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*Full Length Research Paper*

# Physicochemical, toxicological and ecological analysis of Gökçekaya Dam Lake

**B. S. Akin[1]*, T. Atici[2] and H. Katircioglu[2]**

[1]Gazi University, Institute of Science and Technology, Department of Environmental Sciences, Maltepe, Ankara, Turkey.
[2]Gazi University, Gazi Education Faculty, Department of Biology Education, Teknikokullar, Ankara, Turkey.

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**Dams built to supply electricity, irrigation and fresh water, change the characteristics of the region they are located. The ecological, limnological characteristics and the quality of water in the dam reservoir deteriorate with time. In this study, the physicochemical, toxicological and ecological parameters of Gökçekaya Dam Lake's water, which is situated on Sakarya River were examined. The selected area has different characteristics from the others. This lake is situated between two other dam lakes on Sakarya River. So the main water of the lake comes from Sakarya Dam. During the years 2005-2006, water samples were taken from the lake surface and depths in seasonal periods, and the physical, chemical and biological parameters were examined to determine the modifications in the quality of water. It was seen that while the quality had no certain differences, the level of the nutrients in the water was low. The different characteristics of the coming water enriched the varieties of algae. It was concluded that the structure of the water in Gökçekaya Dam Lake is mezotrophic.**

**Key words:** Dam Lake, indicating algae, pollution monitoring, water quality.

## INTRODUCTION

In dam lakes, which are formed at the back of the relieved and accumulated structures on the running water, new organisms come into existence with the effects of different morphological structures. In the running water from the dam lake, the normal creatures of the river are changed in time, because of the cold temperature and low oxygen of the coming water of dam lake (Fair et al., 1971). In order to benefit from our lakes, ponds, dam lakes and rivers, we have to know the characteristics of these waters and the algae which are the first link of the food chain with regards to ecology and taxonomy (Kramer and Botterweg, 1991). In comparison with natural lakes and marshes, dam lakes have the following features: (1) the water level varies irregularly, which physically destabilizes the lake shoreline, and (2) the hydrogeological structure of dam lakes is complicated and could change easily because the water level is regulated artificially (Nakashima et al., 2007). In recent years, activities to preserve the water quality and ecosystem of dam lakes have been encouraged. For example, research on the classification of the water quality of dam lakes (De Ceballos et al., 1998) and the effects of its use on land have been carried out (Bhuyan et al., 2003; Brainwood et al., 2004).

In this study, the physicochemical, toxicological and ecological parameters of Gökçekaya Dam Lake's water, which is situated on Sakarya River were examined. The selected area has different characteristics from the others. This lake is situated between two other dam lakes on Sakarya River. The main water of the lake comes from Sakarya Dam. During the years 2005-2006, water samples were taken from the lake surface and depths in seasonal periods, and the physical, chemical and biological parameters were examined to determine the modifications in the quality of water. The changes in the quality of water will be monitored for 4 years. In this article, the quality changes in seasonal periods in a year are given and the water quality of the Lake is determined. The changing quality of the water by the years is presently being monitored.

*Corresponding author. E-mail: bsakin@gazi.edu.tr. Tel: +90 312 2028214 Fax: +90 312 222 8483.

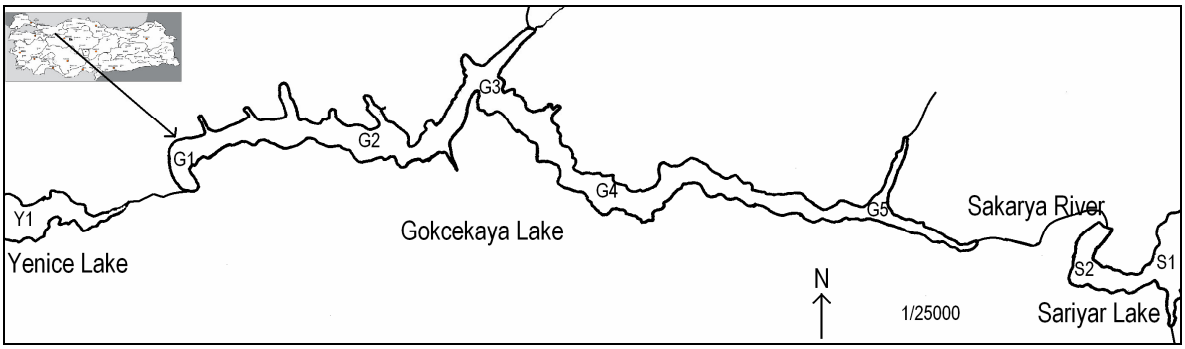


**Figure 1.** Locations of study area and sampling sites on the Gökçekaya, Sarıyar and Yenice Dam Lakes.

**Table 1.** The technical features of Gökçekaya, Sarıyar and Yenice Dam Lakes.

| Feature | Gökçekaya | Sarıyar | Yenice |
|---|---|---|---|
| Location of the dam | Eskişehir | Ankara | Eskisehir |
| River | Sakarya | Sakarya | Sakarya |
| Type | Concrete | Concrete | Soil |
| Height (from foundation) | 115.00 m | 90.00 m | 33.10 m |
| Lake volume | 910.00 $hm^3$ | 1 900.00 $hm^3$ | 57.60 $hm^3$ |
| Lake area | 20.00 $km^2$ | 83.83 $km^2$ | 3.64 $km^2$ |

## MATERIALS AND METHODS

### Study area

Gökçekaya Dam is built to produce hydro-electrical energy in the territories of Eskişehir. The water comes to the Lake from Sarıyar Dam Lake from the upper side. Gökçekaya Dam is situated between Sarıyar Dam Lake and Yenice Dam Lake (Figure 1). The water flows from Gökçekaya Dam Lake to Yenice Dam Lake. The technical features of the 3 lakes are given in Table 1.

The climate of the project site is continental. It is hot and dry in summer and cold and rainy in winter. With the microclimate effects of the lakes, winters are comparatively mild in the region. The topographic structure of the area is mostly hilly, so the rain and snow waters run into the lakes from the surface in a short time. And they carry a lot of clay into the lakes. The soil around the lakes is mostly volcanic. Gökçekaya Dam Lake is situated on the valley which is parallel to Sündiken Mountains. Pine forests on the slope of the hill, wild life and little villages have protected the natural life in the area.

### Sampling

The eight sampling sites were selected: G1, G2, G3, G4, G5 (on the Gökçekaya Dam Lake); S1, S2 on the Sakarya Dam Lake (input to Gökçekaya); Y1 on the Yenice Dam Lake (output from Gökçekaya) (Table 2). Water samples were collected at 0.5 m under the water surface and at full depth. The study was conducted over a period of 1 year (between 2005 and 2006). Sampling was done on a seasonal basis. Locations of the sampling stations are shown in Figure 1.

### Analytical methods

Intellect temperature, electrical conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS), pH and salinity parameters were measured on the designated station points using YSI 6600 multi-parameter water quality probe on the surface of the lake, and in the deep. On territorial studies, the samples taken from every station point were protected in special sample boxes with requisite prevention processing. The biological parameters were measured in Gazi University Laboratory of Algae Culture, and the physical and chemical parameters were measured in Hacettepe University, Laboratory of Research and Application on Hydro-geology according to Standard Methods (APHA, 1989).

## RESULTS AND DISCUSSION

### Physicochemical parameters

The annual average values of seasonal changes of physicochemical parameters of Gökçekaya Dam Lake are given in Table 3. The water of Gökçekaya Dam Lake comes from another Dam Lake, Sarıyar. On G4 and G5 station points the DO and the thermal parameters are lower than the others, because the coming water to the lake is not fresh water. In general, the EC values are between0.55 - 1.22 mS/cm, and the pH values are from 8.9 - 7.4. With increasing depth, the DO concentration in the water falls under 0.5 mg/l.

The annual average values of seasonal changes of chemical parameters of Gökçekaya, Sarıyar and Yenice Dam Lakes are given in Table 4. It is seen that there is no considerable change in the values within a year for each lake. But in the reservoirs (G1, G2, S1, S2) the fluorine concentration is lower than the other station

**Table 2.** Coordinates of the water sample points.

| Lake Name | Sample point | Coordinates | Height from sea (m) | Average depth (m) |
|---|---|---|---|---|
| Gökçekaya Dam Lake | G1 | 40° 01' 21N 31° 00' 55E | 385 | 96 |
| | G2 | 40° 03' 10N 31° 04' 55E | 387 | 50 |
| | G3 | 40° 04' 53N 31° 07' 24E | 379 | 45 |
| | G4 | 40° 02' 52N 31° 11' 56E | 393 | 50 |
| | G5 | 40° 03' 38N 31° 17' 34E | 392 | 12 |
| Sarıyar Dam Lake | S1 | 40° 01' 45N 31° 27' 05E | 469 | 58 |
| | S2 | 40° 01' 12N 31° 24' 28E | 486 | 60 |
| Yenice Dam Lake | Y1 | 40° 02' 16N 30° 55' 10E | 274 | 13.5 |

**Table 3.** The annual average values of seasonal changes of Physicochemical parameters of Gökçekaya Dam Lake.

| Sample point | Depth (m) | Temp (°C) | EC (mS/cm) | TDS (g/l) | Salinity (ppt) | DO (mg/l) | pH |
|---|---|---|---|---|---|---|---|
| G1 | 0.5 (surface) | 15.70 | 0.60 | 0.50 | 0.38 | 10.57 | 8.03 |
| | 10 | 15.64 | 0.60 | 0.50 | 0.38 | 9.46 | 8.01 |
| | 20 | 12.24 | 0.88 | 0.70 | 0.54 | 4.11 | 8.21 |
| | 30 | 11.45 | 0.88 | 0.71 | 0.54 | 3.42 | 8.11 |
| | 40 | 8.50 | 0.89 | 0.73 | 0.56 | 2.10 | 7.80 |
| | 50 | 7.12 | 0.88 | 0.74 | 0.57 | 1.55 | 7.71 |
| | 60 | 6.73 | 0.88 | 0.74 | 2.29 | 0.88 | 7.65 |
| | 70 | 6.33 | 0.95 | 0.75 | 0.58 | 0.50 | 7.66 |
| | 80 | 6.77 | 1.21 | 0.79 | 0.60 | 0.21 | 7.59 |
| | 95 (bottom) | 6.76 | 1.22 | 0.79 | 0.61 | 0.25 | 7.40 |
| G2 | 0.5 (surface) | 15.84 | 0.86 | 0.68 | 0.51 | 12.83 | 8.40 |
| | 10 | 12.94 | 0.82 | 0.69 | 0.53 | 4.47 | 8.19 |
| | 20 | 12.14 | 0.80 | 0.69 | 0.53 | 3.46 | 8.11 |
| | 30 | 11.38 | 0.83 | 0.70 | 0.54 | 2.98 | 8.08 |
| | 40 | 8.39 | 0.77 | 0.73 | 0.56 | 2.01 | 7.80 |
| | 50 | 7.13 | 0.75 | 0.73 | 0.57 | 1.63 | 7.70 |
| | 60 | 7.11 | 0.71 | 0.71 | 0.55 | 1.76 | 7.73 |
| | 70 | 7.12 | 0.74 | 0.73 | 0.56 | 0.28 | 7.62 |
| | 80 (bottom) | 6.93 | 0.75 | 0.74 | 0.57 | 0.27 | 7.58 |
| G3 | 0.5 (surface) | 16.00 | 0.55 | 0.67 | 0.51 | 1.90 | 8.92 |
| | 10 | 13.57 | 0.83 | 0.69 | 0.53 | 5.30 | 8.35 |
| | 20 | 12.13 | 0.80 | 0.69 | 0.53 | 3.93 | 8.16 |
| | 30 | 10.95 | 0.79 | 0.70 | 0.54 | 2.29 | 8.03 |
| | 40 | 8.21 | 0.77 | 0.73 | 0.57 | 1.25 | 7.71 |
| | 45 (bottom) | 7.27 | 0.75 | 0.73 | 0.56 | 1.17 | 7.68 |
| G4 | 0.5 (surface) | 15.49 | 0.54 | 0.67 | 0.51 | 1.25 | 8.79 |
| | 10 | 13.27 | 0.81 | 0.68 | 0.52 | 6.22 | 8.52 |
| | 20 | 12.00 | 0.79 | 0.68 | 0.52 | 4.62 | 8.30 |
| | 30 | 11.18 | 0.78 | 0.69 | 0.53 | 2.57 | 8.02 |
| | 40 | 8.35 | 0.76 | 0.73 | 0.56 | 1.35 | 7.71 |
| | 50 (bottom) | 7.12 | 0.74 | 0.73 | 0.56 | 1.14 | 7.59 |
| G5 | 0.5 (surface) | 14.39 | 0.84 | 0.69 | 0.52 | 1.43 | 8.77 |
| | 12 (bottom) | 11.07 | 0.78 | 0.68 | 0.52 | 5.70 | 8.39 |

**Table 4.** The average seasonal concentrations of the chemical parameters measured at (mg/l) sampling points at the surface of the Gökçekaya, Sarıyar and Yenice Dam lakes.

| Lake | Sample point | $F^-$ | $Cl^-$ | $Br^{+2}$ | $SO_4^{+2}$ | $CO_3^{+2}$ | $HCO_3^+$ | $Na^+$ | $K^+$ | $Mg^{+2}$ | $Ca^{+2}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gökçekaya | G1 | 3.71 | 86.11 | 0.056 | 227.95 | 6.7 | 250.13 | 83.72 | 7.14 | 45.36 | 79.85 |
| | G2 | 8.64 | 79.94 | 0.034 | 244.83 | 8.61 | 206.85 | 84.38 | 7.03 | 45.49 | 78.79 |
| | G3 | 15.57 | 68.61 | 0.038 | 205.25 | 12.22 | 201.55 | 81.92 | 7.19 | 43.61 | 77.02 |
| | G4 | 10.74 | 82.54 | 0.042 | 249.8 | 29.5 | 201.83 | 81.56 | 7.02 | 44.33 | 77.96 |
| | G5 | 11.56 | 64.07 | 0.048 | 198.17 | 11.03 | 219.43 | 66.68 | 5.72 | 37.76 | 88.92 |
| Sarıyar | S1 | 0.31 | 79.27 | 0.04 | 237.44 | 18.24 | 194.92 | 79.62 | 6.95 | 40.69 | 77.03 |
| | S2 | 5.91 | 81.98 | 0.05 | 237.86 | 16.55 | 181.51 | 76.46 | 6.68 | 40.61 | 11.58 |
| Yenice | Y1 | 13.97 | 73.74 | 0.02 | 235.49 | 30.05 | 186.35 | 87.05 | 7.65 | 45.8 | 80.87 |

**Table 5.** The average seasonal concentrations of the water quality parameters measured at sampling points at the surface of the Gökçekaya, Sarıyar and Yenice Dam lakes.

| Lake | Sample point | Turbidity (NTU) | Hardness ($FS^o$) | TSS (mg/l) | $NH_4^+$ (ppm) | $NO_2$ (ppm) | $NO_3^-$ (ppm) | $PO_4^{-2}$ (ppm) | COD (mg/l) |
|---|---|---|---|---|---|---|---|---|---|
| Gökçekaya | G1 | 0.54 | 38.57 | 2.39 | 0 | 0 | 3.01 | 0 | 19.23 |
| | G2 | 0.52 | 38.36 | 2.08 | 0 | 0 | 2.44 | 0 | 15.86 |
| | G3 | 0.40 | 37.15 | 3.59 | 0 | 0 | 5.36 | 0 | 20.36 |
| | G4 | 0.91 | 37.68 | 73.38 | 0 | 0 | 6.71 | 0 | 22.00 |
| | G5 | 4.54 | 37.71 | 12.63 | 0 | 0 | 4.79 | 0 | 31.43 |
| Sarıyar | S1 | 1.06 | 35.95 | 3.46 | 0.49 | 0 | 3.91 | 0 | 21.7 |
| | S2 | 0.54 | 36.05 | 7.76 | 1.37 | 0.12 | 2.08 | 0 | 19.5 |
| Yenice | Y1 | 0.19 | 38.93 | 4.61 | 0.46 | 0 | 2.79 | 0 | 22.6 |

points. The chemical parameters of the three lakes are defined as normal in consideration of the soil of the area.

The values of pollution analyses of the three lakes are given in Table 5. The annual average value of the phosphorus concentration of every three lakes is defined as zero. These results show that the lake is poor in terms of phosphate. While the annual average value of ammonium is 0 - 1.37 mg/l $NH_4^+$ and nitrite is 0 - 0.12 in Sarıyar and Yenice, they are zero in Gökçekaya. However, these amounts are still lower than the limit for eutrophication. In each of the three lakes, the nitrate concentrations change with seasonal periods (6.7 - 2.1 mg/l $NO_3$). As the limiting nutrient for eutrophication is usually the phosphate concentration, there is also no danger in terms of nitrogen contained in the lake.

## Biological parameters

The chlorophyll-*a* values and algae types specified on the station points of Gökçekaya Dam Lake in terms of seasonal periods are given in Table 6. It can be seen that the chlorophyll types and the amount of Chl-*a* increases in springtime naturally. The variety of Bacilariophyta members is not much, but as a population they are crowded.

In summer, algae are eaten by zooplankton and their population is decreased. As a result of this, they lose their biological efficiency. The breakdown of the circulation in the Dam Lake supports the situation. With the changing climate, the decrease in the number of organisms leads to a decrease in Chl-*a* value. Similar circumstances are seen in lakes on the northern hemisphere (Hutchinson, 1967; Moss, 1998).

In autumn, the breeds of Ceratium, Microcystis, Scenedesmus, Nitzschia, Synedra are seen more frequently. And also the value of Chl-*a* decreases slightly (Youngman, 1978).

In winter Bacillariophyta and its breeds are rarely seen in cold weather. In this study, when the Chl-*a* values are considered, the Gökçekaya Dam Lake has a mesotrophic structure, but if the pollution in the waters coming to the lake increases, the structure may become eutrofic.

**Table 6.** The chlorophyll-a values and algae specified on Gökçekaya Dam Lake in terms of seasonal periods.

| Sample point | *Algae* | Chl-a (µg/l) |
|---|---|---|
| G1 | CYANOPHYTA *Chroococcus turgidus*, *Gleocapsa* sp., *Merismopedia* sp., *Microcystis aeruginosa, Microcystis floss-aqua, Microcystis* sp. *Nostoc* sp., *Oscillatoria* sp. CHLOROPHYTA *Choleralla vulgaris, Eudorina elegans, Dictyosphaerium pulchellum, Keratococcus* sp., *Oocystis* sp., *Pediastrum dublex, Scenedesmus quadricauda, Scenedesmus acutus, Scenedesmus* sp., *Selenastrum gracile, Staurastrum* sp. BACILLARIOPHYTA *Amphora ovalis, Cyclotella ocellata, Gomphonema* sp., *Navicula pupula, Navicula tuscula, Nitzschia linearis, Synedra ulna* EUGLENOPHYTA *Euglena viridis* | 3.209 |
| G2 | CYANOPHYTA *Chroococcus turgidus,, Microcystis aeruginosa, Microcystis floss-aqua, Nostoc* sp. CHLOROPHYTA *Choleralla vulgaris, Chlamydomonas* sp, *Eudorina elegans, Dictyosphaerium pulchellum, Dimorphococcus lunatus, Keratococcus* sp., *Oocystis* sp. *Pediastrum dublex, Scenedesmus quadricauda, Scenedesmus acutus, Scenedesmus* sp., *Selenastrum gracile, Sphaerocystis schroeteri, Staurastrum* sp. BACILLARIOPHYTA *Gyrosigma acuminatum, Hantzschia amphioxys, Navicula tripunctata, Neidium dubium, Nitzschia hungarica, Synedra Navicula pupula, Nitzschia linearis, Synedra ulna* | 3.3615 |
| G3 | CYANOPHYTA *Chroococcus turgidus, Gleocapsa* sp., *Microcystis floss-aqua, Microcystis* sp. *Nostoc* sp., *Oscillatoria sp. Lyngbya* sp. CHLOROPHYTA *Choleralla vulgaris, Chlamydomonas* sp, *Eudorina elegans, Dimorphococcus lunatus, Pediastrum dublex, Scenedesmus quadricauda, Scenedesmus acutus, Scenedesmus* sp., *Selenastrum gracile,* BACILLARIOPHYTA *Cyclotella ocellata, Cymbella cymbiformis, Gomphonema* sp.,*Melosira varians, Navicula pupula, Navicula tuscula, Nitzschia linearis, Synedra ulna* | 2.45 |
| G4 | CYANOPHYTA *Gleocapsa* sp., *Microcystis aeruginosa, Microcystis floss-aqua, Microcystis* sp. *Nostoc* sp., *Oscillatoria* sp. CHLOROPHYTA *Choleralla vulgaris, Chlamydomonas* sp, *Eudorina elegans, Dictyosphaerium pulchellum, Keratococcus* sp., *Oocystis* sp. *Scenedesmus quadricauda, Scenedesmus acutus, Scenedesmus* sp., *Selenastrum gracile, Staurastrum* sp. BACILLARIOPHYTA *Amphora ovalis, Cyclotella ocellata, Cymbella cistula, Gomphonema* sp., *Navicula pupula, Navicula tuscula, Nitzschia linearis, Synedra ulna* CHRYSOPHYTA *Ceratium hirundinella* | 2.88 |
| G5 | CYANOPHYTA *Microcystis aeruginosa, Microcystis floss-aqua, Microcystis sp. Nostoc sp., Oscillatoria sp.* CHLOROPHYTA *Choleralla vulgaris, Chlamydomonas* sp, *Eudorina elegans, Dictyosphaerium pulchellum, Dimorphococcus lunatus, Keratococcus* sp., *Oocystis* sp. *Pediastrum dublex, Scenedesmus quadricauda, Scenedesmus acutus. Scenedesmus* sp., *Selenastrum gracile, Sphaerocystis schroeteri, Staurastrum* sp. BACILLARIOPHYTA *Amphora ovalis, Cyclotella ocellata, Navicula pupula, Navicula tuscula, Nitzschia linearis, Synedra ulna* CHRYSOPHYTA *Ceratium hirundinella* | 2.974 |

## Conclusion

Gökçeya Dam Lake, which is not fed by fresh water, has been monitored and its qualities have been defined in terms of physical, chemical and biological parameters in seasonal periods. It is seen that the nutrient level of the lake is poor and the physical and chemical parameters do not change in the annual average. The nitrogen and phosphorus values are fairly low with regards to depth and seasonal changes, and the temperature and DO values are decreased. In consideration of the chlorophyll-a values and algae on the station points of Gökçekaya dam Lake, we may conclude that the lake is mesotrophic.

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