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ORIGINAL ARTICLE

How far can hydrochemical characteristics of surface water meet drinking and irrigation criteria: a pragmatic study for the Euphrates river basin, Turkey

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Abstract

The primary intention of the current work was to appreciate the hydrochemistry characteristics and the water quality of the Euphrates river basin in Turkey. The water quality index technique (WQI) was adopted here for drinking criterion, while the United State salinity diagram and Wilcox's diagram were constructed to assure the river expediency for irrigation standards. Factor analysis (FA) and cluster analysis (CA) were harnessed for identifying the paramount factors influencing the water quality and estimating the spatial variations amongst the sampling sites. It has been demonstrated that water–rock interactions have a pivotal influence on the river basin. It has been inferred from the Piper plot that water in the Euphrates basin is of Mg–HCO_3 type. Alkaline earth metals and weak acids were prevalent rather than alkalis and strong acids. Besides that, silicate weathering is the dominant process within the river basin. Virtually, the majority of samples have met the drinking and irrigation standards. FA has revealed four factors that contributed to 71.453% of the total discrepancy in water quality while two disparate groups of similarities were uncovered between the sampling sites, reflecting palpable pollution levels within the river basin.

Keywords Euphrates river basin · Factor analysis · Cluster analysis · Hydrochemistry · WQI

Introduction

A surge increase in the water demand has been witnessed in the recent few decades as a consequence of the raised population and improved lifestyle quality. Anthropogenic activities, like industrial and agricultural activities, wastewater effluents, groundwater leaching and runoff, have added more pressure on the current freshwater deficiency and surface water pollution (Donohue et al. 2006; Ismail and Muntasir 2018). Nevertheless, the quality of surface water could be prone to change as a result of some natural processes such as the chemical composition of rock-forming minerals (carbonate and silicate weathering), as well as the physical process of erosion, which generates favorable conditions for mineral dissolution (Ismail et al. 2014; Asare-Donkor et al. 2018). Currently, more than 50% of the available surface water resources are undergoing human activities, and this rate is expected to hit the 70% level in 2025, Elhatip and Hinis (2014). On the other hand, about 2 million tons of sewage and industrial and agricultural waste are discharged into the surface water every day. The amount of wastewater produced annually is about 1500 km^3, six times more water than exists in all the rivers of the world (UN WWAP 2003). Indeed, surface water has many indispensable applications for human beings, varying from water supply to irrigation and power generation…etc. These applications may directly be fed from the surface water source or after a series of treatments depending on the water quality required.

Furthermore, water chemistry plays a vital role in determining the hydrochemical characteristic of surface water. Surface water such as rivers and streams gains water from the inflow of groundwater through the streambed when the elevation of the water table in the vicinity of the stream higher than the streamwater surface. This could change the hydrochemical characteristics of surface water due to many

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processes such as precipitation, infiltration, rock–water interaction, and oxidation–reduction reactions, which could impart deterioration into surface water quality (Umar and Alam 2012). Other geochemical activities, such as sorption, redox reactions, ion exchange, and complexation may alter its hydrochemistry and subsequently affect the water quality. Anthropogenic practices such as agricultural activities, industrial and domestic wastewater effluent also cause substantial changes in surface water.

The Euphrates river basin has significant importance for the growing Turkish agriculture and the economy. The Euphrates river, known as one of the longest rivers in western Asia, emerges from the confluence of the Western Euphrates (Kara Su) and the Eastern Euphrates (Murat Su). In the meantime, challenges associated with the population growth, drought and environment have alerted the governmental bodies regarding the expected water shortage crisis in the upcoming decades (İşçen et al. 2009). During the 7th decade of the last century, great efforts have been devoted to launching the Southeastern Anatolia Project (GAP). These efforts are crowned by establishing twenty-two dams and nineteen hydroelectric power plants (Ismail et al. 2020).

Despite the relatively significant importance of this mega project (Bilgen 2020), there has been a noticeable increase in the water salinity downstream of the Euphrates river (Rahi and Halihan 2010; Zowain and Ismail 2015). This unexpected scenario draws the attention of the scientific community to study the hydrochemistry and the water quality of the Euphrates river basin. Numerous studies have been carried out to evaluate the water quality in the river basin and watershed over the worlds (Odemis and Evrendilek 2008; Wang et al. 2011; Asare-Donkor et al. 2018; Zaman et al. 2018; Bilgin 2018; Abdalla and Scheytt, 2012; Nganje et al. 2017; Poletaeva et al. 2018). However, few studies were reported on the hydrochemistry and the water quality of the Euphrates river basin within Turkey. Some previous studies were carried out to evaluate the hydrochemistry of the Euphrates river within Iraq (Awadh and Ahmed 2013; Al-Marsoumi et al. 2006). In the present study, a large data matrix has been gathered, at regular intervals, from different stations within the Euphrates river basin. These data are employed to determine the hydrochemistry of the Euphrates river basin in Turkey and to estimate whether it was suitable for drinking and irrigation purposes along the entire river basin. Multivariate statistical techniques, such as factor analysis (FA) and cluster analysis (CA), were harnessed for identifying the most significant factors influencing the water quality of the river basin along with evaluating the spatial variances between the sampling sites.

Methodology

Study area

The Euphrates River is one of the important water resources in Mesopotamia, which is "expressed as the land between two rivers" and has hosted many civilizations (Altınbilek 2004). In a historical sense, rivers pioneered the initiation of activities such as the settled life of people, the development of agricultural practices, and the domestication of animals, since they carried water and fertile sediments to the regions they passed through (Garzanti et al. 2016). Euphrates river basin includes a portion of Eastern and Southeastern Anatolia in Turkey. It has the second-largest basin feature in terms of population, as well as having the largest in terms of surface area (Değirmenci 2007; Akbaş 2015). The Euphrates River, which has a basin area of 123,200 km^2, hosts approximately 6.9 million people in its basin. The population density of the basin is 54 (Aslan-Alato et al. 2005).

The basin with a sub-tropical climate characteristic has a drought climate in summer as well as being the feature a humid in winter. As a result of the natural climate structure of the basin, a significant part of the river flows is lost by evaporation. Due to the fact that the precipitation falling on the basin is mostly in the form of snow, the river is fed remarkably from snow melting. The snowfall taking place during the winter period (from October to April) on the uplands stays in solid form until early summer (Altınbilek 2004; Beaumont 1998; Ozdogan 2011). The general flow regime of the river starts to rise in early March with the melting of the snow and reaches its highest value in April. The flow of the river gradually decreases in the following months and reaches its lowest level in September (Sen et al 2011). Alp et al. (2010) pointed out that the Euphrates River was located in the Eastern Anatolian fault zone and the Eastern Anatolian fault zone was seismically one of the most active regions in the world. The basin has complicated geology as well as a very active structure in terms of earthquakes. The oldest formations composed of various metamorphic schists are mostly located in the central part of the basin. Although not very frequent, there have been landslides along the main slope surfaces of the river. The younger formations encountered in the basin are sedimentary rocks such as mudstone, marl and limestone, and shale alternation. Quaternary-aged formations are made up of sedimentary and volcanic rocks. Loose alluvial deposits consisting of clay, silt, sand, and gravel layers have been detected throughout the basin and in lakes (Tosun et al 2007).

The Euphrates River flows in the eastern region of Turkey has a length of 2700 km and virtually has formed by

confluence their two major tributaries; Kara and Murat in Kharput. The territory of Turkey contributes to the major share (approximately 90%) of the total annual streamflow in the Euphrates river, while the remaining share was divided between Syria and Iraq (Altınbilek 2004). Table 1 showcases each country contributes to the Euphrates rivers basin (Bozkurt 2013; Öziş and Özdemir 2008). In Turkey, the remaining part of the basin is separated into the up-middle-down sections based on topography and variability in climate. Its upper and middle parts are separated from the down section due to altitude, low temperature, and abundant precipitation (Al-Bomola 2011).

The most important investment effort realized in the Euphrates basin is the Southeastern Anatolia Project (GAP). The GAP project was aimed to bring the economic and social indicators of the region to the national average with investments in agriculture, industry, energy, transportation, education, health, rural and urban infrastructure as well as hydroelectric power plants and irrigation projects. In this project, irrigation investments in the area of 1.8 million hectares, 22 dams, and 19 hydroelectric power were planned in the Euphrates-Tigris Basin (Unver 1997). Cultivated crops such as cotton, cereals, legumes, sunflower, pistachio, paddy, fruit are grown in most of the agricultural areas of the basin (Yigit and Cakmak 2018).

Water quality data

The data sets of eleven parameters, included in this work, were obtained over thirteen years (1997–2009) by the General Directorate of State Hydraulic Works (DSI). The data were subjected to multivariate statistical methods (factor and cluster analyses). These data were collected at monthly intervals from thirteen points along Euphrates river basin, namely; Murat River at Palu, Euphrates River at Keban, Goksu River at Malpinar, Euphrates River at Kemah Bogazi, Munzur River at Melekbahce, Tohma Stream at Hisarcik, Karasu stream at Asagikagdaric, Euphrates River at Bagistas, Goynuk River at Cayagzi, Peri stream at Logmar, Murat river at Akkonak, Tacik stream at Mutu Bogazi and Dumlu stream at Yesildere (Fig. 1). The descriptive statistics of the data are given in Table 2.

Date treatment and multivariate analysis

Prior to conducting the multivariate analysis, the Shapiro–Wilk test was performed to check the normality distribution of the data first. Then, multivariate statistical techniques were harnessed to gain a superior elucidation for the relationship connecting a large number of parameters adopted in this study (Nair et al. 2020). FA and CA were introduced to characterize the most considerable variables that influence the river basin water quality, along with evaluating the spatial variations among the sampling sites. FA was performed through three steps; foremost, through creating a correlation matrix for the water quality variables. Second, extracting the initial set of factors through utilizing the principal component analysis (PCA) method. And the final step was conducted by rotating the extracted factors by Varimax rotation. During the FA, the basic concept was expressed as (Ismail and Robescu 2019a):

$$Z_j = a_{j1}f_1 + a_{j2}f_2 + \cdots + a_{jn}f_n + e_{ij}; j = 1, 2, \ldots p \quad (1)$$

where Z is the measured value, a is the factor loading, f is the factor score, e is the residual term accounting for errors or other sources of variation, j is the number of the variable, i is the number of the sample, and n is the total factors number.

For CA, a hierarchical agglomerative clustering process was carried out using Ward's method of linkage. The geometric distance is computed (Ismail et al. 2015), as follows:

$$\text{Distance}\,(X, Y) = \left\{ \left(\sum i(X_i - Y_i \right)^2 \right\}^{1/2} \quad (2)$$

The similarity distance was determined using Squares Euclidean distance method. FA and CA have been extensively exploited in the literature (Palma et al. 2010; Zhou et al. 2007; Simeonov et al. 2004; Altın et al. 2009). IBM-SPSS 25 software was used to perform all the statistical computations.

Hydrochemistry and water suitability for different uses

Herein, AquaChem software has been utilized to obtain Piper plot. This plot is necessary for understanding the hydrochemical facies and the geochemical evolution of the Euphrates river basin (Piper 1944). Besides, exploring

Table 1 Contributions of the countries on the Euphrates rivers basin (UN 2013)

Euphrates	Turkey	Iraq	Syria	Saudi Arabia	Jordan
Area (km^2)	123.200	206.800	96.800	13.068	132
Percentage (%)	28	47	22	2.97	0.03
Annual mean contribution (10^6 m^3)	31.15 (89%)	–	3.85 (11%)	–	–

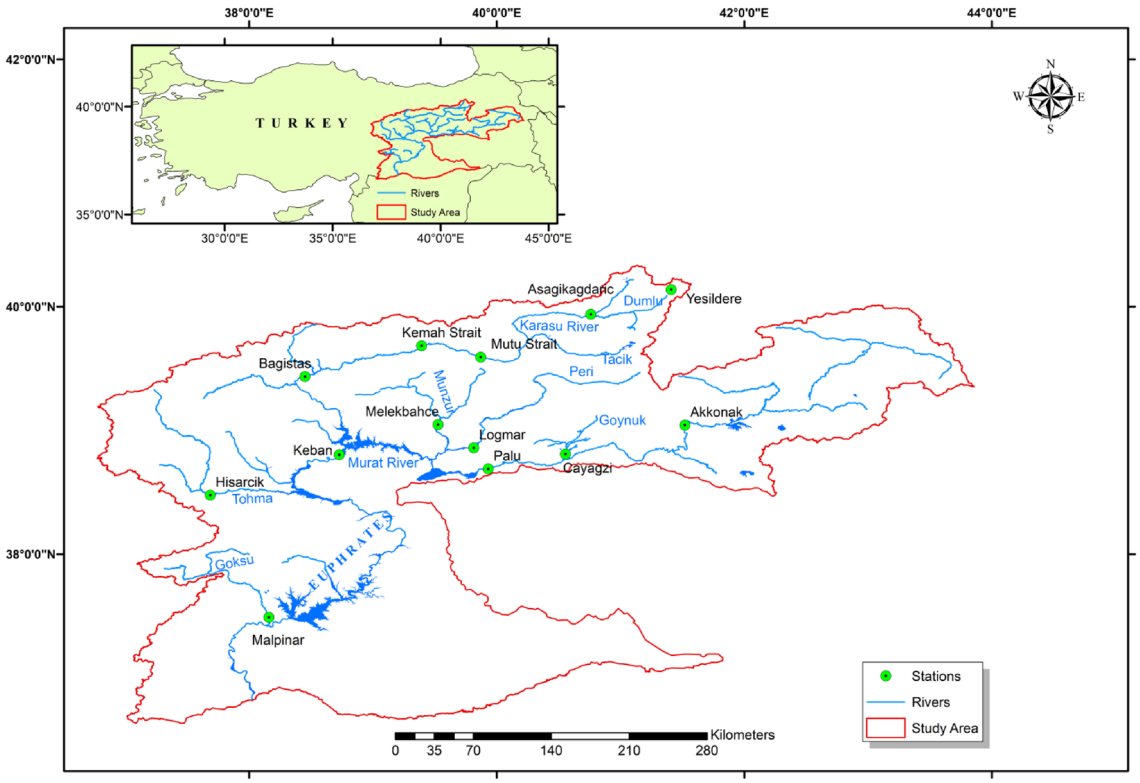


Fig. 1 Map of the study area

Table 2 Descriptive statistical summary of Euphrates river basin data at 13 sampling stations during 13 years (1997–2009), $n = 3116$

Parameters	Abbreviation	Unit	Minimum	Maximum	Mean	Std. deviation
Stream flow rates	Q	m^3/s	0.11	2869.41	134.37	263.30
Water temperature	WT	°C	−5.00	29.00	11.23	6.75
pH	pH		7.79	9.59	8.15	0.34
Electrical conductivity	EC	µS/cm	48.00	2000.00	395.14	144.62
Sodium	Na^+	mg/L	0.23	161.00	22.22	18.37
Potassium	K^+	mg/L	0.00	24.18	2.07	1.99
Calcium + magnesium	$Ca^{2+} + Mg^{2+}$	mg/L	7.38	234.00	57.28	17.44
Carbonate	CO_3^{2-}	mg/L	0.00	64.20	7.83	7.08
Bicarbonate	HCO_3^-	mg/L	6.10	540.46	160.65	49.97
Chloride	Cl^-	mg/L	1.40	262.50	25.10	22.25
Sulfate	SO_4^{2-}	mg/L	0.00	301.92	28.41	22.30
Boron	B	mg/L	0.00	1.70	0.20	0.22

the processes controlling the surface water chemistry was depicted by Gibbs plot since it has critical importance (Gibbs 1970). Furthermore, water quality index (WQI) was utilized according to the world health organization (WHO 2011) standards for drinking water. This was an essential step forward in assessing the water aptness in the river basin for drinking criteria. Meanwhile, the US salinity diagram and Wilcox's diagram were utilized to evaluate the suitability of water for irrigation requirements (USSL 1954; Wilcox 1955).

Results and discussions

Hydrochemistry of surface water

Figure 2 illustrates the Piper plot performed through Aqua-Chem software. This plot is immensely exploited as a graphical technique for classifying any surface water based on the normalized percentages of major cations and anions (Ismail et al. 2018; Akter and Ahmed 2019). According to

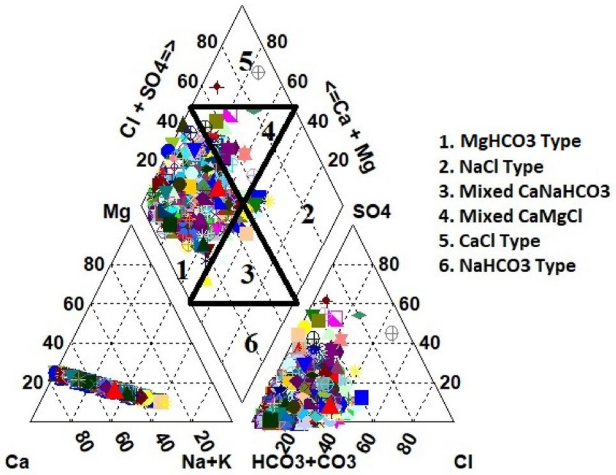


Fig. 2 Piper plot

Fig. 2, it clearly can be observed that the majority of water samples in the field $CaHCO_3$ type of water. This conclusion confirms that alkaline earth metals (Ca^{2+}, Mg^{2+}) are dominant over the alkalies (Na^+, K^+), whilst weak acids (CO_3^{2-}, HCO_3^-).

With a view to understanding the mechanism controlling surface water chemistry, Gibbs ratio (Gibbs 1970) was adopted to define the hydrochemical processes, e.g., evaporation, rocks and precipitation dominance on the characteristics of surface water chemistry. It has manifested that the majority of water samples, within the river basin, were laid within the rock dominance zone (Fig. 3). This observation draws the conclusion that there is a tight connection between rock-water interactions and surface water chemistry with the Euphrates River basin.

Bivariate plots were used to examine the hydrogeochemical processes in the Euphrates basin (Fig. 4) (Das et al. 2017). The plot of $Ca^{2+}+Mg^{2+}$ versus $SO_4^{2-}+HCO_3^-$ is shown in Fig. 4a. As depicted in the figure, more than 50% of the samples lied below the 1:1 line. This plot confirms that the silicate weathering is slightly more dominated than carbonate weathering (dissolution of calcite, dolomite, and gypsum) processes in the river basin. Nevertheless, in the scatter plot of HCO_3^- vs. Na^+ (Fig. 4b), the increased concentration of $HCO3^-$ compared to Na^+ suggests that silicate weathering is the dominant process in the river basin.

Furthermore, the plot of $Ca^{2+}+Mg^{2+}$ vs. total concentration of cations (TCC) (Fig. 4c) shows an increasing contribution of alkalies to major ions which suggests that silicate weathering plays an important role in the Euphrates river basin as 100% of the samples fall below 1:1 line (Singh et al. 2015). In the scatter plot of Na + K vs. TCC (Fig. 4d), all the samples are present below the 1:1 line which indicates that silicate weathering is more significant and is the main source of cations. An increase in alkalies with a slightly simultaneous increase of $Cl^- + SO_4^{2-}$ (Fig. 4e) indicates a common source of these ions, resulting from the dissolution of soil salts (Singh et al. 2015). Na^+/Cl^- ratio vs electrical conductivity (EC) plot is given in Fig. 4f. A ratio of Na^+/Cl^- close to 1 indicates halite dissolution while the dominant process of silicate weathering was confirmed at a ratio of $Na^+/Cl^- > 1$ (higher Na^+). Na^+/Cl^- ratio < 1 (higher Cl^-) suggests that a combination of evaporation and reverse ion exchange of Na^+ with Ca^{2+} are the dominant processes (Das et al. 2015). Herein, in this study, the Na^+/Cl^- ratio of more than one (higher Na^+) was observed in most of the water samples. Indeed, this indicates that the silicate weathering was the dominant process.

Surface water quality for drinking

WQI has been extensively introduced to assess surface water quality for a wide range of applications. To achieve the final WQI, a series of primary steps for WQI formulation

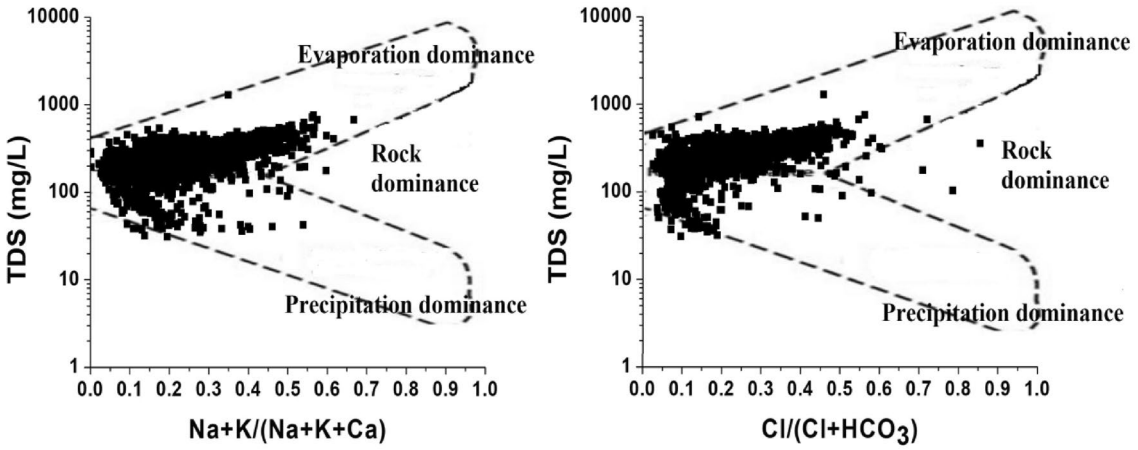


Fig. 3 Gibbs plot

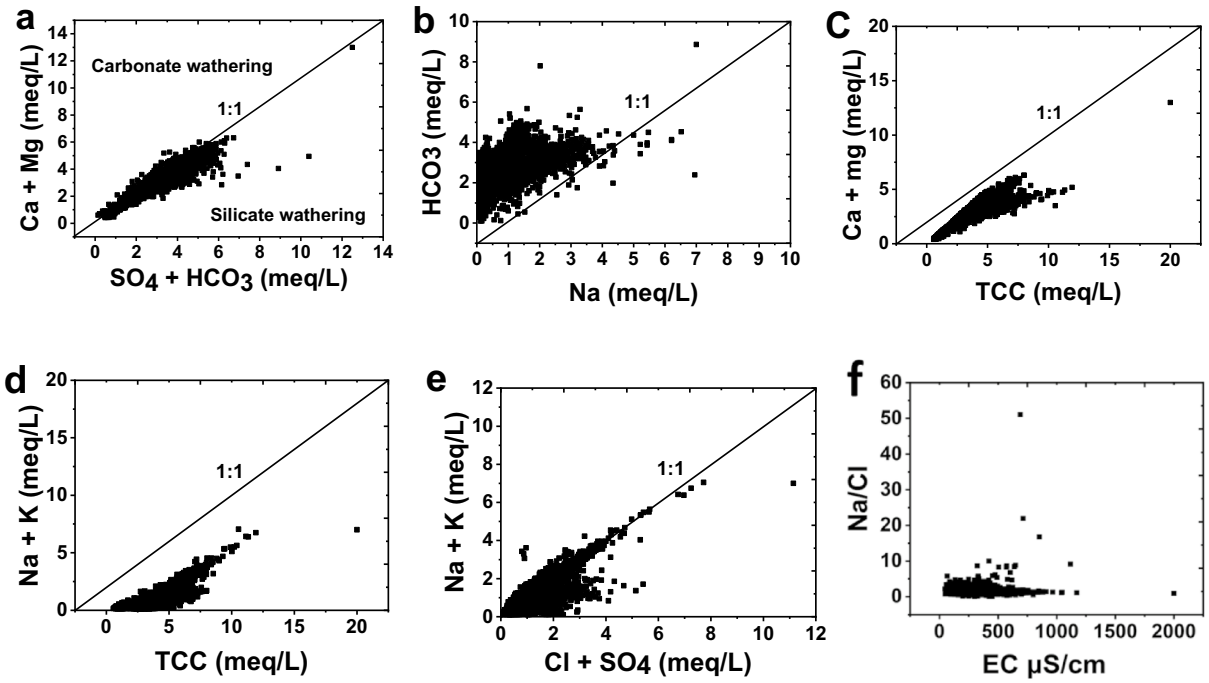


Fig. 4 Ionic scatter diagram of surface water in the Euphrates River basin

Table 3 Weight assignment for each selected water quality parameter along with WHO standards

Water quality parameter	Temporary weight (wi)	Final weight $Wi = wi/\sum_{i=1}^{n} wi$	WHO (2011)
K^+	3	0.11	10
Na^+	4	0.13	200
Mg^{2+}	3	0.11	100
Ca^{2+}	3	0.11	75
Cl^-	5	0.18	250
SO_4^{2-}	5	0.18	250
B	5	0.18	0.3
Sum of weights	28	1	

is carried out. These steps are consisted of; identification and measurement of water quality parameters, sub-index development or quality rating (mostly based on water quality standards), weight assignment for each parameter and finally the aggregations of sub-indices (Ismail and Robescu 2019b; Nair et al. 2020).

In the present work, the drinking water standards (Table 3), set by the world health organization (WHO 2011), were considered during the WQI calculation. As recommended by Ismail et al. (2020), a specific weight has been allocated to each adopted water quality parameter.

Sub-indices of each parameter are calculated from the following equation:

$$\mathrm{Si} = 100 \times \frac{\mathrm{Ci}}{S} \tag{3}$$

where Si is the sub-index, Ci refers to the concentration of water quality parameters (mg/L), and Si is the WHO standard, given in Table 2. The final WQI value has been determined through the following equation:

$$\mathrm{WQI} = \sum_{i=1}^{n} \mathrm{Wi} \times \mathrm{Si} \tag{4}$$

The ultimate value of WQI has been evaluated based on five scales, as follows: excellent (< 50), good (50–100), poor (100–200), very poor (200–300) and unsuitable (> 300). The WQI obtained from the Euphrates basin was ranged from 7.4 to 126.6, with an average value of 27.9. Therefore, for drinking requirements, about 99.5% of the water samples were found within an excellent–good range. This was only applicable when considering only their major ion concentrations with Boron.

Quality of surface water for irrigation

The water quality of the Euphrates river basin was evaluated for irrigation standards using US salinity diagram and Wilcox diagram. The US salinity diagram was firstly suggested by the USSL in 1954. with the aid of AquaChem software, the sodium adsorption ratio (SAR) was plotted versus EC.

This was aimed to reveal the suitability of water for irrigation (Fig. 5). SAR can be calculated from the following formula (Ismail et al. 2019):

$$\mathrm{SAR} = \frac{\mathrm{Na}^{+}}{\sqrt{\frac{\mathrm{Ca}^{2+}+\mathrm{Mg}^{2+}}{2}}} \tag{5}$$

where all values are given in milliequivalent per liter. As illustrated in Fig. 5, it is evident that most of the water samples were laid within the C1S1 and C2S1 zones. This has manifested that these surface water samples are good enough if utilized for irrigation. Virtually, this water can be exploited for irrigation purposes regardless of the soil types and without running a risk of exchangeable sodium (Marghade et al. 2012). In addition to that, sodium percentage (%Na) has been plotted against EC to produce Wilcox diagram (Wilcox 1955). %Na is calculated from the following formula:

$$\mathrm{Na\%} = \left[\frac{\mathrm{Na}^{+}+\mathrm{K}^{+}}{\mathrm{Na}^{+}+\mathrm{K}^{+}+\mathrm{Ca}^{2+}+\mathrm{Mg}^{2+}}\right] \times 100 \tag{6}$$

where all values are given in milliequivalent per liter. The plot indicates that almost 89% of the water samples in the Euphrates river basin are excellent to good if used for irrigation standards. The remained 10% of the samples have enclosed good to permissible while only less than 1% was permissible to doubtful (Fig. 6).

Factor analysis

FA has been performed via the PCA technique for the normalized data sets. Factors with eigenvalues > 1 were eliminated (Shrestha and Kazama 2007). Four factors were retained as these factors have Eigenvalues greater than 1.0

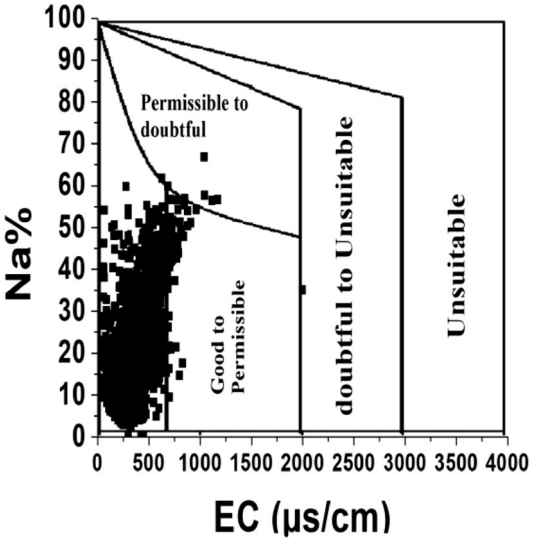


Fig. 6 Wilcox diagram

(Fig. 7). They explain 71.453% of the total variance. The factor loadings have been categorized into strong and moderate, having absolute loading values of > 0.75 and 0.75–0.50, respectively.

The results of FA are listed in Table 4. F1 elucidated 26.316% of the total variation and found to demonstrate a strong positive correlation with Ca^{2+} + Mg^{2+}, HCO_3^- and EC, while there was a positive moderate correlation with SO_4^{2-}. The high loading factor of HCO_3^- is more likely caused by chemical weathering. This factor signifies the contribution of surface runoff throughout the rain season, weathering of mineral-bearing rocks and agricultural fertilizers. F2 explained 23.365% of the total variance that had a strong positive correlation with Na and K while there was a moderate correlation with Cl^- and B. This factor represented

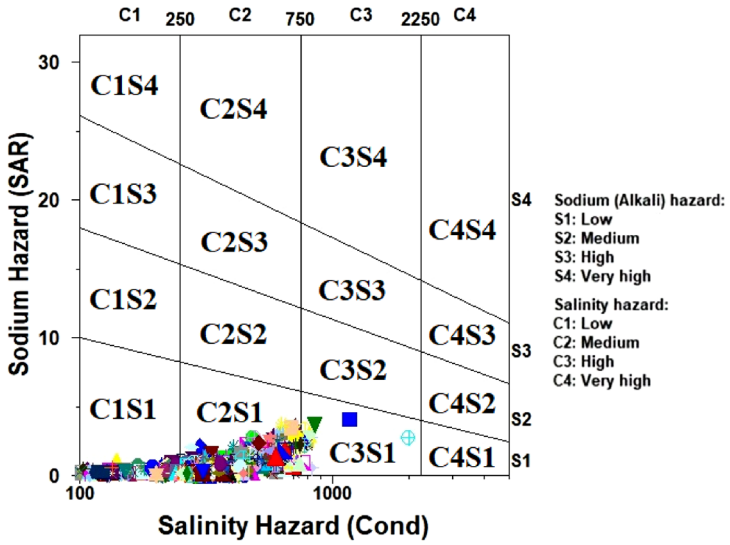


Fig. 5 USSL diagram

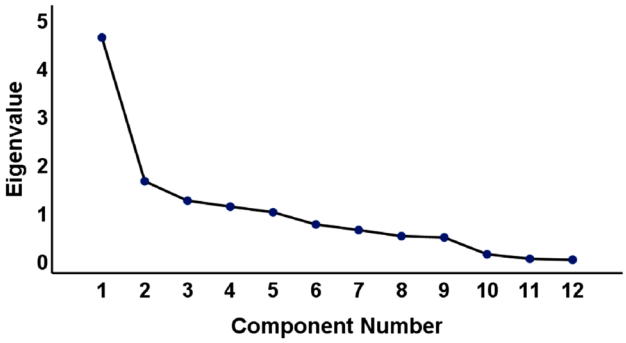


Fig. 7 Scree plot

the impacts that originated from the anthropogenic contaminants by industrial, domestic waste and de-icing salt (Odemis and Evrendilek 2008). The F3 displayed a strong positive correlation with pH and CO_3^{2-} and elucidated 12.352% of the total variance. This factor represents the dissolution of carbonate minerals and may regulate the dissolution of cations and anions as well (Ismail et al. 2015). The last factor (F4) demonstrated 9.421% of the total variance and revealed a strong positive correlation with WT and a negative moderate correlation with *Q*. Herein, in this factor, the negative sign of discharge might refer to the increase of the dilution of dissolved minerals with the discharge (Varol and Sen 2009).

Cluster analysis

Hierarchical CA has been harnessed for classification of the sampling stations, see the dendrogram (Fig. 8), where the distance between two samples corresponds to the similarity and dissimilarity between two samples, i.e. greater will be the distance, lesser will be the similarity. Practically, the output of CA could impart a beneficial graphical tool for defining the number of clusters. These clusters describe the underlying process that may lead to a spatial variation (Boyacioglu and Boyacioglu 2007). As could be seen, the 13 sampling sites within the river basin have been grouped into two significant clusters. Group A; consists of Euphrates River at Keban whereas, group B divided into 2 subgroups (2A and 2B). Group 2A consists of Dumlu stream at Yesildere while the other 11 stations were agglomerated in group 2B. Euphrates River at Keban (Group 1) corresponds to relatively less polluted sites with a high flow rate whereas the Dumlu stream at Yesildere (group 2A) corresponds to relatively less polluted sites with a low flow rate. Other sampling stations (group 2B) represent areas with moderate water pollution. These stations are highly influenced by the geochemical processes and may receive pollution from point and nonpoint sources, i.e., domestic and industrial effluents, surface runoff from the surrounding cities…etc. Clustering clearly shows the demarcation between each station's impact.

Conclusions

Having a comprehensive understand and deep insight into the hydrochemical analysis of the surface water was the major concern of the current work. This becomes more worthy when an area suffers from a water shortage. The water in the Euphrates river basin within Turkey was found to be Mg–HCO_3 type. This observation has well-established the dominance of alkaline earth metals (Ca^{2+}, Mg^{2+}) rather than alkalies (Na^+, K^+) whereas weak acid (CO_3^{2-}, HCO_3^-) has exceeded the strong acid (Cl^-, SO_4^{2-})

Table 4 Rotated factor loading matrix and total variance explained (Varimax rotation)

Parameter	Factor 1 (F1)	Factor 2 (F2)	Factor 3 (F3)	Factor 4 (F4)
Q	−0.081	−0.004	−0.083	−0.646
WT	−0.057	0.027	−0.052	0.808
pH	0.035	−0.018	0.885	0.106
EC	0.827	0.520	0.121	0.071
Na	0.469	0.770	0.123	0.097
K	−0.015	0.828	0.066	−0.026
Ca + Mg	0.937	0.114	0.099	0.028
CO_3	0.071	0.326	0.788	−0.066
HCO_3	0.760	0.372	−0.070	0.086
SO_4	0.741	−0.120	0.024	−0.068
Cl	0.483	0.693	0.091	0.124
B	0.035	0.709	0.104	−0.032
Eigenvalue	4.611	1.632	1.227	1.104
% Total variance	26.316	23.365	12.352	9.421
Cumulative % variance	26.316	49.681	62.033	71.453

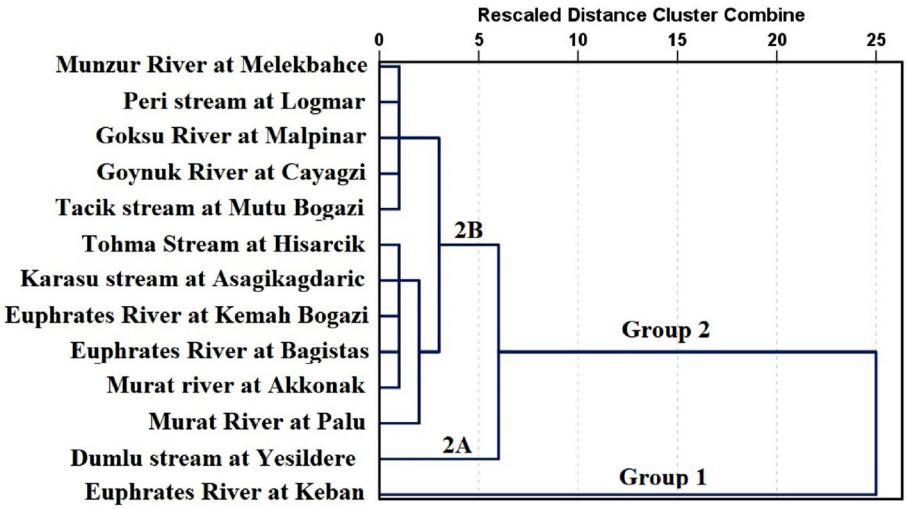


Fig. 8 Spatial clustering of surface water samples in the Euphrates River basin

availability. Noticeably, the river basin was influenced by the chemical weathering and the majority of water samples were laying within the zone of rock dominance, as demonstrated by the Gibbs ratio. About 99.5% of the water samples were proven to be excellent–good for drinking purposes when taking into account only their major ion concentrations with Boron. The US salinity diagram disclosed that the majority of water samples were found within the C1S1 and C2S1 zones, evidencing that these surface water samples are good for irrigation. The Wilcox diagram revealed that almost 89% of the water samples were excellent to good enough for irrigation requirements. However, 10% were good to permissible and less than 1% of the samples were found to be permissible to doubtful. Four factors were identified from the FA results and were representing 71.453% of the total variance. Undoubtedly, the major variations were mainly ascribed to chemical weathering, surface runoff during the rainy season, agricultural fertilizers, anthropogenic contaminants induced by industrial and domestic waste and de-icing salt. On the river basin, CA showcased that the 13 sampling sites were combined into two major clusters. The first group consisted of Euphrates River at Keban station which corresponds to a relatively less contaminated site with a high flow rate. The second group has been divided into two clusters corresponded to a relatively less contaminated site with a low flow rate and moderate water pollution.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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