Journal of Limnology and Freshwater Fisheries Research
http://www.limnofish.org

Determination of Surface Water Quality Parameters of Creeks in Mogan Lake Basin (Ankara, Türkiye)

Dijar LATİFİ[1], Serap PULATSÜ[2]*

[1]Ankara Üniversitesi, Fen Bilimleri Enstitüsü, Ankara, Türkiye
[2]Ankara Üniversitesi Ziraat Fakültesi Su Ürünleri Mühendisliği Bölümü, Ankara, Türkiye

ABSTRACT

The present research focuses on assessing the environmentally significant Mogan Lake and its feeder creeks water quality parameters, all of which hold recreational importance for Ankara. In light of the findings, a) The ranking of the creeks based on the average parameter values for each creek over three months is as follows: for TSS and TOC: Gölcük > Başpınar > Sukesen > Yavrucak; for TN: Başpınar > Gölcük > Sukesen > Yavrucak; for TP: Gölcük > Sukesen >Başpınar > Yavrucak, b) Based on dissolved oxygen values, Sukesen and Yavrucak Creeks were classified as Class I water quality, while in terms of pH values, all creek waters were in Class I. However, in terms of total phosphorus, they were classified as Class III water quality, c) TP, TOC were found to be controlled by wastewater reaching Başpınar and Sukesen Creek from both settlements and agricultural activities, while wastewater originating from agricultural activities was found to be directly responsible for DO, TN and TSS levels as in Gölcük and Yavrucak Creeks. In this context, monitoring the high TP, TN and TOC values of four creeks in the basin, which are exposed to multiple stressors, is important to protect the water quality of these creeks and to control their contribution to the eutrophication of Mogan Lake.

Keywords: Water quality parameters, nutrients, total suspended solids, creeks

ARTICLE INFO

RESEARCH ARTICLE

Received : 06.12.2023
Revised : 05.06.2024
Accepted : 03.04.2024
Published : 25.08.2024

DOI:10.17216/LimnoFish.1400821

**** CORRESPONDING AUTHOR***

spulatsu@agri.ankara.edu.tr
Phone : +90 312 596 16 88
Fax : +90 312 318 52 98

Mogan Gölü Havzası'ndaki (Ankara, Türkiye) Derelerin Yüzey Suyu Kalite Parametrelerinin Belirlenmesi

Öz: Bu araştırmada, Ankara açısından rekreaktif öneme sahip Mogan Gölü'nü besleyen Başpınar, Gölcük, Sukesen, Yavrucak Derelerinin yüzey suyu kalite parametrelerinin değerlendirilmesi amaçlanmıştır. Bulgular ışığında; a) Her bir derenin üç aya ilişkin ortalama parametre değerlerine göre sıralaması; AKM ve TOC için: Gölcük>Başpınar>Sukesen>Yavrucak; TN için: Başpınar>Gölcük>Sukesen>Yavrucak; TP için: Gölcük>Sukesen> Başpınar >Yavrucak olarak belirlenmiştir, b) Çözünmüş oksijen değerlerine göre Sukesen ve Yavrucak Dereleri, pH değerleri açısından tüm dere suları I. Sınıf, toplam fosfor açısından ise III. Sınıf su kalitesine sahiptir, c) TP, TOC'un Başpınar ve Sukesen Deresi'ne gerek yerleşim yerlerinden gerekse tarımsal aktivitelerden ulaşan atık sular tarafından kontrol edildiği, tarımsal faaliyetlerden köken alan atık suların ise, Gölcük ve Yavrucak Dere'lerinde olduğu gibi ÇO, TN ve AKM düzeylerinden doğrudan sorumlu olduğu saptanmıştır. Bu bağlamda, birden çok stres etkenine maruz kalan havzadaki dört dereye ilişkin yüksek TP, TN ve TOC değerlerinin izlenmesi, bu derelerin su kalitesini korumak ve Mogan Gölü'nün ötrofikasyonundaki katkılarını kontrol etmek açısından önem taşımaktadır.

Anahtar kelimeler: Su kalite parametreleri, besin elementleri, askıda katı maddeler, dereler

How to Cite
Latifi D, Pulatsü S. 2024. Determination of Surface Water Quality Parameters of Creeks in Mogan Lake Basin (Ankara, Türkiye).10(2): 81-93. doi: 10.17216/LimnoFish.1400821

Introduction

In terms of the sustainability of water resources, the determination and monitoring of water quality characteristics are important. Regular monitoring helps facilitate the provision of real-time data on water quality, thereby contributing to the preservation of public health and the assurance of water resource utilization safety.

Under the current 'Surface Water Quality Management Regulation' in effect in Türkiye, aquatic environments are categorized into water quality classes based on parameters such as pH, conductivity, oil and grease, dissolved oxygen,

chemical oxygen demand, biochemical oxygen demand, ammonium nitrogen, nitrate nitrogen, total kjeldahl nitrogen, total nitrogen, orthophosphate phosphorus, total phosphorus, fluoride, manganese, selenium, and sulfur. In this context, water quality monitoring results related to specific pollutants and priority substances are also evaluated according to the water body category (rivers/lakes, coastal and transitional waters) (TSWQR 2016). As stated in Anonymous (2022), in the Lake District Special Environmental Protection Plan for Gölbaşı, covering the period 2015-2019 and prepared by the General Directorate for Protection of Natural Assets of the Ministry of Environment and Urban Planning, the goal of achieving compliance with the standards set by the Surface Water Quality Management Regulation for Mogan-Eymir Lakes and the creeks feeding these lakes has been established.

The speed of eutrophication, which is a natural process in aquatic systems, gains momentum as a result of land use, sewage, domestic, agricultural and industrial wastewater reaching the water environment. As nutrient inputs continue to be introduced into aquatic systems in this manner, situations that are not suitable for the intended use of aquatic environments may arise. In this context, before starting to solve the eutrophication problem, a comprehensive analysis of nutrient sources should be carried out and separate management strategies should be developed for point, non-point and endogenous sources to control eutrophication (Pulatsü et al. 2014).

Mogan Lake (Ankara), which is one of the inland freshwater ecosystems exposed to eutrophication, is among the important wetlands in Türkiye nominated for Ramsar status. The increasing population, urbanization, changes in land use, sediment transport, the rise in the use of agricultural pesticides, mining activities, and factors like climate change in the lake basin have made year-to-year water-sediment quality changes in the lake inevitable. Since the early 1990s, the lake has possessed the characteristic of being a natural research area for some government institutions and universities, and due to its proximity to Ankara, it continues to be a focal point of interest (Pulatsü and Topçu 2023). Mogan Lake receives very low groundwater input, and the inflow of water into the lake mainly occurs during summers through irregularly flowing creeks, which often dry up. In this context, adverse interventions on the creeks and their beds can potentially impact both the flow rates and water quality conditions of the creeks that feed the lake. During the autumn season of 2022, rainfall across the country occurred below the normal levels and below the levels observed in the previous year. The autumn season rainfall across the country has shown a 27% decrease compared to the normal levels and a 9% decrease compared to the autumn season of the previous year (Anonymous 2023). The reflections of seasonal changes on all surface water resources are also valid for the Mogan Lake Basin.

In this study: a) the aim was to obtain current data related to some physicochemical parameters (water temperature, dissolved oxygen, pH, suspended solids, total phosphorus, total nitrogen, total organic carbon) for four significant creeks - Başpınar, Gölcük, Sukesen, and Yavrucak Creeks - which had been relatively underrepresented compared to other studies conducted in Mogan Lake, b) the water quality classes of creek waters based on the analyzed water quality parameters were determined, c) the estimation of nutrient and suspended solids loads of Sukesen and Yavrucak Creeks was conducted, d) to assess the impact of creek-specific pollutant sources on water quality parameters. It is believed that the findings are important for establishing the current situation in the context of basin-lake management.

Materials and Methods

Study Area

Mogan Lake is situated within the limits of the Gölbaşı Special Environmental Protection Area and is additionally recognized as one of the important wetlands in our nation proposed for Ramsar designation. The groundwater replenishment of Mogan Lake is quite limited, and during the summer months, water inflow primarily happens via sporadically flowing creeks that often run dry. The key screeks within this group include Sukesen, Başpınar, Gölova, Yavrucak, Çolakpınar, Tatlım, Kaldırım, and Gölcük, situated in the eastern-northwestern regions of the basin (Anonymous 2017). In this research, water samples were collected from four chosen creeks, which serve as pollution sources for Mogan Lake and contribute to its inflow (Figure 1).

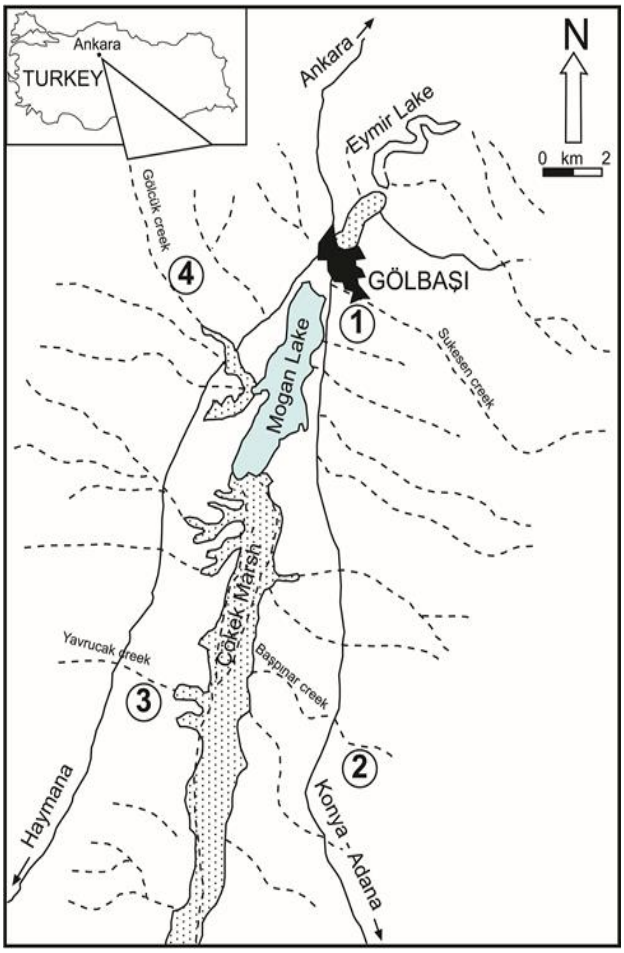
Methods

During this research, three sampling sessions were carried out on the creeks that supply Mogan Lake, precisely in December 2022, February 2023, and April 2023. The choice of sampling months was made by taking into account the potential for substantial rainfall, as indicated by historical meteorological data.

Fieldwork

The water samples were collected in plastic sample bottles after being thoroughly mixed with the surface waters of the mentioned creeks, ensuring there were no air bubbles, and then transported to the laboratory in a cold and dark environment. Water temperature (°C), dissolved oxygen (DO), and pH were measured in the field. Measurements of

DO and temperature were made using a portable oxygen meter (YSI Pro 20; temperature range: 5–45°C, sensitivity: ± 1°C; dissolved oxygen range: 0–15 ppm, sensitivity: ± 0.2 ppm). pH with a portable pH meter (YSI-Ecosense pH 100 A; ± 1°C sensitivity)



1: Sukesen Creek- 39°47,350"N, 32°48,266"E
2: Başpınar Creek- 39°46,616"N, 32°48, 149"E
3: Yavrucak Creek- 39°47,542"N, 32°48,205"E
4: Gölcük Creek-39°45,436"N, 32°45,568" E

Figure 1. Map of the study area and coordinates of the selected creeks

Laboratory work

The unfiltered samples were analysed for total phosphorus (TP), total nitrogen (TN), total organic carbon (TOC) and total suspended sediment (TSS). The analyses were conducted in a laboratory accredited by the Turkish Accreditation Agency (TÜRKAK) with four repetitions, and the methods used in the analyses are presented in Table 1.

Table 1. Methods used in creek water analyses

Parameters	**Methods**
Total phosphorus (TP)	TS EN ISO 17294-1.2
Total nitrogen (TN)	SM 4500 Norg B, SM 4110 B
Total organic carbon (TOC**)**	TS 8195 EN 1484
Total suspended solids (TSS**)**	SM 2540 D

Load estimation

To determine the loads of TP, TN, TOC, and TSS transported to Mogan Lake by the creeks, discharge values for these creeks are required. However, the latest records regarding creek discharge measurements in the basin are only available for Sukesen and Yavrucak Creeks, and they date back to the year 2008. In this context, the average flow values reported by Kapan (2011) were used for calculating the load values of the parameters. These values for December, February, and April are as follows (m^3): Sukesen Creek: 0.011, 0.013, 0.017 and Yavrucak Creek: 0.002, 0.012, 0.085 respectively. The load values for the same months were determined by multiplying the concentration values of the parameters by the daily discharge values.

Statistical analyses

The presence of a significant difference between the measurement-concentration values of parameters across months and creeks was tested using the Kruskal-Wallis test. The difference between which months and creeks were found was determined by Tukey test, one of the post hoc multiple comparisons tests. The presence of a significant relationship between the measurement-concentration values of parameters was obtained using the Spearman correlation coefficient. The correlation coefficient is interpreted as the direction, amount and strength of the relationship between two variables. The amount of the relationship varies between - 1.00 and + 1.00. As for the strength of the relationship correlations between 0.00 and 0.30 are considered low, correlations between 0.31 and 0.70 are moderate, and correlations between 0.70 and 1.00 indicate a high level of relationship between the two variables. In this study, Principal Component Analysis/Factor Analysis (PCA/FA) with varimax rotation was conducted to identify potential sources of water quality parameters. To determine the appropriate dataset for PCA, the Kaiser-Meyer-Olkin (KMO) and Bartlett's sphericity tests were performed. The KMO is a measurement of the acceptability of sampling since it indicates the common variance that might be induced by underlying factors. If the KMO value is close to 1, it suggests that the samples are acceptable, or PCA might be more effective (Kolassa 2020). All statistical analyses were performed by using SPSS 22.

Results

Within the scope of the study, the water temperature values of all the creeks in February and April were statistically significant ($P < 0.05$). The dissolved oxygen values also showed statistically significant differences across months in all creeks ($P < 0.05$). Minimum oxygen values in all creeks were measured in April. The pH values varied between 5.61 and 8.61 during the sampling months. The results of water temperature, dissolved oxygen and pH for the average values of the three months measured on the basis of creeks are shown in Figure 2.

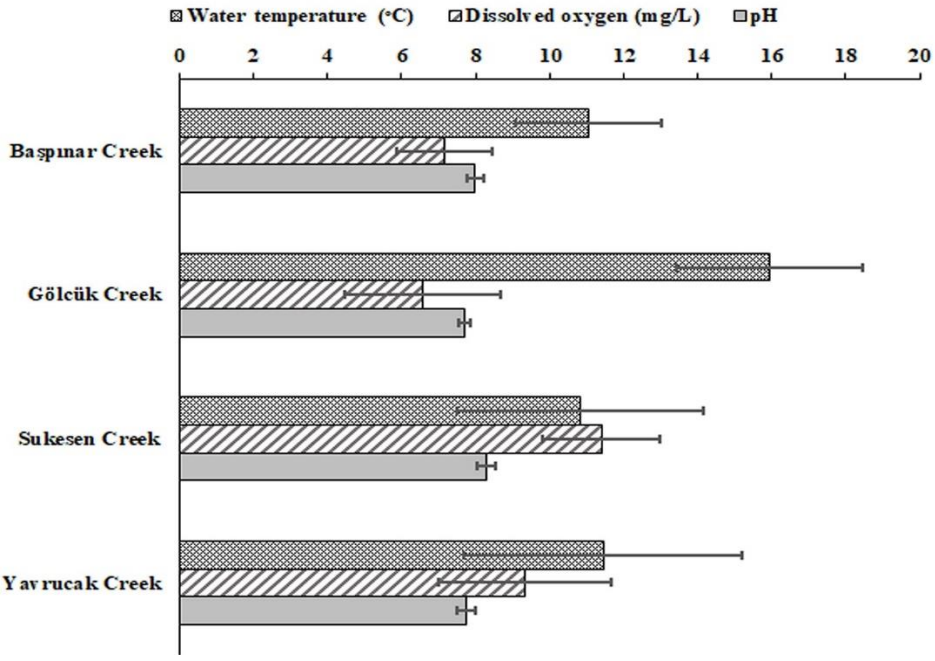


Figure 2. Seasonal variations in water temperature, dissolved oxygen, and pH values for creeks

The monthly variation in total suspended solids values was found to be statistically significant for each river ($P < 0.05$). Maximum total suspended solids values were determined as 23.45 and 3.38 mg/L in Başpınar and Yavrucak Creeks in December, respectively, and 40.30 and 19.63 mg/L in Gölcük and Sukesen Creeks in April, respectively. According to the values in Table 2, minimum TSS values were determined in February in Başpınar, Sukesen and Yavrucak creeks and in December in Gölcük creek. In terms of this parameter, the difference between the creeks in December and February was found to be statistically significant ($P < 0.05$).

As seen in Table 2, the monthly variation of total nitrogen in all creek waters was statistically significant ($P < 0.05$) The maximum total nitrogen value of 8.64 mg/L was determined in Gölcük Creek in April, while the minimum value (0.92 mg/L) belongs to Yavrucak Creek. In terms of this parameter, the difference between the creeks in February and April is statistically significant.

Table 2. Variation of water quality characteristics by months and creeks

		Months		
		December	**February**	**April**
Creeks	**Parameters**	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
Başpınar	TSS	$23.45 \pm 0.57^{aA*}$	16.13 ± 0.25^{bA}	19.18 ± 0.30^{cA}
	TN	6.10 ± 0.12^{aA}	6.75 ± 0.14^{bA}	7.29 ± 0.13^{cA}
	TP	0.07 ± 0.01^{aA}	51.40 ± 1.90^{bA}	18.90 ± 0.91^{cA}
	TOC	3.10 ± 0.11^{aA}	33.33 ± 0.40^{bA}	2.01 ± 1.18^{aA}
Gölcük	TSS	12.15 ± 0.41^{aB}	34.68 ± 0.38^{bB}	40.30 ± 0.42^{cB}
	TN	0.99 ± 0.05^{aB}	8.02 ± 0.08^{bB}	8.64 ± 0.06^{cB}
	TP	0.27 ± 0.02^{aB}	22.99 ± 0.98^{bB}	236.95 ± 3.21^{cB}
	TOC	$5.40 \pm 0.20B^{aB}$	36.60 ± 1.44^{bB}	2.75 ± 0.63^{cA}
Sukesen	TSS	7.50 ± 0.36^{aC}	2.63 ± 0.17^{bC}	19.63 ± 0.22^{cA}
	TN	2.19 ± 0.07^{aC}	4.49 ± 0.01^{bC}	1.00 ± 0.03^{cC}
	TP	0.07 ± 0.01^{aA}	77.45 ± 1.77^{bC}	4.20 ± 0.22^{cC}
	TOC	3.25 ± 0.61^{aA}	29.70 ± 0.86^{bC}	1.91 ± 1.00^{aA}
Yavrucak	TSS	3.38 ± 0.40^{aD}	1.25 ± 0.13^{bD}	1.28 ± 0.17^{bC}
	TN	3.08 ± 0.04^{aC}	2.95 ± 0.04^{bD}	0.92 ± 0.01^{cC}
	TP	0.01 ± 0.00^{aC}	3.99 ± 0.34^{bD}	2.49 ± 0.33^{cC}
	TOC	3.42 ± 0.22^{aA}	23.58 ± 2.17^{bD}	2.53 ± 0.89^{aA}

*The different lower-case letters in the same row show the differences between months in the same creek, while the different capital letters in the same column show the differences between the creeks at the same month ($P < 0.05$)

Monthly variation of total phosphorus values for each creek water was found to be statistically significant ($P < 0.05$). The minimum total phosphorus values in all creeks ranged between 0.01-0.27 mg/L and were measured in December. The highest total phosphorus value determined during the study period was 236.95 mg/L in April in Gölcük Creek (Table 2).

The total organic carbon values of all creeks showed a statistically significant difference in February ($P < 0.05$), while in April, there was not a statistically significant difference among the creeks in terms of this parameter ($P > 0.05$).

The limited number of study findings related to the considered creeks in this research are presented in Table 3. It is observed that the total phosphorus concentration values, total phosphorus concentration values have increased approximately 100 times in all creeks over the years and the ranking of creeks carrying excessive phosphorus changed depending on the type of point and non-point pollution sources affecting creek waters.

Table 3. Results of studies conducted in different periods at Mogan Lake (Total phosphorus-TP, total suspended solids-TSS, total nitrogen-TN)

Creeks	TP (mg/L)	Period	Reference
Başpınar	0.712	1992-1994	Pulatsü and Aydın (1997)
Gölcük	-		
Sukesen	0.325		
Yavrucak	0.478		
Başpınar	-	March 1997-April 1998	Burnak and Beklioğlu (2000)
Gölcük	0.198		
Sukesen	0.143		
Yavrucak	0.336		
Başpınar	0.712	January-December 2003	Fakıoğlu and Pulatsü (2005)
Gölcük	-		
Sukesen	0.292		
Yavrucak	0.478		

Creeks	TP (mg/L)	TSS (mg/L)	Period	Reference
Başpınar	0.22-0.66	108-227	July-1999 October-1999	Karakoç et al. (2003)
Gölcük	0.10-0.13	747-166		
Sukesen	0.35-0.07	< 10-18		
Yavrucak	0.27-0.7	190-85		

Creeks	TP (mg/L)	TSS (mg/L)	TN (mg/L)	Period	Reference
Başpınar	0.06	12.49	2.87	January-December 2008	Kapan (2011)
Gölcük	-	-	-		
Sukesen	0.55	330	11.08		
Yavrucak	0.13	48	2.69		
Başpınar	23.46	19.58	6.71	December 2022, February, April 2023	This study
Gölcük	86.73	29.04	5.88		
Sukesen	27.24	9.92	2.56		
Yavrucak	2.16	1.97	2.31		

In Table 4, water quality classifications for four rivers considered are presented. According to the Turkish Surface Water Quality Regulation (TSWQR 2016), Class I water quality waters are high quality waters and include surface waters with high potential to be drinking water, waters that can be used for recreational purposes including those requiring body contact such as swimming, waters that can be used for trout production and waters that can be used for animal production and farm needs. Within the scope of the study, among the parameters considered, Sukesen and Yavrucak creeks fall into Class I in terms of dissolved oxygen values, while all creek waters meet Class I water quality standards in terms of pH values. Under the same regulation, Class II waters, which are classified as slightly polluted waters, encompass waters that meet both Class I water quality standards and the irrigation water quality criteria determined by the relevant legislation for irrigation purposes. Başpınar and Gölcük Creeks are classified into this category based on their dissolved oxygen and total nitrogen values. Class III waters, classified as polluted waters, can be used for aquaculture and industrial purposes after suitable treatment, excluding facilities requiring high-quality water such as those in the food and textile industries. Within the scope of the study, the total phosphorus values of all creek waters considered indicate Class III water quality.

Table 4. Quality classes in creek waters according to the Turkish Surface Water Quality Regulation (TSWQR 2016)

	Water quality classes			This study			
Parameters	**I**	**II**	**III**	**B***	**G**	**S**	**Y**
Dissolved oxygen (DO) (mg/L)	> 8	6	< 6	II	II	I	I
pH	6-9	6-9	6-9	I	I	I	I
Total phosphorus (TP) (mg/L)	< 0.08	0.2	> 0.2	III	III	III	III
Total nitrogen (TN) (mg/L)	< 3.5	11.5	> 11.5	II	II	I	I

Load estimation results

The results regarding the TP, TN, TOC and TSS loads transported to Mogan Lake through the Sukesen and Yavrucak Creeks are presented in Figure 3. As can also be seen from the figure, in Sukesen Creek, the TSS load value is higher in April, while the TP load value is higher in February compared to Yavrucak Creek. In Yavrucak Creek, especially the TN and TOC load values are considerably higher than those in Sukesen Creek in April. The increase in flow values, in parallel with the increase in precipitation, seems to have led to an increase in the loads of the respective parameters, depending on the pollution sources of both creeks.

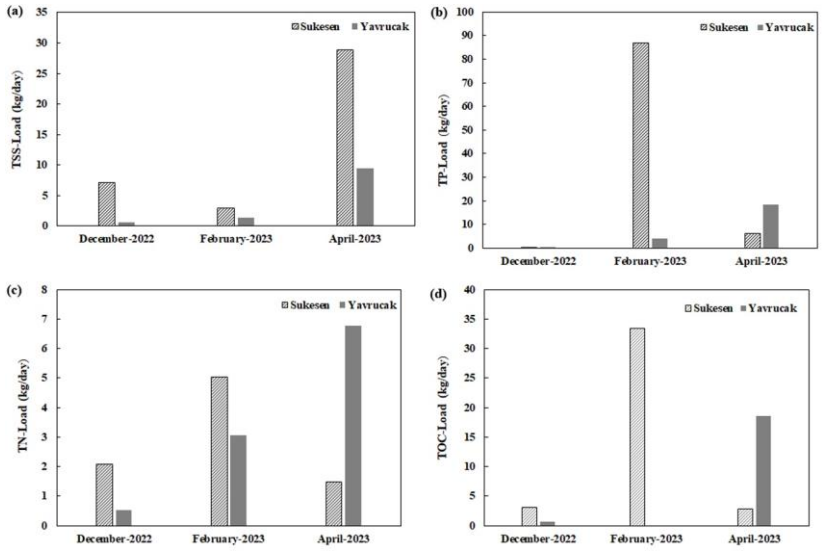


Figure 3. TSS, TP, TN and TOC loads for the Sukesen and Yavrucak Creeks

Correlation analysis

The Spearman correlation coefficient was used to determine whether there was a significant relationship between the measurement-concentration values of the 7 parameters considered in the study (Table 5). There is a moderately significant negative (opposite) relationship between water temperature and dissolved oxygen which is -0.564. In other words, as water temperature increases, the dissolved oxygen values decrease, which aligns with the phenomenon that dissolved oxygen in surface waters is primarily controlled by water temperature. Additionally, the positive correlation of 0.615 between pH values and dissolved oxygen indicates a moderately significant relationship. As can be seen in Table 5, it was found at the correlation between total nitrogen and total suspended solids was found to be at the highest level (0.647) compared to other parameters ($P < 0.05$). Furthermore, the correlation between total phosphorus and total suspended solids, total nitrogen, and total carbon was also found to be significant ($P < 0.05$). The statistically significant correlations among the mentioned four parameters indicate that these parameters likely originate from similar sources.

Table 5. Spearman correlation matrix analysis for all water quality parameters in the studied creeks

		Water temperature	DO	pH	TSS	TN	TP	TOC
Water temperature	r	1.000						
	p							
DO	r	-.564*	1.000					
	p	.000						
pH	r	-.328*	.615*	1.000				
	p	.023	.000					
SS	r	.196	-.152	.040	1.000			
	p	.183	.301	.788				
TN	r	-.079	-.169	-.068	.647*	1.000		
	p	.595	.249	.644	.000			
TP	r	.070	-.213	-.081	.324*	.581*	1.000	
	p	.634	.147	.585	.025	.000		
TOC	r	-.276	-.064	-.395*	-.114	.232	.311*	1.000
	p	.057	.664	.005	.440	.113	.032	

*P < 0.05

Possible sources of parameters in creeks

Factor analysis using the Principal Components method was conducted to determine the factorial structure of the seven measurements taken from Başpınar Creek. A KMO statistic value greater than 0.50 suggests the adequacy of sample size. Barlett's sphericity test assesses the suitability of the data for factor analysis, and a Sig. value lower than 0.05 is expected. According to Table 6, two factors with eigenvalues greater than 1 were found. The seven separate measurements were grouped into two subgroups. In the first factor, TP, TOC, TSS, and pH measurements were present, and these four measurements accounted for 62% of the measured structure. In the second factor, DO, water temperature, and TN measurements were included. Upon examining the factor loadings, it is evident that the TP measurement in the first factor is the most influential parameter for Başpınar Creek, and it has a negative direction. This result supports that the parameters TP and TOC are the most adversely affected by the pollution of this creek, particularly from wastewater originating from residential areas and agricultural activities. In the factor analysis conducted for Gölcük Creek, the first factor includes DO, TN, and TSS measurements, and these three measurements account for 61% of the measured structure. In the second factor, water temperature, TOC, TP, and pH measurements are included. In this context, the DO, TN, and TSS values for Gölcük Creek appear to be the parameters most affected by the pollution level of this creek particularly in the region where agricultural activities are intensive (Table 7).

Table 6. Total variance explaind and component matrixes for water quality parameters in Başpınar Creek

Component	Initial Eigenvalues			Variables	Component	
	Total	% of Variance	Cumulative %		1	2
1	4.308	61.541	61.541	TP	**-.996**	
2	2.583	36.907	98.448	TOC	**-.948**	.315
3	.061	.869	99.317	TSS	**.942**	.327
4	.040	.576	99.892	pH	**.884**	.448
5	.004	.059	99.951	DO		**.956**
6	.002	.025	99.976	Water temp.		**-.952**
7	.002	.024	100.000	TN	-.326	**-.931**

Extraction Method: Principal Component Analysis.

KMO=0.636 Bartlett's Test of Sphericity: Chi-Square=171.048 Df=21 Sig:0.000

Table 7. Total variance explained and component matrixes for water quality parameters in Gölcük Creek

Component	Initial Eigenvalues			Variables	Component	
	Total	% of Variance	Cumulative %		1	2
1	4.275	61.067	61.067	DO	**.993**	
2	2.551	36.438	97.505	TN	**.989**	
3	.168	2.404	99.909	TSS	**.965**	
4	.005	.073	99.982	Water temp.		**.990**
5	.001	.011	99.993	TOC	.502	**-.863**
6	000	.005	99.998	TP	.512	**.852**
7	.000	.002	100.000	pH	.549	**.754**

Extraction Method: Principal Component Analysis.

KMO=0615 Bartlett's Test of Sphericity: Chi-Square=224.997 Df=21 Sig:0.000

According to the results of the factor analysis conducted for Sukesen Creek, two factors with eigenvalues greater than 1 were found (Table 8). In the first factor, all parameters except dissolved oxygen were included, and it was determined that the contribution of wastewate for Yavrucak Creek waters, there is a significant contribution, especially on water temperature, TSS, DO, TP, and TN measurements (Table 9). Sukesen Creek was particularly high in terms of TOC and TP measurement values. In this context, it can be mentioned that the Yavrucak creek, where wastewater from agricultural activities reaches, has a negative impact on TSS and TP parameters.

Table 8. Total variance explained and component matrixes for water quality parameters in Sukesen Creek

Component	Initial Eigenvalues			Variables	Component	
	Total	% of Variance	Cumulative %		1	2
1	5.583	79.753	79.753	TOC	**.984**	
2	1.405	20.069	99.821	TP	**-.969**	
3	.008	.116	99.937	pH	**.957**	
4	.003	.049	99.987	TN	**.887**	.458
5	.001	.007	99.994	Water temp.	**.844**	.536
6	.000	.004	99.999	TSS	**-.729**	-.683
7	.000	.001	100.000	DO		**1.000**

Extraction Method: Principal Component Analysis.

KMO=0.665 Bartlett's Test of Sphericity: Chi-Square=260.613 Df=21 Sig:0.000

Table 9. Total variance explained and component matrixes for water quality parameters in Yavrucak Creek

Component	Initial Eigenvalues			Variables	Component	
	Total	% of Variance	Cumulative %		1	2
1	4.418	63.108	63.108	Water temp.	**-.992**	
2	2.487	35.523	98.631	TSS	**.947**	
3	.037	.535	99.165	DO	**.937**	-.342
4	.036	.507	99.673	TP	**-.788**	.599
5	.020	.279	99.952	TN	**.750**	.656
6	.003	.041	99.993	pH		**-.982**
7	.000	.007	100.000	TOC		**.972**

Extraction Method: Principal Component Analysis.

KMO=0.731 Bartlett's Test of Sphericity: Chi-Square=169.509 Df=21 Sig:0.000

Discussion

Anthropogenic factors in the Mogan Lake basin include the presence of a number of industrial facilities (such as aluminum coating factory, tile factory, machinery factories) due to the efficient highway transportation, unplanned housing development in parallel with the increasing population around the lake, the presence of hobby gardens increasing in number due to its proximity to Ankara as well as agricultural activities, andesite and quarries in operation. It is clear that the creeks that reach the lake by carrying the wastewater of all these elements also play a role in the pollution of the lake. This is in line with many recent studies in which pollution caused by surface waters flowing into inland water ecosystems in Türkiye originates from different anthropogenic sources (Anonymous 2013; Zeybek and Kalyoncu 2016; Tepe and Aydın 2017; Varol and Tokatlı 2023).

The temperature of surface waters is affected by latitude, altitude, season, time of day, air circulation, water flow and depth. Water temperature plays a significant role in determining the interaction and concentration levels of all water quality characteristics, especially the solubility of oxygen in water. As water temperature and salinity increase, the solubility of oxygen in water decreases (Pulatsü et al. 2014). It was determined that dissolved oxygen was generally low in the months when high temperatures were observed in the considered creek waters. The pH level, which is the measure of hydrogen ion concentration in waters, varies according to seasons and different times of the day, and it is observed that the pH measurement values in December are lower compared to the other two months (Figure 2).

Acceptable levels of total suspended solids (TSS) in water quality vary depending on the intended use of the water and represent the measure of the concentration of suspended particles in the water,

including organic and inorganic matter. Lai et al. (2013) categorized the waters based on the TSS value (mg/L) as follows: non-polluted <20; slightly polluted: 20-49; moderately polluted: 50-100; gross-polluted:>100. In this context, when considering average TSS values for all months, only Gölcük Creek (29.04 mg/L) falls into the 'slightly polluted' category. Our finding that Başpınar and Gölcük Creeks have higher TSS levels compared to the other two creeks is similar to the findings of Karakoç et al. (2003). However, the TSS values for Sukesen and Yavrucak Creeks were found to be lower than the values reported by Kapan (2011) (Table 3).

While the total organic carbon concentrations in surface waters are generally less than 10 mg/L, anthropogenic activities have a significant impact on the organic carbon budgets of aquatic ecosystems (Pulatsü et al. 2014). Especially the melting of snow, surface runoff from agricultural lands, domestic and industrial wastewater discharges, as well as rainwater overflows, can lead to significant increases in the levels of total and dissolved organic carbon in surface waters. In this study, it is thought that the maximum values of total organic carbon in creek waters, especially in February, are related to the increased surface runoff due to precipitation. In addition, Gölcük Creek has the highest TOC value (14.92 mg/L) based on the average of the three sampling months. This parameter gives an idea about the total pollution of dense organic compounds reaching this creek.

Çiçek et al. (2023) have indicated that the middle and lower sections of the Simav River (Susurluk Basin) are influenced by pollution originating from intensive agriculture, livestock farming, domestic, and industrial wastewater, and that pollution pressure has also started to increase in the upper sections. The increases observed in total phosphorus and total nitrogen concentrations in the creeks feeding Mogan Lake over the years (Table 3) are in parallel with the increase in settlement, industrial and agricultural activities in the basin. Over the years in the lake basin, it has been observed that anthropogenic activities have led to changes in hydrology. The dramatic increases in total phosphorus concentrations, especially among the parameters considered in the study, are noteworthy. It is clear that more effective reduction and management measures specific to this parameter are a necessity.

In the river mouth section of the Red River, a typical example of Southeast Asian rivers, a significant positive correlation (r^2 = 0.0757) was found between TSS and TP concentrations (Da et al. 2020). In this study, a moderate correlation (r= 0.581) was found between TP and TSS, while a positive high correlation (r = 0.647) was observed between TN and TSS. The result that TP and TN concentration levels in water samples from creeks in four geographical regions and seven provinces of Canada are positively correlated with the percentage of agricultural land in the watershed (Chambers et al. 2012) is in line with the result that the average three-month TP and TN values of Gölcük and Başpınar creeks, which pass through the region where agricultural activities are intense, are found to be high. The same researchers reported predefined trigger ranges according to the Canadian Council of Ministers of the Environment as follows: oligotrophic: ≤ 0.025 mg/L TP and ≤ 0.70 mg/L TN; mesotrophic: 0.025 to 0.075 mg/L TP and 0.70 to 1.5 mg/L TN; eutrophic: ≥ 0.075 mg/L TP and ≥ 1.5 mg/L TN. According to this, it is observed that all the creek waters considered in our study have eutrophic nutrient levels on a monthly average basis.

In surface water resources, several studies were conducted to assess spatial-temporal water quality changes and identify the main sources of pollution (Kagalou et al. 2001; Barakat et al. 2016; Chounlamany et al. 2017). The common point of these studies is related to estimating the sources of the parameters that characterize water quality (temperature, pH, EC, turbidity, total suspended solids, dissolved oxygen, ammonium, ammonia, total phosphorus, biological oxygen demand, chemical oxygen demand, etc.). In this study, the creeks feeding the lake originate from different pollutant sources. For example, Yavrucak and Gölcük Creeks transport pollutants primarily associated with agricultural activities to the lake, while Sukesen Creek carries pollutants from quarries and settlements, and Başpınar Creek conveys pollutants originating from residential areas and agricultural activities to the lake. In this context, changes in creek water quality are primarily believed to be associated with point source pollution (such as domestic and industrial wastewater), non-point source pollution (like agricultural activities), and natural processes (soil erosion). According to the results of the factor analysis conducted within the scope of the study, it can be said that TP and TOC are controlled by wastewater from both residential areas and agricultural activities in Başpınar and Sukesen Creeks. Both parameters are directly affected by urbanization and land use. Wastewater originating from agricultural activities was found to be directly responsible for DO, TN and TSS levels as in Gölcük and Yavrucak creeks. Nevertheless, the fact that Başpınar Creek enters Çökek Wetland before flowing into Mogan Lake provides an important advantage in terms of its contribution to the eutrophication of the lake. Furthermore, it is believed that the increases in various pollutant sources in the basin affect the

transport and diversity of nutrients in the creeks over the years.

Within the scope of this study, the estimated TSS and TP load values for Sukesen Creek also reflect the impact of quarries, in addition to domestic-oriented wastewater. The high TN and TOC load values for Yavrucak Creek indicate the significant amount of organic pollutants carried by agricultural-origin wastewater reaching this creek. Similar results were presented in various other studies. For example, it was reported that the wastewater from the Akçalar Town, located on the shores of Lake Uluabat, carried nutrient elements and suspended solids load to the Akçalar Creek (Musa Creek) and ultimately to Lake Uluabat (Katip et al. 2013). Similarly, it was reported that Solaklı and Sürmene Creeks in Trabzon and several other rivers flowing into the Black Sea carried nutrient elements and suspended solids loads into the sea (Boran and Sivri 2001). It was also reported that ten rivers flowing into Lake Hazar carried nutrient elements and suspended solids loads to the lake (Şen et al. 2002).

In Türkiye, numerous studies (Şen and Gölbaşı 2008, 2014; Baytaşoğlu and Şen 2015; Turan and Ülkü 2013; Gölbaşı and Şen 2019) were conducted to determine the water quality classes of surface waters that carried pollution loads to inland water sources such as lakes and reservoirs in different years. Our study findings, indicating that the dissolved oxygen and total nitrogen values for Sukesen and Yavrucak Creeks, as well as the pH values for all creeks, fall into Class I according to the Surface Water Quality Regulation, align with the results of studies on saline water sources within the Van Lake Basin (Atıcı et al. 2021) and Tersakan Creek in Muğla, which generally fall into the high-quality water class (Kasımoğlu and Yılmaz 2014). Our finding that all the creeks considered in the study fall into the category of polluted waters in terms of total phosphorus concentration supports the presence of potentially threatening pollutants in these creeks.

Within the scope of this study, the diversity of anthropogenic pollutant sources in the Mogan Lake Basin and the effects of uncontrolled increases were revealed through adverse changes in water quality parameters in the creeks. Significant increases, particularly in nutrient values compared to previous years, were detected, and this situation appeared to be related to factors such as land management practices (such as soil tillage methods, drainage applications, types of fertilizers) and climate change. Additionally, the control of water quality parameters in the creeks is challenging due to the diversity of factors contributing to pollution and the complex interactions among these factors. In this context, the development and use of seasonal and discharge-related regression models based on the monthly and yearly concentrations of the parameters considered in the study will be beneficial for making long-term predictions aimed at controlling the eutrophication level of Mogan Lake.

References

Anonymous. 2013. Eğirdir Gölü'nde Kirlilik Durumu ve Kirlilik Kaynakları Modelleme Çalışması. Yedi Renkli Göle Yedi Renkli Hayat Projesi (Doğal Hayatı Koruma Vakfı), İstanbul, Türkiye. 36 s.

Anonymous. 2017. Göller ve Sulak Alanlar Eylem Planı. 2017-2023. T.C. Orman ve Su İşleri Bakanlığı, Su Yönetimi Genel Müdürlüğü, Ankara (in Turkish). 194 s.

Anonymous. 2022. Gölbaşı Özel Çevre Koruma Bölgesi Yönetim Planı. [Erişim tarihi: 8 Temmuz 2022]. Erişim Adresi: http://webdosya.csb.gov.tr/db/tabiat/editordosya/golbasi_yonetim_planı (in Turkish). 130 s.

Anonymous. 2023. 2022 Yılı Yağış Değerlendirmesi. [Erişim tarihi: 18 Ocak 2023]. Erişim Adresi: http://mgm.gov.tr/FILES/arastirma/yagis-degerlendirmesi/2022

Atıcı, A. A., Sepil, A. & Şen, F. 2021. Van Gölü Havzası tuzlu sularının su kalitesi özellikleri ve ağır metal kirlilik indeksinin belirlenmesi. Ege Üniversitesi Ziraat Fakültesi Derg. 8 (2):285-294. doi: 10.20289/zfdergi.750813

Barakat AA, El Baghdadia M, Raisa J, Aghezzafb B, Slassi M. 2016. Assessment of spatial and seasonal water quality variation of Oum Er Rbia River (Morocco) using multivariate statistical techniques. International Soil and Water Conservation Res. 4:284–292. doi: 10.1016/j.iswcr.2016.11.002

Baytaşoğlu H, Şen B. 2015. Keban Baraj Gölü'ne dökülen Haringet Çayı'nın su kalite özelliği üzerine bir araştırma. Fırat University Journal of Sci. 27 (2):17-28.

Boran M, Sivri N. 2001. Trabzon (Türkiye) İl sınırları içerisinde bulunan Solaklı ve Sürmene Derelerinde nütrient ve askıda katı madde yüklerinin belirlenmesi. E.U. Journal of Fisheries & Aquatic Sci. 18 (3-4):343–348.

Burnak S.L, Beklioğlu M. 2000. Macrophyte-dominated clearwater state of Lake Mogan. Turk J. Zool. 24:305-313.

Chambers PA, McGoldrick DJ, Brua RB, Vis C, Culp JM, Benoy GA. 2012. Development of environmental thresholds for nitrogen and phosphorus in streams. J. Environ. Qual. 41:7–20. doi: 10.2134/jeq2010.0273

Chounlamany V, Tanchuling MA, Inoue T. 2017. Spatial and temporal variation of water quality of a segment of Marikina River using multivariate statistical methods. Water Science & Tech. 76:1510-1522. doi: 10.2166/wst.2017.279

Çiçek NL, Güçlü SS, Erdoğan Ö, Küçük F. 2023. Water quality assessment of Simav River (Susurluk Basin/Turkey) according to seasons and stations. International Journal of Computational and

Experimental Science and Engin. (IJCESEN), 9 (2):68-80.

Da LN, Quynh LTP, Binh PTX, Thuy DT, Thu TH, Hai NT, Huong N.T.A. 2020. Establishing an empirical equation for the relationship between total suspended solids and total phosphorus concentrations in the downstream Red River water. Vietnam Journal of Marine Science and Tech. 20 (3):325–332. doi: 10.15625/1859-3097/20/3/14789

Fakıoğlu Ö, Pulatsü S. 2005. Mogan Gölü'nde (Ankara) bazı restorasyon önlemleri sonrası dış kaynaklı fosfor yükünün belirlenmesi. Yüzüncü Yıl Üniversitesi Ziraat Fakültesi Derg. 15 (1):63-69.

Gölbaşı S, Şen B. 2019. Atatürk Baraj Gölü'ne dökülen Kahta Çayı'nın (Adıyaman) su kalitesi. Ege Journal of Fisheries and Aquatic Sci. 36 (4):337-346. doi: 10.12714/egejfas.36.4.04

Kagalou I, Tsimarakis G, Paschos I. 2001. Water chemistry and biology in a shallow lake (Lake Pamvotis–Greece). Present State and Persp. 3 (2):85-94.

Kapan C. 2011. Mogan Gölü (Ankara) kirlilik incelenmesi. [Yüksek Lisans Tezi]. Selçuk Üniversitesi 107 s.

Karakoç G, Erkoç ÜF, Katırcıoğlu H. 2003. Water quality and impacts of pollution sources for Eymir and Mogan Lakes (Turkey). Environment Inter. 29:21-27.

Kasımoğlu C, Yılmaz F. 2014. Tersakan Çayı'nın (Muğla, Türkiye) bazı fiziksel ve kimyasal özelliklerinin araştırılması. BAÜ Fen Bil. Enst. Derg. 16 (2):51-67.

Katip A, Karaer F, İleri S, Onur S.S. 2013. Akçalar (Musa) Deresi azot ve fosfor yüklerinin mevsimsel değişimi ve Uluabat Gölü'ne etkisi. Uludağ Üniversitesi Mühendislik-Mimarlık Fakültesi Derg. 18 (2):71-78.

Kolassa JE. 2020. An introduction to nonparametric statics. Chapman and Hall/CRC Press.

Lai YC, Tu YT, Yang CP, Surampalli RY, Kao CM. 2013. Development of a water quality modeling system for river pollution index and suspended solid loading evaluation. Journal of Hydro. 478:89–101. doi: 10.1016/j.jhydrol.2012.11.050

Pulatsü S, Aydın F. 1997. Water quality and phosphorus budget of Mogan Lake, Turkey. Acta Hydrochimica et Hydrobiologica. 25 (3):128-134.

Pulatsü S, Topçu A, Atay D. 2014. Su Kirlenmesi ve Kontrolü (Genişletilmiş İkinci Baskı) Ankara Üniversitesi Ziraat Fakültesi Yayın No:1617. Ders Kitabı: 569. 384 s. (in Turkish)

Pulatsü S, Topçu A. 2023. Mogan Gölü (Ankara, Türkiye)'nde su-sediment kalitesine ilişkin çalışmalar ve göl yönetim stratejileri: 1992-2022. Ziraat, Orman ve Su Ürünleri Alanında Uluslararası Çalışmalar - Haziran 2023. Serüven Yayınevi.

Şen B, Koçer MA, Alp MT. 2002. Hazar Gölü' ne boşalan akarsuların bazı fiziksel ve kimyasal özellikleri. Fırat Üniversitesi Fen ve Mühendislik Bilimleri Derg. 14 (1): 241 – 248.

Şen B, Gölbaşı S. 2008. Hazar Gölü'ne Dökülen Kürk Çayı'nın bazı fiziksel ve kimyasal Özellikleri. E.U. Journal of Fisheries & Aquatic Sci. 25 (4):353–358.

Şen B, Gölbaşı S. 2014. Hazar Gölü'ne Dökülen Kürk Çayı (Elazığ, Türkiye)'nda bitki besin ve katı madde miktarlarının mevsimsel değişimleri. Fırat Üniversitesi Fen Bilimleri Dergisi, 26 (2):115-124.

Tepe Y, Aydın H. 2017. Water quality assessment of an urban water, Batlama Creek (Giresun), Turkey by applying multivariate statistical techniques. Fresenius Environmental Bull. 26 (11):6413-6420.

TSWQR. 2016. Turkish Surface Water Quality Regulation. The Official Gazette No: 29797.

Turan F, Ülkü G. 2013. Gökpınar ve Çürüksu Çaylarının kirlilik parametre ve yüklerinin izlenmesi. Pamukkale Üniversitesi Mühendislik Bilimleri Derg. 19 (3):133-144.

Varol M, Tokatlı C. 2023. Evaluation of the water quality of a highly polluted stream with water quality indices and health risk assessment methods. Chemosphere 311, 137096. doi: 10.1016/j.chemosphere.2022.137096

Zeybek M, Kalyoncu H. 2016. The determination of water quality of Kargı Stream (Antalya, Turkey) in terms of physicochemical parameters. Ege Journal of Fisheries and Aquatic Sci. 33 (3):223-231. doi: 10.12714/egejfas.2016.33.3.06