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Phytoplankton Dynamics and Some Physicochemical Variables in Cakmak Reservoir (Samsun, Turkey)

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Abstract Phytoplankton dynamics and some physicochemical properties of Cakmak Reservoir were investigated between May 2003 and April 2005 which is used for irrigation and drinking water supply. A total of 132 taxa were identified belonging to the following divisions; Cyanobacteria, Charophyta, Chlorophyta, Cryptophyta, Euglenozoa, Myzozoa and Ochrophyta. Although Ochrophytes were rich in respect to species diversity, Chlorophytes attained a larger population density. *Ulnaria ulna*, *Fragilaria tenera* and *Goniochloris mutica* from Ochrophyta, *Chlorella vulgaris*, *Monoraphidium obtusum* and *Ulothrix tenerrima* from Chlorophyta, *Cryptomonas ovata* and *C. erosa* from Cryptophyta increased in some months. The seasonal variation of phytoplankton based on depth was compatible with surface water. Phytoplankton abundance was lower in winter and there was an increase in summer in Cakmak Reservoir. The reservoir water was slightly alkaline according to the pH; was alkaline according to the calcium; was in the slightly hard water group according to the hardness values; had low and medium productivity degree according to the phosphorus.

Keywords *Phytoplankton, reservoir, seasonal variation, water properties;*

Özet İçme suyu temini ve sulama amaçlı kurulan Çakmak Baraj Gölü'nün fitoplankton dinamiği ve bazı fizikokimyasal özellikleri Mayıs 2003 - Nisan 2005 tarihleri arasında incelenmiştir. Cyanobacteria, Charophyta, Chlorophyta, Cryptophyta, Euglenozoa, Myzozoa ve Ochrophyta divizyolarına ait 132 takson tespit edilmiştir. Ochrophyta divizyosu tür çeşitliliği açısından zengin olmasına rağmen Chlorophyta divizyosunun populasyon büyüklüğü daha fazladır. Ochrophyta divizyosundan *Ulnaria ulna*, *Fragilaria tenera* ve *Goniochloris mutica*, Chlorophyta divizyosundan *Chlorella vulgaris*, *Monoraphidium obtusum* ve *Ulothrix tenerrima*; Cryptophyta divizyosundan *Cryptomonas ovata* ve *C. erosa* türlerinin bazı aylarda sayıca arttığı gözlenmiştir. Derinlik örneklerinde fitoplanktonun mevsimsel değişimi yüzey suyu örnekleri ile benzer mevsimsel değişim göstermiştir. Çakmak Baraj Gölü'nde fitoplankton bolluğu kışın daha düşük iken yaz aylarında artış kaydedilmiştir. Baraj suyunun pH değerlerine göre hafif alkali iken kalsiyum değerlerine göre alkali olduğu; sertlik değerlerine göre hafif sert sular grubunda; fosfor değerlerine göre ise düşük ve orta verimlilik derecesine sahip olduğu belirlenmiştir.

Anahtar sözcükler: Fitoplankton, baraj gölü, mevsimsel değişim, su kalitesi;

1. INTRODUCTION

In order to control flood events and water utilization, reservoir construction is essential in human life. Water quality is a critical factor for its utilization. Therefore, to use water efficiently from a reservoir, water quality monitoring and evaluation are needed [1]. Anthropogenic influences and natural processes impair their use for drinking, industrial, agricultural, recreation or other purposes [2].

Water quality affects species composition, abundance and the physiological status of aquatic species. Studies have shown that most algae are sensitive to changing environmental conditions. Planktonic organisms respond promptly to environmental changes and exhibit more conservative characteristics than physical and chemical variables [3]. The sustainability of aquatic ecosystems can be provided with an effective ecological management of resources and accurate monitoring. According to the Water Framework Directive (WFD), it requires an emphasis on local conditions. WFD's aim is the prevention of further destructions of aquatic ecosystems and other ecosystems, the improvement of the aquatic environment, long-term protection of existing water resources and it also aims to promote the sustainable use of water resources and to reduce the pollution in groundwater [4].

There is no phycological study on Cakmak Reservoir. The aim of this study is to summarize structure of phytoplankton community and to determine water quality in Cakmak Reservoir used for irrigation and drinking water supply.

2. MATERIALS and METHODS

Cakmak Reservoir is located in the south east of Samsun in Turkey (41˚ 44' and 40˚ 05' N; 37˚ 05' and 35˚ 30' E). It was established on River Abdal between 1985 and 1988 in order to ensure drinking water and use it for industrial purposes; the active storage volume is 76 hm^3 and the area is 6.5 km^2 and the highest water level is 122.75 m. It has approximately 5 km length and 1-1.5 km width [5].

Four stations were selected in order to determine phytoplankton dynamics, its seasonal variation and physicochemical properties of water (Figure 1). Water samples were collected from stations, monthly. The water samples were collected with Hydro-Bios Nansen water sampler. Samples were preserved in formaldehyde that will result in concentration of 4%. Phytoplankton were identified and counted at 400X magnification using the method of Utermohl [6] under Prior inverted microscope. The results were calculated according to method of Lund *et al*. [7]. Diatoms were prepared according to the method of Round [8]. Physicochemical variables described below were measured in surface water samples taken from the station 1. The conductivity, temperature, dissolved oxygen and pH were measured with Consort C534 sampling equipment and water transparency was measured with a secchi disc. The ammonia-N, nitrite-N, nitrate-N, bicarbonate, calcium, total hardness, magnesium, ortho-phosphate, sulfate and organic matter analyses were determined according to the standard methods at DSI VII. Quality Control Laboratory [9].

Algal species were identified according to the following: Anagnostidis and Komárek [10], Komárek and Anagnostidis [11-13], Hartley [14], Krammer and Lange-Bertalot [15-18], John *et al*. [19], Wehr and Sheath [20], Krammer [21], Tsarenko *et al*. [22]. All taxa were also checked on the algaebase web site [23].

3. RESULTS and DISCUSSION

Cakmak Reservoir is used for irrigation and drinking water supply. Phytoplankton dynamics and some physicochemical properties of the reservoir were investigated between May 2003 and April 2005. A total of 132 taxa were identified belonging to the following divisions; Cyanobacteria (16), Charophyta (10), Chlorophyta (27), Cryptophyta (2), Euglenozoa (17), Myzozoa (6) and Ochrophyta (54). The taxa identified in Cakmak Reservoir were given in Table 1.

Throughout the investigation period, conductivity, temperature, dissolved oxygen, pH, water transparency, ammonia-N, nitrite-N, nitrate-N, bicarbonate, calcium, total hardness, magnesium, ortho-phosphate, sulfate and organic matter analyses were measured and presented in Table 2.

The temperature which is important for aquatic organisms influences many chemical and biological processes [24]. The temperature was measured between 9.4 °C and 25.6 °C in surface water samples. Fogg and Thake [25] reported that phytoplankton abundance in temperate lakes is low in winter even if there are sufficient nutrients, low temperature and low light intensity. Phytoplankton abundance in reservoir was lower in winter and there was an increase in summer. According to the average secchi disc depth (115 cm), the trophic state of the reservoir has eutrophy [26]. The pH (7.2 to 8.6) indicated that the reservoir water was slightly alkaline. The measured pH values were within the range (6.5-9.0) of freshwater aquatic life [27]. pH measured in the lakes of the Black Sea Region also showed slight alkaline properties [28-29]. The water conductivity (77-104 µmhos cm^{-1}) was between limit values in natural waters according to Boyd [30]. The nitrite-N, nitrate-N and ammonia-N concentrations were determined as 0.000 to 0.084 mg l^{-1}, 0.04 to 1.35 mg l^{-1} and 0.00 to 1.50 mg l^{-1}, respectively. Horne and Goldman [31] reported nitrate and ammonia are low concentrations in natural water and nitrite is too low due to the nitrate conversion in the presence of oxygen. According to measured values (0.00 to 0.06 mg l^{-1}) of phosphorus, the reservoir was between low and medium productivity degrees [32]. The reservoir water hardness was ranged from 137.5 to 212.5 ^{o}FS and in terms of these results, the reservoir water was in the slightly hard water group [33]. Bicarbonate values varied between 113 mg l^{-1} and 203 mg l^{-1} and the calcium levels were determined between 39 mg l^{-1} and 60 mg l^{-1}. Presence of high concentrations of calcium indicated that water showed alkaline character. Low Mg concentrations affect the productivity of phytoplankton in lakes and thus the reservoir (6.7-15.2 mg l^{-1}) has oligotrophic character [33]. The concentration of sulfate in natural waters varied from a few mg l^{-1} to several hundred mg l^{-1} [34]. Sulfate concentrations of reservoir water were measured between 1.9 mg l^{-1} and 59.0 mg l^{-1}.

The most common taxonomic group in phytoplankton was Ochrophyta, occupying the 40% of the diversity among the taxonomic groups as in most of the algological studies in our country [29, 35, 36]. Centric diatoms are described as planktonic organisms by Round [37]. *Cyclotella* species were present in all seasons. *Cyclotella meneghiniana* and *Melosira* spp. are often present in oligotrophic lakes. Among pennate diatoms, *Ulnaria ulna* was over reproduction in the winter. This species is characteristic for eutrophic lakes [38], however it has also been dominant in oligotrophic lakes [39, 40]. The identified species in reservoir *Fragilaria*, *Amphora*, *Nitzschia* and *Navicula* were found in neutral and slightly alkaline waters and *Amphora ovalis*, *Navicula cryptocephala* existed in alkaline waters [41].

Chrysophyceae was represented by *Dinobryon sertularia* in the reservoir. This species was dominant in early autumn and winter. Rawson [42] stated that it was accepted as an indicator of oligotrophic lakes. *Chlorella vulgaris* and *Monoraphidium obtusum* from chloropyhtes increased in number during summer months and *Pediastrum* was represented by 1 species. Legnerova [43] reported that *Monoraphidium* species are common in oligotrophic and mesotrophic lakes while *Pediastrum* members are characteristic of mesotrophic lakes. Charophyta was represented by 10 species in Cakmak Reservoir. *Cosmarium* and *Closterium* are usually present in oligotrophic lakes [37, 38, 42]. *Cosmarium* species are often present in Cakmak Reservoir. *Ceratium* spp. from Myzozoa were observed commonly in phytoplankton. *Ceratium hirundinella* reached significant numbers in the autumn. *C. hirundinella* can be found in oligotrophic and eutrophic lakes and almost all over the world distribution [19]. Myzozoa members were commonly found in spring and autumn and rare in winter in the reservoir. In our country, it was found to be common as well [44]. *Peridinium cinctum* was characteristic dinoflagellate of eutrophic and mezotrophic lakes and this species can be found in many different environments [42]. Reynolds [45] stated that most species are abundant in epilimnion, while dinoflagellates are adapted to deeper waters. Dinoflagellate and ochrophyte density were increased in phytoplankton in Cakmak Reservoir. Euglenozoa members were more abundant in polluted waters [46]. However Euglenozoa members were found in the most of the oligotrophic reservoirs in our country [28, 44, 47].

The seasonal variation in the water column was generally shown as an adjustment to the seasonal change in the surface water in Cakmak Reservoir phytoplankton. The abundance of Chlorophyta and Cyanobacteria descended through deeper water while Ochrophyta and Myzozoa increased. Since light cannot reach to the deep, photosynthetic algae existed near the surface, whereas the heterotrophic or mixotrophic organisms were able to distribute in deeper water levels.

The reservoir water was unpolluted according to the average dissolved oxygen concentration; was slightly alkaline according to pH; was alkaline according to calcium concentration and was in the slightly hard water group according to hardness values. The trophic state of the reservoir had eutrophic character according to the average secchi disc depth, while it was between low and medium productivity degrees according to phosphorus concentration and had oligotrophic character according to Mg concentrations. Furthermore, morphometric structure of the lake, poor aquatic macrophytes, water color ranging from blue to blue-green and phytoplankton dynamics have been supporting that the lake had oligotrophic character.

4. TABLES

Table 1. The taxa identified in Cakmak Reservoir

Divisio	**:Cyanobacteria**
Class	**:Cyanophyceae**
Aphanocapsa incerta (Lemmermann) Cronberg & Komárek	
Chroococcus minor (Kützing) Nägeli	
Chroococcus pallidus Nägeli	
Chroococcus turgidus (Kützing) Nägeli	
Gloeothece linearis Nägeli	
Gomphosphaeria aponina Kützing	
Limnococcus limneticus (Lemmermann) Komárková, *et. al.*	
Merismopedia elegans A. Braun ex Kützing	
Merismopedia glauca (Ehrenberg) Kützing	
Merismopedia punctata Meyen	
Microcystis aeruginosa (Kützing) Kützing	
Oscillatoria tenuis C. Agardh ex Gomont	
Spirulina major Kützing ex Gomont	
Spirulina princeps West & G. S. West	
Spirulina subsalsa Oerstedt ex Gomont	
Wollea saccata (Wolle) Bornet & Flahault	
Divisio	**:Charophyta**
Class	**:Zygnematophyceae**
Closterium acutum Brébisson	
Closterium dianae Ehrenberg ex Ralfs	
Closterium moniliferum Ehrenberg ex Ralfs	
Cosmarium bioculatum Brébisson ex Ralfs	
Cosmarium formosulum Hoff	
Cosmarium granatum Brébisson ex Ralfs	
Cosmarium laeve Rabenhorst	
Spirogyra varians (Hassall) Kützing	
Spirogyra weberi Kützing	
Staurastrum gracile Ralfs ex Ralfs	
Divisio	**:Chlorophyta**
Class	**:Chlorocophyceae**
Acutodesmus obliquus (Turpin) Hegewald & Hanagata	
Ankistrodesmus falcatus (Corda) Ralfs	
Asterococcus sp.	
Chlamydomonas globosa J. W. Snow	
Coelastrum microporum Nägeli	
Desmodesmus abundans (Kirchner) E. Hegewald	
Desmodesmus communis (E. H. Hegewald) E. H. Hegewald	
Monoraphidium griffithii (Berkeley) Komárková-Legnerová	

Monoraphidium minutum (Nägeli) Komárková-legnerová
Monoraphidium obtusum (Korshikov) Komárková-Legnerová
Monactinus simplex (Meyen) Corda
Pediastrum duplex Meyen
Pseudocharacium obtusum (A. Braun) Petry-Hesse
Pseudopediastrum boryanum (Turpin) E. Hegewald
Raphidocelis subcapitata (Korshikov) G. Nygaard *et. al.*
Scenedesmus ecornis (Ehrenberg) Chodat
Scenedesmus obtusus Meyen
Scenedesmus verrucosus Y. V. Roll
Selenastrum gracile Reinsch
Stauridium privum (Printz) E. Hegewald
Tetraedron minimum (A. Braun) Hansgirg
Tetrastrum komarekii Hindák

Class :Trebouxiophyceae

Botryococcus braunii Kützing
Chlorella vulgaris Beyerinck [Beijerinck]
Gloeotila subconstricta (G. S. West) Printz
Oocystis borgei J. Snow

Class :Ulvophyceae

Ulothrix tenerrima (Kützing) Kützing

Divisio :Cryptophyta

Ordo :Cryptophyceae

Cryptomonas erosa Ehrenberg
Cryptomonas ovata Ehrenberg

Divisio :Euglenozoa

Class :Euglenophyceae

Astasia shadowskii Korshikov
Euglena clavata Skuja
Euglena elongata Schewiakoff
Euglena gracilis Klebs
Euglena oxyuris Schmarda f. *skvortzovii* (Popowa) Popowa
Euglena retronata L. P. Johnson
Euglena splendens P. A. Dangeard
Lepocinclus oxyuris (Schmarda) Marin & Melkonian
Phacus acuminatus Stokes
Phacus caudatus Hübner
Phacus longicauda (Ehrenberg) Dujardin var. *rotunda* (Pochmann) Huber-Pestalozzi
Strombomonas verrucosa (E. Daday) Deflandre
Trachelomonas crebea Kellicott var. *brevicollis* Prescott
Trachelomonas hispida (Perty) F. Stein
Trachelomonas inflata Skvortzov var. *crenulatocollis* Skvortzov
Trachelomonas oblonga Lemmermann var. *pulcherrima* (Playfair) Popova
Trachelomonas volvocina (Ehrenberg) Ehrenberg

Divisio :Myzozoa

Class :Dinophyceae

Ceratium furcoides (Levander) Langhans
Ceratium hirundinella (O. F. Müller) Dujardin
Ceratium hirundinella var. *silesiacum* (Schroeder) Huber-Pestalozzi
Peridiniopsis thompsonii (Thompson) Bourrelly
Peridinium aciculiferum Lemmermann
Peridinium cinctum (O. F. Müller) Ehrenberg

Divisio :Ochrophyta

Class :Bacillariophyceae

Amphora ovalis (Kützing) Kützing
Asterionella formosa Hassall
Aulacoseira granulata (Ehrenberg) Simonsen
Aulacoseira granulata var. *angustissima* (O. F. Müller) Simonsen
Aulacoseira islandica (O. F. Müller) Simonsen
Brachysira brebissonii R. Ross
Caloneis dubia Krammer
Cocconeis pediculus Ehrenberg
Cocconeis placentula Ehrenberg
Cocconeis placentula var. *klinoraphis* Geitler
Coscinodiscus rothii (Ehrenberg) Grunow
Cyclotella meneghiniana Kützing
Cyclotella ocellata Pantocsek

Cymatopleura solea (Brébisson) W.Smith
Cymbella affinis Kützing
Diatoma anceps (Ehrenberg) Grunow
Diatoma vulgaris Bory de Saint-Vincent
Discostella glomerata (H.Bachmann) Houk & Klee
Encyonema minutum (Hilse) D. G. Mann
Encyonema prostratum (Berkeley) Kützing
Eunotia pectinalis (Kützing) Rabenhorst
Fragilaria tenera (W. Smith) Lange-Bertalot
Fragilariforma virescens (Ralfs) D. M. Williams & Round
Gomphonema clavatum Ehrenberg
Gomphonema truncatum Ehrenberg
Gyrosigma acuminatum (Kützing) Rabenhorst
Gyrosigma macrum (W. Smith) J. W. Griffith & Henfrey
Halamphora normanii (Rabenhorst) Levkov
Hantzschia amphioxys (Ehrenberg) Grunow
Luticola obligata (Hustedt) D. G. Mann
Melosira varians C. Agardh
Navicula cincta (Ehrenberg) Ralfs
Navicula cryptocephala var. *veneta* (Kützing) Rabenhorst
Navicula longicephala Hustedt
Navicula radiosa Kützing
Navicula rhynchocephala Kützing
Neidium bisulcatum (Lagerstedt) Cleve var. *subampliatum* Krammer
Neidium iridis (Ehrenberg) Cleve
Nitzschia acicularis (Kützing) W. Smith
Nitzschia palea (Kützing) W. Smith
Pleurosigma angulatum (Queckett) W.Smith
Rhoicosphenia abbreviata (C. Agardh) Lange-Bertalot
Stauroneis anceps Ehrenberg
Surirella linearis W. Smith
Surirella ovalis Brébisson
Synedra camtschatica Grunow
Tabellaria fenestrata (Lyngbye) Kützing
Tabularia gaillonii (Bory de Saint-Vincent) Bukhtiyarova
Ulnaria acus (Kützing) M. Aboal
Ulnaria danica (Kützing) Compère & Bukhtiyarova
Ulnaria delicatissima (W. Smith) M. Aboal & P. C. Silva
Ulnaria ulna (Nitzsch) P. Compère

Class :Chrysophyceae

Dinobryon sertularia Ehrenberg

Class :Xanthophyceae

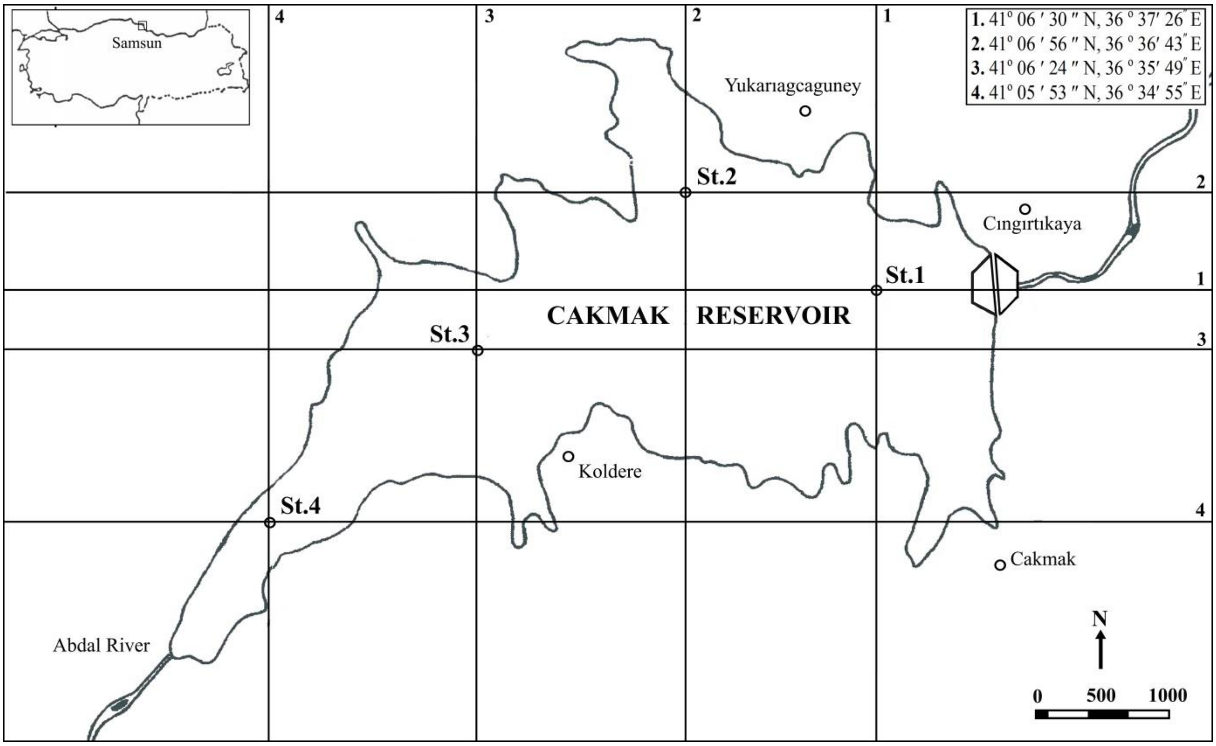
Goniochloris fallax Fott
Goniochloris mutica (A. Braun) Fott

Table 2. Physicochemical variables in surface water samples taken from the station 1 at Cakmak Reservoir

Analysis / Months	rature (°C)	ved oxygen (mg l⁻¹)		ctivity (µmhos/cm)	nia-N (mg l⁻¹)	-N (mg l⁻¹)	e-N (mg l⁻¹)	onate (mg l⁻¹)	m (mg l⁻¹)	ardness (°FS)	sium (mg l⁻¹)	phosphate (mg l⁻¹)	e (mg l⁻¹)	ic matter (mg l⁻¹)	transparency (cm)
May 03	17.9	6.5	8.4	94	0.60	0.000	1.02	143	45	162.5	12.3	0.00	25.9	1.92	210
June 03	25.5	4.3	8.3	104	0.40	0.003	0.04	158	43	142.0	9.7	0.01	21.6	1.56	70
July 03	25.0	4.6	8.5	98	0.10	0.000	0.55	165	46	158.0	12.2	0.02	50.4	1.84	100
August 03	24.8	4.6	8.6	98	0.05	0.007	0.05	170	42	165.0	12.0	0.02	33.6	1.56	80
September 03	22.6	5.0	8.3	96	0.15	0.038	0.11	138	39	142.5	10.9	0.06	13.0	1.76	120
October 03	17.0	6.8	7.8	92	0.00	0.001	0.24	138	40	157.0	14.0	0.03	13.0	1.60	90
November 03	12.4	8.7	8.0	92	1.50	0.084	0.55	150	45	175.0	15.2	0.05	31.7	2.04	150
December 03	11.9	9.0	8.2	92	0.20	0.003	0.40	145	46	156.5	14.6	0.04	27.4	1.98	240

January 04	9.8	11.1	7.9	82	0.10	0.004	0.90	155	48	188.0	9.9	0.02	51.8	1.75	90
February 04	9.4	11.2	7.5	77	0.15	0.006	0.60	163	56	185.0	10.9	0.03	26.4	1.84	90
March 04	11.2	9.2	8.2	92	0.05	0.003	0.60	168	55	197.5	14.6	0.00	30.7	1.68	75
April 04	12.5	8.6	8.1	82	0.00	0.003	0.80	203	59	200.0	12.8	0.03	2.4	1.96	90
May 04	18.1	6.0	7.8	90	0.00	0.010	0.30	140	46	175.0	10.2	0.00	7.7	1.64	180
June 04	25.0	4.6	8.4	98	0.05	0.008	0.35	155	50	155.0	7.3	0.00	1.9	1.80	90
July 04	25.4	4.5	8.5	96	0.20	0.006	1.04	158	52	167.5	9.7	0.01	21.6	1.64	60
August 04	22.5	5.2	8.0	96	0.05	0.003	0.55	165	58	212.5	12.2	0.00	50.4	1.92	80
September 04	18.3	6.0	7.2	99	0.00	0.013	0.20	145	39	142.5	10.9	0.01	2.9	1.68	130
October 04	14.4	8.0	7.6	97	0.15	0.000	0.55	155	42	155.0	12.2	0.02	4.3	1.36	90
November 04	13.1	8.3	8.1	98	0.00	0.003	0.70	160	45	145.0	12.8	0.03	19.7	1.22	120
December 04	11.0	10.2	7.8	96	0.00	0.006	0.70	158	60	190.0	12.4	0.01	33.6	1.44	180
January 05	10.0	11.0	7.2	97	0.05	0.000	0.60	113	44	137.5	6.7	0.00	23.5	1.56	130
February 05	12.2	8.8	8.2	94	0.20	0.000	0.60	158	54	187.5	12.8	0.00	33.1	1.64	100
March 05	16.6	7.5	8.1	101	0.00	0.040	1.05	133	58	187.5	10.3	0.01	59.0	1.68	75
April 05	18.0	5.9	7.9	94	0.05	0.005	1.35	163	52	187.5	13.9	0.01	28.8	0.64	120

5. FIGURE



Şekil 1. Geographic location of the Cakmak Reservoir and sampling stations

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