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RESEARCH ARTICLE

Assessment of the water quality of Bartın Kışla (Kozcağız) Dam by using geographical information system (GIS) and water quality indices (WQI)

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Abstract

This study was conducted to evaluate the water quality of the Kışla (Kozcagiz) Dam located in the province of Bartın in the Western Black Sea Region of Turkey. Water samples were collected monthly from 5 stations for a year and analyses were conducted using 27 water quality parameters. The quality of the dam and the water quality parameters were evaluated using different indices in comparison to the limits determined according to the standards set by the World Health Organization (WHO) and Turkey Surface Water Quality Regulation (SWQR). Water quality index (*WQI*), organic pollution index (*OPI*), sodium adsorption ratio (*SAR*), magnesium adsorption ratio (*MAR*), permeability index (*PI*), and metal pollution index (*MPI*) were calculated and spatial assessment of pollution was made seasonally by making use of the geographic information system (GIS). A piper diagram was used in determining the facies of the water. The types of Ca^{2+}-Mg^{2+}-HCO_3^- predominated in the dam water. Moreover, statistical analyses were used in order to determine if there was a significant difference between the parameters. *WQI* results generally indicate that the water quality was good in all seasons; however, only in the autumn, sampling points S1 (101.58), S2 (100.59), S4 (102.31), and S5 (102.12) showed poor water characteristics. According to the *OPI* results, while winter and spring yielded good water quality, summer samples were lightly polluted and autumn samples were moderately polluted. Given *SAR* results, it can be stated that the water of Kışla Dam could be used as irrigation water. Considering the standards specified by WHO and SWQR, the parameters generally exceeded the threshold values, but the water hardness value was much higher than 100 mg L^{-1} specified in SWQR as very hard water. The principal component analysis (PCA) results showed that the pollution sources were anthropogenic. Thus, for the dam water to not be affected by the increasing pollutant factors, it should be continuously monitored, and attention should be paid to the irrigation methods used in agricultural activities.

Keywords GIS · Irrigation water · Kışla Dam · Statistical analysis · Water quality · *WQI* · Turkey

Introduction

Water is one of the main components of human life and there would be no life without water. The source, from which the water will be obtained, should have a sufficient available capacity and acceptable quality of water. Providing high quality of drinking water is a fundamental factor to protect human health and the environment and ensure sustainable development (Rajini et al. 2010; Farrugia et al. 2016; Titilawo et al. 2018; Saleem et al. 2019; Islam et al. 2022).

Nowadays, water and environmental pollutions are the most critical problems threatening the ecosystem. Increasing water pollution due to industrial and agricultural activities and increasing population is becoming a very important problem (Pavlidou et al. 2015; Mutlu and Aydın Uncumusaoglu 2017; Pignotti et al. 2017; Al-Afify et al. 2018; Mutlu 2019; Şener et al. 2020). In addition to the deterioration of the balance in the ecosystem, the quality of drinking and utility water decreases, causing negative effects on public health (Kükrer and Mutlu 2019 2019; Mukherjee et al. 2020; Mukherjee and Singh 2022a).

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Since it is difficult to assess the water composition due to the spatial and temporal changes in water quality, it should be monitored (Kazi et al. 2009). Water quality might change due to the wastes appropriately treated or released untreated as a result of anthropogenic activities (domestic, agricultural, and industrial) (Wu et al. 2018; Kükrer and Mutlu 2019; Aydin et al. 2021; Howladar et al. 2021; Mutlu 2021). For this reason, water quality should be monitored considering the physical, chemical, and biological parameters (Bakan et al. 2010; Cüce et al. 2022a,b; Üstün Odabaşi et al. 2022). Examining the relationships between these parameters, water quality indexes were created based on the fact that the parameters in different units cause some difficulties. Since 1965, different methods were proposed to integrate various water quality parameters into a single index. The first water quality indices (*WQI*) were proposed by Horton (1965) and Brown et al. (1970) (Taner 2007). *WQI* is mainly based on several factors such as selecting the parameters, assigning the weights and relative weights, and converting to a specific range, which means calculating sub-indices and summing the sub-indices (Abbasi and Abbasi 2012; Hossain and Patra 2020; Yuksel et al. 2021). *WQI* is the most effective and frequently used calculation method for evaluating water quality parameters; however, *WQI* is subjective and domain-specific. *WQI* with fixed weight values may not sufficiently emphasize the impact of pollution characteristics on water quality and may not be applicable to all areas affected by different environmental conditions (Nong et al. 2020; Zhao et al. 2021; Mukherjee and Singh 2022b; Singh et al. 2023). Therefore, different calculation tools can be used in order to meet the requirements of the study area. Pollution indexes such as comprehensive pollution index (CPI), eutrophication index (EI), organic pollution index (*OPI*), and metal pollution index (*MPI*) are among the combined indexes used to determine water quality (Son et al. 2020; Pashaeifar et al. 2021; Tokatli et al. 2022).

Past and present studies focused on geochemical, microbial, and hydrochemical monitoring to determine the quality of water for drinking and use and focused on the assessment of pollution sources in water (Alaya et al. 2014; Zhang et al. 2016; Üstün Odabasi et al. 2018; Şener et al. 2020; Berhe 2020; Haghnazar et al. 2022). In addition, pollutant sources can be revealed using multivariate statistical analyses including correlation matrix and principal component analysis (PCA) (Agyeman et al. 2022). These approaches are useful in finding the complex relationships between the physicochemical parameters of water resources (Zhao et al. 2012; Bhuiyan et al. 2016; Ustaoğlu et al. 2020).

Kışla (Kozcağız) Dam is located within the borders of Bartın Province, in the Western Black Sea Region of Turkey. The Black Sea Region, which receives the highest level of rainfall in Turkey, has a steeply sloping land structure and the risk of erosion and flooding is high in the region (Wahidi 2021). It is also an important agricultural region and has great potential for surface freshwater resources (Varol et al. 2022a, b). Bartın Province, which has a coastline of 59 km in the Black Sea, is surrounded by the Bartın stream passing through it. Bartın stream, Gökırmak coming from Ulus District and Kozcağız streams coming from Kozcağız Town, is a river with waterway transportation opportunity. In our study area, Kışla Dam was built on Kozcağız stream for flood protection and irrigation purposes. Although the Kışla Dam is not used as a drinking water supply, it is not possible to distribute it according to the sources since all the water resources in the region are mixed in the same reservoirs at the same time (BPESR 2022). There are textile and upper workshops around the Kışla Dam, which constitutes an important part of the Bartın Basin, and intensive agriculture and animal husbandry activities are carried out. The good quality of the dam water in the region where mining activities are also carried out is of great importance for the use of the local people. So far, no studies have been conducted to determine the water quality parameters in Kışla Dam. For this reason, a comprehensive study is required to evaluate the concentrations, pollution conditions, and sources of water quality parameters in dam water. For this reason, the present study aims to (a) determine the water quality of Kışla Dam by using water quality indices, (b) assess the water samples collected for 12 months by the SWQR and WHO water quality standards, (c) interpret the water quality index results spatially and seasonally by using GIS, and (d) determine the pollution sources statistically significantly affecting the water quality of Kışla Dam.

Methodology

Study area and analyses

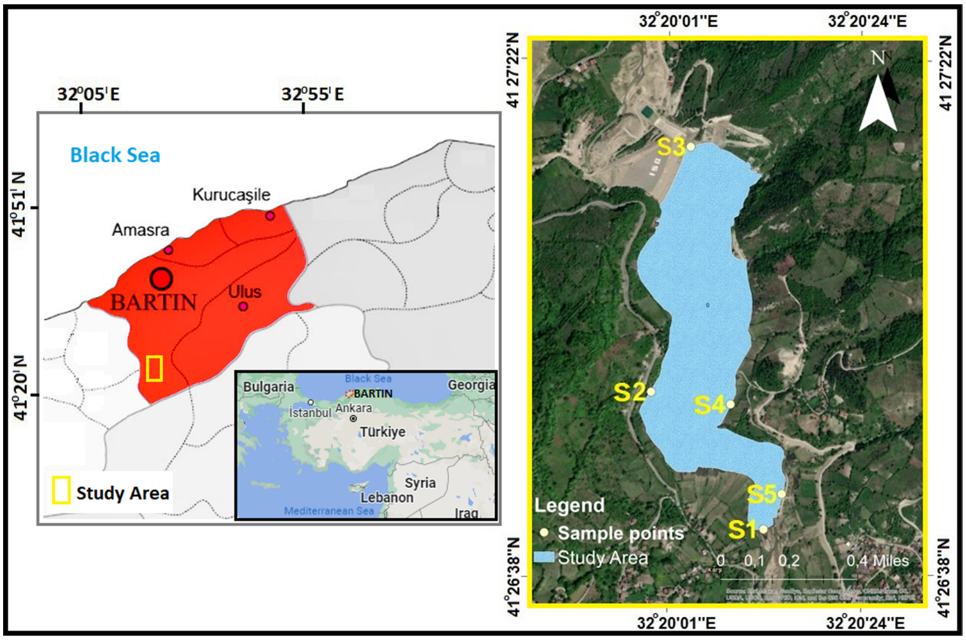
Kışla (Kozcağız) Dam represents a large portion of Bartın Basin. Constructed on Kozcağız Brook, one of three branches of Bartın River, for irrigation and overflow protection, this dam has 332 km^2 of precipitation area and 167.6 hm^3 of mean annual water capacity. Kozcağız brook has a length of 47.50 km. It has the capacity to irrigate 2460 ha of land in Kozcağız plain. The maritime climate is dominant in the region. The foundation of the study area was formed in the Paleozoic and Mesozoic ages and was subjected to folds, fractures, and collapses under the influence of the 3rd Geological Time movements. The region generally has a calcareous structure and sand, clay, and marl layers are encountered in places. Under the limestone layers, very hard, gray-colored rocks called “kayran” occupy a large area (Çubuk 2019). Although Kozcagiz has the typical features of the Black Sea Region, it has a rough land structure. The vegetation consists of evergreen and deciduous plants. Alluvial soils are dominant in the region. Mountain and plateau tourism is carried out. The majority of the population in the study area is engaged in agriculture (BPESR 2022). The Kışla Dam is an important source of irrigation for the local people, who grow hazelnuts, strawberries, forage crops, grains, vegetables, and fruits. Feeding from the Kozcagiz stream, the dam is of remarkable importance in the irrigation of the surrounding agricultural lands. There are industrial facilities operating in the textile, dairy, construction, and timber sectors around the dam, and the wastewater discharges of these industries are discharged into Kozcagiz stream after the wastewater treatment plant. There is no solid waste disposal facility in the region. Since solid wastes are stored as wild landfills and some settlements do not have a fixed storage area, solid wastes can reach the reservoir with rain and flood waters.

In the study area, water samples were monthly collected from five stations thought to represent the entire dam and located between 41°26′32″N–32°20′23″E and 41°27′22″N–32°20′10″E during the period between June 2020 and May 2021 (Fig. 1). Water samples were taken from 50-cm depth by using 500-mL glass bottles cleaned using acid. All the samples were taken to the laboratory and kept at + 4 °C until analyzed. Dissolved oxygen (DO), pH, temperature (*T*), salinity, and electrical conductivity (EC) values were measured in situ with YSI 556 MPS. Chemical oxygen demand (COD), biological oxygen demand (BOD), total hardness (TH), nitrite-nitrogen (NO_2^--N), nitrate-nitrogen (NO_3^--N), ammonium-nitrogen (NH_4^+-N), bicarbonate alkalinity (HCO_3^-), phosphate (PO_4^{3-}), sulfite (SO_3^{2-}), sulfate (SO_4^{2-}), chloride (Cl^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+) analyses were performed using standard methods (APHA/AWWA/WEF 2017). Metal analyses were performed for iron (Fe), lead (Pb), cadmium (Cd), zinc (Zn), nickel (Ni), copper (Cu), and mercury (Hg) by using inductively coupled plasma optical emission spectrometry (ICP-OES) (Spectro, SpectroBlue) in the Kastamonu University's Central Research Laboratory Application and Research Centre accredited by the Turkish Accreditation Agency (TURKAK). The accuracy of the analytical method was tested using a certified reference material (CPAchem—Ref N: 110,580. L1) with 95% precision and accuracy. The metals' recovery values as means were observed to range between 81.47% and 110.33%.

Water quality assessment methods

After laboratory analysis, six different water quality indices were used to evaluate the water quality of the Kışla Dam. *WQI* was used to estimate surface water quality status by combining several water quality variables and converting them into a single value. The Irrigation Water Quality Indices consider only certain components of water quality against their recommended limits for all soil types (EPA 1994). These components are often grouped in some quality indicators based on irrigation and soil management (Bortolini et al. 2018). Excessive salinity reduces the osmotic activity of plants and thus inhibits the absorption of water and nutrients from the soil (Saleh et al. 1999; Subramani et al. 2005; Haque et al. 2020; Batarseh et al. 2021; Mukherjee et al. 2022). Permeability affects the rate of soil infiltration. Toxicity affects sensitive products. In order to evaluate these quality indicators, sodium adsorption ratio (*SAR*),

Fig. 1 The study area (Kışla Dam) and sampling points



magnesium adsorption ratio (*MAR*), permeability index (*PI*), and *MPI* indices were used, whereas *OPI* was used for determining the organic pollution; equations with calculations and explanations are presented in Table 1.

Water quality index

Introduced by Horton (1965), *WQI* is a rating method measuring the combined effect of each of the water parameters considered to be important for water quality and ensuring the integration (Kangabam et al. 2017; Howladar et al. 2021; Kutlu and Mutlu 2021). *WQI* values of pH, electrical conductivity (EC), chemical oxygen demand (COD), biological oxygen demand (BOD), chloride (Cl^-), phosphate (PO_4^{3-}), sulfate (SO_4^{2-}), sodium (Na^+), potassium (K^+), total hardness (TH), bicarbonate (HCO_3^-), magnesium (Mg^{+2}), calcium (Ca^{+2}), nitrite-nitrogen (NO_2^--N), and nitrate-nitrogen (NO_3^--N) parameters, which are important to the degree of affecting the water quality, were calculated for each month and their seasonal averages were taken. In Table S1 (supplementary data), the real weight (w_i) values used in calculations and the drinking water standards set by WHO (2011) are presented. Depending on the effect on water quality and human health, each parameter was assigned a value between 1 and 5 while determining the WOI.

Organic pollution index

COD, dissolved oxygen (DO), dissolved inorganic N (DIN), and dissolved inorganic P (DIP) concentrations were used in assessing and classifying the organic load or the pollution arising from the organic compounds in the water by making use of limits set by Turkey Surface Water Quality Regulation (SWQR 2016). DIN refers to the sum of nitrite (NO_2-N), nitrate (NO_3-N), and ammonium nitrogen (NH_4-N).

Metal pollution index

The combined effect of metals on the water quality was calculated using the metal pollution index (*MPI*) (Eq. (3); Tamasi and Cini 2004). The calculation was made using Fe, Pb, Cu, Cd, Hg, Ni, and Zn metals. The upper limits set by SWQR (2016) were used in assessments.

Table 1 Index calculation and explanations used in water quality assessment

Equation of index	Explanation	Description
$W_i = \frac{Wi}{\sum_{i=1}^{n} Wi}$ $Qi \frac{Ci}{Si} \times 100$ $WQI \sum(Wi \times Qi)$ (1)	W_i is the relative weight, w_i is the weight of each parameter, n is the number of parameters, Q_i is the quality rating, C_i is the concentration of each chemical parameter in each sample in milligrams per liter, and S_i is the World Health Organization standard for each chemical parameter in milligrams per liter according to the guidelines of the WHO (2011)	< 50 excellent water 50–100 good water 100–200 poor water 200–300 very poor water > 300 water unsuitable for drinking purposes (Horton 1965)
$OPI = \frac{COD}{CODs} + \frac{DIN}{DINs} + \frac{DIP}{DIPs} - \frac{DO}{DOs}$ (2)	COD is the chemical oxygen demand (mg L^{-1}), DIN is the dissolved inorganic N (mg L^{-1}), DIP is the dissolved inorganic P (mg L^{-1}), and DO is the dissolved oxygen (mg L^{-1}). CODs, DINs, DIPs, and DOs represent the standard concentrations in the surface water quality regulation in Turkey (SWQR 2016)	$OPI < 0$ excellent $0 < OPI < 1$ good $1 < OPI < 2$ beginning to be contaminated $2 < OPI < 3$ lightly polluted $3 < OPI < 4$ moderately polluted $OPI > 4$ heavily polluted (Quan et al. 2005)
$MPI = \sum_{i=1}^{n} \frac{Ci}{(MAC)i}$ (3)	C_i is the measured concentration of ith metal and MAC is the maximum allowable concentration according to surface water quality regulation in Turkey (SWQR 2016)	< 0.3 represents very pure $0.3 < MPI < 1$ poor $1 < MPI < 2$ slightly affected $2 < MPI < 4$ moderately affected $4 < MPI < 6$ strongly affected > 6 seriously affected (Caerio et al. 2005)
$SAR = \frac{Na^{+}_{meq}}{\sqrt{\frac{Ca^{+2}_{meq} + Mg^{+2}_{meq}}{2}}}$ (4)	All concentrations of ions were calculated as meq L^{-1}	< 10 excellent 10–18 good 18–26 permissible > 26 doubtful (Richards 1954)
$MAR = \frac{Mg^{+2}_{meq} \times 100}{Ca^{+2}_{meq} + Mg^{+2}_{meq}}$ (5)		< 50 suitable > 50 harm to soil (Paliwal 1972)
$PI = \frac{Na^{+}_{meq} + \sqrt{HCO_3^-}}{Na^{+}_{meq} + Ca^{+2}_{meq} + Mg^{+2}_{meq}} \times 100$ (6)		> 75 good 25–75 moderate < 25 poor (Doneen 1975)

Sodium adsorption ratio

SAR in irrigation waters is used as a criterion in determining the risks arising from alkali soil. Increasing Na^+ concentrations might replace Ca^{2+} and Mg^{2+} in soil and it might reduce the soil permeability and the air circulation in soil (Sahoo and Khaoash 2020; Haghnazar et al. 2022; Mukherjee et al. 2022). Introduced by Richards (1954), the calculation (Eq. (4)) and explanations are presented in Table 1.

Magnesium adsorption ratio

Since alkalization of soil reduces productivity, high magnesium concentrations might have negative effects on the soil quality (Kumar et al. 2007). Magnesium adsorption ratios higher than 50% might cause problems (Ehya and Moghadam 2017). *MAR* is calculated using Eq. (5) (Paliwal 1972).

Permeability index

Soil permeability reduces with the constant use of water that is rich in minerals such as Mg^{+2}, Na^+, and Ca^{+2} (Subramani et al. 2005; Mukherjee et al. 2022). Permeability index (*PI*) is a useful criterion used to determine the soil condition and is calculated using Eq. (6).

Determination of the spatial distribution of water quality

The spatial distribution of the water quality of the study area was determined using ArcGIS. Calculating *OPI*, *WQI*, and *MPI* maps of water quality parameters for four seasons (spring, summer, autumn, winter) were created. Since the data coverage of the study was significantly good (12 months, 5 sampling points, and 60 measurements in total) and sampling stations were evenly distributed over the study area, an inverse distance-weighted (IDW) algorithm, a spatial interpolation method, was used in ArcGIS (v10) software (Mukherjee and Singh 2020). IDW is the most popular interpolation method that estimates interpolation points based on their proximity to sampling locations in the study area (Mukherjee et al. 2020). In this method, more weight is given to the points closest to the studied location, and the impact of each point on the other is inversely proportional to the distance between the points (Shukla et al. 2020; Tercan and Dereli 2020). When closer points are given more weight, the effect of the points reduces with distance from the predicted location (Cüce et al. 2022a).

Hydrochemical resource identification and statistical analysis

Piper diagram (Piper 1944) was used in determining the hydrochemical characteristics of Kışla Dam. This diagram contains two triangles, one for anions and the other for cations, which determine the hydrochemical character of water. Based on the idea of hydrogeochemical facies, the anion and cation domains are combined to show a single point in a diamond-shaped area, where the induction was drawn (Patolia and Sinha 2017; Li et al. 2019; Haque et al. 2020; Sahoo and Khaoash 2020; Pashaeifar et al. 2021). In the Piper diagram, there are four dominant classes by the main cations and anions: (A) Mg^{+2} type, (B) Ca^{+2} type, (C) Na^+-K^+ type, (D) non-dominant type, (E) SO_4^{-2} type, (F) HCO_3^- type, and (G) Cl^- type. The hydrochemical facies of the water is classified as (1) Ca^{+2}-Mg^{+2}-HCO_3^-, (2) Na^+-Cl^-, (3) mixed Ca^{+2}-Na^+-HCO_3^-, (4) mixed Ca^{+2}-Mg^{+2}-Cl^-, (5) Ca^{+2}-Cl^-, and (6) Na^+-HCO_3^-.

For descriptive statistics, one-way variance analysis (ANOVA) was used in determining if there was a significant difference between the seasonal results. The direction and level of relationship between physicochemical parameters were determined by using Pearson's correlation coefficient (PCC). By the coefficient of correlation between parameters, the relationship is defined as very weak for the values 0–0.25, weak for the values 0.26–0.49, moderate for the values 0.5–0.69, high for the values 0.7–0.89, and very high for the values 0.9–1. Negative values refer to an inverse relationship, which indicates that one parameter decreases as the other increases (Ustaoğlu and Tepe 2019).

Principal component analysis (PCA) was used in order to reduce the dataset, determine relationships between variables, and reveal potential environmental pressures on the water quality in the present study. Before the use of PCA, Kaiser–Meyer–Olkin (KMO) test was conducted (Haghnazar et al. 2023a). In the present study, the KMO result was found to be 0.766, which indicates the sufficiency of data (>0.5). The eigenvalues higher than 1 were considered as a criterion in the calculation of principal components. Data were analyzed using SPSS 26 statistical package program and the statistical significance was set at $p<0.05$.

Results and discussion

Assessing the water quality by physicochemical parameters

Seasonal and annual mean, min, and max values of Kışla Dam's physicochemical analysis and metal analysis results are presented in Table 2. Compared to the WHO (2011) standards given in Table S1, pH level desired to be 6.5–8.5 was found to be in this range in all the seasons. pH values between 8.00 and 8.51 indicate an alkali water character. There was no statistically significant difference between the stations ($p>0.05$). Similarly, EC values did not exceed the threshold levels. The conductivity in water is directly proportional to the salinity level (Jiang et al. 2015; Zhang et al.

Table 2 Seasonal and annual descriptive statistics of Kışla Dam's water quality parameters

Parameter	Summer ($n=15$)	Autumn ($n=15$)	Winter ($n=15$)	Spring ($n=15$)	Mean ($n=60$)	Standard deviation	Min	Max
DO (mg L^{-1})	12.15	11.51	12.59	13.11	12.34	0.83	10.88	13.68
Sal (‰)	0.06	0.06	0.03	0.06	0.05	0.05	0.02	0.41
pH	8.33	8.33	8.04	8.16	8.22	0.15	8.00	8.51
T (°C)	16.54	14.87	5.55	8.33	11.32	5.21	4.10	20.10
EC (μS/s)	389.10	418.14	354.09	309.05	367.60	47.56	284.60	443.61
COD (mg L^{-1})	3.74	2.68	0.67	2.26	2.34	1.42	0.54	5.34
BOD (mg L^{-1})	1.30	1.14	0.08	0.59	0.78	0.55	0.00	1.60
Cl^{-} (mg L^{-1})	5.58	5.69	3.96	4.21	4.86	1.16	2.78	6.20
PO_4^{3-} (mg L^{-1})	0.19	0.35	0.15	0.06	0.19	0.17	0.01	0.53
SO_4^{2-} (mg L^{-1})	73.52	56.54	52.87	58.57	60.37	9.41	45.06	80.52
SO_3^{2-} (mg L^{-1})	2.19	1.67	1.65	2.24	1.94	0.37	1.24	2.76
Na^{+} (mg L^{-1})	65.96	44.53	47.01	63.61	55.28	12.93	43.48	81.36
K^{+} (mg L^{-1})	10.19	4.83	6.42	8.12	7.39	3.32	4.70	17.46
TH (mg L^{-1})	389.69	374.90	340.46	358.90	365.99	21.14	335.44	398.04
HCO_3^{-} (mg L^{-1})	399.05	384.36	348.23	368.37	375.00	21.74	342.32	407.28
Mg^{+2} (mg L^{-1})	57.66	55.61	38.04	38.18	47.37	10.89	29.70	63.50
Ca^{+2} (mg L^{-1})	75.56	57.65	43.87	59.71	59.20	16.59	7.31	93.88
NO_2-N (mg L^{-1})	0.0005	0.0003	0.0001	0.0004	0.0003	0.0002	0.00004	0.00054
NO_3-N (mg L^{-1})	6.27	2.43	1.26	4.62	3.64	3.09	0.18	11.78
NH_4^{+}-N (mg L^{-1})	0.0001	0.0001	0.00003	0.0001	0.0001	0.0001	0.00001	0.0002
Fe (mg L^{-1})	0.007	0.002	0.002	0.004	0.004	0.005	0.0002	0.020
Pb (μg L^{-1})	0.78	0.30	0.40	0.89	0.59	0.47	0.01	1.80
Cu (μg L^{-1})	5.73	2.33	0.27	3.47	2.95	3.41	0.10	13.00
Cd (μg L^{-1})	0.21	0.24	0.07	0.05	0.14	0.15	0.01	0.60
Hg (μg L^{-1})	0.007	0.004	0.001	0.002	0.003	0.003	0.001	0.010
Ni (μg L^{-1})	0.07	0.73	0.20	0.00	0.25	0.63	0.00	3.00
Zn (μg L^{-1})	13.40	5.60	1.80	6.13	6.73	5.41	1.00	21.00

2016; Taş et al. 2019). Conductivity also increases with the presence of pollutants in water and the increase in temperature (Kutlu and Mutlu 2021; Şimşek et al. 2021). Given the relationship of seasonal mean, min, and max values of salinity and temperature with EC values, it can be seen that there was a proportional increase.

Chemical oxygen demand (COD) and biological oxygen demand (BOD) concentrations are the two important determinants in assessing the water quality in order to represent the level of the organic matter-related pollution (Genevieve and James 2006; Oseke et al. 2021). Given the values set by WHO (2011), COD and BOD values are desired to be 10 mg L^{-1} and 5 mg L^{-1}, respectively, and the parameters did not exceed these threshold values. The reason for the remarkable decrease observed in both parameters in winter is thought to be the dilution in organic load together with seasonal precipitation. Similarly, Kutlu and Mutlu (2021) reported a decrease in organic load in Karaca Dam in the winter season. Dissolved oxygen is a vitally important parameter for aquatic life. As seen in Table 2, DO concentration was very high in every season but not at the level limiting the aquatic life.

There is a relationship between Cl^{-} and SO_4^{-2} ions and salinity. Accordingly, the lowest Cl^{-} and SO_4^{-2} concentrations are observed in the winter season, when the salinity is at the lowest level. The high level of Cl^{-} input into waters reduces the dissolved oxygen that is required for aquatic organisms (Deepa et al. 2016; Pandit et al. 2020). As stated by WHO (2011), Cl^{-} and SO_4^{-2} concentrations are desired to be lower than 250 mg L^{-1}. In the present study, both parameters were found to be lower than the threshold values.

Nitrogen and phosphorus compounds are the most important nutrient matters influencing the surface water quality. These nutrients also cause the eutrophication process (Şener et al. 2017; Ustaoğlu and Tepe 2019; Ustaoğlu et al. 2020). Water quality decreases as the concentrations of these nutrients increase. NO_2^{-}-N, NO_3^{-}-N, and NH_4^{+}-N concentrations, which are the nitrogenous compounds in Kışla Dam, indicate that the water quality was Class I according to Surface Water Quality Regulation (SWQR) of Turkey ($NH_4 < 0.2$ mg L^{-1}, $NO_2 < 0.01$ mg L^{-1}, and $NO_3 < 3$ mg L^{-1}). Given SWQR, the concentration of phosphoric compounds is desired to be between < 0.05 and 0.16 mg L^{-1}. Accordingly, except for the spring season, phosphate concentration was found to be close to the max value of 0.16 mg L^{-1} (0.15 mg L^{-1}) or higher. Similar results were reported in studies carried out by Gümüş (2021) on Akarçay River, and by Kutlu and Mutlu (2021) on Karaca Dam regarding the water quality.

The cation levels (K^+, Ca^{+2}, Mg^{+2}) at sampling points were within the ranges set by WHO for drinking waters. Only the concentration of Ca^{+2} was at the threshold level of 75 mg L^{-1}. Water hardness is related to the concentrations of main elements such as Ca^{+2} and Mg^{+2}. Total hardness values were found to be higher than 100 mg L^{-1}, which is the threshold value, in all seasons and all sampling stations. For water hardness, the general criteria for carbonate were 0–60 mg L^{-1} for soft water, 61–120 mg L^{-1} for mildly hard water, 121–180 mg L^{-1} for hard water, and > 180 mg L^{-1} for very hard water (Boyd et al. 2016). Accordingly, the water hardness level was found to be very hard in all the sampling points. There was no statistically significant difference between seasons and between stations ($p > 0.05$).

Examining the mean heavy metal concentrations in sampling points, Fe was found to be 0–0.02 mg L^{-1}, Pb to be 0–1.8 µg L^{-1}, Cu to be 0–13 µg L^{-1}, Cd to be 0–0.6 µg L^{-1}, Hg to be 0–0.01 µg L^{-1}, Ni to be 0–3.0 µg L^{-1}, and Zn to be 0–21 µg L^{-1}. Accordingly, Fe value of 0.3 mg L^{-1} was lower than the WHO threshold and 0.101 mg L^{-1} set by SWQR. Pb value of 10 µg L^{-1} was found to be WHO threshold and 14 µg L^{-1} set by SWQR; Cu value of 2000 µg L^{-1} was found to be lower than WHO threshold but the values lower than 3.1 µg L^{-1} set by SWQR were achieved only in autumn and winter seasons. Cd, Hg, Ni, and Zn concentrations were found to be lower than the threshold values set in both guidelines. Several trace elements including Fe, Zn, and Cu enter into the water as a result of the disintegration of rock minerals (ATSDR 2004, 2005; Hossain and Patra 2019, 2020). Consequently, high Cu concentration can be thought to be because of anthropogenic and geogenic factors (Haghnazar et al. 2023b).

Assessing the water quality by hydrochemical characteristics

Hydrochemical facies and main chemical structure of Kışla Dam's water were analyzed as specified by Piper (1944). This diagram can be used for identifying hydrochemical facies when combined and is based on a diamond-shaped area or two triangles for main dissolved anions and cations. Here, the main cations (K^+, Ca^{+2}, Mg^{+2}, and Na^{+2}) and anions (HCO_3^-, SO_4^{2-}, and Cl^-) are expressed as meq/L units. As seen in Fig. 2, most of the samples were in Zone (1) referring to Ca^{2+}-Mg^{2+}-HCO_3^-, non-dominant (D), and (F) bicarbonate types. The main source of calcium and bicarbonate ions is thought to be the disintegration of limestone. Bicarbonate is a byproduct of the decomposition of carbonic acid or the decomposition of silicates originating from the solubility of atmospheric carbon dioxide and humic acids in the soil. Azhari et al. (2023) obtained similar results as our study and reported that the Ca^{2+}-Mg^{2+}-HCO_3^- water type was dominant. It was stated that the observed chemical changes could be rock-water interactions, anthropogenic sources, irrigation yields, and chemical fertilizers. Haque et al. (2020) indicated the presence of high amounts of bicarbonates, which may result from the decomposition of the carbonate mineral, in the study conducted in the Ganges River. The existence and sources of different water types are supported by Durov diagram (Durov 1948). In the study by Adimalla (2019), the dominant water type is calcium–magnesium–chloride types (Ca^{2+}-Mg^{2+}-Cl^-), and calcium–sodium–bicarbonate types (Ca^{2+}-Na^+-HCO_3^-), and calcium–bicarbonate (Ca^{2+}-Na^+-HCO_3^-) types were found. As a result of the applied Gibbs diagram (Gibbs 1970), it was reported that the water type is rock dominance, and thus, water–rock interactions gradually increase due to rock-forming minerals; this increased rock-water interactions are due to weathering of parent rocks and chemical weathering of rock-forming minerals.

Assessing Kışla Dam's water quality by indices

In determining the water quality, 6 different indices including *WQI*, *OPI*, *MPI*, *SAR*, *MAR*, and *PI* were used. Table S2, given in the supplementary data, shows the seasonal distribution of all indices between the sampling points. Among these indices, *WQI*, *OPI*, and *MPI* index maps were created using ArcGIS. Virtualization of water quality by using ArcGIS maps is very important in assessing the usability of water. Figure 3 illustrates the *WQI* results of 5 sampling points by 4 seasons. *WQI* scores of sampling points ranged between 83.15 and 89.72 in summer, between 63.07 and 65.75 in winter, between 56.20 and 58.37 in spring, and between 99.55 and 102.31 in autumn.

Given the results, good water (50–100) characteristic was observed in summer, spring, and winter, whereas poor water (100–200) characteristic was observed in autumn. Similarly, Kükrer and Mutlu (2019), Kutlu and Mutlu (2021), and Oseke et al. (2021) reported higher results in the summer and autumn seasons. Considering the highest *WQI* values between the sampling points during four seasons, the highest value in autumn was found in S4 as 102.31, whereas the highest *WQI* values in all other seasons were found in the S5 sampling point. This might be related to the closeness of S4 and S5 sampling points to the residential areas around the dam.

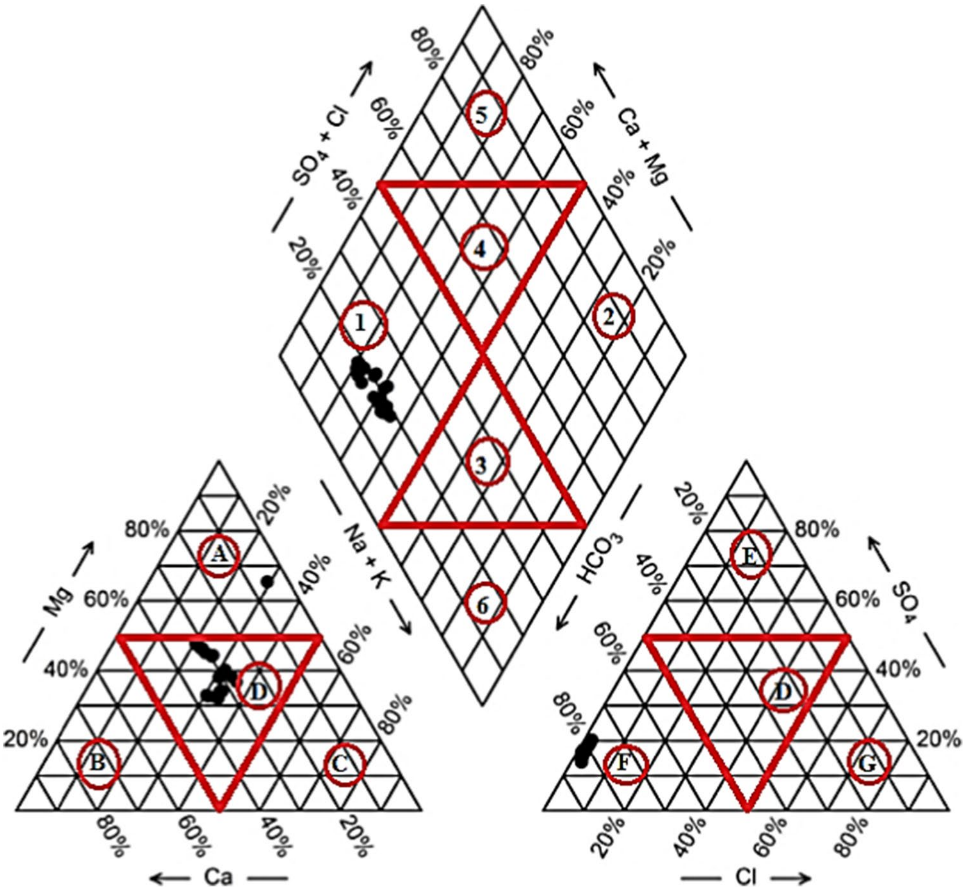


Fig. 2 Chemical facies of Kışla Dam by Piper diagram

In Fig. 4, the spatial distribution of seasonal changes in *OPI* results is illustrated. *OPI* values are desired to be between 0 and 4. It ranged between 2.48 and 3.04 in summer, 3.52 and 3.85 in autumn, 0.60 and 0.84 in winter, and 0.29 and 0.50 in spring. $0 < OPI < 1$ indicates good water quality. Accordingly, all the sampling points yielded good water quality character in the winter and spring seasons. $2 < OPI < 3$ indicates mildly polluted water character and $3 < OPI < 4$ indicates moderately polluted water. As with *WQI*, water quality assessed by *OPI* was found to be moderately polluted in the autumn season. Low *OPI* values found in the spring season might be related to the increase in nutrient consumption by phytoplankton and aquatic plants. In addition, improper fertilization activities in agricultural activities in the area (such as leaving the fertilizer on the soil surface) cause surface water flow with precipitation. In addition to the organic pollution caused by nitrogen and phosphate fertilizers, the lack of sewerage system in the study area and surrounding villages and the use of septic tanks still cause organic pollution in surface and groundwater.

OPI was used in determining the organic pollution of water mass by COD, DIN, DIP, and DO. Examining all sampling points for all seasons, sampling point S5 had the highest *OPI* score in all four seasons. It suggests that sampling point S5 had a moderate level of organic pollution. This sampling point had a higher *OPI* score in comparison to others because of the high organic pollution due to the closeness of sampling point S5 to residential areas and also the agricultural activities. Liu et al. (2011) examining the water quality in coastal waters reported lower *OPI* values in the rainy season. Differing from the present study, Chen et al. (2016) reported a higher organic pollution in the rainy season ($OPI = 25.9$) in comparison to the drier season ($OPI = 13.4$).

Figure 5 illustrates the seasonal changes in Kışla Dam's metal pollution index (*MPI*) results. Index results were 1.47–3.08 in summer, 0.58–1.67 in autumn, 0.032–0.569 in winter, and 0.83–1.82 in spring.

Developed by Caerio et al. (2005), *MPI* utilized a 6-category classification system. Considering the metal pollution, $MPI < 0.3$ refers to ultrapure (Class I), $0.3 < MPI < 1$ to weak (Class II), $1 < MPI < 2$ to mildly affected (Class III), $2 < MPI < 4$ to moderately affected (Class IV), $4 < MPI <$ to strongly affected (Class V), and $MPI > 6$ to severely affected by metal pollution. Given the results achieved, those obtained for the summer showed Class III level in sampling points S2 (1.96) and S3 (1.46) and Class IV results in other sampling points (moderately

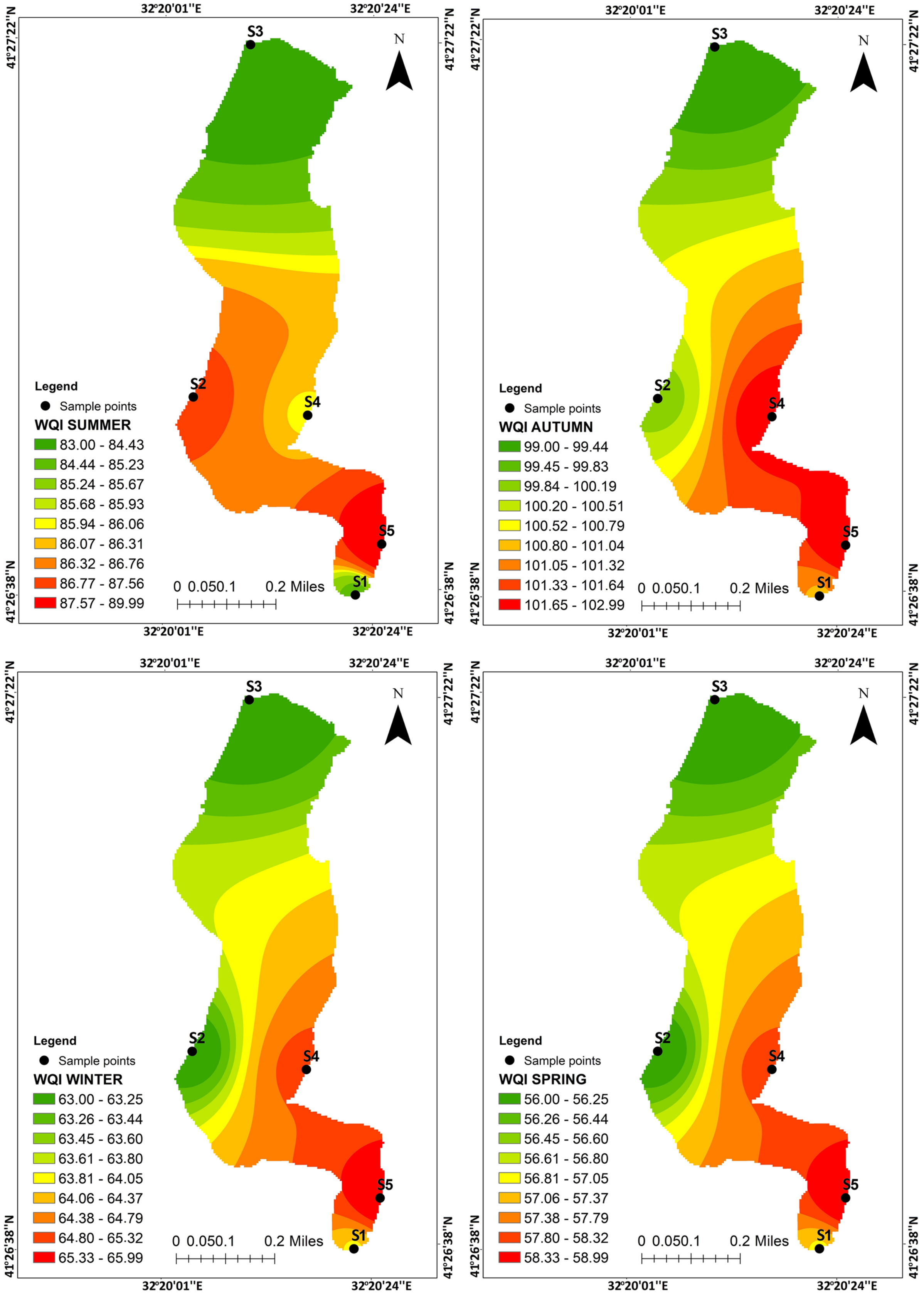


Fig. 3 Spatial distribution of *WQI* values of Kışla Dam

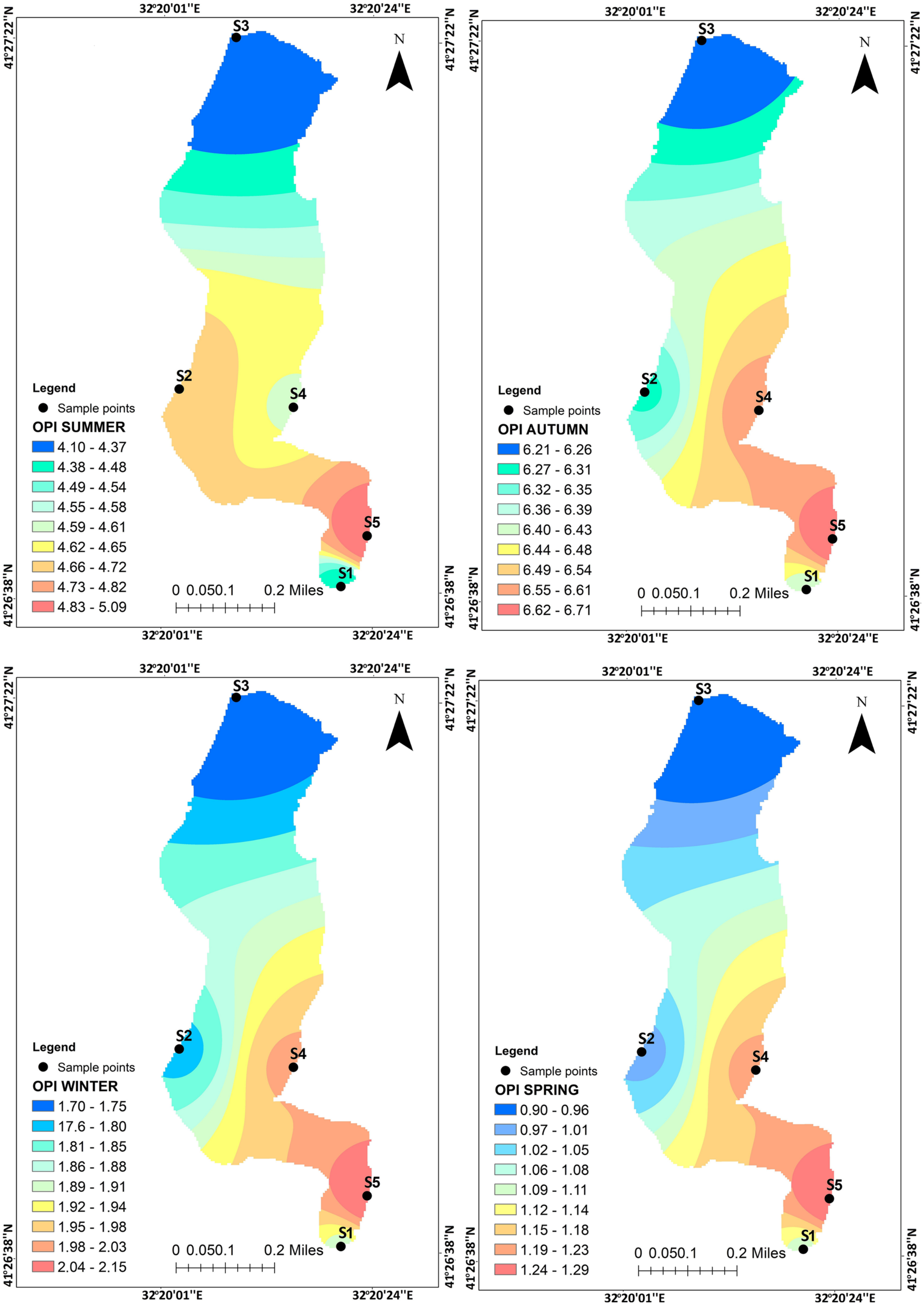


Fig. 4 Spatial distribution of *OPI* values of Kışla Dam

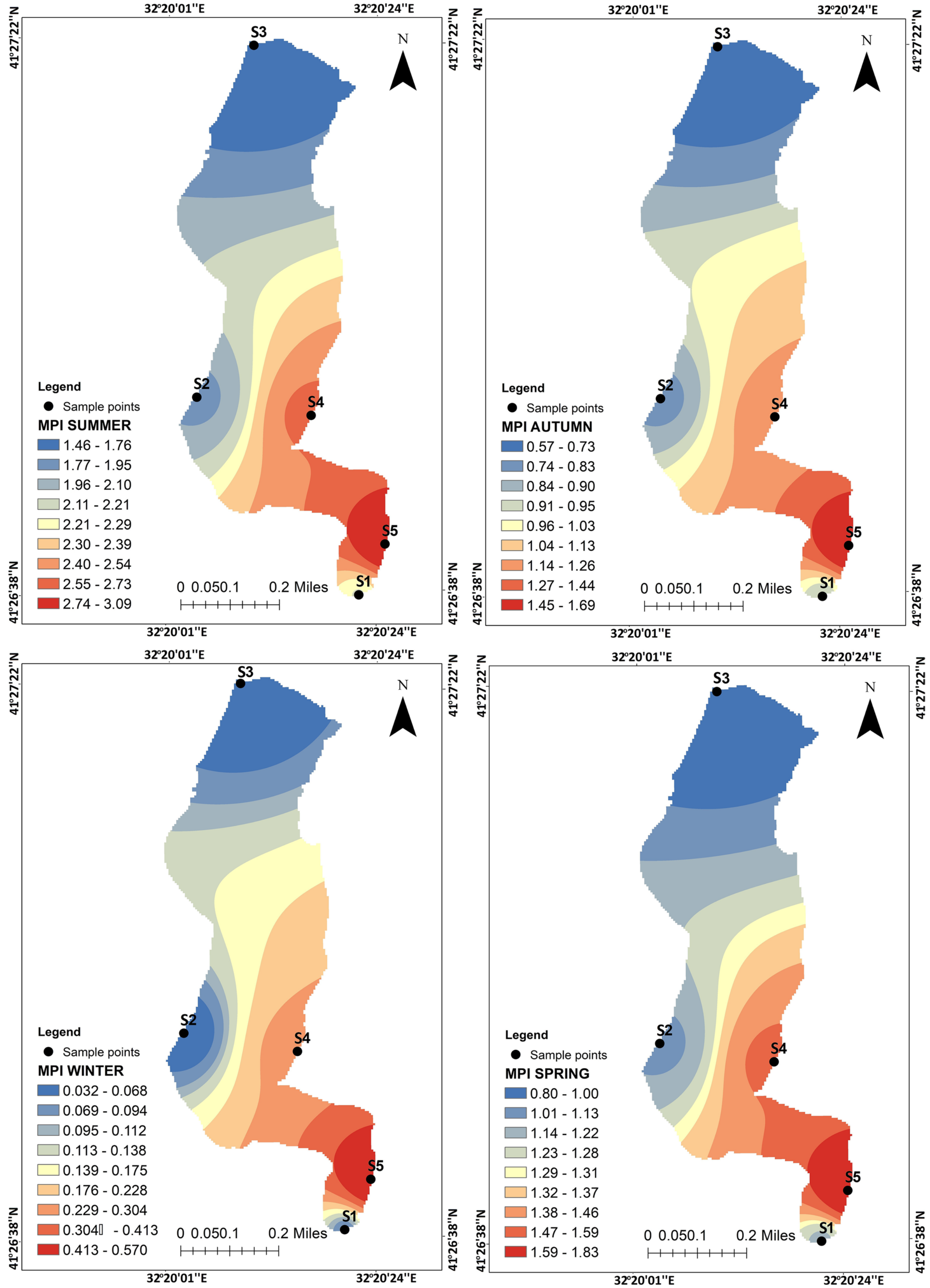


Fig. 5 Spatial distribution of Kışla Dam's *MPI* values

affected). Measurements performed in autumn yielded Class III in sampling points S4 (1.24) and S5 (1.67) and Class II in other sampling points, whereas those performed in winter revealed Class I in all sampling points other than S5 (0.57). The measurements performed in spring showed Class III results in all the sampling points other than S3 (0.83). Thus, it can be said that the highest *MPI* score according to the seasons and sampling points is obtained from the S5 (3.04) sampling point, which is closest to the settlement area. In order to reduce the leakage of heavy metals, which are a source of air pollution, into the soil due to the mining activities carried out in the region, it is recommended to increase the emission monitoring and inspections in the regions where industrial activities are located. With the establishment and regular operation of treatment plants, solid waste storage should be transferred from wild storage to regular storage.

In order to examine the suitability of Kışla Dam's water for irrigation, *SAR*, *MAR*, and *PI* methods were used. A high *SAR* value of irrigation water causes a reduction in soil permeability and, consequently, limits the access of agricultural products to the water (Singh et al. 2014). High magnesium concentration in water is another factor that is harmful to the productivity of soil (Khanoranga 2019). Given the results achieved here, *SAR* was found to range between 0.98 and 1.59, *MAR* between 39.23 and 61.2, and *PI* between 46.11 and 61.62. *SAR* is an approach to determine the tendency of irrigation water to cause a cation exchange reaction in soil and to measure the ratio of Na^+ to Ca^{2+} and Mg^{2+} ions in water. According to FAO Directive "Table 1 — Guidelines for interpretations of water quality for irrigation" (Ayers and Westcot 1985), when the irrigation water quality of the Kışla Dam was evaluated, $SAR < 3$ was found in all seasons. According to these results, it can be said that there will be no problem in the use of the dam for irrigation purposes and there is no alkali threat for the crops. Similar to the findings obtained here, Şener et al. (2021) reported the average *SAR* values as 1.39. Ehya and Moghadam (2017), in their study, reported good water in 1 sampling point and perfect water in the remaining 5 sampling points. Aydin et al. (2021) reported that the *SAR* (0.53) result of the water quality assessment of the Giresun Terme River, located in the North of Turkey, is suitable for irrigation. *MAR* results were found to be lower than 50 in all seasons and all sampling points except for S5 ($MAR = 61.2$) in autumn and it suggests that the water can be used for irrigation purposes. Finally, *PI* values were found to be in the range of $25 < PI < 75$, which refers to a moderate level of permeability, in all seasons and sampling points. Kutlu and Mutlu (2021) reported a *PI* value of 59.95, which was similar to the values reported here.

Correlation matrix and source determination

The direction and level of relationship between physicochemical parameters of water in the study area were determined using a correlation matrix and the results are presented in Table S3 (supplementary data).

While interpreting the main datasets for Kışla Dam, principal component analysis (PCA) was used to classify the environmental variables and estimate the potential environmental pressures on the water quality. Factor loads were classified as "strong," "moderate," and "weak" for the absolute load values of > 0.75, 0.75–0.50, and 0.50–0.30, respectively (Uncumusaoğlu and Mutlu 2019 2019; Taş et al. 2021). Given the PCA results presented in Table 3,

Table 3 Principal component analysis of physicochemical parameters and heavy metals

Parameters	PC1	PC2	PC3	PC4
NO_3^-	**0.973**	0.081	−0.020	−0.002
Cu	**0.956**	0.101	0.094	0.065
Na^{+2}	**0.911**	−0.017	−0.315	0.084
Pb	**0.906**	−0.280	−0.084	0.133
Zn	**0.885**	0.384	0.070	0.013
Fe	**0.869**	0.029	0.130	0.224
K^+	**0.857**	−0.104	−0.334	−0.065
Hg	**0.799**	0.365	0.315	−0.059
Ca^{+2}	**0.784**	0.397	−0.012	0.018
NO_2^-	**0.763**	0.350	−0.056	0.082
COD	**0.719**	0.619	−0.088	0.089
NH_4^+	**0.665**	−0.037	0.474	−0.006
T	0.125	**0.970**	0.099	0.034
TH	0.297	**0.923**	−0.191	0.028
HCO_3^-	0.305	**0.917**	−0.172	0.040
pH	0.143	**0.915**	−0.030	0.094
Mg^{+2}	0.183	**0.852**	0.409	−0.032
EC	−0.306	**0.839**	0.282	0.007
BOD	0.531	**0.794**	0.112	0.090
Cd	−0.147	**0.764**	−0.003	0.101
DO	0.598	**−0.726**	−0.212	0.072
Cl^-	0.344	**0.638**	0.599	0.046
SO_4^{2-}	0.503	**0.540**	−0.506	−0.219
PO_4^{3-}	−0.002	0.297	**0.915**	−0.024
Ni	0.049	−0.026	**0.788**	0.003
SO_3^{2-}	0.545	0.135	**−0.668**	0.023
Sal	0.212	0.184	−0.002	**0.935**
Eigenvalue	12.274	6.949	3.156	1.001
% Total variance	45.459	25.738	11.689	3.706
Cumulative %	45.459	71.197	82.887	86.593

Parameters marked in bold show high correlation with the Principal component to which they belong four factors having eigenvalues higher than 1 explain 86.59% of the total variance.

Given Table 3, the first component (PC1) is determined by NO_3^-, Cu, Na^+, Pb, Zn, Fe, K^+, Hg, Ca^{+2}, NO_2^-, COD, and NH_4^+ and explains 45.46% of the total variance. Considering the results achieved, the presence of metals in Factor 1, especially the strong correlation between Pb and Fe ($r = 0.799$) (Table S3), can be explained by the water–rock relationship arising from the chemical decompositions (Şener et al. 2021). High correlations between organic parameters including COD, NH_4^+, and NO_3^- and between NH_4^+, NO_3^-, and NO_2^- (NH_4^+-NO_3^-, $r = 0.612$; NO_3^--NO_2^-, $r = 0.747$; $p < 0.01$) can be related to agricultural practices and domestic wastes (Vialle et al. 2011; Uncumusaoğlu 2018). This factor indicates the contribution of non-point source pollution arising from ions and heavy metals due to agricultural flow or atmospheric precipitation or basin geology and soil structure, as well as soil or rock structure (Uncumusaoğlu 2018).

The second component (PC2) explains 25.74% of the total variance and consists of the parameters T, TH, HCO_3^-, pH, Mg^{+2}, EC, BOD, Cd, DO, Cl^-, and SO_4^{2-}. The correlation between EC and TH ($r = -0.839$) and the other parameters measured in the present study (Table S3) showed that these parameters were mainly controlled by the main ions (Khalid 2019; Varol et al. 2022a, b). The correlation between Mg and HCO_3^- ($r = 0.765$) represents the dominance of carbonate mineral decomposition in the aquatic system (Sethy et al. 2016). It can be seen that there were moderate and high levels of correlations between Cl^- and BOD ($r = 0.718$), between Cl^- and pH ($r = 0.581$), and between Cl^- and T ($r = 0.714$).

Factor 3 (PC3) explains 11.69% of the total variance and consists of PO_4^{3-}, Ni, and SO_3^{2-} parameters. The presence of these parameters can be explained by the drainage of agricultural wastes into Kışla Dam as a result of excessive use of fertilizers (Kıymaz and Karadavut 2014). In the third factor, the presence of phosphate indicates the effects of fertilizers and organic wastes (Kutlu and Mutlu 2021). There were a positive and moderate correlation between Ni and PO_4^{3-} ($r = 0.587$) and a negative and moderate correlation between PO_4^{3-} and SO_3^{2-} ($r = -0.569$).

Finally, the fourth factor (PC4) explains 3.70% of the total variance and consists only of the salinity parameter. As can be seen from the percentage, since the water of the dam had no significant salinity, there was no high-level correlation with other parameters (Table S3).

Conclusions

In the present study making use of physicochemical parameters and heavy metal analyses, multivariate statistical methods, GIS, and water quality indices, it was aimed to determine the water quality and usability of Kışla Dam located in Bartın Province in the Black Sea Region of Turkey. Making use of the Piper diagram, usage facies of the water was determined to be fundamental water types of Ca^{2+}-Mg^{2+}-HCO_3^- and Ca^{2+}-HCO_3^-. Anthropogenic and litholytic inputs to the dam are important in monitoring the chemical character of water. Given the water quality indices, *WQI* results indicated a “good water quality” in all seasons other than autumn. Similarly, *OPI* values showed that the sampling points were moderately polluted in autumn. Providing information about heavy metal pollution, *MPI* index values showed good conditions only in winter and slight and moderate pollution levels in other seasons. For all seasons and sampling points, *SAR* and *PI* results showed that the water can be used for irrigation purposes. *MAR* index values showed that only the sampling point S5 in the autumn season might be harmful to the soil. PCA results revealed that the main pollutants were atmospheric factors, and anthropogenic factors in the region. These findings show that the main pollutant sources for dams are affected by agricultural practices and human activities. According to the evaluations, although the dam water quality is in good condition in the current situation, it may be greatly affected by polluting sources and accumulate cumulatively in the future. For this reason, it is recommended to increase the treatment facilities in the region, to switch to a solid waste landfill system, and to limit the use of pesticides in agricultural practices in order to protect the water quality. In addition, oxidation/reduction and microbial activity tests are recommended to evaluate the hydrogeochemistry of the dam.

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Data availability Not applicable.

Declarations

Ethics approval and consent to participate No ethics approval or consent was required for this study.

Consent for publication All authors agreed to submission of the manuscript.

Competing interests The authors declare no competing interests.

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