Hydrogeochemistry, water quality and health risk assessment of water resources contaminated by agricultural activities in Korkuteli (Antalya, Turkey) district center

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ABSTRACT

Groundwater is a major water source for drinking, domestic and agricultural activities in the Korkuteli district. However, the intensive agricultural activities in the region negatively affect the groundwater quality. In this study, 30 water samples were collected from springs, wells, and tap waters in dry and wet seasons. Ca-Mg-HCO_3 and Mg-Ca-HCO_3 were dominant water types in the study area. According to the Gibbs diagrams, which were prepared to determine the mechanism controlling the groundwater geochemistry, samples from both seasons fell in the rock-dominance zone. The water quality index indicates the increase of ion concentrations due to the agricultural effect along with the rainwater in the region. Also, according to WHO standards, water samples are not appropriate to use as drinking water in terms of the heavy metal and fertilizers analysis results. In terms of the irrigation usage, most groundwater samples are suitable in dry and wet seasons. According to HCO_3 and SO_4 results, the mentioned samples can induce incrustation on metal surfaces and therefore are not recommended for industrial use. Groundwater chemistry in the study area is affected with water–rock interaction and dense agricultural activities. In conclusion, the study area is at high risk in terms of the health risk assessment.

Key words | groundwater pollution, groundwater quality, health risk assessment, hydrogeochemistry, Korkuteli, water quality index (WQI)

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INTRODUCTION

Water is not only the essence of life, but also one of the most important factors determining the quality of human life. The quality of water is extremely important because it is essential for life. The fact that currently 75% of the earth is covered with water gives the idea that there is no water shortage in the world, but the potable water rate is only 0.74% of all waters worldwide (Akın & Akın 2017). In addition, emerging climate changes, developing technology and increasing population are the biggest problems in reaching healthy water today. These problems cause surface waters to gradually decrease and become unusable. A result of this, groundwater is widely used. However, groundwater is not endless and not always suitable for the intended purpose. For this reason, it is very important to determine the amount of groundwater, the quality of the waters and their usage areas. In addition, knowledge of the geochemical evolution of groundwater characteristics is important for the sustainable development and effective management of water resources.

Pollution of groundwater is one of the most significant environmental problems in the world in recent years (Kumar *et al.* 2014). Groundwater quality depends on the

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quality of the recharged water, rain and geochemical processes. The quality of groundwater reflects the combined effect of many processes along the groundwater flow path, at any point underground. Geochemical processes are responsible for the seasonal and spatial variation of groundwater chemistry. It is possible to divide the factors affecting these geochemical processes into geogenic and anthropogenic. Geogenic factors are related to geological, hydrological and hydrogeological conditions. Anthropogenic factors that change the chemistry and quality of groundwater are the result of domestic, irrigation and industrial uses. However, at the same time, degradation of the groundwater quality affects its use for drinking, agriculture and industrial activities. Today, approximately 80% of diseases all over the world and one third of deaths in developing countries are caused by polluted drinking water (WHO 2004). Therefore, the determination of the groundwater quality is important for the suitability of the water.

In this study, Korkuteli district in Antalya province, located in the southwest of Turkey, was chosen as a study area. In Korkuteli district, groundwater is the major source of water for human consumption and irrigation. Korkuteli district is an important region of Antalya, especially in terms of greenhousing and other agricultural activities related to livestock. These activities pollute the groundwater anthropogenically. Therefore, groundwater quality in this area is very important in terms of determining the suitability of water for drinking, domestic and agricultural purposes in the study area. In relation to this, the fact that the effect of agricultural activity on the water resources of the region has not been studied in detail before is a major deficiency for the study area. This study aims to resolve this deficiency and the results are important to determine the quality and usability with regard to sustainable management of water resources in the region.

MATERIALS AND METHODS

Study area

Korkuteli district center is located between latitude 37° 3′ 51.9336″ N and longitude 30° 11′ 47.7132″ E coordinates (Figure 1). Korkuteli district center (area 121 km^2) was selected as the study area due to the dense agricultural activity and settlement area. The altitude of the district center is 1,020 m. In general, the Mediterranean climate and the terrestrial climate prevail in the district. The mean rainfall for the study area was calculated as 316.39 mm (between 1969 and 2016) by the isohyet method (a line drawn on a map connecting points that receive equal amounts of rainfall) using the data from the meteorological stations in the study area and surrounds. In addition, the mean evapotranspiration was 324.84 mm. The drinking water of the district center is supplied from the springs and well waters in the study area. Also the irrigation waters are supplied from the well and surface flows. Korkuteli and Salamur streams are the most important surface flows in the study area (APESR 2012).

Sampling and analysis

A total of 30 water samples from wells, springs and tap waters were analyzed in November 2016 (dry period) and May 2017 (wet period) for the determination of their major and minor chemical characteristics. The water samples were collected in two plastic bottles, pre-washed with 0.5% nitric acid (HNO_3) and deionized water from each sampling point. During sampling, two bottles were filled with water from each spot, filtered, and a few drops of HNO_3 were added to one water sample that was used to detect major cations, while the second sample was not acidified and was used to detect major anions. All samples were transported and kept in the dark at 4 °C for analysis. The physical parameters, such as hydrogen ion concentration (pH), electrical conductivity (EC), total dissolved solids (TDS), oxidation–reduction potential (Eh) and discharge temperature (°C), were determined *in situ* using a YSI multi-parameter water quality sonde (YSI 6050).

The major chemical constituents (cations) were analyzed by ICP-MS (inductively coupled plasma-mass spectrometer) at the Bureau Veritas Commodities Canada Ltd (ACME Laboratory Vancouver, Canada, an ISO 9002 accredited company). Bicarbonate (HCO_3), carbonate (CO_3) concentrations were determined by the titrimetric method; chlorine (Cl), sulphate (SO_4), nitrate

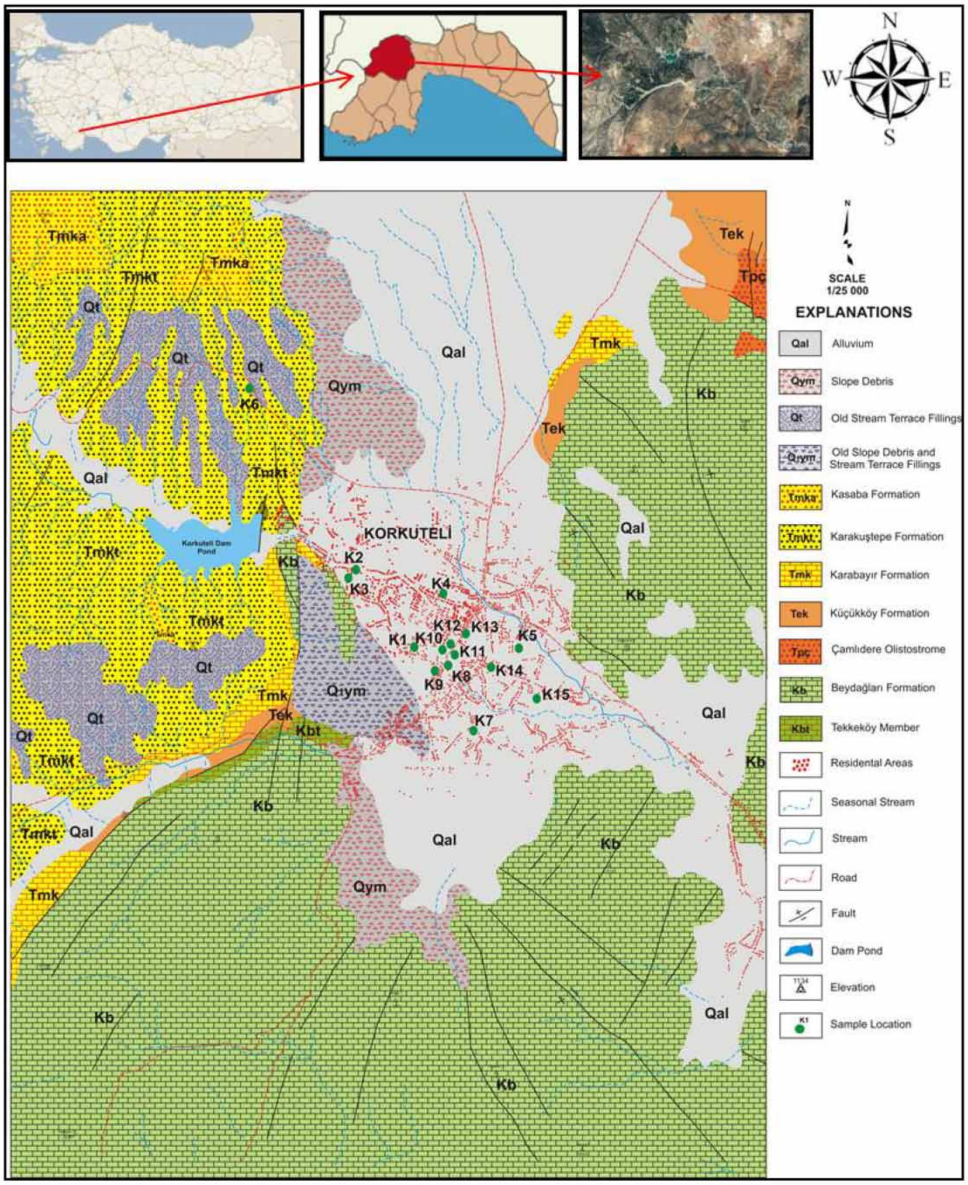

Figure 1 | Location and geological maps of the study area.

(NO_3), nitrite (NO_2) and ammonium (NH_4) were determined using ion chromatography in the Hacettepe University Water Chemistry Laboratory (Ankara, Turkey) (Table 1). The charge–balance error in the water samples was less than 5%, which is within the acceptable limits. All mathematical calculations were calculated using *Excel 2007* (Microsoft Office). Statistical analysis, such as the correlation matrix, was performed using the *SPSS* software version 15.

Methods

Water quality index (WQI)

The relative weight (Wi) is computed from the following equation,

$$Wi = \frac{wi}{\sum_{i=1}^{n} wi} \tag{1}$$

Table 1 | Analytical methods used in the study

Type of samples	Analysis parameters	Method	Name of laboratory
Water samples (Total 30)	Discharge temperature (T/C), pH, TDS and electrical conductivity (EC)	*In situ*	*In situ*
	Ag, Al, As, Au, B, Be, Bi, Br, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Ge, Hf, Hg, Ho, In, Ir, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, Os, P, Pb, Pd, Pr, Pt, Rb, Re, Rh, Ru,S, Sb, Sc, Se, Si, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr	ICP mass spectrometry	ACME Laboratory (Vancouver, Canada, an ISO 9002 accredited company)
	SO_4^{2-}	Ion chromatography	Hacettepe University Water Chemistry Laboratory (Ankara, Turkey)
	Cl^-	Titrimetric	Hacettepe University Water Chemistry Laboratory (Ankara, Turkey)
	NO_3^-, NO_2, NH_4^+	Ion chromatography	Hacettepe University Water Chemistry Laboratory (Ankara, Turkey)
	HCO_3^-, CO_3^{2-}	Titrimetric	Hacettepe University Water Chemistry Laboratory (Ankara, Turkey)

where *Wi* is the relative weight, *wi* is the weight of each parameter, and *n* is the number of parameters.

In the next step a quality rating scale (*qi*) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the World Health Organization (WHO 2011) and Turkish Standards Institution (TSI 266 2005), and the result is multiplied by 100 (Equation (2)):

$$qi = \left(\frac{Ci}{Si}\right) X100 \tag{2}$$

where *qi* is the quality rating, *Ci* is the concentration of each chemical parameter in each water sample (mg/L), and *Si* is the drinking water standard for each chemical parameter (mg/L) according to the guidelines of the WHO (2011) and TSI 266 (2005).

For computing WQI, the *SI* is first determined for each chemical parameter, which is then used to determine the WQI as per the following Equations (3) and (4),

$$\mathrm{SI}i = Wi\,X\,qi \tag{3}$$

$$\mathrm{WQI} = \sum \mathrm{SI}i \tag{4}$$

where SI*i* is the sub-index of *i*th parameter, *qi* is the rating based on concentration of *i*th parameter, and *n* is the number of parameters.

Gibbs ratios

In addition, the Gibbs ratios (Gibbs 1970) were used to determine the mechanism controlling groundwater geochemistry. These ratios were calculated using the following formulas:

$$\text{Gibbs Ratio} - \text{I (for Anion)} = \frac{\mathrm{Cl}^-}{(\mathrm{Cl}^- + \mathrm{HCO}_3^-)} \tag{5}$$

$$\text{Gibbs Ratio} - \text{II (for Cation)} = \frac{(\mathrm{Na}^+ + \mathrm{K}^+)}{(\mathrm{Na}^+ + \mathrm{K}^+ + \mathrm{Ca}^{2+})} \tag{6}$$

Health risk assessment

In this study, both the chronic and carcinogenic risk levels were also assessed. Generally, the hazard quotient (HQ **noncancer**) can be calculated by the following Equation (7) (USEPA 1998),

$$\text{HQ } \mathbf{noncancer} = \frac{\mathrm{ADD}}{\mathrm{RfD}} \tag{7}$$

where the NO_3^-, arsenic (As) and chromium (Cr) toxicity reference doses (RfD) are 1.6, 0.0003 and 0.003 mg/kg/day, respectively (USEPA 2005). Non-cancer risk was represented in terms of an HQ **noncancer** for a single substance separately. If the exposure level of a substance exceeds the corresponding RfD, i.e., HQ **noncancer** exceeds 1, there may be concern for potential non-carcinogenic effects. The higher the mean value the greater the likelihood of an adverse non-carcinogenic health effect (USEPA 1998; Khan *et al.* 2008; Muhammad *et al.* 2010; Varol & Davraz 2016).

The cancer risk (R_{cancer}) was calculated using Equation (8):

$$R_{cancer} = ADD \times CSF \quad (8)$$

where R is the excess probability of developing cancer over a life time as a result of exposure to a contaminant (or carcinogenic risk), ADD is the chronic daily intake (mg/kg/day), and CSF is the slope factor of the contaminant (mg/kg/day) (Equation (8)). According to the US EPA (2005) database the CSF of the contaminant for As is 1.5 mg/kg/day.

RESULT AND DISCUSSION

Geological and hydrogeological setting

The lithological units and interaction time of water with these units control the chemical composition of the groundwater. Firstly the lithological units in the study area have been investigated. All of the lithological units in the study area are autochthonous. These units are Beydağları autochthonous and quaternary alluvium (Qal), slope debris (Qym), old stream terrace fillings (Qt) and old alluvium-slope debris (Q1ym) (Şenel *et al.* 1989; Şenel 1997; Figure 1, Table 2). Beydağları autochthonous units are composed of Beydağları formation (Kb), Tekkeköy members (Kbt), Çamlıdere olistostrome (Tpç), Küçükköy formation (Tek), Karabayır formation (Tmk), Karakuştepe formation (Tmkt) and Kasaba formation (Tmka) (Şenel *et al.* 1989; Şenel 1997).

Secondly, lithological units in the study area were evaluated according to their hydrogeological properties. The general characteristics and hydrogeological properties of the lithological units are given in detail in Table 2. Alluvium and quaternary units represent the most important granular aquifer in the study area (Aqf-1) and have an area of about 45 km^2. Limestones can contain significant amounts of groundwater in cracks and melting spaces which allow water to move. For this reason the Beydağları formation, consisting of neritic limestones, and the Karabayır formation, consisting of algae limestones, are defined as 'karstic aquifer' (Aqf-2). The Karstic aquifer is the other important aquifer in the study area. The majority of water resources in the study area are discharged from the alluvium and limestones (Figure 1). The Kasaba formation, which consists of conglomerates and sandstones, is classified as 'aquitard' (Aqt). Çamlıdere olistostrome, Karakuştepe formation and Küçükköy formation in the study area are classified as 'aquifuge' (Aqj) due to their lithological characteristics (Table 2).

Hydrogeochemistry

Groundwater chemistry is controlled by hydrogeochemical processes. There are many chemical processes during the movement of the groundwater from the recharge area to the discharging area. Some of these processes include precipitation, ion exchange, redox condition, leaching and dissolution. The chemical properties of the water determine the usage status for domestic, industrial or agricultural activities. In many developed and developing countries water pollution is one of the most significant factors for the spread of diseases and infant deaths (Kumar *et al.* 2016). The causes of water pollution can be classified as natural and anthropogenic sources. Accordingly, it is important to know the chemical properties and quality of water for the management and evaluation of groundwater (Kumar *et al.* 2016). For this reason, in this study we have attempted to determine the physicochemical properties, chemical properties and quality of groundwater in the study area.

Seasonal evaluation of physical parameters

The pH of spring waters (according to the measurement method used for pH, the lower limit of quantitation is ±0.01) varied between 8.71–9.36 and 8.88–9.60 for the dry and wet season, respectively. The pH values of the well waters were measured at 8.54–9.33 in the dry season and

Table 2 | Lithostratigraphic relations of the geologic units and hydrogeological properties

Age	Formation	Lithology	Hydrogeological properties
Quaternary	Alluvium (Qal)	Gravel sand and mudstone	Aqf-1 (Granular aquifer)
Quaternary	Slope debris (Qym)	Attached to the loose gravel, sand and mudstone	Aqf-1 (Granular aquifer)
Quaternary	Old stream terrace fillings (Qt)	Round pebbles, medium-sized conglomerates	Aqf-1 (Granular aquifer)
Quaternary	Old alluvium and slope debris, (Q1ym)	Attached to small amount of gravel and sand attached	Aqf-1 (Granular aquifer)
Jurassic-Cretaceous	Beydağları formation (Kb)	Neritic limestones	Aqf-2 (Karstic aquifer)
Jurassic-Cretaceous	Tekkeköy member (Kbt)	Locally cherty nodular and calcarenite intermediate level, locally abundant globotruncanic micrit	Aqj (Aquifuge)
Lower Paleocene (Danian)	Çamlıdere olistostrome (Tpç)	Micrit, clayey micrite, claystone, marl, calcarenite, sandstone and similar rocks	Aqj (Aquifuge)
Upper Lutetian-Priabonian	Küçükköy formation (Tek)	Carbonate intermediate marl, claystone, limestone and clayey limestones	Aqj (Aquifuge)
Akitanian-Lower Burdigalian	Karabayır formation (Tmk)	Algae limestones	Aqf-2 (Karstic aquifer)
Burdigalian	Karakuştepe formation (Tmkt)	Sandstone, claystone, siltstone	Aqj (Aquifuge)
Upper Burdigalian-Lower Langiyen	Kasaba formation (Tmka)	Conglomerates and sandstones	Aqt (Aquitard)

8.89–9.30 in the wet season. Also, the pH of the tap waters varied for the dry and wet season between 8.76–8.93 and 8.85–8.92, respectively. The pH values of all water samples increased in the wet season (Table 3).

The EC values, EC, of spring waters (according to the measurement method used for EC, the lower limit of quantitation is 0.0001–0.01 μS/cm.) were measured to be between 288.80–695.00 μS/cm in the dry season and 279.80–708.00 μS/cm in the wet season. The EC values of well waters also varied in the range of 317.10–794.00 μS/cm in the dry season and 309.90–809.00 μS/cm in the wet season. Also, the EC values of tap waters were measured in the range of 474.60–638.00 μS/cm in the dry season and 424.00–744.00 μS/cm in the wet season (Table 3). The high EC values in the wet season indicated the spatial variability of leaching and dilution with recharging rainfall. Also, the higher EC values in the wet season might be attributed to enhanced chemical weathering and lengthier residence time of groundwater in the aquifers (Oinam *et al.* 2011; Alam *et al.* 2016).

In addition, the temperature, T (°C), values of spring waters (according to the measurement method used for T (°C), the lower limit of quantitation is 0.001 °C) were measured in the range 12.10–15.50 °C in the dry season and 11.80–15.30 °C in the wet season. The T (°C) values of well waters also varied in the range 11.80–17.60 °C in the dry season and 14.70–17.80 °C in the wet season. Also, the T (°C) values of tap waters were measured in the range 13.10–17.10 °C in the dry season and 15.00–16.60 °C in the wet season (Table 3).

Oxidation–reduction potential, Eh, is a measurement that indicates the degree to which a substance is capable of oxidizing or reducing another substance (APHA 1998). In the present study, Eh values were measured to range from 319.50–400.80 mV in the dry season to 298.90–388.70 mV in the wet season (according to the measurement method used for Eh, the detection limit is 0.1 mV) (Table 3).

Seasonal evaluation of major ions

The most common cations in the groundwater were calcium (Ca) and magnesium (Mg). Subsequently, sodium (Na) and potassium (K) ions were present in the

Table 3 | Physicochemical characteristics of groundwater and tap water in the study area (dry and wet season)

		Dry season				Wet season				Drinking water standards		
Parameters (mg/l)	LOQ* (mg/l)	Min.	Max.	Mean	Std. D.	Min.	Max.	Mean	Std. D.	WHO (2004)	WHO (2011)	TSI 266 (2005)
EC (μS/cm)	0.0001–0.01 μS/cm	288.800	794.00	561.28	164.15	279.80	809.00	595.79	177.09	1,500	–	–
T (°C)	0.001 °C	11.800	17.60	14.68	1.77	11.80	17.80	15.49	1.58	–	–	–
pH	±0.01	8.540	9.36	8.93	0.22	8.85	9.60	9.05	0.22		6.5–8.5	6.5–9.5
Eh (mV)	0.1 mV	319.50	400.80	372.88	24.05	298.90	388.70	346.77	27.92	–	–	–
TDS	Variable	187.720	516.100	364.830	106.690	181.87	525.85	387.26	115.11	1,000	–	–
Ca	0.05	59.490	100.170	71.200	11.830	62.55	94.96	73.02	9.09	200	–	–
Mg	0.05	13.040	79.060	45.910	22.370	12.59	79.54	46.03	21.67	150	–	–
Na	0.05	4.630	70.460	25.460	18.740	4.08	74.48	27.93	21.18	200	200	200
K	0.05	0.480	2.260	1.170	0.490	0.45	2.18	1.18	0.44	12	–	–
HCO_3	±0.61	225.70	506.30	387.14	101.96	234.63	517.80	398.38	101.74	500	–	–
CO_3	±0.30	less than LOQ	less than LOQ	–	–	less than LOQ	less than LOQ	–	–	–	–	–
Cl	±0.01	2.190	21.340	11.370	6.250	1.990	27.200	12.740	6.790	600	250	250
SO_4	±0.001	21.070	132.730	59.150	33.400	30.090	155.800	72.470	35.530	250	250	250
NO_2	±0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.000	–	0.2	0.5
NO_3	±0.001	5.570	37.340	19.940	9.700	4.900	52.140	28.810	16.800	45	50	50
NH_4	±0.001	0.001	0.290	0.060	0.020	0.001	0.130	0.020	0.040	–	1.5	0.5
Al	0.001	0.001	0.030	0.004	0.0091	0.001	0.050	0.001	0.010	–	0.2	0.5
As	0.0005	0.080	0.170	0.130	0.020	0.090	0.170	0.130	0.020	–	0.01	0.01
Cd	0.00005	0.050	0.050	0.050	0.000	0.000	0.000	0.000	0.000	–	0.003	0.005
Cu	0.0001	0.001	0.040	0.010	0.010	0.000	0.870	0.070	0.220	–	2	2
Cr	0.0005	0.010	0.070	0.030	0.020	0.010	0.080	0.040	0.020	–	0.05	–
Fe	0.01	0.010	0.110	0.020	0.030	0.010	0.150	0.050	0.030	–	–	0.2
Mn	0.00005	0.00013	0.0039	0.0028	0,0015	0.00022	0.0036	0.020	0.018	–	0.4	0.05
Ni	0.0002	0.0003	0.0034	0.0030	0.0022	0.0002	0.090	0.010	0.020	–	0.07	0.02
Pb	0.0001	0.0001	0.002	0.001	0.001	0.0001	0.010	0.0006	0.0003	–	0.01	0.01
Zn	0.0005	0.0012	0.5306	0.060	0.130	0.0012	2.5351	0.4159	0.76351	–	–	–
Valid n = 15												

*LOQ, the lower limit of quantitation for each parameter.

composition of the water in lesser amounts (Tables 3 and 4). The sources of Ca and Mg in water were generally carbonate-rich rocks such as limestone and dolomitic limestone. An increase in Mg ion in the dry and wet seasons was observed at several locations (K1, K4, K5, K7, K11, K12, and K13). The major source of Mg in the groundwater was from interaction of dolomitic limestone with water.

Bicarbonate (HCO_3) was the main anionic constituent of the groundwater samples ranging from 225.70 to 506.30 mg/L in the dry season and from 236.65 to 517.80 mg/L in the wet season (Tables 3 and 4). HCO_3,

Table 4 | The major ion sequences of water samples

		Dry season (Nov 2016)		Wet season (May 2017)	
No.	**Sample type**	**Cation sequence**	**Anion sequence**	**Cation sequence**	**Anion sequence**
K1	Well	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K2	Well	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K3	Well	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K4	Well	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K5	Well	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K6	Spring	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K7	Well	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K8	Spring	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K9	Well	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K10	Well	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K11	Tap	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K12	Spring	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K13	Well	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Mg > Ca > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K14	Tap	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$
K15	Spring	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$	Ca > Mg > Na > K	$HCO_3 > SO_4 > Cl > CO_3$

representing the major source of alkalinity, generally prevails due to the dissolution of CO_2 and carbonates, reaction of silicates with carbonic acid (Ranjan *et al.* 2013) and oxidation of organic matter (Jeong 2001). Sulphate (SO_4) ion, which originates from the oxidation of sulphite, was the most abundant after bicarbonate (Ranjan *et al.* 2013). Another reason for the excessive amount of sulfate in the groundwater is the presence of anthropogenic inputs. SO_4 concentrations in the study area ranged between 21.07 and 132.73 mg/L in the dry season and between 30.09 and 155.80 mg/L in the wet season (Tables 3 and 4). This situation also indicates the entrance of anthropogenic sulphate related to fertilizers in the study area.

Seasonal evaluation of fertilizers and heavy metals

In the study, NO_2, NO_3, NH_4 and heavy metal analyses (aluminum (Al), As, cadmium (Cd), copper (Cu), Cr, iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), zinc (Zn)) were made to determine pollutant types and sources (Table 3). NO_2, NO_3, and NH_4 are pollutants which come mainly from agricultural and industrial effluents, contain a high concentration of nitrogen and are some of the largest contributors to groundwater pollution in the world (Li *et al.* 2016). According to the results of analysis, NO_2 concentrations were determined as 0.00 mg/L in both periods. The detection limit for nitrite is ±0.001 mg/L. For this reason, the mean and standard deviation values for nitrite were not calculated (Table 3). NO_3 concentrations ranged from 2.19 to 21.34 mg/L in the dry season and ranged from 4.90 to 51.00 mg/L in the wet season. In addition, NH_4 concentrations were 0 mg/L in the dry season and 0–0.13 mg/L in the wet season (Table 3).

According to the heavy metal analysis results, Al concentrations were determined to be 0 mg/L in the dry season, and 0–0.05 mg/L in the wet season. As concentrations ranged from 0.08 to 0.17 mg/L in the dry season and ranged from 0.09 to 0.17 mg/L in the wet season. Cd concentrations were determined to be 0.05 mg/L in the dry season and 0 mg/L in the wet season. Cu concentration ranged from 0 to 0.04 mg/L in the dry season and from 0 to 0.87 mg/L in the wet season. Besides this, Cr concentrations were determined to be between 0.01 and 0.07 mg/L in the dry season and between 0.01 and 0.08 mg/L in the wet season. Fe concentration ranged from 0.01 to 0.11 mg/L in the dry season and ranged from 0.01 to 0.12 mg/L in the wet season. Mn concentration was determined as 0 mg/L in both seasons. Ni concentrations were determined to be 0 mg/L in the dry season, and between 0–0.09 mg/L in the wet season. Pb concentrations were determined to be 0 mg/L in the dry season, and 0–0.01 mg/L in the wet season. Finally, Zn concentration ranged from 0 to 0.17 mg/L in the dry season and 0 mg/L in the wet season (Table 3). Accordingly, seasonal variation in NO_2, NO_3, NH_4 and heavy metals concentrations is thought to be related to infiltration of rainwater and agricultural activities.

STATISTICAL ANALYSIS

Correlation matrix

Correlation analysis was applied to determine the relationship between physicochemical properties of water samples. It is possible to obtain information about the mineral and chemical processes, and the chemical constituents of water with this relationship were determined by correlation analysis (Varol & Davraz 2015).

In this study, the Kolmogorov–Smirnov (K-S) test was initially used to determine the compatibility of the data to normal distribution (Varol & Şen 2009). According to the K-S test, all the variables were normally distributed with 94% confidence. For this reason, to evaluate the potential relationship between various physiochemical parameters and trace elements, Pearson correlation analysis (PCA) was carried out.

In correlation analysis, if the correlation coefficient is close to 1 or 1, it means a good positive relationship between the two variables. The near zero values are significant if $p < 0.05$, but there is no relationship between them. Thus, while it is assumed that there is strong correlation between the parameters with $r > 0.7$, it is said that the r value is moderately correlated between 0.5 and 0.7 (Manish *et al.* 2006).

All the processes were performed using *SPSS* software version 15.0 for Windows. In addition, the Pearson correlation matrix was applied separately for the dry and wet seasons in order to study the changes in the relations between the parameters. The correlation matrix of the parameters is given in Table 5 (dry season), and Table 6 (wet season). The analysis results of CO_3, NO_2, NH_4, Cd, Mn, Ni and Pb in the dry season and CO_3, NO_2, Cd, Mn, Ni in the wet season were 0.00 mg/l, and owing to this results were not evaluated in the correlation matrix.

According to the physicochemical PCA results, EC showed positive strong correlation with TDS, Mg, Na, HCO_3, Cl, SO_4, NO_3, and Cr in dry and wet seasons. Also EC showed negative strong correlation with pH in the dry season. T (°C) showed negative moderate correlation with pH in the wet season. pH showed negative strong correlation with TDS, Ca, K, HCO_3, NO_3 and showed negative moderate correlation with Mg, Cl and Cr ions in the dry season. In the wet season, pH showed negative moderate correlation with only Mg ion. Eh showed positive moderate correlation with As in the wet season only. TDS showed positive strong correlation with Mg, Na, HCO_3, Cl, SO_4, and NO_3, Cr ions in the dry and wet seasons (Tables 5 and 6).

Ca showed positive moderate correlation with K, HCO_3 and NO_3 in the dry season and also showed positive moderate correlation with K. Mg showed positive strong correlation with Na, HCO_3, Cl, SO_4, NO_3, Cr in the dry season. In the wet season it showed positive strong correlation with Na, HCO_3, Cl, NO_3 and Cr, and showed positive moderate correlation with SO_4 the Na showed positive strong correlation with HCO_3, Cl, SO_4 and Cr in the dry and wet seasons. It also showed positive moderate correlation with NO_3 and Cu in the dry season and showed positive moderate correlation with NO_3 and Cl. While K showed a positive moderate correlation with Al in the dry season and negative correlation with Al in the wet season (Tables 5 and 6).

In addition, according to the physicochemical PCA results, HCO_3 showed positive strong correlation with Cl, SO_4, NO_3, Cr in the dry and wet seasons. Cl showed positive strong correlation with SO_4, NO_3, and Cr in the dry season, and showed positive strong correlation with NO_3 and Cr, and positive moderate correlation with SO_4 in the wet season. SO_4 showed positive strong correlation with Cr in the dry and wet seasons and also showed positive moderate correlation with NO_3 and Cr in the dry season (Tables 5 and 6).

According to the PCA results of the heavy metal and pollution parameters, NO_3 showed positive moderate correlation with Cr in the dry and wet seasons. While Al showed positive moderate correlation with Fe in the dry season, it showed positive strong correlation with Fe in the wet season. Cu showed positive moderate correlation with Ni and Pb ions. Ni showed positive moderate correlation with

Table 5 | Correlation martix of dry season parameters waters in the study area

		EC	T	pH	Eh	TDS	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3	Al	As	Cu	Cr	Fe	Zn
EC	r	1																		
	p																			
T	r	−.17	1																	
	p	.53																		
pH	r	−.72	.20	1																
	p	.00	.45																	
Eh	r	.00	.13	−.25	1															
	p	.99	.62	.35																
TDS	r	1.00	−.17	−.72	.00	1														
	p	.00	.53	.00	.99															
Ca	r	.44	−.38	−.79	.27	.44	1													
	p	.09	.16	.00	.32	.09														
Mg	r	.97	−.23	−.62	−.12	.97	.30	1												
	p	.00	.39	.01	.65	.00	.26													
Na	r	.88	−.12	−.40	.07	.88	.17	.87	1											
	p	.00	.65	.13	.79	.00	.52	.00												
K	r	.38	−.21	−.73	−.19	.38	.68	.30	.07	1										
	p	.16	.44	.00	.49	.16	.00	.27	.79											
HCO_3	r	.97	−.27	−.74	−.10	.97	.50	.96	.81	.47	1									
	p	.00	.32	.00	.71	.00	.05	.00	.00	.07										
Cl	r	.97	−.24	−.67	−.12	.97	.37	.98	.82	.34	.97	1								
	p	.00	.37	.00	.65	.00	.17	.00	.00	.21	.00									
SO_4	r	.86	−.17	−.48	.22	.86	.32	.81	.97	.13	.78	.76	1							
	p	.00	.54	.06	.42	.00	.23	.00	.00	.63	.00	.00								
NO_3	r	.90	−.33	−.81	−.05	.90	.54	.90	.64	.45	.92	.94	.63	1						
	p	.00	.22	.00	.85	.00	.03	.00	.00	.08	.00	.00	.01							
Al	r	−.00	−.07	−.22	−.19	−.00	.40	−.07	−.20	.52	.09	.03	−.19	.08	1					
	p	.98	.78	.42	.47	.98	.13	.80	.46	.04	.74	.90	.48	.76						
As	r	−.17	.17	.11	−.06	−.17	−.29	−.16	−.18	−.04	−.14	−.14	−.23	−.20	.27	1				
	p	.52	.54	.68	.83	.52	.28	.56	.51	.88	.59	.60	.40	.45	.31					
Cu	r	.47	−.10	−.33	.28	.47	.20	.40	.62	.30	.40	.32	.66	.20	−.28	−.28	1			
	p	.07	.70	.22	.29	.07	.47	.13	.01	.26	.13	.23	.00	.46	.30	.29				
Cr	r	.96	−.22	−.58	.07	.96	.30	.96	.94	.14	.91	.94	.90	.84	−.16	−.19	.47	1		
	p	.00	.42	.02	.78	.00	.27	.00	.00	.59	.00	.00	.00	.00	.56	.49	.07			
Fe	r	.14	−.06	−.13	−.48	.14	.19	.14	−.05	.42	.28	.22	−.13	.16	.80	.29	−.24	.01	1	
	p	.60	.82	.63	.07	.60	.48	.59	.86	.11	.30	.41	.62	.56	.00	.28	.37	.95		
Zn	r	.35	.20	−.24	.13	.35	.10	.24	.41	.11	.34	.27	.46	.13	.11	.19	.26	.32	.16	1
	p	.19	.47	.38	.63	.19	.71	.37	.12	.68	.21	.31	.08	.62	.68	.49	.33	.23	.55	

Table 6 | Correlation martix of wet season parameters waters in the study area

		EC	T	pH	Eh	TDS	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3	NH_4	Al	As	Cu	Cr	Fe	Ni	Pb
EC	r	1																				
	p																					
T	r	.46	1																			
	p	.08																				
pH	r	−.49	−.60	1																		
	p	.06	.01																			
Eh	r	−.23	−.00	−.17	1																	
	p	.40	.98	.53																		
TDS	r	1.00	.46	−.49	−.23	1																
	p	.00	.08	.06	.40																	
Ca	r	.45	.18	−.37	.16	.45	1															
	p	.09	.49	.16	.55	.09																
Mg	r	.92	.37	−.51	−.37	.92	.29	1														
	p	.00	.17	.05	.17	.00	.29															
Na	r	.84	.29	−.40	−.24	.84	.32	.85	1													
	p	.00	.29	.13	.38	.00	.23	.00														
K	r	.29	.22	−.37	.23	.29	.63	.17	−.01	1												
	p	.29	.42	.16	.39	.29	.01	.54	.95													
HCO_3	r	.92	.23	−.39	−.26	.92	.46	.91	.79	.34	1											
	p	.00	.40	.15	.33	.00	.08	.00	.00	.21												
Cl	r	.86	.34	−.41	−.30	.86	.11	.85	.60	.13	.84	1										
	p	.00	.20	.12	.26	.00	.68	.00	.01	.63	.00											
SO_4	r	.81	.18	−.28	−.05	.81	.26	.69	.87	.03	.75	.64	1									
	p	.00	.51	.30	.84	.00	.34	.00	.00	.90	.00	.00										
NO_3	r	.79	.35	−.34	−.46	.79	.34	.80	.51	.38	.86	.82	.43	1								
	p	.00	.19	.20	.07	.00	.21	.00	.05	.15	.00	.00	.10									
NH_4	r	−.39	−.00	−.12	.31	−.39	−.28	−.42	−.42	.00	−.34	−.15	−.24	−.24	1							
	p	.14	.98	.65	.25	.14	.30	.11	.11	.97	.20	.57	.38	.38								
Al	r	−.40	−.04	.24	−.32	−.40	−.36	−.35	−.32	−.50	−.42	−.23	−.36	−.22	.46	1						
	p	.13	.88	.37	.23	.13	.18	.19	.23	.05	.11	.40	.18	.41	.08							
As	r	.23	.26	−.14	.60	.23	.00	.15	.13	.10	.19	.27	.22	.01	.04	−.46	1					
	p	.39	.34	.60	.01	.39	.97	.57	.62	.71	.49	.32	.43	.94	.87	.08						
Cu	r	.14	.15	−.19	−.48	.14	−.27	.46	.21	−.18	.24	.27	−.16	.36	−.20	.03	.00	1				
	p	.61	.57	.49	.06	.61	.32	.08	.45	.51	.37	.32	.55	.18	.47	.89	.98					
Cr	r	.95	.41	−.52	−.12	.95	.45	.90	.93	.20	.87	.75	.87	.65	−.42	−.42	.26	.11	1			
	p	.00	.12	.04	.65	.00	.09	.00	.00	.45	.00	.00	.00	.00	.11	.11	.34	.68				

(*continued*)

Table 6 | continued

		EC	T	pH	Eh	TDS	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3	NH_4	Al	As	Cu	Cr	Fe	Ni	Pb
Fe	r	−.08	.48	.09	−.21	−.08	−.19	−.22	−.09	−.28	−.25	−.05	−.04	−.07	.35	.68	−.10	−.16	−.11	1		
	p	.76	.06	.74	.43	.76	.48	.42	.73	.30	.35	.84	.86	.77	.19	.00	.70	.54	.68			
Ni	r	.20	−.11	−.12	−.22	.20	−.02	.44	.29	−.15	.30	.28	.01	.13	−.25	−.08	.15	.66	.20	−.36	1	
	p	.46	.67	.65	.41	.46	.94	.09	.28	.59	.27	.31	.95	.64	.35	.76	.58	.00	.47	.18		
Pb	r	.33	.16	−.21	−.45	.33	.13	.46	.35	−.06	.34	.34	.04	.32	−.33	−.02	−.01	.58	.29	−.02	.78	1
	p	.23	.55	.44	.09	.23	.64	.08	.19	.81	.20	.20	.87	.24	.23	.92	.96	.02	.29	.92	.00	

Pb ion (Tables 5 and 6). Statistical analysis results indicated that water resources were affected from rock-water interaction, climatic conditions, ion exchange processes and excess application of fertilizer in the study area.

Hydrogeochemical facies

Hydrogeochemical facies are a useful tool for determining the chemical history and origins of groundwater. They are used to show similarities and differences in the chemistry of groundwater samples based on dominant cations and anions (Piper 1944, 1953). The hydrogeochemical evolution of groundwater in the study area was prepared separately for both dry and rainy periods and was evaluated using a Piper diagram using the concentrations of major cations (Ca, Mg, Na and K) and anions (HCO_3, SO_4, and Cl) in meq/l.

According to the Piper diagrams, in the study area Ca-Mg-HCO_3 and Mg-Ca-HCO_3 as the dominant water types were observed in both the dry and wet seasons (Figure 2). Ca-Mg-HCO_3 and Mg-Ca-HCO_3 facies represented 53.33% and 46.66% of the total water samples, respectively (Table 4; Figure 2). These water types originated from the dissolution of limestone and dolomitic limestone in the aquifer material.

Mechanism controlling the groundwater geochemistry

Some diagrams have been proposed by Gibbs (1970) to determine groundwater chemistry, rock–water interaction in aquifers, and sedimentation mechanism in groundwater. There are two types of diagrams. The parameters used in these diagrams are dominant anions (Gibbs Ratio I) and cations (Gibbs Ratio II) and TDS values. These diagrams are extensively used to determine the chemical composition of the water in relation to processes such as precipitation, rock and evaporation dominance.

In this study, Gibbs Ratio I values varied from 0.01 to 0.04 with an average value of 0.02, and Gibbs Ratio II values varied from 0.08 to 0.52 with an average value of 0.24 in the dry season. Gibbs Ratio I values varied from 0.01 to 0.05 with an average value of 0.02, and Gibbs Ratio II values varied from 0.06 to 0.53 with an average value of 0.25 in the wet season. According to the Gibbs diagrams, water samples from dry and wet seasons fall in the rock dominance zone (Figure 3). The diagram indicates that chemical weathering

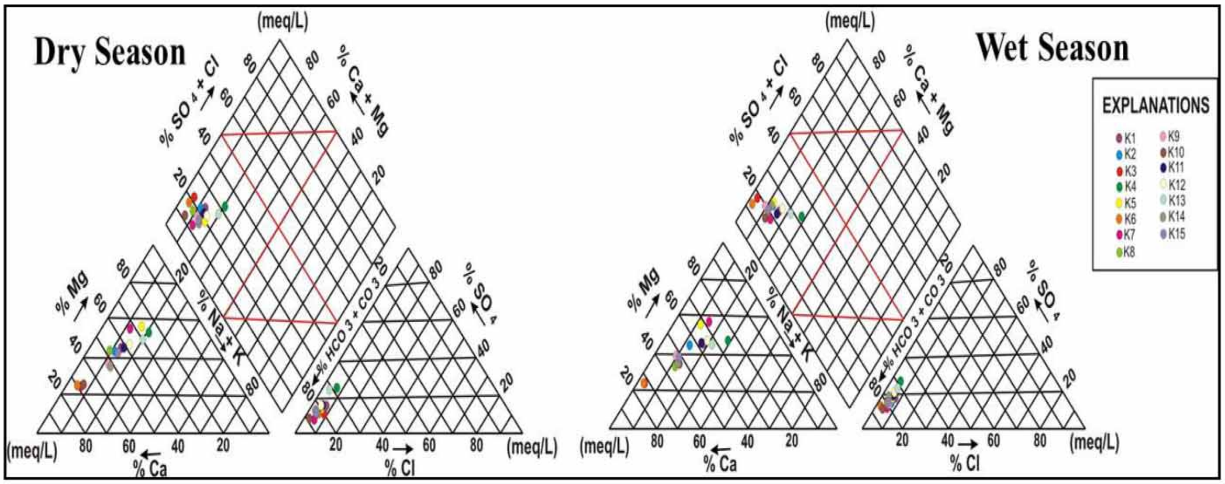

Figure 2 | Piper diagrams in dry and wet season (Piper 1944).

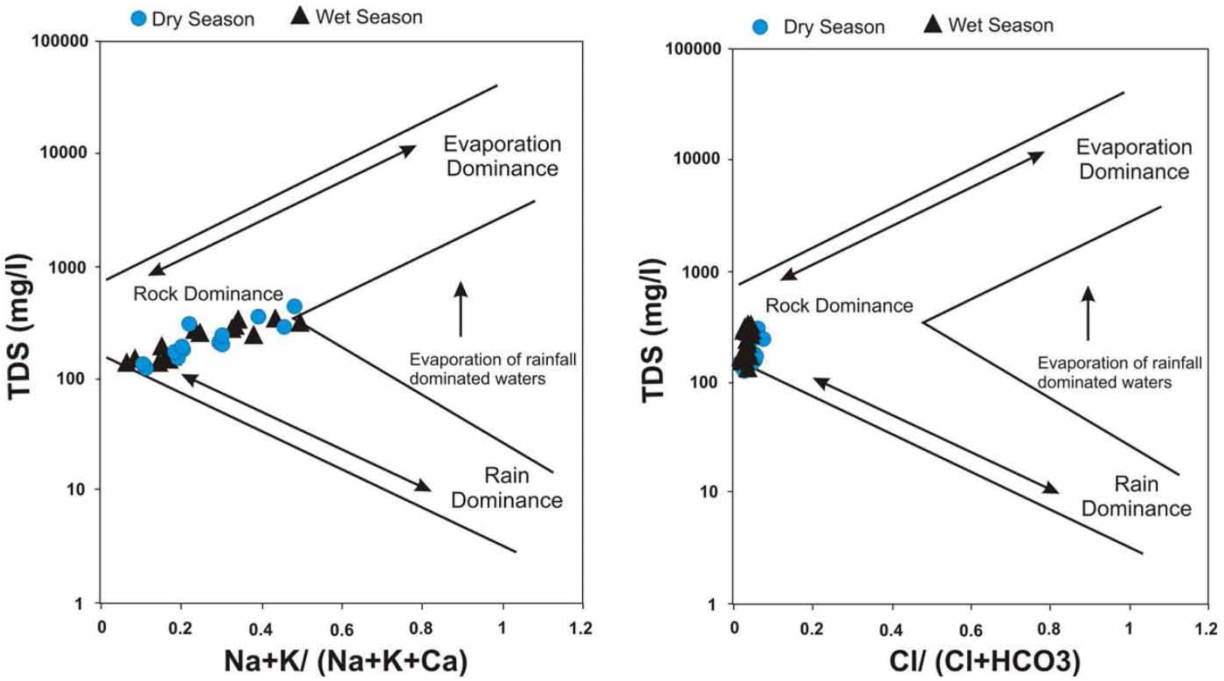

Figure 3 | Gibbs diagrams (Gibbs 1970) illustrating the mechanisms controlling the chemistry of groundwater samples.

of the rock-forming minerals is the main process through which ions are contributed to the groundwater.

EVALUATION OF WATER QUALITY

In this section of the study, the water quality assessments were carried out to identify its suitability for drinking, irrigation, and industrial purposes.

Evaluation of water quality as drinking water

Water quality index (WQI) evaluations

Water quality index (WQI) is defined as a method to determine the influence of each water quality parameter on the overall quality of water for human consumption (Varol & Davraz 2015). WQI is an important parameter for determining groundwater quality and its suitability for drinking water. The WQI index is a measure of the composition of water in light of certain defined objectives. In general, the purpose of the index is to compare each of the main parameters of drinking water with the World Health Organization (WHO) and national standards (Yidana *et al.* 2010). In this study, WQI was computed in three steps. The analysis results were evaluated and compared with WHO (2011) and TSI 266 (2005) (Table 7).

Each of the 21 parameters (pH, TDS, Ca, Mg, Na, K, HCO_3, Cl, SO_4, NO_2, NO_3, NH_4, As, Cr,) has been assigned a weight (wi) according to its relative importance for drinking water quality (Table 7). Greater weight is assigned to parameters which have critical health effects and whose presence above certain critical concentration limits could limit the usability of the resource for domestic purposes (Yidana *et al.* 2010). Therefore in this study, the maximum weight of 5 has been assigned to parameters including TDS, Cl, SO_4, NO_3, NO_2, NH_4, As and Cr due to their major importance for water quality assessment (Srinivasamoorthy *et al.* 2008). The minimum weight (1) has been assigned to the parameter HCO_3 due to its having the least importance for water quality assessment. Other parameters, including pH, Ca, Mg, Na, and K, were assigned to weights between 1 and 5 depending on their importance in water quality determination.

Table 7 | Relative weight of physicochemical parameters in study area

Chemical parameters	WHO (2011) standards	Turkısh Drinking Water Standard (TS 266) (2005)	Weight (wi)	Relative weight (Wi)
Total dissolved solids (TDS)	500–1,500	1,500	5	0.04
pH	6.5–8.5	6.5–9.5	4	0.05
HCO_3 (mg/l)	–	–	1	0.01
Cl (mg/l)	250	250	5	0.05
SO_4 (mg/l)	250	250	5	0.05
NO_3 (mg/l)	50	50	5	0.05
NO_2 (mg/l)	3.0	0.50	5	0.05
NH_4 (mg/l)	0	0	5	0.05
Ca (mg/l)	300	200	3	0.03
Mg (mg/l)	30	150	3	0.03
Na (mg/l)	200	200	4	0.04
K (mg/l)	–	12	2	0.02
As (mg/l)	0.01	0.01	5	0.05
Cr (mg/l)	0.05	–	5	0.05
			$\sum wi = 57$	$\sum wi = 1$

Finally, the WQI values obtained from the calculations were evaluated together with the water quality types in Table 8. In addition, the WQI values for each sample and their types are shown in Table 9. According to Table 9, the calculated WQI values ranged from 113.15 to 177.67 and from 103.84 to 204.00 for dry season and wet seasons, respectively. In addition, during the dry season, 100% of groundwater samples represent 'Poor water'; during the wet season 93.33% of groundwater samples represent 'Poor water' and 6.66% indicate 'Very Poor water'. This indicates that the quality of wet season samples is very low. So, the increase of ion concentrations is related to infiltration of rainwater in the farmland.

Potability of water in terms of fertilizers and heavy metal concentrations

In many parts of the world, groundwater is exposed to pollution from fertilizers and pesticides due to human activities, mostly involving intensive agriculture and urbanization. Fertilizer usage varies according to soil structure, climate and plant species and nowadays, the most widely used fertilizers are nitrogen and its derivatives urea, phosphate and potassium fertilizers. One of the most common ways in which nitrogen and its derivatives pass into groundwater is leaching from agricultural lands. Accordingly, the nitrate level in the groundwater is greatly affected by fertilizer quantity and types (Rahmati *et al.* 2015). Chemical or artificial fertilizers contain heavy metals and metalloids at lower amounts compared with nitrogen and its derivatives. The continuous application

Table 8 | WQI water types (Sahu & Sikdar 2008)

Range	Type of water
<50	Excellent water
50–100.1	Good water
100–200.1	Poor water
200–300.1	Very poor water
>300	Water unsuitable for drinking purposes

Table 9 | The WQI values and their types for each sample in dry and wet season in the study area

	Dry season		**Wet season**	
Sample no.	**∑ SI**	**Type of water**	**∑ SI**	**Type of water**
K1	113.15	Poor water	142.85	Poor water
K2	148.08	Poor water	128.61	Poor water
K3	114.26	Poor water	103.84	Poor water
K4	148.44	Poor water	156.38	Poor water
K5	162.80	Poor water	164.45	Poor water
K6	151.53	Poor water	106.70	Poor water
K7	169.72	Poor water	166.60	Poor water
K8	143.00	Poor water	181.55	Poor water
K9	175.45	Poor water	166.55	Poor water
K10	141.40	Poor water	140.34	Poor water
K11	173.25	Poor water	185.40	Poor water
K12	157.84	Poor water	177.81	Poor water
K13	177.67	Poor water	204.00	Very Poor water
K14	122.58	Poor water	143.11	Poor water
K15	154.88	Poor water	163.86	Poor water

of these fertilizers over the last fifty years may have contributed to increasing heavy metals and metalloids in soil and groundwater (Jayasumana *et al.* 2015).

In addition, chemicals associated with the use of excessive fertilizers and pesticides may cause negative effects on human health. Notably, excess nitrate in the drinking water can cause health risks such as methemoglobin, which depletes blood oxygen levels in infants, causes gastric problems in adults, decreased functioning of the thyroid gland, and cancer due to formation of nitrosamines, as well as multiple sclerosis (Zhaia *et al.* 2017). Other agrochemicals, such as arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni) and lead (Pb), have toxic properties and pollute groundwater. Phosphorus-containing artificial fertilizers are the main source of agricultural As pollution in groundwater (Sönmez *et al.* 2008). Triple Super Phosphate (TSP) type phosphate fertilizers are one of the main sources of As. The amount of As in the TSP is 15 times greater than the insecticide *Dimethoate*, which has contained the highest level of As among insecticides. Arsenic in soil can contaminate drinking water and food crops including vegetables, fruits and field crops (Jayasumana *et al.* 2015). Groundwaters containing As considerably affect human health and cause fatal consequences due to their carcinogenic effects. Epidemiologic studies have shown that As exposure is related to skin, liver, bladder, and other cancers (Lin *et al.* 2016).

The study area is an important region of intensive agricultural activity, particularly when it comes to greenhousing (Figure 4; ADPFAL 2011; APESR 2012). Agricultural products and cultivated areas in the region are given in Table 10 (ADPFAL 2016). The use of artificial fertilizers is very high in the study area. The fertilizer types and consumption quantities in the study area are given in Table 11 (ADPFAL 2016). According to Table 11, nitrogen and its derivatives urea, phosphate and potassium are the main groups of chemical fertilizers used in Korkuteli district.

WHO has specified the maximum safe nitrite, nitrate and ammonium concentration in drinking water to be 0.2, 50 and 1.5 mg/L, respectively (WHO 2011). Nitrate

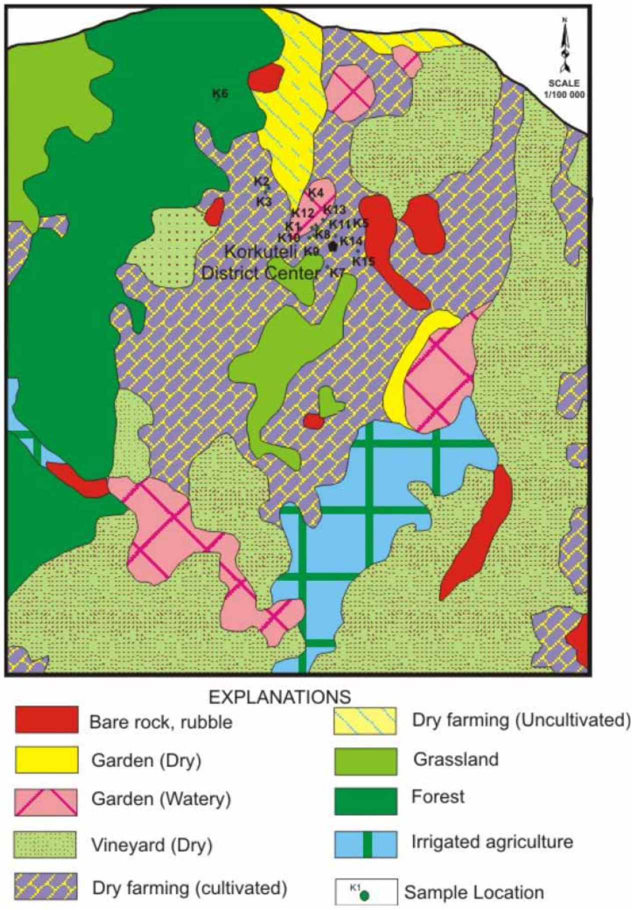

Figure 4 | Land use map of the study area (ADPFAL 2011; APESR 2012).

Table 10 | Agricultural products and cultivated field quantities in the Korkuteli district (ADPFAL 2016)

Veg.	Dec.*	Fruit	Dec.	Field crops	Dec.	Forage crops	Dec.	Cereal	Dec.	Legumes	Dec.
Cauliflower	400	Apple	21.050	Anise	6.500	Vetches	13.500	Barley	243.248	Chickpea	120.000
Mushroom	21.000 ton	Pear	39.810	Potato	4.125	Clover	5.500	Wheat	238.187	Beans	3.150
Tomato	6.400	Apricot	15.000	Sugar beet	2.943	Corn	3.000	Oat	3.373	Lentil	5
Beans	3.750	Peach	14.000	Sunflower	1.665	Sainfoin	1.200	Safflower	950	Total	123.155
Watermelon	3.200	Cherry	12.000	Fennel	1.500	Triticale	1.050	Rye	800		
Cantalpe	3.000	Plum	7.500	Loveinamist	250	Pea	75	Tritikale	504		
Cucumber	2.950	Sour cherry	7.500	Lavender	5	Forage Turnip	30	Total	487.062		
Pepper	1.655	Walnut	6.000	Balm	5	Sorghum	10				
Lettuce	1.100	Grape	5.130	Dead nettle	5	Mangel	5				
Cabbage	900	Olive	1.200	Coriander	5	Total	24.370				
Onion	800	Almond	1.200	Thyme	5						
Garlic	800	Strawberry	150	Sage	5						
Kidney bean	800	Quince	90	Total	17.013						
Pumpkin	410	Pomegranate	65								
Spinach	400	Antep Peanuts	20								
Leek	400	Oleaster	9								
Eggplant	245	Cranberry	5								
Celery	80	Mulberry	5								
Okra	80	Total	130.734								
Broccoli	25										
Radish	12										
Enginar	10										
Cress	5										
Mint	5										
Total	27.427										
Overall Total											809.771

*Dec. = decare (1,000 m^2).

Table 11 | The types of fertilizers used and consumption quantities in the Korkuteli district (ADPFAL 2016)

Type of fertilizer	Composition of the fertilizer	Tonne
AMMONIUM SULFATE 21%	21% Ammonium Nitrogen (NH_4-N). 24% Sulphur (S)	1,168
AMMONIUM NİTRATE 26%	33% Nitrogen (N). 16% Ammonium Nitrogen (NH_4-N). 16%Nitrate Nitrogen (NO_3-N)	817
AMMONIUM NİTRATE 33%	33% Total Nitrogen (N). 16.5% Ammonium Nitrogen (NH_4-N). 16.5%Nitrate Nitrogen (NO_3-N)	1,785
UREA 46%	46% Urea Nitrogen (NH_2-N)	957
TRIPLE SUPER PHOSPHATE	43–44% Phosphorus Pentoxide (P_2O_5) in neutral ammonium citrate soluble	29
DAP (Diammonium Phosphate) 18-46-0	18% Nitrogen (N). 18% Ammonium Nitrogen (NH_4-N). 46% Phosphorus (P_2O_5)	817
20-20-0 COMPOUND	20% Nitrogen (N). 20% Ammonium Nitrogen (NH_4-N). 20% Phosphorus (P_2O_5)	5,189
20-20-0 + Zn	20% Nitrogen (N). 17% Ammonium Nitrogen (NH_4-N). 3% Urea Nitrogen (NH_2-N). 20% Phosphorus (P_2O_5). 1% Zinc (Zn)	198
15-15-15 COMPOUND	15% Total Nitrogen (N). 13% Ammonium Nitrogen (NH_4-N). 5% Urea Nitrogen (NH_2-N). 13% Phosphorus Pentaoxide Soluble in Water (P_2O_5). 15% Phosphorus Pentoxide (P_2O_5) in neutral ammonium citrate soluble. 15% Potassium Oxide Soluble in Water (K_2O)	645
15-15-15 + Zn COMPOUND	15% Nitrogen (N). 15% Phosphorus Pentaoxide Soluble in Water (P_2O_5). 15% Potassium Oxide Soluble in Water (K_2O). 9% Sulphur (S). 1% Zinc (Zn)	822
MAP (Mono Ammonium Phosphate)	12% Total Nitrogen (N). 12% Ammonium Nitrogen (NH_4-N). 61% Phosphorus Pentaoxide Soluble in Water (P_2O_5).	27
POTASSIUM NITRATE	13% Total Nitrogen (N). 13%Nitrate Nitrogen (NO_3-N). 45.5% Potassium Oxide Soluble in Water (K_2O)	46
POTASSIUM SULPHATE	50% Potassium Oxide Soluble in Water (K_2O). 46% Sulphur Trioxide (SO_3) Soluble in Water	50
CALCIUM NITRATE	15.5% Total Nitrogen (N). 14.5% Nitrate Nitrogen (NO_3-N). 1.1% Ammonium Nitrogen (NH_4-N). 25.6% Calcium Oxide (CaO) Soluble in Water	101
COMPOUND (25-05-10)	25% Total Nitrogen (N). 21% Ammonium Nitrogen (NH_4-N). 5% Phosphorus Pentaoxide Soluble in Water (P_2O_5). 10% Potassium Oxide Soluble in Water (K_2O)	414
COMPOUND (13-24-13)	13% Total Nitrogen (N). 9.1% Ammonium Nitrogen (NH_4-N). 3.9% Urea Nitrogen (NH_2-N). 24% Phosphorus Pentoxide (P_2O_5) in neutral ammonium citrate soluble. 12% Potassium Oxide Soluble in Water (K_2O). 10% Total Sulphur Trioxide (SO_3) Soluble in Water. 1% Total Iron. 1% 0.5% Iron Soluble in Water. 1% Total Zinc (Zn)	166
COMPOUND (12-30-12)	12% Total Nitrogen (N). 9% Ammonium Nitrogen (NH_4-N). 3% Urea Nitrogen (NH_2-N). 28% Phosphorus Pentaoxide Soluble in Water (P_2O_5). 30% Phosphorus Pentoxide (P_2O_5) in neutral ammonium citrate soluble. 12% Potassium Oxide Soluble in Water (K_2O)	0
COMPOUND (16-16-16)	16% Total Nitrogen (N). 4% Ammonium Nitrogen (NH_4-N). 2% Nitrate Nitrogen (NO_3-N). 10% Urea Nitrogen (NH_2-N). 16% Phosphorus Pentaoxide Soluble in Water (P_2O_5). 16% Potassium Oxide Soluble in Water (K_2O)	56
COMPOUND (10-25-20)	10% Total Nitrogen (N). 7% Ammonium Nitrogen (NH_4-N). 3% Urea Nitrogen (NH_2-N). 15% Phosphorus Pentoxide (P_2O_5) in neutral ammonium citrate soluble. 13% Phosphorus Pentaoxide Soluble in Water (P_2O_5). 25% Potassium Oxide Soluble in Water (K_2O). 20% Total Sulphur Trioxide (SO_3) Soluble in Water. 1% Zinc (Zn)	28
COMPOUND (20-32-0)	20% Total Nitrogen (N). 16% Ammonium Nitrogen (NH_4-N). 4% Urea Nitrogen (NH_2-N). 32% Phosphorus Pentoxide (P_2O_5) in neutral ammonium citrate soluble. 30% Phosphorus Pentaoxide Soluble in Water (P_2O_5). 15% Total Sulphur Trioxide (SO_3) Soluble in Water. 1% Zinc (Zn)	637
COMPOUND (10-20-20)	10% Total Nitrogen (N). 20% Phosphorus Pentaoxide Soluble in Water (P_2O_5). 20% Potassium Oxide Soluble in Water (K_2O). 6% Sulphur (S). 1% Zinc (Zn)	32
TOTAL (TONNE)		13,984

concentrations exceeding the 50 mg/l limit value in drinking water can endanger human health, especially in infants (Vidyalakshmi *et al.* 2013). According to the analysis results, nitrate concentrations in the study area exceed the limit value only in the wet season (K2, K5 and K7). In addition, a nitrate level of 3 mg/L or greater indicates contamination. Water with a nitrate concentration of greater than 10 mg/L should not be used to prepare infant formula or other foods or be given to a child younger than 1 year to drink (Greer & Shannon 2005; PWP 2009). As water in the study area is used by people of all ages living in the region, this underlines the importance of this study. The analysis results showed that all waters in the study area both in dry and wet seasons were contaminated and these waters are not suitable for drinking owing to their nitrate concentrations (Table 3).

In addition, arsenic concentrations in all samples exceeded the threshold value determined by WHO (2011) in both periods. Cr concentrations exceeded the limit values at K1, K4 and K5 samples in the dry season and exceeded the limit values at K1, K2, K4, K5, K7, K11 and K12 samples in the wet season. In addition, Ni (K7 and K12) and Pb acceptable concentrations (K1, K7 and K12) were determined to be exceeded only during the wet season. Accordingly, it is not appropriate to use as drinking water according to the heavy metal analysis results (Table 3).

Evaluation of water quality as irrigation use

The sodium adsorption ratio (SAR), permeability index (PI), sodium percentage (Na %), magnesium hazard (MH), and residual sodium carbonate (RSC) indices were used to determine the suitability of groundwater for agricultural irrigation and the results are indicated in Table 12.

Sodium adsorption ratio

The calculated values of SAR ranged from 0.76 to 8.24, and 86.67% of the samples were considered 'no problem' for irrigation, but 13.33% of samples were considered as an 'increasing problem' for irrigation in the dry season. Apart from this, all samples fall into the 'no problem' category in the wet season (Table 12).

In addition, the relationship between SAR and EC values was prepared using a US salinity diagram for both seasons and the suitability of the waters for irrigation was evaluated. According to the diagram, 86.67% of the samples fall in the field of C_2–S_1, indicating

Table 12 | Irrigational quality parameters results in groundwater samples in the study area

			Samples (n = 15) in dry season		Samples (n = 15) in wet season	
Parameters	**Range**	**Groundwater class (irrigation uses)**	**In (no.)**	**In (%)**	**In (no.)**	**In (%)**
SAR (Bouwer 1978)	<6	No problem	13	86.67	15	100
	6–9	Increasing problem	2	13.33	–	–
	>9	Severe problem	–	–	–	–
Permeability index (PI) (Doneen 1964)	<60	Suitable	15	100	15	100
	>60	Unsuitable	–	–	–	–
Na % (Wilcox 1955)	<20	Excellent	13	86.67	13	86.67
	20–40	Good	2	13.33	2	13.33
	40–60	Permissible	–	–	–	–
	60–80	Doubtful	–	–	–	–
	>80	Unsuitable	–	–	–	–
Magnesium hazard (Paliwal 1972)	<50	Suitable	8	53.33	8	53.33
	>50	Unsuitable	7	46.66	7	46.66
Residual sodium carbonate (Lloyd & Heathcote 1985)	<1.25	Suitable	15	100	15	100
	1.25–2.50	Marginal	–	–	–	–
	>2.50	Unsuitable	–	–	–	–

medium salinity and low alkalinity content. These waters can be suitable for irrigation. 6.66% of the samples fall in the field of C_2–S_2 indicating medium salinity and medium alkalinity content, and 6.66% of the samples fall in the field of C_3–S_2 category in the dry season, indicating high salinity and medium alkalinity content (Figure 5). The use of waters in C_2–S_2 and C_3–S_2 categories is limited to irrigation water. In the wet season, 73.33% of the samples fall in the category of C_2–S_1 and 26.66% of the samples fall in the C_3–S_1 category, indicating that these water samples are found to have high salinity and low sodium content, which can be used for irrigation in all soil types with low risk of sodium in the wet season (Figure 5).

Permeability index

The PI values were between 37.21 and 50.63 in the dry season, and between 34.99 and 53.54 in the wet season. All samples fall into the 'Suitable' category for irrigation in dry and wet seasons (Table 12).

Sodium percentage

In all natural waters, sodium percentage (%Na) content is one of the most important parameters to assess their suitability for agricultural purposes. This is because sodium increases the hardness of the soil, and decreases its permeability (Varol & Davraz 2015). This soil type prevents plant growth. Sodium percentage values of groundwater samples were calculated for the dry and wet seasons (Table 12). Sodium percentage of these samples was plotted against EC in a Wilcox diagram (Figure 6) and given in Table 12. According to the Wilcox diagram, 86% of all samples were in the 'Excellent to good' irrigation water class and 13% (K4, K13) were in the 'Good to permissible' irrigation water class in the dry and wet seasons.

Magnesium hazard

Paliwal (1972) introduced a ratio MH for assessing the suitability of irrigation water quality. Generally, Ca and Mg maintain a state of equilibrium in water. Magnesium

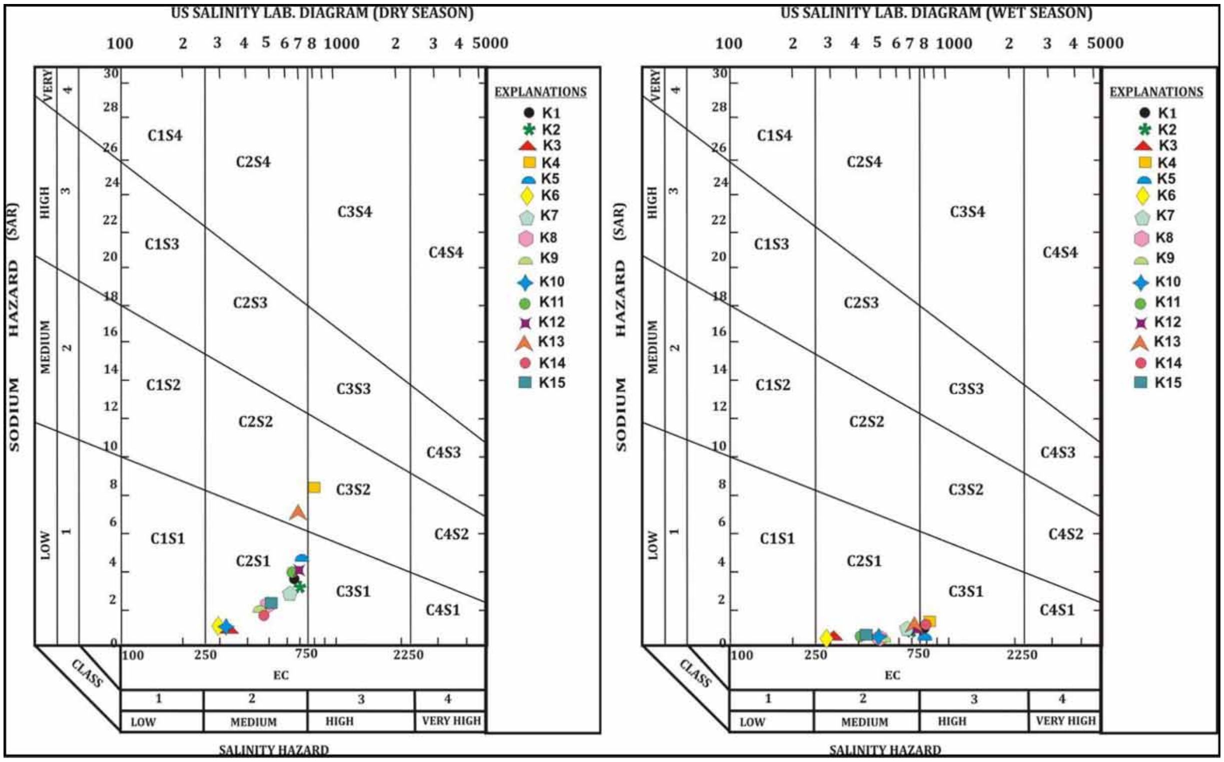

Figure 5 | Salinity (EC) and sodium hazard (SAR) of irrigation water in US salinity diagram (dry and wet season).

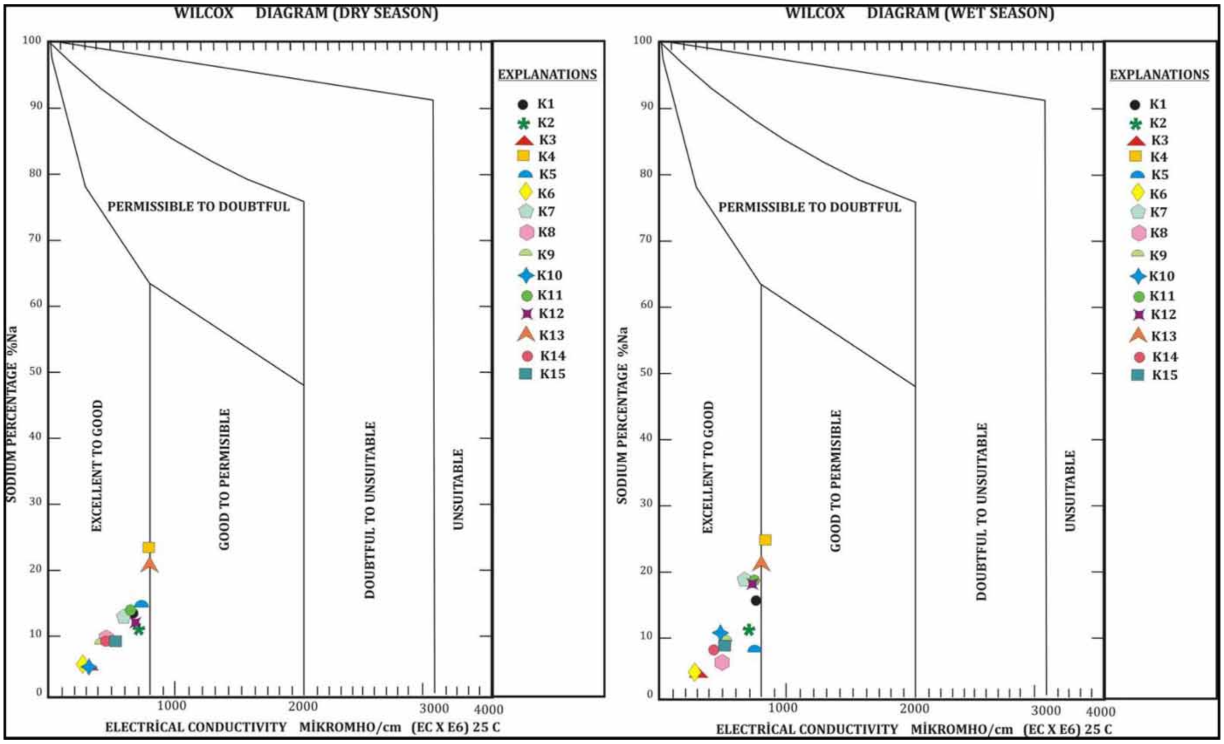

Figure 6 | According to the Wilcox (1955) diagram, irrigational suitability of groundwater in the dry and wet season.

damages the soil structure when water contains more Na and is highly saline. Generally, a high concentration of Mg is caused by the exchange of Na in irrigated soils. In equilibrium, the high Mg concentration can affect soil quality by changing its alkalinity. Thus, this situation affects crop yields (Varol & Davraz 2015). The MH values in the study area ranged from 41.51 to 68.04 and 53.33% of the samples were considered suitable for irrigation, the remainder of samples being considered unsuitable for irrigation owing to their adverse effect on crop yields in the dry and wet seasons (Table 12).

Residual sodium carbonate

RSC is an important parameter for the suitability of irrigation water (Siddiqui *et al.* 2005; Varol & Davraz 2015). Excessive magnesium and calcium ions tend to precipitate as carbonate. The sodium concentration is increased and fixed to the soil and thus the soil permeability is reduced. The high RSC value in water causes an increase in the adsorption of sodium in the soil (Eaton 1950; Selvakumar *et al.* 2017). Lloyd & Heathcote (1985) have classified irrigation water based on RSC as suitable (<1.25), marginal (1.25–2.5) and unsuitable (>2.5). According to RSC values, 100% of groundwater samples were suitable for irrigation in dry and wet seasons (Table 12).

Evaluation of water quality for industry

Quality classifications for industrial water usage lie within a wide range and nearly every industrial unit has its own standards. Industries often have problems with the chemical reactions associated with poor water quality, such as incrustation and corrosion. Incrustation involves the deposition of undesirable $CaCO_3$ on metal surfaces, whereas corrosion is a chemical process which causes the metals to wear out. For this reason, industrial use of water in the study area has also been examined in this study. The following water quality criteria were adopted when classifications were made (Johnson 1983; Subba Rao *et al.* 2012; Varol & Davraz 2015): (a) if water contains 400 mg/L of excess HCO_3 or 100 mg/L of excess SO_4, it may cause incrustation; (b) if water contains $pH < 7$, TDS more than

1,000 mg/L or Cl more than 500 mg/L, this water may cause corrosion.

In the present study, about 53.33% of the HCO_3 concentrations of the samples (K1, K2, K4, K5, K7, K11, K12 and K13) exceeded the limit of 400 mg/L in dry and wet seasons. Also, in 13.33% of the samples (K4 and K13), the SO_4 concentrations were more than 100 mg/L in dry and wet seasons. According to these results, the mentioned samples can induce incrustation on metal surfaces and are therefore not recommended for industrial use.

If the groundwater $pH > 7$, TDS is less than 1,000 mg/L and Cl is less than 500 mg/L, there is no corrosion effect. Therefore, there is no corrosion effect for any waters in the study areas.

Health risk assessment

Risk assessment is an effort to identify and measure the effects of various pollutants on human health. It also includes evaluating toxicity data for human exposure to chemicals and estimating the potential exposure levels. There are three main routes to of exposure: ingestion, inhalation, and dermal absorption. Only the ingestion path was taken into account in this study due to its being the most common form of exposure to trace elements (Varol & Davraz 2016).

Generally, local people in the study area use both groundwater and tap water for drinking and domestic purposes. Therefore the water resources in this study, with regard to WHO (2011) and TSI 266 (2005) standards, exceed the safe limits of concentration for NO_3, As and Cr and could be the origin of problematic health effects (Tables 13 and 14). We evaluated the origin of these problems and their effects on health. The NO_3, As and Cr concentrations in drinking water have been used to calculate potential health risk assessments: chronic and carcinogenic effects such as average daily dose (ADD), HQ **noncancer** and carcinogenic risk (R cancer). The calculated health risk for residents is presented in Tables 13 and 14.

According to Tables 13 and 14, the values of ADD were between 0.16–1.07 (mg/kg) in the dry season and 0.21–1.49 (mg/kg) in the wet season for NO_3. The values of ADD were 0.00 (mg/kg) in the dry season and 0.09 and 0.17 mg/kg in the wet season for As. The values of ADD were 0.00 (mg/kg) in dry season and wet season the wet season for Cr. The values of $HQ_{noncancer}$ were 0.10–0.67 in the dry season and 0.13–0.93 in the wet season for NO_3. For As, the values of $HQ_{noncancer}$ were between 7.62–16.19 in the dry season and 8.72–16.44 in the wet season. For Cr, the values of $HQ_{noncancer}$ were 0.10–0.67 in the dry season and 0.11–0.75 in the wet season. Also, values of R_{cancer}, were 0.00–0.01 in the dry season and 0.13–0.25 in the wet season for As. Carcinogenic risk is the likelihood of developing any type of cancer against the risk of exposure to a substance that has a life-long toxic effect on a person. Acceptable or tolerable risk, as determined by the regulators of the subject, is in the range of 10^{-6} to 10^{-4} (USEPA 2000; WHO 2004; Muhammad *et al.* 2010).

According to Tables 13 and 14, the possibility of developing cancer is 1–2 patients out of every 10 healthy people in dry and wet seasons. Excessive consumption of water with a high concentration of As in the study area carries a high risk of cancer. In addition, there is a high risk of noncarcinogenic effects in terms of As. Furthermore, according to Turkish drinking water standards, concentrations of heavy metals (As and Cr) in water were evaluated in dry and wet seasons, and they also exceeded the limit values (Tables 13 and 14). This also supports the results of the health risk assessment. For this reason, it is an urgent requirement to develop more efficient As removal methods in this emerging situation. These results show that the study area is at high risk in terms of health. This is an alarming situation and there is a need to develop more effective arsenic removal methods and urgent remediation to protect the health of at-risk people in the study area.

CONCLUSIONS

Groundwater quality and its suitability for different uses such as drinking, agriculture and industry in Korkuteli district were evaluated because groundwater is a major resource for domestic, agricultural, and industrial activities in the study area. In this study, a total of 30 water samples taken from wells, springs, and tap waters were analyzed in dry and wet seasons. The hydrogeochemical and water quality studies conducted in the groundwater of the Korkuteli district provides the following conclusions.

Table 13 | Calculated carcinogenic and noncarcinogenic risk of drinking water (dry season)

Substance	Water sample no.	C (mg/l)	IR (l/day)	ED (years)	EF days/ years	BW (kg)	AT (days)	ADD (mg/kg)	*RfD (mg/kg/d)	*CSF $(mg/kg/d)^{-1}$	R_{cancer}	$HQ_{noncancer}$	(TSI 266) (2005) (mg/l)	WHO (2011) standards (mg/l)
NO_3	K1	27.90	2	30	365	70	10950	0.80	1.60	–	–	0.50	50	50
	K2	31.40	2	30	365	70	10950	0.90	1.60	–	–	0.56		
	K3	5.57	2	30	365	70	10950	0.16	1.60	–	–	0.10		
	K4	23.78	2	30	365	70	10950	0.68	1.60	–	–	0.42		
	K5	37.34	2	30	365	70	10950	1.07	1.60	–	–	0.67		
	K6	5.65	2	30	365	70	10950	0.16	1.60	–	–	0.10		
	K7	23.04	2	30	365	70	10950	0.66	1.60	–	–	0.41		
	K8	17.19	2	30	365	70	10950	0.49	1.60	–	–	0.31		
	K9	13.60	2	30	365	70	10950	0.39	1.60	–	–	0.24		
	K10	5.84	2	30	365	70	10950	0.17	1.60	–	–	0.10		
	K11	25.62	2	30	365	70	10950	0.73	1.60	–	–	0.46		
	K12	27.71	2	30	365	70	10950	0.79	1.60	–	–	0.49		
	K13	21.78	2	30	365	70	10950	0.62	1.60	–	–	0.39		
	K14	13.32	2	30	365	70	10950	0.38	1.60	–	–	0.24		
	K15	19.37	2	30	365	70	10950	0.55	1.60	–	–	0.35		
As	K1	0.08	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.00	7.62	0.01	0.01
	K2	0.12	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	11.43		
	K3	0.11	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.00	10.48		
	K4	0.11	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.00	10.48		
	K5	0.13	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	12.38		
	K6	0.15	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	14.29		
	K7	0.15	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	14.29		
	K8	0.13	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	12.38		
	K9	0.17	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	16.19		
	K10	0.14	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	13.33		
	K11	0.15	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	14.29		
	K12	0.13	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	12.38		
	K13	0.15	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	14.29		
	K14	0.11	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.00	10.48		
	K15	0.14	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	13.33		
Cr	K1	0.05	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.48	0.05	–
	K2	0.04	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.38		
	K3	0.01	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.10		
	K4	0.07	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.67		
	K5	0.06	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.57		
	K6	0.01	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.10		
	K7	0.04	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.38		
	K8	0.02	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.19		
	K9	0.02	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.19		
	K10	0.01	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.10		
	K11	0.05	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.48		
	K12	0.05	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.48		
	K13	0.06	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.57		
	K14	0.02	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.19		
	K15	0.03	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.29		

*Data from USEPA (2005).

The seasonal variation of physical, major ion and heavy metal and pollutant concentrations of the water resources in the study area were evaluated. As a result, changes in the physical and major ion concentrations of the water are associated with rock–water interactions. However, changes in the concentrations of heavy metals and nitrogen

Table 14 | Calculated carcinogenic and noncarcinogenic risk of drinking water (wet season)

Substance	Water sample no.	C (mg/l)	IR (l/day)	ED (years)	EF days/ years	BW (kg)	AT (30×365 days)	ADD (mg/kg)	*RfD (mg/kg/d)	*CSF $(mg/kg/d)^{-1}$	R_{cancer}	$HQ_{noncancer}$	(TSI 266) (2005) (mg/l)	WHO (2011) standards (mg/l)
NO_3	K1	47.7	2	30	365	70	10950	1.36	1.60	–	–	0.85	50	50
	K2	51	2	30	365	70	10950	1.46	1.60	–	–	0.91		
	K3	7.32	2	30	365	70	10950	0.21	1.60	–	–	0.13		
	K4	35.25	2	30	365	70	10950	1.01	1.60	–	–	0.63		
	K5	52.14	2	30	365	70	10950	1.49	1.60	–	–	0.93		
	K6	4.9	2	30	365	70	10950	0.14	1.60	–	–	0.09		
	K7	50.02	2	30	365	70	10950	1.43	1.60	–	–	0.89		
	K8	27.08	2	30	365	70	10950	0.77	1.60	–	–	0.48		
	K9	20.5	2	30	365	70	10950	0.59	1.60	–	–	0.37		
	K10	7.31	2	30	365	70	10950	0.21	1.60	–	–	0.13		
	K11	36.43	2	30	365	70	10950	1.04	1.60	–	–	0.65		
	K12	20.12	2	30	365	70	10950	0.57	1.60	–	–	0.36		
	K13	33.54	2	30	365	70	10950	0.96	1.60	–	–	0.60		
	K14	10.28	2	30	365	70	10950	0.29	1.60	–	–	0.18		
	K15	28.69	2	30	365	70	10950	0.82	1.60	–	–	0.51		
As	K1	0.11	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.00	10.08	0.01	0.01
	K2	0.09	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.00	8.72		
	K3	0.09	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.00	8.95		
	K4	0.11	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.00	10.80		
	K5	0.13	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	12.64		
	K6	0.10	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.00	9.43		
	K7	0.13	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	12.72		
	K8	0.17	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	16.17		
	K9	0.15	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	14.44		
	K10	0.13	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	12.20		
	K11	0.15	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	14.73		
	K12	0.15	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	14.23		
	K13	0.17	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	16.44		
	K14	0.13	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	12.52		
	K15	0.15	2	30	365	70	10950	0.00	3.10^{-4}	1.5	0.01	14.00		
Cr	K1	0.06	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.59	0.05	–
	K2	0.05	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.48		
	K3	0.01	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.13		
	K4	0.08	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.75		
	K5	0.05	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.45		
	K6	0.01	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.11		
	K7	0.05	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.47		
	K8	0.03	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.30		
	K9	0.04	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.34		
	K10	0.03	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.30		
	K11	0.07	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.62		
	K12	0.06	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.60		
	K13	0.07	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.68		
	K14	0.03	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.25		
	K15	0.03	2	30	365	70	10950	0.00	3.10^{-3}	–	–	0.32		

*Data from USEPA (2005).

derivatives in the water are also related to anthropogenic inputs. In the wet season, infiltration of rain water changes the concentration values.

Statistical analyses were carried out to determine the hydrochemical properties of groundwater and tap water in the study area, and their relationships with each other.

The correlation analysis is a bivariate method that is applied to describe the degree of relationship between two hydrochemical parameters in dry and wet seasons. The parameters used for correlation analysis were T (°C), pH, Eh, EC, TDS, Ca, Mg, Na, K, HCO_3, CO_3, Cl, SO_4, NO_3, NO_2, NH_4, Al, As, Cu, Cr, Fe and Zn values of water. There was a moderate to strong correlation between some of the correlation groups in the study area ($r > 0.7$). The reason for this is considered to be mainly the dissolution/precipitation reactions, concentration effects and anthropogenic inputs, in relation to the simultaneous increase/decrease in cations.

Ca-Mg-HCO_3 and Mg-Ca-HCO_3 were the dominant water types observed in dry and wet seasons, due to water–rock interaction in the study area. According to the Gibbs diagrams, samples from both seasons fell in the rock-dominance zone, suggesting precipitation induced chemical weathering along with dissolution of rock forming minerals.

The WQI was applied to determine the drinking water quality of the water samples in the study area. According to the WQI, in the dry season, 100% of groundwater samples represent ‘Poor water’ and during the wet season 93.33% of groundwater samples represent ‘Poor water’ and 6.66% indicate ‘Very Poor water’. This indicates that the quality of wet season samples is very bad. The increase in ion concentrations is related to the infiltration of rain water in the farmland. In addition, nitrogen derivatives and heavy metal concentrations of water samples were compared and assessed with the limit values determined by the World Health Organization (WHO 2011) for the usability of drinking water. Accordingly, it is not appropriate to use as drinking water in terms of the heavy metal and nitrogen derivatives analysis results.

In addition, use as irrigation water in the study area was evaluated by SAR, PI, Na%, MH, RSC, USSL classification and Wilcox diagram. A large majority of water samples were suitable for irrigation purposes according to RSC, SAR, PI and Na%. According to the MH values, 53.33% of the samples were considered suitable for irrigation; meanwhile, 46.66% of samples were considered unsuitable for irrigation indicating their adverse effect on crop yields in the dry and wet seasons.

The groundwater quality was evaluated in terms of industrial usage. Because some water types can cause incrustation and corrosion on metal surfaces, they cannot be used. Therefore, HCO_3, SO_4, pH, TDS and Cl concentrations of waters were evaluated. According to HCO_3 and SO_4 results, the studied samples can induce incrustation on metal surfaces and are not recommended for industrial use. But there are no corrosion effects from any waters in terms of pH, TDS and Cl concentrations in the study area.

The health risk assessment for NO_3, As and Cr (separately for dry and wet seasons) was carried out on the grounds. The arsenic concentrations exceeded the limit values. According to the health risk assessment, the study area is categorized as a high risk area.

As a result, the use of Korkuteli district center water resources is not suitable as drinking water. Use of these waters as drinking water will affect human health negatively. Taking this into consideration, precautions must be taken.

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