DOI: 10.1556/JRNC.268.2006.3.14 *Journal of Radioanalytical and Nuclear Chemistry, Vol. 268, No.3 (2006) 529–537*

Physical and chemical investigation of water and sediment of the Keban Dam Lake, Turkey:

Part 2: Distribution of radioactivity, heavy metals and major elements

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(Received November 22, 2005)

Thirtynine surface water and 20 deep sediment samples were taken in different locations in Keban Dam Lake (Elazig, Turkey) to identify major sources and assess major elements, heavy metals, ^{137}Cs, ^{90}Sr, total alpha- and, total beta-distribution in 2003 and 2004 in four seasons each year. As a preliminary study heavy metal (Zn, Fe, Mn, Ni, Cu, Cr, and Co), major element (Mg, Ca, Na, K) and radioactivity concentrations of ^{137}Cs, ^{90}Sr, total-α and total-β in the surface water and deep sediments were determined.

Introduction

Heavy metals in surface waters are formed by natural or anthropogenic sources. Currently, anthropogenic inputs exceed natural inputs. Excess metal levels in surface waters may pose a health risk to humans and to the environment.

The determination of the pollution of heavy metals as well as the environmental radioactivity is very important. Artificial radioactive elements released into the atmosphere after the Chernobyl explosion in 1986 affected East-Europe, the Black Sea and North Coasts of Turkey. The radioactive fallouts were examined in both East-Europe and the north regions of Turkey after the explosion.[1] According to our best knowledge, no research has been performed in the Keban Dam Lake. Since its interesting geological and geographic characteristics, it was chosen as a pilot region to be studied.

Keban Dam Lake is the second largest freshwater body in Turkey. It is situated at latitude 38°5' N and 38°4' E longitude at an elevation of 1134 m above sea level. Surface water and deep sediment samples were taken at 39 and 20 stations, respectively (Fig. 1) in 2003 and 2004, in April, May, September and October, representative of the four seasons.

Experimental

Chemistry

Surface water samples taken at 25 cm depth were stored in 2-l polyethylene bottles for subsequent preparation and analyses. The bottles were rinsed at least three times with double-distilled water and 1:1 HNO_3:H_2O. Water samples were passed through Whatman glass microfibre filters (GF/C) and were acidified with (0.2 v/v) ultra pure nitric acid (E. Merk, Darmstadt, Germany) to pH<2 to minimize the absorption of metals onto the wall of containers and stored approximately at 4 °C.[2,3]

The deep sediment samples were collected using a stainless steel dredge. Sampling depth ranged between 20 and 25 m. The sediment samples were put into polyethylene bags and stored at 4 °C during their transportation to the laboratory. Sediments were dried in an oven at 50 °C for 48 hours. About 200 mg of each sample were digested with HNO_3, HF and H_2O_2 in a teflon bomb.

Measurement of radioactivity

Determinations of the radioactivity concentrations of surface water samples were performed by the Krieger method.[4] The alpha and beta activities were calculated as in Reference 2.

Results and discussion

Some physical and chemical behavior of heavy metals, total alpha- and beta-radioactivity in Uluova Region (approximately 250 km^2 area) of Keban Dam Lake have been obtained by homogenous scanning of the defined area.

Surface water

Total alpha- and beta-radioactivity: The total alpha-radioactivity for 10 stations was about 0.05 Bq/l. The Gaussian distribution lies between 0.013 and 0.125 Bq/l (Fig. 2). The closest frequency distribution of the total beta-radioactivity in the water samples was obtained in 8 stations and determined to be about 0.013 Bq/l (Fig. 5). However, the obtained data were about 0.019 Bq/l and 0.025 Bq/l at 7 stations.

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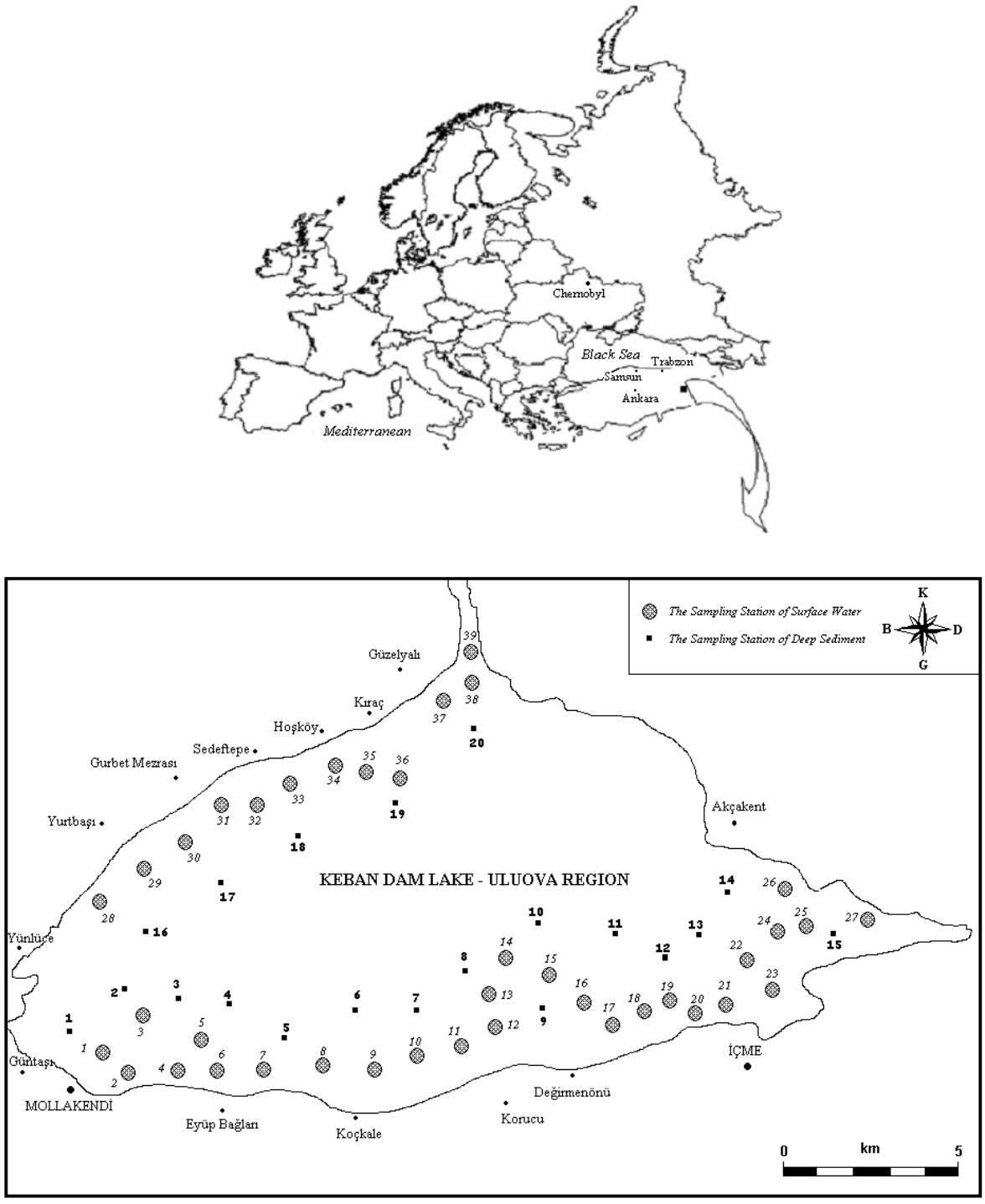

Fig. 1. Map showing the sampling stations of surface water and deep sediments in the Keban Dam Lake

Figure 3 shows that the total alpha-activity of 14 samples changed between 0.050 and 0.075 Bq/l, 5 samples had around 0.025 Bq/l and 5 samples had 0.125 Bq/l. The total beta-activity of 25 samples ranged between 0.001 and 0.05 Bq/l, while the activity of 7 samples was about 0.1 Bq/l. The normal distribution curve changed steadily between these values (Fig. 3).

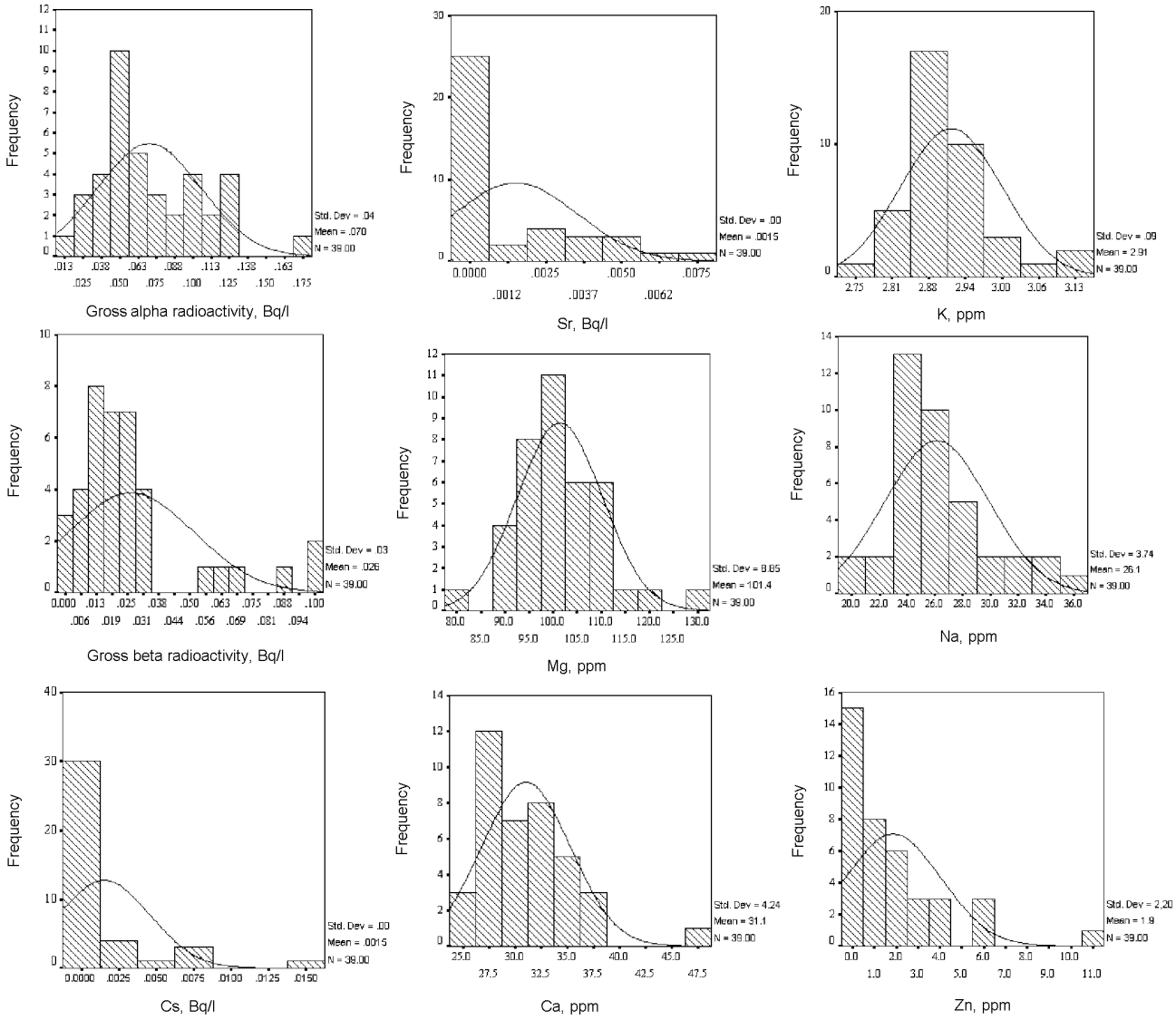

Fig. 2. Distribution of analysis data of water samples taken in autumn in the Keban Dam Lake

^{137}Cs: We have determined 0.0012 Bq/l activities in five stations (Fig. 3). There was not any ^{137}Cs concentration in 30 samples out of 39 taken in the spring period. On the contrary, there was a considerable decrease in ^{137}Cs concentration in autumn. The concentration determined in 5 samples were between 0.0025 and 0.0075 Bq/l (Fig. 2).

^{90}Sr: There was not any ^{90}Sr in 12 samples taken in the spring period. On the other hand, approximately 0.0125 Bq/l for ^{90}Sr was determined in 7 stations (Fig. 3). ^{90}Sr values were almost zero in the water samples taken from 25 samples in autumn. They changed between 0.0012 and 0.0075 Bq/l in the other samples (Fig. 2).

Heavy metals and major elements: The change in concentration of Mg was about 100 ppm in one liter based on 11 samples (Fig. 2). In 8 samples, the average value was about 95 ppm. In 12 samples 110 ppm was obtained. For Ca, in 12 stations the average value 27.5 ppm was repeated. The concentration of K reached 2.28 ppm at 17 stations out of 20. The value of Na reached 24 ppm at 13 stations and reached 26 ppm at 10 stations. The concentration of Zn was determined between 0.01 and 0.009 ppm at 15 stations.

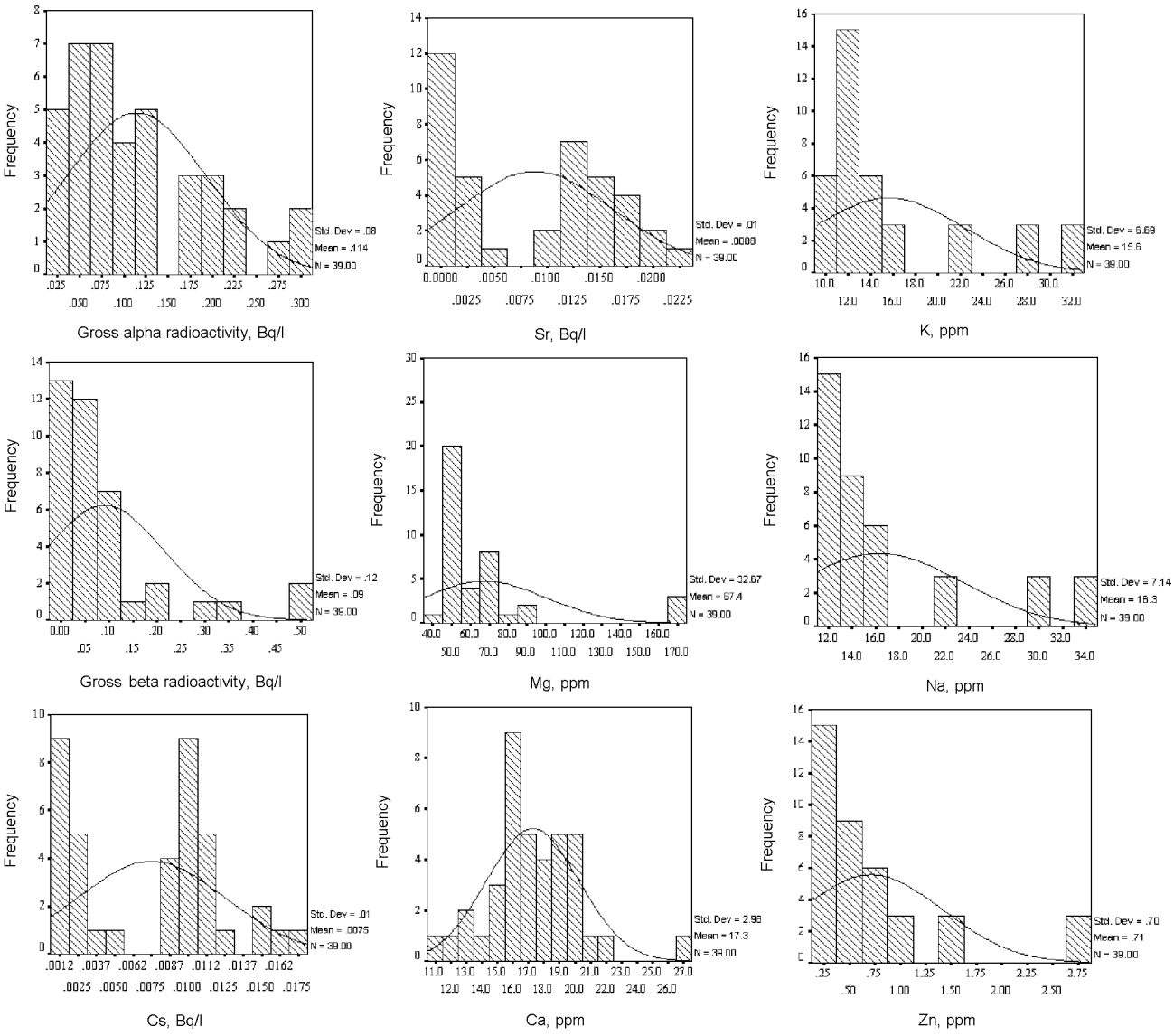

Fig. 3. Distribution of analysis data of water samples taken in spring in the Keban Dam Lake

The results of heavy metals and major elements in the water are illustrated in Fig. 3. According to Fig. 3, the compiled data for Mg from 20 stations were about 50 ppm, 20 stations had a quite high proportion of about 49%. The average concentration of Mg was 50 ppm. The measurements show that the Ca concentration was 16 ppm at 9 stations and K concentration was 12 ppm at 15 stations. The concentration of Na was 12 ppm at 15 stations, however, the concentration of Zn was 0.25 ppm at 15 stations.

Deep sediments

Total alpha- and beta-radioactivity: It is seen in Fig. 5 that the total alpha-activity obtained from 8 deep sediment samples varied between 200 and 350 $Bq \cdot kg^{-1}$. The total beta-radioactivity obtained from 13 samples ranged between 0 and 60 $Bq \cdot kg^{-1}$ and 5 stations had around 60 $Bq \cdot kg^{-1}$. These results show the lake radioactivity characterization in respect to beta-radioactivity.

Figure 4 shows the change of the total alpha-activity in deep sediments. The dominant alpha-activity samples taken during spring changed between 250 and 380 $Bq \cdot kg^{-1}$ and was found at 12 stations. Figure 4 illustrates how often the amount of total beta-radioactivity in deep sediment changes. According to Fig. 4, the activity of 7 samples was found to be 13 $Bq \cdot kg^{-1}$. The activity of 4 samples was rather low, between 1 and 9 $Bq \cdot kg^{-1}$, while the amount of the other 4 samples has been found to be about 38 $Bq \cdot kg^{-1}$.

^{137}Cs: We have not determined ^{137}Cs in the deep sediment samples taken from 10 stations during the spring period. ^{137}Cs concentration found in 14 out of 20 samples was approximately zero. In 4 stations, the concentration values were between 1.2 and 2.5 Bq·kg^{-1} (Fig. 5).

^{90}Sr: Out of 20 stations where deep sediment samples were taken, Sr concentration was determined as 0.6 Bq·kg^{-1} in 6 samples and from 1.2 to 2.5 Bq·kg^{-1} in 3 samples (Fig. 4).

^{90}Sr concentration was almost zero in the soil samples taken from 14 stations in autumn. They were 2.5 Bq·kg^{-1} in 4 samples, 1.2 Bq·kg^{-1} in 2 samples and it changed between 3.7 and 10 Bq·kg^{-1} in the other samples (Fig. 5).

Heavy metals and major elements: Including Fe, Mg, Ca, K, Na, Zn, Cu, Cr, Co, N, Mn in the samples taken during the spring period were analyzed (Fig. 4). The values of Fe were found to be 20,000 ppm at 6 stations and reached between 10,000 and 15,000 ppm at 8 stations. The values of Mg were found to be 100,000 ppm at 7 stations, and Ca values were 90,000 ppm in 4 samples, 95,000 ppm, 105,000 ppm, 110,000 ppm in 3 samples. The value of K in 14 samples which almost characterizes all the lake was 1,000 ppm. 6,000 ppm was determined for Na at 6 stations and Zn values were between 1 and 1,000 ppm at 14 stations.

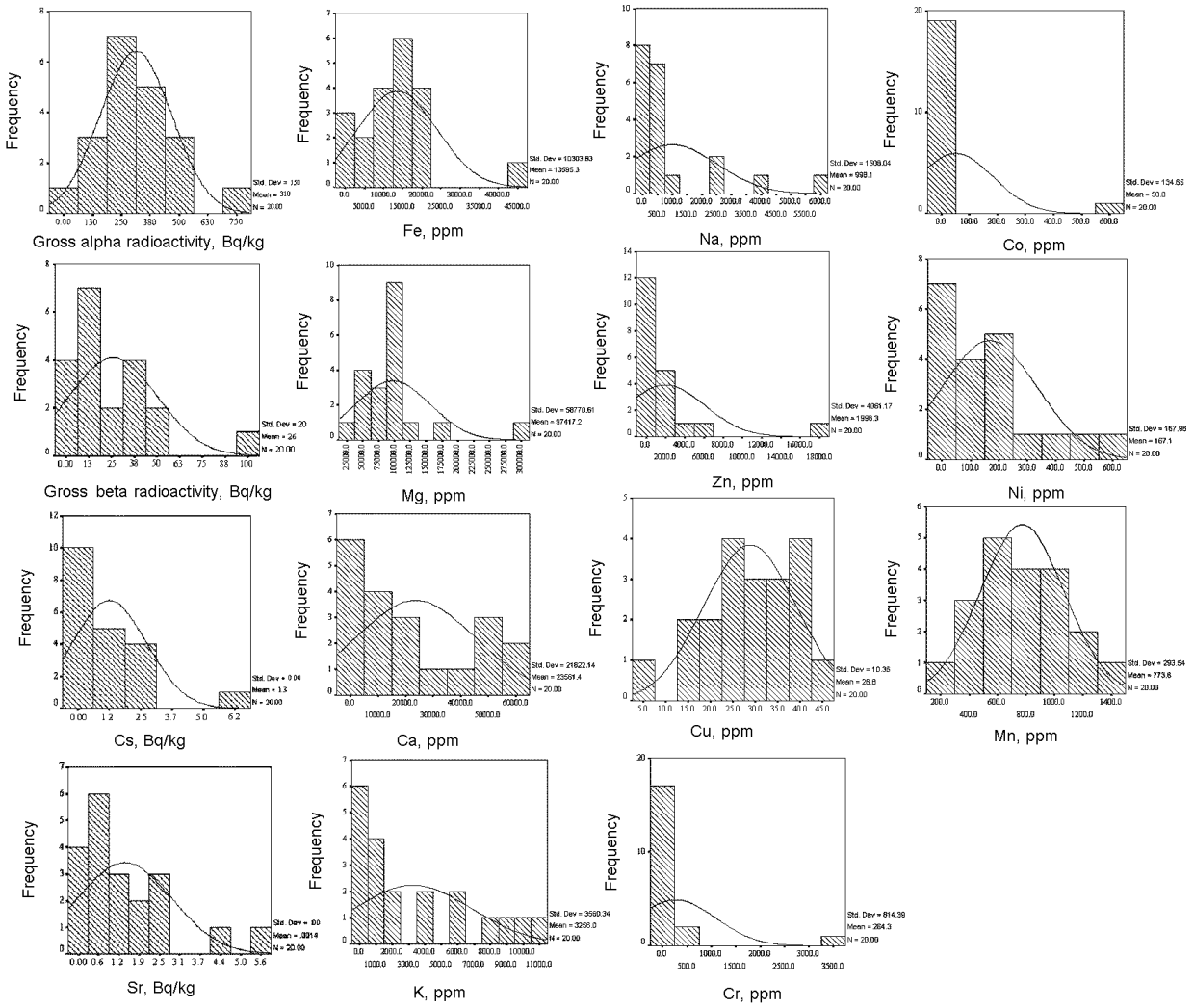

Fig. 4. Distribution of analysis data of deep sediment samples taken in spring in the Keban Dam Lake

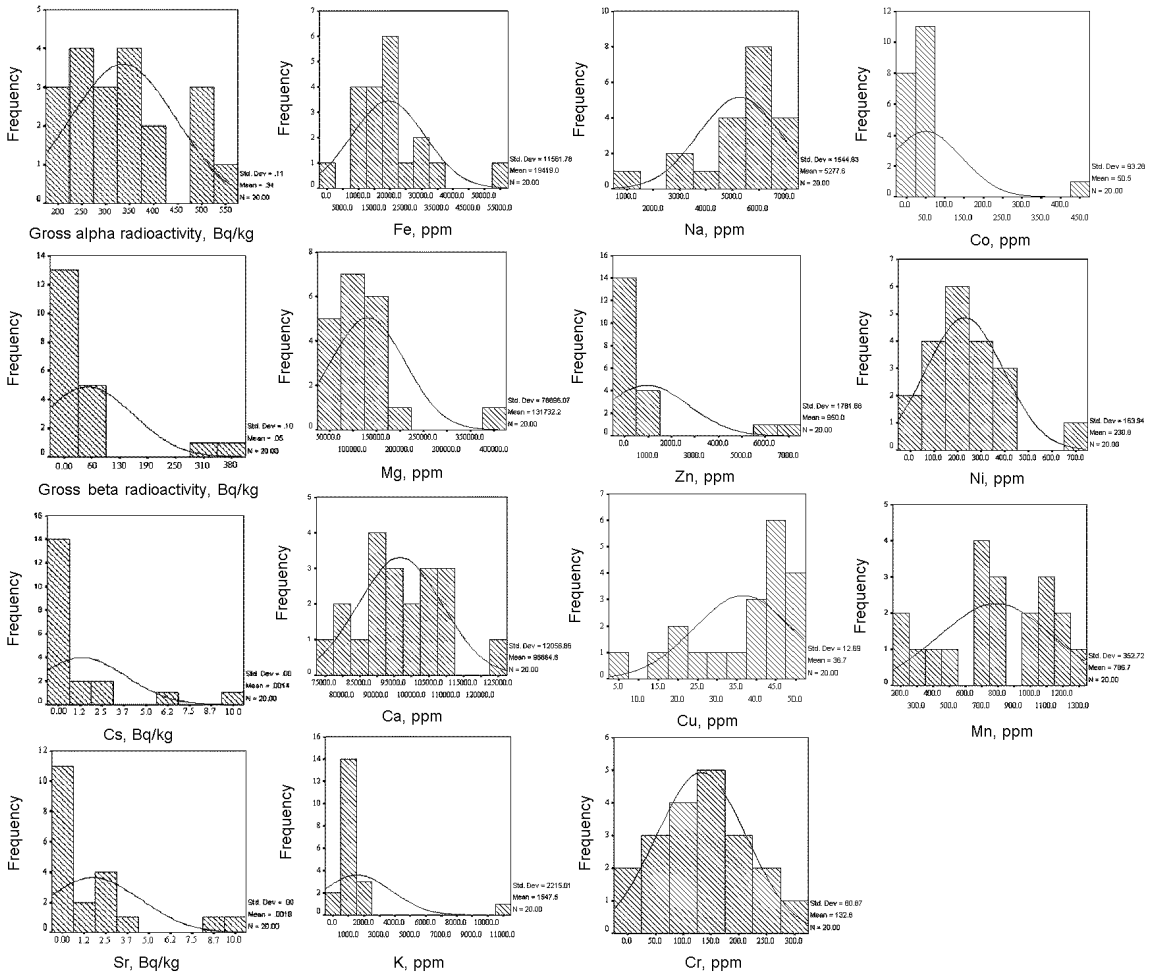

Fig. 5. Distribution of analysis data of deep sediment samples taken in autumn in the Keban Dam Lake

For Co the repeated value at 11 stations was 50 ppm. The value of Ni at 6 stations was 200 ppm, for Mn at 4 stations 700 ppm and at 3 stations 800 ppm, 1100 ppm was mostly repeated a value.

The change of the deep sediment taken in spring period is illustrated in Fig. 4. The average concentration for Fe at 6 stations was 15,000 ppm. The concentration of Mg was found to be 100,000 ppm at 9 stations and similar values were acquired at another 4 stations (50,000 ppm). For the concentration of Ca changeable values were acquired (1 to 10,000 ppm in 6 stations), however, the acquired data at 4 stations were 10,000 ppm. The data determined for the concentration of K at 6 stations were between 1 ppm and 1,000 ppm, for N the acquired data at 6 and 8 stations were 1 and 1,000 ppm, respectively. The concentration of Zn in 12 stations changed between 1 ppm and 2,000 ppm. The concentration values of Zn at 4 stations were 25 ppm and 40 ppm at the other 4 stations. The determined values for Cr at 18 stations were between 1 ppm and 500 ppm. For Co, all the concentration values were between 1 and 100 ppm, however, in only one (1st station) the value was about 600 ppm. The concentration values of Ni were between 1 and 100 ppm in 7 stations, and were about 200 ppm at 5 stations. The values of Mn were 600 ppm at 5 stations, 800 ppm at 4 stations and 1,000 ppm at another 4 stations.

Conclusions

Heavy metals and major elements

Mg, Ca and Na concentrations were determined as the highest heavy metals in surface water of the region. The most of these basic cations were provided by the geochemical and the ion-exchange reactions between soil and rocks.

The result of the heavy metal analysis are shown in Table 1 with the literature data for comparison. The concentration of Mg in the literature is higher than in Texoma Lake and other studies made for Keban Dam Lake. The concentration levels of Ca are almost lower

than in all the other lakes. The concentration of K is higher than Texoma Lake. Moreover, the concentration of Zn is higher than in all the other lakes. The basic sources of Zn are foundries, electric centrals, and volcanic movements, fertilizing processes and plants.[10] The reason for higher concentration levels of Zn in surface waters and deep sediments of the region may be due to the fertilizing processes around the lake.

The sediments are the source of the trace elements in aquatic environment and in different geochemical phases which provide the mobility of the elements. The higher metal concentrations in sediment and water samples maybe due to heavy metals captured by sediments.

The results from heavy metal analyses in the deep sediment samples of the region were compared with the literature data (Table 2). The obtained Fe concentrations in this analysis were lower than the sediment samples obtained only in Atatürk Dam Lake (Adıyaman, Turkey). Concentrations of Zn, Cr, Co, Ni, Mn were higher than those in all lakes given in Table 2. Comparison of Cu concentration within other lake's results shows that the obtained results have a mean value comparable to those of the literature data.

Metals rusting in water are the source of Fe motor oil and oil wastes of Ni.[19] Fishing boats which are using Diesel fuel are considered to be another source of these elements.

The oil wastes from boats are very effective at the 1st and 5th stations where Cu was abundant. Heavy metals such as Cu and Zn which are toxic for animals exist in very low concentrations in water but are seriously dangerous for the ecosystem.[20] Therefore, it is necessary to make measurements continuously, so as to keep these elements in balance in the lake.

The standards of the heavy metals and major elements in water and deep sediments are shown and compared to our results in Table 3. Mg, Ca, Zn, Cr, Co, Ni and Mn in the sediment samples were higher than the standards, especially, Mg, Ca, and Zn. These elements are inclined to concentrate in the deep sediments. In addition, the arrival of the wastes of cement factory by means of sewage may increase the values of Ca in deep sediments.[6] Having very high Zn can cause serious problems among the living organisms in the region. The concentration values of Fe, K and Na are under the standard limits. The wastes of the slaughter house which reaches the lake by means of drainage are also a source of Fe in the region. Fe which exists in blood and organic matters was determined in the deep sediments and surface water in the lake.[6]

Table 1. Major element and heavy metal analysis in the water of some lakes

Lake	Mg, ppm	Ca, ppm	K, ppm	Na, ppm	Zn, ppm	Reference
This study	84	24	8.5	16	1.28	
Keban Dam Lake	18	42	2.63	20.7		5
Keban Dam Lake	15	50	5	21	0.7	6
Atatürk (Bozyazı)					0.064	7
Atatürk (Adıyaman)					0.197	7
Texoma	38	102	5.342	204	0.059	8
Burtnieks		34			0.003	9
Juglas		70.5			0.345	9
Ķīšezers		59.5			0.287	9
M. Baltzers		59			0.435	9
Rušons		42.6			0.512	9
Rāznas		35.5			0.328	9
Liepājas		52.9			0.407	9
Bušnieku		28			0.329	9
Zebrus		31.1			0.680	9
Cieceres		32.6			0.425	9
Engures		28.9			0.355	9
Alūksnes		25.5			0.290	9
Dreimaņu		52.3			0.310	9
Čertogs		4.4			0.425	9
Tolkojas		1.5			0.390	9
Lubāns		74.1			0.320	9

Table 2. Heavy metal analysis in deep sediments of some lakes

Lake	Fe, ppm	Zn, ppm	Cu, ppm	Cr, ppm	Co, ppm	Ni, ppm	Mn, ppm	Reference
This study	16500	1473	32.7	198.45	50	198	779	
Atatürk (Bozyazı)	12587	60.79	14.57			43.69	73.60	7
Atatürk (Adıyaman)	19265	59.14	22.70			139.69	514.07	7
Burtnieks		23.75	4.37			4.06	31.25	9
Juglas		78.43	15.34			11.18	79.12	9
Ķīšezers		69.73	16.34			6.74	81.17	9
M. Baltzers		25.65	6.15			4.18	54.12	9
Rušons		48.17	3.04			3.25	28.47	9
Rāznas		64.31	6.15			4.15	48.31	9
Liepājas		68.35	55.62			6.95	49.55	9
Bušnieku		49.24	9.58			13.27	28.27	9
Zebrus		29.73	1.33			2.48	37.85	9
Cieceres		56.38	6.48			6.42	37.85	9
Engures		22.53	13.52			10.75	78.36	9
Alūksnes		25.39	8.39			9.35	41.21	9
Dreimaņu		15.32	4.32			2.04	15.38	9
Čertogs		36.54	9.13			7.14	58.43	9
Tolkojas		18.32	2.85			3.11	14.28	9
Lubāns		65.24	3.76			3.31	41.55	9
Kali Nadi River		90.4	0.2	7.3				11
L. Kariba		42.4	16.1	29.3				12
L. Victoria (Uganda)		86	41	67				13
L. Victoria (Kenya)		138.8	39.8					14
L. Victoria (Tanzania)		29.6	21.6	11				15
Black Sea	9554.12	58.97	80	25.59	3.69	12.96	302	16
Lake 1		73	5			55		17
Lake 2		185	166			52		17
Lake 3		55	28			20		17
Lake 4		43	26		5	40		17
Lake 5		33	6		9	10		17
Taihu		679.6	462	68.6	11.8	31.3	547	18

Table 3. Heavy metal and major element standards in water and sediment samples (average values)

	T_α, Bq/l	T_β, Bq/l	Fe, ppm	Mg, ppm	Ca, ppm	K, ppm	Na, ppm	Zn, ppm	Cu, ppm	Cr, ppm	Co, ppm	Ni, ppm	Mn, ppm	Reference
Sediment														
This study	0.0605	0.055	16500	114574	60112	2400	3137	1473	32.7	198	50	198	779	
Turkey			35400	13900	28700	28400	24500	60	30	70		44	690	21
Hungary								100				25		22
Water														
This study	0.32	0.039		84	24	8.5	16	1.28						
TSE-266	0.037	0.37		50	200	12	175	5						23
WHO	0.5	1					200							24
EC							200							25
EPA	0.555	1.85						5						26

It is seen from Table 3 that only Mg values were higher than the limits. The main sources of Mg in the region can be the geochemical ion-exchange between soil and rocks.[6]

Radioactivity

After the Chernobyl accident, ^{137}Cs and ^{90}Sr were deposited on deep sediments and surface waters. Their decay is very slow due to the long physical half-life of these isotopes (30.1 and 28.6 years, respectively). Indeed, these are still observed today, 19 years after the Chernobyl accident.

In respect to the total alpha- and beta-radioactivity in Uluova Region in Keban Dam, the results are hardly higher than the environmental radioactivity limits. Although 19 years have passed, since the Chernobyl accident, ^{137}Cs and ^{90}Sr rarely exist in the studied area.

The conclusions of the data taken seasonally from the water and deep sediment samples are summarized as:

^{137}Cs water samples: spring>autumn, deep sediments: spring<autumn,

^{90}Sr water samples: spring>autumn, deep sediments: spring<autumn,

Total α water samples: spring>autumn, deep sediments: spring<autumn,

Total β water samples: spring>autumn, deep sediments: spring<autumn.

As seen the average radioactivity in all water samples in the spring period was higher than that in autumn. However, the radioactivity values in deep sediments were relatively higher in autumn. Average values of heavy metals in water and deep sediments were lower than the standard ones.

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This work was supported by the University of Fırat Scientific Project Support Unit Project No. FÜBAP-894.

References

1. S. TOPCUOĞLU, D. KUT, N. ESEN, N. GÜNGÖR, E. ÖLMEZ, Ç. KIRBAŞOĞLU, J. Radioanal. Nucl. Chem., 250 (2001) 381.
2. H. ÖZMEN, F. KÜLAHCI, A. ÇUKUROVALI, M. DOĞRU, Chemosphere, 61 (2004) 401.
3. M. DOĞRU, F. KÜLAHCI, J. Radioanal. Nucl. Chem., 260 (2004) 557.
4. L. H. KRIEGER, Interim Radiochemical Methodology from Drinking Water, EPA 600/4-75-008, Ohio, 1975.
5. LERKL, Limnology Etude Report of Keban Dam Lake, T.C. Energy and Natural Sources Ministry Administration Department, Ankara, 1982.
6. H. SAY, A. ÇUKUR, Ş. KUNÇ, Trace Element Analysis of Waste Water and Mud by AAS, Ondokuz Mayıs Univ., Samsun, Turkey, 1989.
7. H. KARADEDE, E. ÜNLÜ, Chemosphere, 41 (2000) 1371.
8. Y. J. AN, D. H. KAMPBELL, Environ. Pollut., 122 (2003) 253.
9. M. KLAVINŠ, V. RODINOV, G. VERESKUNS, Bull. Environ. Contam. Toxicol., 60 (1998) 538.
10. D. J. SWAINE, Fuel Proces. Technol., 65 (2000) 21.
11. M. AJMAL, R. UDDIN, A. U. KHAN, Environ. Intern., 14 (1988) 515.
12. H. BERG, K. REMANE, African Inland Fisheries, Aquaculture and Environment, Oxford, Blackwell, 1997.
13. J. S. MOTHERSILL, Sedimentology, 23 (1976) 553.
14. J. M. ONYARI, S. O. WANDIGA, Bull. Environ. Toxicol., 42 (1989) 807.
15. M. A. KISHE, J. F. MACHIWAB, Environ. Intern., 28 (2003) 619.
16. V. SIMEONOV, D. L. MASSART, G. ANDREEV, S. TSAKOVSKI, D. L. MASSART, Chemosphere, 41 (2000) 1411.
17. V. DAUVALTER, S. ROGNERUD, Chemosphere, 42 (2001) 9.
18. X. C. WANG, W. D. YAN, Z. AN, Q. LU, W. M. SHI, Z. H. CAO, M. H. WONG, Chemosphere, 50 (2003) 707.
19. R. ERLACHER, Regression Analysis of Dissolved Heavy Metals in Storm Water Runoff from Elevated Roadways, PhD Thesis, University of Innsbruck, 2004.
20. U. FÖRSTNER, G. T. W. WITTMAN, Metal Pollution in the Aquatic Environment, Springer-Verlag, Berlin, 1983.
21. K. HAKTANIR, Cevre Kirliligi, Univ. Ankara, Ziraat Fakültesi Ders Notu, Ankara, 1987.
22. E. FLEIT, G. LAKATOS, Toxic. Lett., 140 (2003) 323.
23. TSE, Institution of Turkish Standards, Annual Progress Report, Istanbul, 1997.
24. WHO, Drinking-water Quality, Vol. 1, Recommendations, Geneva, 2004.
25. EC, Europe Community Report, Denmark, 1998.
26. EPA, Environment Protection Agency Report, USA, 2002.