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Comprehensive Surface Water Quality Appraisal of Divanbaşı Pond (Samsun) Using National and International Standards

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ABSTRACT

This study aims to assess the water quality of the Divanbaşı Pond and evaluate its suitability for irrigation. Monthly water samples were collected from four stations between June 2023 and May 2024. Seventeen physicochemical parameters were analyzed in accordance with the thresholds defined by the Surface Water Quality Regulation of Türkiye (SWQR) and the World Health Organization (WHO) Drinking Water Standards. Furthermore, the pond's water quality was evaluated using several irrigation-related indices, including the Water Quality Index (WQI), Sodium Adsorption Ratio (SAR), Sodium Percentage (Na%), Magnesium Hazard (MH), Kelley Ratio (KR), and Residual Sodium Carbonate (RSC). The mean values recorded were 40.01 for WQI, 1.39 for SAR, 32.79% for Na%, 53.07 for MH, 0.47 for KR, and –4.60 for RSC. Overall, the findings suggest that the Divanbaşı Pond is generally suitable for irrigation purposes; however, the potential accumulation of Mg^{2+} should be monitored.

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Introduction

Water is one of the most important parts of living life, and it is also a basic input for economic sectors such as agriculture, animal husbandry, and aquaculture. However, increasing population, standards brought by modern life, rapid industrialization, unplanned urbanization, as well as excessive and unconscious use of pesticides and fertilizers in agricultural activities, pollute water resources, which are then transported by precipitation and rivers, polluting other underground and surface water resources (Joarder et al., 2008, Valentini et al., 2021). This pollution in water resources causes deterioration in water quality, threatening human health, disrupting the aquatic ecosystem balance, and negatively affecting economic development and social welfare (Ewaid et al., 2018). In this context, periodic monitoring of the quality of water resources and identification of pollutant sources is a critical necessity for both ecosystem health and human use (Anonymous, 2021).The ecological importance of water for living organisms, and its decisive role in ensuring access to clean water, sanitation, and hygiene, as well as its impact on health and development, are included in the targets and indicators within the framework of sustainable development goals accepted by countries (WHO, 2022). In line with these goals, water is stated as a fundamental element that everyone should have access to, while water being a scarce resource in nature also creates a competitive environment (Şimşek & Aydınbaş, 2025).

Numerous studies are being conducted on the causal relationships between sectors that use large amounts of water, such as agriculture, tourism, and industry (Murzakulova et al, 2019; Şimşek &Aydınbaş, 2025). According to a working document published by the Ministry of Agriculture and Forestry as part of the 1st Water Council held in 2021, the annual per capita water amount in Türkiye was 1.347 m^3. This document also stated that, considering population growth and the effects of climate change, Türkiye could be among the countries experiencing water constraints in the coming years (Anonymous, 2021). The General Directorate of Meteorology's 2024 precipitation assessment report noted that Türkiye has an irregular precipitation regime, while the areal precipitation amount in the same year was 537.2 mm, a 6.3% decrease compared to long-term precipitation averages and a 16.3% decrease compared to the previous year (Anonymous, 2024).

Classified among water-stressed countries, Türkiye is vulnerable to desertification, with more than half of its territory experiencing water scarcity (Türkeş, 2021). This situation necessitates the accurate determination and effective monitoring of the quality of existing surface and groundwater resources. Regular monitoring and protection of water quality are of critical importance not only for human health and agricultural production but also for ecosystem balance and economic development. By presenting the current status of the studied water resource, this research aims to contribute to both national and global studies as well as to the achievement of sustainable development goals.

Materials and Methods

Study Area and Water Analyses

The Divanbaşı Pond is located within the boundaries of Kavak District in Samsun Province, approximately 8 kilometers from the district center, at an elevation of about 600 meters (Figure 1). The pond has a surface area of approximately 24 hectares and a maximum storage capacity of 2.10 hm^3. It was commissioned by the Stated Hydraulic Works for irrigation purposes (Yılmaz et al., 2007).

A total of 48 surface water samples were collected monthly from four representative stations at the pond over a 12-month period between June 2023 and May 2024 (Table 1). Sterilized and pre-cleaned plastic bottles were used for sample collection (Valentini et al., 2021).

Dissolved oxygen, pH, water temperature, and electrical conductivity values were measured in situ during sample collection using a portable multiparameter device,YSI 556 MPS. The collected samples were preserved under appropriate conditions and transported to the Central Research Laboratory of Kastamonu University for physicochemical analyses aimed at determining water quality, including biological oxygen demand (BOD_5), chemical oxygen demand (COD), calcium (Ca^{2+}), chloride (Cl^-), magnesium (Mg^{2+}), sulfate (SO_4^{2-}), orthophosphate (PO_4^{3-}), sodium (Na^+), potassium (K^+), total hardness (TH), bicarbonate (HCO_3^-), ammonium-nitrogen (NH_4^+-N) and nitrate-nitrogen (NO_3^--N). The analyses were conducted in accordance with the methods defined by APHA (2005).

The threshold values used in this study were primarily based on the standards specified in the Turkish Surface Water Quality Regulation (SWQR, 2016). For parameters without limits listed in this regulation, values recommended by the World Health Organization (WHO, 2022) were taken into consideration.

Water Quality Index (WQI)

The Water Quality Index (WQI) method aims to classify water based on its purity level by utilizing the evaluated water quality parameters (Brown et al., 1972). In this study, the WQI was calculated following the approach described by Wang et al. (2023) (Equation 1).

$$\mathrm{WQI} = \Sigma[\mathrm{W} \times (\mathrm{C_i}/\mathrm{S_i})] \times 100 \quad (1)$$

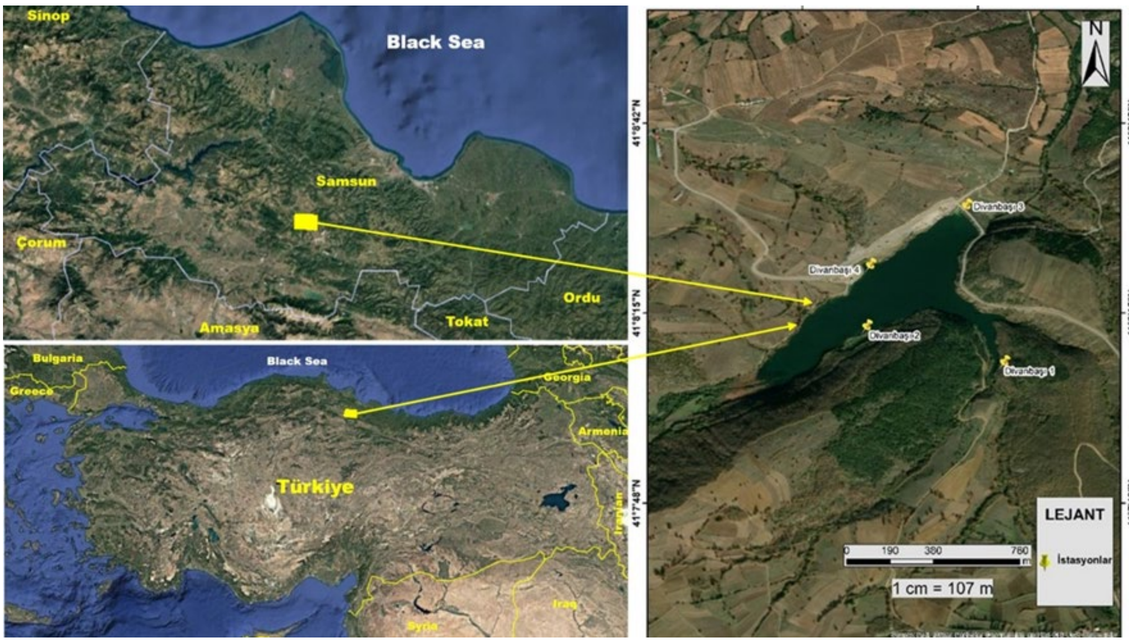

Figure 1. Divanbaşı Pond

Table 1. Coordinates of the stations

Station Number	Latitude Coordinate	Longitude Coordinate
1	41° 8’60.42”N	35°59’37.38”E
2	41° 8’90.81”N	35°59’14.35”E
3	41° 8’28.83”N	35°59’32.00”E
4	41° 8’21.65”N	35°59’19.68”E

Table 2. Standards for irrigation water quality indices (Eaton, 1950; Richards, 1954; Wilcox, 1955; Kelley, 1963)

SAR		Na%		MH		KR		RSC	
0-10	Excellent	<20	Excellent	<50	Suitable	<1	Suitable	<1,25	Good
10-18	Good	20-40	Good	>50	Unsuitable	>1	Unsuitable	1,25-2,50	Doubtful
18-26	Fair	40-60	Permissible					>2,50	Unsuitable
>26	Poor	60-80	Doubtful						
		>80	Unsuitable						

Here, S_i represents the permissible standard value for the *i*th parameter, while C_i denotes the measured concentration of the *i*th parameter in the analyzed water sample. W_i indicates the relative importance assigned to each parameter based on factor loadings derived from Principal Component Analysis (PCA), and it is calculated according to the equation below (Equation 2).

$$W = W_i \;/\; \sum_{i=1}^{n} Wi \quad (2)$$

The obtained WQI values were classified according to specific ranges. Based on this classification, WQI values between 0 and 49 are categorized as Excellent; 50-99 as Good; 100-199 as Poor; 200-299 as Very Poor and values of 300 and above are classified as Unsuitable for drinking water purposes (Brown et al., 1972; Meng et al., 2016).

Irrigation Water Quality Indices

To assess the irrigation water quality of Divanbaşı Pond, the sodium adsorption ratio (SAR), sodium percentage (Na%), residual sodium carbonate (RSC), Kelley ratio (KR) and magnesium hazard (MH) values were calculated using the formulas provided below (Equations 3–7) and classified according to the criteria listed in Table 2.

Units for the parameters used in the calculations were converted from mg/L to meq/L (Eaton, 1950; Richards, 1954; Wilcox, 1955; Kelley, 1963).

$$SAR = \frac{Na^{+}_{meq}}{\sqrt{\frac{Ca^{2+}_{meq}+Mg^{2+}_{meq}}{2}}} \quad (3)$$

$$Na\% = \frac{(Na^{+}_{meq}+K^{+}_{meq})x\ 100}{(Na^{+}_{meq}+Ca^{2+}_{meq}+Mg^{2+}_{meq}+K^{+}_{meq})} \quad (4)$$

$$MH = \frac{(Mg^{2+}_{meq})}{(Ca^{2+}_{meq}+Mg^{2+}_{meq})} \quad (5)$$

$$KR = \frac{(Na^{+}_{meq})}{(Ca^{2+}_{meq}+Mg^{2+}_{meq})} \quad (6)$$

$$RSC = (Alkanity\ x\ 0{,}0333) - (Ca^{2+}_{meq}+Mg^{2+}_{meq}) \quad (7)$$

Statistical Analysis

The IBM SPSS 23 software package was used for data analysis. Based on the normality tests conducted, skewness and kurtosis values within the range of -2.0 to +2.0 were considered indicative of a normal distribution (George & Mallery, 2010). ANOVA tests were applied to determine the significance of differences between stations and months.

Principal Component Analysis (PCA) was employed to determine the weighting of each parameter during the calculation of the WQI. An unrotated component matrix was preferred in this analysis (Yidana et al., 2010; Sutadian et al., 2016).

Additionally, maps related to the pond in the current study were created using ArcGIS Desktop 10.5, Google Earth Pro version 7.3 and Microsoft Office Professional Plus 2021 softwares.

Results and Discussion

Within the scope of the study, the physicochemical water quality of Divanbaşı Pond was examined with reference to the SWQR (2016) and WHO (2022) standards. By the ANOVA test, it was determined that the differences among stations were statistically insignificant ($p>0.05$), whereas differences across months were statistically significant ($p<0.05$) for all parameters. The similarity among stations is thought to be due to the relatively homogeneous geological structure of the pond and the exposure to similar anthropogenic influences, whereas seasonal variations are considered to be driven by factors such as precipitation, surface runoff, snowmelt, temperature fluctuations, and increased biological activity. Similar findings have also been reported by Varol et al. (2012), Edoreh et al. (2019), and Uncumusaoğlu & Mutlu (2019). Additionally, the Water Quality Index (WQI) and irrigation water quality indices (SAR, Na%, MH, KR, RSC) were calculated to assess the suitability of the pond for irrigation purposes.

Dissolved oxygen (DO), an important parameter for aquatic ecosystems, was measured as 9.42 mg/L in this study. According to WHO (2022) criteria, this value is considered suitable, and based on the SWQR (2016) classification, it falls within the very good water quality category (>8 mg/L) (Table 3). Wang et al. (2024) reported that increased dissolved oxygen content in irrigation water positively influences soil structure, bacterial activity, and nutrient uptake by plants. The fact that even the lowest DO value detected in this study exceeds guideline standards indicates that the irrigation water examined is unlikely to cause any adverse effects related to dissolved oxygen throughout the year. This finding is consistent with the results of Kesmez and Dalkıran (2023).

The pond's pH value was determined to be 8.67. This value slightly exceeds the upper limit specified by WHO (2022), but falls within the acceptable range defined by SWQR (2016) (Table 3). The pond water exhibits alkaline characteristics. This result is similar to that reported by Bulut et al. (2011), but lower than findings by Mutlu and Güzel (2024). Elevated pH values may reduce the amount of dissolved oxygen required by aerobic organisms (Dewangan et al., 2023). Therefore, monitoring the pH parameter is important in alkaline waters.

Table 3. Descriptive statistics of the water quality data from Divanbaşı Pond

Parameters	Minimum		Maximum			SWQR	WHO
	Value	Month	Value	Month	Mean±SD	Standarts	Standarts
DO	6.84	May	11.13	Sept.	9.42±1.53	6	6
pH	8.49	Feb.	9.02	Oct.	8.67±0.15	6-9	6.5-8.5
WT	0.63	Feb.	18.93	Sept.	9.14±5.61	-	-
EC	282.40	March	437.28	Oct.	359.00±52.22	1000	1000
COD	0.61	Feb.	2.94	June	1.53±0.69	50	50
BOD_5	0.00	Feb.	1.19	Sept.	0.56±0.40	8	8
Na^+	36.51	June	73.25	Oct.	48.35±12.74	-	200
Cl^-	3.37	Jun	6.69	Dec.	5.37±1.02	-	250
Ca^{+2}	19.61	Janu.	68.01	June	46.12±15.67	-	150
Mg^{+2}	18.88	Janu.	42.60	Oct.	30.51±7.79	-	70
K^+	2.56	Jun	15.72	Oct.	6.09±3.54	-	12
PO_4^{-3}	0.00	Feb.	0.46	Nov.	0.09±0.13	0.16	-
SO_4^{-2}	15.77	Jun.	59.83	Dec.	36.08±13.82	-	250
TH	275.42	Sept.	340.06	Dec.	308.40±20.75	-	-
HCO_3^-	346.40	Sept.	421.65	Dec.	383.61±23.64	-	-
NO_3^-	0.39	Janu.	3.69	Sept.	1.95±1.28	10	50
NH_4^+	0.00004	Janu.	0.00154	Sept.	0.0004±0.001	1	-

Table 4. Descriptive statistics of SAR, Na%, MH, KR and RSC indices

Parameters	Minimum		Maximum		
	Value	Month	Value	Month	Mean±SD
SAR	0.88	Ekim	1.90	Mayıs	1.39±0.37
Na%	20.34	Ekim	45.29	Şubat	32.79±8.46
MH	46.63	Mayıs	62.11	Şubat	53.07±5.37
KR	0.25	Ekim	0.75	Şubat	0.47±0.17
RSC	-6.27	Ekim	-2.34	Ocak	1.53±1.41

Temperature is associated with numerous parameters such as dissolved oxygen content, microbial activity, biological load increase, chemical reaction rates, and salinity in pond water (Ayers & Westcot, 1985; Boyd, 1990). In this study, the average water temperature was measured as 9.14 °C, with the highest temperature recorded in September at 18.93 °C and the lowest in February at 0.63°C.

The electrical conductivity (EC) of the pond water was determined to have an annual average of 359.00 µS/cm. Throughout the year, EC values varied between a minimum of 282.40 µS/cm and a maximum of 437.28 µS/cm. These findings indicate that the pond water falls within the limits set by SWQR (2016) and WHO (2022) (Table 3). EC is considered a critical parameter for agricultural production because it can restrict plant access to water in irrigated soils (Bauder et al., 2011). Additionally, the measured values were found to be below the damage thresholds (<750 µS/cm) proposed by Follett & Soltanpour (1985) and Bauder et al. (2011). The EC values detected in this study are consistent with those reported by Emin & Mutlu (2024).

Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD_5) are essential parameters for assessing organic pollution load in water resources (Galal-Gorchev et al., 1993). The highest COD and BOD_5 values obtained in this study were 2.94 mg/L and 1.19 mg/L, respectively. These values are well below the threshold limits defined by SWQR (2016) and WHO (2022), categorizing the pond water as first-class "very good" quality (COD < 25 mg/L; BOD_5 < 4 mg/L) (Table 3). The results are consistent with those reported by Kutlur & Mutlu (2021) and lower than those found in the study by Du et al. (2024). Du et al. (2024) attributed higher COD and BOD_5 concentrations to the proximity of water resources to urban and industrial areas. The direct discharge of untreated wastewater into water bodies was identified as the primary source of elevated levels.

Sodium in natural waters is commonly present as sodium chloride or calcium carbonate (Kutlu & Mutlu, 2024). Elevated sodium levels can adversely affect soil permeability (Bhateria & Jain, 2016). In this study, sodium concentrations were lowest in June and highest in October (Table 3), aligning with findings reported by Kükrer & Mutlu (2019). Although chloride concentration is generally low in natural waters, it remains an important parameter for agricultural irrigation monitoring (Tepe & Kutlu, 2019). The annual average chloride concentration in this study was found to be 5.37 mg/L, consistent with studies conducted by Kurnaz et al. (2016) (Table 3). Calcium concentration was measured with an annual average of 46.12 mg/L, which aligns with values reported by Ustaoğlu (2020). Magnesium, widely distributed in the earth's crust, influences water hardness (Bhateria & Jain, 2016). Typically found in mineral rocks, magnesium can enter water resources naturally or through anthropogenic activities (Kutlu & Mutlu, 2024). In this study, magnesium concentrations were lowest in January and highest in October (Table 3). All values for sodium, chloride, calcium, and magnesium parameters were below the limit values specified by WHO (2022). Potassium, an essential element for both human and plant nutrition, is generally present in groundwater as a result of mineral dissolution (APHA, 2005). The annual average potassium value measured in this study was within the limits specified by WHO (2022), although the highest value recorded in October exceeded this limit (Table 3). Skowron et al. (2018) reported that local wastewater treatment plants significantly influenced potassium pollution in their study conducted in a river basin. Since there is no wastewater treatment plant in the Divanbaşı reservoir, the potassium increase observed in December is considered to be driven by hydrogeological processes, such as precipitation-induced surface runoff and groundwater inputs, as well as inputs originating from the application of potassium-based fertilizers in agricultural areas. This finding indicates that the seasonal variability of potassium concentrations reflects the combined influence of natural processes and anthropogenic activities.

Phosphorus and nitrogen, primarily in the forms of phosphate (PO_4^{3-}) and nitrate (NO_3^-), are among the most important nutrients in aquatic ecosystems. However, the accumulation of these nutrients in aquatic environments can enhance plant and algal growth, leading to eutrophication. This process causes a reduction in dissolved oxygen levels, consequently degrading water quality and potentially resulting in fish mortality (Rossana, 2013). In this study, the annual average concentrations were found to be below the threshold values reported by SWQR (2016) and WHO (2022) (Table 3). However, phosphate concentrations in October and November were measured at 0.23 mg/L and 0.45 mg/L, respectively. This increase is thought to be associated with the sowing period of annual crops and the surface runoff and groundwater transport of widely and indiscriminately applied chemical fertilizers into the pond during this period. Sulfate ions contribute significantly to salinity in irrigation waters (Bauder et al., 2011). The sulfate concentrations detected in Divanbaşı Pond throughout the year were below the limits specified by WHO (2022) (Table 3). These findings are consistent with results reported by Kutlu & Mutlu (2024). Excessively high bicarbonate concentrations can cause lime deposition, leading to reduced flow rates in water conveyance systems and clogging in agricultural irrigation systems, particularly drip and micro-sprinkler irrigation (Bauder et al., 2011). Isaac et al. (2009) reported that bicarbonate levels in irrigation water should remain below 10 meq/L (~600 mg/L). In this study, bicarbonate content was highest during the peak month and lowest in September. All bicarbonate values measured throughout the year remained below the limit specified by Isaac et al. (2009) (Table 3). Water hardness refers to the concentration of divalent cations in water, primarily calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions (Rossana, 2013). The annual average total hardness (TH) in this study was measured at 308.40 mg/L, consistent with findings reported by Kurnaz et al. (2016) and Kesmez & Dalkıran (2023). Ammonium (NH_4^+), a common nitrogen form found in organic matter and various fertilizers, generally poses no toxic effect except at excessively high concentrations (Rossana, 2013). However, under high temperature and pH conditions, ammonium can convert to ammonia (NH_3), which presents a toxicity risk to aquatic organisms (Mutlu & Uncumusaoğlu, 2022). The ammonium concentrations measured in this study varied throughout the year, remaining below the drinking water limit of 0.5 mg/L recommended by WHO (2022) and TS 266 (2005) in all samples (Table 3).

The risk posed by sodium in irrigation water is evaluated using the sodium adsorption ratio (SAR), which is critical due to its effects on soil physical properties (Korkmaz et al., 2016). High sodium concentrations increase soil osmotic pressure, restricting plant water uptake and causing physiological drought (Zaman et al., 2018).

In this study, the annual average SAR value was calculated as 1.39 (Table 4), classifying the pond's water quality as "excellent" (SAR < 10). These results are in agreement with values reported by Ustaoğlu (2020).

Another parameter used to evaluate the potential effects of sodium in irrigation water is the sodium percentage (Na%), which has notable impacts on soil structure and plant development (Kutlu & Mutlu, 2024). In the present study, the annual average Na% value was determined as 32.79% (Table 4), classifying the water quality as "good." These findings are consistent with the values reported by Kükrer & Mutlu (2019).

Although magnesium is an essential element for plant metabolism, high concentrations in irrigation water can have adverse effects on soil and plant health (Khalid, 2019). In particular, magnesium's replacement of calcium disrupts soil aggregate structure, leading to physical degradation and reduced permeability of the soil (Korkmaz et al., 2016). The Magnesium Hazard (MH) value was calculated as 53.07 in this study, slightly exceeding the recommended threshold for irrigation use (Table 4). These results align with values reported by Ustaoğlu (2020).

Both Na% and MH scores reached or exceeded limits in February, coinciding with the regional rainy period when surface runoff is enhanced. The predominant agricultural activities in the region include cereals (wheat, corn, oats, barley) and crops requiring intensive fertilization (sugar beet, tobacco, potatoes). The Na and Mg contents in commonly used fertilizers (potash salts with Na impurities, magnesia-kainite, magnesium sulfate) likely contribute to this accumulation through agricultural runoff during the rainy season (Anonymous,2025).

The Kelley Ratio (KR), an important parameter for assessing irrigation water quality, is calculated as the ratio of sodium to calcium and magnesium in the water. A KR value below 1.00 is considered suitable for irrigation purposes (Kelley, 1963). In this study, KR values ranged between 0.25 and 0.75 throughout the year (Table 4). Accordingly, the pond water was deemed suitable for agricultural irrigation. These results are consistent with data reported by Aşık & Kapdı (2023).

Residual Sodium Carbonate (RSC), used to evaluate the persistent effects of sodium carbonate in irrigation water, considers values below 1.25 meq/L as suitable for irrigation. RSC values were found to be negative across all stations and months in this study (Table 4), indicating that the pond water is suitable for agricultural irrigation with respect to potential adverse effects from sodium carbonate. These findings are similar to those reported by Mutlu & Uncumusaoğlu (2024).

In the calculation of the Water Quality Index (WQI) for Divanbaşı Pond, nine commonly used parameters affecting soil-water interactions and plant health were included: pH, electrical conductivity (EC), sodium (Na^+), chloride (Cl^-), sulfate (SO_4^{2-}), nitrate (NO_3^-), bicarbonate (HCO_3^-), magnesium (Mg^{2+}), and calcium (Ca^{2+}) (El Tahlawi et al., 2016; Wang et al., 2023; Laoufi et al., 2025).

Table 5. Factor loadings of the parameters and (W_i) weights calculated for WQI with PCA

Variables	PC1	PC2	Wi
Ca^{2+}	0.953	0.115	0.12
NO_3^-	0.947	-0.107	0.11
EC	0.915	-0.292	0.11
pH	0.851	-0.104	0.11
Mg^{2+}	0.844	-0.353	0.10
HCO_3^-	0.827	0.274	0.10
Cl^-	0.747	-0.267	0.09
Na^+	0.229	0.910	0.13
SO_4^{2-}	0.470	0.873	0.13
Eigenvalues	5.594	1.982	
Variance (%)	62.16	22.02	
Cumulative (%)	62.16	84.18	

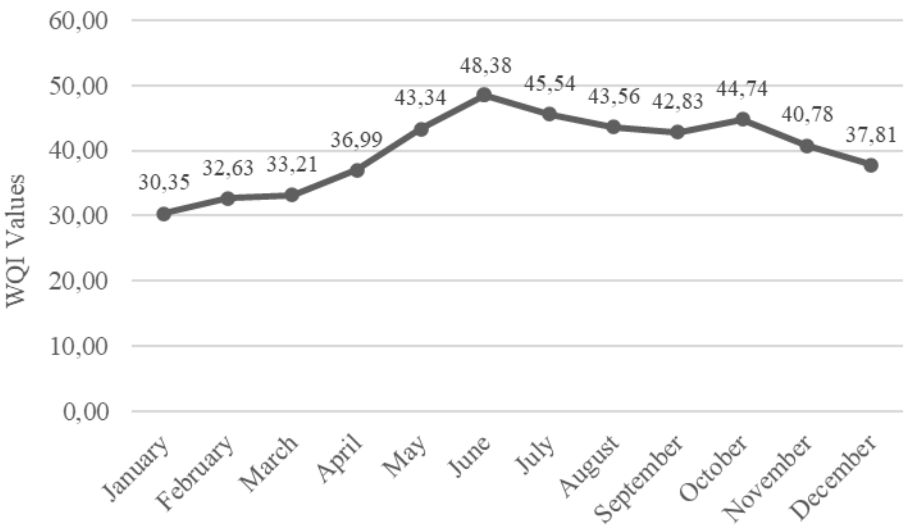

Figure 2. Monthly change of WQI values

The suitability of the data for Principal Component Analysis (PCA) was evaluated using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity (Li et al., 2011; Wang et al., 2017). Prior to PCA, data were standardized using Z-scores (Chen et al., 2007; Helena et al., 2000; Simeonov et al., 2003; Wang et al., 2017). The analysis yielded a KMO value of 0.73 (KMO > 0.50) and a significant Bartlett test ($p<0.001$), indicating the data were suitable for analysis. The weighting coefficients (W_i) used in WQI calculation were determined based on factor loadings obtained from PCA; details of these values are presented in Table 5. The PCA revealed two main hydrochemical processes in Divanbaşı Pond water quality. PC1 (62.16% variance) showed high loadings for Ca^{2+}, NO_3^-, EC, pH, Mg^{2+}, HCO_3^-, and Cl^-, representing "General Mineralization." PC2 (22.02% variance) was dominated by Na^+ and SO_4^{2-}, indicating "Sodium-Sulfate Dominance" from potential specific (domestic, industrial or agricultural) contamination sources. Together, these components explain 84.18% of the total hydrochemical variability.

A total of 48 WQI values were calculated based on data obtained from four different stations during the 12-month monitoring period of Divanbaşı Pond. The WQI values ranged from 30.33 to 48.48 throughout the year (Figure 2). The annual average WQI was determined as 40.01, classifying the pond's water quality as "excellent" for irrigation purposes.

Conclusion

This study conducted at Divanbaşı Pond provides a comprehensive assessment of water quality and irrigation suitability, leading to the following conclusions:

The obtained physicochemical parameters were evaluated according to SWQR (2016) and WHO (2022) standards. Considering the annual average values, the pond water was generally found suitable for drinking and usage purposes. However, potassium (K^+) and phosphate (PO_4^{3-}) concentrations peaked in October and November, likely due to fertilizer application, seasonal hydrogeological processes and increased temperatures. This situation poses a local pollution risk that should be monitored as part of sustainable development goals aimed at improving water quality.

The calculated SAR, Na%, RSC, KR, and WQI values for irrigation water quality assessment generally indicated that the pond water is suitable for agricultural irrigation. However, the Magnesium Hazard (MH) value was slightly above the upper limit of 50, indicating a potential risk of Mg^{2+} accumulation in the soil over time. To preserve soil fertility within the framework of sustainable agricultural practices under sustainable development goals, this accumulation should be monitored, and necessary precautions should be taken before reaching levels that could affect crop yield.

Based on the results obtained in this study, the following recommendations are proposed:

The seasonal increase in pollutants potentially originating from fertilizers in the pond water highlights the impact of agricultural activities on water quality in the region. Therefore, farmer training and awareness programs regarding the use of agricultural inputs could be organized. To minimize nutrient runoff into the ponds, practical fertilizer application guidelines, including timing, dosage, and application methods, could be developed and made available to farmers.

Regular soil and water monitoring programs might be implemented to track potassium and magnesium levels, enabling early intervention before they impact crop yield.Farmer training and awareness programs on sustainable agricultural practices and nutrient management may help reduce anthropogenic impacts on water quality.

Declarations

Ethical Approval Certificate

Ethical approval was not required for this study, as it did not involve any experiments on human participants or animals.

Author Contribution Statement

E.M.: Conceptualization of the study, data collection, analysis and evaluation, preparation of the original draft.

E.S.Ö.: Statistical analyses, interpretation of data, and preparation and submission of the original draft.

Fund Statement

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Conflict of Interest

"The authors declare no conflict of interest."

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