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Full Length Research Paper

Ecological effects of some heavy metals (Cd, Pb, Hg, Cr) pollution of phytoplanktonic algae and zooplanktonic organisms in Sarıyar Dam Reservoir in Turkey

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Accumulation of heavy metals (Cd, Pb, Hg, Cr) in water and plankton of Sarıyar Dam Lake (SDR) was seasonally studied from April, 2000 to December, 2004. In addition, seasonal changes in phytoplankton and zooplankton populations and species abundance were also determinate. Some physio-chemical parameters of water and their correlation with heavy metals were also determinated. The dominant phytoplanktonic algae determined were *Choroococcus, Gomphospheria, Oscillatoria, Phormidium, Anabaena, Nostoc, Cystodinium, Dinobryon, Ankistrodesmus, Chlorella, Coelastrum, Oocystis, Pediastrum, Scenedesmus, Cosmarium, Oedogonium, Cyclotella, Achnanthes, Amphora, Anomoneis, Cocconeis, Cymbella, Diatoma, Diploneis, Fragilaria, Gomphonema, Navicula, Nitzschia, Nitzschia, Rhoicosphenia, Surirella* and *Synedra*. The dominant zooplanktonic organisms determined were *Asplachna priodonta, Brachionus angularis, Keratella quadrata, Keratella cochlearis, Keratella tropica, Polyarthra vulgaris, Proales decipiens, Bosmina longirostris, Ceriodaphnia quadrangula, Chydorus sphaericus, Daphnia longispina, Diaphanosoma brachyurum, Macrothrix laticornis, Acanthocyclops robustus* and *Acanthodiaptomus denticornis*. High concentrations of all heavy metals were recorded in the plankton. Hg was lowest and Pb highest; but the concentration of each metal varied seasonally.

Key words: Heavy metals, accumulation, water pollution, algae, zooplankton.

INTRODUCTION

Lake ecosystems are increasingly affected by various anthropogenic impacts, such as excess of nutrients causing eutrophication, toxic contamination of industrial, agricultural and domestic origin, as well as heat pollution reaching the lakes through their catchments area and the atmosphere. Typical results of 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 (Schüürmann and Markert, 1998). This study was conducted to determine the accumulation of heavy metals in water and plankton (phyto and zoo) of Sarıyar Dam Reservoir (SDR).

SDR is interconnected hydrologically in the close vicinity of Ankara, Turkey. Potential impacts from extensive agriculture, recreation, incomplete infrastructure and other human activities, such as residential settlements, are addressed with reference to previous and more recent pollution monitoring. The study, while addressing water quality and interactions due to human activities in

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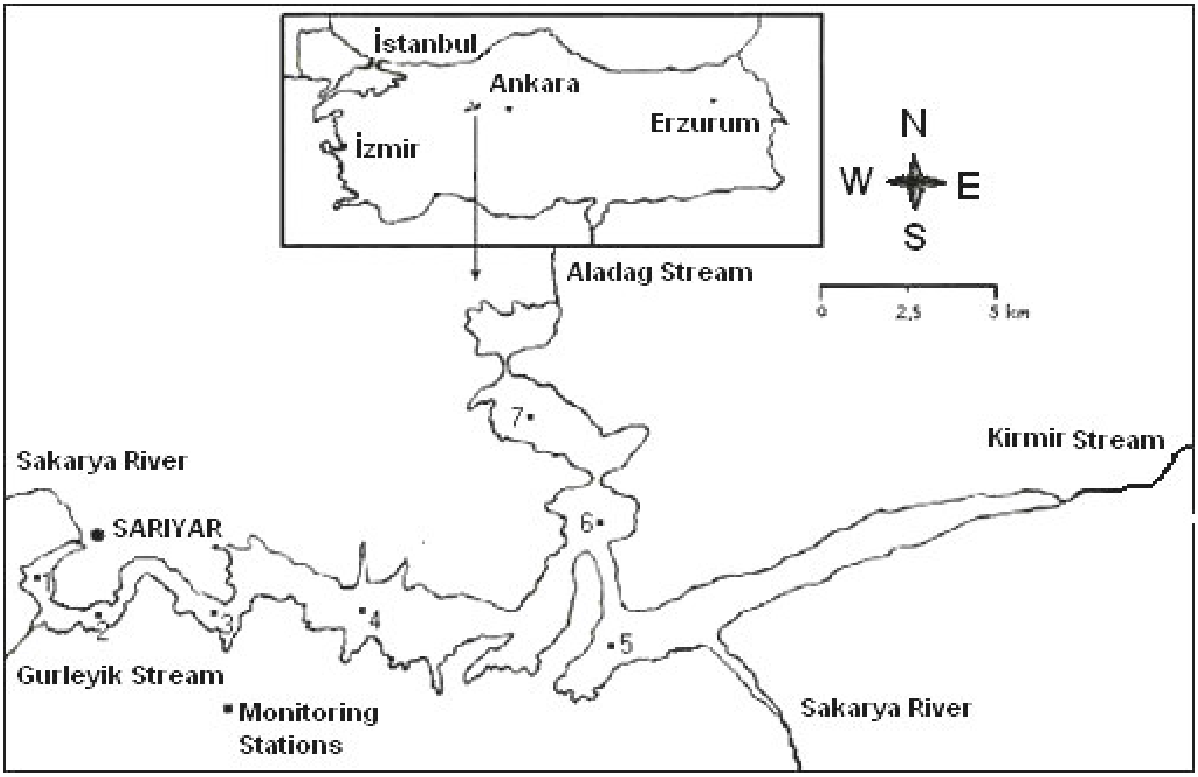

Figure 1. Location and sampling station of the Sarıyar Dam Reservoir in Turkey.

shallow lakes, also highlight problems associated with human impacts in protected areas with the aim of presenting a complicated case study.

MATERIALS AND METHODS

Sampling site and date

SDR lies of Central Anatolia at altitude of 475 m, and is located at 40°03' 00'' N latitudes and between 30° 45' 36'' and 31° 45 40'' E longtitudes, 180 km northwest of Ankara (Figure 1). The reservoir was constructed for the purpose of hydroelectric power generation; is 106 m high with maximum depth of 90 m and has average water volume of 1.900X10^6 m^3. The dam has approximate surface area of 84 km^2. The nearest populated areas are Davutoglan and Sarıyar villages, with total population of 6610 (Figure 1).

The SDR is surrounded by diverse volcanic rocks, along with brown soils, characteristic of central Anatolia (Erentöz and Pamir, 1975). The surroundings of SDR have a meager flora. However, the southern side of the reservoir, has rich plantation of pine (*Pinus nigra* Arn.), juniper (*Juniperus excelsa* Bieb.), oak (*Quercus pubescens* Wild.), thicket (*Paliurus spina-christi* Miller*, Berberis crataegina* DC.), poplar (*Populus tremula* L.), willow (*Salix sp.*) etc. along the stream banks.

The area is a bird paradise and attracts migrating birds (*Ciconia ciconia* L. *Ciconia nigra* L., *Egretta alba* L. *Ardea cinera* L. *Ardea purpurea* L. *Alcedo atthis* L. *Phalacrocorax pygmeus* Pallas) every year. Most of the birds remigrate. Other birds live in trees and thickets, which are widespread in this area. Besides, the area is also abundant with water frogs (*Rana ridibunda* Pallas) and water snakes (*Natrix natrix* Laurenti).

Experimental

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 55µ 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 with concentrated planktons left in laboratory for some time for small evaporation of water. Age-weight was determined following Toker (1998). Material was then dried in oven at 90°C for 24 h and its dry weigh was noted. The material was then kept at 550°C for 4 h and then cooled down. It was digested at 80°C by adding 20 ml of 1,5N 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 made according to Kolisko (1974), Koste (1978), Edmondson (1959), Round (1973), Pestalozzi (1982), Gerrath and Denny (1979), Oskar and Gonzales (1979), Van Den Hook et al. (1995), Ustaoğlu (2004).

RESULTS AND DISCUSSION

The maximum water temperature was 31°C, the lowest temperature was recorded as 4°C. Maximum dissolved

Table 1. Some (chemical and physical) features of Sarıyar Dam Reservoir in Turkey (during 2001-2002; maximum, minimum and average level).

Date (2001-2002)	Temp. (°C)	DO2 (mg/l)	pH	Elect. Conduct. (mmhos/cm)	Secchi Depth (cm)	NH_4^{+1} (μmol/l	NO_2^{-1} (μmol/l)	NO_3^{-1} (μmol/l)	Chl-a (μgl^{-1})
Maximum	31	15.5	10.4	890	420	1.42	0.96	0.94	34.6
Minimum	4.3	4.7	7.12	475	62	0.01	0.02	0.03	1.08
Average	23.0	9.9	8.8	640	270	0.50	0.55	0.74	5.25

Table 2. Phytoplanktonic organisms in Sarıyar Dam Reservoir in Turkey.

Cyanophyta	Chlorophyta	Bacillariophyta
Anabaena affinis	*Actinastrum gracillimum*	*Achnanthes linearis*
Anabaena flos-aquae	*Actinastrum hantzschii*	*Amphora ovalis*
Aphanizomenon flos-aquae	*Actinotaenium cucurbita*	*Amphora pediculus*
Chroococcus limneticus	*Ankistrodesmus falcatus*	*Anomoeoneis sphaerophora*
Chroococcus minutus	*Ankyra judayi*	*Asterionella formosa*
Chroococcus turgidus	*Aphanochaeta vermiculoides*	*Caloneis silicula*
Cylindrospermum minimum	*Chlamydomonas globosa*	*Cocconeis pediculus*
Cylindrospermum stagnale	*Chlamydomonas snowiae*	*Cocconeis placentula*
Gloeothece rupestris	*Chlorella vulgaris*	*Cyclotella meneghiniana*
Gloeotrichia pisum	*Chlorolobion braunii*	*Cyclotella ocellata*
Gomphosphaeria aponina	*Closteriopsis longissima*	*Cymatopleura elliptica*
Lyngbya lagerheimii	*Closterium aciculare*	*Cymatopleura solea*
Lyngbya versicolor	*Closterium dianaea*	*Cymbella affinis*
Merismopedia elegans	*Closterium kuetzingii*	*Cymbella amphicephala*
Merismopedia punctata	*Closterium setaceum*	*Cymbella helvetica*
Microcystis aeruginosa	*Coelastrum microsporum*	*Denticula elegans*
Microcystis incerta	*Coelastrum sphaericum*	*Diatoma elongatum*
Nostoc commune	*Cosmarium botrytis*	*Diatoma vulgaris*
Nostoc pruniforme	*Cosmarium granatum*	*Diploneis elliptica*
Oscillatoria amoena	*Cosmarium monomazum*	*Diploneis ovalis*
Oscillatoria bornetii	*Cosmarium obtusatum*	*Epithemia argus*
Oscillatoria splendida	*Dimorphococcus lunatus.*	*Epithemia zebra*
Oscillatoria tenuis	*Franceia amphitricha*	*Fragilaria dilatata*
Phormidium ambiguum	*Mougeotia viridis*	*Fragilaria pinnata*
Phormidium mucicola	*Oocystis borgei*	*Fragilaria ulna*
Rhabdogloea hungarica	*Oocystis elliptica*	*Fragilaria ulna* var. *acus*
Spirulina laxa	*Oocystis eremosphaeria*	*Gomphonema lanceolatum*
Spirulina major	*Oocystis parva*	*Gomphonema olivaceum*
Spirulina princeps	*Oocystis solitaria*	*Gyrosigma acuminatum*
	Pandorina morum	*Gyrosigma attenuatum*
Pyrrophyta	*Pediastrum boryanum*	*Hantzschia amphioxys*
Cystodinium cornifax	*Pediastrum dublex*	*Melosira granulata*
Gymnodinium fuscum	*Scenedesmus acuminatus*	*Meridion circulare*
Peridinium cinctum	*Scenedesmus arcuatus*	*Navicula cryptocephala*
	Scenedesmus bicaudatus	*Navicula cuspidata*
Euglenophyta	*Scenedesmus communis*	*Navicula lanceolata*
Euglena acus	*Scenedesmus obliquus*	*Navicula pupula*
Lepocinclis playfairiana	*Scenedesmus spinosus*	*Navicula radiosa*
Trachelomonas armata	*Schizochlamys gelatinosa*	*Navicula tripunctata*

Table 2. Contd.

Trachelomonas lacustris	*Selenastrum gracile*	*Neidium dubium*
	Sphaerocystis schroeteteri	*Nitzschia hungarica*
Xanthophyta	*Staurastrum cyclacantum*	*Nitzschia linearis*
Ophioctium sp.	*Staurastrum gracile*	*Nitzschia palea*
	Stigeoclonium attennuatum	*Nitzschia vermicularis*
Chrysophyta	*Tetraedron minimum*	*Pinnularia microstauron* var. *brebissonii*
Dinobriyon sertularia	*Tetrastrum triangulare*	*Pinnularia viridis*
Paraphysomonas vestita	*Traubaria setigera*	*Rhopalodia gibba*
		Surirella caproni
Rhodophyta		*Surirella ovata*
Lemanea fucina		*Tryblionella acuta*

O_2 was 15.5 mg/ml^{-1}, the lowest value was 4.7 mg/ml^{-1}. pH varied from 7.4 - 10.0. Secchi depth ranged from 4.2 - 0.62 m, depending on the concentration of chlorophyll a and other factors. The lowest electrical conductivity (EC) was 475 mmhos/cm and the highest was 890 µmhos/cm The amount of ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-) was found to be 0.01 - 1.42, 0.02 - 0.96 and 0.03 - 0.94 µmol/l, respectively. In the classification of natural waters, since pH is inversely proportional to the free ammonium concentration, which is biologically active ammonium concentration, vary. Maximum chlorophyll a concentration was recorded as 34.6 µgl^{-1} (Table 1).

The predominant phytoplanktonic species belong to the classes Cyanophyta, Pyrrhophyta, Euglenophyta, Xanthophyta, Chrysophyta, Rhodophyta, Chlorophyta and Bacillariophyta. Bacillariophyta and Chlorophyta members were very abundance in samples taken with plankton net for quantification (Table 2). Among zooplankton fauna, a total of 37 species (24 Rotifera, 9 Cladocera and 4 Copepoda) were identified in SDR. *Brachionus calyciforus* belonging to the dominant group and *Keratella cochlearis*, *Kachuga tecta* and *Keratella tropica* (Rotifera) was observed in all seasons throughout the year. *Arctodiaptomus denticornis* (Copepoda) was found abundant in spring and winter (Table 3).

In water sample from SDR the accumulation order of heavy metals was found as Pb>Cr>Cd>Hg in spring; Pb>Cr>Cd>Hg in summer; Pb>Cr>Cd>Hg in autumn and Pb>Cr>Cd>Hg in winter. The heavy metals accumulation in plankton samples from SDR were as Pb>Cr>Cd>Hg in spring; Pb>Cr>Cd>Hg in summer; Pb>Cr>Cd>Hg in autumn; and Pb>Cr>Cd>Hg in winter (Figure 2).

The physico-chemical parameters and secchi depth values showed that SDR is a mesotrophic lake. The pH and EC values in SDR were higher than the standard values. According to Hellawell (1988) and Avila et al. (1999), 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.

High accumulation of heavy metals was observed in plankton, compared with water. The average Pb value is very high with comparison to the concentrations allowed for irrigation water. According to the quality criteria for inter-continental waters for Pb, Cr, Cd, and Hg, the water quality of the lake falls in the 4th class of the polluted waters (Uslu and Türkman, 1997).

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 SDR, the average accumulations was arranged in order as Pb>Cr>Cd>Hg, respectively. According to Marshal and Melinger (1980), Cd affects the photosynthesis and reduces the primary productivity of phytoplankton even at 0.2 and 5 mg/l, respectively; itaffects the community structure of zooplankton. Apart from this, Koivisto et al. (1992) reported that 0.32 and 2 mg/l Cr affected the growth and chlorophyll structure of *Euglena* sp. and *Chlorella vulgaris*, 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 they have been reported as characteristic species of eutrophic waters. The term biomonitor 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* was reported by Conway (1978). Conway (1978) found that 2 mg/l Cd limited the growth of algae at population level, and 10 mg/l Cd also 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). According to Nakanishi et al. (2004) *Achnanthes minutissima* has a tolerance to copper ion. 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. Hg accumulates in algae and in other aquatic plants. In lakes, Hg accumulation is fast; however, elimination is slow. Among crustaceans, *Daphnia magna* has been reported as more susceptible species to Hg. In soft water

Table 3. Zooplanktonic organisms in Sarıyar Dam Reservoir in Turkey (according to season).

Rotifera	Spring	Summer	Autumn	Winter
Asplachna priodonta (Gosse, 1850)	+	+	+	+
Brachionus angularis (Gosse, 1851)	+	+	+	+
*Brachionus calyciflorus (*Pallas, 1766)	+	+	+	-
Brachionus urceolaris (Müller, 1773)	-	+	+	-
Brachionus quadridentatus (Hermanns, 1783)	+	+	-	-
Conochilus unicornis (Rousselet, 1892)	+	+	-	-
Euchlanis dilatata (Ehrenberg, 1832)	+	-	+	-
Gastropus stylifer (Imhof, 1891)	-	+	-	-
Keratella quadrata (Müller, 1786)	+	+	+	+
Keratella cochlearis (Gosse, 1851)	+	+	+	+
Keratella tecta (Gosse, 1886)	+	-	+	-
Keratella tropica (Apstein, 1907)	+	+	+	+
Lecane bulla (Gosse, 1886)	+	-	+	-
Lecane closterocerca (Schmarda, 1859)	+	+	-	-
Lecane luna (Müller, 1776)	-	+	+	-
Lecane lunaris (Ehrenberg, 1832)	+	+	-	-
Lepadella patella (O.F.Müller, 1786)	-	+	-	-
Lophocharis salpina (Ehrenberg, 1834)	-	+	-	-
Notholca squamula (O.F.Müller, 1786)	+	-	-	-
Polyarthra vulgaris Carlin, 1943	+	+	+	+
Polyarthra dolichoptera Idelson, 1925	-	+	+	-
Pomplolyx sulcata (Hudson, 1885)	-	+	-	-
Proales decipiens (Ehrenberg, 1832)	+	+	+	+
Trichocerca pusilla (Lauterborn, 1898)	-	+	+	-
Cladocera				
Alona rectangula (Sars, 1862)	+	+	+	-
Bosmina longirostris (Müller, 1785)	+	+	+	+
Ceriodaphnia quadrangula (Müller,1785)	+	+	+	+
Chydorus sphaericus (Müller,1776)	+	+	+	+
Daphnia galeata (Sars, 1864)	+	+	-	-
Daphnia longispina (Müller, 1785)	+	+	+	+
Diaphanosoma brachyurum (Lievin, 1848)	+	+	+	+
Leydigia leydigi (Schodler, 1863)	+	+	+	-
Macrothrix laticornis (Fischer, 1848)	+	+	+	+
Copepoda				
Acanthocyclops robustus (Sars, 1863)	+	+	+	+
Acanthodiaptomus denticornis (Wierzejski, 1887)	+	+	+	+
Arctodiaptomus acutilobatus (Sars, 1903)	+	-	+	-
Arctodiaptomus bacillifer (Koelbel, 1885)	+	-	+	-

(45 mg/l $CaCO_3$), 5 mg/l Hg leads to deaths and 3 - 4 mg/l Hg cause 16% harmful effects on *D. manga* population, after an exposure of 48 h (Biesinger and Christensen, 1972).

Chen et al. (2000) found that highest heavy metal concentrations may be that of Pb in eutrophic lakes and in agricultural areas. Also, the Pb concentration may be raised by road traffic and exhaust-gasses and also by other means. In our study, Pb was the highest in concentration among the heavy metals.

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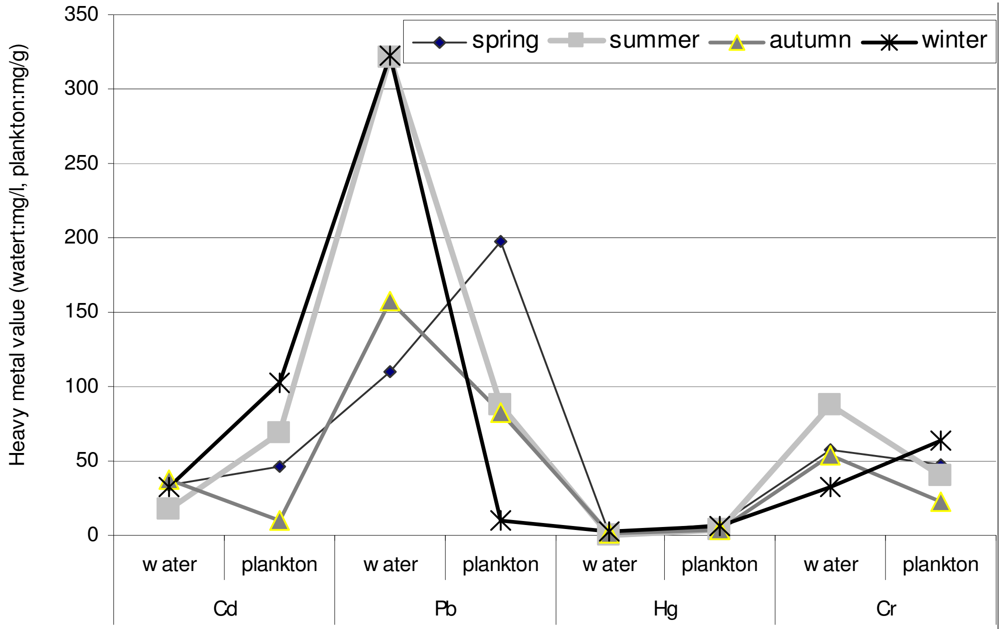

Figure 2. Seasonally heavy metal concentration in water (mg/l) and in plankton (mg/l).

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