J. BIOL. ENVIRON. SCI.,
2014, 8(22), 19-28

Original Research Article

Assessment of Some Pollution Parameters with Geographic Information System (GIS) in Sediment Samples of Lake Uluabat, Turkey

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Received: 30.01.2014; Accepted: 08.04.2014; Published Online: 27.06.2014

ABSTRACT

The scope of work is to determine the quality of the lake Uluabat sediment. pH, electrical conductivity (EC), orthophosphate phosphorus (PO_4-P), total phosphorus (TP), ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), total nitrogen (TN), organic matter, and water content were monitored from June 2008 to May 2009 monthly with the samples taken from 8 different stations in the lake. Additionally sediment quality parameters were mapped to the ArcGIS 9.1 software and distribution of pollution were visualized with pollution distribution maps. As a result, in the stations 1., 5., 7., 8. have been found to be more intense pollution load when these maps were examined.

Key Words: Sediment Quality, Sedimentation, Geographic Information System, Lake Uluabat

Uluabat Gölü Sediment Örneklerinde Bazı Kirlilik Parametrelerinin Coğrafi Bilgi Sistemleri (GIS) ile Değerlendirilmesi, Türkiye

ÖZET

Çalışmanın amacı, Uluabat Gölü sediment kalitesinin belirlenmesidir. Bu nedenle, pH, elektriksel iletkenlik (EC), ortofosfat fosforu (PO_4-P), toplam fosfor (TP), amonyum azotu (NH_4-N), nitrat azotu (NO_3-N), toplam azot (TN), organik madde içeriği ve su içeriği (nem miktarı) değerleri, Haziran 2008-Mayıs 2009 dönemlerinde, aylık olarak gölde 8 farklı istasyondan alınan numunelerde izlenmiştir. Ayrıca sediment kalite parametreleri ArcGIS 9.1 yazılımı yardımı ile görselleştirilmiş ve kirlilik dağılım haritaları oluşturulmuştur. Haritalar incelendiğinde sonuç olarak 1., 5., 7., 8. örnekleme noktalarının bulunduğu bölgelerde daha yoğun kirlilik yükü tespit edilmiştir.

Anahtar Kelimeler: Sediment Kalitesi, Sedimantasyon, Coğrafi Bilgi Sistemleri, Uluabat Gölü

INTRODUCTION

Sediment is essential parts of lake ecosystems due to the complex physical and chemical adsorption mechanisms of inside (Burton, 2002; Katip, 2010). Pollutants which deposited in sediment can be stored in the food chain or can switch on the water layer from sediment as a result of physical, chemical and biological processes. Therefore, the effect on the water-sediment layers can be determined together with the analysis of sediment and water (Bakan, 2000; Simeonov *et al.,* 2007; You *et al.,* 2007). Sediment layer plays the role of long-term source of pollutants because it is the last stop of contaminants in the aquatic environment (Bakan, 2000; Burton and Pitt, 2002).

Lithological characteristics, vegetation, slope and rainfall intensity is located at the beginning of the natural effects which causing formation of sediment load in Uluabat Lake Basin. An important part of the basin is coated with lithology clastics which are poorly consolidated. This kind of material which is sensitive for lithological decomposition, degradation and wear, has the effect on increasing erosion in areas where slope is higher. Also human activities affect the erosion. The basin Mustafakemalpaşa (MKP) Brook is very important in terms of erosion and sediment transport. Particularly Orhaneli and Emet Creeks carry large amounts of sediment into the lake and water quality are affected negatively (İleri, 2010; Aksoy and Özsoy, 2002). The lake becomes

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Footnote: This study is a part of MSc thesis of the first author accepted on 19.07.2010 by the Graduate School of Natural and Applied Sciences of Uludag Univ.

shallower and smaller each year due to sedimentation from the basin (Anonymous, 2012; Sarmaşık, 2011; İleri, 2010; Katip, 2010; Özsoy, 2007). In average water level, the surface area of the lake was determined as 160 km^2 in reports which were made previously in relation to the lake. In another study, the surface area of the lake was determined as 133.1 km^2 with decrease of 2% in 1984. After 1984, the lake stuffed rapidly with sediments brought by MKP Brook, so the surface area of the lake was determined as 120 km^2 with decrease of 10% in 1993. In a study conducted in 1998, it was determined that the surface area of the lake decreased in 116 km^2 (Anonymous, 2012; Karaer *et al.*, 2012; Sarmaşık, 2011; İleri, 2010; Aksoy and Özsoy, 2002; Elmacı *et al.*, 2008).

The present study has been initiated with the following objectives: (1) to examine the concentration of selected some sediment quality parameters at different stations in Lake Uluabat from June 2008 to May 2009; (2) to analysis of these physicochemical parameters with GIS; (3) to identify the sources of contamination and to determine the causes of pollution. Also precautions for the prevention of pollution were discussed.

MATERIALS AND METHODS

Study Area, Sampling and Analysis

Lake Uluabat is located in Marmara region in northwest of Turkey between the coordinates of 42^o 12$'$ North and 28^o 40' East which is an important part of Susurluk Basin. The major rivers feeding and draining to the lake are Mustafakemalpaşa (MKP) Brook and Kocasu Brook respectively. The Lake is a large but shallow lake with an average depth of 1.5-2 m. Lake Uluabat was designated as a “RAMSAR site” in 1998 and was chosen as a partner of “International Living Lakes Network” in the 4th International Conference at EXPO 2000 (Karaer *et al.*, 2012, Katip *et al.* 2011, İleri 2010).

Sediment samples were taken from eight different stations in the lake. The location of Lake Uluabat and the sampling stations are shown in Figure 1.

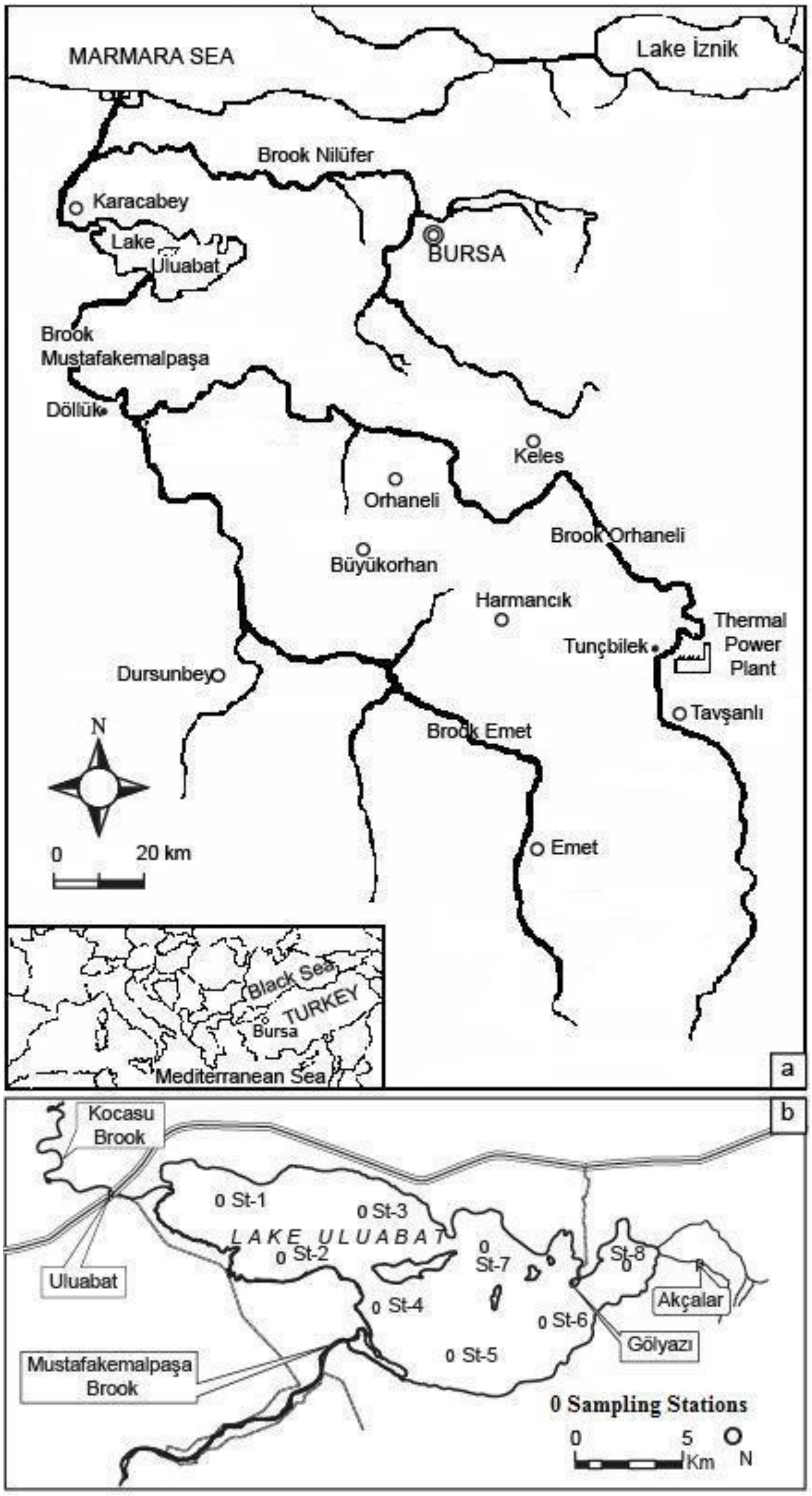

Figure 1. a) Location of Lake Uluabat within the Susurluk Basin, b) Sampling Stations in Lake Uluabat (Sarmaşık *et al.,* 2011).

In determining the frequency of measurement, sampling locations, number of the samples, distance between sampling stations and laboratory are taken into account. Therefore, samples were taken monthly and synchronously for a year from June 2008 to May 2009. The locations of the sampling stations, determined with global positioning system tool (Magellan XL-GPS). The coordinates of sampling stations are presented in Table 1.

Table 1. Geographic Coordinates of Sampling Stations in Lake Uluabat.

Number of Stations	X (East) m	Y (North) m
1	626865	4451240
2	629634	4448777
3	633217	4450699
4	633953	4446460
5	637299	4444284
6	641498	4445781
7	638853	4449214
8	645313	4448410

Sediment samples were taken from the top 5 cm of sediment using a Hydro-Bios brand Ekman sediment sampler and were transferred to laboratory in dark plastic bags (APHA, 1998; Burton and Pitt, 2002). The samples were air-dried until the weight stabilized and sieved through a 2-mm mesh size (Zeien and Brümmer 1989). pH and EC parameters of sediment were measured by 1:10 sediment-water mixture using Hach Brand Sension 156 device (Radojević and Bashkin 1999). PO_4-P and TP were measured by the ascorbic acid method (APHA, 1998). NH_4-N and NO_3-N were measured after potassium chloride (KCl) extraction followed by vapor distillation where TN was extracted by wet digestion with the mixture of nitric acid and sulfuric acid, and then measured by vapor distillation method (Kaçar, 1994; Keeney and Nelson, 1982; Bremner and Mulvaney, 1982). Organic matter and water content percentages were measured by incineration method.

The Creation of GIS Maps

The locations of the sampling stations, determined with global positioning system tool (Magellan XL-GPS) according to the Europe 1950_UTM coordinate system. The data which obtained from the monitoring process were interpolated using IDW (Inverse Distance Weighted) method, GIS analysis tool. The IDW interpolation method has been widely used on many types of data because of its simplicity in principle, speed in calculation, easiness in programming and credibility in interpolating surfaces (Xu *et al.,* 2001). The IDW interpolation method is based on the principle of assigning higher weights to data points closest to unvisited points relative to those which are further away (Bing *et al.,* 2011). In this way the data point transformed into spatial map data and the distribution of pollution maps in the lake have been obtained.

RESULTS AND DISCUSSION

In this study, sediment samples were taken from the top 5 cm of sediment from the eight sampling stations in Lake Uluabat and physico-chemical analysis were carried out. After a one year monitoring process, the average values of lake sediment (of all stations) were given in Table 2. When the Table 2 is examined, the pH reached the highest value in October (8.41) and the lowest value in May (7.78). The pH of sediment gives an overview chemical status of the surface layer. The results are analyzed this layer is generally at levels close to neutral. The highest EC was measured in June (394.87 µs/cm) and the lowest value was measured in May (233.75 µs/cm). The percentage of organic matter refers to the accumulation load of organic matter transported from the lake to sediment. The load of organic matter is usually caused by domestic wastewater and agricultural activities. The percentage of organic matter content of lake sediment is about 3.8 % on average. When the organic matter contents were analyzed, there were not very large variations in terms of spatial and temporal. The highest organic matter content was measured in June of 4.35%, the lowest was measured in February of 3.19%. In environmental sedimentology, water content has an important place. Because the water content generally indicates a typical range. Water content has been observed lower in shallow waters than deep waters (Bakan and Şenel, 2000). This situation was also observed in our field work sediment samples. The moisture content of the sediment, also known as the water content were measured the highest in November of 38.2% and the lowest in July of 16.2%. Phosphate-phosphorus concentrations in water generally increase after fertilization of agricultural land around the lake. Various fertilizers and pesticides are used in Mustafakemalpaşa where holds an important place in agricultural activities (Sarmaşık *et al.,* 2011). In addition, phosphate can pass in water through sewage and treatment plants (Elmanama *et al.,* 2006; Dalkıran *et al.,* 2006; Yenilmez and Aksoy, 2007; Karaer *et al.,* 2012). With the increase of temperature due to seasonal conditions phosphorus passage from sediment into the water, increasing the phosphate concentration in water (Pulatsü and Topçu, 2006). Increase in nitrogen and phosphorus loads in surface waters are also important for microbial growth as well as the control of eutrophication. Microbial changes, growth of algae and other aquatic plants restricts the use of water for fisheries, industry and recreational with degradation of water quality (Davis *et al*., 2005; Richardson *et al.,* 2011). The changes in nutrient concentrations and phytoplankton amount are affected by the hydrodynamic properties of the environment. Maximum change in nutrient concentration increases with the long retention time, high sedimentation rate, and dominant advective current as well as the parameters of short retention time, low sedimentation rate, and dispersive current cause minimum change in nutrient concentration. Dispersive flow regime occurs as a result of the mixture caused by the wind (Hejzlar and Vyhnalek, 1998). Sedimentation is an important factor for the decrease of the phosphorus concentration. The net loss caused by the sedimentation is very small in shallow lakes. This is because of the instable lamination, the resuspension of the settled material into the water. This explains why shallow lakes have higher phosphorus ratios and phytoplankton biomass when compared to deep lakes (Hejzlar and Vyhnalek, 1998; Karaer *et al.,* 2009). Within this study, ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), total nitrogen (TN), phosphate phosphorus (PO_4-P) and total phosphorus (TP) were measured on sediment samples. When Figure 2 is analyzed; it is observed that sediment quality parameters change on the basis of stations. The reason for the different values measured on the basis of the stations, as well as differences in the structure of the sediment measurement stations, there may be differences between these stations for water movements. The highest value of TP concentration was measured in April (1822.4 mg/kg), and the lowest TP concentration was measured in June (350.6 mg/kg). The concentrations of phosphorus in sediment decreased rapidly with the arrival of summer. This decline continued until November. The reason for this decline, phosphorus passes through from sediments to the water as a result of low oxygen concentration with the warm weather (Singh and Steinnes, 1994; Singh *et al.,* 2008). Among the PO_4-P concentrations, highest and lowest values were found in July and October as 282.8 and 34.86 mg/kg. One of the important indicators of trophic level is nitrogen (Bakan and Şenel, 2000). The measured values of the nitrogen forms were given in below. The TN concentrations, highest and lowest values were measured in August and February as 7087.5 and 2817.5 mg/kg. Average TN concentration of the lake was observed as 4466.54 ± 1709.52 mg/kg. The highest value of NO_3-N concentration was measured in August (28.6 mg/kg), and the lowest NO_3-N concentration was measured in March and April (0.7 mg/kg). The NH_4-N concentrations, highest and lowest values were measured in August and February as 87.5 and 3.5 mg/kg. It is estimated that the nitrogen forms which are observed in the sediment due to domestic discharge and agricultural activities. Industrial and agricultural activities that occur in the basin are significant influences on the lake pollution with superficial flow. In addition, Turkey's most important mines and ore enterprises take place in the basin such as boron, lignite, colemanite and chrome. This situation contributes to the pollution load of heavy metals (As, Cr, B) from the lake (Karaer *et al.,* 2012; Sarmaşık *et al.,* 2011; Akdeniz *et al.,* 2011).

In Table 3, seasonal changes in the evaluated parameters are presented. As shown in Table 3, all the variables are seen that the maximum levels in the summer except for the moisture content and total phosphorus. Moisture content is decreasing depending on the decrease of water level and decrease of rainfall in summer. Also, total phosphorus passes through from sediment to water with the increase of temperature due to seasonal changes. Therefore it is estimated that total phosphorus are lower in the summer.

Table 2. The Average and Standard Deviation Values of Sediment Quality Lake Uluabat 2008 June-2009 May.

Months	pH	EC (µs/cm)	Org. Matter (%)	Water Content (%)	NH_4-N (mg/kg)	NO_3-N (mg/kg)	TN (mg/kg)	PO_4-P (mg/kg)	TP (mg/kg)
June	8.40±0.609	394.87±240.0	4.35±0.36	24.5±3.91	39.9±13.5	23.8±7.70	6037.5±1133.5	279.6±88.49	350.60±93.09
July	8.19±0.163	286.75±65.10	3.39±0.18	16.2±2.26	44.8±10.8	24.85±6.2	6667.5±1025.8	282.8±72.61	356.60±82.50
August	8.12±0.070	310.11±124.7	4.23±0.45	20.5±1.82	87.5±34.5	28.6±11.7	7087.5±1050.1	38.85±13.62	364.28±179.2
September	8.08±0.042	351.75±49.31	3.74±0.53	29.5±3.09	31.5±14.5	1.43±0.75	5390.0±1474.0	35.71±19.00	758.76±365.7
October	8.41±0.150	279.62±130.8	4.08±0.23	33.1±5.45	22.75±6.2	3.50±6.48	4690.0±1166.5	34.86±20.18	674.20±331.6
November	7.98±0.105	343.51±141.8	3.73±0.47	38.2±5.12	13.26±2.5	23.5±27.2	4336.0±2382.2	42.64±23.50	820.4±398.81
December	8.37±0.073	317.37±72.12	3.37±0.29	36.2±2.55	27.3±13.2	9.80±9.81	3815.0±642.65	119.1±37.10	1487.7±342.3
January	8.17±0.091	264.30±143.3	4.08±0.36	33.9±3.17	17.5±8.16	6.30±5.55	2922.5±432.72	136.0±27.35	1765.8±324.4
February	8.20±0.088	272.37±134.4	3.19±0.25	22.3±2.44	3.50±5.13	2.80±4.23	2817.5±800.50	138.5±27.50	1631.8±303.8
March	7.86±0.043	247.21±110.3	3.92±0.67	19.7±4.07	4.20±5.80	0.70±1.97	2940.0±729.38	148.8±20.15	1725.6±244.2
April	7.98±0.105	277.62±125.2	3.65±0.51	18.2±2.39	11.2±5.18	0.70±1.97	3307.5±639.10	138.9±20.34	1822.4±416.4
May	7.78±0.063	233.75±71.98	4.00±0.44	22.9±2.79	29.4±11.8	7.00±7.77	3587.5±634.70	195.1±30.65	1560.0±344.3

Table 3. Average and Seasonal Average Values Sediment Quality Lake Uluabat 2008 June-2009 May.

Parameter	Lake Average	Summer	Autumn	Winter	Spring
pH	8.13	8.24	8.16	8.25	7.87
EC (µs/cm)	298.26	330.57	324.96	284.68	252.86
Organic Matter (%)	3.8100	3.9937	3.8566	3.5507	3.8631
Water Content (%)	26.300	20.432	33.647	30.837	20.295
NH_4-N (mg/kg)	27.73	57.4	22.51	16.1	14.93
NO_3-N (mg/kg)	11.08	29.86	13.15	6.30	2.80
TN (mg/kg)	4466.54	6539.16	4805.33	3185	3278.33
PO_4-P (mg/kg)	132.66	200.753	37.736	131.212	160.964
TP (mg/kg)	1109.87	357.182	751.153	1628.438	1702.707

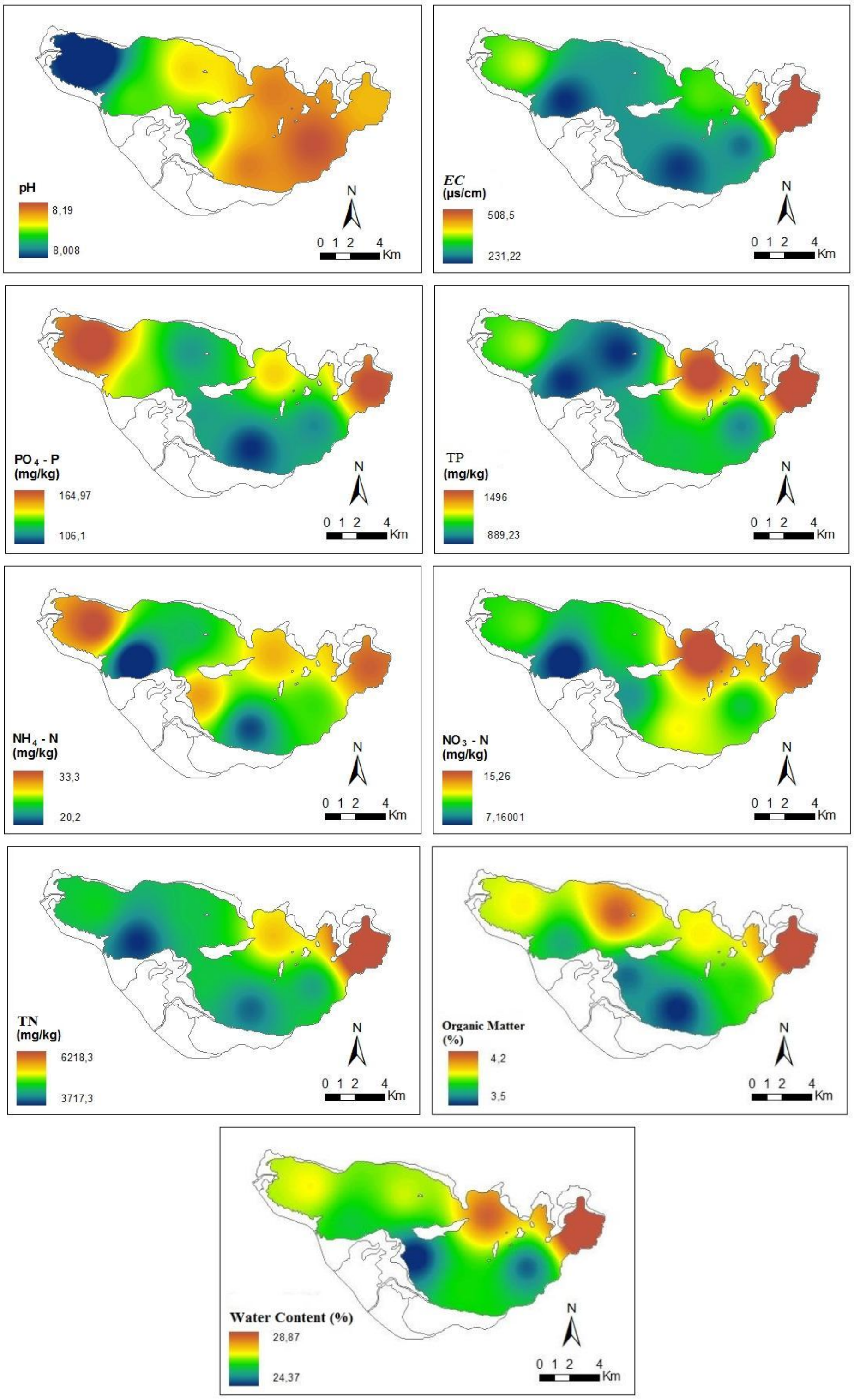

Figure 2. Pollution Distribution Maps in Sediment Quality of Uluabat Lake.

All the parameters distribution maps are given in Figure 2 according to distribution of stations. When these maps are examined, it is observed that each parameter show differences according to the stations. In particular, pollution is observed at higher stages where 1 and 8 stations in areas. Station 1 is located at the outlet of the lake (which is close to the downstream station). In this region, Uluabat and Atabay pumping stations are located which are feeding the lake with the drainage water. It is considered that the amount of contamination in the region is observed as a result of loads from these stations by the effect of the hydrodynamic flow. Also the lake outlet Stream Kocasu is located in there. Sometimes the reverse current (feed-back) is observed in Kocasu Stream. Thus pollution is likely to concentrate the result of reverse current (Ileri, 2010; Sarmaşık *et al.*, 2011). Stations7 and 8 are located near the Akçalar Town. It is seen that eutrophication is at very high levels in these stations. Because these stations are located a stagnant region, far from the input and output points of the lake. It is known that the domestic and industrial wastewater is discharged to the Lake from Akçalar Town (Dalkıran *et al.*, 2006). Therefore, pollution in these stations have been observed more intense. The major river feeding the lake is Mustafakemalpaşa (MKP) Creek which is entrance close to the station 5. In the station 5 has a relatively more intense pollution load in terms of the parameters pH, TP, NH_3-N ve NO_3-N. There are 67 centers of population in the basin of MKP Creek. Therefore MKP Creek carries significant amount of organic pollutants and suspended solids (Aksoy and Özsoy, 2002). For these reasons pollution has been observed in the station 5. In a study of Aksoy and Özsoy in 1998, it is observed that surface area and volume of the lake decreased to a ratio of 12 % during the years of 1984, 1993, and 1998. The reason of this is explained by the Lignite Plants and Sand Pits around the MKP (Aksoy and Özsoy, 2002). In a study of monitoring Lake Uluabat in 2008-2009 which is updated of the lake bathymetry, it is observed that surface area of the lake decreased to a ratio of 2.59 % and volume of the lake decreased to a ratio of 4.98 % in the 15-year period from 1995 to 2010. In addition, it was observed that the depth reduced due to sedimentation accumulation towards the outlet of the lake (Anonymous, 2012). In the stations 2, 3, 4 and 6 are cleaner than the others when these maps are examined. This state of these stations estimated that they are far away from pollution sources.

CONCLUSIONS

The main purpose of this study was to investigate of sediment quality and determined most polluted points of Lake Uluabat in terms of physico-chemical parameters. GIS applications have been utilized for the study. Concentration profiles of the pollution parameters were obtained with the GIS maps within the lake. In this way which areas of the lake were under more pressure and comments on what could be the reasons for these were included. With many studies in recent years heavy metal pollution have been identified as well as eutrophication problem. According to these pollutants, the limit values for the control of sediment pollution should be developed and evaluated in conjunction with the water quality. However, the lack of sediment quality standards in our country, leads to orientation of international standards. The importance of the sediment quality emphasizes the need to develop that the control of sediment pollution limit values which Turkey does not yet exist and the need to evaluate with the quality of water. In addition, the results obtained that the existing basin management plan for the lake indicates that activation.

ACKNOWLEDGMENTS

The project was funded by the Environment, Atmosphere, Earth and Marine Sciences group (ÇAYDAG) (Project No: 107Y278) of the Scientific and Technical Research Council of Turkey (TÜBİTAK) and Scientific Research Foundation (Project No: M-2007/27) of Uludağ University.

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