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Araştırma Makalesi / Research Article

A Study on Physicochemical Characteristics of Surface Waters in The Area of Dereli (Giresun, Turkey)

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Surface water; Physicohemistry; Quality; Dereli

Abstract

Some physicochemical characteristics of surface waters (main river and some streams) in the area of Dereli (Giresun) were investigated. Additionally, certain parameters and quality indices, which may affect the usability of waters for agriculture, were assessed. Available data indicate that the waters have slightly alkaline in character, with pH values ranging from 7.6 to 8.35. The waters are classified as fresh based on their EC values, which ranges from 210–590 µS/cm. The predominant anion in nearly all of the investigated waters is bicarbonate (HCO_3^-). Sulfate (SO_4^{2-}) is, after bicarbonate, the second most abundant anion in the waters, followed by chloride (Cl^-). Calcium (Ca^{2+}) is the most abundant cation in the waters examined, followed by magnesium (Mg^{2+}), sodium (Na^+) and potassium (K^+) in descending order. The levels of all ions examined in the waters are in the ranges recommended by the Food and Agriculture Organization (FAO) for irrigation water. Moreover, the calculated values of U.S. Salinity (SAR), Residual sodium carbonate (RSC), Sodium Percentage (Na %), Kelly's ratio (KR) and Magnesium hazard (MH) indicate suitable of the waters for irrigation. In general, the surface waters in the locations studied are of good physicochemical quality, and also adequate for irrigation.

Dereli (Giresun, Türkiye) Bölgesi Yüzey Sularının Fizikokimyasal Özellikleri Üzerine Bir Araştırma

Anahtar kelimeler
Yüzey Suyu; Fizikokimya; Kalite; Dereli

Öz

Bu çalışmada, Dereli bölgesi yüzey sularının (ana nehir ve akarsular) bazı fizikokimyasal özellikleri incelenmiştir. Ayrıca, suların tarımsal sulama için kullanılabilirliğini etkileyebilecek bazı parametreler ve kalite indeksleri değerlendirilmiştir. Mevcut veriler, suların hafif alkali karakterde olduğunu ve pH değerlerinin 7.6 ile 8.35 arasında olduğunu göstermektedir. İncelenen sular 210-590 µS/cm arasında değişen EC değerlerine göre taze olarak sınıflandırılır. İncelenen suların neredeyse tamamında baskın olan anyon bikarbonattır (HCO_3^-). Sülfat (SO_4^{2-}), bikarbonattan sonra sularda en bol bulunan ikinci anyondur ve bunu klorür (Cl^-) takip eder. İncelenen sularda en bol bulunan katyon ise kalsiyum (Ca^{2+}) olup, bunu sırasıyla magnezyum (Mg^{2+}), sodyum (Na^+) ve potasyum (K^+) izlemektedir. Sularda belirlenen tüm iyon seviyeleri Gıda ve Tarım Örgütü (FAO)' nün sulama suları için önerdiği aralıktadır. Ayrıca, ABD Tuzluluğu (SAR), Kalıntı Sodyum Karbonat (RSC), Sodyum Yüzdesi (Na %), Kelly oranı (KR) ve Magnezyum Tehlikesi (MH) için hesaplanan değerler, suların tarımsal amaçlı sulama için uygun olduğunu göstermektedir. Genel olarak, incelenen lokasyonlardaki yüzey suları fizikokimyasal kimyasal olarak iyi kalitededir ve tarımsal amaçlı kullanım için elverişlidir.

1. Introduction

Water is the most essential necessities for all lives on the Earth. Based on its source, water may be classified, in general, ground and surface water (Gupta, and Gupta 2002). Surface waters are an extremely important water source. They make up the majority of the water used for public supply and irrigation. Rivers and streams constitute the flowing surface waters (Int. ref. 1). However, natural processes or man's activities may cause the contamination of surface waters (Kabata-Pendias 2010). When the surface water is contaminated in an area, it not only affects the plants and animals, it harms also people. Therefore, in order to protect both human health and environment, it is essential to review existing water quality in the area.

Giresun is located in Eastern Black Sea Region, which is one of the most important metallogenic area in Turkey. The area hosts numerous metallic mineral deposits and occurrences, particularly in copper, lead and zinc (Int. ref, 2). Dereli is a district of Giresun province. The region has steep topography and a humid and rainy climate. The average annual precipitation is 867 mm with a mean temperature of 12.7 °C. The main river running through the Dereli is Aksu. (Figure 1). A large number of streams merge with the main river, and finally all the water flows into the Black Sea. There are many villages along Aksu river. The parts of the main river and some stream is used by nearby inhabitants for fish farming, agriculture and/or husbandry. However, agriculture and husbandry are fairly limited owing to very steep topography of the area. Corn, cabbage and green bean are the main crops cultivated in the area.

There are scarce number of studies concerning natural waters in the Dereli area. One of which has been made by Kazancı et al. (2010), is relevant to the assessment of the ecological quality of Aksu river water. The other one is a study carried out by Kacmaz (2020) to determine the heavy metal contamination in natural waters of the Dereli area. The present study has focused to assess primarily on some physicochemical characteristics might adversely affecting the quality of surface waters. In addition, the suitability of surface waters for irrigation purposes, was evaluated using various indices, such as sodium absorption ratio (SAR), Sodium percentage (Na %), residual sodium carbonate (RSC), Kelly's ratio (KR) and magnesium hazard (MH).

2. Material and Methods

The studied area, Dereli, is a district of Giresun. The main river flowing through the Dereli area is the Aksu River. In total, 16 samples of surface water were collected from the area. The samples have been taken from the River Aksu and some streams that merge with Aksu River (Figure 1). The water samples taken in the field were filtered using a 0.45-µm membrane (milipore) filter and then divided into two polyethylene bottles. One of bottle was acidified to pH< 2 with ultrapure HNO_3 and kept in a refrigerator at 4 °C until analysis. The other, unacidified sample was used for anion analyses. The samples acidified, were shipped to ACME laboratory (internationally accredited lab. in Canada) for chemical analysis by inductively coupled plasma mass spectrometry (ICP-MS).

Electrical conductivity (EC), pH, and the temperature (T) values were determined at each sampling point by using WTW field kit. Alkalinity was measured by titration with hydrochloric acid (HCl) and expressed as bicarbonate (HCO_3^-).

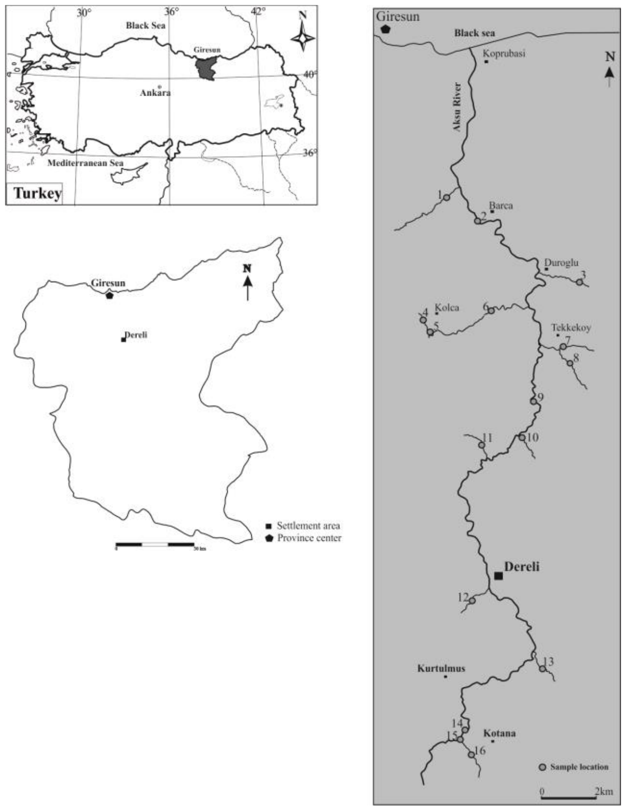

Figure 1. Map showing sampling points in the study area.

3. Results and Discussion

3.1. Some physicochemical characteristics of sampled waters

The certain physicochemical properties of the waters are represented in Table 1. The range values recommended by the FAO (Ayers and Westcot 1985) for irrigation water are also included in Table 1.

pH is one of the most important parameter of water quality. In general, the surface waters are alkaline with pH value of 6.5 to 8.5 (Int. ref. 3). Aquatic organisms are extremely sensitive to pH levels. A slight change in the pH of natural waters can damage creatures that live in that water. For example, the optimal pH levels for fish are from 6.5 to 9.0. They cannot survive in waters below pH 4 and above pH 11 for long periods. (Int. ref. 4). Likewise, the measurement of pH is needed to determine the suitability of the water for irrigation. The FAO (Ayers and Westcot 1985) recommends a range of pH from 6.0 to 8.5 in irrigation water to protect crops. In this study, the pH of water samples varies from 7.60 to 8.35, which is within the safe range for fish as well as irrigation.

The other quality parameter preferred in all waters is a low total salt content. Total salt content in water is commonly expressed in terms of electrical conductivity (EC) (Wilcox, 1958). EC greatly affects the types of creatures that can survive in water. Most natural waters have EC value of much less than one mho/cm (Wilcox 1955). Freshwater streams ideally should have a conductivity between 150 to 500 µS/cm to support varied aquatic life. The conductivity of rivers in the United States usually ranges from 50 to 1500 µmhos/cm and this is ideal for fish (Int. ref. 5). Similarly, EC is an important factor affecting irrigation. An ECw of 3 dS/m is noted the upper limit for irrigation (Ayers and Westcot 1985), and water with an EC of less than 700 µS/cm has no of restriction use for irrigation. As seen in Table 1, the measured EC values of the waters are in the range of 210–590 µS/cm and are below the FAO upper limit value (Table 1). In addition, the waters could be classified as fresh water due to their EC values less than 1,500 µS/cm stated by Charalambous (2013). Therefore, the values of present EC are appropriate for fish and some other forms of aquatic life in the water.

Major ions

Bicarbonate (HCO_3^-) is the predominant anion in nearly all the surface waters examined. its concentration varies between 1.08 and 5.18 me/L, and these values are below the usual range (0-10 me/L) recommended by the FAO for irrigation.

Sulfate (SO_4^{2-}) is an important source of sulfur, an essential nutrient for plants and animals. However, toxicity usually is not a problem, except at elevated concentrations, where can interfere with uptake of other nutrients (Weiner 2008). FAO (1985) recommends a maximum sulphate value of 20 me/L for irrigation. Sulfate is the second most abundant anion with values ranging from 0.13 to 1.44 me/L. The stream water samples (4 and 5) taken near the Kolca site demonstrated markedly elevated levels of sulphate relative to the other samples. However, levels are all considerably less than the maximum value recommended by the FAO (1985) for irrigation.

Chloride (Cl^-) is present in all natural waters, but mostly the concentrations are low. In most surface streams, its concentrations are lower than those of sulfate or bicarbonate (Hem 1985). Low amounts of chloride are essential for plants. However, elevated concentrations are undesirable, as it is toxic to some plants (Wilcox, 1955). The usual range of chloride in irrigation water is 0-30 me/L and water with a chloride of less than 4 me/L has no of restriction use for irrigation (Ayers and Westcot 1985). The chloride is present in the studied waters, at low concentration ranged from 0.06 to 0.93 me/L and hence does not pose any restriction for irrigation.

Ca, Mg, and K are essential plant foods. Na is taken up freely by many plants, but it probably is not essential in the same quantity as the other nutrients and it may be toxic for some plants (Wilcox 1955). Usual range noted in irrigation waters is 0–20 me/L for Ca, 0–5 me/L for Mg, and 0-40 me/L for Na (Ayers and Westcot 1985). The predominant cation in the studied waters is calcium, which had concentration values varying between 1.39 and 4.78 me/L. Calcium is followed by magnesium that its concentration varied, ranging from 0.46 to 1.89 me/L. Sodium is much less abundant than calcium and magnesium in studied samples. The sodium concentrations of the samples changes from 0.23 me/L to 0.99 me/L. The concentrations of Ca, Na and

Mg are within the recommended ranges by the FAO (see Table 1).

Table 1. Some physicochemical properties of investigated water samples.

Sample	Type of water	pH	EC (µS/cm)	Ca^{2+} me/l	Mg^{2+} me/l	Na^{+} me/l	K^{+} mg/l	HCO_3^- me/l	Cl^- me/l	SO_4^{2-} me/l	B mg/l
1	Stream	8.17	310	2.55	0.60	0.40	1.40	2.96	0.14	0.31	0.019
2	River	8.20	470	3.19	1.45	0.67	2.12	3.60	0.56	0.88	0.065
3	Stream	8.35	420	2.45	0.61	0.33	0.93	2.93	0.08	0.13	0.013
4	Stream	7.60	270	2.06	0.68	0.29	1.04	1.60	0.08	1.19	0.006
5	Stream	7.70	210	1.39	0.68	0.28	1.14	1.08	0.06	1.44	0.007
6	Stream	8.05	220	1.72	0.46	0.24	1.21	1.76	0.06	0.44	0.009
7	Stream	8.17	500	1.95	0.70	0.43	1.15	2.68	0.08	0.13	0.010
8	Stream	8.20	410	2.09	0.52	0.25	1.25	2.43	0.08	0.13	0.008
9	River	8.23	500	2.80	1.36	0.61	1.82	3.40	0.45	0.81	0.058
10	Stream	8.20	390	2.41	0.64	0.23	0.92	2.80	0.06	0.19	0.006
11	Stream	7.98	410	4.26	0.87	0.51	5.27	5.00	0.28	0.13	0.036
12	Stream	7.95	490	3.43	1.28	0.40	1.26	3.60	0.28	0.81	0.037
13	Stream	8.07	470	3.38	1.12	0.41	1.79	4.00	0.23	0.44	0.060
14	River	8.12	590	4.78	1.89	0.99	2.19	5.18	0.93	1.06	0.101
15	River	8.11	390	3.24	1.73	0.85	2.01	3.80	0.76	0.88	0.088
16	Stream	8.12	430	4.03	1.62	0.35	1.93	4.36	0.14	1.0	0.018
USEPA		6.5-8.5									
* Usual range in irrigation water		6.0-8.5	0-3 ds/m	0-20	0-5	0-40	0-2	0-10	0-30	0-20	0-2

* Ayers and Westcot 1985, me/l: milliequivalents per liter.

Potassium (K) seldom occurs in high concentrations in natural water (Hem, 1985). Its concentration is generally less than 10 mg/L in natural fresh waters (Int. ref. 6). The median potassium value is of 2.3 mg/L noted for surface water (Langmuir 1997). The usual range of K in irrigation water is recommended by the FAO as 0-2 mg/L. The concentrations of potassium in the waters examined are relatively lower in comparison with the other major cations and ranged from 0.92 to 5.27 mg/L. The highest value of 5.27 mg/L was recorded at sample number 11 taken from stream water. However, the K concentrations in the most samples are generally low, and rarely exceed FAO's maximum limit of 2 mg/L.

Boron and other toxic elements

Boron, like sodium, is an essential nutrient for plant growth. However, and if present in amounts appreciably greater than needed, it becomes toxic. The usual range of boron in irrigation water is from 0 to 2 mg/L. Furthermore, there are no restrictions for values for less than 0.7 mg/L (Ayers and Westcot 1985). Boron is present at concentrations between 0.006 and 0.101 mg/L in the studied waters. The concentrations of boron in some of the water samples (see Table 1) are much higher compared with the median value (10 µg/L) reported by Langmuir (1997) for surface waters. However, these concentrations are well below the recommended values of the FAO (see Table 1).

Like boron, some other elements, (e.g. Hg, Pb, Zn, As, Cd, Co, Cu, Ni, etc.,) could be toxic to plants if present in excess amount of concentrations in irrigation water (Ayers and Westcot 1985). It was reported earlier by Kacmaz (2020) that the surface waters, in general, have low heavy metal concentrations that did not exceed criteria for drinking water of the United States Environmental

Protection Agency (USEPA, 2018). Based on this, it can be said that the values of existing concentrations in the waters are not a level to pose threat to plants.

3.2. Suitability of surface waters for irrigation

Certain quality indices, which help in determining the suitability of water for irrigation such as, sodium absorption ratio (SAR), sodium percentage (Na %), residual sodium carbonate (RSC), Kelly's ratio (KR) and magnesium hazard (MH) were calculated. The calculated values of quality indices for each samples are depicted in Table 2.

Sodium adsorption ratio

The sodium status of the water is expressed in terms of sodium adsorption-ratio (SAR) (Wilcox, 1955). SAR is an indicator used to determine whether the suitability of a water for agricultural irrigation. It is calculated using the Richards (1954) equation below where, ion concentrations are expressed in milliequivalents per liter (me/L).

$$SAR= Na/ [(Ca + Mg)]/2]^{0,5}$$

The usual range of SAR in irrigation water is given as 0-15 me/L (Ayers and Westcot 1985). Typically, a SAR value below 2.0 is considered safe for plants especially if the sodium concentration is also below 50 mg/L (Sharma 2021).

Table 2. The calculated quality indices value of the water samples.

Sample	Type of water	SAR me/L	% Na	RSC	KR	MH
1	Stream	0.31	12.08	-0.18	0.13	19.0
2	River	0.44	13.56	-1.03	0.15	31.2
3	Stream	0.27	10.40	-0.13	0.11	19.9
4	Stream	0.25	10.51	-1.13	0.11	24.7
5	Stream	0.27	12.83	-0.99	0.13	33.0
6	Stream	0.23	11.16	-0.41	0.11	21.0
7	Stream	0.38	14.82	0.03	0.16	26.3
8	Stream	0.22	9.89	-0.18	0.10	19.7
9	River	0.42	13.64	-0.76	0.15	32.7
10	Stream	0.18	7.58	-0.25	0.07	20.8
11	Stream	0.32	11.24	-0.13	0.10	16.9
12	Stream	0.26	8.45	-1.10	0.09	27.1
13	Stream	0.27	9.21	-0.50	0.09	24.9
14	River	0.54	13.52	-1.50	0.15	28.3
15	River	0.54	15.37	-1.16	0.17	34.7
16	Stream	0.20	6.53	-1.28	0.06	26.6
* Usual range in irrigation water		0-15				

*Ayers and Westcot (1985), me/l: milliequivalents per liter.

The calculated values of SAR in the surface water samples of the study area ranges from 0.18 me/l to 0.54 me/L. The values of SAR are also all below the FAO permissible limit, as shown in Table 2. In addition, the waters were classified using the US Salinity Laboratory (USSL, 1954) diagram based on the EC and the SAR. As represented in Figure 2, the most of waters in the study area fall within the low salinity-low sodium (alkali) hazard class (C1S1) and medium salinity-low sodium (alkali) hazard class (C2S1) hence can be used for irrigation without adverse effects.

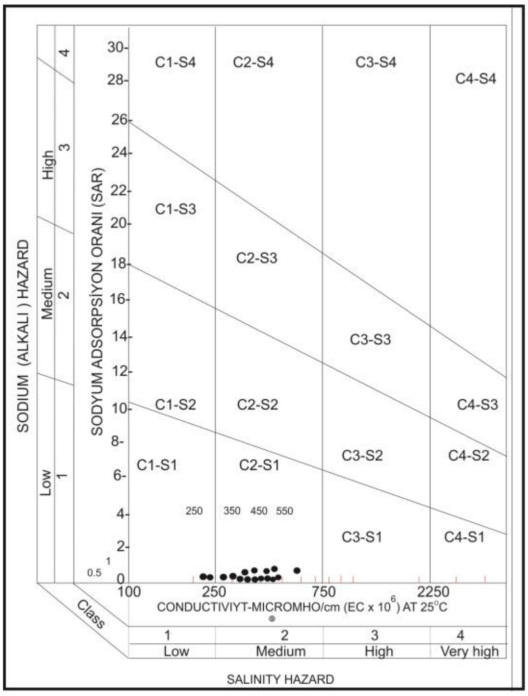

Figure 2. Distribution of the studied waters in the US Salinity Laboratory (USSL, 1954) diagram.

% Na (Sodium Percentage)

The sodium percentage (Na %) is calculated by using the following formula:

$$\% Na= [(Na^{+} + K^{+})*100]/(Ca^{2+}+Mg^{2+} + Na^{+} + K^{+})$$

As shown in Table 1, the sodium percentage values (Na %) of the water samples vary from 6.53 to 15.37. Wilcox's diagram which the basis of Na % and EC values was used to classify the waters (Figure 3). The diagram demonstrates that the waters are excellent to good quality.

Residual sodium carbonate (RSC)

RSC is an estimate of the potential increase in sodium hazard and is calculated by the following equation;

$$RSC= (CO_3^{-}+HCO_3^{-})-(Ca^{2+}+Mg^{2+})$$

According to Eaton (1950), water with has a RSC value in excess of 2.50 is not appropriate for irrigation. On the other hand, water that has a RSC value less than 1.25 is considered safe for irrigation. In all analyzed water samples, RSC values are below 1.25 (Table 2). This shows that the waters of the study area were low potential for sodium hazard and thus, appropriate for irrigation.

Kelly's ratio (KR)

Excess sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability (Kelly 1951). The Kelly's ratio (KR) is another indicator used to ascertain whether the suitability of water for irrigation. The level of Na^{+} measured against Ca^{2+} and Mg^{2+} is known as KR and this ratio is defined by the equation in which the concentrations are in me/l.

$$KR= [(Na^{+})/ (Ca^{2+}+Mg^{2+})]$$

Typically, water with Kelly's ratio less than one (KR<1) are regarded as suitable for irrigation (Kelly, 1940). The calculated KR values (max. 0.17) indicate that, the studied waters are permissible for irrigation (Table 2).

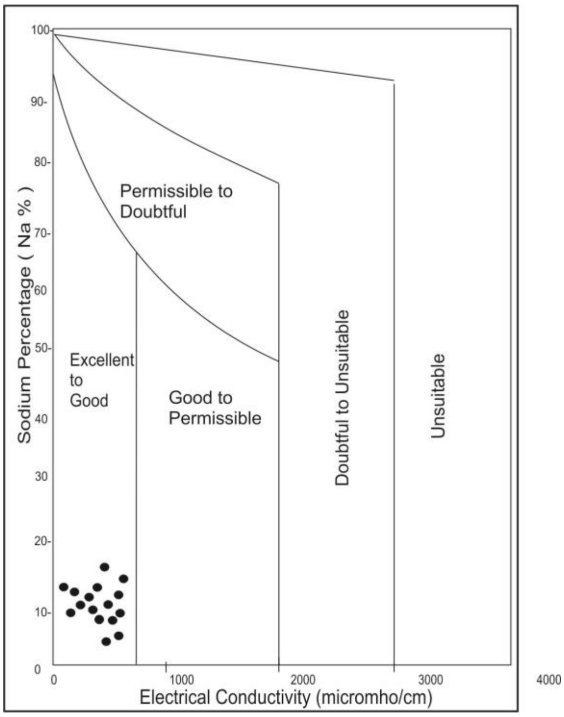

Figure 3. Classification of the water samples on the Wilcox diagram (Wilcox, 1955).

Magnesium hazard (MH)

Ca^{2+} and Mg^{2+} commonly present in natural waters are also essential nutrients for the crop. However, an excessive amount of Mg in irrigation water would adversely affect the crop yield by converting soil into alkaline (Srivastava *et al.* 2020). Therefore, it is necessary to assess magnesium hazards (MH) of waters before irrigation. It is calculated using the formula below;

$$MH= Mg^{2+}/[Ca^{2+}+Mg^{2+}]*100$$

Water that MH value exceeding 50 (MH >50) is not recommended for irrigation use (Szabolcs and Darab 1964). As seen in Table 2, the studied waters have MH value less than 50. This indicates that the waters are suitable for irrigation use.

4. Conclusion

This study is providing an overview of surface waters physicochemical characteristics in Dereli area located in south part of Giresun. In addition, the suitability of water for irrigation were evaluated using some of the water quality criteria and standards. The surface water samples examined show slightly alkaline pH values varied from 7.6 to 8.35. The majority of samples have low values of EC (<500 µs/cm) indicating of fresh water. Calcium and magnesium are the major cations and bicarbonate is the major anion in the water. The levels of calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, and boron in the waters of the area are fall within the limits set by the FAO. The suitability of the surface waters for irrigation were evaluated based on the quality indices viz SAR, Na %, RSC, KR, and MH. According to US salinity diagram, the majority of the water samples belong to the medium salinity-low alkali hazard class (C2S1) and can be used for irrigation. As per classification of Wilcox, the waters are excellent to good quality for irrigation. The RSC values show that all the waters studied is suitable for irrigation. The KR values exhibit that there is no substantial excess of sodium in the waters and hence could be used for irrigation. The values of the MH indicate that they are suitable for irrigation use. Currently available data indicate that in the physicochemical aspect, the quality of the surface waters in the study area are, in general good, and fit for irrigation.

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