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Evaluation of physical, chemical and microbiological properties of lake Uluabat, Turkey

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Abstract: *Lake Uluabat, known for its scenic beauty and richness of aquatic life, is situated in Marmara Region, Bursa (Turkey). On account of its importance, lake Uluabat was designated by the Ministry of Environment as a Ramsar site in 1998.Physical, chemical and microbiological parameters of the aquatic ecosystem in lake Uluabat were measured monthly at five stations from February 2003 to January 2004. The results showed that lake Uluabat can be classified as Class I with respect to temperature (16.36 ± 7.47°C), nitrate nitrogen (0.63 ± 0.50 mgl^{-1}), sodium (9.64 ± 2.78 mgl^{-1}), chloride (20.45 ± 4.59 mgl^{-1}), sulphate (54.80 ± 29.97 mgl^{-1}); as Class II with respect to dissolved oxygen (7.62 ± 1.99 mgl^{-1}), ammonium nitrogen (0.52 ± 0.49 mgl^{-1}), chemical oxygen demand (35.74±10.66 mgl^{-1}), total coliform (2027 MPN100 ml^{-1} (average value)); as Class III with respect to pH (8.69 ± 0.16) and as Class IV with respect to total nitrogen (84.94 ± 66.13 mgl^{-1}), total phosphorus (1.11 ± 3.01 mgl^{-1}), biochemical oxygen demand (21.21 ± 6.60 mgl^{-1}) according to TWPCR (Turkey Water Pollution Control Regulation). The nutrient content of lake water apparently indicated that lake had an eutrophic characteristic. Phosphorus was determined as a limiting factor in lake. The measured hardness values (140.94 ± 14.61 $CaCO_3$ mgl^{-1}) indicated that lake water was classified as soft/hard during the study period. Eutrophic characteristic of the lake and contaminant accumulation in water will probably affect the future use of the lake. Therefore, pollution parameters must be regularly monitored and evaluated according to aquatic living and local regulations.*

Key words: *Water quality, Lake Uluabat, Ramsar site, Turkey*
PDF of full length paper is available with author ***(*aelmaci@uludag.edu.tr)***

Introduction

Population growth, advancement in agriculture, urbanization and industrialization have made surface water pollution a great problem and have decreased the availability of drinking water. Many parts of the world face such a scarcity of water. Most of wastewaters are dumped straight into rivers, lakes and estuaries without any treatment. One major goal of surface water quality data collection may be the estimation of magnitude of changes in the concentration of various constituents (Giljanovic, 2005; Sachidanandamurthy and Yajurvedi, 2006; Krishnan *et al.,* 2007; Anand *et al.,* 2006).

Lake Uluabat, which is located in Marmara Region, Bursa (Turkey) (40°10' N, 28°35' E) is one of the most productive lakes with respect to aquatic ecosystems. It has a surface area of 133 km^2 in 1984, 120 km^2 in 1993 and 117 km^2 in 1998. Uluabat, an eutrophic lake, is one of the largest freshwater lakes in Turkey. It has been well known for its scenic beauty and richness of aquatic life.

Mustafakemalpasa and Karacabey districts are the two large residential areas around the lake Uluabat. The main human activity at the lake is fishing. Agricultural lands and industry also surround the lake. The river Mustafakemalpasa is the lake's major inflow but there is also input from underground springs. It drains a large part of southern Marmara and northern Aegeis regions, bringing large quantities of urban and industrial waste into the lake basin each year (Altinsacli 2001). Furthermore, drainage water from the surrounding fields leaks back into the lake, rendering lake Uluabat eutrophic.

On account of its importance, lake Uluabat was designated by the Ministry of Environment as a Ramsar site in 1998 and consequently, it was chosen as a partner of International living lakes network in the 4th International conference at EXPO 2000 (Aksoy and Ozsoy, 2002).

The objectives of this study were to present some data related to the systematic study of physical, chemical and microbiological characteristics of lake Uluabat at 5 locations and to discuss the case of lake Uluabat in respect of human impact on the environment with a view to provide good insight for future management of similar freshwater resources.

Materials and Methods

Field sampling: The water samples were collected monthly from February 2003 to January 2004 at five different locations. The study area and the sampling locations are shown in Fig. 1. Polyethylene bottles (2000 ml) were rinsed and filled with lake water. All samples collected were immediately delivered to the analytical laboratory for further analysis.

Physical parameters: The physical water quality parameters considered during monitoring period were temperature, pH, secchi disc depth and electrical conductivity. pH and temperature were measured by Metrohm pH-meter. Electrical conductivity [$EC_{(25°C)}$] was measured by Jenway conductivity meter (Model 4310). Secchi disc depth was measured by Secchi disc (Windaus).

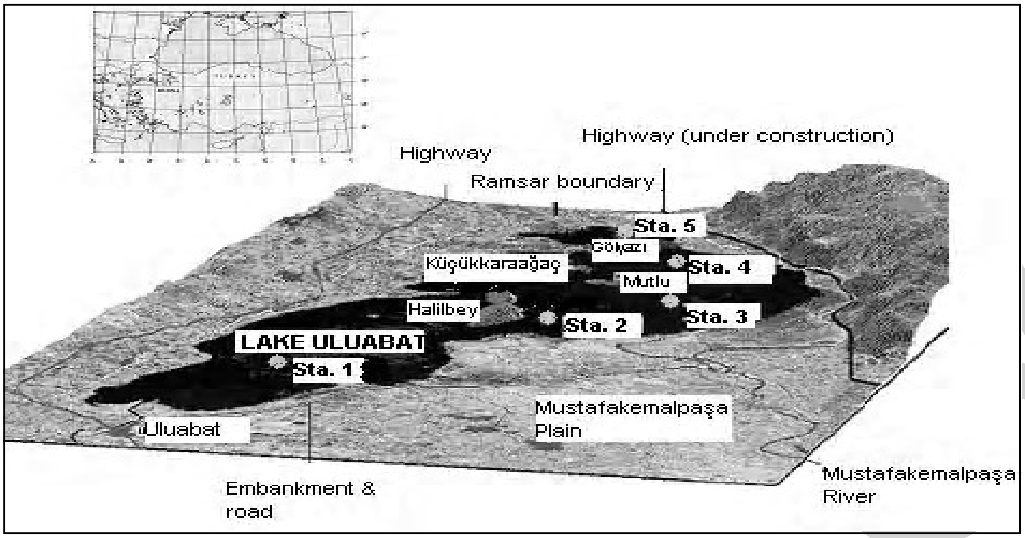

Fig. 1: A map of lake Uluabat (Aksoy and Ozsoy, 2002)

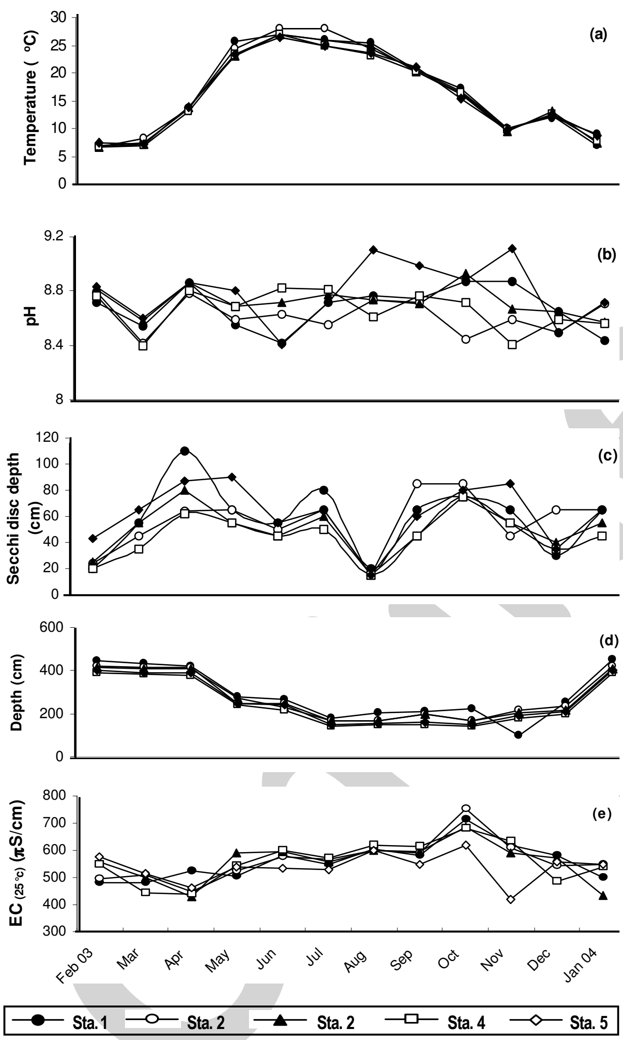

Fig. 2: Seasonal variations of physical parameters, a = Temperature, b = pH, c = Secchi disc depth, d = Depth, e = $EC_{(25^oC)}$

Nutrient and chemical parameters: The parameters measured in the samples obtained from the lake area included dissolved oxygen (DO), total nitrogen (TN), nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N), total phosphorus (TP), ortho-phosphate phosphorus (PO_4-P), main cations and anions (Ca^{++}, Mg^{++}, Na^+, K^+, Cl^-, CO_3^{2-}, HCO_3^-, SO_4^{2-}), hardness, alkalinity, chemical oxygen demand (COD) and biochemical oxygen demand (BOD). Parameters were analysed according to standard methods (APHA, 2005).

Microbiological parameters: Total coliform numbers were determined by the most probable number method of standard methods (APHA, 2005). Brilliant green bile broth was used as growing medium. Inoculated tubes were incubated at 37°C for 48 hours.

Statistical analysis: All statistical analysis of physical, chemical and microbiological variables of the water quality was performed using MINITAB (version 14) statistical software (MINITAB, 2003).

Results and Discussion

Temperature is an important variable as critical temperatures vary for many species. The annual average surface water temperature of lake Uluabat was approximately 16.36 ± 7.47°C during the sampling period. The highest temperature (28°C) and the lowest temperature (6.6°C) were recorded in June and February, respectively (Fig. 2a). Temperature values showed the expected seasonal pattern with no differences between the sampling stations, similar to works of Kagalou *et al.* (2001) and Sivri *et al.* (2007).

Hydrogen ion concentration of lake water are quite variable throughout the seasons and pH >7 indicates that alkaline conditions are dominant in the lake (Karafistan and Colakoglu, 2005). The observed pH values in Uluabat indicated that slight alkaline conditions were dominant possibly due to carbonate and bicarbonate content. In this research, the pH of lake water reached maximum value (9.11) in November and minimum value (8.40) in March (Fig. 2b). It

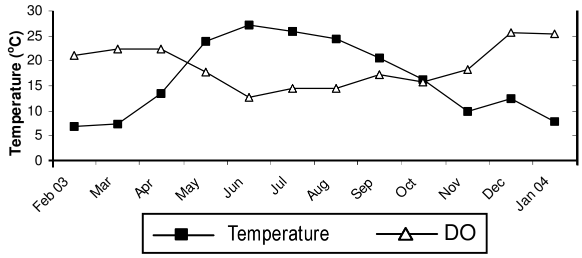

Fig. 3: Monthly variation of DO and temperature

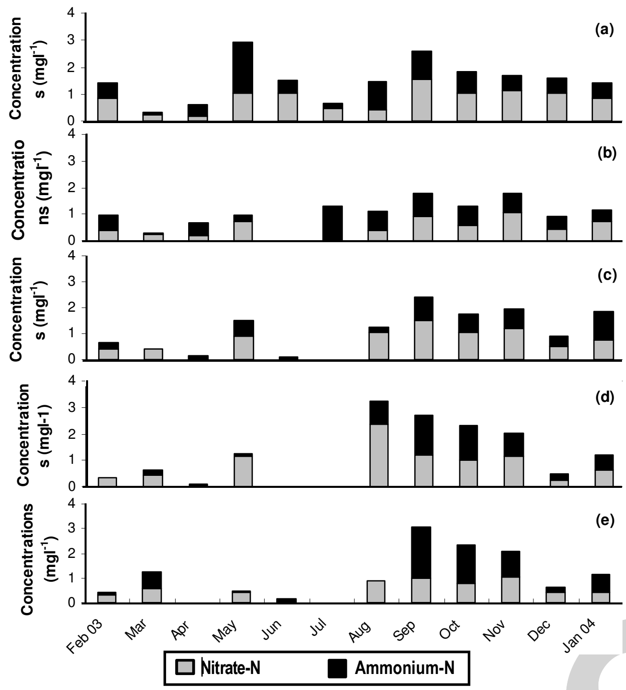

Fig. 4: Variation of dissolved inorganic nitrogen according to months a = Station 1, b = Station 2, c = Station 3, d = Station 4, e = Station 5

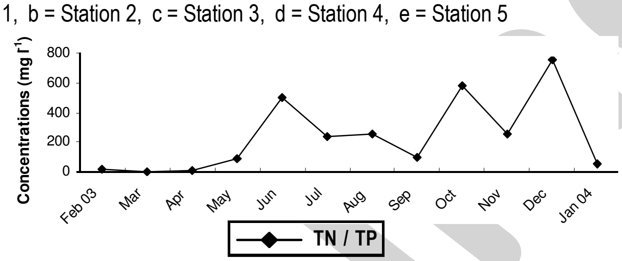

Fig. 5: Monthly variation of medium TN/TP ratio of five stations in lake Uluabat

was stated in many studies that lower pH values were observed in late spring and summer (Temponeras *et al.,* 2000; Geraldes and Boavida, 2004). Similarly, the higher pH levels (reaching 9.3) were recorded in Rostherne Mere (UK), presumably as a result of the increase uptake of CO_2 by primary production (Krivtsov *et al.,* 2001). It is known that sudden pH changes may adversely affect some biological processes resulting in deterioration of whole water chemistry. However, no significant changes in water chemistry of lake Uluabat is expected as monthly pH variations were rather slight.

The seasonal variation of secchi disc depth is shown in Fig. 2c. Maximum secchi disc depth of 110 cm was observed in April at station 1, whereas minimum value of 15 cm was measured in August at stations 2, 3, 4 and 5. The annual average of secchi disc depth was calculated as 54.42 ± 21.47 cm for lake Uluabat. The observed values indicated that secchi disc depth increased in spring and autumn seasons and decreased in winter and summer seasons at all stations.

Fig. 2-d indicates the seasonal variation of lake depth. No significant variation was observed in all stations with respect to lake depth with the average value of 268.4 ± 106.8 cm. A general trend of increase was observed in winter whereas lake depth decreased in summer months. Irrigational use of the lake water for Mustafakemalpasa plain and around the lake basin has reduced the water depth, especially in the summer months. An increase in vaporization and decrease in precipitation intensity are the other two factors that have also decreased the water level. However, the water-level decrease has affected the nutrient status. It was reported that morphometry of lake influences the patterns of change in nutrient concentrations on both a seasonal and inter annual basis. Because of the shallow characteristics of the lake, the absence of thermal stratification, together with wind-induced mixing in summer time, seems to have affected nutrient concentrations (Søndergaard *et al.,* 2005).

Measurement of electrical conductivity [$EC_{(25^oC)}$] in lake water provides rather sufficient information about the quantity of dissolved material found in water. Water bodies that have an $EC_{(25^oC)}$ value of 50-200 μScm^{-1}, 200-500 μScm^{-1} and 500-2000 μScm^{-1} are classified as very soft, soft and hard, respectively (Hütter, 1992). The measured $EC_{(25^oC)}$ values in lake Uluabat were similar in all stations. The annual mean $EC_{(25^oC)}$ value of the lake was around 555.75 ± 68.16 μScm^{-1} indicating lake Uluabat can be classified as soft/hard waters (Fig. 2e).

Oxygen is the most important gas for most aquatic organisms and for self-purification processes (Said *et al.,* 2004). Therefore, determination of monthly and stational variations of dissolved oxygen (DO) is of high importance in lake observation studies. In this research DO values observed in lake Uluabat decreased in summer months whereas they increased in winter. Similar finding was also stated for lake Pamvotis (Greece) by Kagalou *et al.* (2006) with the minimum and maximum DO values of 2.1 mgl^{-1} in July and 12.5 mgl^{-1} in January, respectively. DO values observed at all stations were comparable to results of Kagalou *et al.* (2001) and Karakoc *et al.* (2003). Fig. 3 apparently indicates significant negative correlation (r = -0.59) between temperature and DO of average values of all stations.

Fig. 4 shows seasonal variations of dissolved inorganic nitrogen (Nitrate-N and Ammonium-N) concentrations belonging to stations 1 to 5. In general, it has been known from literature that nitrate concentrations vary between 0.4 - 8 mgl^{-1} (0.09 - 1.8 mgl^{-1} as NO_3^--N) in surface waters (Hutter, 1992). The measured nitrate values in lake Uluabat varying between these limits indicate that there is probably no significant nitrate pollution risk in the water body. Generally it is known that NH_4^+-N concentrations are below 0.1 mgl^{-1} in surface waters over the year. In lake Uluabat, the observed NH_4^+-N

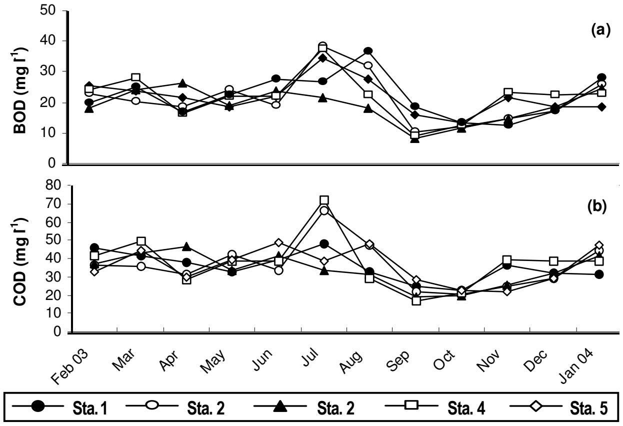

Fig. 6: Monthly variation of COD and BOD values for all stations (a) BOD, (b) COD

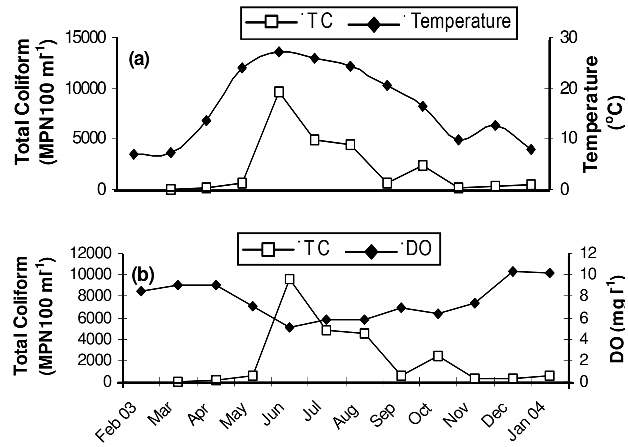

Fig. 7: Relationship between total coliform and temperature (a) and total coliform and dissolved oxygen (b)

concentrations generally exceeded this level (mean value: 0.52 ± 0.49 mgl^{-1}). The settlement around the lake and municipal or agricultural runoff from agricultural lands might have caused this increment.

It's shown in Fig. 4 that the observed NO_3-N concentrations were extremely high in Station 1, 3 and 4 (annual mean: 0.84 ± 0.49 mgl^{-1}, 0.66 ± 0.51 mgl^{-1} and 0.72 ± 0.71 mgl^{-1}, respectively) probably due to nitrification process. In lake Mogan and lake Eymir annual mean concentrations of NO_3 + NO_2-N were 95 ± 26 μgl^{-1} and 54 ± 18 μgl^{-1} respectively (Burnak and Beklioglu, 2000; Beklioglu *et al.,* 2000). Besides, highest NH_4-N concentrations were observed in Station 2 and 5 (annual mean: 0.55 ± 0.36 mgl^{-1} and 0.55 ± 0.69 mgl^{-1}, respectively) in lake Uluabat as a result of denitrification process.

Nutrient limitation is the control of growth or production by a nutrient or nutrients (in contrast to limitation by other factors, such as light, predation, or temperature). Survey of tests of nutrient limitation in lakes indicate that either nitrogen or phosphorus most commonly limits primary production and that many lakes are colimited by both nitrogen and phosphorus (Dodds, 2002). Phosphorus is important for all living organisms; however, excessive phosphorus causes algal blooms, harmful to most aquatic organisms. They may cause a decrease in the DO levels of water and in some cases temperature increases. This can result in a fish kill and the death of many organisms (APHA, 2005; Said *et al.,* 2004). Total phosphorus (TP) was mostly generated in the forested part of the watershed where most of the sediment originates. Total nitrogen concentrations in the water entering the wetland typically range from 7-10 N mgl^{-1} with 90-95% as nitrate (Blindow *et al.,* 2002). It is important to know if there is a limiting nutrient in lake Uluabat, as an increase of the limiting nutrient may affect the quality of lake water.

When monthly variation of mean TN/TP ratio of five stations in lake Uluabat were examined (Fig. 5), there was a decreasing trend during summer months, possibly due to the marked increment of TP. On the other hand TN/TP ratio was generally increased during winter. Highest level of TN/TP ratio was measured in December (751.9) and lowest level of TN/TP ratio was measured in March (0.45). It was known that in eutrophic shallow lakes phosphorus concentrations in summer being much higher than in winter because of net release of phosphorus from the sediment (Willender and Persson, 2001; Søndergaard *et al.,* 2001). Similarly Sondergaard *et al.* (2005) reported that internal loading of phosphorus especially in summer caused an unsatisfactory water quality in 12 Danish lakes in spite of the reduced external phosphorus loading. According to evaluated values phosphorus was determined as a limiting factor in lake Uluabat. In lake Krankesjon, N/P ratio decreased from 52 to 34-40 in summer season (Blindow *et al.,* 2002). Rai (2000) stated that phosphorus was the limiting element in Phewa, Begnas and Rupa lakes of Nepal during their study about PC:PN,PN:PP and Red field ratio (106C : 16N : 1P) ratios.

Hardness is the result of two positive ions dissolved in water such as Ca^{++}, Mg^{++}, Sr^{++}, Fe^{++}, Mn^{++}. In addition to these cations, some anions (mainly SO_4^{2-}, Cl^-, NO_3^- and SiO_3^-) naturally exist in water. Inland lakes are generally dominated by calcium and bicarbonate. The most common ion sequences, as equivalent lakes, is Ca>Mg>Na>K, HCO_3>SO_4>Cl (Kalff, 2002). Na is an element encountered in different types of water. Concentration of Na varies between 1 and 500 mgl^{-1}. When agricultural lands are irrigated with water containing high concentration of Na, Na replaces Ca and Mg ions, which causes negativity in land structure. Source of Ca ion is calcium minerals with carbonate and sulphate. In this respect, different concentrations of calcium may exist in water. Higher concentrations of Ca and Mg restrict use of drinking, industrial and irrigation water (Disli *et al.,* 2004). Table 1 shows monthly variation of anion and cation values of lake Uluabat. Average annual concentrations of Ca^{++}, Mg^{++}, Na^+, K^+, Cl^-, CO_3^{2-}, HCO_3^- and SO_4^{2-} were 44.17 ± 21.79 mgl^{-1}, 37.83 ± 9.04 mgl^{-1}, 9.64 ± 2.78 mgl^{-1}, 3.28 ± 0.76 mgl^{-1}, 20.45 ± 4.59 mgl^{-1}, 45.03 ± 20.91 mgl^{-1}, 181.07± 47.85 mgl^{-1} and 54.80 ± 29.97 mgl^{-1}, respectively.

It is known from the literature that generally potassium levels of surface waters do not exceed 1-2 mgl^{-1}. Low solubility of feldspats containing K^+ and the fixation of available K^+ by soil particles causes these low levels (Hutter, 1992). High concentration of potassium in lake Uluabat (average 3.28 ± 0.66 mgl^{-1}) may be due to leakage of potassium fertilizers from surrounding lands with rainfall.

Table - 1: Monthly variation of cation and anion values

	Feb. 03	Mar. 03	Apr. 03	May 03	Jun. 03	Jul. 03	Aug. 03	Sep. 03	Oct. 03	Nov. 03	Dec. 03	Jan. 04	Mean±SD
Ca^{++}	20.32	45.02	38.88	43.84	43.05	35.52	34.48	38.48	109.6	39.36	44.64	36.80	44.17 ± 21.79
Mg^{++}	23.23	36.77	38.98	38.54	40.44	41.57	47.14	44.69	19.68	43.01	40.99	38.98	37.83 ± 9.04
Na^{+}	14.32	13.13	10.10	8.47	8.75	9.33	8.31	7.43	6.16	9.12	8.41	12.08	9.64 ± 2.78
K^{+}	3.51	2.94	2.38	2.72	3.04	4.64	4.33	3.38	3.26	3.23	3.11	3.53	3.28 ± 0.76
Cl-	20.01	20.56	15.62	25.52	22.69	25.53	20.56	23.97	20.57	18.44	17.73	14.18	20.45 ± 4.59
CO_3^{2-}	33.60	23.60	50.40	48.00	43.20	50.40	63.60	67.20	60.00	21.12	14.40	64.80	45.03 ± 20.91
HCO_3^{-}	252.50	227.40	134.20	163.48	190.32	141.50	187.90	195.20	158.60	209.80	196.98	114.90	181.07 ± 47.85
SO_4^{2-}	37.70	41.70	65.50	40.25	39.23	50.20	22.37	33.31	106.98	67.70	89.17	63.50	54.80 ± 29.97
Hardness	134.40	138.00	135.80	138.00	138.00	131.60	142.20	145.00	178.50	140.80	140.80	128.20	140.94 ± 4.61

All values are in mgl^{-1}

Cl^- ion is another indicator of pollution and 20 mgl^{-1} is accepted as the beginning value of pollution in natural waters. It is reported that in lake Sapanca Cl^- ion varies between 2.48 - 6.38 mgl^{-1} indicating significantly lower levels than standard values of (200-600 mgl^{-1}) Turkey Water Pollution Control Regulation (Yalcin and Sevinc, 1993). The annual average concentration of Cl^- (annual average 20.45 ± 4.59 mgl^{-1}) in lake Uluabat was about 20 mgl^{-1}.

In some cases natural waters significantly consist of carbonate, bicarbonate and hydroxide alkalinity. This situation is especially valid for surface waters where algae reproduction is present. Algae take free and ionized carbondioxide from water and therefore pH level increases to 9-10 (Sengul and Muezzinoglu, 1993). Mansour and Sidky (2003) stated that the water from the different studied lakes proved to be slightly alkaline with an average pH of 8. Carbonate anions were detected at concentrations lower than bicarbonates in lake Qarun. Corresponding values were found compared with that of lake Uluabat (with an average pH of 8.4).

Hardness of water indicates regional variation in hydrosphere. As a rule, surface waters are softer than underground waters in general. Hardness degree of water is related to geological structure contact throughout watershed (Sengul and Muezzinoglu, 1993). According to annual mean value of five stations, the hardness of lake Uluabat is classified as medium level with a value of 140.94 ± 14.61 $CaCO_3$ mgl^{-1}.

Fig. 6 indicates monthly variation of BOD (Biochemical oxygen demand) and COD (Chemical oxygen demand). BOD provides broad measure of the effects of organic pollution on receiving water. High mean BOD values in lake Uluabat (mean value: 21.21 ± 6.60 mgl^{-1}) points out significant entry of organic pollution load to the lake (Usha *et al.*, 2006). When the average BOD values were compared with Turkey Water Pollution Control Regulation, the water quality of lake Uluabat was classified as IV Class during the study period (Anonymous, 2004).

COD parameter, as BOD, is used for determination of lake pollution level based on oxidation of organic matter with redox reaction. In general, COD values are higher than BOD values (Samsunlu, 1999). Highest COD value of lake was observed in July (71.8 mgl^{-1}) and the lowest COD value was observed in September (16.4 mgl^{-1}). The annual average value of COD was calculated as 35.74 ± 10.66 in lake Uluabat.

Higher ratio of COD/BOD points out excessive quantity of organic matter which is not decomposed by microorganisms. COD/BOD ratios for each station in lake Uluabat were determined as 1.2; 1.69; 1.09; 1.7 and 1.62. These closer values also show that the structures of organic matter entering to lake Uluabat were similar in all stations.

Total coliform (TC) is one of the important microbiological parameters of water quality. The average total coliform number was determined as 2027 MPN100 ml^{-1} in lake Uluabat. This high value in coliform count probably arisen from untreated wastewater discharges from households, other domestic sources and industrial sewage. Several factors including temperature, pH and dissolved oxygen influence the decay of coliform bacteria (An and Breindenbach, 2005). Fig. 7 shows the correlation between TC-temprature and TC-DO. A dry season after the wet season results in the higher loading of total coliform bacteria. The total coliform numbers were positively correlated with temperature ($r = 0.41$), whereas it was negatively correlated with dissolved oxygen ($r = -0.27$).

Lau and Lane (2002) and Karakoc *et al.* (2003) studied the water quality parameters and ecological characteristics of Barton Broad in UK and Mogan and Eymir lake in Turkey, shallow lake systems similar to lake Uluabat and concluded as follows: a) trophic inter-relationships in eutrophic lake are strongly related to temporal heterogeneity; b) seasonality was identified as an important variable affecting lake eutrophication; c) it is difficult to restore an eutrophic lake solely by nutrient reduction; d) the complexity of environmental factors involved necessitates long-term data for an understanding of interacting variables and lake ecosystem behaviour.

Although it is difficult to judge about the degree of longterm pollution and water quality from short period measurements yet, they supply seasonal information about the lake water quality and enable the comparison of observed data with former studies. In this research physical, chemical and microbiological parameters were monitored seasonly in five sampling station from February-2003 to January-2004 in lake Uluabat for evaluation of water quality parameters. According to Turkey Water Pollution Control Regulation, lake Uluabat has been identified as Class I with regard to temperature, nitrate-N, sodium, cloride, sulphate; as Class II with regard to DO, ammonium-N, COD, total coliform; as Class III with regard to pH and as Class IV with regard to total-N, total-P, BOD (Anonymous, 2004).

The results showed that Uluabat lake has an eutrophic characteristic. Phosphorus was a limiting factor in lake Uluabat. The measured hardness values indicate lake Uluabat can be classified as soft/hard during the study period.

The use of lake Uluabat for different purposes is a great importance for Bursa city. According to determined physical and chemical parameters use of lake Uluabat for irrigation, water products, recreation, *etc.* was found appropriate. Eutrophic characteristic of lake Uluabat and contaminant accumulation in water may affect the future use of the lake. Therefore, pollution parameters must be regularly monitored and evaluated according to aquatic living and local regulations. In further studies management strategies may be developed to provide sustainability of lake Uluabat. In addition, an effective coordination among the related governmental and local agencies would give benefical results.

Acknowledgment

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