] Figure 2 shows the As concentration map. It is clear that there is As-contaminated water in different parts of the plain. Such information has also been reported in previous studies.[10] However, in some parts of Kurdistan province, including northern and northeastern parts of Qorveh, As, due to the regional geology and above-mentioned minerals, is an integral part of soil. Furthermore, due to the travertine hot springs and bedrock type, water sources are contaminated with As. From Regional geology and As appropriate distribution maps, extracted from Geological Survey of Iran, it can be seen that there is a risk of land structures containing As. Thus, the inclusion of As in drinking water in rural areas shows that there are specific problems for consumers facing As. Depending on the circumstances of each village, measures need to be considered in accordance with US Environmental protection agency guidelines, such as replacement of water supply, safe water distribution among consumers, use of home methods with the capability of As removal for water purification or water treatment methods in small areas.

Conclusion

In this study, the concentrations of water quality parameters in a number of villages Qorveh city were measured using Piper, Schuler, and Wilcox graphical diagrams, for drinking, agricultural, and industrial applications. Results from hydrochemical analysis showed that, apart from As and Se in a number of sources, concentrations of other quality parameters are less than the allowable limit. Nitrate concentration in some of the resources was close to its maximum allowable amount, which is mostly due to agricultural activities in the area, application of different fertilizer and pesticides. It was found that in 23.8% of the studied water supplies As concentration of water is higher than the recommended standard, and in 9.5% of them, it is close to the maximum allowable amounts. Thus, there is a risk of exposure to As for consumers, and it is necessary to evaluate and monitor the As in water. In summary, though, except As and selenium, other properties of the studied water supplies are suitable for drinking, but the continuation of the current trend, particularly in the agricultural activities and uncontrolled use of groundwater resources in agriculture, will lead to change and declining of water quality. Hence, in order to prevent health hazards resulting from the process (especially NO_3^- and As), preventive measures are necessary.

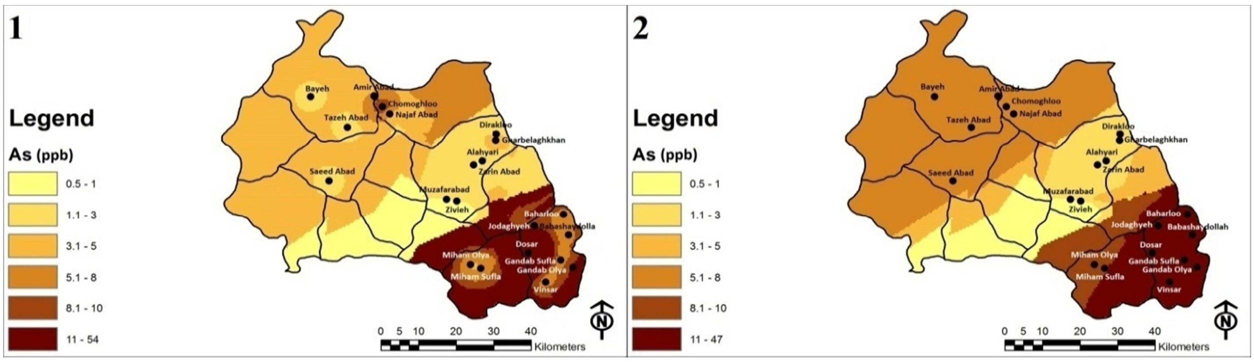

Figure 2. Spatial distribution of arsenic in ground water in low- and high-water seasons

Conflict of Interests

Authors have no conflict of interests.

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