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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 *Staurastrum* 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 calyciforus* while *Arctodiaptomus* sp., *Keratella quadrata*, *Filinia longiseta* 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 µ 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 Spectrophometer) 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° 450 North, 31° 300 East). It is tectonic/jips in origin and is the 3rd largest freshwater Lake of the country. It has 1121 m altitude and 656 km^2 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^2) eutrophic Lake with a total of 925 km^2 drainage area situated 20 km south of Ankara (Figure 2). The Lake is mainly fed by four main in 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 µS/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 calyciforus* (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 µS/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 Chysophyta 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

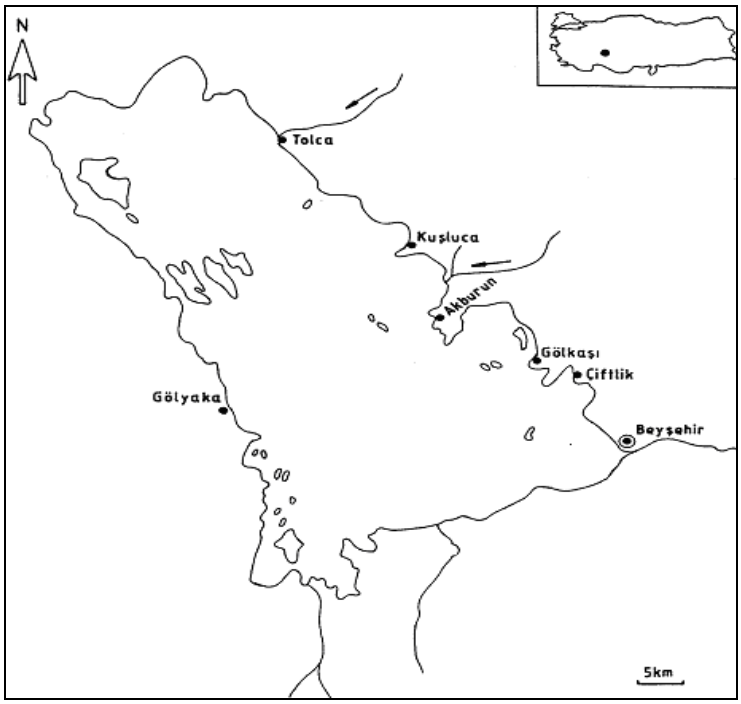

Figure 1. The location and sampling station of the Beysehir Lake.

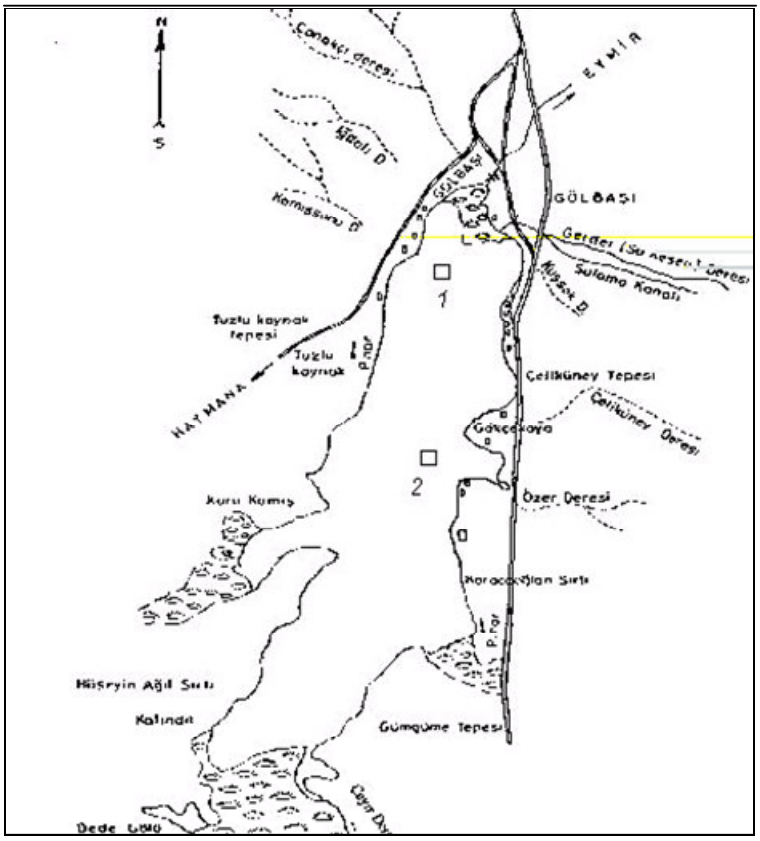

Figure 2. Map of Mogan Lake and the sampling stations used in this study.

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 0_2 (mg/l)	8.0	8.4	11.8	10.8
EC_{25}^{o} (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. Hellawell (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 intercontinental waters for Pb, Cd, and Hg, the water of the Lake falls in the 4^{th} 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^{nd} 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^{nd} 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 $CaCO_3$) 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.

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

Table 2. contd.

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

Table 2. contd.

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

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

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

Table 3. Contd.

Daphnia longispina	+	-	+	+
Diaphanosoma brachyurum	-	+	+	+
Eurycercus lamellatus	+	-	-	-
Grabtoleberis testudinaria	+	-	-	-
COPEPODA				
Eudiaptomus drieschi	+	+	+	+
Cyclops sp.	+	+	+	-

Table 4. Seasonally heavy metal concentration in water (mg/l) and in plankton (µg/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 (^{o}C)	12.7	20.4	14.0	3.0
pH	8.9	9.0	9.1	8.8
Dissolved 0_2 (mg/l)	9.0	8.2	9.8	11.5
EC_{25}^{o} (µs/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, Choroococcales	Spring	Summer	Autumn	Winter
Chroococcus disperus	+	-	-	-
Chroococcus limneticus Lemmermann	-	+	+	+
Merismopedia teniussima	+	+	-	+
Microcystis aeroginosa	-	+	-	+
Synechococus aeroginosa Nageli	+	+	+	+
Oscillatoriales				
Oscillatoria formosa (Boryanum) Gomont	+	+	-	-
Oscillatoria granulata Gardner	-	+	-	+
Oscillatoria tenius (C. Agardh) Gomont	+	-	+	-
Spirulina subsalsa (Oersted) Gomont	-	+	-	+
Spirulina platensis (Nordstedt) Gomont	+	-	-	+
Nostocales				
Anabaena affinis	+	+	-	+
Anabaena minutissima Lemmermann	+	+	-	+
Aphanizemnon flos-aqua	+	-	+	-

Table 6. Contd.

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

Table 6. Contd.

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

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

ROTİFERA	**Spring**	**Summer**	**Autumn**	**Winter**
Anueropsis fissa	-	+	+	-
Ascomorpha ecualis	-	+	+	-
Ascomorpha saltans	-	+	+	-
Asplachna priodonta	+	+	+	+
Asplachna priodenta	-	+	+	+
Brachionus angularis	-	+	+	-
Brachionus calyciflorus	-	-	+	+

Table 7. Contd.

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

Table 7. Contd.

Diaphanosoma brachyurum	+	+	+	+
Macrothrix laticornis	-	-	+	_
Pleuroxus aduncus	+	+	-	+
Simouphalus vetulus	+	+	-	+
COPEPODA				
Acanthodiaptomus sp.	+	+	+	+
Cyclops sp.	+	-	+	+
Nauplius sp.	+	+	+	+

Table 8. Seasonally heavy metal concentration in water (mg/l) and in plankton (µg/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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REFERENCES

Farkas A, Salanki J, Sspecziar A, Varanka I (2001). Metal pollutionas health indicatorof Lake ecosystems. Int. J. Occup. Med. Environ. Health, 14(2): 163-170.

Veena B, Radhakrishnan CK, Chacko J (1997). Heavy metal induced biochemical effects in an estuarine teleost. Indian J. Marine Sci. 26: 74-77.

Toker C (1998). Uptake of lead by Barley (*Hordeum distichon* L.) roots and its relation to potassium. Turk. J. Biol. 12(2): 128-133.

Van Den Hook C, Mann DG, Jahns HM (1995). Algae, An Introduction to Phycology. Cambridge Univ.

Chen CY, Stemberg RS, Klaue Blum JD, Pickhardt C, Folt CL (2000). Accumulation of heavy metals in food web components across a gradient of Lakes, Lim. Ocean. 45(7): 1525-1536.

Round FE (1973). The Biology of the Algae. Second Edition, London.

Gerrath FJ, Denny P (1979). Freshwater Algae of Sierra Leone I. Euglenophyta, *Nova Hedwigia,* Band XXXI. 1+2, Braunschweig.

Schuurman G, Markert B (1998). Ecological Fundamentals, Chemical Exposure and Biological Effects.In: Ecotoxicology. John Wiley & Sons, Inc. and Spectrum Akademischer Verlag, p. 900.

Pestalozzi HG (1982). Das Phytoplankton Des Susswassers, Systematik und Biologie, Teil, 1. Conjugatophyceae, Zygnematales and Desmidiales, E. Schweizerbart'sche Verlo'gsbuchhandlung, (Naegele u Obermiller), Stuttgart.

Conway HL (1978). Sorption of arsenic and cadmium and their effects on growth, micronutrient utilization and photosynthetic pigment composition of *Asterionella formosa.* J. Fish. Res. 35: 286-294.

Marshal JS, Mellinger DL (1980). Dynamics of cadmium-stressed plankton communities. Can. J. Fish. Aquat. Sci. 37: 403-414.

Besinger KE, Christensen GM (1972). Effects of various metals on survival growth, reproduction and metabolism of *Daphnia magna*. J. Fish. Res. 29: 1691-1700.

Nilsson L (1978). Breeding waterfowl in eutrophicated Lakes in south Sweden. Wilfowl, 29: 101-110

Kelly MG, Whitten BA (1989). Interspecific Differances in Zn, Cd and Pb Accumulation by Freshwater Algae and Bryophytes, Hydrobiologia, 175(1): 1-11.

Hellawell MJ (1988). Biological Indicators of freshwater pollution and Environmental Manegement, Pollution Monitoring Series, 50: 61-85.

Mangi J, Schmidt K, Pankow J, Gaines L, Turner P (1978). Effects of chromium on some aquatic plants. Environ. Pollut. 16: 285-291.

Oskar PO, Mariela G (1978). Freshwater Algae of Chiloe Island Chile. *Nova Hedwigia*, Band XXX. Braunschweig

Uslu O, Turkman A (1997). Toxic Substance, Su kirliligi ve Kontrolu, TC Basbakanlik Cevre Genel Mudurlugu Yayinlari,, Ankara,

Avila-Pe'rez P, Balcazar M, Zarazua-Ortega G, Barselo Quintal I, Diaz-Deldago C (1999). Heavy metal concentrations in water and bottom sediments of a Mexican reservoir. Sci. Total Environ. 234: 185-196.

Kolisko RM (1974). Plankton Rotifers Biology and Taxonomy, Biological Station. Lunz of the Austrian Academy of Science, Stuttgart.

Koivisto S, Ketola M, Walls M (1992). Comparison of five Cladoceran

species in short and long term copper exposure. Hydrobiologia, 248: 125-136.
Radwan S, Kowalik A, Kornijow R (1990). Accumulation of heavy metals in a Lake ecosystems. Sci. Total Environ. 96: 121-129.
Burnak SL, Beklioglu M (2000). Macrophyte-dominated clearwater state of Lake Mogan. Turk. J. Zool. 24: 305-313.
Ward TJ (1987). Temporal variation of metals in the sea grass *Posidonia australis* and its potential as a sentinel accumulator near a lead smelter. Marital Biol. 95: 315-321.
Koste W (1978). Die Radertiere MitteleuropasI Textband, Berlin, Stuttgart
Edmondson WT (1959). Freshwater Biology. John Wiley and Sons Inc. London.Chapman & Hall Limited.
Nakanishi Y, Sumita M, Yumita K, Yamada T, Honjo T (2004). Heavy-Metal Pollution and Its State in Algae in Kakehashi River and Godani River at the Foot of Ogaya Mine, Ishikawa Prefecture. Anal. Sci. 20: 73-78.