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Assessment of metal concentrations and physicochemical parameters in the waters of Lake Tecer

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Abstract

Aim of the study: The objectives of this study are to observe the monthly and annual changes in water samples using physical–chemical methods in order to determine the water quality properties, to reveal pollution problems, to determine the suitability of water quality for aquatic life and to classify the quality of water in accordance with the Surface Water Quality Management Regulation’s Inland Surface Water Classes criteria.

Area of the study: Lake Tecer is located in the southeastern area of Sivas city and at the end of Brook Tecer, a branch of the Kızılırmak. The lake has a mean depth of 2.4 m and is fed by surface waters and snowmelt.

Material and methods: The study period was from March 2011 to February 2012. Samples analysed for several chemical and physical parameters representing water quality were collected monthly over a period of 12 months.

Main results: It was observed that the condition of the lake in terms of water quality is good. According to the Classification of the Intra-Continental Water Resources in the WPCR, the lake shows Class I, II and III water quality characteristics.

Research highlights: In order to protect the water quality of this water source, to reduce further pollution and to sustain the natural ecological balance consisting of natural fish stocks and other aquatic animals, this lake should be monitored continuously.

Keywords: Metal Concentration, Water Quality, Wetland Area, Water Pollution

Tecer Gölü’nün metal konsantrasyonu ve fizyokimyasal parametrelerinin belirlenmesi

Özet

Çalışmanın amacı: Bir yıl boyunca, gölün bütününü temsil eden üç istasyondan aylık olarak alınan su numunelerinde aylık ve mevsimsel fiziko- kimyasal değişiklerinin izlenerek, su kalitesi özelliklerinin belirlenmesi, kirlilik sorunlarının ortaya çıkartılması, sucul yaşam açısından uygunluk düzeyinin belirlenmesi ve sınıflandırılmasıdır. Ayrıca Yüzeysel Su Kalitesi Yönetim Yönetmeliği Yüzey Su Sınıfları kriterlerine göre suyun kalitesinin belirlenmesidir.

Çalışma alanı : Sivas'ın güneydoğusunda bulunan ve Kızılırmak'ın bir kolu olan Tecer ırmağınınca beslenen, 2.4 m derinliğe sahip olup yüzey suları ve kar suları ile beslenen bir göldür

Materyal ve Yöntem: Bu çalışma Mart 2011- Şubat 2012 tarihleri arasında 1. yıl boyunca gölün bütününü temsil eden üç noktadan aylık olarak alınan su örneklerinin bazı kimyasal ve fiziksel parametrelerin analiz edilmesiyle gerçekleştirilmiştir.

Sonuçlar: Tecer Gölün su kalitesi açısından iyi durumda olduğu belirlenmiştir. Yüzeysel Su Kalitesi Yönetim Yönetmeliğinin Kıta İçindeki Su Kaynakları Sınıflamasına göre göl I –III sınıf su kalitesi özellikleri göstermektedir.

Araştırma vurguları: Ulusal Öneme Sahip Sulak Alan sözleşmesi kapsamında koruma altına alınan Tecer Gölünün daha fazla kirlenmemesi, mevcut su kalitesinin korunması ve doğal balık stokları ve sucul canlılardan oluşan doğal ekolojik dengenin sürdürülebilir olması için bu göl periyodik olarak izlenmelidir

Anahtar kelimeler: Metal yoğunluğu, Su kalitesi, Sulak Alanlar, Su kirliliği

Introduction

Since water plays a very important role both for the future of human life and for the continuity of other organismal life forms on Earth, studies focussing on pollution and water quality are common these days. Even though ¾ of Earth's surface is covered with water, the level of freshwater suitable for use by human beings is very limited. Further, despite 2.5% of the total amount of water on Earth being freshwater, only 0.3% consists of freshwater resources that are suitable for use by humans. The remaining portion of freshwater exists in glaciers at the poles and in high mountains, and in underground water reserves (Mahanda *et al*., 2010). For these reasons, freshwater resources are natural resources that should be very carefully and consciously protected. Determining and protecting the ecological status of natural freshwater resources and improving the poor conditions in the remaining waters are very important (EEA, 2006).

Freshwater is a limited resource necessary for agriculture, industry, aquaculture and human needs. In case of any deficiency in the required quality and amount of freshwater, the sustainability of life becomes impossible. Lakes, ponds, dams and rivers are most sensitive to pollution, and these ecosystems happen to be affected at the highest level. Leakage of wastes, originating from domestic, industrial, agricultural and tourist activities, into surface waters without a sufficient level of treatment causes water pollution. It is therefore necessary to regularly examine the water quality and pollution levels of lakes, ponds and dams (Taş, 2006).

The decrease or increase in some of the physicochemical parameters of lakes, ponds and dams, and the extremely high or low level of reproduction of certain aquatic species deteriorate the balance in the aquatic environment and reduce the water quality (Mutlu and Uncumusaoğlu, 2017).

In our country, the most important water supply for table, usage and irrigation water comes from lakes, ponds and dams. These lakes and ponds are generally located in the central regions of Anatolia, influenced by a continental climate, and are near residential areas. They are exposed to high evaporation rates because of higher temperatures and lower precipitation levels during the summer months. Water quality levels are characterised by the physical and chemical parameters, heavy metals and salinity ratios.

The objectives of this study are to observe the seasonal changes in the physicochemical parameters of water, to examine the effects of other pollutants on the lake and to classify the quality of water in accordance with the Surface Water Quality Management Regulation's Inland Surface Water Classes criteria. The study was carried out at three sampling stations on Lake Tecer over a 12-month period.

Material and Method

Study Area

Samples analysed for several chemical and physical parameters representing water quality were collected monthly from three stations over a period of 12 months between March 2011 and February 2012. The water samples were taken to the laboratory for analysis within a maximum of three hours from collection. Temperature, pH, dissolved oxygen and electrical conductivity were measured in the field using hand-held measurement devices. Dissolved oxygen and temperature were measured using a YSI S2 model oxygen-meter. pH was measured using an Orion 420A model pH-meter. Electrical conductivity (µs/cm) and salinity (ppt) were measured using a YSI 30/50 FT model conductance-meter.

Other parameters used for determining water quality include total hardness, total alkalinity, nitrite, ammonium nitrogen, nitrate, sulphite, sulphate, phosphate, chloride, sodium, potassium, biological oxygen demand (BOD), chemical oxygen demand (COD), suspended solid matter (SSM), magnesium, calcium, lead, ferrous iron, zinc, copper, nickel, cadmium and mercury. Analyses of the water samples were conducted in the laboratory of the Sivas Directorate of Provincial Food Agriculture and Livestock on the same day.

Monthly mean values and standard deviations were calculated, and graphics were created for each of the parameters using

Office Excel 2007, which is a part of the Microsoft Office Professional Edition 2007.

Water Analyses

Samples analysed for several chemical and physical parameters representing water quality were collected monthly from three stations over a period of 12 months between March 2011 and February 2012. Cleaning and maintenance of all of the equipment, hand-held measurement devices and glass sampling containers to be used in sampling were executed one day prior to sampling. Sampling tubes were immersed into an acidic solution and then dried in a drying oven after being rinsed with de-ionised water. Water samples were collected from a depth of 15 cm below the water surface after initial flushing.

The obtained water samples were taken to the laboratory for analyses within a maximum of two hours from collection. Temperature, pH, dissolved oxygen, salinity and electrical conductivity were measured in the field using hand-held measurement devices. Dissolved oxygen and temperature were measured using a YSI S2 model oxygen-meter. pH was measured using an Orion 420A model pH-meter. Electrical conductivity (µs/cm) and salinity (ppt) were measured using a YSI 30/50 FT model conductance-meter.

Other parameters used for determining water quality include total hardness, total alkalinity, nitrite, ammonium nitrogen, nitrate, sulphite, sulphate, phosphate, chloride, sodium, potassium, biological oxygen demand (BOD), chemical oxygen demand (COD), suspended solid matter (SSM), magnesium, calcium, lead, ferrous copper and cadmium. Analyses of the water samples were conducted in the laboratory of the Sivas Directorate of Provincial Food Agriculture and Livestock on the same day.

Titration with sulphuric acid (for total alkalinity) and titration with EDTA (for total hardness) were executed. The results are presented in units of mg/L $CaCO_3$. Chemical oxygen demand was calculated through titration with ferrous ammonium sulphate based on the determination of the amount of oxygen being used while lysing the natural and organic pollutant load using powerful chemical oxidants. The analyses of ammonia, nitrite, nitrate, ammonium nitrogen (NH_4^+), phosphate, sulphate, sulphite, chloride, sodium, potassium, calcium and magnesium were conducted using a CECİL CE4003 spectrophotometer with Merck photometric test kits according to standard procedures. The analyses of lead, copper, ferrous iron and cadmium water samples were conducted using a PERKIN ELMER ANALYST 800 Atomic Absorption Spectrometer. The analyses for suspended solid matter (SSM) were conducted by filtering the water through Whatman Nr. 42 0.45 µm membrane filters, followed by weighing and drying the filter papers at 103°C for 24 hours and calculating the weight difference.

Monthly mean values and standard deviations were calculated, and graphics were created for each of the parameters using Office Excel 2007, which is a part of the Microsoft Office Professional Edition 2007.

Results

Water temperatures showed significant annual and monthly variability amongst measurement stations across the lake (Figure 1). The lowest value of 4.2°C was measured at the 1st station in February 2012, and the highest water temperature of 24°C was measured at the 2nd station in September 2012. The annual average temperature of the lake was recorded to be 14.60°C.

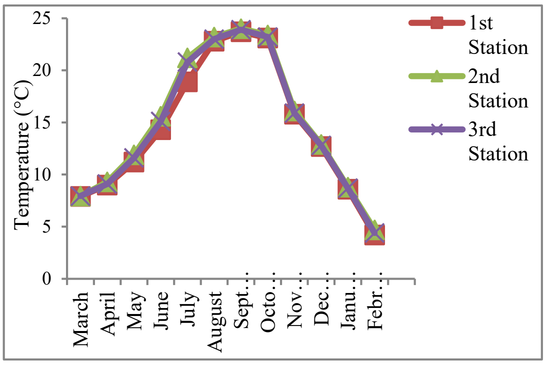

Figure 1. Monthly mean temperature values (^{0}C)

The pH values denoted that Lake Tecer is mildly basic. During this study, the lowest pH value of 7.80 was measured at the 1st station in February, and the highest pH value of 8.17 was measured at the 3rd station in September. The mean annual pH value of the lake was found to be 7.96. Also, the seasonal averages were 7.93 in spring, 8.02 in summer, 8.05 in winter and 7.85 in autumn.

During the study, the dissolved oxygen concentration showed variability between months and seasons. The lowest value was 9.00 mg/L (September 2012, 3rd station), and the highest value was 11.57 mg/L (February 2012, 1st station). The annual average of all of the measurement stations in the lake was 10.74 mg/L. The seasonal dissolved oxygen values were 11.34 mg/L in winter, 11.19 mg/L in spring, 10.34 mg/L in summer and 9.85 mg/L in autumn.

Chemical oxygen demand (COD) in Tecer Lake showed an increasing trend across all stations from February to September and peaked in September (Figure 2). The lowest COD value of 3.78 mg/L was found in February 2012, and the highest value of 28.70 mg/L was observed at the 3rd station in September 2011. The mean annual value amongst all stations was 10.74 mg/L.

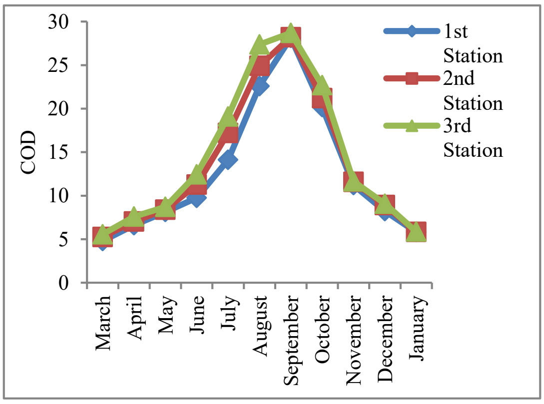

Figure 2. Monthly mean chemical oxygen demand (COD) in mg/L across stations

The salinity of Lake Tecer peaked in all stations in September when the water temperature was at its highest and the dissolved oxygen concentrations were at a minimum. The highest value was measured to be 0.12 ppt at the 3rd station in September 2012, and the mean salinity of the lake was found to be 0.006 ppt.

Similar to chemical oxygen demand (COD), the biological oxygen demand (BOD) of Lake Tecer showed a regular increase between February and September and peaked in September at all of the measurement stations (Figure 3). The lowest COD value in the lake of 2.64 mg/L was observed at the 1st station in February 2012, and the highest value of 15.28 mg/L was observed at the 3rd station in September 2011. The mean annual value for all stations was 9.60 mg/L.

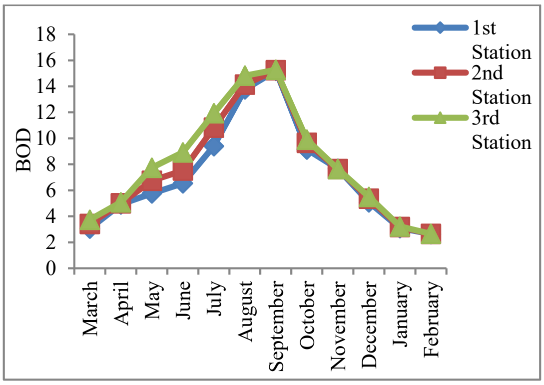

Figure 3. Monthly mean biological oxygen demand (BOD) in mg/L

The electrical conductivity (EC) of Lake Tecer showed significant variability amongst months and seasons, and across stations (Figure 4). The electrical conductivity (EC) increased in the autumn months and decreased in the winter months. The lowest value of 137.60 µs/cm was measured at the 1st station in February 2012, and the highest value of 295.92 µs/cm was observed at the 3rd station. The seasonal average ECs of Lake Tecer were 184.10 µs/cm in spring, 247.64 µs/cm in summer, 253.75 µs/cm in autumn and 150.53 µs/cm in winter.

The suspended solid matter (SSM) amounts in the lake showed significant changes between months and seasons, and across stations. The highest observed value was 24.40 mg/L (September 2011, 3rd station), and the lowest value was 5.24 mg/L (February 2011, 1st station). The mean annual value was 12.42 mg/L.

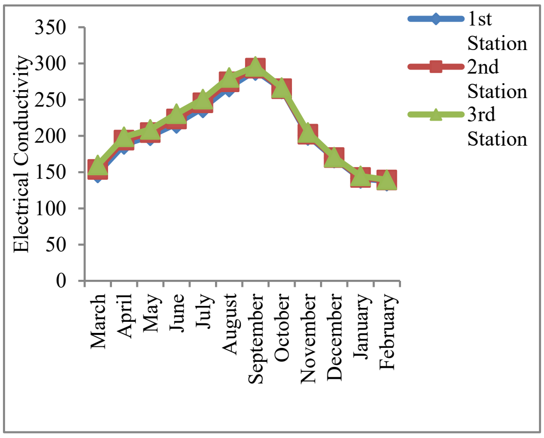

Figure 4. Monthly mean electrical conductivity values (µs/cm)

The measured nitrite, nitrate and ammonium nitrogen concentrations of Lake Tecer were lower in the winter months than during other seasons. The nitrite (NO_2) concentrations were found to be at a minimum in February 2012 at all three of the measurement stations. The NO_2 concentrations in Lake Tecer showed a regular increase between February and July. The minimum value of the lake, 0.0004 mg/L, was measured at the 1st and 2nd stations, and the highest value of 0.0124 mg/L was measured at the 3rd station. The mean value for all of the stations was 0.0048 mg/L.

Nitrate (NO_3) concentrations continued to increase at all three of the measurement stations between February and September and peaked at 9.83 mg/L at the 3rd station in September 2011, and the minimum value of 1.98 mg/L was measured at the 1st station in February 2012. The mean annual concentration amongst stations was found to be 4.66 mg/L.

The minimum concentration of ammonium nitrogen (NH_4) in Lake Tecer was observed in February 2012 at all three of the stations. Similarly to the NO_2 concentrations, they showed an increase between February and July. The minimum concentration of 0.0002 mg/L was measured at the 1st station in February 2012, and the highest value of 0.0084 mg/L was measured at the 3rd station in July 2011. The mean annual value was 0.0006 mg/L.

Total alkalinity and total hardness values of Lake Tecer showed parallelism during the study, and their results were very close to one another. Total alkalinity and total hardness values increased in the spring months and decreased in the winter months.

The lowest alkalinity and total hardness values were observed in February 2012 at all stations. The values then showed an increasing trend between February and June. The lowest total alkalinity value of 258.18 mg/L $CaCO_3$ was measured at the 1st station in February 2012, and the highest value of 313.90 mg/L $CaCO_3$ was observed at the 3rd station in June 2012.

The sulphate (SO_4) concentrations in Lake Tecer showed variability amongst the stations and seasons. The highest SO_4 concentration of 149.75 mg/L was measured at the 3rd station in September 2011, and the lowest value of 54.1 mg/L was observed at the 1st station in February 2012. The mean annual concentration for all stations was 95.83 mg/L.

Sulphide (SO_3) values increased at all stations between February and September, with a maximum value of 9.93 mg/L measured at the 3rd station in September and a minimum value of 3.46 mg/L observed at the 1st station in February 2012. Sulphide concentrations showed variability amongst seasons and months. The seasonal mean SO_3 concentrations were 6.64 mg/L in spring, 8.70 mg/L in summer, 7.31 mg/L in autumn and 3.34 mg/L in winter.

The chloride values in Lake Tecer showed significant variability between months and seasons. The highest value of 8.18 mg/L was observed at the 1st station in July 2011, and the lowest value of 6.53 mg/L was recorded at the 3rd station in September 2011. The mean annual concentration for all stations was 7.37 mg/L.

The highest concentrations of phosphate (PO_4) in Lake Tecer were determined to be 0.10 mg/L (February 2012, 1st station) and 0.74 mg/L (November 2011, 3rd station). The PO_4 concentrations increased between August and November at all three of the stations.

The magnesium (Mg^{++}) and calcium (Ca^{++}) values measured in Lake Tecer showed parallelism. Magnesium and calcium values increased in the spring months and decreased in the autumn months. The highest magnesium value of 51.90 mg/L was observed at the 3rd station in June 2011, and the lowest value of 27.20 mg/L was observed at the 1st station in February 2012.

The seasonal Ca values were 45.42 mg/L in spring, 44.8 mg/L in summer, 32.36 mg/L in autumn and 32.78 mg/L in winter. The lowest Ca concentration of 52.28 mg/L was observed at the 1st station in February 2012.

The sodium (Na) and potassium (K) values in the lake also showed parallelism. The highest Na concentration of 61.20 mg/L was measured at the 3rd station in June 2011, and the lowest concentration of 35.44 mg/L was observed at the 1st station in September 2011. The mean K value in Lake Tecer was found to be 8.36 mg/L. The highest K concentration of 9.88 mg/L was observed at the 3rd station in June 2011, and the lowest concentration of 6.94 mg/L was observed at the 1st station in September 2011. The lead (Pb), copper (Cu) and cadmium (Cd) values of Lake Tecer showed variability amongst the months. The lowest Pb concentrations of 0.02 mg/L were observed at the 2nd and 3rd stations in September, and the highest Cu concentration of 0.018 mg/L was observed at the 3rd station in April 2011. The highest Cd concentration of 0.009 mg/L was observed at all of the stations in September 2011.

Discussion

Located within the borders of the Ulaş district of Sivas city, Lake Tecer is located at the southern end of Brook Tecer, a branch of the Kızılırmak. It is a natural lake with an average depth of 2.4 m and is fed by both surface waters and snowmelt.

The seasonal mean values and standard deviation values of water quality parameters investigated at three stations in Lake Tecer through monthly measurements over a period of one year are given in Table 1.

Table 1. Seasonal Values of Water Quality Parameters Investigated in Lake Tecer

Investigated Water Quality Parameters	**Spring**	**Summer**	**Autumn**	**Winter**
pH	7.93	8.02	8.05	7.85
Dissolved Oxygen (mg/L)	11.19	10.34	9.84	11.34
Saltiness (ppt)	0.04	0.08	0.09	0.04
Electrical Conductivity (µs/cm)	184.1	247.64	253.75	150.53
Nitrite (mg/L)	0.0042	0.0103	0.0045	0.0005
Nitrate (mg/L)	2.74	6.69	7.15	2.09
Ammonium Nitrogen (mg/L)	0.0034	0.0247	0.0036	0.0004
Total Alkalinity (mg/L) $CaCO_3$	293.56	292.64	265.54	266.44
Total Hardness (mg/L) $CaCO_3$	292.61	292.17	264.76	265.97
Sulphate (mg/L)	87.37	124.97	111.69	59.31
Sulphide (mg/L)	6.64	8.7	7.31	3.34
Chloride (mg/L)	7.71	7.4	7.12	7.25
Phosphate (mg/L)	0.212	0.206	0.55	0.221
Magnesium (mg/L)	49.19	44.55	31.99	32.32
Calcium (mg/L)	45.42	44.81	32.36	32.78
Sodium (mg/L)	54.86	51.02	43.61	49.11
Potassium (mg/L)	9.16	8.48	7.77	8.09
Lead (mg/L)	0.0054	0.0127	0.0146	0.0034
Cadmium (mg/L)	0.0042	0.007	0.0073	0.001
Copper (mg/L)	0.0154	0.0091	0.0096	0.0048
Ferrous Iron (mg/L)	0.0193	0.0176	0.0075	0.0003

Water temperature is the most important factor affecting the biological activity of aquatic organisms and fish. Changes in water temperature result from seasonal temperature changes (Mutlu *et al*., 2013b). Lake Tecer shows typical characteristics of inland waters. The temperature differences measured at the three stations over a period of 1 year were not significant enough to negatively affect aquatic life in the lake. According to the Water Pollution Control Regulations (WPCR), the water of the lake is first class.

pH is the most important factor for chemical and biological systems in natural waters. The weak acid and weak bases can separate from each other through pH changes. This separation affects the toxicity of many compounds (Atay and Pulatsü, 2000). In order for a pH value of any aquatic medium to not jeopardise the aquatic life and in order for a water resource to be suitable for aquaculture, it should remain within the range of 6.5–8.5 (Kara and Gömlekçioğlu, 2004). The mean value of water samples taken monthly from Lake Tecer over a period of 1 year was found to be 7.96, and the highest value was found to be 8.17. According to these results, the lake has mildly basic character and is Class I–II in accordance with the WPCR.

The dissolved oxygen (DO) concentrations are an important criterion for developing a balanced fauna. Beyond dissolved oxygen being a necessary compound for aquatic life, it is also necessary for biochemical oxidation. In sweet waters, there should be at least 5 mg/L of dissolved oxygen for aquatic life to persist (Atay and Pulatsü, 2000).

The lowest dissolved oxygen level of 9.00 mg/L in this study was observed at the 3rd station in September 2011, equivalent to Class I in accordance with the WPCR.

Chemical oxygen demand (COD) is a very important parameter for determining the pollution level of water and wastewater (Mutlu *et al*., 2013c). A concentration of more than 25 mg/L COD in waters indicates pollution, whereas values higher than 50 mg/L indicate severe pollution and possible toxicity for aquatic organisms (Güler, 1997). The highest COD value of 28.27 mg/L measured in Lake Tecer was found at the 3rd station in September 2011. According to the WPCR, in harmony with the rule that the worst value determines the class, Lake Tecer is classified as Class II in terms of the COD parameter.

Biological oxygen demand (BOD) defines the amount of oxygen required for microorganisms to dissolve organic matter in an aquatic medium under aerobic conditions. This parameter is used for determining the environment's pollution potential and the receiver environment's assimilation capacity based on the ability of organisms to consume dissolved oxygen when they are released into the receiver mediums (Anonymous, 2013). The highest BOD value of 15.28 mg/L in the lake was observed at the 3rd station in September 2011, equivalent to Class III according to the WPCR in terms of BOD.

Salinity is a unitless representation of salts dissolved in 1 L of water in terms of gram (Yanık *et al*., 2001). Salinity is closely related with temperature and electrical conductivity (Mutlu *et al*., 2013a). The mean annual salinity of the lake was calculated to be 0.06 ppt, with the observed variability being related to changes in water temperature and electrical conductivity.

Electrical conductivity (EC) is very important for aquatic products, and as the conductivity passes beyond the level of 100 µs/cm, the pollution capacity increases (Verep *et al*., 2005). The electrical conductivity values in this study decreased in the winter months and increased in the months when increases in water temperature and salinity were also observed. The highest EC value measured in the lake was 295.92 µs/cm, and it is considered Class I according to the WPCR in terms of electrical conductivity.

The amount of SSM rises as a function of inorganic matter content, such as clay and loam. The maximum permissible SSM level for aquaculture is 10 mg/L (Ntengue, 2006). The highest SSM amount in Lake Tecer was measured to be 24.40 mg/L at the 3rd station in September 2011, and it means that the lake is not appropriate for aquaculture activities.

The nitrogen mixing into surface waters originates mostly from natural domestic and agricultural sources (Mutlu *et al*., 2013a).

Nitrogen derivatives such as nitrite (NO_2), nitrate (NO_3) and ammonium nitrogen (NH_4) play a significant role in water pollution and can have significant effects on dissolved oxygen concentrations and, ultimately, eutrophication. The maximum levels of NO_2 and NH_4 in the lake were observed at the 3rd station in July 2011. These concentrations derive from point sources of domestic and animal wastes into surface waters during that month. According to the WPCR, the lake shows Class III water characteristics in terms of NO_2 and NH_4. Nitrate is the final oxidation product of nitrogenous compounds. The existence of NO_2 in surface waters indicates the pollution of those waters due to domestic and industrial wastewaters containing ammonium and organic nitrogen and the nitrogenous fertilizers used on agricultural lands (Topal and Arslan, 2012). The highest amount of NO_3 of 9.83 mg/L in the lake was observed at the 3rd station in September 2011, which is not at a dangerous level. According to the WPCR, the lake shows Class II water in terms of NO_3.

The total alkalinity and total hardness values in lime soils are generally similar (Boyd and Tucker, 1998). The total alkalinity and total hardness values measured in the lake in this study were observed to be very close to each other. The mean hardness value of the lake was measured to be 278.87 mg/L $CaCO_3$, and the highest value of 313.42 mg/L $CaCO_3$ was observed at the 3rd station in June 2011. The lake shows mildly hard water characteristics.

Amongst natural anions in the water, sulphate (SO_4) should exist in natural resources for improved biological productivity (Taş *et al*., 2010). The highest concentration limit for SO_4 in water from an aquatic ecosystem perspective was determined to be 90 mg/L (Küçük, 2007). The mean SO_4 value of the lake was found to be 95.83 mg/L, and the highest value of 149.75 mg/L was observed at the 3rd station in September 2011. It was determined that the lake is not suitable for aquatic products in terms of SO_4.

The sulphite (SO_3) measured in this study was sodium sulphate (Na_2SO_4), and its highest level of 9.93 mg/L in the lake was found at the 3rd station in September 2011. The highest concentration limit for SO_3 required for aquatic products was determined to be 10 mg/L (Mutlu *et al*., 2013b). Because the highest level of SO_3 measured in the lake does not exceeded 10 mg/L, Lake Tecer is deemed suitable for aquaculture.

Chloride ions are important indicators of healthy water. The highest chloride concentration of 8.18 mg/L observed in this study was found at the 1st station in July 2011, well within the values suitable for aquaculture.

Phosphorous is the primary basic element in water contributing to eutrophication (Harper, 1992). Terrestrial phosphate-containing fertilizers used for wheat production are the likely cause for the observed increase in the concentration of phosphorous in the lake in October and November. Alternatively, the increase may be explained by the observed amount of algae that are capable of binding PO_4 directly from the air. The highest level of phosphate of 0.74 mg/L in the lake was observed at the 3rd station in November 2011, indicating dangerous levels for aquaculture and aquatic life.

Calcium (Ca^{++}) and magnesium (Mg^{++}) are the most important dissolved solids in water (Mutlu *et al*., 2013b), stemming from alkali soil minerals, and are amongst the most common ions existing in sweet waters. The highest recommended Ca^{++} concentration is 75 mg/L (Taş, 2006). In our study, the highest concentration of Ca^{++} of 52.28 mg/L was observed at the 3rd station in June 2011, and the mean annual value was 38.84 mg/L. In light of these findings, it was observed that the amount of Ca^{++} in Lake Tecer is within the normal limits.

The concentration of Mg^{++} in normal waters should be between 5 and 60 mg/L. In mildly hard waters, values between 60 and 100 mg/L can be accepted as normal, with a recommended concentration of 50 mg/L (Taş, 2006). In our study performed in Lake Tecer, the highest Mg^{++} concentration of 51.90 mg/L was observed at the 3rd station in June 2011, and the mean annual value amongst all stations was 38.51 mg/L, which is accepted to be normal.

Potassium (K) exists in natural waters in concentrations of between 1 and 10 mg/L, and the concentration of sodium (Na) varies between 2 and 100 mg/L (Boyd, 1998). In our study on Lake Tecer, the highest K concentration of 9.88 mg/L was observed at the 3rd station in June 2011, which is accepted to be within normal values.

The highest concentration of Na of 61.20 mg/L in this study was found at the 3rd station in June 2011, and the lowest concentration of 44.7 mg/L was measured at the 1st station in February 2012. The mean annual value was 49.65 mg/L. In light of these results, it was determined that the concentration of Na in the lake was within the normal limits.

The heavy metal elements investigated in our study are lead (Pb), copper (Cu), cadmium (Cd) and ferrous iron (Fe). The concentration of Pb was found to be 0.02 mg/L and that of Cd was 0.009 mg/L. In light of these values, the lake shows Class II water characteristics in terms of Pb and Class III water characteristics in terms of Cd according to the WPCR.

Although Cu was detected in trace amounts during the winter months in Lake Tecer, the level suddenly increased in April 2011. Although the mean concentration of Cu in the lake in March was 0.007 mg/L, the concentration in April was 0.015 mg/L. It is thought that this increase was caused by the penetration of Cu, accumulated in nearby soils because of the dense usage of copper vitriol during maintenance and pruning processes in fruit gardens in the spring season, into the lake waters through precipitation runoff. According to the WPCR, the lake shows Class II water characteristics in terms of Cu.

Ferrous iron was detected in all three of the stations in each month of the study. Its level was low in the winter months, increased during the spring months and peaked in the summer months. The highest concentration of Fe of 0.040 mg/L in our study was observed at the 3rd station in May 2011. The peak value of Fe observed in May and June is thought to result from wheat planting around the lake. Because ferrous-containing agricultural pesticides are densely used in May and June to increase the grain productivity of wheat plants, ferrous-containing waters and particles may leak into the lake through precipitation runoff and leakages.

Since Lake Tecer was determined to have international importance in terms of being an Aquatic Bird Habitat, its environment should be utilised for recreational and ecotourism purposes. According to the Classification of the Intra-Continental Water Resources in the WPCR, the lake shows Class I, II and III water quality characteristics. It was determined that the shallow depth of the lake, SSM, BOD, SO_4, SO_3, lead and cadmium concentrations in the lake are not appropriate for aquaculture activities.

According to the terms of the RAMSAR convention, more attention should be paid to the protection of Lake Tecer by decreasing the pressures on it and by protecting the water level of the lake in a way that will not harm the ecological balances. Besides that, the continued pollution of this water source should be prevented, and water quality protection provisions required for sustaining and improving the ecological balance constituted by the natural fish stocks and other aquatic organisms should be made immediately. Finally, this lake should be monitored continuously.

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