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Water pollution in Küçükçekmece Lake, İstanbul, Turkey

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ABSTRACT

Water samples collected in February and August 1997 from the Küçükçekmece Lake were analysed by ICPMS-200 to determine the heavy metal concentrations (i.e., Hg, Cd, Pb, As, Cu, Cr, Co, Ni, Zn, Fe, Mn, Se, Ba, Al, and U). A comparison of these data with those of 1985, 1989, and 1995 revealed Hg and U contamination in the northern region, whereas Pb, Cu and Se contamination in the southern region of the Küçükçekmece Lake. Besides, the influent waters were collected from the respective stream mouths, and were also analysed for heavy metal concentrations. The results showed the following contaminants: Hg, Se and U in the Ispartakule Stream, Hg, Cu and Se in the Sazli Stream, and Cu, Se and U in the Nakkaş Stream. On the other hand, a comparison of the results of February 1997 with those of August 1997 revealed that the amounts of As, Cu, Cr, Mn, Ba and Fe had decreased, but those of Pb, Ni, Zn and Se had increased in the lake since February 1997. Such kind of seasonal variation in concentration of heavy metals is attributed to pollution of the lake water by domestic waste, industrial effluents, and water-rock interactions.

INTRODUCTION

The Küçükçekmece Lake lies between the Avcılar and Küçükçekmece districts of İstanbul (Fig. 1). The waters of the Ispartakule, Nakkaş and Sazlı streams feed the lake. Its drainage basin covers an area of about 340 km^2 and receives annual mean rainfall of 700 mm. The Küçükçekmece Lake drains into the Marmara Sea in the south with mean annual discharge of 104 million m^3. The maximum depth of the lake is 21 m and the surface area is approximately 16.5 km^2. In the drainage basin, there are ten municipalities, one university campus (i.e., İstanbul University), one nuclear power station (ÇNAEM), and one customs' zone (i.e. Halkalı Customs). The population density in the drainage basin is 2275 persons per km^2.

GEOLOGY

The oldest lithostratigraphic unit found in the drainage basin of the Küçükçekmece Lake is the Trakya Formation of Lower Carboniferous age. It is composed of turbidites containing sandstone, siltstone, and shale.

The next succession is represented by the Kırklareli Formation and the Sazlıdere Formation of Eocene age. The Kırklareli Formation is represented by folded reef limestone. This unit covers a large area, and its typical outcrops are located near Arnavutköy, and in the vicinity of the dam across the Sazlı Stream. It is followed by the Sazlıdere Formation containing clay-bearing limestone.

The youngest succession of Oligocene-Miocene age is represented by the Gürpınar Formation, Çukurçeş me Formation, and the Bakırköy Formation, respectively from bottom to top. The Gürpınar Formation is composed of sandstone and limestone extending to 1 km south of Esenyurt with outcrops across the western parts of the Küçükçekmece Lake. The Çukurçeş me Formation is made up of silt, sand, and gravels exposed at the eastern and western parts of the Küçükçekmece Lake. And the Bakırköy Formation is a clay-bearing limestone unit (Pehlivan and Yılmaz 1998).

HEAVY METAL CONTAMINATION IN THE KÜÇÜKÇEKMECE LAKE WATER

The lake was fairly clean before 1985. Till that time, it was under the İstanbul Water and Sewerage Administration (ISKI). For the study of lake water pollution, a comparison of the data of 1989 and 1995 (ISKI 1996) was made with those of earlier than 1985 (DSİ 1985). It revealed that there existed artificial or man-made contamination other than the natural contamination in the lake. On the other hand, the data of February 1997 and August 1997 revealed also heavy metal contamination in the lake water.

For the study of heavy metal contamination, water samples were taken from various places of the Küçükçekmece Lake in February 1997 (Fig. 2). The samples were collected at depths of 0.5, 5, 10, and 15 m. The concentrations of Hg, Cd, Pb, As, Cu, Cr, Co, Ni, Zn, Fe, Mn, Se, Ba, Al, and U in the lake and stream waters (Tables 1, 2) were analysed at the laboratory of SGS-XRAL, Canada, with the analytical precision of 0.01 ppb.

The change in heavy metal content in the lake water samples indicates that there is Hg and U contamination in the northern region (location number 1 in Fig. 2), and Pb, Cu and Se contamination in the southern region (location number 3 in Fig. 2). Besides, the lake near the İspartakule

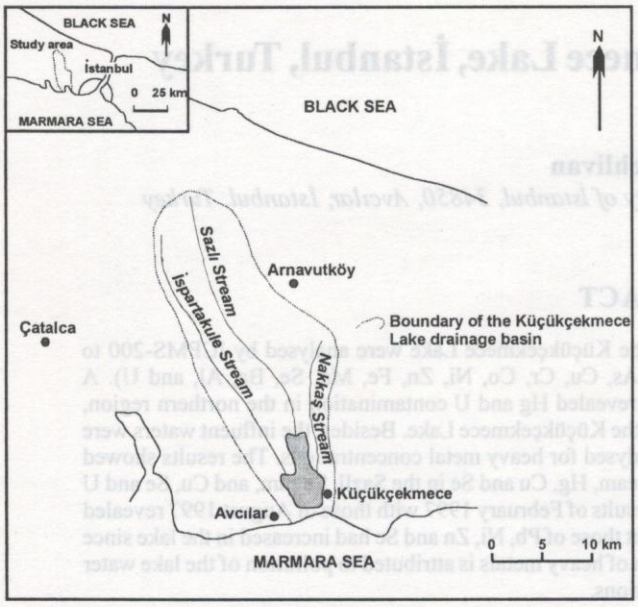

Fig. 1: Location map of the Küçükçekmece Lake and its drainage basin

Stream contains higher concentrations of Hg, Se and U, whereas the Sazlı Stream is contaminated by Hg, Cu and Se, and the Nakkaş Stream is by Cu, Se, U. The heavy metal concentrations in the water samples taken in February 1997 from the Küçükçekmece Lake do not show any variations in vertical direction. Therefore, in August 1997, the samples were taken from a depth of 0.5 m at 4 locations (Fig. 2), and the influent stream water was collected from each stream mouth (Fig. 2). A comparison of the two sets of data reveals an increase in concentrations of As, Cu, Cr, Mn, Ba, and Fe; but a decrease in concentrations of Pb, Ni, Zn, and Se in the lake water from February to August 1997. On the other hand, there was an increase in heavy metal concentration in the mouths of the İspartakule (i.e., Hg and U), Sazlı (i.e., Hg, Cu, Se, and U), and Nakkaş (i.e., Cu, Se and U) streams during the same period.

WATER QUALITY OF THE KÜÇÜKÇEKMECE LAKE

Present and previous data on water chemistry of the Küçükçekmece Lake were evaluated according to the Environmental Regulations for Water Pollution Control (Environmental Law of Turkey 1992). The study shows that there is a significant seasonal fluctuation of the lake water quality. According to the water chemistry analysis results of February 1997, the lake water belongs to Quality Class 2 based on Hg, Cu, and As; and to Quality Class 4 based on Se concentration (Fig. 3). On the other hand, the concentration of U in the lake water is significantly higher (i.e., 2.08 ppb) than the recommended limit of 0.5 ppb. Besides, according to the results of August 1997, the water belongs to Quality Class 2 based on Hg and Cu concentrations, but it is of Quality Class 4 based on Se concentration, whereas the concentration of U in the lake water is 1.10 ppb.

The water belonging to Quality Classes 1 and 2 can be made suitable for drinking purposes, respectively after disinfection and purification. Similarly, that of Quality Class 3 can be used as industrial water after purification, and the water belonging to Quality Class 4 should be taken as excessively polluted water not suitable for any purposes (Pehlivan and Yılmaz 1997).

CAUSES AND CONSEQUENCES OF POLLUTION

The seasonal variation of heavy metal concentrations in the lake water reveals that the Küçükçekmece Lake is heavily contaminated by industrial and domestic wastes, and is unsuitable for domestic as well as industrial purposes.

Average abundances of some elements in limestone, sandstone, and soil as well as concentrations of dissolved elements in freshwater, seawater, and stream water are given

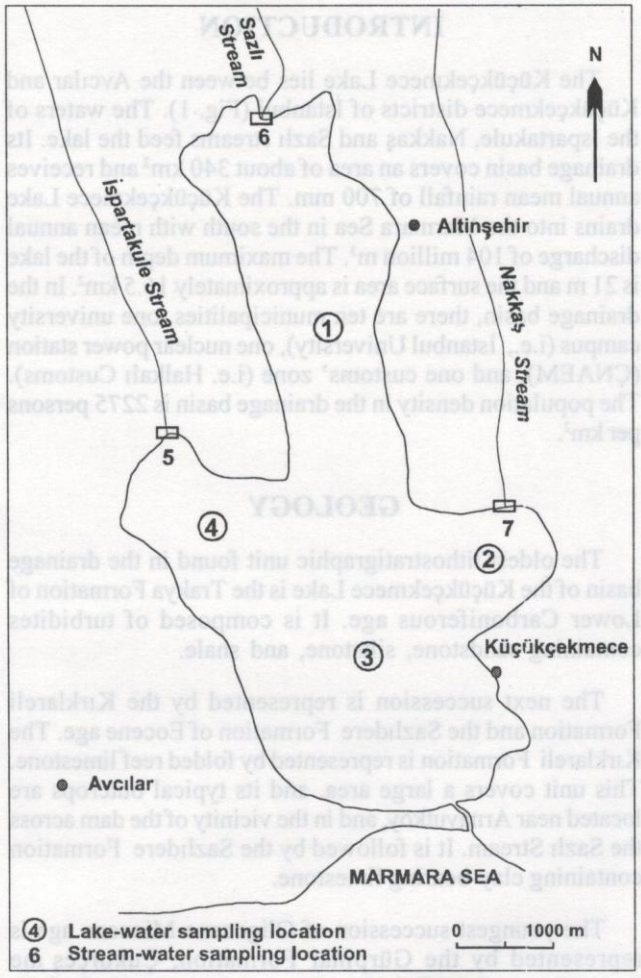

Fig. 2: Water sampling locations in the Küçükçekmece Lake and its influent streams

Table 1: Results of heavy metal analysis of water samples taken from the Küçükçekmece Lake and influent streams in February 1997 (mg/l)

Sample No-Depth (m)	Hg	Cd	Pb	As	Cu	Cr	Co	Ni	Zn	Mn	Se	Ba	U	Al	Fe
KG1-0.5	0.20	0.02	0.03	24.2	35.3	6.9	0.5	3.5	4.3	56.6	19.3	68.3	1.70	40	55.3
KG1-5	0.20	0.01	0.01	22.6	39.6	5.9	0.5	3.2	4.4	2.4	18.8	72.3	2.08	45	58.2
KG2-0.5	0.10	0.01	0.01	22.4	42.7	6.1	0.5	3.4	4.3	35.4	21.0	73.3	1.97	30	64.0
KG2-5	0.10	0.01	<0.01	22.3	43.7	5.9	0.5	3.4	5.6	4.3	18.7	72.2	1.75	45	66.5
KG3-0.5	0.10	0.01	0.02	21.1	41.3	5.9	0.5	3.3	3.8	31.0	16.9	74.2	1.96	20	60.2
KG3-5	0.10	<0.01	0.05	20.7	40.7	5.9	0.6	3.2	4.5	56.5	17.3	74.2	1.94	25	59.4
KG3-10	0.19	0.01	0.14	20.2	40.0	5.8	0.5	3.2	5.2	52.9	18.5	73.0	1.87	15	59.2
KG3-15	0.19	0.01	0.02	25.4	50.6	5.8	0.6	3.5	3.4	128.0	21.5	75.0	1.71	65	61.0
KG4-0.5	0.19	<0.01	0.03	19.7	38.1	5.4	0.4	3.1	5.1	26.6	16.9	73.8	1.76	30	57.0
KG4-5	0.10	<0.01	0.02	19.4	36.7	5.2	0.5	3.1	4.2	34.6	17.2	72.8	1.84	40	51.5
KG5 (İspartakule stream mouth)	0.19	<0.01	<0.01	12.0	17.3	5.4	0.4	3.0	2.1	0.6	9.4	85.7	3.15	49	53.0
KG6 (Sazlı stream mouth)	0.15	0.05	0.09	3.1	27.1	0.9	0.3	5.0	5.3	22.8	40.7	50.7	0.88	45	49.0
KG7 (Nakkaş stream mouth)	0.10	0.01	<0.01	18.4	31.0	4.8	0.4	2.9	4.0	1.2	15.4	73.6	2.09	47	50.0

Table 2: Results of heavy metal analysis of water samples taken from the Küçükçekmece Lake and influent streams in August 1997 (μg/l)

Sample No. Depth (m)	Hg	Cd	Pb	As	Cu	Cr	Co	Ni	Zn	Mn	Se	Ba	U	Al	Fe
KG1-0.5	0.30	0.01	0.13	0.3	20.5	15.3	0.3	6.1	5.9	1.3	129	42.0	0.69	43	56.4
KG2-0.5	0.20	0.01	0.01	0.5	19.7	13.9	0.3	5.9	4.7	0.1	133	43.0	0.97	35	49.0
KG3-0.5	0.15	0.02	0.01	0.4	20.0	14.5	0.3	6.0	4.7	0.3	127	43.0	1.10	34	47.1
KG4-0.5	0.15	0.01	0.07	0.3	19.9	15.4	0.3	5.9	4.3	1.6	126	44.0	0.83	27	40.5
KG5 (İspartakule stream mouth)	0.15	0.01	0.01	0.3	19.8	15.0	0.3	6.0	4.3	0.1	125	45.0	0.93	32	38.6
KG6 (Sazlı stream mouth)	0.20	0.01	0.06	0.3	20.1	21.9	0.3	5.9	3.7	6.6	127	49.0	0.74	35	32.1
KG7 (Nakkaş stream mouth)	0.20	0.01	0.05	0.9	18.7	18.9	0.3	6.5	4.9	1.2	118	46.0	0.70	32	31.5

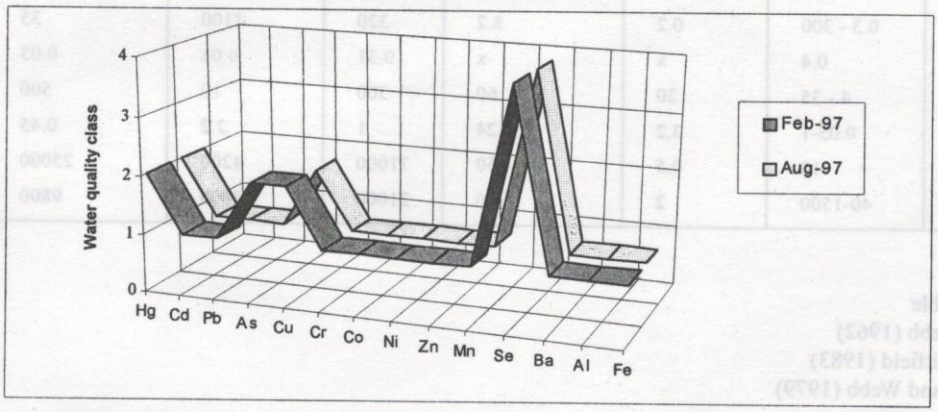

Fig. 3: Comparison of water quality in the Küçükçekmece Lake

in Table 3. A comparison of these values with those of Tables 1 and 2 indicates that the heavy metal concentrations could also have derived from the naturally occurring geological sources, via river runoff and coastal erosion.

There are haphazard settlements in the drainage basin of the Küçükçekmece Lake, and many illegal buildings are constructed at Zero Point of the lake. Consequently, the effluents from sewerage and industry contaminate severely the Küçükçekmece Lake. Similarly, leachates from the closed Halkali solid waste dump have also added to water pollution.

Moreover, a barrage to be constructed across the Sazlı Stream will perhaps meet some of the potable water requirements of the people in İstanbul but will further aggravate the situation in the lake. The already polluted Küçükçekmece Lake (Plates 1 and 2) will lose the annual discharge of about 55 million m^3 of freshwater from its biggest feeder.

Fate of the Küçükçekmece Lake may be similar to that of Haliç. As it is known, Haliç (Golden Horn) was one of the leading recreational centres of İstanbul many years ago (from the time of Ottoman Empire to the first years of Republic). Because of the unplanned settlement, industrial wastes, and uncontrolled sewerage effluents, Haliç became a swamp where no aquatic life could live. Its cleaning would take many years and cost millions of dollars. But if the government and local administration had protected Haliç, the consequences would not have been so severe.

WATER TREATMENT PLANS

ISKI initiated studies on formulating a master plan for water treatment in 1992. According to the master plan, the water treatment and wastewater management in İstanbul will be completed by 2032. The sewerage and domestic (bathroom and kitchen) wastewater will be transferred via pipelines to a treatment plant to be constructed around the Küçükçekmece Lake. Similarly, the effluents of about 161 workshops and factories around the Küçükçekmece Lake will also be taken to the treatment plant through a network of pipelines and tunnels. However, the investigation should be completed in a shorter time period, and the construction of effluent collectors in the western and eastern parts of the Küçükçekmece Lake as well as the sewerage treatment plant and installations related to discharge in the sea should be started as early as possible at the specified locations. If the above plan is realised timely, the Küçükçekmece lake water could be used for industrial purposes.

Table 3: Average amounts of elements in limestone, sandstone, soil, and elements present in freshwater, seawater and stream water

Elements	Freshwater[1] ppb	Seawater[2] ppb	Stream water[2] ppb	Soil[3] ppm	Limestone[4] ppm	Sandstone[4] ppm
Hg	0.01 - 0.1	x	x	0.056	0.2	0.3
Cd	0.5 - 40	0.01	0.02	0.5	0.09	0.01
Pb	0.3 - 3	0.003	0.1	17	9	7
As	1 - 30	1.5	1.7	7.5	1	0.8
Cu	0.2 - 30	0.1	1.5	15	4	2
Cr	0.5 - 40	0.3	1.0	43	11	20
Co	0.03 - 10	0.05	0.2	10	0.1	0.3
Ni	0.02 - 10	0.2	0.5	17	20	2
Zn	1 - 200	0.1	30	36	20	16
Mn	0.3 - 300	0.2	8.2	320	1100	35
Se	0.4	x	x	0.31	0.08	0.05
Ba	4 - 35	20	60	300	10	500
U	0.05-1	3.2	0.24	1	2.2	0.45
Al	10	0.5	50	71000	4200	25000
Fe	40-1500	2	40	21000	3800	9800

Explanations :

x data not available
[1]Hawkes and Webb (1962)
[2]Martin and Whitfield (1983)
[3]Rose, Hawkes and Webb (1979)
[4]Mason and Moore (1982)

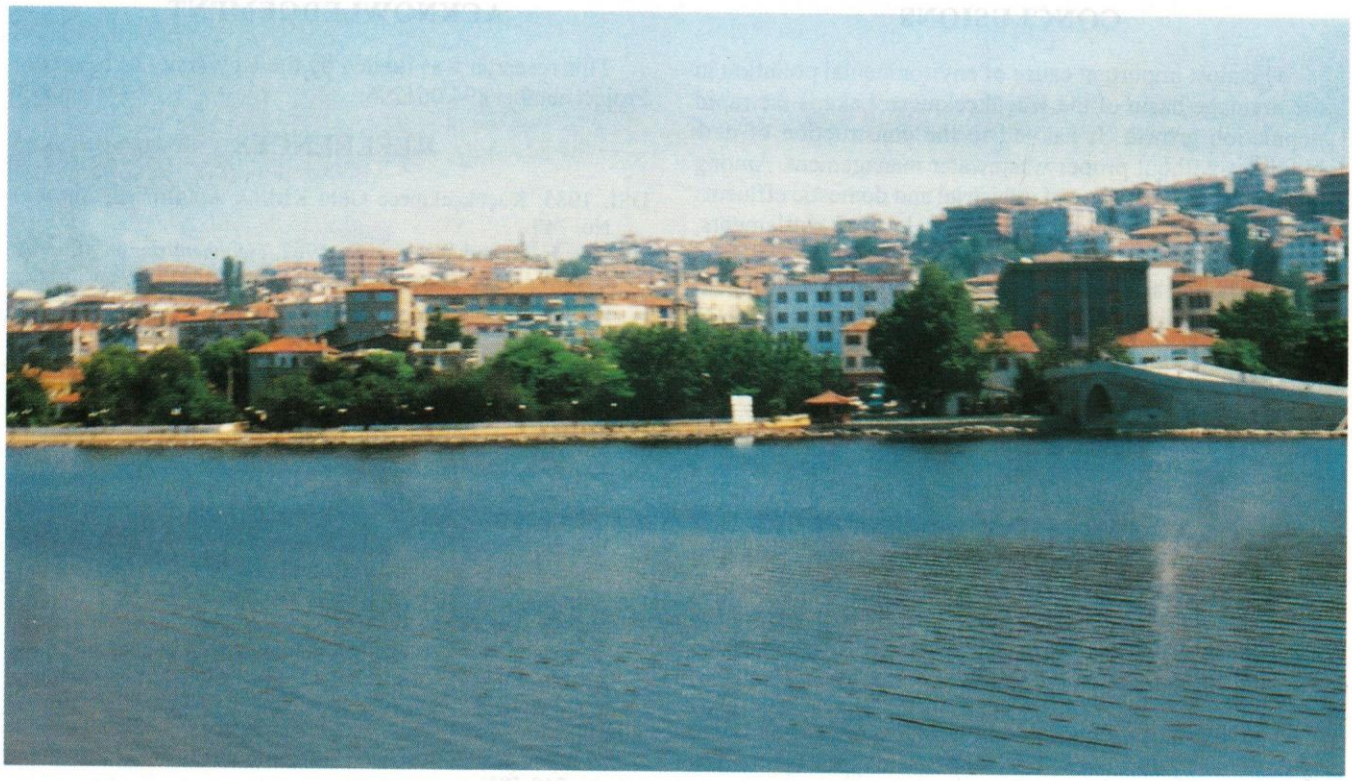

Plate 1: Unplanned settlement surrounding the Küçükçekmece Lake

Plate 2: Water pollution in the Küçükçekmece Lake

CONCLUSIONS

The most important cause of environmental pollution in the drainage basin of the Küçükçekmece Lake is the rapid population growth. It has led to the construction of new buildings without proper wastewater management. Among other reasons are inflow of industrial and domestic effluents to the lake from many haphazardly located settlements, increase of the heavy metal contamination in the lake sediments, and addition of leachates from the closed Halkalı solid waste dump. In order to prevent the contamination of the Küçükçekmece Lake, the workshops and factories that pollute the lake water with their wastes should purify their wastes, otherwise they should be closed. Similarly, the sewerage flowing directly into the lake should be stopped immediately.

By considering the İzmit, İzmir, Gemlik and Bandırma bays where there exist severe environmental and water pollution problems in the Black Sea and Marmara Sea, the Küçükçekmece Lake should not be permitted to be another Haliç of the future. It is urgently needed to take serious steps for the protection of the lake for next generation.

The lake and influent stream waters should be sampled systematically to determine the source and type of pollution. They should also be monitored for the seasonal variation in the concentration of contaminants.

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