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HYDROCHEMISTRY, HYDROBIOLOGY: ENVIRONMENTAL ASPECTS

Evaluation of Freshwater Water Quality with Indexes and GIS-Based: A Case Study, Güren Stream (Küre Mountains National Park, Western Black Sea Basin, Turkey)

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Abstract—Turkey is separated into 25 river basins, and the Güren Stream is found in Kastamonu Province's West Black Sea Basin. Güren Stream originates inside the borders of Küre Mountains National Park and flows into Black Sea. Küre Mountains National Park, in addition to being one of the 9 hot spots to be protected in Turkey, is the country's first Protected Area Network Parks (PAN park). At this research, monthly stream water samples were taken from different 14 stations in the Güren Stream between 2018–2019. Subsequently, the concentration of 28 parameters, consisting of pH, water temperature, electrical conductivity, suspended solid matter, salinity, total hardness, total alkalinity, dissolved oxygen, chemical oxygen demand, biochemical oxygen demand, NH_4-N, NO_2-N, NO_3-N, SO_4, SO_3, PO_4-P, Cl, Fe, Na, K, Mg, Ca and six potential toxic elements, including Pb, Cu, Cd, Hg, Ni, and Zn were measured. The results were compared to the criteria of the Turkish Water Pollution Control Regulation and the World Health Organization (WHO). In addition, the association between the obtained data and Geographic Information Systems, spatial distribution maps, ecotoxicological indexes, quality classifications, multivariable statistical pearson corelation and factor analysis inter-parameter associations were evaluated. According to the results, the Güren Stream's water is of the highest quality, designated first class, and did not exceed WHO limits. According to water quality and ecotoxicological indexes, Güren Stream is classified as "excellent, good, no pollution, permissible and low." To identify relationship between parameters, correlation and factor analysis were applied to data. Natural sources, anthropogenic activities and forestry factor inputs were determined as the main accumulation sources of river by the result.

Keywords: Güren stream, water quality indices, GIS, factor analysis, freshwater quality, Küre Mountains National Park

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INTRODUCTION

Water resources have been an important natural resource throughout human history. From the past until the present, human habitation has almost always been established near water, which shows the importance of ensuring the sustainability of water resources.

The world's total water supply (97%) is saline water; freshwater makes up only 2.5% of this amount (1.2%: surface/other freshwater; 30.1%: ground-water: 68.7%: from glaciers and ice caps). About 1.2% or less of all freshwater is surface water which rivers make up 0.49% of surface freshwater, which satisfies most human needs (drinking and using water, agriculture and industrial activities, hydropower energy generation, fisheries and additional anthropogenic activities) [29, 46]. In the 21st century, many researchers agree that the primary environmental risks today are water pollution, the water crisis, climate change, and global warming [8, 34, 42, 45]. Water pollution is a significant environmental issue, and it is well known that regular monitoring the quality of the water is important components of freshwater source management [8]. Water-quality evaluation indices are essential instruments that may help assess the quality of aquatic environments.

Freshwater's water quality can be assessed using conventional research techniques by comparing it to the standards for water quality established by national and international organizations (physico-chemical and microbiological variables) [4]. However, the Water Quality Index (WQI), which is more efficient than other research techniques, integrates a number of water quality criteria to provide a single value that accurately reflects water quality [10, 15, 35]. This value is commonly used to assess water suitability for consumption by humans [3, 23, 24, 33, 34, 40, 42, 43]. This approach, first developed by Horton in 1965, is regarded as an effective tool for evaluating water quality [17].

The WQI is divided into five categories ranging from 0 to 100. Scores between 0 and 25 are classified as excellent, whereas scores above 100 are classified as unfit for consumption [21, 25]. For example, the suitability of using surface waters as irrigation water, with indices such as the sodium adsorption rate (SAR) and sodium percentage (Na%) to determine the nutrient pollution status of surface water resources, and the Nutrient Pollution Index (NPI) and Heavy Metal Evaluation Index (HEI), which reveal the general state of water according to heavy metal concentrations in the water, are other commonly used water quality indices [13, 21, 26–28, 38, 43, 48].

Geographical information systems (GIS) are a powerful, computer-based technological tool used for efficiency in many fields, including in the engineering and environmental sectors, to assess and map water quality, understand the natural environment, and manage and develop water resources at scale [1, 32]. Therefore, combining indices and GIS tools for environmental management and planning can be practical when combined by water-quality assessment and monitoring techniques. In developing countries such as Türkiye, assessment of the quality of water sources has always been paramount in the field of environmental quality management. Güren stream is within the boundaries of the where Küre Mountains National Park and was the monitoring and assessment of the water quality are important. Güren Stream, which has a significant freshwater potential, is known as one of Turkey's most clean and seen to be protected lotic habitats. Especially in recent years, WQI and GIS tools have played an important role in protecting, developing, and managing surface waters and frequently used in tandem in water quality studies worldwide [5, 22, 30].

The aim of this study for the Güren River are as follows:

(1) determining the concentrations of physicochemical parameters and comparing these with water quality parameters (WPCR, WHO);

(2) using a multivariate statistical technique such as the Pearson Correlation Index and Factor Analysis;

(3) determining the concentration of heavy metals and evulating using indices such as the WQI, HEI;

(4) determining the usage of as irrigation water in agriculture according to factors such as SAR, Na%, and NPI;

(5) showing the distribution of water quality indices values at the sample stations based on GIS maps.

MATERIALS AND METHODS

Study Area

Güren Stream, which is located in the Küre Mountains National Park area in the Black Sea region, arises from the northern skirts of the İsfendiyar (Küre) fold mountains corresponding to the coast, and is located in the Cide district at 41°49′39″ North and 32°58′43″ East coordinates. The regime of the stream is erratic and it empties into the Black Sea by merging with Devrekani Stream by digging deeply in the beds where the land has a high and rough structure. The local residents do not consume the water from Güren Stream. The Devrekani Stream, on the other hand, is actively used by the locals, and the stream combines with it before flowing into the Black Sea. In the region where Güren Stream is located; The Black Sea climate dominates, with cool summers and not too cold winters, rainy in all seasons. The lowest mean temperature in winter is 5.2°C in February and 22°C in summer. The annual mean temperature is 13.3°C. The annual total precipitation is around 1228 mm [2]. The sampled stations and the study area map is shown in Fig. 1.

Water Sampling and Analysis

Water samples were taken from 14 stations monthly between 2018 and 2019 from the Güren Stream in the Cide district of Kastamonu (Fig. 1). In total, 28 water quality parameters were measured. Water temperature, pH, salinity, EC and DO parameters were measured in situ using portable multi-parameter device (Hach Lange, HQ40D). The SO_4, SO_3, PO_4-P, NH_4-N, NO_3-N, NO_2-N, Cl, Na, K, Ca, Mg, and COD, parameters of the stream water were measured with a spectrophotometer (WTW 7600 UV-VIS); TA and TH parameters were measured using the titrimetric method; suspended particles were measured using the Whatman filter paper (0.45 m) filtration method. The BOD parameter was measured with the biochemical oxygen demand (BOD) measurement set (WTW OXITOP 12). To determine macro and microelements of water samples, pH values were adjusted to 2 by adding HNO_3 to each sample, and stream water samples were filtered with a 0.45-μm cellulose nitrate filter. After diluting their volumes to 50 mL with ultrapure distilled water, macro and microelement concentrations were determined using an ICP-OES instrument (Spectro, SpectroBlue) [11]. The accuracy of the analytical procedure was checkedby analyzing the standard reference materials. Recoveryrates ranged from 99 to 100% for all investigated elements.

Creating Thematic Maps with GIS

Spatial distribution maps of the data in the GIS environment were completed with the ArcMap 10.3 program. The satellite images in JPEG format taken from the WGS84-Zone 33 coordinate plane, con-

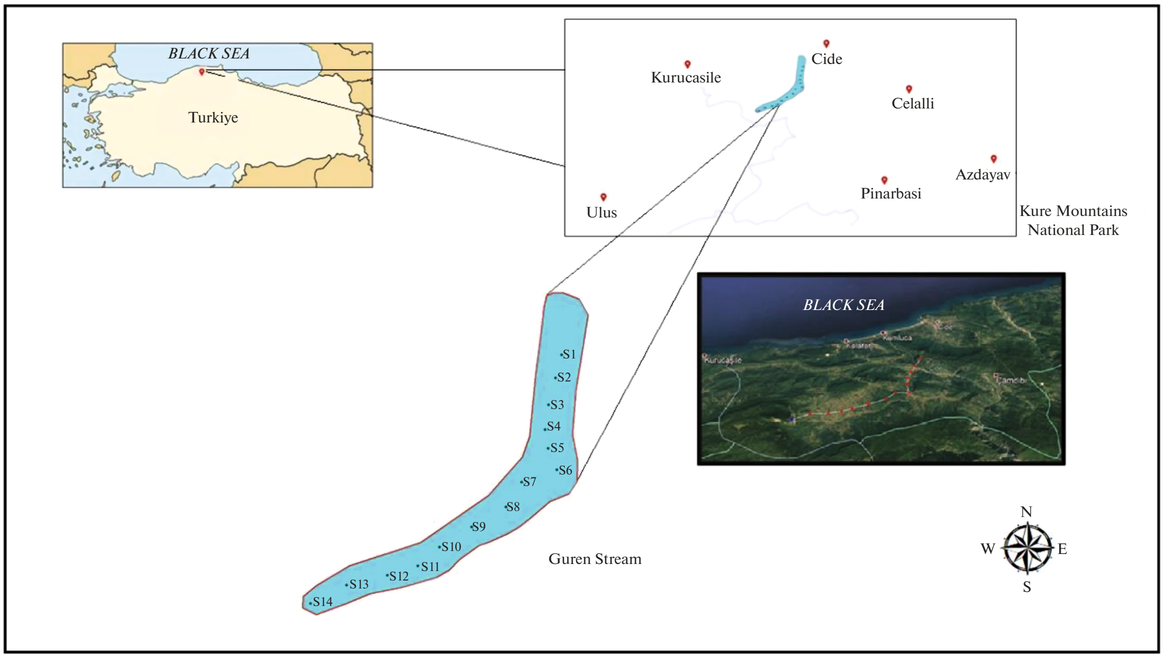

Fig. 1. Güren River and sample stations.

nected to the metric coordinate system from Google Earth Pro, were transferred to the ArcMAP environment. The Güren Stream research area and determined measurement points were digitized and converted into vector data using satellite images in JPEG format.

Calculation of Water Quality Indexes

Nutrient Pollution Index (NPI) [18], Sodium adsorption rate (SAR) [28], Percent sodium (Na%) [48], Water quality index (WQI) [17, 21] and Heavy metal evaluation index (HEI) [9] were calculated using the at Table 1 equations.

RESULTS AND DISCUSSION

Physicochemical Parameters and Their Evaluation with Turkish Water Pollution Control Regulation and World Health Organization

The Güren Stream was analyzed for 28 parameters in water samples taken from 14 stations. The results were compared and classified with the limit values determined by the Turkish Water Pollution Control Regulation (WPCR 2016) and World Health Organization (WHO 2011) [37, 49]. The average values of physicochemical parameters and heavy metals for average of all stations and months are shown in Table 2. While the water quality of the Güren Stream was classified as first quality according to WPCR class, only the total hardness (TH) value was found to be 241.4 mg/L and the latter value was found to exceed the limit value (100 mg/L) set by WHO (Table 2). The total TH value is mainly because of the calcium's dissolution, magnesium, and other metals. A TH value less than 100 mg/L reduces the water buffering capacity and causes corrosion in water pipes [39]. Drinking very hard water for extended periods may result in heart disease, and very soft water consumption for extended periods may have a negative impact on the mineral balance in the body of a person [47].

DO. The dissolved oxygen (DO) amount in the Güren Stream was measured at 14.5 mg/L at annual (Table 2). Since the average DO concentration values are greater than 8 mg/L, the stream's water quality in terms of DO was determined as "Class I" water (high-quality water) according to the WPRC. Dayıoğlu reported that the DO values in the Andik Stream ranged from 6.25 to 7.1 mg/Lt [7]. The DO values in the Andik Stream were observed at lower levels than in the Güren Stream. The reason for this difference is that the DO concentration levels are inversely lower in the Andik Stream, where the altitude is lower than that of the Güren Stream; therefore, higher temperatures are observed because there is an inverse relationship between temperature and DO.

pH. pH, an indicator of water's acidity, is an important factor affecting aquatic life. If the water shows high pH values, the harmful effects of ammonia and nitrogen compounds increase [41]. The presence of various types of chemicals in water is primarily governed by pH and temperature [19]. In the analyses made in the Güren Stream, the pH value was measured at 8.4 (Table 2). Topal et al. reported that the

Table 1. Calculation of water quality indexes

Quality Index	Formula of Index	Quality class		References
Water Quality Index (WQI)	$\mathrm{WQI} = \sum Q_n W_n / \sum W_n$*	0–25	Excellent	[17, 21]
		26–50	Good	
		51–75	Poor	
		76–100	Very poor	
		>100	Unsuitable	
Sodium Adsorption Rate (SAR)	$\mathrm{SAR} = \dfrac{\mathrm{Na}^+}{\sqrt{\dfrac{\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}}{2}}}$	0–10	Excellent	[28]
		10–18	Good	
		18–26	Fair	
		>26	Poor	
Nutrient Pollution Index (NPI)	$\mathrm{NPI} = \dfrac{C_N}{MAC_N} + \dfrac{C_P}{MAC_P}$**	<1	No pollution	[48]
		1 < 3	Moderate polluted	
		3 > 6	Considerable polluted	
		>6	Very high polluted	
Percent Sodium (Na%)	$\mathrm{Na\%} = \dfrac{\mathrm{Na} + \mathrm{K}}{(\mathrm{Ca} + \mathrm{Mg} + \mathrm{K} + \mathrm{Na})} \times 100$	<20	Excellent	[48]
		20–40	Good	
		40–60	Permissible	
		60–80	Doubtful	
		>80	Unsuitable	
Heavy Metal Evaluation Index (HEI)	$\mathrm{HEI} = \sum_{i=1}^{n} H_c / H_{\mathrm{mac}}$***	<10	Low	[9]
		10–20	Between	
		>20	High	

* Q_n: the nth water quality parameters quality rating, W_n: the nth water quality parameters unit weight.
** C_N: the amount of NO_3-N in a water sample (mg/L), C_P: the amount of PO_4-P in a water sample (mg/L), MAC_N: maximum limit value of NO_3-N (mg/L), MAC_P: maximum limit value of PO_4-P (mg/L).
*** H_c: the ith parameter's monitored value, H_{mac}: the ith parameter's maximum allowable concentration.

highest pH value in the Caro Stream was 8.3 [36]. It was also observed that the highest pH value in the Caro Stream was lower than the highest pH value in the Güren Stream.

EC. Electrical conductivity (EC) is used to investigate the presence of ions in water. Minerals ionized in water allow electricity to flow, and as the number of minerals increases, so does the conductivity value [41]. In the Güren Stream, the EC was measured as 328.3 μS/cm (Table 2). Since the mean EC concentration was less than 400 μS/cm, the water was designated Class I (high-quality water). The low levels of mean EC might originate from the low periodical precipitation in the region, the fact that underground water high in minerals does not merge with the stream, the geological structure of the area, or the flow of surface water that does not affect the stream in terms of salinity [14].

COD. The number of COD is an important parameter in identifying water pollution levels. In the analyses conducted on the Güren Stream, the number of COD was determined as 0.9 mg/L (Table 2). Since the COD values were lower than 25 mg/L, the stream's water quality was determined to be first-class (high-quality water). Topal et al. reported that the highest COD value in the Caro Stream was 46 mg/L [36].

BOD. The amount of BOD is an important parameter in identifying the amount of organic material microorganisms distill in water. In the analyses, the amount of BOD was measured as 0.5 mg/L and since the value was lower than 4 mg/L, the quality of the stream's water was determined as first-class (high-quality water). The highest amount of BOD Dayıoğlu recorded in the Andık Stream was between 5.4–0.17 mg/L [7].

NH_4-N. The ammonium nitrogen values in the Güren Stream were observed to be very low. The amount of NH_4-N identified was 0.0002 mg/L. Some measures taken around the stream involved not mixing sewage into the stream and not polluting the lake premises with solid waste [46]. In addition, low levels of ammonium nitrogen result from the region's low levels of agricultural activity and organic degradation. In the study, the highest NH_4-N value identified by Dayıoğlu was 0.12 mg/L [7].

Table 2. Güren Stream average values of physicochemical parameters and heavy metals at stations, WHO and WPRC quality class values

Stations/Parameters, mg/L	Average of all stations	WHO	WPRC		
			I	II	III
DO	14.5	–	>8	6	<6
Salinity, ‰	0.03	–	–	–	–
pH	8.4	8.5	–	–	–
WT, °C	10.7	–	–	–	–
EC, µs/cm	328.3	400	<400	1000	>1000
SS	2.1	–	–	–	–
COD	0.9	–	<25	50	>50
BOD	0.5	–	<4	8	>20
Cl	8.4	250	–	–	–
PO_4-P	0.02	–	<50	160	>160
SO_4	34.6	200	–	–	–
SO_3	1.8	–	–	–	–
Na	47.6	200	–	–	–
K	18	–	–	–	–
Total Hardness	**241.4**	100	–	–	–
Total Alkalinity	262.2	–	–	–	–
Mg	21.4	–	–	–	–
Ca	25.7	–	–	–	–
NO_2-N	0.0001	3	<0.01	0.06	0.1
NO_3-N	1.4	50	<5	10	>10
NH_4-N	0.0002	–	<0.2	1	2
Fe	0.004	–	300	–	–
Pb, µg/L	0.9	10	≤10	20	50
Cu, µg/L	12	2000	≤20	50	200
Cd, µg/L	0.5	3	≤2	5	7
Hg, µg/L	0.0	6	≤0.1	0.5	2
Ni, µg/L	3.9	70	≤20	50	200
Zn, µg/L	8.3	3000	≤200	500	2000

PO_4-P. The phosphate density in natural water depends on the property morphometric and the chemical content of the geological structure of the basin, whether or not there is organic matter mixed with the water, and the organic activity in the water [46]. The average phosphate value in the Güren Stream was measured as 0.02 mg/L at the 14th station.

SO_4. The increase in biological efficiency varies depending on the presence of SO_4 [46]. The amount of SO_4 in the Güren Stream was measured as 35.2 mg/L. It is understood from the recorded low values that the water is of first-class quality and has no sulfate-related pollution.

TH. The average TH in the Güren Stream was found 241.4 mg/L. TH value was increased towards to the southwest side of the stream. The WHO classifies water as soft water if it is between 0–75, medium-hard water between 75–150, hard water between 150–300, and very hard water above 300. According to these values, the Güren Stream's water is classified as hard water.

The metal concentration of the Güren Stream did not exceed the limit determined by the WHO and showed the properties of first-class water in categories specified in the WPCR. The concentration of the six elements (Pb, Cu, Cd, Hg, Ni, and Zn) with ecotoxicological properties in the water was analyzed using the HEI. The HEI was broadly classified into three categories [9]. The HEI results in Table 3 each station and month were identified as "low" (HEI value <10) and according to at Table 1 categorization. Data from

Table 3. Values of the at stations and months in the Güren stream water quality index (WQI), sodium adsorption rate (SAR), nutrient pollution index (NPI), sodium percentage (Na%), heavy metal evaluation index (HEI) and with of quality class

Stations/Months	WQI	Class	SAR	Class	NPI	Class	Na%	Class	HEI	Class
St 1	11.2	Excellent	6.2	Excellent	0.021	No pollution	50.0	Permissible	0.000	Low
St 2	14.8	Excellent	8.4	Excellent	0.047	No pollution	55.3	Permissible	0.104	Low
St 3	13.9	Excellent	8.5	Excellent	0.049	No pollution	55.4	Permissible	0.179	Low
St 4	15.09	Excellent	8.9	Excellent	0.063	No pollution	56.1	Permissible	0.196	Low
St 5	16.2	Excellent	9.4	Excellent	0.083	No pollution	57.2	Permissible	0.261	Low
St 6	17.08	Excellent	9.6	Excellent	0.093	No pollution	57.7	Permissible	0.292	Low
St 7	18.1	Excellent	9.9	Excellent	0.099	No pollution	58.3	Permissible	0.334	Low
St 8	19.01	Excellent	10.2	Good	0.109	No pollution	58.9	Permissible	0.363	Low
St 9	20.2	Excellent	10.4	Good	0.122	No pollution	59.2	Permissible	0.435	Low
St 10	20.2	Excellent	10.5	Good	0.125	No pollution	59.3	Permissible	0.437	Low
St 11	21.4	Excellent	10.6	Good	0.135	No pollution	59.5	Permissible	0.517	Low
St 12	22.1	Excellent	10.8	Good	0.138	No pollution	59.7	Permissible	0.531	Low
St 13	23.9	Excellent	11.3	Good	0.145	No pollution	61.6	Doubtful	0.595	Low
St 14	24.4	Excellent	11.7	Good	0.152	No pollution	62.6	Doubtful	0.651	Low
Mean	18.3	Excellent	9.8	Excellent	0.099	No pollution	57.9	Permissible	0.350	Low
Monhts										
June	18.1	Excellent	14.05	Good	0.105	No pollution	65.0	Doubtful	0.378	Low
July	17.4	Excellent	8.8	Excellent	0.173	No pollution	56.0	Permissible	0.297	Low
August	18.3	Excellent	8.7	Excellent	0.146	No pollution	56.6	Permissible	0.340	Low
September	24.5	Excellent	8.0	Excellent	0.171	No pollution	54.6	Permissible	0.526	Low
October	25.7	Good	8.5	Excellent	0.151	No pollution	55.7	Permissible	0.561	Low
November	20.8	Excellent	9.3	Excellent	0.119	No pollution	57.3	Permissible	0.410	Low
December	18.1	Excellent	10.2	Good	0.055	No pollution	58.9	Permissible	0.263	Low
January	14.7	Excellent	8.7	Excellent	0.043	No pollution	55.3	Permissible	0.353	Low
February	15.1	Excellent	8.4	Excellent	0.037	No pollution	55.7	Permissible	0.284	Low
March	17.7	Excellent	9.8	Excellent	0.040	No pollution	58.4	Permissible	0.417	Low
April	17.7	Excellent	10.1	Good	0.044	No pollution	58.4	Permissible	0.472	Low
May	17.7	Excellent	12.7	Good	0.076	No pollution	63.4	Doubtful	0.447	Low
Annual	18.8	Excellent	9.8	Excellent	0.097	No pollution	57.9	Permissible	0.395	Low

13 parameters, six of which are heavy metals, were analyzed and transformed into one single value. The results obtained were also supported by the index results showing that there was no pressure of pollution in the water classified as excellent. In terms of WQI, the data of 13 parameters, six of which are heavy metals, were analyzed and converted into a single value. The results obtained were supported by the index results showing that there was no pressure of pollutants in water classified as excellent.

The other parameter, the Na% results, was found to be in the "permissible" and "doubtful" categories, with values ranging from 50–63.4 (Fig. 2). To avoid inflicting any harm on soil or plants, the Na value should not exceed 50–60. Using waters high in Na% in irrigation is not desirable for soil and plant health. Soleimani et al. reported that the Na value was between 15.37–15.59% in their study and that the groundwater observed was in the "excellent" category [31]. In addition, Yousefi et al. found the Na% value in groundwater in their study to be between 63.8–66.5 and placed the water in the "doubtful" category [51].

The correlation of the physicochemical parameter and heavy metal values in the Güren Stream is shown in Table 4. The relationship between the parameters is significant ($p < 0.01$). The correlation between DO and salinity, temperature, EC, suspended solid matter, COD, BOD, phosphate, and sulfate is strongly negative, and the correlation between chloride is strongly positive. The correlation between the temperature EC, suspended solid matter, COD, BOD, and sulfate is strongly positive. The correlation between EC and the

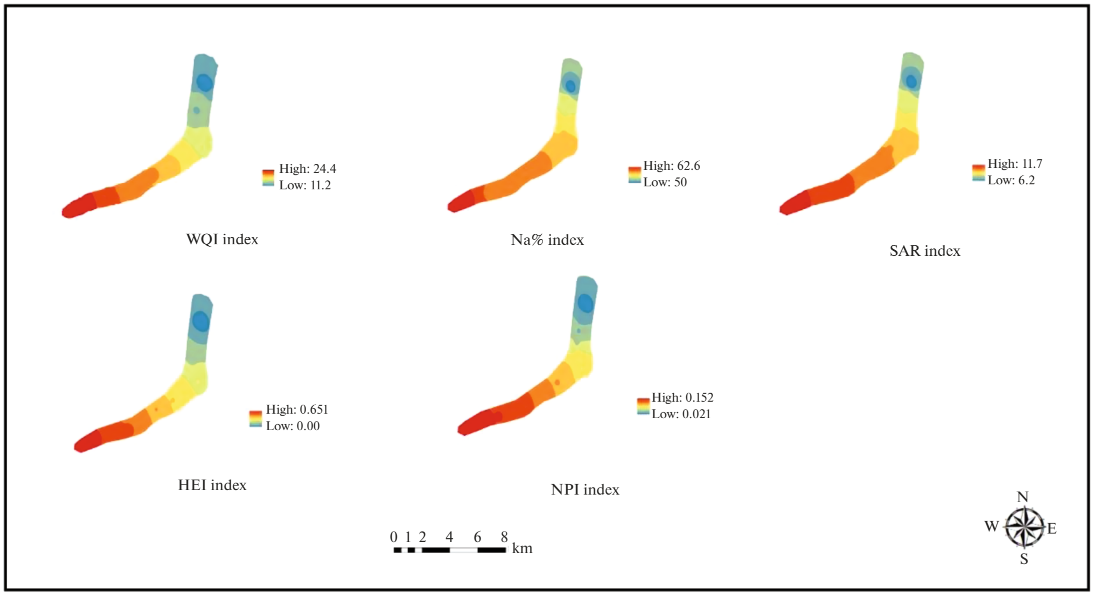

Fig. 2. Spatial distribution maps of Güren Stream water quality indexes (WQI, HEI, SAR, NPI, %Na).

suspended solid material, COD, BOD, and sulfate is strongly positive. The correlation between the suspended solid matter, COD, BOD, sulfate, and potassium is strongly positive. The correlation between nitrite and nitrate is strongly positive. The correlation between lead metal and nickel, copper, and zinc is strongly positive. The correlation between iron and nickel and copper and zinc is also highly strongly positive.

Kaiser–Meyer–Olkin analysis is a measure of sampling sufficiency for the ratio of common variance caused by principal factors [16]. The KMO value calculated as 0.720 in this study indicated that dataset was good for factor analysis. Thus, factor analysis of the data was performed to determine the possible sources of the variables. Four factors with eigenvalue >1 were identifed and these factors explained 83.31% of the total variance (Table 5). The first factor, consisting of NO_3-N, WT, EC, SS, NO_2-N, BOD, SO_4, salinity and COD explained 40.95% of the total variance. The water was found to be excellent according to environmental quality standards in terms of variables such as F1, this factor was considered to represent natural degradation processes and other environmental factors that have an effect on them [6]. Thus, F1 could be evaluated as the efect of anthropogenic activities and natural sources. The second factor, consisting of Zn, Pb, Fe, Cu and Ni, explained 29.73% of the total variance. It can be said that the reason for the presence of these metals is related to agricultural activities and forestry factor. In addition, Cu and Zn values are affected by a long-term anthropogenic activity such as pesticides, while the presence of Nickel can be associated with various rock types [44, 50]. The third factor explained 9.05% of the total variance and Na, TA, Cl, TH and Mg compound in this factor, solutes in seawater. Thus, F3 is called the salinization factor. This factor represents the main dissolved load of groundwater as a result of the interaction with minerals or trapped saline fluids in aquifers and chemical weathering of catchment rocks [20]. At the same time, the correlations of the parameters in F1, F2 and F3 were found to be positive strong, and the analysis results support each other. Finally, the fourth factor explained 6.01% of the total variance and consists of Hg and Cd which are included in this factor differently from the other metals and this indicates a different source for them. Finally, the fourth factor explained 6.01% of the total variance and, unlike other metals, it consists of Hg and Cd in this factor, which indicates a different source for them, for example, it could be traffic or atmospheric origin [12].

Water Quality and Evaluation Indices, Multivariate Statistical Technique and Spatial Distribution

Water quality classification and heavy metal concentration were calculated using indices such as WQI and HEI, and stream water quality was evaluated for irrigation water with the NPI, Na% and SAR indices (Table 3). Relationships between parameters with a multivariate statistical technique such as Pearson Correlation Index are shown in Table 4 and the spatial distribution of water quality index values at stations is shown in Fig. 2.

The WQI of the stream was found to be the lowest at 11.2 (station 1) and the highest at 25.7 (in October) (Fig. 2). According to the average values of all stations and months, WQI was 19.7, which means that the stream is in the "excellent" category (Table 6). Water

Table 4. The correlation of the physicochemical parameter and heavy metal values in the Güren Stream

	DO	Salinity	pH	WT	EC	SS	COD	BOD	Cl	PO_4-P	SO_4	SO_3	Na	K		TH	TA	Mg	Ca	NO_2-N	NO_3-N	NH_4-N	Fe	Pb	Cu	Cd	Hg	Ni	Zn
DO	1	–,478**	–0.139	–,539**	–,503**	–,539**	–,790**	–,429**	,538**	–,228**	–,314**	–0.047	,293**	–0.133	TH	1	,980**	,669**	–0.070	,581**	,450**	0.007	,596**	,597**	,547**	,236**	,576**	,443**	,658**
Salinity		1	0.045	,761**	,854**	,864**	,733**	,701**	–,406**	,584**	,782**	0.016	,315**	,563**	TA		1	,717**	–0.065	,586**	,409**	0.060	,598**	,569**	,578**	0.166	,601**	,425**	,676**
pH			1	0.078	0.081	0.052	0.105	0.069	–0.059	0.069	0.084	–0.001	–0.063	–0.032	Mg			1	0.048	,687**	,422**	0.115	,478**	,553**	,547**	0.084	,355**	,374**	,543**
WT				1	,875**	,801**	,855**	,798**	–,724**	,282**	,836**	0.007	–0.070	,193*	Ca				1	–0.058	–0.064	–,306**	–,188*	–0.031	–0.012	0.011	–0.044	–0.168	–0.116
EC					1	,903**	,854**	,821**	–,540**	,515**	,887**	0.063	,193*	,425**	NO_2-N					1	,863**	0.090	,184*	,385**	0.103	,316**	,321**	,341**	,378**
SS						1	,818**	,861**	–,413**	,506**	,884**	0.105	,258**	,647**	NO_3-N						1	0.056	0.087	,216**	–0.106	,559**	,264**	,211*	,183*
COD							1	,727**	–,705**	,246**	,722**	–0.005	–,297**	0.148	NH_4-N							1	0.147	–0.060	0.059	–0.052	–0.062	–0.010	–0.011
BOD								1	–,532**	,501**	,770**	0.020	–,227**	,288**	Fe								1	,712**	,838**	0.080	,441**	,532**	,790**
Cl									1	–0.105	–,415**	0.008	,438**	0.102	Pb									1	,790**	0.136	,366**	,728**	,868**
PO_4-P										1	,396**	,522**	,179*	,496**	Cu										1	0.129	,585**	,658**	,807**
SO_4											1	0.022	,338**	,458**	Cd											1	,547**	,326**	0.122
SO_3												1	0.070	,161*	Hg												1	,556**	,564**
Na													1	,660**	Ni													1	,691**
K														1	Zn														1

* $p < 0.05$.
** $p < 0.01$.

Table 5. Factor analysis distribution of parameters

	F1	F2	F3	F4
NO_3-N	0.966			
WT	0.962			
EC	0.959			
SS	0.950			
NO_2-N	0.885			
BOD	0.873			
SO_4	0.847			
Salinity	0.832			
COD	0.825			
Zn		0.940		
Pb		0.893		
Fe		0.882		
Cu		0.836		
Ni		0.629		
Na			0.760	
TA			0.750	
Cl			0.725	
TH			0.701	
Mg			0.613	
Hg				0.835
Cd				0.754
Eigen values	8.601	6.244	1.901	1.263
Percent of variance	40.957	29.734	9.054	6.012
Cumulative variance	39.170	59.363	73.99	83.31

quality was classified as "excellent" (except for water quality in October, which was classified as "good") according to all WQI values (Table 3).

In Cüce et al.'s study, conducted on the Kızılırmak River, the authors reported that the river was classified as "good" in terms of WQI value and in the "low pollution" category with an HEI value under 10 [5]. Singha et al., in a study they conducted on underground water, reported that the WQI value they found at most of the stations they chose was "unfit for drinking" [30]. Mutlu reported that WQI values changed from "excellent to very poor" at stations in the study he conducted in 2019. Zerveli Stream reported that the decrease in water quality was caused by the ingress of substances from the rains and that the change in water quality increased after spring [22].

The SAR (6.2–14.05) was determined as "excellent" and "good" (Fig. 2). The HEI (0.0–0.651) was "low," and the NPI (0.021–0.173) was determined as "no pollution," while Na% (50–65) was classified as "permissible" and "doubtful" (Table 3) and (Fig. 2). If the water has a high bicarbonate ion content, the sodium hazard also rises. There is a propensity for calcium and magnesium to precipitate as carbonates as concentration of the soil solution increases, increasing the relative fraction of sodium as a result [27]. In our study, considering the percentage distribution of the WQI results, all stations were categorized as 100% "excellent," and the monthly distribution as 91% "excellent" and 9% "good." The SAR distribution in stations was categorized as 50% "excellent" and 50% "good." The NPI distribution in stations and months was classified as 100% "no pollution," the Na% distribution in stations as 85% "permissible," 15% "doubtful," and in months 83% "permissible" and 17% "doubtful." Finally, the HEI distribution was categorized as 100% "low." The concentration of water quality index values increases from northeast to west and increases which is the from station 1 to the to 14 (Fig. 2).

CONCLUSIONS

Turkey has 25 freshwater basins that include many water regions. Each basin has different geological, geomorphological and hydrographic features. Güren Stream, located in the Black Sea region, is located in

Table 6. Calculation of water quality index of Güren stream at annual, WQI = $\sum WiQn/\sum Wi = 19.7$

Parametres	Standard value (Vs)	Mean concentration value (Vn)	*Wi*	*Qn*	*WiQn*
pH	8.5	8.4	0.1	98.8	10.4
Cl	250	8.4	0.003	3.36	0.01
Sulphate	200	35.23	0.004	17.6	0.07
Na	200	47.64	0.004	23.8	0.1
Total Hardness	100	241.42	0.009	241.4	2.14
Nitrit	3	0.0001	0.3	0.003	0.0008
Nitrate	50	1.45	0.01	2.9	0.05
Pb	10	0.99	0.09	9.9	0.89
Cu	2000	12.95	0.0004	0.64	0.0002
Cd	3	0.58	0.3	19.3	5.8
Hg	6	0.005	0.15	0.08	0.01
Ni	70	4.99	0.01	7.12	0.09
Zn	3000	7.92	0.0003	0.26	0.0001
			$\sum Wi = 1$		$\sum Wi = 19.7$

the Western Black Sea Basin and within the borders of Küre Mountains National Park, Turkey's first PAN park. The National Park, which stretches from east to west, serves as a physical and social threshold for the area around it. The Küre Mountains National Park, which hosts the most beautiful wild examples of the "Black Sea Moist Karst Forest" ecosystems, which are endangered today, is among the 100 Forest Hot Spots in Europe that should be protected. "North Anatolian and Caucasian Temperate Zone Forests" is one of the 200 priority ecoregions of the World Wildlife Fund (WWF) in terms of nature protection at the global level. The Küre Mountains National Park area is this extemely also a part of this very valuable region, home to 157 endemic plant species and 59 endangered plant taxa [2].

The region is far from the polluting elements created by industry and urbanization. According to the study results, the stream was observed not to have any pollution pressure. Therefore, the Güren Stream has first-class water properties according to its physico-chemical parameters and heavy metal concentrations. However, it is worth noting that changes in the level of contamination might occur due to increased industrialization and population. This can be prevented with various measures. To protect the current water quality of the Güren Stream and avoid future pollution, changes and developments should be identified using water-quality indexes. At the same time, the water should be evaluated in terms of "reference water" water body properties.

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ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This article does not contain any studies with human participants performed by any of the authors.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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