



## Investigations on Some Physicochemical Parameters of Demirköprü Dam Lake (Manisa, Turkey)

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### ABSTRACT

This study was carried out at 3 different stations in Demirköprü Dam Lake, Köprübaşı, situated in Manisa, between June 2015 – May 2016. Samples collected from the surface and the bottom of the lake were analyzed seasonally in terms of depth (m), temperature (°C), dissolved oxygen (DO), pH, salinity (‰), total dissolved solids (TDS), electrical conductivity (EC), secchi disk depth (SD), suspended solid matter (SSM), particulate organic matter (POM), particulate inorganic matter (PIM), ammonium nitrogen (NH<sub>4</sub><sup>+</sup>-N), nitrite nitrogen (NO<sub>2</sub><sup>-</sup>-N), nitrate nitrogen (NO<sub>3</sub><sup>-</sup>-N), phosphate phosphorus (PO<sub>4</sub><sup>-3</sup>-P), silica (SiO<sub>2</sub>) and Chlorophyll-a parameters. As a result of this study, according to Inland Water Quality Standards defined in Surface Water Quality Management Regulations (SWQMR) Demirköprü Dam Lake can be considered; Class-I quality according to measured temperature (15±1.3°C), NO<sub>2</sub>-N (0.010±0.003 mg/l) and NO<sub>3</sub>-N (0.04±0.01 mg/l) values; Class-II quality according to measured DO (6.86±0.90 mg/l), EC (591±6.4 µS/cm), SSM (5.90±6.40 mg/l), NH<sub>4</sub><sup>+</sup>-N (0.30±0.09 mg/l) and PO<sub>4</sub><sup>-3</sup>-P (0.08±0.01 mg/l) values; Class-III quality according to measured pH (8.72±0.09) values. Also, according to Turkish Boundary Values of Trophic Classification System of Lakes, Ponds and Reservoirs; the trophic level of the lake is considered eutrophic in regard to PO<sub>4</sub><sup>-3</sup>- and SD values and hypereutrophic in regard to Chlorophyll-a values.

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### Introduction

As the most widespread form of water pollution, eutrophication and its negative effects on aquatic ecosystems are not only significant problem for natural habitats (lakes and rivers etc.) but also artificial reservoirs or dam lakes (Starling, 1993; Cai and Hu, 2006; Borduqui and Ferragut, 2012). Unlike natural lakes, external nutrient loadings in reservoirs are generally high, variable and unpredictable due to larger drainage basins, more human activity, and greater water level changes (Thornton et al., 1990). Dam lakes are built for producing energy, protecting from floods and obtaining irrigation water in developing countries and have a greater importance than thermal and nuclear power plants in terms of their environmental effects (Küçükylmaz et al., 2010). Main criteria used for determining the pollution in dam lakes are physicochemical and biological factors and there are many studies on this subject (Sömek et al., 2005; Bulut et al., 2011; Varol 2013; Varol 2015; Mutlu et al., 2018). There are 706 dam lakes in Turkey (DSİ, 2015). One of these dam lakes, Demirköprü Dam Lake was built between 1954-1960 for energy, irrigation and flood control. Demirköprü Dam Lake was made on the Gediz

River. The main water sources of the dam lake are Gediz River and Demirci stream. It has been reported that the Gediz river basin is under the pressure of various pollutants originated from industrial, agricultural and domestic waste discharges (Delibacak et al., 2002). Additionally, commercial fisheries and aquaculture activities have been performed in the dam lake since 2003 (Anonymous, 2014). The only study associated with the water quality of Demirköprü Dam Lake was conducted by Tenekecioğlu (2011). In this study, it was aimed to determine the present water quality and trophic level of Demirköprü Dam Reservoir more extensively.

### Material and Method

Demirköprü Dam Lake is located at coordinates 38° 36' 59.80" N and 28° 18' 40.69" E in Manisa-Turkey (Figure 1). This study was carried out seasonally at 3 different stations (surface and bottom) in Demirköprü Dam Lake between June 2015 – May 2016. Temperature (°C) dissolved oxygen (DO), pH, total dissolved solids (TDS), electrical conductivity (EC) and Secchi disk depth

(SD) were measured in situ. Suspended solid matter (SSM), particulate organic matter (POM) and particulate inorganic matter (PIM) were analyzed with gravimetric methods (Stirling, 1985). Analyses of nitrogen forms, phosphate phosphorus, silica and Chlorophyll-a have been performed using spectrophotometer (Strickland and Parsons, 1972; Wood, 1975; Parsons et al., 1984; Egemen and Sunlu, 2003). Water quality and trophic level of the dam lake have been determined referring to Turkish Surface Water Quality Management Regulation and the Boundary Values of Trophic Classification System of Lakes, Ponds and Reservoirs (Table 1). In the study, the data were classified according to months and stations, checked in terms of their normality and homogeneity and then their average values and standard errors were calculated. Significance test between stations and seasons was conducted with Two-Way ANOVA and Duncan test was applied in cases where the difference was statistically significant. All the statistical analyses were carried out in the computer environment using the Microsoft Excel Program and SPSS 15.0 © package software (Sümbüloğlu and Sümbüloğlu, 2010).

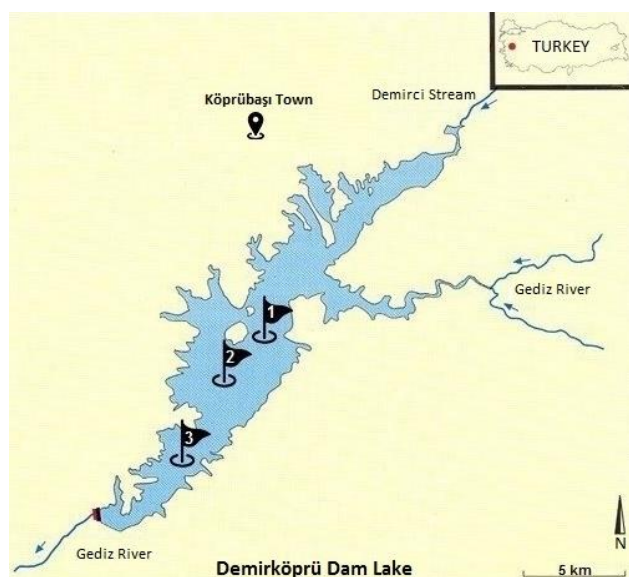


Figure 1 The study area and sampling stations

Table 1 Turkish Boundary Values of Trophic Classification System of Lakes, Ponds and Reservoirs (SWQMR, 2015).

Trophic State	TP (µg/L)	Chlorophyll-a (µg/L)	Secchi Depth (m)
Oligotroph O	< 10	< 3.5	> 4
Mesotroph M	10-30	3.5-9.0	4-2
Eutroph E	31-100	9.1-25.0	1.9-1
Hypertroph H	> 100	> 25.0	< 1

## Results and Discussion

In this study, physicochemical parameters of bottom and surface waters sampled from 3 stations were evaluated seasonally. During seasonal changes, all parameters measured were statistically significant ( $P>0.05$ ). Temperature is a very important parameter for aquatic life in that it affects the rate of biochemical reactions that occur in the aquatic environment and the

solubility of gases by altering the viscosity and density of the water. It is also important in reproduction, nutrition and metabolic activities, increasing the biological activity rate and reducing oxygen saturation (Kırankaya and Ekmekci, 2005). In this study, annual mean water temperature obtained from measurements made from 3 stations was determined as  $15.0\pm 1.3^\circ\text{C}$ . Similar water temperature values were obtained at Almus Dam Lake ( $14.8^\circ\text{C}$ ) and Derbent Dam Lake ( $15.6^\circ\text{C}$ ) (Buhan et al., 2010; Taş, 2006). The highest temperature was measured in surface water in the summer ( $26.3^\circ\text{C}$ ) and the lowest temperature was measured in bottom water in the spring ( $8.5^\circ\text{C}$ ) when the temperature stratification started to take place. In the study, a clear temperature stratification was observed in the summer between temperatures of the surface and bottom water. During the winter season when the mixture is in the process, no significant temperature difference was observed between surface and bottom water. It has been stated that there is an apparent decrease in vertical curve of oxygen in eutrophic lakes from the surface to the hypolimnion at summer, and its primary reasons are temperature and organic matter oxidation (Tanyolaç, 2009). A similar result was observed by Tenekecioğlu (2011) in Demirköprü Dam Lake ( $26.5-6.0^\circ\text{C}$ ) and by Sömek (2011) in Adıgüzel Dam Lake ( $20.0-8.2^\circ\text{C}$ ). Considering the criteria specified by SWQMR (2015); Demirköprü Dam Lake is in the category of I. Class water quality in terms of average water temperature values in all stations and depths.

The DO value in the aquatic environment varies depending on the temperature, the photosynthesis rate of the plants, the trophic level of the lakes, the altitude, the depth and the formation of the thermocline layer (Akbulut and Yıldız, 2001, Tenekecioğlu, 2011). In this study, the mean annual DO value in lake water was determined as  $6.86\pm 0.90$  mg/l, the mean value of the surface water was 10.23 mg/l and the mean value of the bottom water was 3.5 mg/l. In the summer and autumn seasons the DO values in the bottom waters of all stations were low. Tenekecioğlu (2011), who performed a study in the same region, also measured DO values in bottom waters as low. The researcher reported that the reason for this was due to the consumption of oxygen during decomposition of hypolimnion detritus by saprophytic bacteria and the interruption of the transfer of matter and energy between epilimnion and hypolimnion layers resulted from thermocline layer that acts as a barrier. Another similar result was observed at the Adıgüzel Dam Lake. It was stated that the DO value decreases beginning from 10m to 1 mg/l or less in periods when the summer stratification continues and anoxic environment is formed (Sömek 2011). Sömek (2011) also stated that this was due to the rapid consumption of dissolved oxygen by metabolic activities of bacteria, and that the vertical curve of oxygen in eutrophic lakes showed a significant decrease from surface to hypolimnion in summer, and that these events occurred due to temperature and oxidation of organic matter. In this study, DO value is thought to be decreased due to the same reasons. DO values in surface waters was higher in spring compared to other seasons. As the reason for this, it is considered that the DO value in the environment was increased due to the density of phytoplankton at that time. As is indicated by SWQMR

(2015), comparing DO values with water quality parameter values; they are in the II. Class category without discriminating station and depth, I. Class category according to surface waters and III. Class category according to deep waters.

pH is a sign of acid or base properties of water and is one of the important factors affecting living in the aquatic environment. Aquatic creatures develop well in the pH range of 6.5 to 8.5 (Arrignon, 1976; Dauba, 1981). The annual average pH value determined in the lake water in study was  $8.72 \pm 0.09$  and it was an alkaline structure. The average pH value determined in the spring season was higher than the other seasons. The pH of the water is generally balanced by the carbonate system. It was reported that the pH decreases when the equilibrium shifts to  $\text{CO}_2$  and  $\text{HCO}_3^-$ , and the pH increases when it shifts towards  $\text{CO}_3^{2-}$  (Göksu, 2015). The pH value in the Demirköprü Dam Lake is thought to increase due to the use of  $\text{CO}_2$  by phytoplankton in surface waters in the spring. The value of chlorophyll-a detected in the spring season also supports this situation. Similarly, Gürevin (2004) reported that the pH increase in the water is due to the decrease in the amount of  $\text{CO}_2$  in the environment resulted from the increase in phytoplankton density. Tenekecioğlu (2011) stated that the mean pH values of Demirköprü Dam Lake was between 7.70-8.80, that the buffer capacity of the lake water was high and that excessive pH fluctuations were not seen. Comparing pH values determined in the study with water capacity parameter values specified by SWQMR (2015); it is seen that surface waters are in the IV. Class category, deep waters I. Class category and all stations and depths III. Class category. In the same study conducted by Sarıyıldız et al. (2008) in the same lake and in another study conducted by Küçükylmaz et al. (2014) in Işıktepe Dam Lake, it was reported that pH value was in the III. Class category in general terms.

The sources of TDS are natural, domestic, industrial wastewater and substances from agricultural lands. The main ions contributing to the amount of TDS are carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium, magnesium etc. In addition, clay, silt, small particles in organic structure, inorganic substances, soluble organic compounds, plankton and other microscopic organisms constitute TDS (Taş and Çetin, 2011). Knowing the total amount of substances or minerals dissolved in natural waters is a useful parameter for defining the chemical content of water (Tanyolaç, 2009). The annual average TDS value obtained at Demirköprü Dam Lake is  $590.29 \pm 6.4$  mg/l. TDS values in study were generally high in winter and low in summer (Table 2). Walling and Webb (1986) reported that TDS in water originated from rock and soil minerals. It is believed that the reason for the high TDS value in winter, due to atmospheric changes and terrestrial inputs carried by rainwater to the lake. The mean TDS value determined at Yamula Dam Lake was 1119 mg/l (Çevik and Elibol, 2009), which is considerably higher than the values determined at Demirköprü Dam Lake. According to SWQMR (2015) water quality parameter values, TDS is located in the II. class water category.

EC is an indication of the total dissolved solids in the water. EC changes depending on the geological structure and amount of precipitation (Bremond and Vuichard, 1973). In this study, the annual average EC value determined in the lake water is  $591.4 \pm 6.4$   $\mu\text{S}/\text{cm}$ . EC values measured at Demirköprü Dam Lake were high in winter and low in summer (Table 2). Increasing EC value in the winter season is thought to be due to terrestrial inputs carried by rainwater to the lake, and in the summer season due to the increase in temperature. Decreasing EC values during the summer may be caused by precipitation of major ions such as calcium from the surface to deeper (Varol, 2015). When the other dam lakes and this study are compared, it is seen that EC value in Gököl ( $1294.3$   $\mu\text{S}/\text{cm}$ ) is higher and EC values ( $619.2$   $\mu\text{S}/\text{cm}$ ) of Tenekecioğlu (2011) in the same lake is similar. EC value according to SWQMR (2015) water quality parameter values is in the II. class water category.

SSM is a parameter which, after a certain amount, usually causes physical contamination of water, clouding, condensation and toxicity, as well as damaging water organisms by decreasing the light permeability and oxygen content (Uslu and Türkman, 1987). According to SKKY (2004), the required SSM value for the eutrophication control of dam lakes is 5 mg/l. The annual average SSM value determined at Demirköprü Dam Lake is  $5.41 \pm 0.61$  mg/l. Generally, SSM values were high in spring and low in summer (Table 2). It is thought that the SSM values are high due to the increase of phytoplankton population and the terrestrial inputs carried by rainwater and snow melt. A similar case was also found in the Dicle Dam Lake ( $3.15$  mg / l) (Varol, 2015). Sarıyıldız et al. (2008) stated that SSM at Demirköprü Dam Lake entered in the polluted water category. It is considered that the high PIM values were originated from the surface waters resulted from the rainfall in winter while originated from the POM values of the increasing phytoplankton density in the spring (Table 2).

In this study, annual mean  $\text{NH}_4^+\text{-N}$  value determined in lake water is  $0.30 \pm 0.09$  mg/l. It is thought that the reason for the relatively low detection of  $\text{NH}_4^+\text{-N}$  values in the Demirköprü Dam Lake during the spring season is that increasing phytoplankton biomass is consumed in this period as nutrients and the ammonium is converted to ammonia with increasing pH. The pH in the water is a parameter that is effective in the conversion of ammonium into ionized or non-ionized ammonia. Increase or decrease of the pH in the water causes the ammonia to be very toxic (Howell and Baynes, 2004). The pH and chlorophyll-a values determined in the study also support this. The highest  $\text{NH}_4^+\text{-N}$  values were found in bottom waters in autumn (Table 2). This increase in bottom water may be due to the presence of an anoxic environment in the hypolimnion and the inability of the nitrification processes to occur. Similarly, Wetzel (1983) reported that ammonium is a main product resulting from the destruction of organic material by bacteria. Likewise, Uslu and Türkman (1987) stated that the toxic effect of ammonia may also be increased by the lack of oxygen, the increase in temperature and the presence of other toxic substances. It was also found in a study that there is a statistically negative correlation between ion concentrations of oxygen and ammonium (Mutlu and

Aydın Uncumusaoğlu, 2018). The average NH<sub>4</sub><sup>+</sup>-N value determined in the study is smaller than the value determined by Çevik and Elibol (2009) in Yamula Dam Lake (0.460 mg/l); greater than the value determined by Bulut et al. (2011) in Selevir Dam Lake (0.063 mg/l); and similar with the value determined by Buhan et al. (2010)

in Almus Dam Lake (0.290 mg/l). General average value of NH<sub>4</sub><sup>+</sup>-N is in the II. Class category. On the other hand, in the study by Sarıyıldız et al. (2008) conducted with samples taken from the area where Gediz River flows into the same river, it was reported that NH<sub>4</sub><sup>+</sup>-N value was in the IV. Class category according to SKKY (2004).

Table 2 Average and minimum-maximum values of physicochemical parameters and trophic classifications in the study area (nd: not detected).

Parameters		Summer		Autumn		Winter		Spring		Mean Values
		S	B	S	B	S	B	S	B	
Temp. (°C)	Av	26.3	13.0	22.2	19.8	10.4	9.1	16.7	8.5	15±1.3
	Mn	25.7	9.8	22.0	10.4	10.3	8.7	16.6	8.2	
	Mx	26.8	18.5	22.4	20.4	10.5	9.7	17.2	9.1	
DO (mg/L)	Av	9.61	1.00	7.46	2.14	8.98	6.58	14.87	4.27	6.86±0.90
	Mn	9.44	0.90	7.21	0.28	7.93	5.47	14.57	3.46	
	Mx	9.78	1.19	7.74	5.67	10.21	8.44	15.08	4.72	
pH	Av	9.22	8.39	8.96	8.24	8.73	8.50	9.42	8.33	8.72±0.09
	Mn	9.12	8.37	8.89	7.99	8.66	8.35	9.41	8.25	
	Mx	9.27	8.59	9.05	8.70	8.78	8.72	9.42	8.39	
EC (µS/cm)	Av	525.56	592.00	585.67	605.22	619.56	619.22	566.89	610.67	591±6.4
	Mn	522.67	566.00	579.67	579.67	618.33	617.67	565.33	609.67	
	Mx	527.33	605.33	589.67	609.67	623.67	621.00	568.00	612.67	
TDS (mg/L)	Av	524.78	590.89	585.11	605.44	619.44	619.22	566.78	610.67	590±6.4
	Mn	523.00	564.67	578.00	597.67	618.33	617.67	565.33	609.67	
	Mx	527.00	604.38	589.67	610.00	620.67	621.00	568.00	612.67	
SSM (mg/L)	Av	5.37	2.93	5.47	4.81	3.53	6.46	10.16	4.52	5.41±0.61
	Mn	4.90	2.23	2.80	1.73	2.87	3.30	8.80	2.90	
	Mx	6.27	4.20	8.03	10.47	4.00	10.30	11.27	6.17	
POM (mg/L)	Av	3.73	1.61	2.53	1.78	1.97	1.84	7.60	1.31	2.80±0.42
	Mn	3.50	1.27	1.97	1.20	1.90	1.47	6.63	0.93	
	Mx	3.90	2.27	3.10	2.47	2.03	2.13	8.13	1.93	
PIM (mg/L)	Av	1.63	1.38	2.93	3.07	1.57	4.61	2.54	3.21	2.62±0.42
	Mn	1.10	0.77	0.83	0.60	0.83	1.83	2.17	1.97	
	Mx	2.37	1.93	4.93	8.03	2.03	8.17	3.20	4.23	
SiO <sub>2</sub> (mg/L)	Av	3.505	7.843	4.045	7.966	4.539	6.770	7.275	7.059	6.13±0.42
	Mn	3.287	5.217	3.966	4.624	4.350	5.565	7.134	6.950	
	Mx	3.696	9.341	4.624	9.692	4.709	7.481	7.381	7.230	
NH <sub>4</sub> <sup>+</sup> -N (mg/L)	Av	0.019	0.341	0.014	1.175	0.109	0.466	0.015	0.213	0.30±0.09
	Mn	0.015	0.153	0.010	0.306	0.095	0.156	0.008	0.009	
	Mx	0.024	0.439	0.018	1.736	0.123	0.703	0.029	0.026	
NO <sub>2</sub> <sup>-</sup> -N (mg/L)	Av	0.003	0.040	0.003	0.006	0.005	0.011	0.005	0.006	0.010±0.003
	Mn	0.003	0.023	0.002	0.003	0.004	0.009	0.005	0.004	
	Mx	0.003	0.074	0.004	0.012	0.006	0.013	0.006	0.007	
NO <sub>3</sub> <sup>-</sup> -N (mg/L)	Av	0.005	0.120			0.037	0.049	0.004	0.116	0.04±0.01
	Mn	0.003	0.076	nd	nd	0.032	0.044	0.002	0.107	
	Mx	0.007	0.154			0.042	0.054	0.006	0.129	
PO <sub>4</sub> <sup>-3</sup> -P (mg/L)	Av	0.021 <sup>M</sup>	0.083 <sup>E</sup>	0.021 <sup>M</sup>	0.186 <sup>H</sup>	0.063 <sup>E</sup>	0.130 <sup>H</sup>	0.034 <sup>E</sup>	0.087 <sup>E</sup>	0.08±0.01 <sup>E</sup>
	Mn	0.018 <sup>M</sup>	0.028 <sup>E</sup>	0.019 <sup>M</sup>	0.064 <sup>H</sup>	0.053 <sup>E</sup>	0.071 <sup>H</sup>	0.025 <sup>E</sup>	0.068 <sup>E</sup>	
	Mx	0.024 <sup>M</sup>	0.130 <sup>E</sup>	0.024 <sup>M</sup>	0.262 <sup>H</sup>	0.061 <sup>E</sup>	0.164 <sup>H</sup>	0.042 <sup>E</sup>	0.097 <sup>E</sup>	
Chlorophyll-a (µg/L)	Av	28 <sup>H</sup>	3.67 <sup>M</sup>	28.35 <sup>H</sup>	11.81 <sup>E</sup>	17.28 <sup>E</sup>	3.53 <sup>M</sup>	147.03 <sup>H</sup>	5.26 <sup>M</sup>	30.58±9.51 <sup>H</sup>
	Mn	22 <sup>H</sup>	1 <sup>M</sup>	22 <sup>H</sup>	2 <sup>E</sup>	15 <sup>E</sup>	3 <sup>M</sup>	135 <sup>H</sup>	5 <sup>M</sup>	
	Mx	40 <sup>H</sup>	9 <sup>M</sup>	33 <sup>H</sup>	32 <sup>E</sup>	20 <sup>E</sup>	4 <sup>M</sup>	162 <sup>H</sup>	6 <sup>M</sup>	
SD (m)		2.06±0.14 <sup>M</sup>		1.88±0.17 <sup>E</sup>		2.79±0.17 <sup>M</sup>		1.12±0.02 <sup>E</sup>		1.96±0.21 <sup>E</sup>

S: Surface, B: Bottom, Av: Average, Mn: Minimum, Mx: Maximum, O: Oligotroph, M: Mesotroph, E: Eutroph, H: Hypertroph

$\text{NO}_2^-$ -N is an intermediate product which occurs as a result of oxidation of ammonia or reduction of nitrate in the oxidation reaction of ammonia and does not accumulate in the environment. Nitrite originates from the biodegradation of some organic proteins (Giritlioğlu, 1975; Boyd and Tucker, 1998). The mean  $\text{NO}_2^-$ -N value in this study is  $0.010 \pm 0.003$  mg/l. Buhan et al. (2010) reported no pollution due to  $\text{NO}_2^-$ -N (0.011 mg/l) values in the Almus Dam Lake. It has been determined that  $\text{NO}_2^-$ -N values determined in Demirköprü Dam Lake in summer are higher than other seasons. This difference is thought to be due to the rapid nitrite oxidation of the ammonium unused by phytoplankton (Egemen and Sunlu, 2003). Tenekecioğlu (2011) measured highest nitrite value at Demirköprü Dam Lake in July. According to the SWQMR (2015) water quality parameters, the values of  $\text{NO}_2^-$ -N are in I. class water category.

According to SWQMR (2015), the amount of  $\text{NO}_3^-$ -N significantly increases during periods of heavy precipitation and organic pollution. As a result of washing the agricultural land of the rain water, the nitrate, which easily dissolves in the water, mixes with the natural water environment.  $\text{NO}_3^-$ -N, which occurs as a byproduct of bacterial nitrification, is destroyed by consumption of plants and reduction to ammonia (Giritlioğlu, 1975). The average  $\text{NO}_3^-$ -N value determined in the study is  $0.04 \pm 0.01$  mg/l. These  $\text{NO}_3^-$ -N data are less than the values of Demirköprü Dam Lake (9.06 mg/l) and Adıgüzel Dam Lake (0.40 mg/l) (Tenekecioğlu, 2010; Sömek, 2011), and higher than Selevir Dam Lake (0.006 mg/l) (Bulut et al., 2011). In addition,  $\text{NO}_3^-$ -N values determined in Demirköprü Dam Lake in spring and summer are higher than other seasons. This difference is thought to be due to the acceleration of the nitrification bacteria's activities with increasing water temperature above  $15^\circ\text{C}$  in the spring and summer seasons. A similar result was found by Ayvaz et al. (2011) in Afşar Dam Lake. According to the SWQMR (2015) water quality parameters, the values of  $\text{NO}_3^-$ -N are in I. class water category.

Phosphorus is found in relatively small quantities in uncontaminated natural waters and determines the productivity of lakes (Tepe and Boyd, 2003). In contrast to nitrogen, which has many forms in lake systems, the most apparent form of inorganic phosphorus is orthophosphate. In freshwater more than 90% of phosphorus is present in the cells of living organisms as organic phosphate (Wetzel, 1983). Ortho-phosphate anion is the basic constituent of all organic phosphorus compounds (Uslu and Turkman, 1987). The average  $\text{PO}_4^{3-}$ -P value determined in the Demirköprü Dam Lake is  $0.08 \pm 0.01$  mg/l. The highest values were found in autumn in bottom water (0.186 mg/l), while the lowest values were found in surface water in summer and autumn (0.21 mg/l) (Table 2). It was determined that winter season differs from other seasons in terms of  $\text{PO}_4^{3-}$ -P values. Source of  $\text{PO}_4^{3-}$ -P in Demirköprü Dam Lake is thought to be due to the geological structure of the lake, the nutrients coming from the Gediz River and the surface waters coming from the terrestrial environments with rain water because of the inclination of the area. Wetzel, (2001) reported that the main source of phosphorus in the areas where human activities are not directly affecting the nutrient quantities is reach of

phosphorus in rock and soil structure by surface flows to the lake. Tenekecioğlu (2011) and Anonymous (2014) obtained similar results in studies conducted at different times in the same dam lake. In addition, main source of  $\text{PO}_4^{3-}$ -P detected in Demirköprü Dam Lake were suggested to be Gediz River under the pressure of various pollutants and releasing of phosphorus from the dam lake sediment to the water. In the study, this situation is supported with relatively higher  $\text{PO}_4^{3-}$ -P in the deep waters compared to the surface waters and low DO values in hypolimnion. Comparing  $\text{PO}_4^{3-}$ -P values determined in Demirköprü Dam Lake with water quality parameter values specified by SWQMR (2015); it is seen that they are included in the II. Class category and in the eutrophic class according to the Boundary Values of Trophic Classification System of Lakes, Ponds and Reservoirs. The studies being conducted report that many lakes in Turkey have a eutrophic structure in terms of total amount of phosphorus (Küçükylmaz et al., 2014; Taş, 2006; Alpaslan et al., 2015).

Silica is not present as an element in freshwater yet it is usually in the form of silicon dioxide. More than 60% of the stone and land on the earth's surface contains silicon dioxide ( $\text{SiO}_2$ ). Considering this ratio, it can be said that  $\text{SiO}_2$  rich waters are not polluted. It is natural that it has high density in the water of the lakes in the siliceous sediments. (Tanyolaç, 2009). In natural waters, silicon is 1-80 mg/l (Tepe et al., 2006). The average  $\text{SiO}_2$  value in Demirköprü Dam Lake was determined as  $6.13 \pm 0.42$  mg/l. Similar to these values, Sömek (2011) found  $\text{SiO}_2$  value between 1.02-7.71 mg/l in Adıgüzel Dam Lake, Saadoun et al. (2010) reported that the  $\text{SiO}_2$  value of the Wadi Al-Arab Dam in Bulgaria varies between 2.33-7.60 mg/l. Egemen and Sunlu (2003) stated that in the spring season when the amount of diatom is high, the silica concentration is very low and is high in the winter season when the photosynthesis activity is low. However, in this study, it is considered that the main source of silica, which is at the maximum level in the spring season, is derived from terrestrial inputs due to precipitation.

Chlorophyll-a is a photosynthetic pigment present in all phytoplanktonic organisms. Nutrient production is possible by chlorophyll through photosynthesis and chemosynthesis. In a freshwater ecosystem, the first ring of the food chain is phytoplanktonic organisms and plants. The amount of chlorophyll-a is therefore the most important indicator of phytoplankton biomass and productivity in a lake (Çevik and Elibol, 2009). Chlorophyll-a values determined in Demirköprü Dam Lake were inversely proportional with nutrient elements, and it reached to higher values in spring season (147.03  $\mu\text{g/l}$ ) while it was detected in lower values in winter season (3.53  $\mu\text{g/l}$ ) with lower production. In this period, bloom of Cyanobacteria and blue-green coloring were observed in the surface water. The mean Chlorophyll-a was measured as  $30.58 \pm 9.51$   $\mu\text{g/l}$  in this study. This value was calculated by Ayvaz et al. (2011) in Afşar Dam Lake (49.5  $\mu\text{g/l}$ ) and by Tenekecioğlu (2011) in Demirköprü Dam Lake (1.12  $\mu\text{g/l}$ ) Demirköprü Dam Reservoir are higher than the average Chlorophyll-a values. Average Chlorophyll-a amount determined in Demirköprü Dam Lake is in the hypereutrophic class

according to the SWQMR (2015) Boundary Values of Trophic Classification System of Lakes, Ponds and Reservoirs.

SD depth is a simple method used to determine luminous transmittance or transparency of the water and is one of the important parameters used in determining the trophic structure of the lake. Luminous transmittance of the water is crucial in terms of the amount of light used by phytoplankton and other water plants that make up the first ring of the organic food chain in the aquatic environment (Cirik and Cirik, 1999). The seasonally adjusted SD value is  $1.96 \pm 0.21$  m. The highest SD depth was measured in winter and the lowest in spring (Table 2). This difference between the seasons is thought to be due to the increase resulted from the increase in the depth due to the river waters that feed the dam lake, while the decrease is due to transportation of SSM load resulted from precipitation and snow melt. When the chlorophyll-a values are high, the depth of SD is low and when the chlorophyll-a is low, SD depth is high (Varol, 2013). Tenekecioğlu (2011) expressed similar comments in his study in the same region. The SD values obtained at Demirköprü Dam Lake are eutrophic according to SWQMR (2015) Limit Values of Trophic Classification System in Lakes, Ponds and Dam Lakes. This result is supported by in desk values indicating that SD depth is 1-4 m eutrophic (Taylor et al., 1980, Hakanson and Jansson, 1983).

Consequently, primary factors negatively affecting the water quality of Demirköprü Dam Lake are; transition of a branch of Gediz River to the dam lake and waters carried by Demirci Stream to the region, mixture of rain waters and surface waters (agricultural areas) into the lake due to the sloping land around the lake and geological structure of the lake. According to SWQMR (2015); Demirköprü Dam Lake is in the I. Class category in terms of the values of average temperature ( $15 \pm 1.3^\circ\text{C}$ ),  $\text{NO}_2^-$ -N ( $0.010 \pm 0.003$  mg/l) and  $\text{NO}_3^-$ -N ( $0.04 \pm 0.01$  mg/l), II. Class category in terms of the values of DO ( $6.86 \pm 0.90$  mg/l), EC ( $591 \pm 6.4$   $\mu\text{S/cm}$ ), TDS ( $5.90 \pm 6.40$  mg/l),  $\text{NH}_4^+$ -N ( $0.30 \pm 0.09$  mg/l) and  $\text{PO}_4^{3-}$ -P ( $0.08 \pm 0.01$  mg/l) and in the III. Class category in terms of pH value ( $8.72 \pm 0.09$ ). According to SWQMR (2015) Boundary Values of Trophic Classification System of Lakes, Ponds and Reservoirs; trophic level of the lake is eutrophic in terms of the values of  $\text{PO}_4^{3-}$ -P and SD and hypereutrophic in terms of Chlorophyll-a value. It is of great importance to protect the ecological balance of Demirköprü Dam Lake and conduct water quality follow-up studies in order to sustain the utilization of the lake.

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