Acta Aquatica Turcica
E-ISSN: 2651-5474 16(3), 305-312 (2020) DOI: https://doi.org/10.22392/actaquatr.626918

Seasonal Changes of Water Quality of Murat River (Bingöl, Turkey) in Terms of Physico-Chemical and Biological Parameters

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Research Article

Received 30 September 2019; Accepted 13 August 2020; Release date 01September 2020.

How to Cite: Koyun, M., Ulıupınar, M., Şen Özdemir, N., Kırıcı, M., & Caf, F. (2020). Seasonal changes in water quality of Murat River (Bingöl, Turkey) in terms of physico-chemical and biological parameters. *Acta Aquatica Turcica, 16*(3), 305-312. https://doi.org/10.22392/actaquatr.626918

Abstract

Murat River is the most important tributary of the Euphrates River, which has the highest water potential in Turkey. The seasonal variation of water quality parameters and water quality status of Murat River were determined according to the "Regulation on Surface Water Quality Management" criteria. 19 different parameters were measured in water samples taken from four different stations during the research. These parameters were temperature, pH, dissolved oxygen, electrical conductivity, total hardness, total alkalinity, Biochemical Oxygen Demand (BOD), total phosphorus, fluoride, chloride, nitrite, nitrate, ammonium, sulfate, sodium, potassium, calcium, magnesium, and chlorophyll-*a* (Chl-*a*). According to "Regulation on Surface Water Quality Management", physical and chemical analysis data showed that Murat River waters had "first-class water quality" in terms of temperature, dissolved oxygen, BOD, total phosphorus, fluoride, chloride, nitrate, ammonium, sulfate, "third-class water quality" for sodium, pH and "fourth class water quality" for nitrite. The electrical conductivity and alkalinity values were within normal limits and as "medium-hard" water. Considering all the results, it has been evaluated that there is no significant pollution problem in the Murat River.

Keywords: Water quality, Chl-*a*, BOD, pH, Murat River

Murat Nehri'nin (Bingöl, Türkiye) Su Kalitesinin, Fizikokimyasal ve Biyolojik Parametreler Açısından Mevsimsel Değişimi

Özet

Murat Nehri, Türkiye'de en yüksek su potansiyeline sahip Fırat Nehri'nin en önemli koludur. Murat Nehri su kalitesi parametrelerinin mevsimsel değişimi ve su kalitesi durumu "yüzey suyu kalite yönetmeliği" kriterlerine göre tespit edilmiştir. Araştırma sürecinde dört farklı istasyondan alınan su örneklerinde sıcaklık, pH, çözünmüş oksijen, elektriksel iletkenlik, toplam sertlik, toplam alkalinite, Biyokimyasal Oksijen İhtiyacı (BOİ), toplam fosfat, florür, klorür, nitrit, nitrat, amonyum, sülfat, sodyum, potasyum, kalsiyum, magnezyum ve klorofil-a (Chl-*a*) ölçülmüştür. Yüzey suyu kalite yönetmeliğine göre, Murat Nehri sıcaklık, çözünmüş oksijen, BOİ, toplam fosfat, florür, klorür, nitrat, amonyum, sülfat açısından "birinci sınıf" , sodyum, pH için "üçüncü sınıf" , ve nitrit için "dördüncü sınıf" su kalitesine sahipti. Elektriksel iletkenlik ve alkalilik değerleri normal sınırlarda ve "orta sert" su olarak kabul edildi. Tüm sonuçlar dikkate alındığında, Murat Nehrinde önemli bir kirlilik sorunu olmadığı tespit edilmiştir.

Anahtar kelimeler: Su kalitesi, Chl-*a*, BOİ, pH, Murat Nehri

INTRODUCTION

Murat River is one of the largest rivers and tributary of the Euphrates River in South East Anatolia of Turkey. The river originates from Mount Muratbaşı and is located near Mount Ararat, north of Lake Van, in Eastern Turkey, and flows westward, from Muş to Bingöl, for 722 km through the mountainous area. The length of the river in the province of Bingol is 96 km that is one of the most important water resources of this city (38.8 N, 41.05 E) (Koyun, 2011; Kirici et al., 2016).

Murat River has a vast catchment area, which supports diverse agricultural activities and also carries high amounts of nutrient matters (especially phosphate). The flow rate of the Murat River can

be as high as 2000 m^3 in spring. On the other hand, it carries a mere 30-40 m^3 during the dry season (Akbay et al., 1999). Due to these reasons, changes in the flow rate of the Murat River is regarded as a negative effect to fish fauna. Therefore, this study aimed at the assessment of seasonal changes of Murat River water quality using physicochemical and biological parameters to determine the present status of pollution and compared with "Regulation on surface water quality management" acceptable limit.

MATERIALS and METHODS

Water samples were taken from Soğukpınar (38º 45' 818"N - 40º 36' 690"E), Göynük (38º53'390" N - 40º57'667"E), Çamlık (38º46'471" N-040º36'500"E), and Murat Village (38°45'432"N - 40º31'864"E) stations on Murat River (Figure 1). Figure 1 indicates station numbers; 1-Soğukpınar 2- Göynük 3- Çamlık 4- Murat Village.

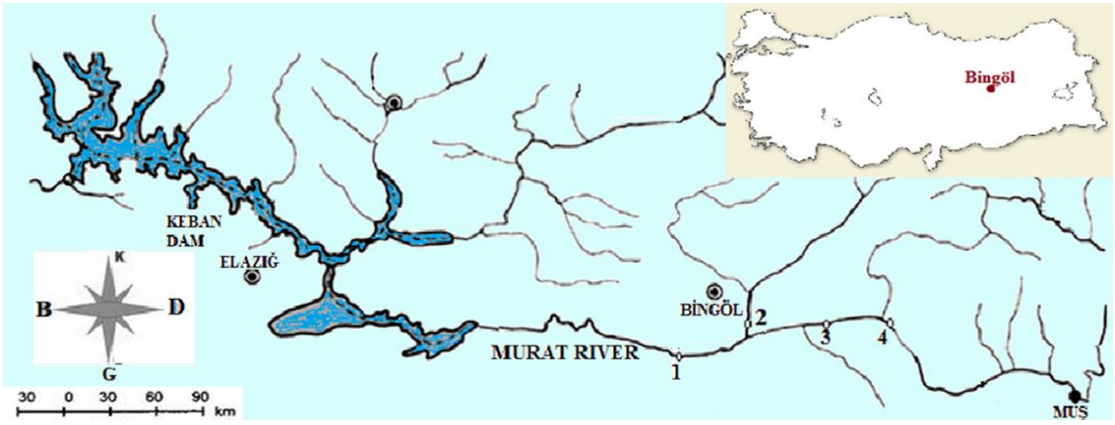

Figure 1. Research Area 1) Soğukpınar 2) Göynük 3) Çamlık 4) Murat Village

Water samples were taken seasonally, generally in monthly periods during the sampling period (December 2010-November 2011). Water temperature, pH, dissolved oxygen (DO), electrical conductivity was measured immediately. Sampling, preservation, and transportation of the water samples were made by the Fisheries Research Center Analysis Laboratory (FRCAL, Elazığ). It was used as per standard methods (APHA, 1998).

The water samples were taken to FRCAL within the shortest time to analyze, since the water samples which were not capable of analyzing at the riverside. Total phosphorus, chlorophyll-a (Chl-*a*) and ammonium (NH_3) determination were performed with UV-VIS spectrophotometer (Thermo Electron Cooperation) and total phosphorus (P), fluoride (F^-), chloride (Cl^-), nitrite (NO_2^-), nitrate (NO_3^-), sulfate (SO_4^{-2}), sodium (Na^+), potassium (K^+), magnesium (Mg^+) and calcium (Ca^+) analyzes are carried out with Ion Chromatograph device (Dionex ICS-1000). Titrimetric methods were used for total hardness and total alkalinity (APHA, 1998). Chl-*a* analysis was done according to Parsons et al. (1984). For the analysis, two liters of water were filtered through GF/F filters. Filters were stored at -20 °C till the pigment determination. The pigments on the filter were extracted using a 90% acetone solution and absorbance of Chl-*a* measured with a spectrophotometer. Biochemical oxygen demand (BOD) analyses were analyzed by BOD-System Oxdirect Aqualytic. According to the stations, water quality parameter values were performed using by SPSS 17 statistical program and Murat Rivers water quality levels which are based on obtained physico-chemical and biological parameters assessed according to the classification of surface waters quality management that is cited in "Regulation on surface water quality management".

The differences among the mean values obtained for each season and the station in relation to the water quality variables of the Murat River evaluated by univariate analysis at level significance of 0.01. The data corresponding to these variables were analyzed with an ANOVA mixed model by using a factorial nested design (Montgomery, 2012). Analyzing the effect of one variable at a time with the ANOVA technique can provide useful information, and in some cases, the univariate approach is the best and easiest tool.

RESULTS and DISCUSSION

Surface water temperature can be affected by latitude, altitude, and season, within a day, air circulation, weather condition, flow, and depth of water mass. Therefore, the temperature is the most important parameter that affects physico, chemical, and biological processes of the water (Michaud, 1991; Chapman, 1996). We researched changes in water temperature during a year in different stations. We observed that water temperatures varied seasonally at all the stations and statistically was the significant seasonal difference ($p<0.01$) (Table 1). The average lowest water temperature was recorded in winter at Murat Village (4.30 ºC), while the highest was 21.80 ºC at Soğukpınar and Çamlık in summer (Table 1). The assessed temperature averages indicated that Murat River's water temperature has first-class water quality according to "Regulation on surface water quality management".

In Murat River, pH showed an alteration between 8.20 in summer (Murat Village) and 9.73 in spring (Çamlık) on average of the station. According to "Regulation on surface water quality management", the evaluation of the average pH at four different stations showed that Murat River has third-class water quality. We determined that pH of Murat River varied depending on the station and the changes were statistically important except for winter and summer ($p<0.01$) (Table 1). In our results, pH was not lower than 8 in any station and season on the river during the sampling period and the water quality for pH was third class. Water quality was first class for pH in the other research.

DO is a barometer of the ecological health in the rivers. If DO content is less than 3 mg/L fishes cannot survive. Therefore, it is the most important parameter for protecting fish (Novotny, 2002; Chang, 2005). In the study, DO has varied between 7.80 mg/L in summer (Soğukpınar) and 12.0 mg/L in winter (Murat Village) in the Murat River, when we consider at the stations average. In the other study at Porsuk River, DO value showed a variation between 8.74 ppm and 11.04 ppm and the water was reported as a first-class quality (Altın et al., 2009). We determined that DO of Murat River varied depending on the station and the changes were statistically important except for winter and spring. ($p<0.01$) (Table 1). According to the "Regulation on surface water quality management", amount of DO in the Murat River for all seasons in all stations it might be said that has first-class water quality.

Electrical conductivity (EC) Conductivity in a stream can vary as a function of flow. As flow decreases, the concentration of total dissolved solids can increase, thereby increasing the conductivity. The lowest EC values were measured in spring, due to high water flow (Varol et al., 2010). Average electrical conductivity (EC) values were seen in the Murat River varied between 289 µS/cm and 464 µS/cm during the sampling period. The lowest average at Göynük (289 µS/cm) in spring and the highest average at Murat Village (464 µS/cm) in autumn have been identified. Seasonally, it seems to be low in spring (330 µS/cm) and high in autumn (379 µS/cm) on average of all the stations (Table 1). EC values had also statistically significant differences as seasonal and stations ($p<0.01$). EC values in all the seasons and all the stations are compatible with the drinking water value proposed by TS 266 (TSE, 1997).

The average total hardness of river water ranged from 75 mg/L in winter (Soğukpınar) and 170 mg/L in autumn (Soğukpınar). When we evaluate the seasonally highest average (157 mg/L) in autumn and the lowest (105 mg/L) was found in spring. Total hardness values were lower during rainy season and higher during summer seasons (Ustaoglu et al., 2017). In our study shows similar results. Total hardness was the lowest in spring (rainy season). According to EPA, Murat River water can call slightly hard. Comparative seasonal variation is shown in Table 1. Total hardness was not statistically important among season and stations ($p<0.01$).

Total alkalinity ranged from 7.93 mg/L in spring (Soğukpınar) to 11.68 mg/L in autumn (Göynük). The average seasonal low alkalinity 9.08 mg/L in spring while the mean highest alkalinity 11.2 mg/L was recorded in summer (Table 1). The winter and autumn seasons were statistically similar ($p<0.01$). Changes of alkalinity were not statistically important among season and stations ($p<0.01$). The seasonal averages of all the stations were the lowest in spring with 0.76 mg/L and the highest in winter with 2.12 mg/L in Murat River. The statistical difference between the seasons was especially important in these two seasons ($p<0.01$) (Table 1).

BOD average for all the stations varied 0.53-2.76 (Çamlık-Spring; Soğukpınar-Winter). We showed that BOD values for all the seasons are the first-class quality of river water by "Regulation on surface water quality management". Additionally, Murat River has un-pollutant and natural waters according to WHO and NESREA. There was no organic pollution load at a level that could cause

pollution because there are no important industrial activities to be a pollutant in the region, especially the research area.

The average of total phosphorus in Murat River water 0.09 mg/L in winter (Murat Village) and 0.26 mg/L in spring (Murat Village) has been changed (Table 1). The orthophosphates that are used as fertilizer in agricultural terrains are washed away to the surface water by the rain and this process is regarded as the main reason for the high amount of total phosphorus in spring (Wetzel, 1983; Beaton et al., 1995). Also, it is expected that the basic cause of the minimum level of total phosphorus in river-wide is the lack of industrial plants and the large residential areas. According to "Regulation on surface water quality management", the water quality is first class. Changes of total phosphorus were not statistically important among season and stations ($p<0.01$).

Fluoride quantity at all the stations of Murat River showed an alteration between 0.08 mg/L in spring (Murat Village) and 0.34 mg/L in autumn (Göynük). Seasonal averages of all the stations measured as 0.18 mg/L (winter), 0.14 mg/L (spring), 0.23 mg/L (summer) and 0.18 mg/L (autumn) (Table 1). According to "Regulation on surface water quality management" in terms of fluoride quantity, the river water has first-class water quality.

Chloride quantity showed an alteration between 7.02 mg/L in summer (Göynük) and 44.32 mg/L in autumn (Soğukpınar) during the research (Table 1). According to "Regulation on surface water quality management", the river water in terms of chloride, has first-class water quality. Changes of fluoride and chloride were not statistically important among season and stations ($p<0.01$).

The lowest nitrite level was seasonally 0.04 mg/L in spring and highest level of 0.16 mg/L in summer for average all the stations. The highest average between stations was 0.2 mg/L in Murat Village (summer) (Table 1). According to this result, water quality in terms of nitrite we may say that Murat River has generally third and fourth-class water quality according to "Regulation on surface water quality management".

The lowest nitrate was 1.52 mg/L in autumn (Çamlık), and the highest nitrate was 3.21 mg/L in winter (Soğukpınar). Nitrate was seasonally reached the highest value in spring (2.83 mg/L) (Table 1). According to these results, in terms of nitrate in river water by "Regulation on surface water quality management", first quality can be said. Changes of nitrite and nitrate were not statistically important among seasons and stations ($p<0.01$).

The Ammonium level is changed with a minimum 0.02 mg/L (winter-Murat Village) and a maximum 1.18 mg/L (autumn-Göynük). Seasonal averages for the stations were identified as 0.15 mg/L (winter), 0.13 mg/L (spring), 0.17 mg/L (summer) and 035 mg/L (autumn). According to EC Directive, ammonium value in water for salmonid and cyprinid species need to be 1 mg/L or less than this value (OJEU, 2006). Average value at all stations and during the seasons, 1 mg/L or less than was determined, and according to "Regulation on surface water quality management" the river has shown that first-class water quality. Changes of ammonium were not statistically important among seasons and stations ($p<0.01$).

The average sulfate values at the stations of Murat River were between 11.84 mg/L in spring (Göynük) and 19.56 mg/L in winter (Göynük). The average sulphate values varied seasonally between 14.95 mg/L (summer) 18.06 mg/L (winter). According to "Regulation on surface water quality management", sulphate was the first water quality in Murat River. It was important statistically among stations and seasons ($p<0.01$) (Table 1).

Potassium quantities measured between 2.6 mg/L in spring (Göynük) and 4.81 mg/L in autumn (Göynük). Potassium was seasonally the lowest with 2.89 mg/L in spring and the highest with 4.07 mg/L in autumn (Table 1).

Sodium and potassium levels of Murat River are optimum for both of potable water and aquatic biota in all the stations and all the seasons. Changes of sodium and potassium were not statistically important among seasons and the stations ($p<0.01$).

Calcium concentration was between 21 mg/L (Göynük-spring) and 50.8 mg/L (Soğukpınar-autumn). Calcium measured seasonally 25.7 mg/L (winter), 30.0 mg/L (spring), 38.6 mg/L (summer) and 41.7 mg/L (autumn). According to results, calcium level of the river water is optimum in all the seasons for all aquatic biota.

Magnesium concentration varied between 4.9 mg/L in spring (Göynük) and 14.27 mg/L in autumn (Murat Village). While Göynük and Soğukpınar stations were similar in winter, spring and summer, Göynük and Çamlık stations were similar in autumn ($p<0.01$) (Table 1). According to the results, it

would be said that the rate of magnesium in river water is optimum level in all seasons for all aquatic biota. Changes of calcium and magnesium were not statistically important among the seasons and the stations ($p<0.01$).

Chl-*a* value changed from 0.4 µg/Lµg/L/L (spring- Göynük) to 3.80 mg/L (summer-Çamlık). Chl-*a* was the lowest in winter (1.4 µg/L/L) and the highest in summer (1.8 µg/L/L) on average of all the seasons. Chl-*a* showed constantly an increase from winter to summer. Additionally, Chl-*a* had a significant statistical difference in all the seasons and stations ($p<0.01$) (Table 1). Phytoplankton abundance was significantly and positively correlated with Chl-*a* and temperature (Baykal et al., 2011). Therefore, in this study, higher Chl-*a* is an expected result due to the high abundance of phytoplankton and high temperature in hot seasons (summer). In aquatic ecosystems, physico, chemical, and biological factors cause variability in the amount of Chl-*a* overtime. The reason for the variability in the same parameters in different stations may be spatial variability and anthropogenic impact (El-Shabrawy et al., 2015).

CONCLUSIONS

In this study, some physico-chemical parameters were evaluated which are used to detect the water quality of Murat River at four different stations. Murat River water quality was classified by "Regulation on surface water quality management". It is regarded as high-quality water in terms of temperature, DO, BOD, total phosphorus, fluoride, chloride, nitrite, nitrate, ammonium, sulphate, and sodium. However, Murat River had "third-class water quality" for sodium, pH, and "fourth class water quality" for nitrite. The EC and alkalinity values were within normal limits and as "medium hard" water. Considering all the results, it has been evaluated that Murat River is not an important pollution problem. But it could be categorized as slightly-pollution water and pollution water in terms of pH and nitrate, respectively. This can cause problems for drinking water and aquatic life. Although Bingol has not a significant endustrial waste, the main source of the pollution can be sewage and domestic wastes. For this reason, we have considered that the reasons of pH and nitrate pollution should be researched in more detail in the next research in the same area.

Table 1. Physico-chemical and biological parameters of Murat River for the stations and the seasons

Water Quality Parameters	Season and Stations									
	Winter					Spring				
	1	2	3	4	Average	1	2	3	4	Average
Water Temperature (C°)	4.60 ± 0.23^{d}	4.40 ± 0.4^{b}	4.50 ± 0.9^{c}	4.30 ±0.73^{a}	4.45 ±0.34^{A}	9.73±1.15^{c}	9.97 ± 1.04^{d}	9.5 ±2.11^{b}	9.37±1.64^{a}	9.6 ±1.53^{B}
pH	8.50 ± 0.68^{a}	8.50 ±0.75^{a}	8.66 ±1.21^{b}	8.56 ±1.83^{ab}	8.55±1.02^{A}	9.5 ±1.94^{b}	9.44±1.63^{ab}	9.73±1.42^{c}	9.35± 2.14^{a}	9.50 ±1.72^{C}
DO (µg/L/L)	11.5±1.01^{ab}	11.3 ±3.93^{a}	11.7 ±2.83^{b}	12.0±3.18^{bc}	11.6 ±2.64^{C}	11.3±2.73^{b}	11.0±1.97^{a}	11.0 ± 2.17^{a}	11.5±2.73^{bc}	11.2 ±2.11^{C}
Electrical Conductivity (µS/cm)	377 ±33.93^{b}	379±30.32^{bc}	396±25.02^{c}	352 ±28.09^{a}	368.2 ± 26^{A}	303±30.62^{ab}	289 ±25.82^{a}	353.6 ±31^{ab}	376 ±30.82^{b}	330 ± 24.8^{B}
Total Hardness (mg/L)	75 ± 4.5^{a}	110 ± 7.98^{b}	119 ± 6.93^{b}	116 ± 4.92^{b}	105 ±5.83^{A}	129 ±14.63^{a}	124 ±10.71^{a}	152 ±10.29^{b}	159 ±10.73^{b}	141 ± 8.53^{B}
Alkalinity (mg/L)	12.3 ± 0.45^{a}	9.6 ± 2.54^{b}	9.6 ± 1.94^{b}	8.8 ± 1.14^{b}	10.07±1.7^{AB}	7.93 ± 1.01	9.12 ± 2.41	10.15±2.54	9.12 ± 2.82	9.08±2.58^{A}
BOD (mg/L)	2.76 ± 0.21^{a}	1.92±0.09^{ab}	1.68 ±0.74^{b}	2.14 ± 0.92^{a}	2.12 ±0.36^{C}	1 ± 0.01	0.67 ± 0.14	0.53 ± 0.26	0.85 ± 0.35	0.76 ±0.16^{A}
Total P (mg/L)	0.16 ± 0.03	0.16 ± 0.05	0.14 ± 0.09	0.09±0.009	0.13 ± 0.03	0.12 ± 0.06^{a}	0.16 ± 0.09^{a}	0.12 ± 0.02^{a}	0.26 ± 0.07^{b}	0.16 ± 0.04
F^- (mg/L)	0.14 ± 0.01	0.2 ± 0.04	0.19 ± 0.02	0.19 ± 0.01	0.18±0.02^{AB}	0.19 ± 0.03^{a}	0.22 ± 0.02^{a}	0.1 ± 0.01^{ab}	0.085±0.02^{b}	0.14 ±0.02^{A}
Cl^- (mg/L)	25.2 ± 3.86^{b}	18.1 ± 1.73^{a}	36.2 ± 5.39^{c}	39.4 ± 3.92^{c}	29.7±3.74^{BC}	19.01±3.76^{b}	3.36 ± 0.50^{a}	28.17±2.61^{c}	33.3 ± 3.10^{c}	20.96 ± 2.5^{A}
NO_2^- (mg/L)	0.12 ± 0.02	0.13 ± 0.03	0.14 ± 0.04	0.17 ± 0.04	0.14 ±0.04^{B}	0.04 ±0.002	0.04 ± 0.01	0.05 ± 0.01	0.06 ±0.008	0.04 ± 0.01^{A}
NO_3^- (mg/L)	3.21 ± 0.97^{a}	3.41 ± 0.08^{a}	2.24 ±1.01^{b}	2.14 ± 0.07^{b}	2.75 ± 0.73	2.88 ± 0.59	2.73 ± 1.25	2.82 ± 0.07	2.89 ± 0.23	2.83 ± 0.46
SO_4^{-2} (mg/L)	16.64 ±2.11	19.56 ±5.82	17.6 ±2.88	18.37±1.63	18.06 ±3.52	14.54 ±4.9^{ab}	11.84±2.74^{a}	16.49±1.6^{ab}	18.13±1.81^{b}	15.25 ± 2.6
Na^+ (mg/L)	24.3 ±4.84^{ab}	21.5 ± 6.27^{a}	27.8±3.92^{bc}	32.9 ± 4.24^{c}	26.6± 5.52^{B}	19.5 ± 2.53^{b}	10.3 ± 1.05^{a}	25.2±2.72^{bc}	28.3 ± 2.02^{c}	20.8 ± 2.23^{A}
NH_4 (mg/L)	0.18 ± 0.01^{a}	0.35 ± 0.03^{a}	0.03 ±0.01^{b}	0.02±0.003^{b}	0.15 ±0.01^{A}	0.04 ± 0.01^{a}	0.17 ± 0.02^{b}	0.05±0.005^{a}	0.27 ±0.05b	0.13 ± 0.02^{A}
K^+ (mg/L)	3.57 ± 0.91	3.71 ± 1.81	3.55 ± 0.07	3.98 ± 0.05	3.70±0.08^{BC}	2.79 ± 0.91	2.6 ± 0.09	2.9 ±0.25	3.21±1.04	2.89 ± 0.04^{A}
Mg^+ (mg/L)	8.1 ± 1.51^{a}	8.1 ± 2.96^{a}	8.4 ± 2.51^{ab}	12.0 ± 1.25^{b}	9.2 ± 1.93^{AB}	8.2 ± 1.53^{b}	4.9 ± 1.52^{a}	10.4 ± 3.28^{b}	11.4 ±2.92^{b}	8.7 ± 2.02^{A}
Ca^+ (mg/L)	25.9 ±5.12^{ab}	22.1 ± 3.71^{a}	25.5±3.07^{ab}	29.2 ± 2.18^{a}	25.7 ±4.02^{A}	35.7 ± 7.18^{a}	21.0 ± 3.92^{b}	30.5 ± 4.83^{a}	35.7 ± 3.82^{a}	30.0 ± 3.8^{AB}
Chl-*a* (µg/L/L)	1.3 ± 0.01	1.0 ± 0.01	1.7 ± 0.19	1.5 ± 0.15	1.4 ± 0.07	2.0 ± 0.22^{a}	0.4 ± 0.04^{b}	1.7 ± 0.01^{a}	2.0 ± 0.42^{a}	1.6 ± 0.12

	Summer					Autumn				
	1	**2**	**3**	**4**	**Average**	**1**	**2**	**3**	**4**	**Average**
Water Temperature (C°)	21.8±3.54^{c}	21.65±2.64^{a}	21.80±1.96^{c}	21.70±1.78^{b}	21.73± 2.1^{D}	11.70±1.47^{a}	11.80±2.24^{b}	11.70±1.67^{a}	15.30±2.63^{c}	12.62±2.03^{C}
pH	8.36± 1.52^{bc}	8.29 ± 1.03^{b}	8.39 ± 1.64^{c}	8.20 ± 1.42^{a}	8.31± 1.43^{A}	9.30 ± 1.11^{c}	8.88 ± 2.84^{b}	8.82 ± 1.07^{b}	8.62 ± 1.08^{a}	8.90 ± 1.96^{B}
DO (mg/L)	7.8 ± 0.74^{a}	8.7 ± 1.01^{b}	8.8 ± 0.59^{b}	8.9 ± 0.97^{b}	8.6 ± 0.99^{A}	9.7 ± 1.13^{bc}	9.2 ± 1.03^{b}	9.9 ± 1.98^{c}	8.8 ± 2.01^{a}	9.4 ± 1.35^{B}
Electrical Conductivity (ppm)	357.5±21.7^{ab}	321 ± 20.7^{a}	365 ± 24.9^{b}	370.5±22.9^{b}	353.5± 23^{AB}	351±25.64^{a}	342± 34.27^{a}	362± 30.83^{a}	464± 33.33^{b}	379.75±31.3^{A}
Total Hardness (mg/L)	147± 11.45^{ab}	149±10.28^{ab}	140 ±10.11^{a}	145±11.18^{ab}	145±10.29^{B}	170 ±12.36^{b}	152 ±10.35^{a}	152 ± 7.54^{a}	156±11.27^{ab}	157 ±11.74^{B}
Alkalinity (mg/L)	10.46 ± 7.29	12 ± 9.29	11.48 ±2.72	10.97 ±2.11	11.2 ±1.38^{B}	9.63 ± 2.45	11.68 ±3.34	10.66 ±1.58	10.66 ±2.35	10.6 ± 2.46^{AB}
BOD (mg/L)	1.15 ± 0.02	1 ± 0.01	1.4 ± 0.02	1.7 ± 0.01	1.31 ±0.01^{B}	1 ± 0.07	0.93 ± 0.27	1 ± 0.11	1.05 ± 0.18	0.99 ± 0.19^{AB}
Total P (mg/L)	0.06 ± 0.01^{a}	0.14 ± 0.02^{b}	0.11 ± 0.05^{a}	0.05±0.001^{b}	0.09 ± 0.01	0.09 ± 0.01	0.1 ± 0.01	0.07 ± 0.01	0.14 ± 0.03	0.10 ± 0.02
F^- (mg/L)	0.3 ± 0.03	0.32 ± 0.02	0.12 ± 0.01	0.18 ± 0.01	0.23 ±0.02^{B}	0.21 ± 0.04^{a}	0.34 ± 0.03^{a}	0.06 ± 0.01^{b}	0.14 ± 0.03^{a}	0.18± 0.01^{AB}
Cl^- (mg/L)	23 ± 4.29^{b}	7.02 ± 0.91^{a}	30.3± 3.84^{c}	31.49±3.26^{c}	22.96±2.8^{AB}	44.32±4.73^{b}	10.14±2.46^{a}	43.23±7.36^{b}	41.68±4.83^{b}	34.84±4.07^{BC}
NO_2^- (mg/L	0.17 ± 0.03	0.19 ± 0.01	0.1 ± 0.01	0.2 ± 0.02	0.16 ±0.01^{B}	0.1 ± 0.05	0.07 ± 0.01	0.04 ±0.001	0.06 ± 0.01	0.06 ±0.008^{A}
NO_3^- (mg/L)	1.85 ± 0.23	2.03 ± 0.37	1.85 ± 0.83	1.99 ± 0.92	1.93 ± 0.87	1.62 ± 0.39^{a}	4.42 ± 0.44^{b}	1.52 ± 0.75^{a}	1.56 ± 0.25^{a}	2.28 ± 0.57
SO_4^{-2} (mg/L)	14.14± 1.82	13.85± 2.12	15.77± 2.90	16.06± 1.23	14.95± 2.76	16.01± 1.82	19.86± 3.49	14.77± 2.59	17.19 ±1.75	16.95 ± 2.25
Na^+ (mg/L)	20.9 ± 2.18^{b}	16.0 ± 1.83^{a}	24.8 ± 2.92^{c}	25.0 ± 3.11^{c}	21.71 ±2.1^{A}	35.3 ± 3.97^{b}	23.4 ± 2.34^{a}	34.7 ± 3.65^{b}	37.8± 3.04^{bc}	32.82± 3.16^{C}
NH_4 (mg/L)	0.17 ± 0.01^{a}	0.28 ± 0.02^{a}	0.05± 0.01^{b}	0.09± 0.01^{ab}	0.14± 0.01^{A}	0.09 ± 0.03	1.18 ± 0.73	0.05 ± 0.02	0.08 ± 0.01	0.35 ± 0.05^{B}
K^+ (mg/L)	2.98 ± 0.12	3.74 ± 0.52	3 ± 0.63	3.05 ± 0.27	3.19±0.34^{AB}	3.83 ± 0.33	4.81 ± 1.24	3.67 ± 0.36	3.99 ± 0.39	4.07 ± 0.75^{C}
Mg^+ (mg/L)	10.8 ± 1.04^{b}	8.57 ± 0.93^{a}	11.86±1.2^{bc}	11.9± 1.11^{bc}	10.78± 0.9^{B}	13.53±2.34^{b}	9.9 ± 2.48^{a}	13.37±1.35^{b}	14.27±3.83^{b}	12.76± 2.57^{C}
Ca^+ (mg/L)	37.6 ± 5.82	43.1 ± 6.01	36.8 ± 4.16	36.9 ± 3.87	38.6±4.09^{BC}	39.5 ± 6.73^{a}	50.8 ± 7.08^{b}	37.3 ± 3.95^{a}	39.2 ± 4.17^{a}	41.7 ± 5.64^{C}
Chl-*a* (µg/L/L)	0.7 ± 0.01^{a}	0.6 ± 0.02^{a}	3.8 ± 0.09^{b}	2.1 ± 0.08^{b}	1.8 ± 0.05	0.7 ± 0.07^{a}	1.0 ± 0.01^{a}	1.1 ± 0.13^{a}	4 ± 0.88^{a}	1.7 ± 0.05

Means followed by different letters and letter groups in the same row are significantly different according to stations ($^{a....d}$) and seasons ($^{A....D}$) ($p<0.01$), values are means±SD 1, 2, 3, 4: Numbers of the stations (Given in Figure 1)

Acknowledgments: This study financed by the Bingöl University Scientific Research Foundation (BÜBAP/2010/18). The authors wish to acknowledge the support for this project.

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