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Determining the water quality of Lake Delice (İmranli-Sivas).

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ABSTRACT

The objectives of this study were to observe the monthly and annual changes in water samples through physico-chemical methods, to determine the water quality properties, to reveal the pollution problems, to determine the suitability level in terms of aquatic life, and to classify the quality of water in accordance with the ISWC criteria. This study has been carried out through monthly sampling during April 2011-March 2014 in 3 stations at Lake Delice. The samples have been immediately taken to the laboratories for analyses. 1st station is at the Western side of the lake (roadside), 2nd point is at entrance point of Brook Araba into the lake (northwestern side of the lake), and the 3rd station is located at Southwestern side of the lake (the deepest point). It has been determined that the lake is suitable for aquaculture of cold water fish in winter and spring months and for warm-water fish in summer and autumn months. Furthermore, the pollution of this water resource should be prevented, and the water quality protection provisions required for sustaining and improving the ecological balance constituted by the natural fish stocks and other aquatic creatures should be made immediately, and this lake should be monitored continuously.

Introduction

Given the amount of free water in entire world, it can be thought that the water stock in the earth is plenty enough to satisfy all of water requirements, and hence it is a never-ending resource. But, most of these waters are the salty waters in the seas (Akyurt and Ayık 1995). The fresh water resources consisting of glaciers in poles, underground waters, lakes and rivers constitute only 3% of the total consumable waters. In total water resources, the portion of the lakes and rivers, which are ready to be directly used by the living organisms, is only 0.27% (Gleick 1996). Although this portion is very low among the total water amount, living organisms need to use these fresh water resources in order to satisfy their various water requirements (Tüzün et al. 2006).

There is an increasing inclination and awareness about protecting the earth, and tracking the environmental effects and changes in the entire world. For this reason, the concepts of “sustainable development” and “environment management” nowadays became two fundamental concepts that should be considered together. The most important one of these interactions is the negative effects of environmental or water pollution on the aquatic organisms and aquatic life (Mert et al. 2010).

Besides more than 120 natural lakes, there are more than 715 reservoirs in Turkey that can be used in order to satisfy the fresh water requirements. Nevertheless, due to irregular precipitation regimes and geographical conditions, water problems emerge in many regions. As a solution for water problems, generally the reservoirs and ponds are constructed. Dams and ponds are constructed for the purposes such as energy production, irrigation, potable water requirements, protection against floods, and aquaculture (Anonymous 2013).

With the increasing population of today, the socioeconomic development, unplanned urbanization, and insufficient infrastructural facilities lead significant pollution threat. Water quality affects the biological

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diversity, productivity, and the physiological conditions of aquatic species (Ayvaz et al. 2011). Lakes and ponds that continuously exhibit the recipient characteristic are primarily affected from this pollution.

Under the effects of these negative factors, the use of constant-recipient lakes and ponds for aquaculture and watering purposes is gradually limited, and large amounts of water purification costs emerge.

The pollution in ponds does not only affect the species they host, but this pollution also reaches at humans through the food chain (Akbulut et al. 2011). The water quality of an aquatic environment is affected negatively by the discharges such as organic matters, heavy metals, oil derivatives, artificial agricultural fertilizers, detergents, radioactivity, inorganic salts, artificial organic chemical matters, and waste temperature (Arslan et al. 2011). For this reason, it is very important to well know the properties of the water used in aquaculture, and to protect the natural balance in using the natural resources. In order to take required measures in protecting the ecological balance, the physical and chemical factors of aquatic medium must be investigated periodically (Ayvaz et al. 2011).

Through analyzing the water samples taken monthly between April 2011 and March 2014 from 3 sampling stations representing the characteristics of entire lake, the aim of this study is to reveal the actual water quality of Lake Delice in İmranlı district of Sivas city constituting the water group that is most sensitive to pollution, to determine the suitability for aquatic life, and to classify the water in accordance with Quality Criteria of Classification of Intra-Continental Water Resources of Surficial Water Quality Regulation (SWQR).

Material and methods

Study Area

Delice Lake in Yukarı – Kızılırmak basin is located within the borders of Delice Village of İmranlı district of Sivas city. It is 4 km far from İmranlı district, and 167 km far from Sivas city. The surface area of the lake fed with precipitation and snow waters is 267 ha, and its mean depth is 4.8 m. Besides being an important recreational area for İmranlı district, the pond is used for irrigation of agricultural lands around the lake. The water resources of the lake are Brook Araba and precipitation and snow waters.

While determining the sampling stations on the lake, 3 points that can homogenously represent the water quality characteristics of the lake have been selected.

1st station: Western side of the lake (roadside).

2nd station: The entrance point of Brook Araba into the lake (northwestern side of the lake).

3rd station: Southwestern side of the lake (the deepest point).

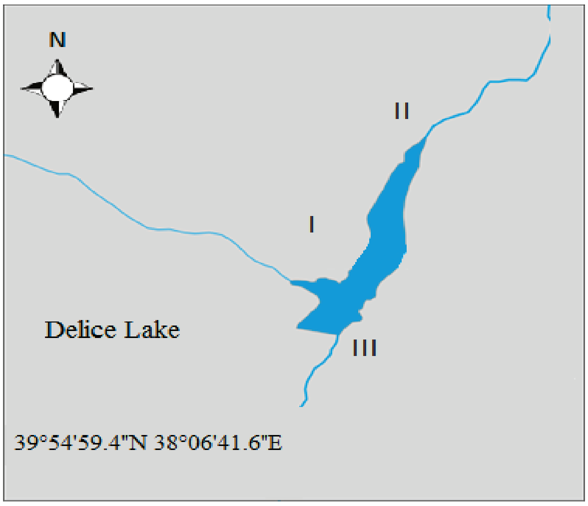

Figure 1. Location of the Lake Delice.

Water Analysis

In this study starting from April 2011, samples used in analyses of some chemical and physical parameters constituting the water quality have been monthly collected during 36 months from 3 stations. The sampling ended at March, 2014. The sampling tubes to be used in water sampling have been flushed and immersed into 15 cm below water surface for taking water sample.

The obtained water samples have been taken to the laboratory within maximum 4 hours for analysis. Temperature, pH, dissolved oxygen, and electrical conductivity parameters have been measured in-place via land-type measurement devices. Dissolved oxygen and temperature were measured via YSI brand 52 model oxygen-meter, pH measurement was conducted with Orion brand 420A model pH-meter, and the electrical conductance (NS/cm) were measured by using YSI brand 30/50 FT model conductance-meter.

Among other parameters determining water quality; total alkalinity, total hardness, ammonium nitrogen, nitrite, nitrate, phosphate, sulfite, sulfate chloride, sodium, potassium, suspended solid matter (SSM), chemical oxygen demand (COD), biological oxygen demand (BOD), calcium, magnesium, ferrous, lead, copper, zinc, nickel, mercury and cadmium analyses of water samples were conducted in Cumhuriyet University Hafik Kamer Örnek Vocational High School Laboratory in same day.

Titration with sulfuric acid (for total alkalinity) and titration with EDTA (for total hardness) were executed. The results were presented in mg/L $CaCO_3$ unit. Chemical oxygen level was calculated through titration with ferrous ammonium sulfate based on determination of amount of oxygen being used while lysing the natural and organic pollutant load by using powerful chemical oxidants. The level of biological oxygen was calculated via WTW brand Oxi Top BSB BOD DBO biological oxygen measurement device. The analyses of ammoniac, nitrite, nitrate, ammonium nitrogen (NH_4^+), phosphate, sulfate , sulfite, chloride, sodium, potassium, calcium, and magnesium were conducted with CECIL CE4003 spectrophotometer by using Merck photometric test kits according to standard methods for the Examination of Water and Wastewater (Anonymous

1998). The analyses of lead, copper, ferrous and cadmium, mercury, nickel, and zinc of water samples were conducted with ELMER ANALIST 800 Atomic Absorption Spectrometer from PERKIN ELMER in laboratory. The analysis of Suspended Solid Matter (SSM) was conducted by filtering the water through Whatman brand 42 Nr 0.45 NM membrane filters, and then keeping filter papers at 103°C for 24 hours and calculating the weight difference.

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

Results

The temperature values have shown non-significant variation between the years. While the minimum temperature has been observed in 2011 (3.8°C), the maximum temperature has been observed in 2013 (25.4°C). The annual mean temperature values were 14.03°C for 2011, 14.09°C for 2012 and 14.70 for 2013. These results indicate that no statistically significant change has been observed in temperature values.

The pH values shown in Figure 2 represent the acidic and basic character of the water. Given the pH values of the Lake Delice, it can be seen that the mean pH value during 3 years was 7.93 indicating that the lake was mildly basic. The annual mean pH values were 7.90 for 2011, 13.05 for 2012, and 10.80 for 2013. The differences between the annual mean pH values were statistically significant. The results indicate that the differences between the years were significant.

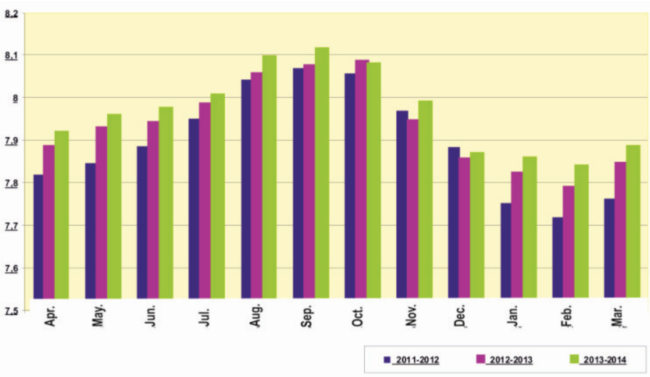

Figure 2. Monthly mean pH values

From the aspect of dissolved oxygen amount in Lake Delice, the differences observed were statistically significant. While the lowest dissolved oxygen amount observed was 9.10 mg/L in year 2012, the maximum value has been measured to be 12.44 mg/L in year 2011. The annual mean dissolved oxygen amounts measured on the lake were 11.41 mg/L for 2011, 11.10 mg/L for 2012, and 10.81 mg/L for year 2013.

The changes in electrical conductivity values of the lake were not statistically significant. While the minimum level of electrical conductivity has been measured to be 130.18 µs/cm in year 2011, the maximum electrical conductivity value has been measured to be 261.70 µs/cm in year 2012. The annual mean electrical conductivity values were 190.30 µs/cm for 2011, 193.83 µs/cm for 2012, and 194.98 for 2013. These results indicate that the mean electrical conductivity value of the lake has gradually increased during the period of 2010-2013.

The changes observed in suspended solid matter levels were statistically significant. As seen in Figure 3, the maximum value has been measured to be 8.04 mg/L in 2012, while the minimum level of suspended solid matter has been measured to be 2.94 mg/L in 2011. The annual mean values of suspended solid matter were 4.43 mg/L for 2011, 5.64 mg/L for 2012, and 5.51 mg/L for 2013.

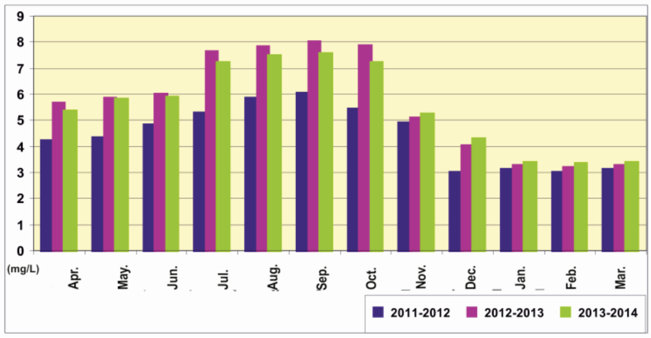

Figure 3. Monthly mean SSM values

The chemical oxygen demand values of the lake have shown statistically significant variation between the years. While the minimum level of chemical oxygen demand has been measured to be 0.80 mg/L in 2011, the maximum value of the chemical oxygen demand has been measured to be 2.58 mg/L in 2013. The annual mean chemical oxygen demand values were 1.32 mg/L for 2011, 1.51 mg/L for 2012, and 2.04 mg/L for 2013. These results indicate that, as seen in Figure 4, the level of chemical oxygen demand increased gradually.

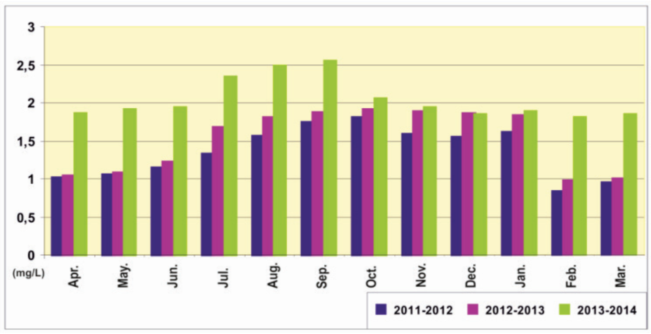

Figure 4. Monthly mean COD values

The biological oxygen demand values of the lake have shown statistically significant variation between the years. While the minimum level of biological oxygen demand has been observed to be 0.40 mg/L in 2011, the maximum value has been observed to be 0.99 mg/L in year 2012. The annual mean values of biological oxygen demand were 0.66 mg/L for 2011, 0.75 for 2012, and 0.80 for 2013. These results indicate that, as seen in Figure 5, the level of biological oxygen demand has shown constant increase during 3 years of study.

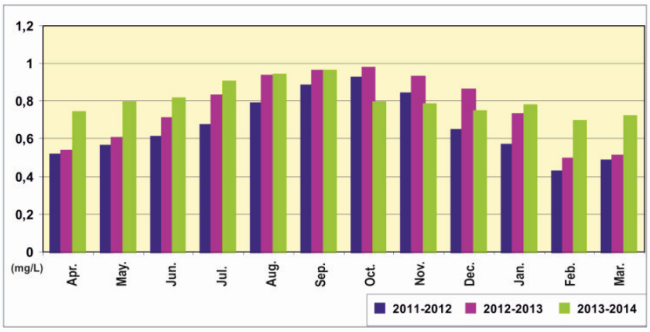

Figure 5. Monthly mean BOD values

The chloride levels of the lake have shown statistically non-significant variation between the years. While the minimum level of chloride has been found to be 5.42 mg/L in year 2011, the maximum value has been found to be 8.10 mg/L in year 2012. The annual mean levels of chloride have been found to be 6.96 mg/L for 2011, 6.89 for 2012, and 6.80 mg/L for 2013.

The phosphate levels of the lake have not shown statistically significant variation during 3 years of study. While the minimum phosphate value has been found to be 0.00 mg/L (under the measurable limits) in year 2011, the maximum value has been found to be 0.14 mg/L in 2011. The annual mean phosphate values have been found to be 0.30 mg/L in 2011, 0.19 mg/L in 2012, and 0.24 mg/L in 2013. These results indicate that the level of phosphate in the lake has shown a gradual increase.

The sulfate values measured on the lake have shown statistically non-significant variation between the years. While the minimum level of sulfate has been found to be 15.94 mg/L in 2011, the maximum value has been found to be 94.78 mg/L in 2011. The annual mean sulfate values have been found to be 47.08 mg/L in 2011, 39.28 mg/L in 2012, and 42.33 mg/L in 2013.

The changes in sulfite levels of the lake during the study period were not statistically significant. While the minimum level of sulfite has been found to be 2.07 mg/L in 2011, the maximum value has been found to be 5.16 mg/L in 2012. The annual mean sulfite values have been found to be 3.16 mg/L in 2011, 3.47 mg/L in 2012, and 3.48 mg/L in 2013. These results indicate that the annual mean sulfite values have increased during the study, even though the peak value of the sulfite has been observed in year 2012.

The changes observed in sodium concentrations of the lake have not been statistically significant. While the minimum level of sodium in the lake has been found to be 37.40 mg/L in 2012, the maximum sodium concentration has been found to be 54.40 mg/L in 2013. The annual mean sodium concentration values have been found to be 45.56 mg/L for 2011, 45.55 mg/L for 2012, and 46.58 mg/L for 2013.

The potassium values measured in the lake have shown non-significant variation between the years. While the minimum potassium concentration has been found to be 4.18 mg/L in 2012, the maximum potassium value has been found to be 8.12 mg/L in 2013. The annual mean potassium concentrations have been found to be 6.28 mg/L for 2011, 6.35 mg/L for 2012, and 6.46 for 2013. These results indicate the gradual increase in potassium concentration of the lake.

The variations in total hardness values of the lake have not been found to be statistically significant. While the minimum total hardness value has been found to be 237.42 mg/L $CaCO_3$, the maximum value has been found to be 309.14 mg/L $CaCO_3$ in 2011. The annual mean total hardness values of the lake have been found to be 279.38 mg/L $CaCO_3$ for 2011, 275.74 mg/L $CaCO_3$ for 2012, and 279.77 mg/L $CaCO_3$ for 2013.

The total alkalinity values of the lake have shown statistically non-significant variation between the years. While the minimum total alkalinity value has been found to be 252.92 mg/L $CaCO_3$ in 2011, the maximum value has been found to be 310.36 mg/L $CaCO_3$ in 2011. The annual mean total alkalinity values have been found to be 280.77 mg/L $CaCO_3$ for 2011, 276.07 mg/L $CaCO_3$ for 2012, and 280.20 mg/L $CaCO_3$ for 2013. These results indicate that the alkalinity of the lake didn't change significantly.

The magnesium concentration in the lake has not shown statistically significant variation during the study period. While the minimum magnesium concentration has been found to be 25.04 mg/L in 2011, the maximum value has been found to be 54.06 mg/L in 2011. The annual mean magnesium values have been found to be 37.99 mg/L for 2011, 39.14 mg/L for 2012, and 40.68 mg/L for 2013. These results indicate that the annual mean magnesium values have shown constant increase during the study despite the fact that minimum and maximum values have been observed in same year (2011).

The calcium concentration in the water has not shown significant variation between the years. While the maximum calcium concentration has been found to be 54.90 mg/L in 2011, the annual mean calcium concentration values have been found to be 38.35 mg/L for 2011, 38.77 mg/L for 2012, and 40.98 mg/L for 2013. These results indicate the constant increase in calcium concentration during the study period.

The variation in nitrite concentration determined in the lake has been shown to be statistically significant. While the minimum nitrite concentration has been found to be 0.00 mg/L (lower than the measurable limits) in 2011, the maximum level of nitrite has been found to be 0.01 mg/L in 2013. The annual mean nitrite concentration values have been found to be 0.0012 mg/L for 2011, 0.0013 mg/L for 2012, and 0.0021 for 2013. As seen in Figure 6, these results indicate the constant increase in the nitrite concentration during the study.

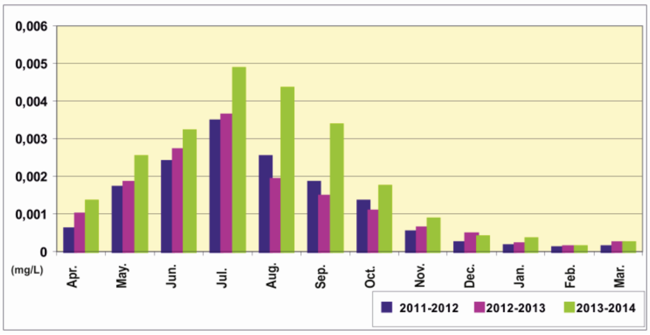

Figure 6.Monthly mean nitrite values

The variation of nitrate concentration in the water has been shown to be statistically significant. While the minimum nitrate concentration has been found to be 0.40 mg/L in 2012, the maximum concentration has been found to be 5.48 mg/L in 2012. As seen in Figure 7, the annual mean nitrate concentration values have been found to be 1.49 mg/L for 2011, 2.29 mg/L for 2012, and 2.18 mg/L for 2013.

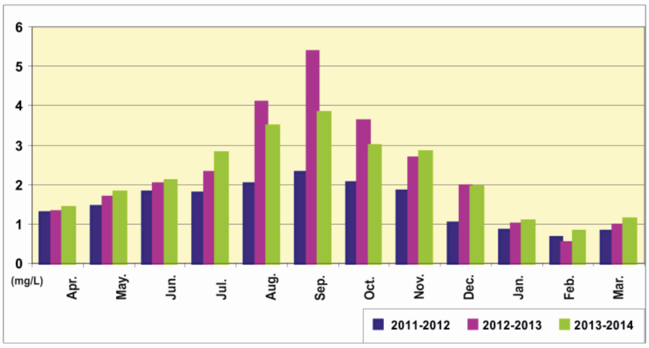

Figure 7. Monthly mean nitrate values

The ammonium nitrogen concentrations of the lake haven't varied statistically significantly. While the concentrations of ammonium nitrogen have been found to be lower than measurable limits for all the years, the annual mean ammonium nitrogen concentration values of the lake have been found to be 0.0008 mg/L for 2011, 0.0006 mg/L for 2012, and 0.0006 mg/L for 2013.

The concentrations of the ferrous have not varied statistically significantly during the study period. While the minimum concentrations of the ferrous during the study have been found to be lower than measurable limits, the maximum concentration value has been found to be 0.02 mg/L in 2011. The annual mean ferrous concentration values have been found to be 0.0041 mg/L for 2011, 0.0032 mg/L for 2012, and 0.0044 mg/L for 2013. As it can be seen, the level of ferrous concentration has stayed relatively stable.

The lead concentration of the water has varied statistically significantly during the study period. While the minimum lead concentration has been found to be 0.40 µg/L in 2012, the maximum lead concentration has been found to be 7.80 µg/L in 2012. The annual mean lead concentration values have been found to be 1.92 µg/L for 2011, 2.99 µg/L for 2012, and 3.16 µg/L for 2013. As seen in Figure 8, these values indicate the constant and significant increase in the concentration of the lead.

The copper concentration of the water has not varied statistically significantly. While the minimum copper concentration has been found to be 1.00 µg/L in 2011 and 2012, the maximum copper concentration has been found to be 20.00 µg/L in 2011 and 2013. The annual mean copper concentrations have been found to be 7.06 µg/L in 2011, 6.17 µg/L in 2012, and 8.19 µg/L in 2013.

The results of analyses have shown that the cadmium concentration in the water has changed statistically significantly. While the minimum cadmium concentration has been found to be 0.01 µg/L in 2011, the maximum concentration has been found to be 1.80 µg/L in 2013. The annual mean cadmium concentration values have been found to be 0.50 µg/L for 2011, 0.67 µg/L for 2012, and 0.90 µg/L for 2013. As shown in Figure 9, these results indicate the constant increase in cadmium concentration.

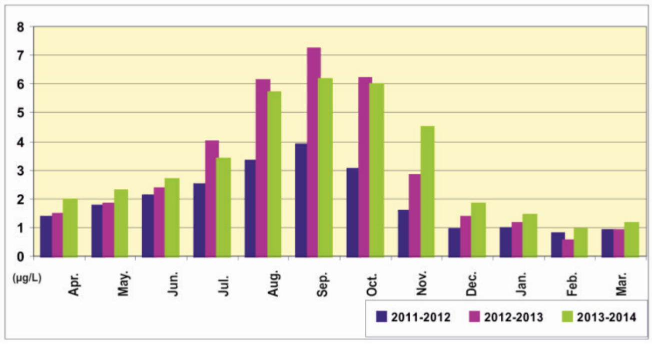

Figure 8. Monthly mean lead values

The variation in mercury concentration of the water has not been found to be statistically significant. While the minimum mercury concentration has been found to be lower than the measurable limits in all the years during the study, the highest mercury concentration has been found to be 0.01 µg/L in every year. The annual mean mercury concentration values have been found to be 0.0037 µg/L for 2011, 0.0034 µg/L for 2012, and 0.0042 µg/L for 2013.

The nickel concentrations in the water have not varied statistically significantly during the study. While the minimum nickel concentration in the water has been found to be lower than the measurable limits in 2011 and 2012, the maximum nickel concentration value has been found to be 18.00 µg/L in 2011. The annual mean nickel concentrations have been found to be 7 µg/L for 2011, 5.78 µg/L for 2012, and 7.89 µg/L for 2013.

The concentration of zinc, the last parameter, has not varied statistically significantly during the study. While the minimum zinc concentration has been found to be 9.00 µg/L in 2011, the maximum zinc concentration has been found to be 98.00 µg/L in 2013. The annual mean zinc concentration values have been found to be 51.81 µg/L for 2011, 52.44 µg/L for 2012, and 58.36 µg/L for 2013. These results indicate the constant increase in zinc concentration in the lake.

The seasonal mean, maximum and minimum values of water quality parameters investigated in Lake Delice during 3-year study period are given in Table 1.

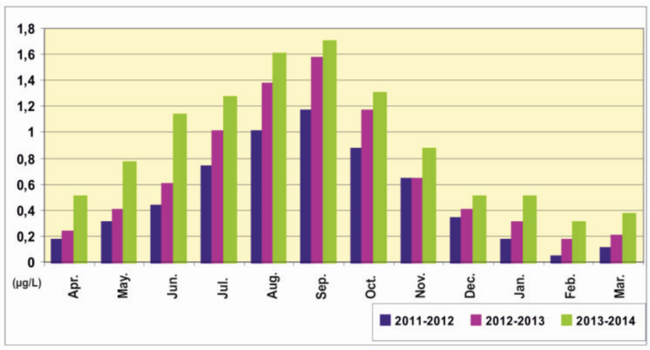

Figure 9. Monthly mean cadmium values

Table 1. Seasonal Values and Standard Deviation Values of Water Quality Parameters Investigated in Lake Delice

	Year											
	April 2011 - March 2012			April 2012 - March 2013			April 2013 - March 2014			Average		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Dissolved Oxygen (mg/L)	11.4	9.9	12.42	11.1	9.13	11.39	10.8	9.16	11.85	11.1	9.39	11.88
pH	7.89	7.72	8.07	7.93	7.79	8.08	7.96	7.84	8.11	7.92	7.783	8.08
Temperature (°C)	14	3.9	24.2	14.0	4	24.4	14.7	5.9	25.3	14.2	4.6	24.6
Electrical Conductivity (μs/cm)	190.3	130.82	244.9	193.82	134.33	259.62	194.97	141.66	245.06	193.03	135.60	249.86
Suspended Solid Matter (mg/L)	4.42	2.99	6.03	5.63	3.2	8	5.51	3.32	7.56	5.18	3.17	7.19
Chemical Oxygen Demand (mg/L)	1.34	0.82	1.8	1.51	0.97	1.91	2.03	1.81	2.54	1.62	1.2	2.08
Biological Oxygen Demand (mg/L)	0.65	0.42	0.92	0.75	0.49	0.97	0.8	0.69	0.96	0.73	0.53	0.95
Chloride (mg/L)	6.96	5.44	7.97	6.89	6.07	8.01	6.8	5.82	7.6	6.88	5.77	7.86
Phosphate (mg/L)	0.029	0.001	0.1266	0.0186	0.009	0.043	0.0238	0.0163	0.0493	0.0238	0.0087	0.0729
Sulfate (mg/L)	47.07	17	93.58	39.27	19.65	61.81	43.19	20.1044	74.47	43.17	18.91	76.62
Sulfite (mg/L)	3.15	2.21	4.01	3.47	2.36	5.1	3.47	2.4	4.74	3.36	2.32	4.61
Sodium (mg/L)	45.55	39.32	53.08	45.54	37.5	53.01	46.57	39.05	54.15	45.88	38.62	53.41
Potassium (mg/L)	6.28	4.48	7.84	6.35	4.46	7.98	6.76	6.22	8.06	6.46	5.05	7.96
Total Hardness (mg/L $CaCO_3$)	279.37	252.62	308.81	275.74	254.38	307.81	279.77	256.52	308.24	278.29	254.50	308.28
Total Alkalinity (mg/L $CaCO_3$)	280.76	253.27	309.79	276.07	253.64	308.02	280.19	257.04	308.8	279.01	254.65	308.87
Magnesium (mg/L)	37.98	25.07	54.02	39.13	26.17	52.86	40.68	31.1	52.96	39.26	27.44	53.28
Calcium (mg/L)	38.35	25.38	54.83	39.6	34.7	53.16	40.97	26.99	53.3	39.64	29.02	53.76
Nitrite (mg/L)	0.0012	0.0001	0.0034	0.0012	0.0001	0.0027	0	0.0001	0.0048	0.0008	0.0001	0.0036
Nitrate (mg/L)	1.4852	0.65	2.3	2.29	0.53	5.36	2.18	0.8	3.83	1.98	0.66	3.83
Ammonium Nitrogen (mg/L)	0.0007	0	0.0022	0.0005	0.0001	0.0016	0.0006	0.0001	0.0015	0.0006	6.6666	0.0017
Ferrous (mg/L)	0.004	0	0.0133	0.0031	0.001	0.0083	0.0043	0.001	0.0113	0.0038	0.0006	0.0109
Lead (μg/L)	1.9211	0.78	3.86	2.98	0.9	7.23	3.15	0.9333	5.9666	2.6837	0.8711	5.6855
Copper (μg/L)	7.0555	1.33	18.33	6.16	2	12.33	8.19	3.02	17.66	7.1351	2.1166	16.1066
Cadmium (μg/L)	0.495	0.04	1.16	0.66	0.16	1.56	0.9	0.3	1.7	0.685	0.1666	1.4733
Mercury (μg/L)	0.0037	0	0.008	0.0034	0.001	0.007	0.004	0.0013	0.0086	0.0037	0.0007	0.0078
Nickel (μg/L)	7.0555	0	16.66	5.77	0.33	13	7.88	1.33	15.66	6.9018	0.5533	15.1066
Zinc (μg/L)	51.8055	10.33	79	52.44	17	80.66	58.36	22.33	94.66	54.2018	16.5533	84.7733

Discussion

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 Delice shows inland water characteristic. The temperature differences measured in 3 stations during one year were not at the level affecting the aquatic life in the lake negatively. According to the Water Pollution Control Regulations (WPCR), the water of lake is first class (the temperature value exceeds the value of 25°C in 3rd year, but the average of three years of study is 24.8°C).

pH is one of the most important factors indicating the chemical and biological properties of the natural waters. pH is capable of separating the weak acid and bases. This separation affects the toxicity of many compounds (Atay and Pulatsü 2000). In order for a pH value of any aquatic medium to not jeopardize the aquatic life and in order for a water resource to be suitable for aquaculture, it should not pass the limit of 6.5 – 8.5 (Kara and Çöylekçioğlu 2004). The mean value of water samples taken monthly from Lake Delice during three years has been found to be 8.11, while the highest value has been found to be 8.13. According to these results, the lake has mildly basic character, and is first class in accordance with WPCR in terms of pH value, and suitable for aquaculture.

One of the other factors affecting the development of a balanced fauna is the dissolved oxygen (DO) concentration. As well as the dissolved oxygen is a compound necessary for aquatic life, it is also necessary for biochemical oxidations. In sweet waters, there should be at least 5 mg/L dissolved oxygen for aquatic life (Atay and Pulatsü 2000). The lowest DO value measured in this study has been found to be 9.10 mg/L, so the water of Lake Delice is suitable for aquaculture in terms of DO concentration, and it is in Class I in accordance with WPCR.

Chemical Oxygen Demand (COD) is another very important parameter used in determining the pollution level of waters and waste waters (Mutlu et al. 2013c). The concentration of chemical oxygen demand in waters more than 25 mg/L indicates the pollution, while the values more than 50 mg/L indicates severe pollution and possible toxicity for aquatic animals (Güler 1997). The highest COD value measured in Lake Delice has been found to be 2.58 mg/L in year 2003. According to the WPCR and the rule that the worst value determines the class, the Lake Delice is Class I in terms of COD parameter.

Biological Oxygen Demand (BOD) identifies the amount of oxygen needed by microorganisms for dissolving the organic matters in an aquatic environment under aerobic conditions. It is the parameter that is used for determining the environment's pollution potential and the receiver environment's assimilation capacity by calculating the amount of dissolved oxygen that they consume while being released into the receiving mediums (Anonymous 2013). The highest BOD value in the lake has been found to be 0.99 mg/L, and it is Class I according to WPCR in terms of BOD.

Electrical conductivity (EC) is very important for aquatic products, and the conductivity passes beyond the level of 100 µs/cm as the pollution increases (Verep et al. 2005). The electrical conductivity values have decreased in winter months, and increased in months when the water temperature and inorganic salts in the system increased. The highest electrical conductivity value measured in the lake has been found to be 245.48 µs/cm in year 2011, and it is Class I according to WPCR in terms of electrical conductivity.

Suspended Solid Matter (SSM) amount consists of inorganic matters such as clay and loam. The maximum acceptable level of SSM in aquaculture has been specified as 10 mg/L (Ntengue 2006). The highest SSM amount determined in Lake Delice during 3 years of the study has been found to be 8.04 mg/L year 2013, and it means that the conditions in the lake is suitable for aquaculture activities.

The sources of the nitrogen mixing into surface waters can be originated from natural domestic and agricultural resources (Mutlu et al. 2013a). The nitrite (NO_2) sources in waters are the organic matters, nitrogenous fertilizers, and some of minerals. The nitrite concentration in waters higher than 1 mg/L indicates pollution (Taş 2011). While the concentration of NO_2 in natural waters is low, it is high in waters where the organic pollution is high (İmamoğlu 2000). Nitrogen derivatives of nitrite (NO_2), nitrate (NO_3) and ammonium nitrogen (NH_4) have significant roles in water pollution, and they also have significant effects on the level of dissolved oxygen and eutrophication. The maximum level of nitrite in the lake has been found to be 0.01 mg/L, while the level of ammonium nitrogen has stayed below the measurable limits during 3 years of study. According to the WPCR, the lake shows Class II and I water characteristic in terms of nitrite (NO_2) and ammonium nitrogen, respectively.

Nitrate (NO_3) is the final product of nitrogenous organic matters. High concentration of nitrate in surface waters indicates that the water has been polluted before by the industrial and domestic wastewaters containing ammonium and organic nitrogen and the fertilizers used in agricultural lands and containing nitrate (Topal and Arslan 2012). Although the low doses of nitrate are not toxic for fish, it has been reported that fish mortality starts at the doses of 4 mg/L and higher (Acu 2000). Its concentration within surface waters is an indicator of the pollution of those waters caused by domestic and industrial waste waters containing ammonium and organic azote and the nitrogenous fertilizers used in agricultural lands (Topal and Arslan 2012). The highest amount of nitrate in the lake has been found to be 5.48 mg/L which is not at hazardous level. According to the WPCR, the lake shows Class II water in terms of nitrate (NO_3).

The total alkalinity and total hardness values in lime soils are generally close to each other (Boyd and Tucker 1998). The alkalinity values of the natural waters vary between 5 and 500 mg/L, and are closely related with the structure of the lake. The carbonate and bicarbonate provide the water with alkalinity (Tepe et al. 2006). The mean alkalinity value of the lake has been measured to be 279.01 mg/L $CaCO_3$, while the mean hardness value has been calculated to be 278.30 mg/L $CaCO_3$. According to these results, the lake shows mildly hard water characteristics.

Among natural anions of the water, the presence of the sulfate (SO_4) in natural resources is important for improved biological productivity (Taş et al. 2010). The highest limit for sulfate in water from the aspect of aquatic products has been determined as 90 mg/L (Küçük 2007). The mean sulfate value of the lake has been found to be 42.90 mg/L, while the highest value has been observed in 2011 as 94.78 mg/L.

Chloride ions are important indicators of the healthy water. The highest chloride amount in the lake has been found to be 8.10 mg/L. These values are suitable for aquaculture.

The phosphorus found in water resources is the basic element of eutrophication (Harper 1992). The reason of increase seen in phosphorus level of the lake in October and November is possibly caused from phosphate-containing fertilizers used in lands, because the wheat farming is very common around the lake and throughout Hafik district. Besides that, an increase has been seen in amount of algae being capable of binding the phosphor in the air. The highest level of phosphate in the lake has been calculated to be 0.14 mg/L, and this result indicates that there is no threat in terms of aquaculture and aquatic life.

Ca^{++} and Mg^{++} are the most important dissolved solid matters in water (Mutlu et al. 2013b). Mg and Ca^{++} are alkali soil minerals, and are among the ions existing in fresh waters at most. The highest recommended Ca^{++} level is 75 mg/L (Taş 2006). In our study, the highest calcium (Ca^{+}) level has been found to be 54.90 mg/L. Under the light of these findings, it has been observed that the amount of Ca^{++} in Lake Delice is within the acceptable limits.

The concentration of magnesium in normal waters should be between 5 mg/L and 60 mg/L. In mildly hard waters, the values between 60 and 100 mg/L can be accepted as typical, and the recommended concentration of Mg^{++} is 50 mg/L (Taş 2006). In our study performed in Lake Delice, the highest value found is 54.90 mg/L, which could be accepted as typical.

Potassium (K) exists in natural waters in concentration of 1-10 mg/L, while sodium's concentration varies between 2 and 100 mg/L (Boyd 1998). In our study at Lake Delice, the highest potassium concentration has been found to be 8.12 mg/L could be accepted to be within the normal ranges. The highest level of sodium concentration has been found to be 54.40 mg/L, while the lowest amount has been determined to be 37.40 mg/L. Under the light of these results, it has been determined that the sodium and potassium concentrations in the lake have been found to be within the acceptable limits.

The heavy metal elements investigated in our study were the lead (Pb), copper (Cu), cadmium (Cd), ferrous (Fe), cadmium (Cd), Mercury (Hg), Nickel (Ni) and Zinc (Zn) elements.

The presence of lead (Pb) in waters at the concentration of 0.01 mg/L and higher is accepted as an indicator of pollution. It has been determined that the lead affects the osmotic balance and ion arrangement in fish and leads to histopathologic change in liver (Atay and Pulatsü 2000). Although the presence of cadmium (Cd) in waters at the concentration of 5 µg/L and higher is toxic and it directly leads to mortality in aquatic organisms at high concentrations, it leads to metabolic and physiologic disorders and changes especially in fish (Mutlu 2013). The mean concentrations of lead (Pb) and cadmium (Cd) during the study have been found to be 2.69 µg/L and 0.69 µg/L, respectively. The reason of this this level of cadmium concentration in the lake can be attributed to the artificial phosphate fertilizers used for the agricultural activities around the lake. Under the lights of those values, it has been determined that the lake shows Class I water characteristic in terms of lead (Pb) and cadmium (Cd) elements according to WPCR.

The concentration of the copper (Cu) element during the study has been found to be 7.14 µg/L, while the highest concentration has been found to be 20 µg/L. The reason of this increase is thought to be caused from the penetration of copper, which has been accumulated in the soil due to dense usage of copper vitriol during maintenance and pruning processes in fruit gardens in spring season, into the lake waters through rain. According to the WPCR, the lake shows Class I water characteristic in terms of copper (CU).

The highest concentration of ferrous (Fe) in the lake has been found to be 0.02 mg/L in year 2011. The concentrations of ferrous have peaked during summer season due to wide wheat planting around the lake. Since the use of ferrous-containing agricultural pesticides in order to increase the grain productivity of wheat plants increases especially between May and June, the ferrous-containing waters and particles may leak into the lake through rain and leakages.

The mean concentrations of Zinc (Zn), nickel (Ni) and mercury (Hg) during the study have been found to be 54.20 µg/L, 6.89 µg/L, and 0.004 µg/L, respectively. This level of mercury concentration in the lake may be caused by flows from cultivation areas into the lake, since the use of fertilizers is very common in Hafik district. The level of concentration of zinc is caused by the incineration of wastes of mining and coal mining industries and the processes of iron and steel industry. It is used as oxide stain material in plastics, cosmetics, copy and wall papers, printer inks, ceramics, rubber industry, and fertilizers. Under the lights of these values, it has been determined that the lake shows Class I water characteristic in terms of Zinc (Zn), nickel (Ni) and mercury (Hg) according to WPCR.

It is known that the heavy metals constitute an important pollutant group, and they incline to accumulate within the bodies of living organisms, as well as they have significant toxic and carcinogenic effects. Heavy metals having strong poisonous effects even at very low concentrations may inhibit the self-cleaning process of natural waters, and they also affect water sources' usability in irrigation and aquaculture negatively.

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