

Monitoring of Sediment Quality and Nutrients Dynamics of Lake Uluabat, Turkey*

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Received: 07.03.2015; Accepted: 07.04.2015; Published Online: 13.05.2015

ABSTRACT

Lake Uluabat, as being an important RAMSAR site, is located in Marmara Region, Turkey. Lake is one of Turkey's rich shallow lakes in terms of aquatic plants, fish and birds. The wetlands of Lake Uluabat and its catchments face a number of problems and threats which could make these valuable resources change or degrade. Human activities, both direct and indirect, are great contributors to degradation and loss of Lake Uluabat wetlands and its water quality. There is no law or regulations about sediment quality assessment and protection works in Lake Uluabat. The objective of this research is to evaluate the sediment quality and nutrients dynamics of Lake Uluabat. For this purpose pH, electrical conductivity, total nitrogen, hydrolysable total nitrogen, total phosphorus, available phosphorus, organic carbon parameters, anions (Cl^- , CO_3^{2-} , $CaCO_3$) and cations (Ca^{++} , Mg^{++} , Na^+ , K^+) of the sediment were analysed at five stations which are close to urban/industrial locations, inlet/outflow points of lake and drain point of Mustafakemalpaşa Creek. The obtained results have shown that alkaline conditions are dominant in Lake Uluabat. The results of this study are to guide for sediment quality monitoring and assessment studies for Lake Uluabat and for further studies.

Keywords: Chemical physical variables, Lake Uluabat, Nutrients, Sediment quality

Uluabat Gölü'nün Sediman Kalitesi ve Besin Elementleri Dinamiğinin Değerlendirilmesi

ÖZET

Uluabat Gölü, önemli bir Ramsar Alanı olarak, Türkiye'de Marmara Bölgesinde yer almaktadır. Göl su bitkileri, balıklar ve kuşlar açısından Türkiye'nin en zengin sığ göllerinden birisidir. Uluabat Gölü sulakalanı ve çevresindeki havzaların karşı karşıya kaldıkları birçok problem ve tehdit, bu değerli kaynakların değişmesine veya bozulmasına neden olmaktadır. Doğrudan ve dolaylı insan faaliyetlerinin etkilerinin bir sonucu olarak Uluabat Gölü sulakalanı zarar görmekte ve yok olmaktadır, aynı zamanda su kalitesi de olumsuz etkilenmektedir. Uluabat Gölü sediman kalitesini değerlendirmeye ve korumaya yönelik herhangi bir yasa ve düzenleme bulunmamaktadır. Bu araştırmanın amacı, Uluabat Gölü'nün sediman kalitesi ve besin elementleri dinamiğini değerlendirmektir. Bu amaçla; kentsel/ endüstriyel yerleşimlere, göl girişine/ göl ayağına ve Mustafakemalpaşa Çayı drenaj noktasına yakın seçilen beş istasyonda pH, elektriksel iletkenlik, toplam azot, hidrolize olabilen toplam azot, toplam fosfor, elverişli fosfor, organik karbon parametreleri, anyonlar (Cl^- , CO_3^{2-} , $CaCO_3$) ve katyonlar (Ca^{++} , Mg^{++} , Na^+ , K^+) analiz edilmiştir. Elde edilen sonuçlar alkali koşulların Uluabat Gölü'nde baskın olduğunu göstermiştir. Bu çalışmanın sonuçları, Uluabat Gölü sediman kalitesi izleme ve değerlendirme çalışmaları ve daha sonraki çalışmalar için rehberlik edecektir.

Anahtar Kelimeler: Besin elementleri, Fiziksel-kimyasal değişkenler, Sediman kalitesi, Uluabat Gölü

INTRODUCTION

Lake Uluabat, located in Marmara Region, Bursa, Turkey (40°10' N, 28°35' E), is a productive, shallow lake with a watershed area of 10.555 km² (Altınsacli and Griffiths 2001). Lake Uluabat is one of the largest fresh-water lakes and the eutrophic ones. It has been well known for its scenic beauty and richness of aquatic life. The main human activity at the lake is fishing. Agricultural lands and industry also surround the Lake.

The major rivers feeding and draining the lake are Mustafakemalpaşa (MKP) Creek and Kocasu Creek respectively. MKP Creek, joining with Emet and Orhaneli Creeks, has a drainage area of 10414 km² and is located in Aegean and South Marmara Regions (Kazanci *et al.* 2010). MKP drains a large part of the regions of Southern Marmara and Northern Aegean is bringing large quantities of urban and industrial waste into the lake basin each year (Altınsacli and Griffiths 2001). In a study of Aksoy and Ozsoy (2002), it is observed that surface area and volume of the lake decreased to a ratio of 12% between the years of 1984, 1993, and 1998. This was caused by the lignite plants and the sand pits around the lake (Aksoy and Ozsoy 2002, Katip *et al.* 2012a).

* This article was prepared from a part of the MSc thesis of the first author.

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Due to 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).

Sediments are an important component of lake ecosystems in which toxic compounds accumulate through complex physical and chemical adsorption mechanisms depending on the nature of the sediments matrix and the properties of the adsorbed compounds (De Bartolomeo *et al.* 2004). Sediments provide habitat for many benthic organisms (Bakan 2000). Persistent organic and inorganic chemicals may accumulate in sediments and however, they can persist for many years in the sediment, where they can cause adverse effects to aquatic organisms and to human health (Bakan *et al.* 2003)

In the world literature, firstly Canadian Council of Ministers of the Environment (CCME) and United States Environmental Protection Agency (USEPA) have been started to study sediment quality guidelines and protections. The extend and severity of sediment contamination in the U.S. has been studied by United States Environmental Protection Agency's National Sediment Inventory (Usepa 1998) and a data base is formulated (Bakan *et al.* 2003). The aim of this research is to present some data related to the systematic study of physical, chemical and nutrients variables in sediment, and assessment of sediment quality of Lake Uluabat. The results of this study can be used for sediment quality monitoring and assessment studies for Lake Uluabat and the others in the future.

MATERIALS AND METHODS

The study area and sampling stations have shown in Figure 1. The study area is located on the border of Bursa. Sampling of the sediment for analytical purposes was performed monthly from February 2003 to January 2004 from 5 different stations. Sediment samples were taken by Ekman sampling device (NY, USA) and stored in polyethylene bags. Sediment samples were immediately taken to the laboratory and air-dried. Then stones and plant fragments were removed by passing the dried sample through 2 mm sieve. The measured variables for the sediments included pH, $EC_{(25^{\circ}C)}$ (Electrical conductivity), TN (Total nitrogen), H-TN (Hydrolysable total nitrogen), TP (Total phosphorus), AP (Available phosphorus), OC (Organic carbon), anions (Cl^{-} , CO_3^{-} , $CaCO_3$) and cations (Ca^{++} , Mg^{++} , Na^{+} , K^{+}). pH and $EC_{(25^{\circ}C)}$ was measured by Metrohm pH-meter (Herisau, SWISS) and Jenway conductivity meter (Model 4310) (Essex, UK), respectively. The other analyses were performed according to standard methods (Anonymous 1992, Apha 1998). Statistical analyses were performed using Minitab (version 15) statistical software (Minitab 2006). The values in the figures are the average of five stations.

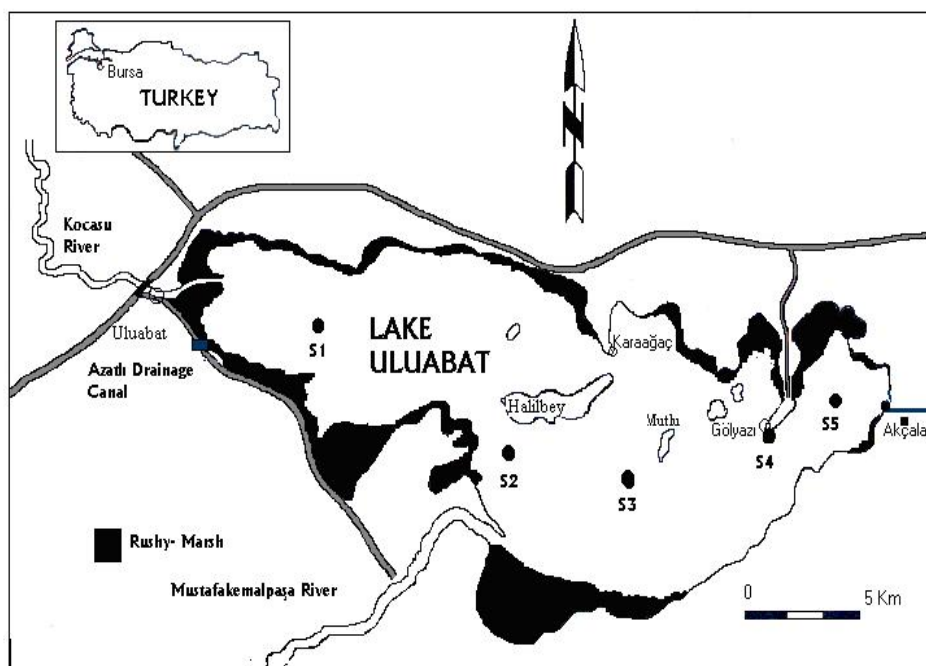
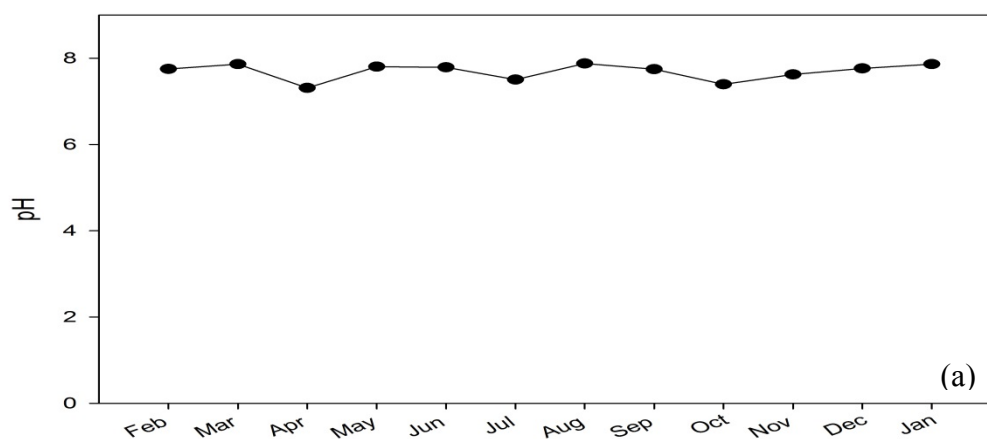


Figure 1. The view of study area and sampling stations (Adapted from Aksoy and Ozsoy, 2002).

RESULTS AND DISCUSSION

The mean monthly variations of pH and EC variables at all stations of Lake Uluabat have been given in Figure 2. The mean annual values of pH and EC were 7.69 ± 0.23 and $461 \pm 134.2 \mu\text{S cm}^{-1}$, respectively. Mean pH values of stations are quite variable throughout the seasons and $\text{pH} > 7$ indicate that alkaline conditions are dominant in Lake Uluabat. Lakes Volvi and Koronia were studied (Fytianos and Lourantou 2004) which is located in N. Greece. The whole area has been protected by the Ramsar Convention as a site of international importance for the value of the wetland habitat. EC and pH values of Volvi 1 ($1145 \mu\text{S cm}^{-1}$, 8.87), Volvi 2 ($1134 \mu\text{S cm}^{-1}$, 8.95) and Koronia ($5080 \mu\text{S cm}^{-1}$, 8.95) have been reported, respectively. Volvi with mean depth 13.5 m has been classified on the basis of chemical and biological water parameters, as meso-to eutrophic lake and Koronica Lake with mean depth 2 m has been classified as hypertrophic (Kaiserli *et al.* 2002). Mean depth of Lake Uluabat was 3 m (Barlas *et al.* 2005) and was classified as eutrophic (Akdeniz 2005). Comparing the pH and EC in sediments Koronia, Volvi and Uluabat Lakes, it was concluded that pH and EC values in sediments of Volvi and Koronica Lakes are considerably higher than those of Lake Uluabat.



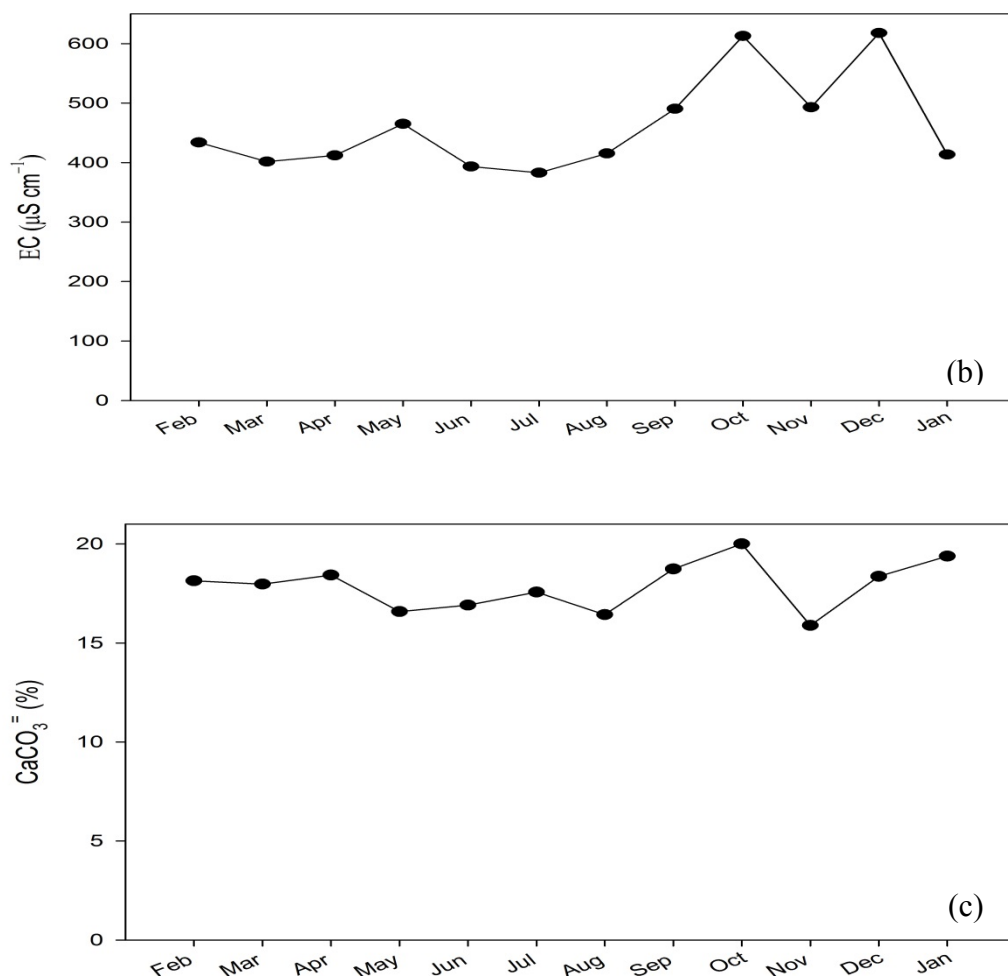


Figure 2. The mean monthly variations of (a) pH, (b) EC and (c) CaCO₃ variables at five stations of Lake Uluabat.

Biogenic particles (algal material, terrestrial plants), domestic and industrial waste waters, iron and manganese oxides and the percentage of calcium carbonate affect the sediment structure (Katip *et al.* 2012b, Karaer *et al.* 2014). The mean annual concentrations of Ca⁺⁺, Mg⁺⁺, Na⁺, K⁺, Cl⁻ ions and CO₃⁼ percentage were detected as 3.29±0.88 mg g⁻¹, 3.07±1.05 mg g⁻¹, 0.06±0.01 mg g⁻¹, 0.17±0.06 mg g⁻¹, 0.00±0.00 mg g⁻¹, and 2.14±0.15 (%), respectively. Major cations in lake sediment of Uluabat have found in the form of Ca> Mg> K> Na, respectively. There are numerous settlements, plants, workplaces, agricultural fields and mines within the Lake Uluabat Basin, which is located in Marmara Region (Turkey) - a focus of population and industry (Akdeniz *et al.* 2011, Katip and Karaer 2011, Katip and Karaer 2013). Kurttas (2002) stated that both surface waters and underground waters is dominated by calcium and magnesium cations, the drainage area of the outcropping rocks forming minerals of igneous and metamorphic rocks have resulted from a low-resolution. Also stated that basin water can be considered homogeneous in terms of water chemistry. In this research, the reason of domination of calcium and magnesium cations in Uluabat lake sediments can be explained by ions arise from MKP Creek and groundwater carried by. The mean monthly variations of CaCO₃ percentages at all stations of Lake Uluabat have been seen in Figure 2. The mean annual percentage of CaCO₃ in the sediments was 17.87±4.41 (%).

Table 1. The mean monthly variations of ionic content values at five stations of Lake Uluabat.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Mean±SD
Ca ⁺⁺ mg/g	2.98	3.00	3.26	5.94	3.14	3.02	2.76	3.00	3.52	2.48	3.48	2.90	3.29±0.88
Mg ⁺⁺ mg/g	2.80	2.62	3.19	2.65	1.04	2.36	4.20	2.66	4.12	5.04	3.59	2.56	3.07±1.05
Na ⁺ mg/g	0.04	0.05	0.05	0.09	0.04	0.06	0.06	0.07	0.07	0.06	0.05	0.04	0.06±0.01
K ⁺ mg/g	0.20	0.11	0.18	0.30	0.15	0.16	0.18	0.16	0.12	0.12	0.22	0.11	0.17±0.06
Cl ⁻ mg/g	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00±0.00
CO ₃ ⁻ (%)	2.18	2.16	2.21	1.99	2.03	2.11	1.97	2.25	2.40	1.91	2.20	2.32	2.14±0.15

Previous studies in various lakes indicated that nutrients play a very important role in transporting various materials to the sediments (Katip *et al.* 2012b). The mean monthly variations of TN, H-TN, TP, AP variables have been shown in Figure 3 and 4. The mean annual values of TN, H-TN, TP, AP and OC were 0.81 ± 0.24 mg g⁻¹, 0.36 ± 0.09 mg g⁻¹, 0.34 ± 0.06 mg g⁻¹, 0.05 ± 0.03 mg g⁻¹, 0.77 ± 0.07 mg g⁻¹, respectively.

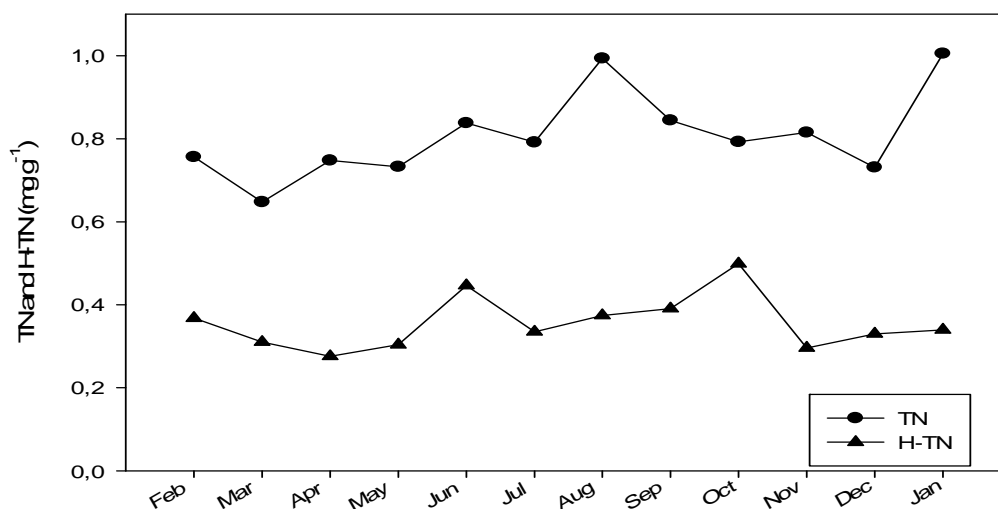


Figure 3. The mean monthly variations of TN and H-TN variables at five stations of Lake Uluabat.

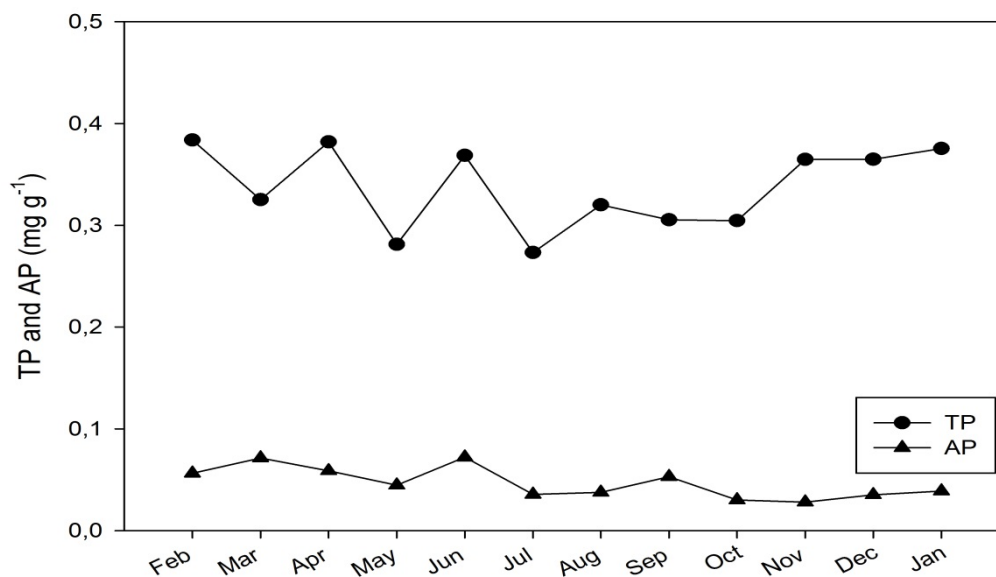


Figure 4. The mean monthly variations of TP and AP variables at five stations of Lake Uluabat.

In the literature, it was reported that amount of phosphorus contained in lake sediments is based on largely to the structure of the sediment. The adsorption capacity of the sediment causing phosphorus to be stored and released again under suitable conditions in the sediment depends on highly the mineral structure and the particle size of the sediment. It is also increasing in parallel with the clay content of sediment (Topkaya 1992). TP contents in the sediments of the Lakes in China ranged from 217.8 to 1.640 mg kg⁻¹ (Wang *et al.* 2005). Comparing the TP in Lake sediments, it has been shown that TP values (max-min; 0.42-0.12 mg g⁻¹) in sediments of Lake Uluabat are higher. In Lake Uluabat phosphorus is the limiting nutrient (Elmaci *et al.* 2008).

The mean monthly variations of OC values in Lake Uluabat have been shown in Figure 5. Lakes play an important role in carbon cycle. They often act as sources of the greenhouse gases as carbon dioxide and methane and they bury significant amounts of organic carbon in their sediments. In Lake Uluabat, measurements among stations have been pointed out parallel values. Generally, the increase of OC in summer in lakes may be explained by general trend in amount of organisms that concurred with rise of temperature in summer as observed in Lake Uluabat. In this context, productivity may also increase at the same season.

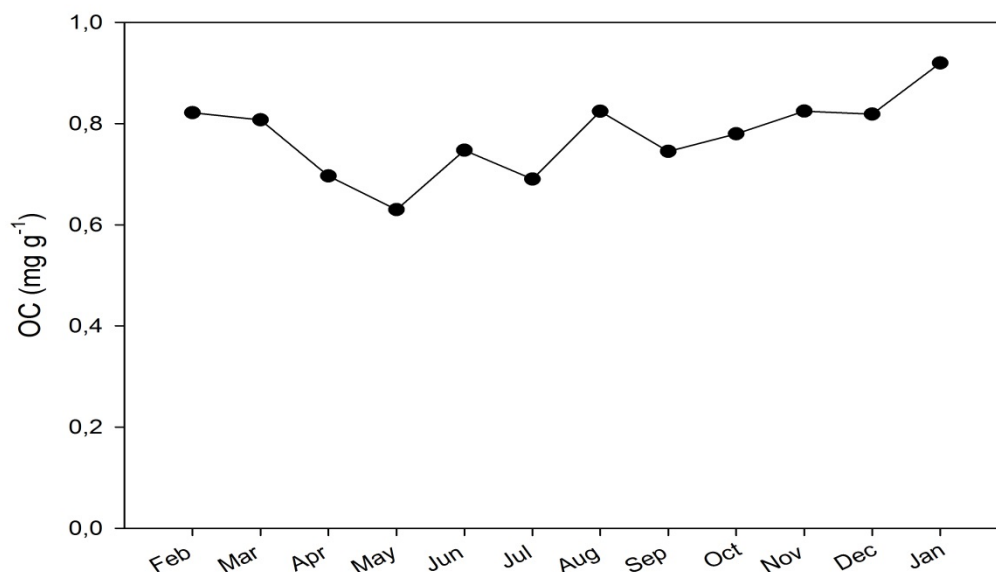


Figure 5. The mean monthly variations of OC variable at five stations of Lake Uluabat.

The mean monthly variations of TN and TP variables have shown in Figure 6. The highest concentration of TN and TP observed in Lake Uluabat sediments is thought to cause by animal, agricultural and industrial wastewater arising from Mustafakemalpasa and Karacabey towns and domestic and industrial wastewater carried from Emet and Orhaneli towns. The highest concentration of TN and TP occurred in winter seasons, which might be related to seasonal runoff conditions in the watershed. Rainfall during the winter season accounts for more than the annual total. The mean annual rainfall was 682.8 mm. 41.2 % percent in winter, 23.1% percent in spring, 26.6% percent in autumn and 9.1% percent of this value falls in the summer (Anonymous, 1992).. Similarly, the highest concentrations of TN and TP were reported to have occurred in August and November (summer and autumn) was in Lake Chao. In Chao, rainfall during the summer and autumn seasons accounts for more than 60% of the annual total (Xu *et al.* 2003).

The correlations among variables OC, TN, H-TN, TP and AP have been pointed out OC contents were all significantly correlated with H-TN and AP contents; there were no significant relationships between TN and TP contents. TN contents were all significantly correlated with H-TN contents, there were no significant relationships for TN and AP contents. H-TN contents were all significantly correlated with AP contents. It is reported that, in Lake Chao, there are slightly positive relationships between the concentrations of TN, TP and pH values in the sediments, the concentrations of TN in the sediments have negative relationships with EC values, no obvious relationships were observed between EC and TP (Xu *et al.* 2003). In Lake Chinese relationships between EC and pH values with the TN and TP concentrations in the lake sediments are quite similar to the results obtained in Lake Uluabat.

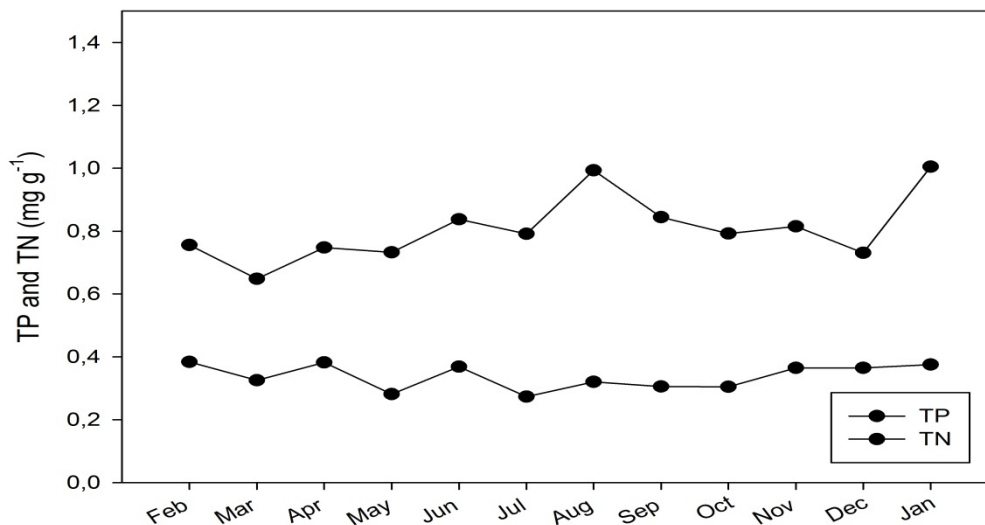


Figure 6. The mean monthly variations of TN and TP variables at five stations of Lake Uluabat.

From the point of view to present some data related to the systematic study of physical, chemical and nutrients parameters in sediment, and assessment of sediment quality of Lake Uluabat, obtained results were as follows; alkaline conditions were dominant in Lake Uluabat; major cations in lake sediment of Uluabat have found in the form of $Ca > Mg > K > Na$, respectively; the OC contents were all significantly correlated with H-TN and AP contents; there were no significant relationships for TN and TP contents. TN contents were all significantly correlated with H-TN contents, there were no significant relationships for TN and AP contents. H-TN contents were all significantly correlated with AP contents. Higher concentration of TN and TP in sediments occurred in winter seasons, which might be related to seasonal runoff conditions in the watershed. Rainfall during the winter season accounts for more than the annual total. The obtained results can be a guide for sediment quality monitoring and assessment studies in Lake Uluabat and the others in the future.

ACKNOWLEDGEMENTS

This work was partly supported by grants the Scientific Research Projects Council of Uludag University (Project number 2001-31), Bursa, Turkey. This article was prepared from a part of the MSc thesis of the first author (Kurtoglu 2006).

REFERENCES

- Akdeniz S (2005). Uluabat Gölü su kalitesinin değerlendirilmesi ve coğrafi bilgi sistemi ortamında analizi. Yüksek Lisans Tezi, Uludağ Üniversitesi Fen Bilimleri Enstitüsü, Bursa, Türkiye (in Turkish).
- Akdeniz S, Karaer F, Katip A and Aksoy E (2011) A GIS-Based Method for Shallow lake Eutrophication Assessment. *J. Biol. Environ. Sci.*, 5 (15): 195-202.
- Aksoy E and Ozsoy G (2002). Investigation of multi-temporal land use/cover and shoreline changes of the Uluabat Lake Ramsar Site using RS and GIS. In: *The International Conference On Sustainable Land Use and Management*, Canakkale, Turkey.
- Altinsacli S and Griffiths H I (2001). Ostracoda (Crustacea) of Lake Uluabat (Apoloyont Golu) (Bursa Province, Turkey). *Limnologia*, 31: 109-117.
- Anonymous (1992) *Methods of soil analyses, part 2, chemical and microbiological properties*, second edition. Wisconsin, USA.
- Apha (1998). *Standart methods for the examination of water and wastewater 20th edition*. American Public Health Association, Baltimore, USA.
- Bakan G (2000). Studies of environmental sedimentology and sediment quality criteria. *Çevre Bilim ve Teknoloji*, 1: 14-23 (in Turkish).
- Bakan G, Ariman S and Ozkoc H (2003). Methods using for monitoring and evaluating of sediment quality, In: *V. Ulusal Çevre Mühendisliği Kongresi*, Ankara, Türkiye, 126-141 (in Turkish).

- Barlas N, Akbulut N and Aydogan, M (2005). Assessment of heavy metal residues in the sediment and water samples of Uluabat Lake, Turkey. *Bulletin of Environmental Contamination and Toxicology*, 74: 286-293.
- De Bartolomeo A, Poletti L, Sanchini G, Sebastiani B and Morozzi G (2004). Relationship among parameters of lake polluted sediments evaluated by multivariate statistical analysis. *Chemosphere*, 55: 1323-1329.
- Elmaci A, Topac FO, Ozengin N, Teksoy A, Kurtoglu S and Baskaya HS (2008). Evaluation of physical, chemical and microbiological properties of Lake Uluabat, Turkey. *Journal of Environmental Biology*, 29(2): 205-210.
- Fytianos K and Lourantou A (2004). Speciation of elements in sediment samples collected at Lakes Volvi and Koronia, N. Greece. *Environment International*, 30: 11-17.
- Kaiserli A, Voutsas D and Samara C (2002). Phosphorus fractionation in the lake sediments –Lakes Volvi and Koronia, N.Greece. *Chemosphere*, 46: 1147-55.
- Karaer F, Katip A, İleri S, Sarmaşık S, Aksoy E, Öztürk C (2014). The Spatial and Temporal Changes in Water Quality Parameters of a Shallow Lake, *Environmental Engineering and Management Journal*, (in press).
- Katip A and Karaer F (2011). Assessment of Water Quality of Uluabat Lake in Accordance with Turkish Legislation and International Criteria, *Uludağ University Journal of the Faculty of Engineering and Architecture*, 16(2): 25-34.
- Katip A, Karaer F, İleri S, Sarmaşık S, Aydogan N and Zenginay S (2012a). Analysis and Assessment of Trace Elements Pollution in Sediments of Lake Uluabat, Turkey. *Journal of Environmental Biology*, 33(5): 961-968.
- Katip A, Karaer F, Başkaya H S, İleri S and Sarmaşık S (2012b). Fraction distribution and risk assessment of heavy metals and trace elements in sediments of Lake Uluabat, *Environmental Monitoring and Assessment*, 184: 5399-5413.
- Katip A and Karaer F (2013). Research on the Non-Point Pollution Loads in the Lake Uluabat Basin, *Journal of Environmental Protection*, 4: 29-37.
- Kazancı N, Leroy SAG, Oncel S, İleri O, Toprak O, Costa P, Sayılı S, Turgut C and Kibar M (2010). Wind control on the accumulation of heavy metals in sediment of Lake Ulubat, Anatolia, Turkey *J Paleolimnol*, 43: 89–110.
- Kurtoglu S (2006). Uluabat Göl Sedimentinde Bazı Kimyasal Parametrelerin ve Mevsimsel Değişimlerinin İncelenmesi. Yüksek Lisans Tezi, Uludağ Üniversitesi Fen Bilimleri Enstitüsü, Bursa, Türkiye (in Turkish).
- Kurttaş T (2002). Sulakalanların Yönetimi Projesi Uluabat Gölü Mustafa Kemalpaşa Çayı Sistemi Sediment Birikimi Araştırması Alt Projesi. Hacettepe Üniversitesi Uluslararası Karst Su Kaynakları Uygulama ve Araştırma Merkezi, Ankara, s. 1-155 (in Turkish).
- Minitab Inc. (2006). MINITAB Statistical Software, Release 15 for Windows, State College, Pennsylvania.
- Topyaka B (1992). Keban Baraj Gölü Uluova Bölgesi Sedimentlerindeki Fosfor Miktarının İncelenmesi. *Su Kirlenmesi Kontrolü Dergisi*, 2(2): 61-66 (in Turkish).
- Usepa-Nsi (1998). EPA's Contaminated Sediment Management Strategy. USEPA 823-R-98-001, USEPA Office of Water, Wash. D.C.
- Wang S, Jin X, Pang Y, Zhao H, Zhou X and Wu F (2005). Phosphorus fractions and phosphate sorption characteristics in relation to the sediment compositions of shallow lakes in the middle and lower reaches of Yangtze River Region, China. *Journal of Colloid Interface Science*, 289: 339-346.
- Xu FL, Tao S, Dawson RW, Xu ZR (2003). The distributions and effects of nutrients in the sediments of a shallow eutrophic Chinese lake. *Hydrobiologia*, 429: 85-93.