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Investigation of Water Quality of Akgöl Lake in the Göksu Delta

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Abstract: Akgöl lake is located on the coast of Göksu Delta that is the most important wetland of the Eastern Mediterranean. Akgöl that is a freshwater lake, has a depth of 40 cm and a surface area of 1,245 km^2. As a result of intensive agricultural activities, annual fertilizer use is much higher than the national average in the Göksu delta. The Akgöl lake water quality is also affected by the delta agricultural activities.

In this study, the water quality change of Akgöl was investigated depending on years. For this purpose, water samples were taken 7 times from 2006 (June), 2007 (July), 2008 (January-April), 2011(February-July), 2012 (September) in the same place. In the samples; pH, temperature, electrical conductivity (EC), salinity (Sal) and dissolved oxygen (DO), nitrate nitrogen, nitrite nitrogen, ammonium nitrogen and total phosphorus were analyzed.

The analysis results were compared with "*The Surface Water Quality Regulation Annex-5*" limit values. The relationship of dissolved oxygen which is an important parameter for evaluating water quality of lakes, to other parameters (nitrate, ammonium, phosphorus, temperature, pH, and electrical conductivity) was explained by the regression analysis..

Key words: Akgöl lake, regression analysis, water quality

1. Introduction

Water is life and Earth's water is (almost) everywhere: above the Earth in the air and clouds, on the surface of the Earth in rivers, oceans, ice, plants, in living organisms, and inside the Earth in the top few miles of the ground (Shiklomanov's 1993). Water resource management is a very important issue. Water resources are irreplaceable strategic sources for the continuation of their living. Particularly, the continuous monitoring of surface water can be made easier thanks to today's spatial technologies.

A lake's condition is influenced by many factors, such as the amount of recreational use it receives, shoreline development, and water quality. Lake water quality is a general term covering many aspects of

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chemistry and biology. The health of a lake is determined by its water quality. A lake's condition is influenced by many factors, such as the amount of recreational use it receives, shoreline development, and water quality. Lake water quality is a general term covering many aspects of chemistry and biology. The health of a lake is determined by its water quality (CLMP, 2008). Surface water presence in the Göksu Delta and the quality of this water is of vital importance for both species and individuals in the wetland ecosystem, as well as for close settlements most interacting with these areas. Göksu Delta is an important wetland where the Göksu River reaches to sea in the eastern of the town Tasucu-Mersin.

The Göksu delta and the surrounding lakes, unlike many other wetlands, have various conservation statuses due to their ecological and biological values (Karabulut, 2015). The Göksu Delta is not only an urban area but it is also surrounded by densely cultivated orchards (mostly citrus), traditional vegetable farms and greenhouse cultivations, where farming activities continue all year long due to favorable climate (Demirel et al.2011). However, the intensive agricultural activities carried out in the delta and accordingly the increasing amount of pesticide used, have a negative effect on the quality of the water sources (Demirel et al.2011; Demirel et al.2010).

Numerous studies have been carried out on the quality of water in Delta, and it has been revealed that domestic wastewater from cesspools and fertilizers originating from agricultural activities negatively affect Paradeniz and Akgöl lake (Başıbüyük and Evliya 1993; Özer, 2008. Kumbur et al. (2004) determined the water quality of rivers, lakes and drainage channels in the Gösu Delta. At the end of study, they detected to temperature (9,7-32,3 ◦C) , pH (7,18-8,21), DO 2,38-7,82 mg / L, salinity (0,0-14,0), conductivity (338-23,300 μS / cm), COI (10-300 mg / L), suspended solid (4-763 mg / L), Nitrite nitrogen (0.0-16 mg / L), nitrate nitrogen (0.4-4.3 mg / L), phosphorus (0.02-0, 52 mg / L).

Some of the nutrient salts (nitrogen, phosphorus, etc.) of agricultural origin that enter the lagoons through the drainage channels are filtered in reeds and the other part is mixed with Akgöl (Gürkan et al,1999) .

Site description

The Göksu Delta is situated in the Mediterranean Sea region of the southeastern part of Turkey and extends from 36^o 15 –36^o 25 of latitude north to 33^o 55-34^o 05 of longitude west. In the Göksu Delta area, climate is characterized by hot and dry periods in summer and by warm and wet periods in winter, which is typical for the coastal zones around the Mediterranean Sea. There are two large lakes in Delta. The Paradeniz lake(492 ha) is in direct contact with the sea and salty, while the Akgöl (820 ha) is carrying a fresh water character . Both lakes are quite shallow. The depth is maximum 1 m in Akgöl and 1.5 m in Paradeniz Lagoon (Demirel et al. 2011). While Akgöl was a very salty lake with salt up to 1945, the agricultural areas in the north were opened to irrigation and the drainage waters were connected to the lake and it has turned into a freshwater lake. Akgöl is fed with 2 drainage channels entering the lake from the north and is discharged through a channel opening to the Paradeniz Lagoon from the south east. Depending on the tides, sea water enters the lake from this channel (Erdem et al.,2009). Surrounding the Akgöl lagoon there is an agriculture field with hazelnut, maize, wheat, sugar beet and tobacco growing around the lake. In addition to them, there are many fruit and industrial trees. The salinity level decreases up north where freshwater flows into the system. The salinity of Akgöl is low and is covered with dense reed beds. The sandy strip between Akgöl and the sea is covered with dwarf shrubs of the species Genistra. Both of these wetland systems were formed as a result of bed displacements of the Göksu River and sea movements (Ayas and Kolankaya 1996; Demirel et al. 2011). Akgol lake is a permanent nutrient rich freshwater lake supporting rich marsh vegetation (including extensive Potamogeton, Scirpus, Typha and phragmite beds) (BLI, 2008). The nutrient level of many lakes and rivers has increased dramatically over the past 50 years in response to increased discharge of domestic wastes and non-point pollution from agricultural practices and urban development (Mainstone and Parr, 2002). Dissolved oxygen and temperature are two fundamental measurements of lake productivity. The amount of dissolved oxygen in the water is an important indicator of overall lake health. The dissolved oxygen and temperature regime of a lake is important to know in order to develop appropriate management plans. A lake’s oxygen and temperature patterns not only influence the physical and chemical qualities of a lake but the sources and quantities of phosphorus, as well as the types of fish and animal populations (CLMP, 2008).

In this study, the water quality change of Akgöl was investigated depending on years. For this purpose, water samples were taken 7 times from 2006 (June), 2007 (July), 2008 (January-April), 2011 (February-July), 2012 (September) in the same place. In the samples; pH, temperature, electrical conductivity (EC), salinity (Sal) and dissolved oxygen (DO), nitrate-nitrogen, nitrite-nitrogen, ammonium-nitrogen and total phosphorus were analyzed. The analysis results were compared with "The Surface Water Quality Regulation Annex-5" limit values (WQR, 2016). The relationship of dissolved oxygen which is an important parameter for evaluating water quality of lakes, to other parameters (nitrate, ammonium, total phosphorus, temperature, pH, and electrical conductivity) was explained by the regression analysis.

2. Methodology

This study was conducted between June 2006 and September 2012 (total 7 times) in order to determine change of water quality in the lake. According to "Water Pollution Control Regulations the Sampling and Methods of Analysis" (WPCR-SMA, 2009) water samples were taken from only one station. The samples were stored 4^{o}C in the refrigerator at until analyzed. The sample point are shown in Figure 1.

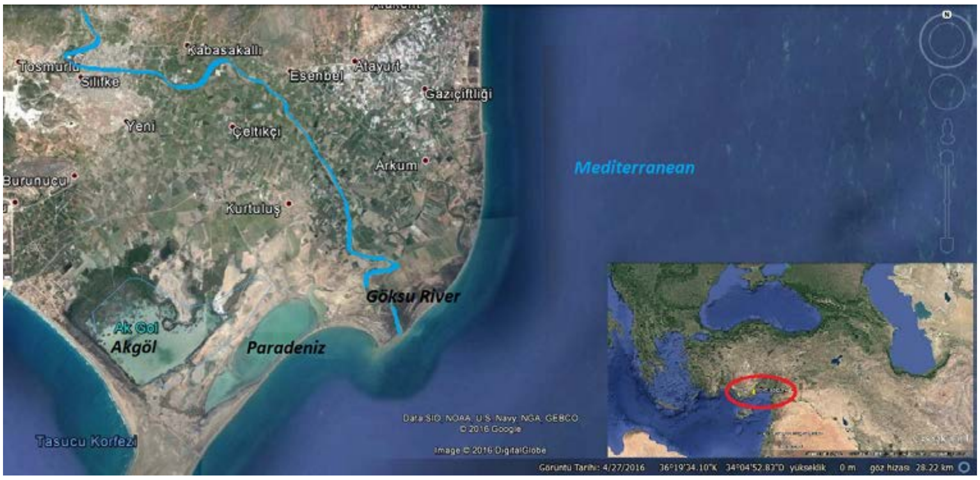

Figure 1. The location map of the study area and sample point.

Measurements of Electrical Conductivity (EC), Salinity (Sal), Temperature (T) and pH were made in the field using a pH/Cond. 340i WTW meter. Ammonium, nitrate, nitrite and phosphate ions analyses were carried out at the Mersin University Environmental Engineering Department, Mersin, Turkey. Nitrite, Nitrate, Ammonium, total phosphorus ions were measured with Hanna C200 multi parameter photometer.

The goal of regression analysis is to describe the relationship between two variables based on observed data and to predict the value of the dependent variable based on the value of the independent variable. Linear regression analysis was performed by the Microsoft Excel software to evaluate the relationship between parameters.

3. Results and Discussion

Water quality monitoring is the integrated activity for evaluating the physical, chemical and biological characteristics of water in relation to human health, ecological conditions and designated water uses (USGS,1995). The most widely measured parameters in the real time water quality stations are pH, Dissolved Oxygen (DO), Electrical Conductivity (EC), temperature (T) (Wagner et.al, 2006). The results of the analysis (Temperature (T), Electrical Conductivity (EC), Salinity (sal), Dissolved Oxygen (DO) pH, Nitrite, Nitrate, Ammonium, total phosphorus (TP)) taken from samples in Akgöl Lake were given in Table 1.

Table 1. Analysis results of Akgöl Lake (mg/L).

	June **06**	July **07**	January **08**	April **08**	February **11**	July **11**	September **12**
Temperature(°C)	33,90	30,00	11,80	19,10	15,70	29,50	26,90
pH	9,10	8,04	6,90	7,12	6,90	8,56	8,24
EC(µS/cm)	439	494	760	728	6720	2040	3120
Sal	0,00	0,00	0,10	0,10	9,70	0,90	1,50
DO (mg/L)	5,50	7,80	8,63	8,02	8,30	7,10	7,30
NO_3-N(mg/L)	9,30	4,60	1,20	4,10	3,90	6,64	6,60
NO_2-N(mg/L)	1,3	0,3	0,018	0,03	0,02	0,4	0,6
NH_4-N(mg/L)	1,2	0,2	0,01	0,05	0,02	0,5	0,3
TP(mg/L)	0,88	0,28	0,62	0,04	0,71	0,32	0,23

The results of the analysis (*Nitrite-N*, *Nitrate-N*, *Ammonium-N*, *total phosphorus*) with the Microsoft Excel program was transferred to the chart to compare with "The Surface Water Quality Regulation Annex-5"(WQR, 2016).

Temperature (T)

In the Göksu Delta area, climate is characterized by hot and dry periods in summer and by warm and wet periods in winter, which is typical for the coastal zones around the Mediterranean Sea. The mean annual temperature in this area is 19^{o}C. Showers start in October, and continue till mid April and the maximum rainfall occurs in December. Recently, it has been emphasized that temperature (T) is an important parameter affecting water quality in many studies on shallow lakes (Xu et al. 2012; Spears et al. 2008; Xia ve Zhang 2008). Since the temperature affects the biological chemical processes in the water source, the concentration of many parameters changes. The irrigation drainage water flows from the channels to Akgöl. The irrigation drainage water flows from the channels to Akgöl. Surface water is therefore in motion during the year. The water level in Akgöl is the highest level in the irrigation period of maximum (end of May - end of September). Akgöl has associated with the delta only groundwater system, and there is no direct connection with the Göksu river. In the summer months, due to the falling water level resulting from excessive evaporation, lake water enters the Paradeniz (Özer,2014). All these events have explained the change in lake water temperature.

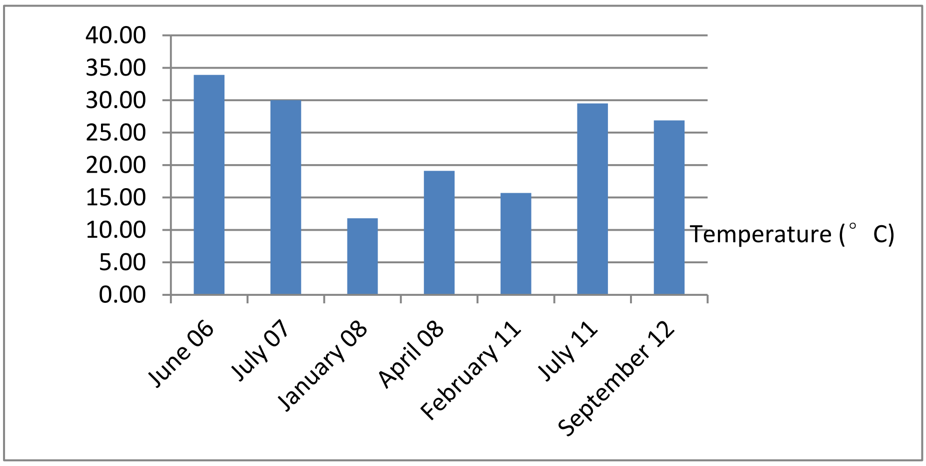

Figure 2. Change of temperature depending on time in the Akgöl Lake

The highest temperature value was measured as 33.9 °C in June 2006 and the lowest temperature value as 11.8 °C in January 2008 in the Akgöl lake water (Figure 2).

pH

The pH value is a very important factor in the study of water chemistry. It is a major factor affecting the availability of nutrients to plants and animals. pH will cycle in the presence of large quantities of algae and macrophytes due to the photosynthetic cycling of CO2 (APHA 1995). A range of 6.5–8.2 is optimal for most organisms (Campbell and Wildberger 1992, Radke 2000). The highest pH value was measured as the 9,42 mg/L in June 2006 and the lowest pH value was measured as the 6,9 mg/L in January 2008- February 2011 in the Akgöl lake water (Figure 3).

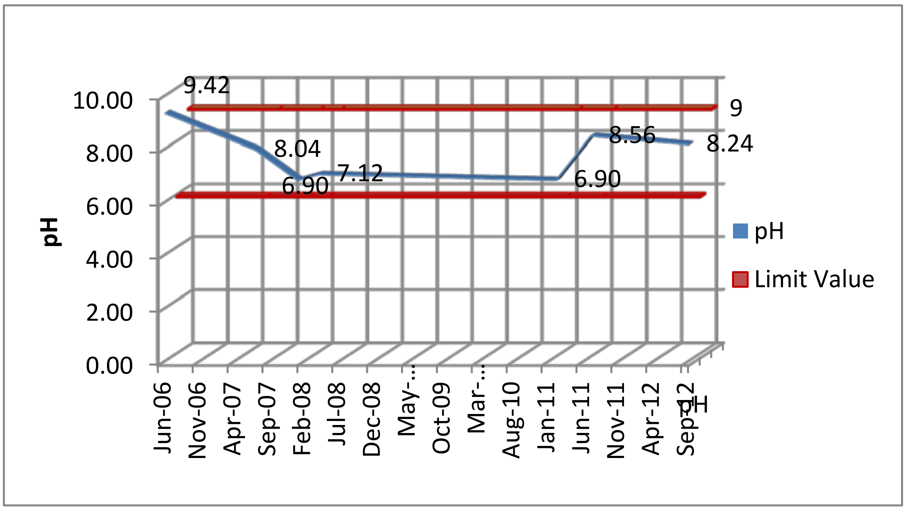

Figure 3. Change of pH depending on time in the Akgöl Lake

It is the reduction of acidic properties during the planktonic assimilation of dissolved inorganic carbon during photosynthesis, which is the cause of high pH value in summer (Ünlü et al. 2008).

Electrical conductivity (*EC*)

The common method for evaluating the total salt content in water is by measuring the electrical conductivity of water (EC) at 25°C. Electrical Conductivity is a measure of the ability of water to pass an electrical current. EC indicates the amount of dissolved substances (salts). Electrical conductivity is expressed in mmhoS/cm (mS/cm). There is a relation between the electrical conductivity and the concentration of salts in milliequivalents per liter. Every 10 meq/liter of salts (cation concentration) creates 1 mS/cm EC. The sum of cations should equal the sum of anions. The accuracy of the chemical water analyses should be checked on the basis of this relationship(Phocaides 2000; Özer 2014). The highest Electrical Conductivity value was measured as the 6720 µS/cm in February 2011 and the lowest Electrical Conductivity value was measured as the 439 µS/cm in June 2006 in the Akgöl lake water (Figure 4).

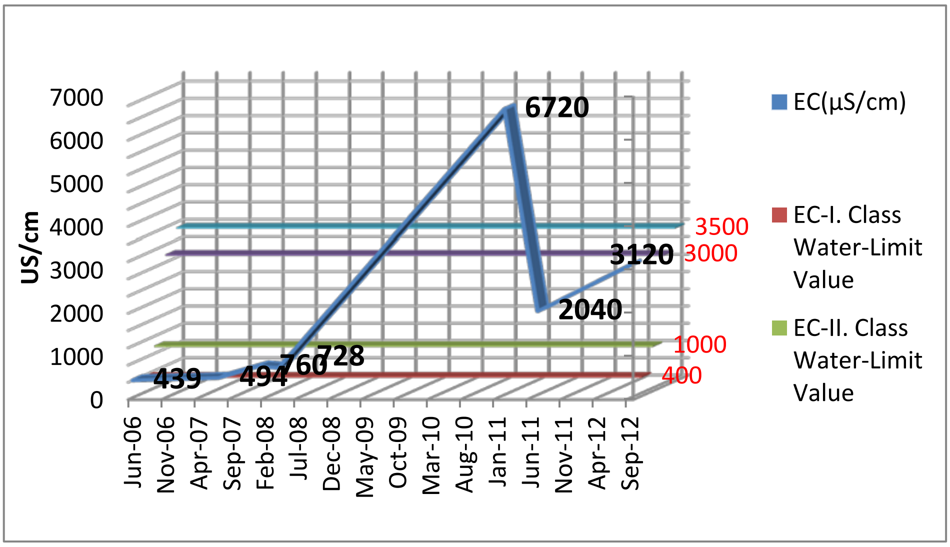

Figure 4. Change of Electrical Conductivity depending on time in the Akgöl Lake

In Delta, floods are observed between January and June, caused by the hard storms that occur in Ermenek and Gökçay branches of the basin. Floods are rarely effective around Akgöl. The high electrical conductivity value observed in Akgöl in February was also due to the Akgöl-Paradeniz interaction, which was caused by these floods (Özer 2014).

Dissolved oxygen (DO)

Dissolved oxygen is a measure of the amount of oxygen freely available in water. The concentration of Dissolved Oxygen (DO) gives information on the possibilities for flora and fauna living in the water system. Dissolved oxygen (DO) concentration explains water pollution the concentration of organic matter in the water, and how much water can cleanse itself (ÜNLÜ et al. 2008). Low dissolved oxygen level (0–8 mg/L) is an indicator of high oxygen demand on the water caused by either high biological or chemical oxygen demand (BOD or COD). Midrange dissolved oxygen values (8–12 mg/L) are usually an indicator of a healthy system (Sallam and Elsayed, 2018 ; Kock et al. 2009)

The highest Dissolved oxygen (DO) value was measured as the 8,63 mg/L in January 2008 and the lowest Dissolved oxygen (DO) value was measured as the 5,50 mg/L in June 2006 in the Akgöl lake water (Figure 5).

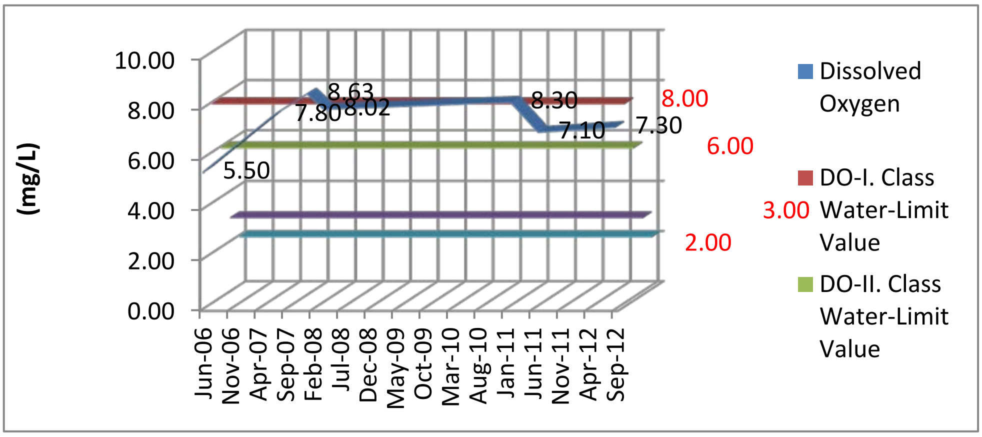

Figure 5. Change of Dissolved oxygen depending on time in the Akgöl Lake

There is clear evidence that nutrient loading to lakes, estuaries and coastal oceans have greatly increased through human activities over the past few decades and that this has caused or enhanced many of the symptoms of the aquatic ecosystem transformation known as eutrophication (Bishop et al., 2006).

Phosphorus and Nitrogen

Phosphorus (P) and nitrogen (N) are the primary nutrients that in excessive amounts pollute our lakes, streams, and wetlands. N and P input and enrichment in water are the most primary factors to induce water eutrophication. The “experienced molecular formula” of alga is as “C106H263O110N16P” based on the chemical components of algae. N and P are the two elements which account for least proportion in the molecular formula of algae, especially P, it is the main limiting factor to control the growth of alga in water (Mainstone and Parr, 2002). Nitrogen is essential to the production of plant and animal tissue. It is used primarily by plants and animals to synthesize protein. Nitrogen enters the ecosystem in several chemical forms and also occurs in other dissolved or particulate forms, such as tissues of living and dead organisms. Nitrates in water can cause severe illness in infants and domestic animals. Common sources of excess nitrate reaching lakes and streams include septic systems, animal feed lots, agricultural fertilizers, manure, industrial waste waters, sanitary landfills, and garbage dumps (Minnesota Pollution Control Agency 2008). Phosphorus in the water ecosystem is one of the key components of a versatile and complex biochemical and chemical balance. In particular, the growth of autotrophs and heterotrophic organisms, which are particularly photosynthesis, is inhibited if phosphorus, which is limiting in growth, is not present in the water in sufficient quantities. The highest ammonium nitrogen value was measured as the 1,2 mg/L in June 2006 and the lowest ammonium nitrogen value was measured as the 0,01 mg/L in January 2008 in the Akgöl lake water (Figure 7). The highest nitrate nitrogen value was measured as the 9,3 mg/L in June 2006 and the lowest nitrate nitrogen value was measured as the 1,2 mg/L in January 2008 in the Akgöl lake water (Figure 6). Phosphorus concentrations are generally known to be higher in summer (Søndegaard et al., 2001).The highest phosphorus value was measured as the 0,88 mg/L in June 2006 and the lowest phosphorus value was measured as the 0,04 mg/L in January 2008 in the Akgöl lake water (Figure 8).

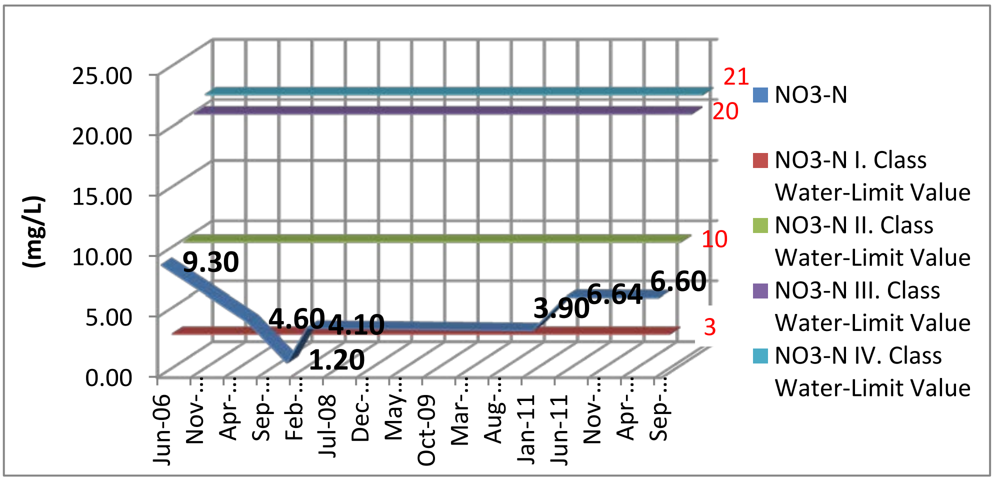

Figure 6. Change of nitrate nitrogen depending on time in the Akgöl Lake

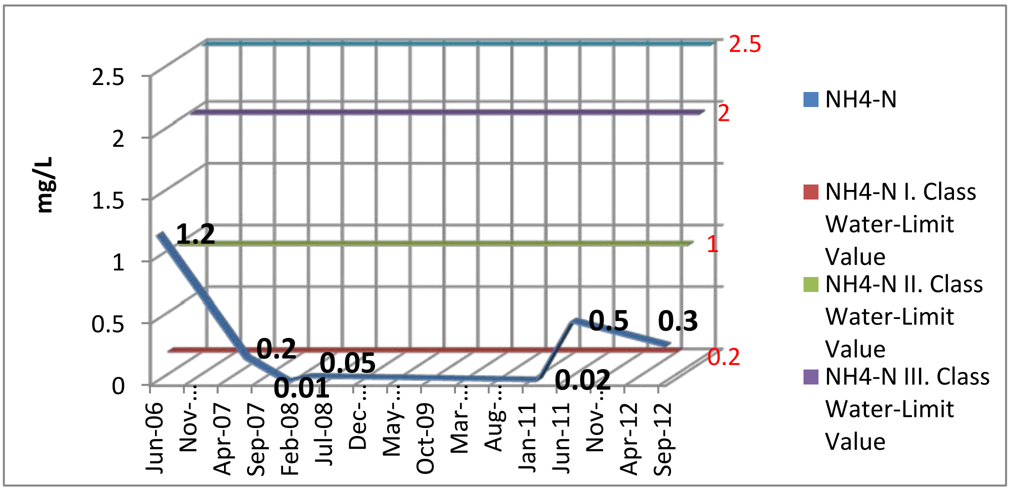

Figure 7. Change of ammonium nitrogen depending on time in the Akgöl Lake

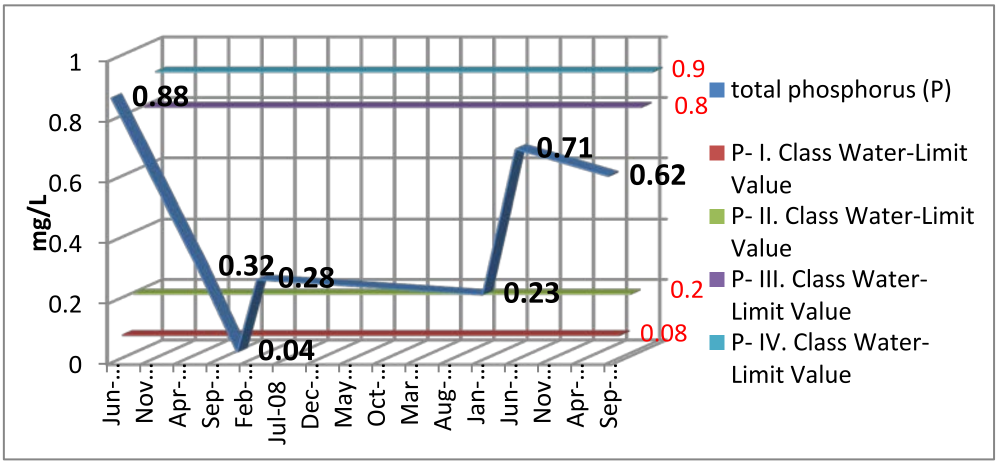

Figure 8. Change of total phosphorus depending on time in the Akgöl Lake

When the analysis results were compared with "The Surface Water Quality Regulation Annex-5" limit values;

- The EC values increased from 2006 to 2012 and the latest analysis showed to exceeded the third class water limit value.
- When the DO values were examined, it was found that the values changed between 7-9 mg/L and it was determined as the 2nd class water category.
- When the nitrate-nitrogen values were examined, it was observed an increase in recent years. In terms of nitrate, the lake water was determined the second class water category.
- The ammonium nitrogen values were variable depending on time and in the last analysis, it was determined to exceed the 1st class water limit value.
- The total phosphorus values decreased from 2006 to 2012 and it was determined as the 2nd class water category.

Regression analysis is the process of mathematical equations of relations between a dependent variable and an independent (simple regression) or multiple independent (multiple regression) variables. In regression analysis; If the relationship between the variables is linear, it is called linear regression, otherwise, it is called non-linear regression. According to simple linear regression analysis made between temperature and dissolved oxygen; the dissolved oxygen change described 71% of the change in the temperature (R^2=0,71). There is a strong negative correlation between the two parameters (r = -0,84) and this relationship was found to be significant at a high level (p<0,01). (Figure 9).

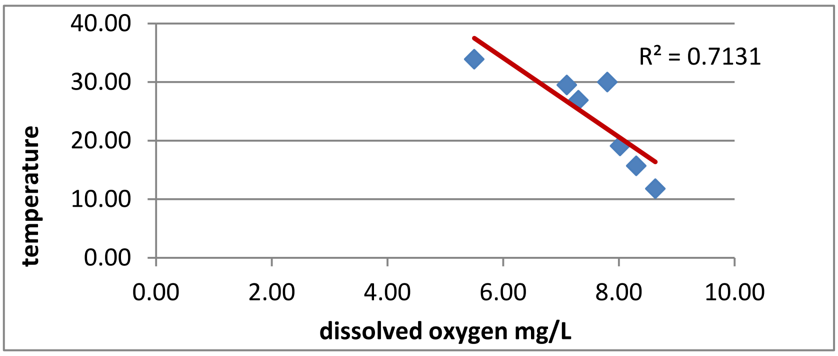

Figure 9. The relationship between of dissolved oxygen - temperature

According to simple linear regression between the electrical conductivity and the dissolved oxygen, the electrical conductivity change described the change of dissolved oxygen by 8% (R^2 = 0,08) . There was a weak correlation between the two parameters (r =0,29) and this relationship was found to be statistically insignificant (p>0,1) (Figure 10).

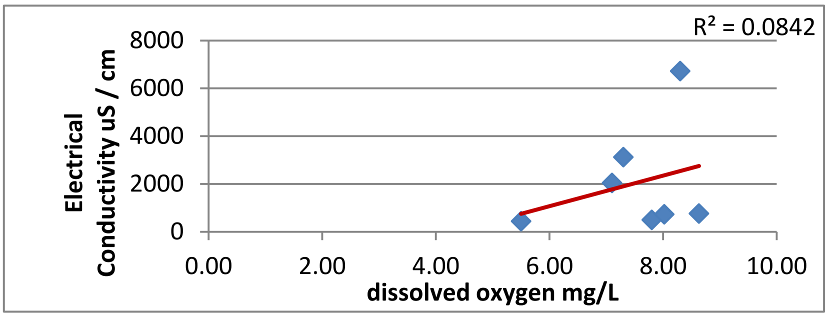

Figure 10. The relationship between of dissolved oxygen - electrical conductivity

According to simple linear regression analysis made between pH and dissolved oxygen; the dissolved oxygen change described 90% of the change in pH (R2=0,90). There is a very strong negative correlation between two parameters (r=-0,95) and this relationship was found to be "a very high statistical significance"(p<0,001) (Figure 11).

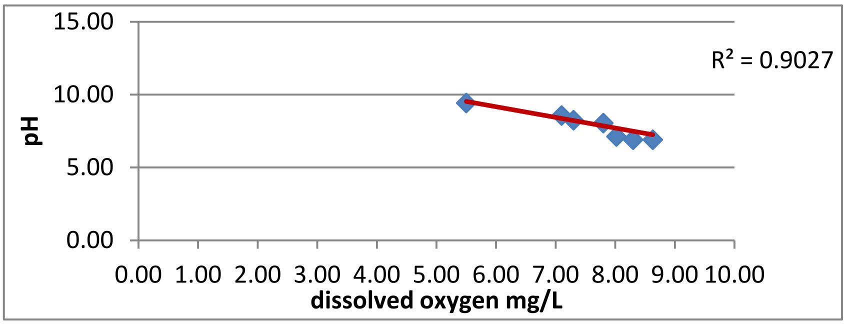

Figure 11. The relationship between of dissolved oxygen – pH

According to simple linear regression analysis made between nitrate-nitrogen and dissolved oxygen concentration; the dissolved oxygen concentration change described 90% of the change in the nitrate-nitrogen concentration (R^2 = 0,90). There is a very strong negative correlation between two parameters (r =-0,95) and this relationship was found to be "a very high statistical significance" ($p<0,001$) (Figure 12).

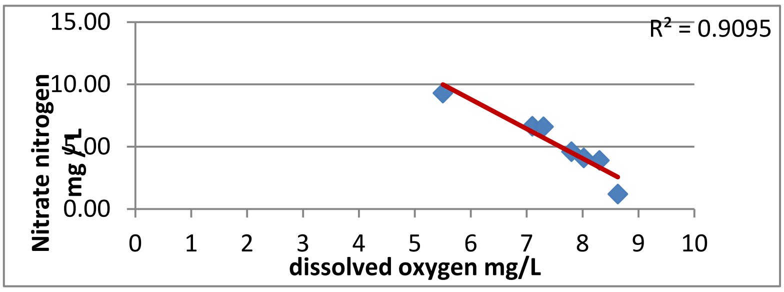

Figure 12. The relationship between of dissolved oxygen – nitrate-nitrogen

According to simple linear regression analysis made between ammonium-nitrogen and dissolved oxygen concentration; the dissolved oxygen concentration change described 96% of the change in the ammonium-nitrogen concentration (R^2 = 0,96). There is a very strong negative correlation between two parameters (r =-0,98) and this relationship was found to be "a very high statistical significance"($p<0,001$) (Figure 13)

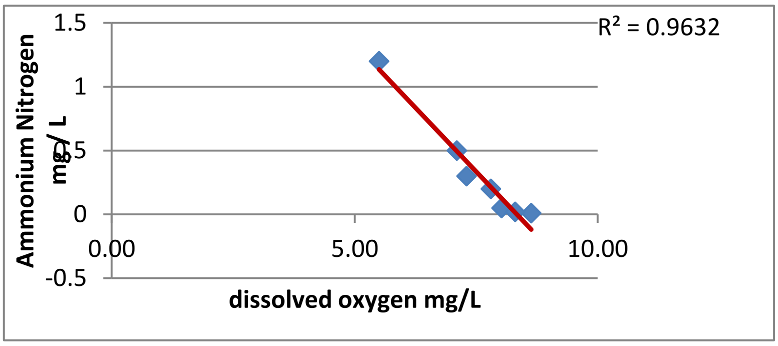

Figure 13. The relationship between of dissolved oxygen – ammonium-nitrogen

4. Conclusions

Akgöl lake is located on the coast of Göksu Delta that is the most important wetland of the Eastern Mediterranean. The Göksu Delta is not only an urban area but it is also surrounded by densely cultivated orchards (mostly citrus), traditional vegetable farms and greenhouse cultivations, where farming activities continue all year long due to favorable climate.

In this study, the water quality change of Akgöl was investigated depending on years. For this purpose, water samples were taken 7 times from 2006 (June), 2007 (July), 2008 (January-April), 2011 (February-July), 2012 (September) in the same place. In the samples; pH, temperature, electrical conductivity (EC), salinity (Sal) and dissolved oxygen(DO), nitrate nitrogen, nitrite nitrogen, ammonium nitrogen and total phosphorus were analyzed. The analysis results were compared with "*The Surface Water Quality Regulation Annex-5*" limit values. Akgöl water quality class was determined as a 2nd class water and the analyzes made in this study show that intense agricultural activities in the delta negatively affect lake water quality.

In this study was determined that was a "very strong negative correlation" between dissolved oxygen and temperature / nitrogen compounds / pH in the Akgöl Lake. The relationship between these parameters (temperature/nitrogen compounds / pH) and dissolved oxygen were determined to be "a very high statistical significance". The low values of R^2 for EC mean that there is no empirical relationship between dissolved oxygen and EC. In the reduction of nutrient concentration in the water, sedimentation is an important mechanism. Due to the fact that unstable stratification and nutrients are released into the water through sediment release, the net loss due to sedimentation is very small in shallow lakes. For this reason, shallow lakes have a higher nutrient concentration than deep lakes. Akgöl is also a shallow lake. Therefore, more detailed analyzes are needed in assessing the trophic class of the lake.

In the Göksu Delta, which is designated and protected as a RAMSAR area, agricultural activities should be controlled, monitoring of water quality in the lake should be ensured and a management plan should be established and effective for protecting water quality.

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