

## Full Length Research Paper

# The accumulation of heavy metals (Cd, Pb, Hg, Cr) and their state in phytoplanktonic algae and zooplanktonic organisms in Beysehir Lake and Mogan Lake, Turkey

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Beysehir and Mogan Lakes are two shallow Lakes that are under environmental protection status. Phytoplanktonic dominant algae determined in Beysehir Lake were *Oscillatoria* sp., *Cladophora* sp., *Achnanthes* sp., *Gomphonema* sp., *Navicula* sp., *Cosmarium* sp., *Cymbella* sp., *Fragilaria* sp., *Oocystis* sp., *Spirogyra* sp., *Diatomae* sp., *Microcystis* sp. and *Staurostrum* sp. While in Mogan Lake, *Spirogyra* sp., *Zygnema* sp., *Euglena* sp., *Achnanthes* sp., *Cymbella* sp., *Fragilaria* sp., *Navicula* sp., *Scenedesmus* sp., *Oocystis* sp., *Synedra* sp., *Oscillatoria* sp., *Chlorella* sp., *Cosmarium* sp. and *Nitzshia* sp. were determined. Zooplanktonic dominant organisms determined in Beysehir Lake were *Eudiaptomus drieshi*, *Daphnia longispina* and *Brachionus calyciflorus* while *Arctodiaptomus* sp., *Keratella quadrata*, *Filinia longisetata* and *Diaphanosoma lacustris* were determined in Mogan Lake. Accumulation of heavy metals (Cd, Pb, Hg and Cr) in the water and plankton of Beysehir and Mogan Lakes was studied seasonally, from April 2000 to December 2004. Higher concentration with all heavy metals was recorded in plankton. Mercury (Hg) was found in lowest and lead (Pb) in the highest correlation; however, the concentration of each metal varied seasonally. In addition, the seasonal changes in phytoplankton and zooplankton populations and species abundance were also determined. Some physical-chemical parameters of water and their correlation with heavy metals were also examined.

**Keywords:** Accumulation, algae, Beysehir Lake, heavy metals, Mogan Lake, water pollution, zooplankton.

## INTRODUCTION

Lake ecosystems are increasingly affected by various anthropogenic impacts, like the excess of nutrients causing eutrophication, toxic contamination of industrial, agricultural and domestic origin, heat pollution reaching the Lakes through their catchment area and the atmosphere. Typical results of the human activities proved to be elevated levels of heavy metals present in fresh water and among these microelements lead (Pb), cadmium (Cd), mercury (Hg), chrome (Cr) are most specific (Farkas et al., 2001). They are considered to be one of the most important pollutants of the aquatic ecosystems

due to their environmental persistence and tendency to be concentrated in aquatic organisms (Veena et al., 1997). In addition, heavy metals show harmful effects even at very low concentration on the aquatic organisms including plankton, aquatic plants invertebrates and vertebrates (Schuurman and Markert, 1998). The study was conducted to determine the accumulation of heavy metals in water and plankton (phyto and zoo) of Beysehir and Mogan Lake.

Beysehir and Mogan Lakes are two shallow Lakes, interconnected hydrologically in the close vicinity of Ankara, Turkey. Watershed is under environmental protection status. Potential impacts from extensive agriculture, recreation, incomplete infrastructure and other human activities, such as residential settlements, are discussed with reference to previous and more recent

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pollution monitoring. The aggravation of the pollution state of the Lakes is attributed to the construction of a sewage system going around Beysehir and Mogan Lakes and collecting wastewater discharges and restrictions to urban settlement development around the Lakes. The study, while addressing water quality and interactions due to human activities in shallow Lakes, also discusses problems associated with human impacts in protected areas with the aim of presenting a complicated case study.

## MATERIALS AND METHODS

The water and plankton samples were collected twice a month from selected stations of the Lake and transferred to the laboratory for heavy metal analysis. The phytoplankton samples were collected by Nansen water collecting apparatus and zooplankton by plankton net (25 cm diameter and 55  $\mu$  mesh size) by horizontal and vertical hauls at each station. Besides the plankton sampling for heavy metal determination, the additional samples of algae and zooplankton were collected from the same stations for species identification to assess seasonal distributions.

The samples collected for plankton analyzed were filtered through ashless filter paper while concentrated planktons were left in laboratory for a period of time for evaporation of water. Age-weight was determined following Toker (1998). Materials were then dried in oven at 90°C for 24 h and the dry weights were noted. The materials were then kept at 550°C for 4 h and then cooled. Digestion was carried out at 80°C by adding 20 ml of 1.5 N HCl, filtered into 100 ml test tubes. 100 ml distilled water was added and samples were analyzed with a Hitachi Z 8200 polarized Zeeman AAS (Atomic Absorption Spectrophotometer) at the Ankara University Research Center (Kelly and Whitten, 1989). The identification of each species of the plankton was conducted according to Kolisko (1974), Koste (1978), Edmondson (1959), Round (1973), Pestalozzi (1982), Gerrath and Denny (1979), Oskar and Mariela (1978) and Van Den Hook et al. (1995).

### Sampling site and date

The Beysehir Lake is located at the east of Western Toros, 75 km from the city of Konya (37° 45' North, 31° 30' East). It is tectonic/jips in origin and is the 3<sup>rd</sup> largest freshwater Lake of the country. It has 1121 m altitude and 656 km<sup>2</sup> surface area. The Lake is mainly own fed from its care, however, Deli and Bademli streams support it (Figure 1).

The water of the Lake is processed by chlorine and is used for drinking and other purposes. Due to lack of industry in the surrounding area, the Lake is clean, beautiful and an important tourist point. In this Lake, four fish species (*Leuciscus cephalus*, *Cyprinus carpio*, *Tinca tinca*, *Lucioperca lucioperca*) are present and it is an important visiting site for several bird species.

Lake Mogan (30° 47' North, 32° 47' East) is a shallow (mean depth 2.5 m, maximum depth 3.5 m, 5.4 - 6 km<sup>2</sup>) eutrophic Lake with a total of 925 km<sup>2</sup> drainage area situated 20 km south of Ankara (Figure 2). The Lake is mainly fed by four main flows namely Sukesen brook in the north, Colovasi brook in the east, Golcuk and Yavrucak brooks in the west. These brooks first run through agricultural lands and then through before reaching the Lake. The outflow of the Lake empties into downstream Lake Eymir. In 1990, Lake Mogan was given the status of "Specially Protection Area" by the Ministry of Environment (Burnak and Beklioglu, 2000). The study was conducted between April 2000 and December 2004 to examine the accumulation of heavy metals in water and plankton of the Beysehir and Mogan Lake.

## RESULTS AND DISCUSSION

The physico-chemical parameters determined in the Beysehir Lake are summarized in Table 1. The temperature varied between 3.0 - 25.5°C; the pH between 7.8-8.2; the dissolved oxygen (DO) between 8.0-11.8 mg/l; the electrical conductivity (EC) 2.1-2.4  $\mu$ S/cm and the secchi depth between 138 - 175 cm.

A total of 88 phytoplankton genera were collected from Beysehir Lake (Table 2) and 45 identified belong to Bacillariophyta, 21 to Chlorophyta, 13 to Cyanophyta, 4 to Euglenophyta, 3 to Dinophyta, 2 to Chrysophyta division. Dominant genera of the Beysehir Lake were *Oscillatoria* sp., *Cladophora* sp., *Achnanthes* sp., *Gomphonema* sp., *Navicula* sp. in spring; *Oscillatoria* sp., *Cosmarium* sp., *Cymbella* sp., *Fragilaria* sp., *Oocystis* sp. in summer; *Oscillatoria* sp., *Spirogyra* sp., *Diatomae* sp., *Fragilaria* sp., *Navicula* sp. in autumn; *Microcystis* sp., *Cladophora* sp., *Staurastrum* sp., *Fragilaria* sp., *Diatomae* sp., *Cymbella* sp. in winter. Among zooplankton fauna, a total of 28 species (Table 3) (20 Rotifera, 8 Cladocera and 2 Copepoda) were identified in Beysehir Lake. *Eudiaptomus drieshi* which belongs to the dominant group Copepoda was observed in all seasons throughout the year. *Daphnia longispina* (Cladocera) was found abundant in spring and winter. *Brachionus calyciflorus* (Rotifera) was found in summer. In water sample from Lake Beysehir, the accumulation order of heavy metals was found as Pb > Cd > Cr > Hg in spring; Pb > Cd > Cr > Hg in summer; Pb > Cd > Cr > Hg in autumn and Pb > Cr > Cd > Hg in winter. The heavy metals accumulation in plankton samples from Beysehir Lake were as Pb > Cr > Cd > Hg in spring; Pb > Cd > Cr > Hg in summer; Pb > Cd > Cr > Hg in autumn; Pb > Cd > Cr > Hg in winter (Table 4).

The physico-chemical parameters determined in the Mogan Lake is summarized in Table 5. The temperature varied between 3.0 - 20.4°C; the pH between 8.8-9.0; the dissolved oxygen between 8.2 - 11.5 mg/l; the EC 2100 - 2400  $\mu$ S/cm and the secchi depth between 85.0-207 cm.

A total of 81 phytoplankton genera were collected from Mogan Lake (Table 6) and identified 39 belong to Bacillariophyta, 23 to Chlorophyta, 11 to Cyanophyta, 4 to Euglenophyta and two each to Dinophyta and Chrysophyta division.

Dominant genera of the Mogan Lake were *Spirogyra* sp., *Zygnema* sp., *Euglena* sp., *Cymbella* sp., *Fragilaria* sp. and *Navicula* sp. in spring; *Scenedesmus* sp., *Oocystis* sp., *Cymbella* sp., *Fragilaria* sp. and *Synedra* sp. in summer; *Oscillatoria* sp., *Chlorella* sp., *Cosmarium* sp., *Cymbella* sp. and *Nitzshia* sp. in autumn; *Oocystis* sp., *Synedra* sp., *Navicula* sp. and *Cymbella* sp. in winter. A total of 65 taxa of zooplankton (54 Rotifera, 9 Cladocera and 2 Copepoda) were identified. The dominant group of the Mogan Lake (Table 7) was Rotifera. Dominant species of Mogan Lake *Arctodiaptomus* sp. (Copepoda) was observed in all seasons throughout the year and was found abundant in summer. Among rotifera species in



Figure 1. The location and sampling station of the Beyşehir Lake.

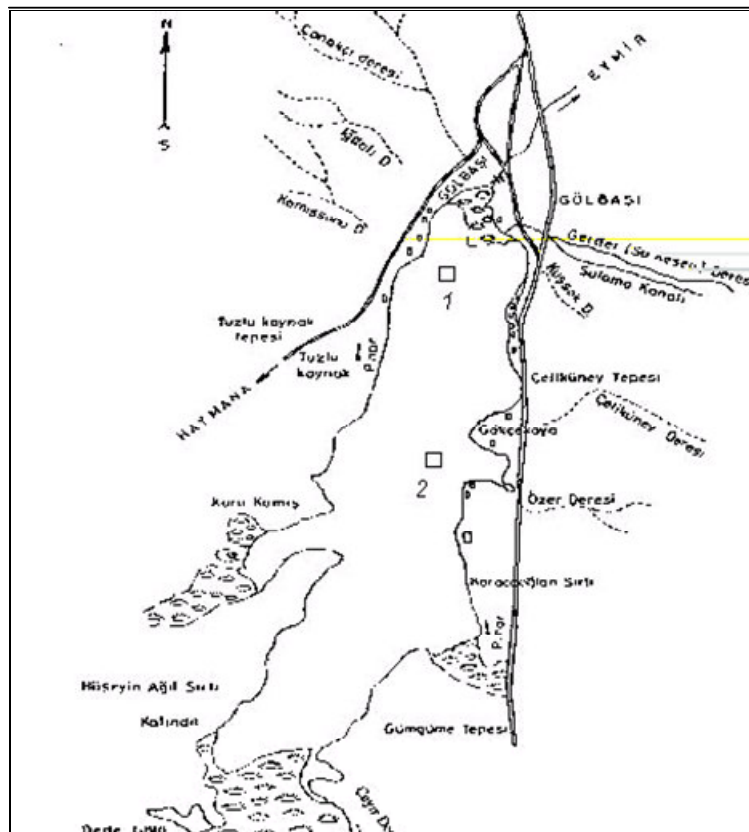


Figure 2. Map of Mogan Lake and the sampling stations used in this study.

**Table 1.** Some features of Beysehir Lake water.

Parameters	Spring	Summer	Autumn	Winter
Temperature (°C)	12.0	25.5	3.0	5.5
pH	7.8	8.2	8.0	8.1
Dissolved O <sub>2</sub> (mg/l)	8.0	8.4	11.8	10.8
EC <sub>25</sub> <sup>o</sup> (µs/cm)	0.34	0.3	0.3	0.4
Secchi Disc (cm)	138	160	142	175

*Keratella quadrata* (summer) and *Filinia longiseta* in autumn and *Diaphanosoma lacustris* (Cladocera) in summer were identified samples in water.

The accumulation order of heavy metals in water samples was found as Pb > Cr > Cd > Hg in spring; Pb > Cd > Cr > Hg in summer; Pb > Cr > Cd > Hg in autumn and Pb > Cd > Cr > Hg in winter. The highest rate was recorded for Pb (0.307 mg/l) and the lowest for Hg (0.001 mg/l). The heavy metals accumulations in plankton samples were as Pb > Cr > Cd > Hg in spring; Pb > Cd > Cr > Hg in summer; Pb > Cd > Cr > Hg in autumn and Pb > Cr > Cd > Hg in winter (Table 8).

The physico-chemical parameters and secchi depth values of Beysehir Lake were found to be normal. The pH and EC values in Mogan Lake were found to be higher than the normal. Hellowell (1988) and Avila et al. (1999) reported that heavy metals toxicity is affected by temperature, DO concentrations and pH and an increase in pH generally decreases the solubility of many toxic heavy metals. In Mogan Lake, DO was found to be normal and secchi depth values were found to be lower than that in the oligotrophic Lake.

In both Lakes, high accumulation of heavy metals was observed in plankton when compared with water. The average Pb concentrations in Lake Beysehir and Mogan water samples were 0.191 and 0.257 mg/l, respectively and Cd concentrations were 0.090 and 0.074 mg/l which are both very high when compared to the concentrations allowed for irrigation water. The Hg concentrations were found to be 0.005 and 0.027 mg/l, respectively. According to the quality criteria of both within state and inter-continental waters for Pb, Cd, and Hg, the water of the Lake falls in the 4<sup>th</sup> class of polluted waters (1997). In both Lakes, the Cr concentrations (0.072 and 0.058 mg/l) in water samples were found to be much lower than the maximum recommended levels (5 - 20 µg/l). On the basis of Cr concentrations, the water of the Lakes falls in the 2<sup>nd</sup> class of polluted water criteria.

The bioaccumulation of heavy metals in plankton depends on many factors, such as absorptive ability of individual species and season (Radwan et al., 1990). In plankton collected from Beysehir and Mogan Lake, the average accumulations order was found as Pb > Cr > Cd > Hg and Pb > Cd > Cr > Hg, respectively. According to Marshal and Mellinger (1980) Cd affects photosynthesis and reduces the primary productivity of phytoplankton. Even at 0.2 and 5 mg/l, it affects the community structure

of zooplankton. Apart from this, Koivisto et al. (1992) reported that 0.32 and 2 mg/l Cr affect the growth and chlorophyll structure of *Euglenoida* sp. and *Chlorella pryrenoidasa*, respectively. Nilsson (1978) stated that eutrophic Lakes generally lead to a loss of biodiversity and the numbers of certain species increase. In this connection, rotifer species were found to be dominant in the Lake and reported as characteristic species of eutrophic waters. The term bio-monitor means the geographic distribution of metals and their assessment and control by organisms of that area by metal analyzed (Ward, 1987). Toxic effects of Cd on algae, *Asterionella formasa* (Diatoms) has been reported by Conway (1978). Conway found that 2 mg/l Cd limited the growth of algae at population level and 10 mg/l Cd inhibited the growth at population level in a one day exposure. The toxic effects of Cr on algae have been reported by Mangi et al. (1978). Hg accumulates in algae and in other aquatic plants at primary levels of food chain and therefore appears in lowest concentration in surroundings. According to Nakanishi et al. (2004), *Achnanthes minutissima* (Diatoms) has a tolerance to copper ion and the 2<sup>nd</sup> grade taxon was *Surirella angustata*. Based on this result, it turned out that there was a good correlation between the relative abundance of *A. minutissima* and the concentrations of heavy-metals in aquatic areas. In both Lakes, *Achnanthes* sp. was a widely and abundant diatom. Hg accumulation was fast; however, elimination was slow. Among crustaceans, *Daphnia magna* have been reported more susceptible to Hg. In soft water (45 mg/l CaCO<sub>3</sub>) 5 mg/l Hg cause deaths and 3 - 4 mg/l Hg cause 16% harmful effects on *Daphnia manga* population in 48 h exposure (Besinger and Christensen, 1972).

Chen et al. (2000) found out that the highest concentrations may be of Pb in eutrophic Lakes, but also in agricultural areas. In addition, the Pb concentration may be raised by road traffic and exhaust-gasses and also by other means. In this study, the highest concentration was recorded for Pb. Chen et al. (2000) also suggested that the highest concentration of Cd in a Lake may be attributed to land use variables and the high percentages of agricultural land.

In conclusion, the heavy metal concentration in the water and plankton in Beysehir and Mogan Lake were found to be higher than the values recommended by WHO for irrigation waters (Uslu and Turkman, 1997). According to inland water pollution, Beysehir Lake is

**Table 2.** The recording list of phytoplanktonic organisms in Beysehir Lake.

<b>CYANOPHYTA, CYANOPHYCEAE, Choroococcales</b>	<b>Spring</b>	<b>Summer</b>	<b>Autumn</b>	<b>Winter</b>
<i>Chroococcus limneticus</i> Lemmermann	-	+	+	+
<i>Chroococcus turgidus</i> (Kutzing) Nageli	+	-	-	-
<i>Merismopedia elegans</i> A. Braun in Kutzing	+	+	-	+
<i>Merismopedia glauca</i> (Ehrenberg) Nageli	-	+	-	+
<i>Microcystis floss-aquae</i> (Wittrock) Kirchner	-	+	-	+
<i>Synechococcus aeruginosus</i> Nageli	+	+	+	+
<b>Oscillatoriales</b>				
<i>Aphanothece castagnei</i> (Brebissoni) Rabenhorst	+	-	-	+
<i>Aphanothece gardneri</i> de Toni	+	+	-	+
<i>Aphanothece microscopica</i> Nageli	+	-	-	-
<i>Lyngbya diguettii</i> Gomont in Hariot	+	-	-	+
<i>Oscillatoria formosa</i> (Boryanum) Gomont	+	+	-	-
<i>Oscillatoria granulata</i> Gardner	-	+	-	+
<i>Oscillatoria princeps</i> (Vaucher) Gomont	-	+	-	+
<i>Oscillatoria tenius</i> (C. Agardh) Gomont	+	-	+	-
<i>Spirulina subsalsa</i> (Oersted) Gomont	-	+	-	+
<i>Spirulina platensis</i> (Nordstedt) Gomont	+	-	-	+
<i>Tricodesmium lacustre</i> Klebahn	-	+	-	-
<b>Nostocales</b>				
<i>Anabaena cylindrica</i> Lemmermann	+	+	-	+
<i>Anabaena minutissima</i> Lemmermann	+	+	-	+
<i>Anabaenopsis luzonensis</i> R. Taylor	-	+	-	+
<i>Aphanizemnon gracile</i> Lemmermann	+	-	+	-
<i>Calothrix fusca</i> (Kutzing) Bornet et Flahault	-	-	+	-
<i>Dichothrix gypsophila</i> (Kutzing) Bornet et Flahault	+	-	-	+
<i>Plectonema notatum</i> Schmidle	+	-	+	+
<b>PYRROPHYTA, Peridinales</b>				
<i>Ceratium hirundinella</i> (O. F. Muller) Dujardin	+	+	+	-
<i>Peridinium cinctum</i> (O. F. Muller) Ehrenberg	+	+	+	-
<b>EUGLENOPHYTA, EUGLENOPHYCEAE, Euglenales</b>				
<i>Astasia variabilis</i> Skvortzov	-	+	+	-
<i>Euglena gracilis</i> G. A. Klebs	+	+	-	-
<i>Euglena polymorpha</i> P. A. Dangeard	+	+	+	-
<i>Lepocinclis playfairiana</i> Deflandre	+	-	+	-
<i>Trachelomonas pulchella</i> Drezepolski	+	+	+	-
<b>CHRYSOPHYTA, CHRYSOPHYCEAE, Chrysomonadales</b>				
<i>Chlorobotrys gloeotheca</i> Pascher	-	+	-	+
<i>Chloropedia plana</i> Pascher	-	+	-	-
<i>Dinobryon sertularia</i> Ehrenberg	+	+	+	-
<b>CHLOROPHYTA, CHLOROPHYCEAE, Chlorococcales</b>				
<i>Botryococcus braunii</i> Kutzing	+	+	+	-
<i>Chlorella vulgaris</i> Beijerinck	+	+	-	-
<i>Coelastrum microporum</i> Nageli in A. Braun	-	+	-	-
<i>Coenococcus polycooccus</i> (Korschikov) Hindak	-	+	+	-
<i>Nephroctium agardhianum</i> Naegeli	+	+	+	-
<i>Oocystis borgei</i> J. Snow	-	+	-	+
<i>Pediastrum boryanum</i> (Turpin) Meneghini	+	+	+	+
<i>Scenedesmus arcuatus</i> (Lemmermann) Lemmermann	+	+	+	+
<i>Scenedesmus communis</i> E. H. Hegewald	+	-	-	+
<i>Scenedesmus obliquus</i> (Turpin) Kutzing	-	+	+	-
<i>Tetrastrum komarekei</i> Hindak	+	+	+	+

Table 2. contd.

<b>Chaetophorales</b>				
<i>Stichococcus subtilis</i> (Kutzing) Klercker	+	-	-	+
<i>Stigeoclonium lubricum</i> (Dillwyn) Kutzing	-	-	+	-
<i>Stigeoclonium nanum</i> (Dillwyn) Kutzing	+	+	-	-
<b>ZYGNEMAPYCEAE, Desmidiales</b>				
<i>Closterium kuetzingii</i> Brébisson	+	-	-	+
<i>Cosmarium botrytis</i> Meneghini ex Ralfs	+	+	+	-
<i>Cosmarium granatum</i> Brebisson in Ralfs	+	+	+	-
<i>Mougeotopsis calospora</i> Palla	+	+	-	-
<i>Staurastrum gracile</i> Ralfs.	+	+	+	-
<b>Zygnematales</b>				
<i>Spirogyra gratiana</i> Transeau	-	+	+	-
<i>Spirogyra novaeangliae</i> Transeau	-	+	-	+
<i>Zygnema chalybeosermum</i> Hansgirg	-	+	-	-
<i>Zygnema pectinatum</i> (Vaucher) C. Agardh	+	+	+	+
<b>BRYOPSIDOPYCEAE, Cladophorales</b>				
<i>Cladophora fracta</i> (O. F. Muller ex Vahl) Kutzing	+	+	+	+
<i>Cladophora glomerata</i> (Linnaeus) Kutzing	+	+	+	+
<b>OEDOGONIOPHYCEAE, Oedogoniales</b>				
<i>Oedogonium upsaliense</i> Wittrock	+	+	+	-
<b>BACILLARIOPHYTA, CENTROBACILLARIOPHYCEAE, Centrales</b>				
<i>Cyclotella meneghiniana</i> Kutzing	+	+	+	-
<i>Cyclotella ocellata</i> Pantocsek	+	+	+	-
<i>Melosira varians</i> C. Agardh	+	+	+	-
<i>Stephanodiscus minutulus</i> (Kutzing) Cleve & Möller	+	-	-	+
<b>PENNATIBACILLARIOPHYCEAE, Pennales</b>				
<i>Achnanthes minutissima</i> Kutzing	+	+	+	-
<i>Amphora ovalis</i> (Kutzing) Kutzing	-	+	+	-
<i>Amphora pediculus</i> (Kutzing) Grunow	+	+	+	-
<i>Amphora venata</i> Kutzing	+	+	+	-
<i>Asterionella formosa</i> Hassal	+	-	-	+
<i>Campylodiscus clypeus</i> Ehrenberg	+	+	+	-
<i>Cocconeis placentula</i> Ehrenberg var. <i>euglypta</i> (Ehrenberg) Grunow	+	-	+	+
<i>Cymatopleura solea</i> (Brébisson) W. Smith	+	-	+	+
<i>Cymbella affinis</i> Kutzing	-	+	+	-
<i>Cymbella amphicephala</i> Nageli in Kutzing	+	+	+	+
<i>Cymbella cistula</i> (Ehrenberg) Kirchner	+	+	+	-
<i>Cymbella cymbiformis</i> Agardh	+	-	+	-
<i>Cymbella helvetica</i> Kutzing	+	+	-	-
<i>Diatoma tenuis</i> C. Agardh	+	+	+	-
<i>Diatoma vulgare</i> Boryanum	+	+	+	-
<i>Diploneis elliptica</i> (Kutzing) Cleve	+	+	+	-
<i>Diploneis ovalis</i> (Hilse) Cleve	+	+	+	-
<i>Fragilaria brevistriata</i> Grunow in Van Heurck	+	+	+	-
<i>Fragilaria capucina</i> Desmazieres	+	-	-	-
<i>Fragilaria dilatata</i> (Brébisson) Lange-Bertalot	+	+	+	+
<i>Fragilaria pinnata</i> Ehrenberg	+	+	-	+
<i>Fragilaria ulna</i> Lange-Bertalot	+	+	-	+
<i>Gomphonema acuminatum</i> Ehrenberg	+	+	-	+
<i>Gomphonema olivaceum</i> (Hornemann) Brébisson	+	+	+	-
<i>Gomphonema parvulum</i> (Kutzing) Kutzing	+	+	+	+

Table 2. contd.

<i>Gyrosigma acuminatum</i> (Kutzing) Rabenhorst	+	+	-	+
<i>Gyrosigma attenuatum</i> (Kutzing) Rabenhorst	+	+	+	+
<i>Hantzschia amphioxys</i> (Ehrenberg) Grunow	-	+	+	-
<i>Mastoglia smithii</i> Thwaites	+	+	-	+
<i>Navicula cryptocephala</i> Kutzing	+	+	+	-
<i>Navicula cuspidata</i> (Kutzing) Kutzing	+	+	+	-
<i>Navicula lanceolata</i> (Agardh) Ehrenberg	+	+	+	-
<i>Navicula pupula</i> Kutzing	+	+	+	-
<i>Navicula tripunctata</i> (O. F. Muller) Boryanum	+	+	+	-
<i>Neidium dubium</i> (Ehrenberg) Cleve	+	-	+	-
<i>Nitzschia gracilis</i> Hantzsch	+	+	+	-
<i>Nitzschia hungarica</i> Grunow	+	+	-	-
<i>Nitzschia intermedia</i> Hantzsch ex Cleve & Grunow	+	+	+	-
<i>Nitzschia linearis</i> (Agardh) W. Smith.	+	+	-	-
<i>Nitzschia palea</i> (Kutzing) W. Smith	+	+	+	-
<i>Nitzschia sigma</i> (Kutzing) W. Smith	+	+	+	-
<i>Pinnularia gibba</i> Ehrenberg	+	+	+	+
<i>Pinnularia viridis</i> (Nitzsch) Ehrenberg	-	+	+	-
<i>Rhoicosphaenia abbreviata</i> (C. Agardh) Lange-Bertalot	+	+	+	-
<i>Rhopalodia gibba</i> (Ehrenberg) O. Muller	+	+	+	-
<i>Surirella caproni</i> Brébisson in Kitton	-	+	+	-
<i>Surirella ovalis</i> Brébisson	+	+	+	-
<i>Surirella robusta</i> Ehrenberg	+	+	+	-
<i>Synedra acus</i> Kutzing	+	-	-	-

Table 3. The recording list of Zooplanktonic organisms in Beysehir Lake.

ROTIFERA	Spring	Summer	Autumn	Winter
<i>Brachionus calyciflorus</i>	-	+	-	-
<i>Brachionus plicatilis</i>	-	-	+	+
<i>Colurella adriatica</i>	-	-	+	-
<i>Colurella uncinata</i>	-	-	+	-
<i>Euchlanis dilatata</i>	+	-	+	-
<i>Hexarthra</i> sp.	-	+	-	-
<i>Lecane closterocerca</i>	-	-	+	-
<i>Lecane grandis</i>	-	-	+	-
<i>Lecane lamellata</i>	-	-	-	+
<i>Lecane luna</i>	-	-	+	-
<i>Lecane lunaris</i>	+	-	+	-
<i>Lepadella patella</i>	-	+	+	-
<i>Lophpcharis alpina</i>	-	+	-	-
<i>Notholca squamula</i>	+	-	-	-
<i>Polyarthra vulgaris</i>	-	+	+	+
<i>Testudinella patina</i>	+	+	+	-
<i>Trichotria pocillum</i>	+	-	-	-
<i>Trichotria tetractis</i>	-	-	+	-
<i>Trichocerca</i> sp.	-	-	+	-
CLADOCERA				
<i>Alona rectangula</i>	+	-	+	-
<i>Alona guttata</i>	-	+	-	-
<i>Chydorus sphaericus</i>	+	-	+	+

**Table 3.** Contd.

<i>Daphnia longispina</i>	+	-	+	+
<i>Diaphanosoma brachyurum</i>	-	+	+	+
<i>Eurycerus lamellatus</i>	+	-	-	-
<i>Grabtoleberis testudinaria</i>	+	-	-	-
COPEPODA				
<i>Eudiaptomus drieschi</i>	+	+	+	+
<i>Cyclops</i> sp.	+	+	+	-

**Table 4.** Seasonally heavy metal concentration in water (mg/l) and in plankton ( $\mu\text{g/l}$ ) samples from Beysehir Lake.

Parameters		Spring	Summer	Autumn	Winter	Mean
Cd	Water	0.070	0.121	0.107	0.065	0.090
	Plankton	8.07	12.88	30.42	28.98	20.80
Pb	Water	0.165	0.235	0.169	0.195	0.191
	Plankton	12.70	13.99	48.70	57.08	33.11
Hg	Water	0.004	0.002	0.009	0.006	0.005
	Plankton	0.61	1.03	1.75	0.83	1.05
Cr	Water	0.065	0.093	0.053	0.080	0.072
	Plankton	10.94	8.48	18.56	26.23	16.52

**Table 5.** Some features of Mogan Lake water.

Parameters	Spring	Summer	Autumn	Winter
Temperature ( $^{\circ}\text{C}$ )	12.7	20.4	14.0	3.0
pH	8.9	9.0	9.1	8.8
Dissolved $\text{O}_2$ (mg/l)	9.0	8.2	9.8	11.5
$\text{EC}_{25}^{\circ}$ ( $\mu\text{s/cm}$ )	2.3	2.1	2.2	2.4
Secchi Disc (cm)	207	150	172	85

**Table 6.** The recording list of phytoplanktonic organisms in Mogan Lake.

CYANOPHYTA, CYANOPHYCEAE, Chroococcales	Spring	Summer	Autumn	Winter
<i>Chroococcus disperus</i>	+	-	-	-
<i>Chroococcus limneticus</i> Lemmermann	-	+	+	+
<i>Merismopedia tenuissima</i>	+	+	-	+
<i>Microcystis aeruginosa</i>	-	+	-	+
<i>Synechococcus aeruginosa</i> Nageli	+	+	+	+
<b>Oscillatoriales</b>				
<i>Oscillatoria formosa</i> (Boryanum) Gomont	+	+	-	-
<i>Oscillatoria granulata</i> Gardner	-	+	-	+
<i>Oscillatoria tenuis</i> (C. Agardh) Gomont	+	-	+	-
<i>Spirulina subsalsa</i> (Oersted) Gomont	-	+	-	+
<i>Spirulina platensis</i> (Nordstedt) Gomont	+	-	-	+
<b>Nostocales</b>				
<i>Anabaena affinis</i>	+	+	-	+
<i>Anabaena minutissima</i> Lemmermann	+	+	-	+
<i>Aphanizemnon flos-aqua</i>	+	-	+	-



Table 6. Contd.

<b>PYRROPHYTA, Peridinales</b>				
<i>Ceratium hirundinella</i> (O. F. Muller) Dujardin	+	+	+	-
<i>Peridinium cinctum</i> (O. F. Muller) Ehrenberg	+	+	+	-
<b>EUGLENOPHYTA, EUGLENOPHYCEAE, Euglenales</b>				
<i>Euglena acus</i>	-	+	+	-
<i>Euglena polymorpha</i> P. A. Dangeard	+	+	+	-
<i>Trachelomonas lacustris</i>	+	-	+	-
<i>Trachelomonas pulchella</i> Drezepolski	+	+	+	-
<i>Trachelomonas volvocina</i>	+	-	+	-
<b>CHRYSOPHYTA, CHRYSOPHYCEAE, Chryomonadales</b>				
<i>Dinobryon divergens</i>	+	+	-	-
<i>Dinobryon sertularia</i>	+	+	+	-
<b>CHLOROPHYTA, CHLOROPHYCEAE, Volvocales</b>				
<i>Chlamydomonas</i> sp.	+	+	+	-
<b>CHLOROPHYTA, CHLOROPHYCEAE, Chlorococcales</b>				
<i>Botryococcus braunii</i> Kutzing	+	+	+	-
<i>Chlorella vulgaris</i> Beijerinck	+	+	-	-
<i>Crucigenia quadrata</i>	-	+	+	-
<i>Oocystis borgei</i> J. Snow	-	+	-	+
<i>Oocystis parva</i>	-	+	-	+
<i>Scenedesmus obliquus</i> (Turpin) Kutzing	-	+	+	-
<i>Scenedesmus ovelterinus</i>	+	+	+	-
<i>Scenedesmus princeps</i>	+	-	-	+
<i>Scenedesmus quadricauda</i>				
<b>Chaetophorales</b>				
<i>Stigeoclonium nanum</i> (Dillwyn) Kutzing	+	+	-	-
<b>ZYGNEMAPYCEAE, Desmidiiales</b>				
<i>Closterium kuetzingii</i> Brébisson	+	-	-	+
<i>Cosmarium botrytis</i> Meneghini ex Ralfs	+	+	+	-
<i>Cosmarium granatum</i> Brébisson in Ralfs	+	+	+	-
<i>Staurastrum brachiatum</i>	+	+	-	-
<i>Staurastrum brachiatum</i>	+	+	+	-
<i>Staurastrum polymorphum</i>	+	-	-	-
<b>Zygnematales</b>				
<i>Spirogyra gratiana</i> Transeau	-	+	+	-
<i>Spirogyra mirabilis</i>	-	+	-	+
<i>Zygnema chalybeosermum</i> Hansgirg	-	+	-	-
<i>Zygnema pectinatum</i> (Vaucher) C. Agardh	+	+	+	+
<b>BRYOPSISIDOPYCEAE, Cladophorales</b>				
<i>Cladophora fracta</i> (O. F. Muller ex Vahl) Kutzing	+	+	+	+
<i>Cladophora glomerata</i> (Linnaeus) Kutzing	-	+	+	+
<b>OEDOGONIOPHYCEAE, Oedogoniales</b>				
<i>Oedogonium upsaliense</i> Wittrock	+	+	+	-
<b>BACILLARIOPHYTA, CENTROBACILLARIOPHYCEAE, Centrales</b>				
<i>Cyclotella meneghiniana</i> Kutzing	+	+	+	-
<i>Cyclotella ocellata</i> Pantocsek	+	+	+	-
<i>Melosira granata</i>	+	+	+	-
<i>Melosira italica</i>	+	+	-	+
<i>Melosiravarians</i>	+	+	+	-
<i>Stephanodiscus astrea</i>	+	-	+	+

Table 6. Contd.

<b>PENNATIBACILLARIOPHYCEAE, Pennales</b>				
<i>Achnanthes lapponica</i>				
<i>Achnanthes minutissima</i> Kutzing	+	+	+	-
<i>Amphora ovalis</i> (Kutzing) Kutzing	-	+	+	-
<i>Amphora pediculus</i> (Kutzing) Grunow	+	+	+	-
<i>Campylodiscus clypeus</i> Ehrenberg	+	+	+	-
<i>Cocconeis placentula</i> Ehrenberg var. <i>euglypta</i> (Ehrenberg) Grunow	+	-	+	+
<i>Cymatopleura elliptica</i>	+	-	+	+
<i>Cymbella amphicephala</i> Nageli in Kutzing	+	+	+	+
<i>Cymbella cistula</i> (Ehrenberg) Kirchner	+	+	+	-
<i>Cymbella cymbiformis</i> Agardh	+	-	+	-
<i>Cymbella gracilis</i>	+	+	-	-
<i>Diatoma elongatum</i>	+	+	+	-
<i>Diatoma vulgare</i> Boryanum	+	+	+	-
<i>Diploneis ovalis</i> (Hilse) Cleve	+	+	+	-
<i>Epithemia sorex</i>	-	-	-	+
<i>Fragilaria intermedia</i>	+	+	+	+
<i>Fragilaria capucina</i> Desmazieres	+	-	-	-
<i>Fragilaria pinnata</i> Ehrenberg	+	+	-	+
<i>Fragilaria vauchaeria</i>	+	+	-	+
<i>Gomphonema constrictum</i>	+	+	-	+
<i>Gomphonema olivaceum</i> (Hornemann) Brébisson	+	+	+	-
<i>Gomphonema lanceolatum</i>	+	+	+	+
<i>Gomphonema olivaceum</i>	-	+	+	+
<i>Gyrosigma acuminatum</i> (Kutzing) Rabenhorst	+	+	-	+
<i>Navicula cuspidata</i> (Kutzing) Kutzing	+	+	+	-
<i>Navicula lanceolata</i> (Agardh) Ehrenberg	+	+	+	-
<i>Navicula pupula</i> Kutzing	+	+	+	-
<i>Navicula tripunctata</i> (O. F. Muller) Boryanum	+	+	+	-
<i>Nitzschia amphibia</i>	+	+	+	-
<i>Nitzschia linearis</i> (Agardh) W. Smith.	+	+	-	-
<i>Nitzschia palea</i> (Kutzing) W. Smith	+	+	+	-
<i>Pinnularia biceps</i>	+	+	+	+
<i>Pinnularia viridis</i> (Nitzsch) Ehrenberg	-	+	+	-
<i>Stauroneis smithii</i>	+	+	+	-
<i>Surirella angustata</i>	+	+	+	-
<i>Surirella ovalis</i> Brébisson	-	+	+	-
<i>Synedra acus</i> Kutzing	+	+	+	-
<i>Synedra capitata</i>	+	+	+	-
<i>Synedra ulna</i>	+	-	-	-

Table 7. The recording list of zooplanktonic organisms in Mogan Lake.

<b>ROTIFERA</b>	<b>Spring</b>	<b>Summer</b>	<b>Autumn</b>	<b>Winter</b>
<i>Anueropsis fissa</i>	-	+	+	-
<i>Ascomorpha eucalis</i>	-	+	+	-
<i>Ascomorpha saltans</i>	-	+	+	-
<i>Asplachna priodonta</i>	+	+	+	+
<i>Asplachna priodonta</i>	-	+	+	+
<i>Brachionus angularis</i>	-	+	+	-
<i>Brachionus calyciflorus</i>	-	-	+	+

Table 7. Contd.

<i>Brachionus urceolaris</i>	-	+	+	-
<i>Brachionus quadridentatus</i>	-	+	+	-
<i>Cephalodella catellina</i>	-	+	+	-
<i>Cephalodella gibba</i>	-	-	+	-
<i>Colurella adriatica</i>	-	+	+	-
<i>Dicranephorus epidrans</i>	-	+	-	-
<i>Dicranephorus fercipales</i>	-	+	-	-
<i>Euchlanis dilatata</i>	-	-	+	-
<i>Filina limnetica</i>	-	+	+	+
<i>Filina longiseta</i>	-	+	+	+
<i>Filina pejleri</i>	-	+	-	-
<i>Gastropus stylifer</i>	-	-	+	-
<i>Hexarthra mira</i>	-	+	-	-
<i>Keratella cochlearis</i>	+	-	-	-
<i>Keratella quadrata</i>	-	-	+	+
<i>Keratella tecta</i>	-	+	-	-
<i>Keratella tropica</i>	-	+	-	-
<i>Lecane bulla</i>	-	+	+	+
<i>Lecane closterocerca</i>	-	+	-	-
<i>Lecane hamata</i>	-	+	+	-
<i>Lecane ludwigii ichtyoura</i>	-	-	-	+
<i>Lecane ludwigii ohiensis</i>	-	+	+	+
<i>Lecane luna</i>	-	+	+	-
<i>Lecane lunaris</i>	+	+	-	-
<i>Lecane rugosa</i>	-	+	-	-
<i>Lepadella triptera</i>	-	+	-	-
<i>Lophpcharis salpina</i>	-	+	-	-
<i>Mytilim ventralis</i>	-	-	+	-
<i>Notholca squamula</i>	-	-	+	-
<i>Notomnata cyrhipus</i>	-	-	-	+
<i>Polyarthra vulgaris</i>	-	+	+	+
<i>Polyarthra dolichoptera</i>	-	+	+	-
<i>Ptygaura meliceria</i>	-	+	-	-
<i>Philodina megalotiocha</i>	+	-	-	+
<i>Resticula mellanderosus</i>	-	-	+	+
<i>Rotaria neptunina</i>	-	-	+	+
<i>Rotaria rotaria</i>	+	-	+	-
<i>Rotaria targidrata</i>	+	-	+	-
<i>Synchaeta oblonga</i>	-	+	+	+
<i>Synchaeta pectinata</i>	-	+	+	+
<i>Testudinella patina</i>	-	+	+	+
<i>Trichocerca elongata</i>	-	-	+	-
<i>Trichocerca paraula</i>	-	+	-	-
<i>Trichocerca pocillum</i>	-	+	+	-
<i>Trichocerca pusilla</i>	-	+	+	-
<i>Trichocerca rattus</i>	-	+	+	-
<i>Trichocerca stylata</i>	-	+	+	-
<i>Trichocerca tetractis</i>	-	+	+	-
<b>CLADOCERA</b>				
<i>Alona rectangula</i>	+	+	-	+
<i>Ceriodaphnia quadrangula</i>	+	+	-	+
<i>Daphnia longispina</i>	+	+	-	-

Table 7. Contd.

<i>Diaphanosoma brachyurum</i>	+	+	+	+
<i>Macrothrix laticornis</i>	-	-	+	-
<i>Pleuroxus aduncus</i>	+	+	-	+
<i>Simouphalus vetulus</i>	+	+	-	+
<b>COPEPODA</b>				
<i>Acanthodiptomus</i> sp.	+	+	+	+
<i>Cyclops</i> sp.	+	-	+	+
<i>Nauplius</i> sp.	+	+	+	+

Table 8. Seasonally heavy metal concentration in water (mg/l) and in plankton ( $\mu\text{g/l}$ ) samples from Mogan Lake.

Parameters		Spring	Summer	Autumn	Winter	Mean
Cd	Water	0.035	0.113	0.042	0.105	0.074
	Plankton	6.21	10.87	8.36	13.26	0.67
Pb	Water	0.307	0.244	0.207	0.271	0.257
	Plankton	24.42	20.95	36.01	33.07	28.62
Hg	Water	0.005	0.001	0.002	0.085	0.027
	Plankton	0.60	0.38	1.57	0.80	0.84
Cr	Water	0.043	0.052	0.047	0.088	0.058
	Plankton	7.26	6.78	3.16	21.94	9.79

processed by chlorine and is used for drinking and other purposes and Mogan Lake is the shelter and breeding site of birds. Furthermore, the Lakes are internationally important wetlands due to the rich and diverse community of waterfowl. For these reasons, measurements should be taken as protective ones for the survival of biodiversity in the Lakes.

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