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

Part 1: Iso-curves of radioactivity

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The gross alpha- gross beta-activity, ^{137}Cs and ^{90}Sr in the water and sediment samples taken from the Keban Dam Lake, Uluova Region, was investigated in 2003 and 2004. We have found that in spring the concentration of ^{137}Cs in the surface water and deep sediment changed between 0.001–0.01 Bq/l (0.4–2.5 Bq·kg^{-1}) that of ^{90}Sr between 0.0001–0.009 Bq/l (0.1–9 Bq·kg^{-1}) and in autumn the values were 0.0001–0.009 Bq/l (0.4–8 Bq·kg^{-1}) for ^{137}Cs and 0.0002–0.005 Bq/l (0.6–4 Bq·kg^{-1}) for ^{90}Sr, respectively. The results were presented in form of iso-curves.

Introduction

Artificial radionuclides enter the environment from different activities. There are three main sources of artificial radionuclides influencing the Keban Dam water. The most dominant source has been the global fallout of atmospheric nuclear weapons tests, the second one was the Chernobyl accident of 1986 (especially for the present research area). This accident was detected as a sudden increase of ^{137}Cs concentration in the surface seawater, although that contribution diminished after the accident within a few years.[1,2] The third radioactive source is that of soil and rock.

The radioactive contamination of the environment has been attracted the attention of the public by the Chernobyl accident, which happened on April 26, 1986. Radioactive clouds were produced and blown by the wind over large parts of Europe and Asia.[3–5] Approximately 10^{18} Bq artificial radionuclides were released into the atmosphere as a result of the nuclear weapon tests performed between 1952–1997 and by accidents such as happened in Chernobyl.[6]

After the Chernobyl accident, researches on environmental radioactivity were done, especially in the north regions of Turkey,[7] but not at the lakes of the same region. The field of the present investigation is at a distant of 1500 km from Chernobyl. Therefore, the determination of ^{137}Cs and ^{90}Sr as a result of atmospheric phenomena in the region, would be important.

The area of the research field in the Uluova Region, at the Keban Dam Lake is approximately 250 km^2, and lies at the latitude 38°5’ N and 38°4’ E longitude in Eastern Turkey. There are industrial and sewage plants as well as restaurants serving fish in one of the main dwelling zones in question.

The samples containing ^{137}Cs and ^{90}Sr activities are originated from the lake water and deep sediments. The samplings were performed in every autumn and spring during two years in 59 sampling locations, in total 20 deep sediments and 39 surface water samples were taken.

The main target of our research was to determine the natural and artificial radioactivity of the lake. For this reason, radioactivity iso-curve maps were drawn and evaluated. The data were compared with those of a similar research performed for the Japan Sea.

Experimental

Determination of radioactivity

The water samples were collected into sterilized clean 2 l-polyethylene-bottles for subsequent preparation and analyses. 0.5 ml 3N nitric acid was added to prevent the precipitation and absorption of the sample on the container walls. Each sample was divided into three equal parts. Each part was evaporated at low temperature (about 60 °C) until a small amount of water remained. The residue was poured into about 4.6 cm^3 aluminum planchette and dried. The result was given as the arithmetic mean calculated of the results of each parts of the sample.[9]

Twenty deep sediment samples were collected using a stainless steel dredge. The measurement of the radioactivity of the water and deep sediment samples were performed by the Krieger method using a total alpha- and total beta-counting system. The alpha-radioactivity was counted by a ZnS(Ag) scintillator supported by a photomultiplier tube with a 7286 low-level alpha-counter from NE Technology, Inc. The ZnS(Ag) scintillator had a radius of 44 mm. Global β-counting was performed by a low background plastic β-scintillation system supported by a plastic β-scintillator (2059) and a photomultiplier tube through a SR8 dual radiation counter from NE Technology Inc. Lead shielding were used for both systems for the protection against external radiation.

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The gross-α, gross-β, activities of ^{137}Cs and ^{90}Sr were calculated using the net counts in the following equations:[8,9]

$$A_\alpha = (N \cdot ECF)/0.016$$
$$A_\beta = (0.0144 \cdot R \cdot N_m)/N_0 \tag{1}$$

where A_α and A_β are the α- and β-activities in Bq, respectively, N is the sample net counts per minute for alpha-activity, ECF is the efficiency correction factor, R is the sample net counts for beta-activity, N_m is the specific mass of the sample in mg/cm^2, N_0 is the count corresponding to the specific activity determined from the standard calibration curve obtained by a KCl source. The correlation coefficient (r) of the obtained curve was found to be 0.998. The correction factor ECF for alpha-activity was obtained from the measurement of the sediment on the aluminum planchet:

$$ECF = 1/E{\cdot}T \tag{2}$$

where T was determined from the U_3O_8 self-absorption curves, in mg/cm^2 and E is the absolute efficiency.[9,14]

The calculated standard deviation was found to be between 1% and 5% of the determined values.

Results and discussion

When the parameters, such as altitude, wind speed, temperature, and barometric pressure are to be represented in meteorology, geography and geological studies, the respective iso-curves are fairly suitable. The iso-curves give very detailed information about the relevant parameter in a region and show how the parameters are changing. Therefore, to represent the change of seasonal radioactivity of the region in detail radioactivity iso-curves were used. The change of radioactivity is shown by these curves in form of high radioactivity islands and low radioactivity islands, a conception suggested by us.[9]

Surface water

Total alpha-radioactivity: The radioactivity iso-curves drawn for the alpha-radioactivity of the water samples collected in spring are seen in Fig. 1a. The highest radioactivity values were observed in Mollakendi-Eyyüp Bağları (0.27 Bq/l). Radioactivity in the samples of İçme region also reached 0.17 Bq/l. This region presents a low radioactivity island which starts from 0.17 Bq/l and decreases to 0.09 Bq/l. It has a geological formation which is associated with radioactivity (limestone, clay).[10] In the north part, the radioactivity proportion changes between 0.04 Bq/l and 0.02 Bq/l, i.e., the radioactivity of the north part is less than that of the south part.

The radioactivity iso-curves drawn for the alpha radioactivity of the water samples taken in autumn are seen in Fig. 1b. The alpha-radioactivity was found about 0.1 Bq/l in Mollakendi and Güzelyalı vicinity, the lowest value was determined in the Koçkale-Demirönü region (0.03 Bq/l).

Total beta-radioactivity: Concerning the total beta-radioactivity of the water samples taken in spring (Fig. 2a), the highest activity was determined in the vicinity of İçme (0.45 Bq/l). An other line (0.3 Bq/l) of high activity was found around Mollakendi, and the medium radioactivity values varied between 0.03 and 0.09 Bq/l. The lowest radioactivity was determined in the Yünlüce-Ağmezra region. Going southwards from Güzelyalı, the radioactivity gradually decreases from 0.17 to 0.05 Bq/l. Perhaps, the abundance of radioactivity is due to the fault line and the geological formation (clay, silt, limestone) of the south region.[10,13]

The radioactivity iso-curves drawn for the beta-radioactivity of the water samples collected in autumn are shown in Fig. 2b. The lowest value in this season was determined in Güzelyalı (0.005 Bq/l). On the north region of the lake approximately 5 km along the shore various values of radioactivity were measured. In the south part of the lake, along the line between Eyüp Bağları and İçme similar radioactivity values (approximately 0.03 Bq/l) were found. The Eyüp Bağları-Değirmenönü region had the less radioactivity.

Due to the geological characteristics of the basin of the lake, the radioactivity decreases with depth near the coast, and increases in deep currents, depending on the mobility of the radioactive elements.[9,13,14] The highest radioactivity was determined in Yurtbaşı and İçme (0.08 and 0.05 Bq/l, respectively), the lowest one in Güzelyalı (0.005 Bq/l).

^{137}Cs: The distribution of the ^{137}Cs concentration in spring is illustrated in Fig. 3a. In this region, approaching the coastline the radioactivity concentration considerably decreased; between Mollakendi and Koçkale, the ^{137}Cs concentration changed to about 0.01 Bq/l and the dominant value was 0.0082 Bq/l, building a "low level radioactivity island". Between Koçkale and İçme, the ^{137}Cs concentration changed from 0.003 to 0.0087 Bq/l. A special region of 0.0015 Bq/l deserves attention in the İçme offshore; here the ^{137}Cs concentration was 0.01 Bq/l in the belt, from the east of İçme to the north of the lake. The dominant ^{137}Cs concentration in the north region was 0.001 Bq/l. Going towards north-west, it increased to 0.01 Bq/l.

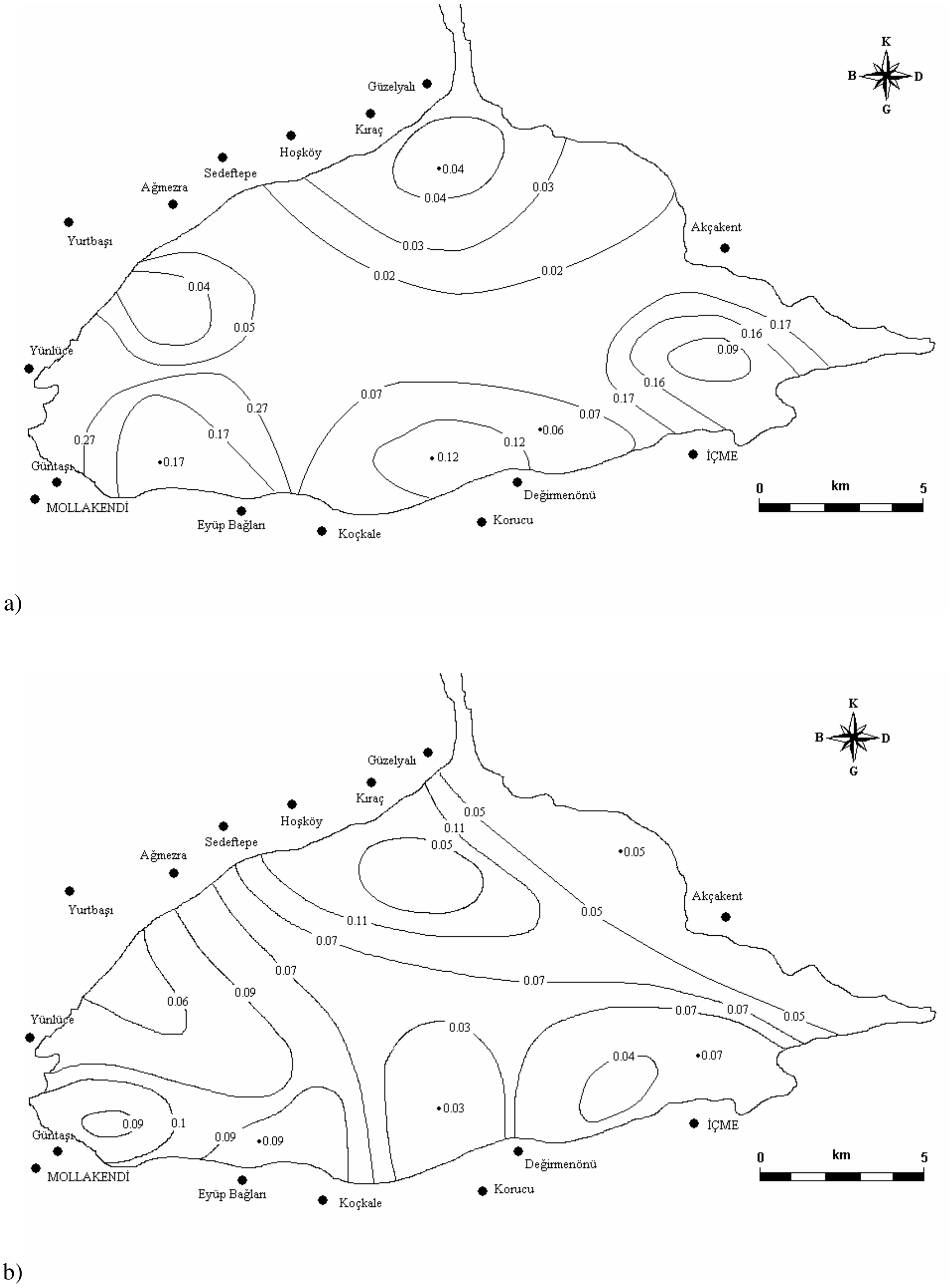
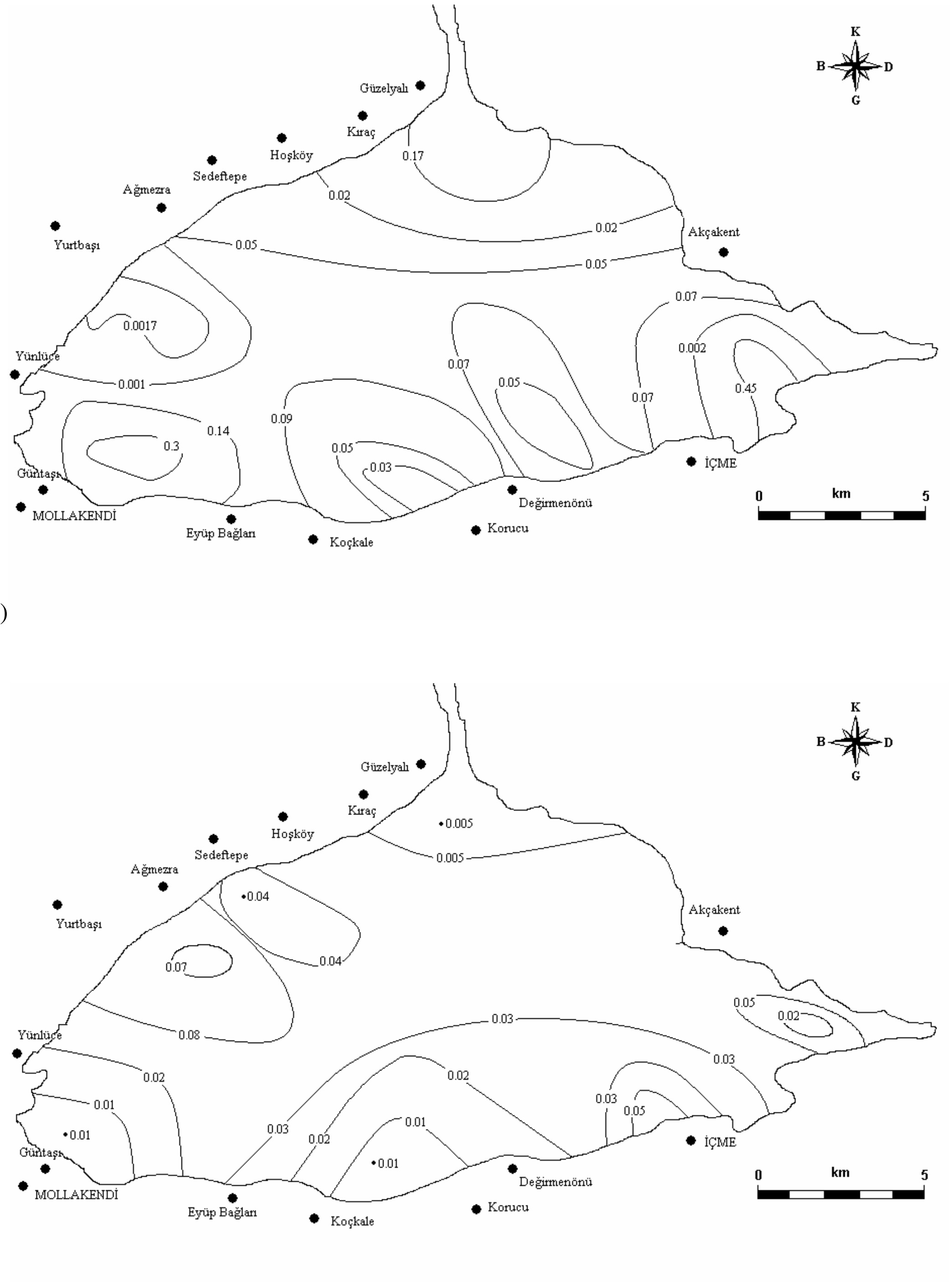


Fig. 1. Map of iso-curves of alpha-radioactivity (in Bq/l) of water samples in spring (a); in autumn (b)



a)

b)

Fig. 2. Map of iso-curves of beta-radioactivity (in Bq/l) of water samples in spring (a); in autumn (b)

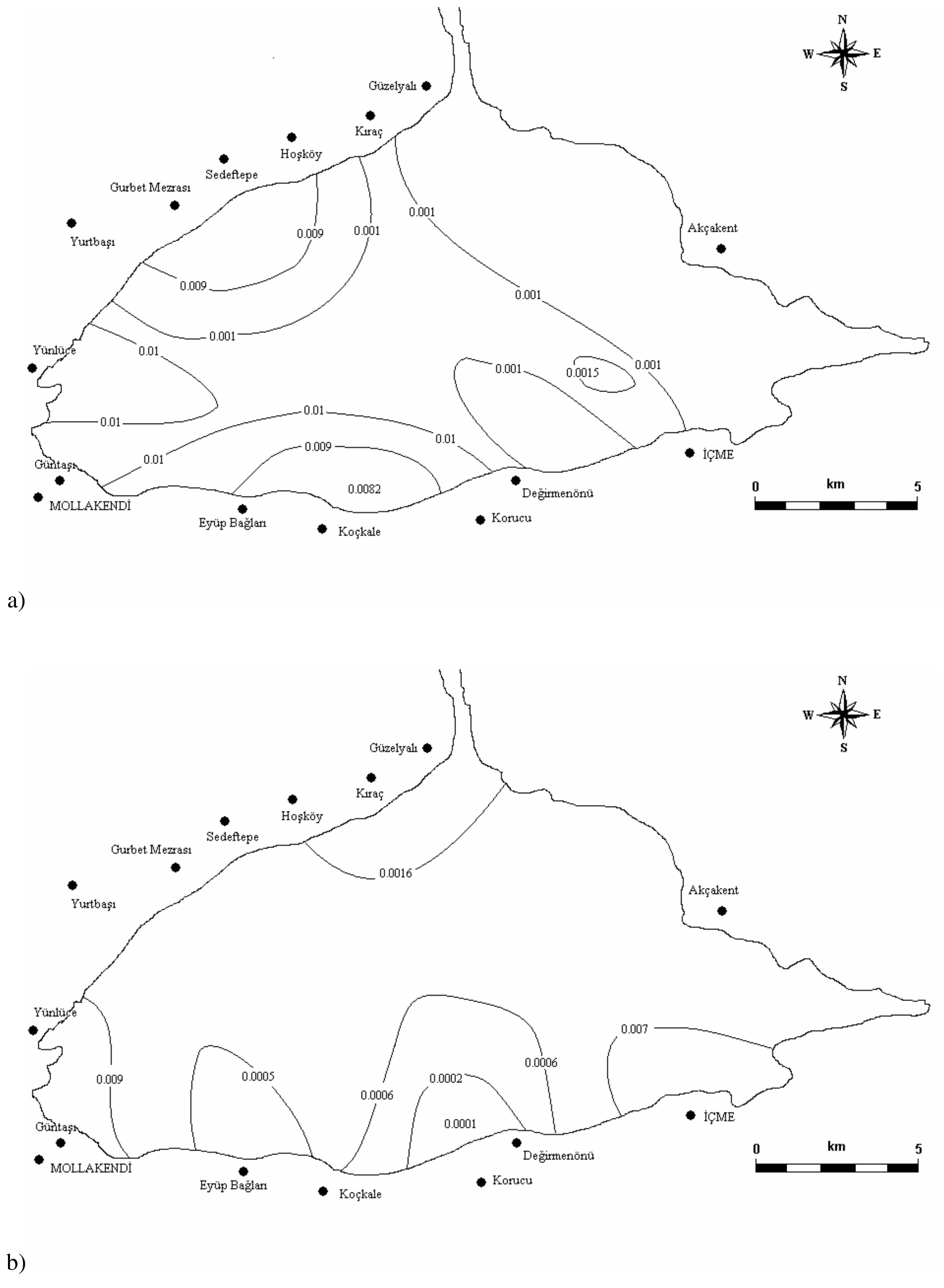


Fig. 3. Map of iso-curves of ^{137}Cs concentration (in Bq/l) of water samples in spring (a); in autumn (b)

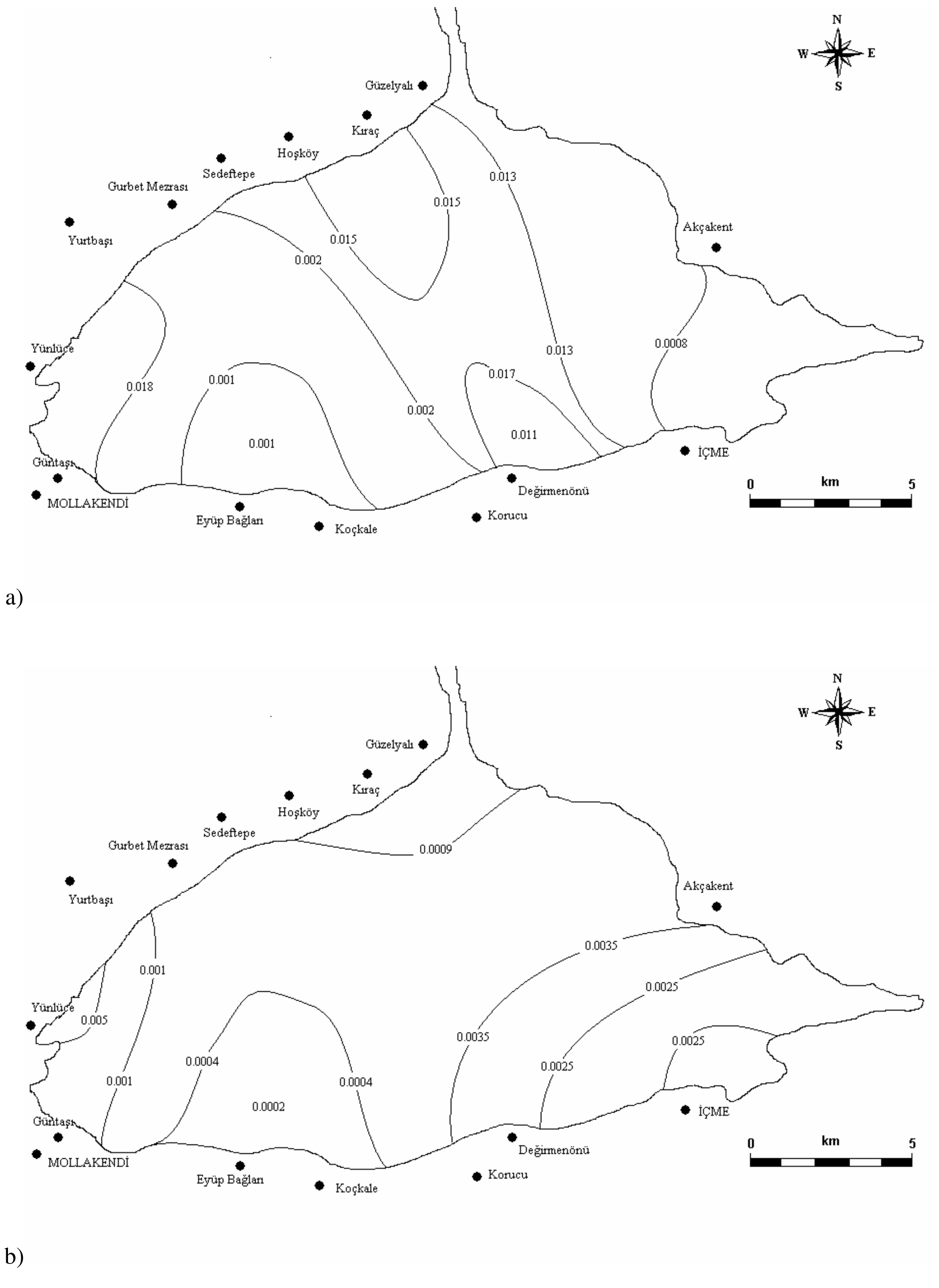


Fig. 4. Map of iso-curves of ^{90}Sr concentration (in Bq/l) of water samples in spring (a); in autumn (b)

The concentration of ^{137}Cs in the water samples taken in autumn was 0.0016 Bq/l in the north of the lake, however, with a high variation in the south part: a change from 0.009 to 0.007 Bq/l was determined (Fig. 3b). The ^{137}Cs concentration decreased from 0.0006 to 0.0002 Bq/l in the region between Koçkale and İçme.

^{90}Sr: The distribution of ^{90}Sr in the water samples taken in spring is illustrated in Fig. 4a. The ^{90}Sr concentration changed from 0.001 to 0.002 Bq/l in the

south of the region, from Mollakendi to Koçkale. A zone of 0.002 Bq/l extended from south to the north. Going from this region southwards, the ^{90}Sr concentration decreased from 0.017 Bq/l to 0.0008 Bq/l and increased from 0.002 Bq/l to 0.013 Bq/l in the north region.

It is seen that the ^{90}Sr concentration was less than the ^{137}Cs concentration of the water samples taken in autumn (Fig. 4b). In the north of Güzelyalı region of the lake, the change was 0.0009 Bq/l and in the north-west of the region 5 Bq/l. The activity change along the zone from north to south was 0.001 Bq/l. Going eastwards; a higher decrease of ^{90}Sr concentration (0.0025 Bq/l) can be seen in the Mollakendi-Koçkale region.

Deep sediments

Total alpha-radioactivity: The radioactivity iso-curves for the alpha-radioactivity of the soil samples taken in spring are seen in Fig. 5a. In the region of a total of 250 km^2, extending from Ağmezra in north to Güzelyalı, the determined total alpha-radioactivity was about 300 Bq·kg^{-1}. Towards west, the radioactivity decreased, between that region and Yünlüce it varied between 200 and 220 Bq·kg^{-1}. The radioactivity in 10 km length of the sea-shore from Eyüp Bağları to Değirmenönü and from the coast to 5 km away in the sea, increased to 500 Bq·kg^{-1}. However, in the region from İçme to the end of the lake in the east, the radioactivity rised to 700 Bq·kg^{-1}, perhaps because a fault line crosses İçme and the sea-shore line.[10] The radioactivity increases along the fault line.[10,11] Examining Fig. 5a carefully, it can be seen that the radioactivity on the south region of the lake was higher than that in the north region in respect to the gross alpha-radioactivity of the deep sediment. Since, the sea-shore of the south region is relatively more perpendicular to the lake base, it is more likely that a soil erosion happens here than in other regions.[10] So, in this region, the terrestrial contribution is higher than in the north part. The contribution to the radioactivity of such additions as soil and rocks entering the lake by erosion is quite high.[9,12] In respect of the deep sediment taken in spring, the highest values of alpha-radioactivity (700 Bq·kg^{-1}) were obtained in the vicinity of İçme Village, and the lowest ones were observed in the Değirmenönü region.

The radioactivity iso-curves representing the alpha-radioactivity of the samples collected in autumn are seen in Fig. 5b. The radioactivity in the deep sediment samples was 300 Bq·kg^{-1} in this season. The highest radioactivity was determined in the vicinity of Koçkale, Değirmenönü and İçme (500 Bq·kg^{-1}). It can be seen that the radioactivity in the south of the lake is higher than in the north region.

Total beta-radioactivity: The beta-radioactivity iso curves obtained by the samples collected in spring are seen in Fig. 6a. The alpha-radioactivity in the deep sediment examined in this season was 12 times higher than the beta-radioactivity. This surplus may be attributed to the alpha-active elements which are in majority in all the three decay series.[13] The highest radioactivity was about 100 Bq·kg^{-1}, and found in the vicinity of Yünlüce-Ağmezra, the lowest values were about 4 Bq·kg^{-1}.

The radioactivity iso-curves representing the beta-radioactivity of the samples collected in Uluova in autumn are seen in Fig. 6b. The lowest radioactivity was measured along the Ağmezra-Mollakendi line and was 2.8 Bq·kg^{-1}. High radioactivity lines were determined in the vicinity of İçme (390 Bq·kg^{-1}). Analyzing the iso-radioactivity map, it can be seen that the radioactivity on the south part of the lake was higher than that in the north part. It can be said that the geological formation (clay, silt) has a strong effect on this situation.

^{137}Cs: In the deep sediment samples taken in spring, the ^{137}Cs concentration, which was dominant in the north of the lake, was 5 Bq·kg^{-1} (Fig. 7a), and varied between 1.5 and 2.5 Bq·kg^{-1} in the south region. Almost no ^{137}Cs was found in the region between Mollakendi and Koçkale.

The change of ^{137}Cs concentration in the deep sediment samples taken in autumn has been found negligible in the north of the lake. There is a region in the vicinity of Mollakendi, in the south region having 8 Bq·kg^{-1}. Going from Mollakendi westwards, the ^{137}Cs concentration varied between 2 and 4 Bq·kg^{-1} (Fig. 7b).

^{90}Sr: The change in the radioactivity of ^{90}Sr in the deep sediment samples taken from the lake in spring has been found negligible in the north part of the lake. Going towards the coast in the south region, the ^{90}Sr concentration decreased from 9 to 0.1 Bq·kg^{-1} (Fig. 8a).

The ^{90}Sr concentration in the deep sediment samples taken from the lake in autumn, which was dominant in the north of the lake, was 4 Bq·kg^{-1}. It increased from 0.6 to 2 Bq·kg^{-1} in the south-east region. ^{90}Sr was not determined in the centre of this region. From Koçkale eastwards, an increase of ^{90}Sr-concentration from 2 to 3 Bq·kg^{-1} was observed. In the very east of the lake there was a change in the ^{90}Sr concentration where it was 2 Bq·kg^{-1} (Fig. 8b).

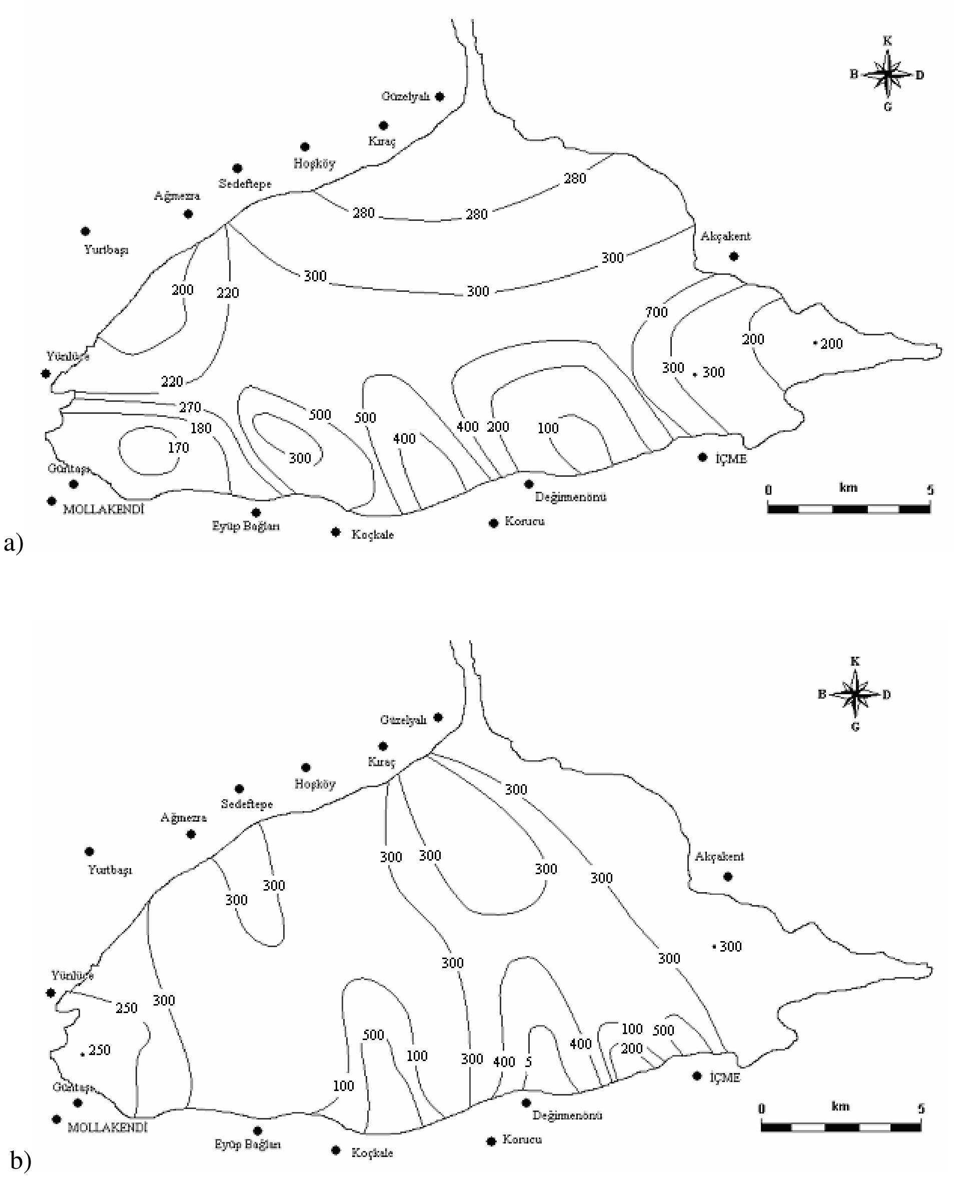


Fig. 5. Map of iso-curves of alpha-radioactivity (in Bq·kg^{-1}) of deep sediment samples in spring (a); in autumn (b)

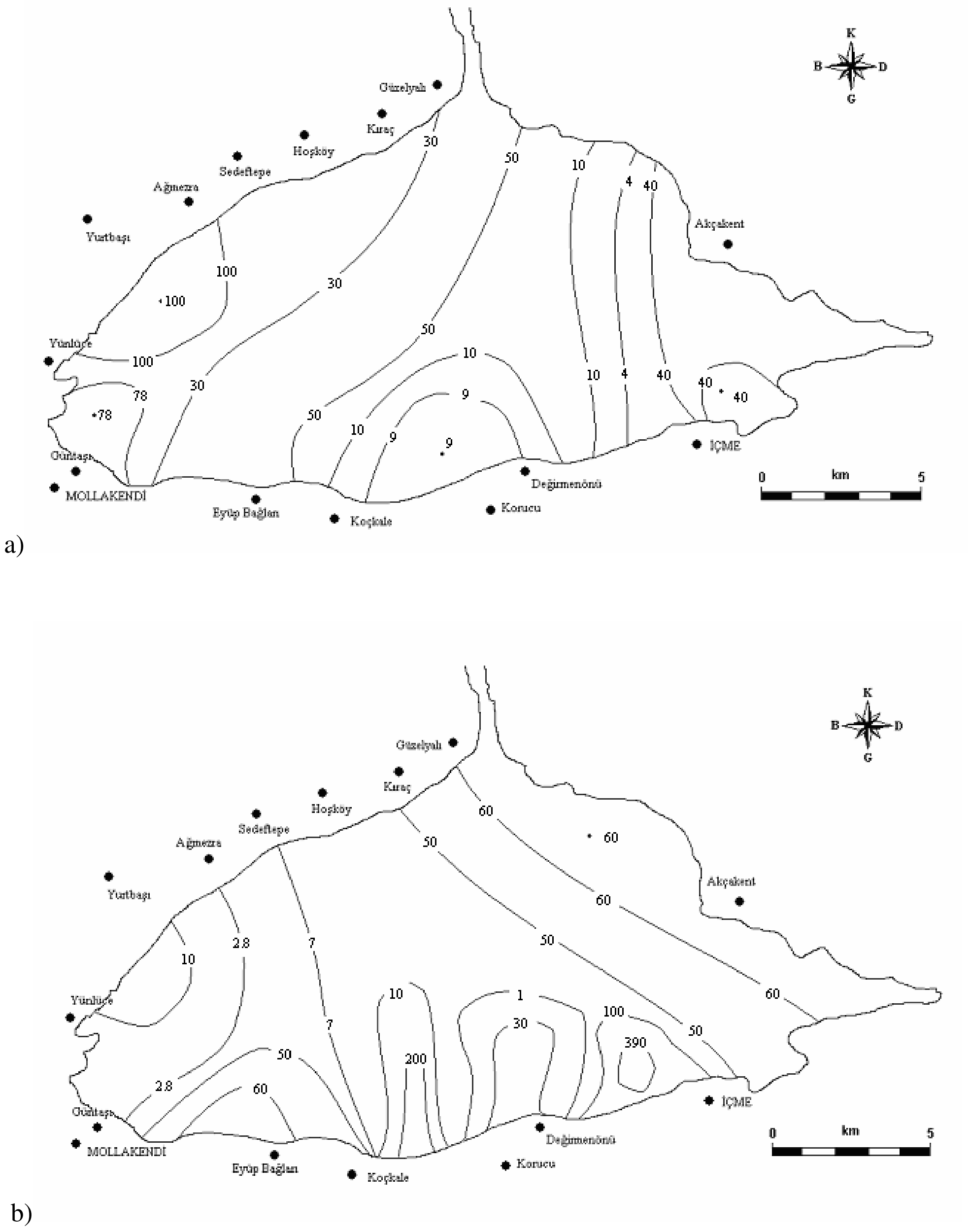


Fig. 6. Map of iso-curves of beta-radioactivity (in Bq·kg^{-1}) of deep sediment samples in spring (a); in autumn (b)

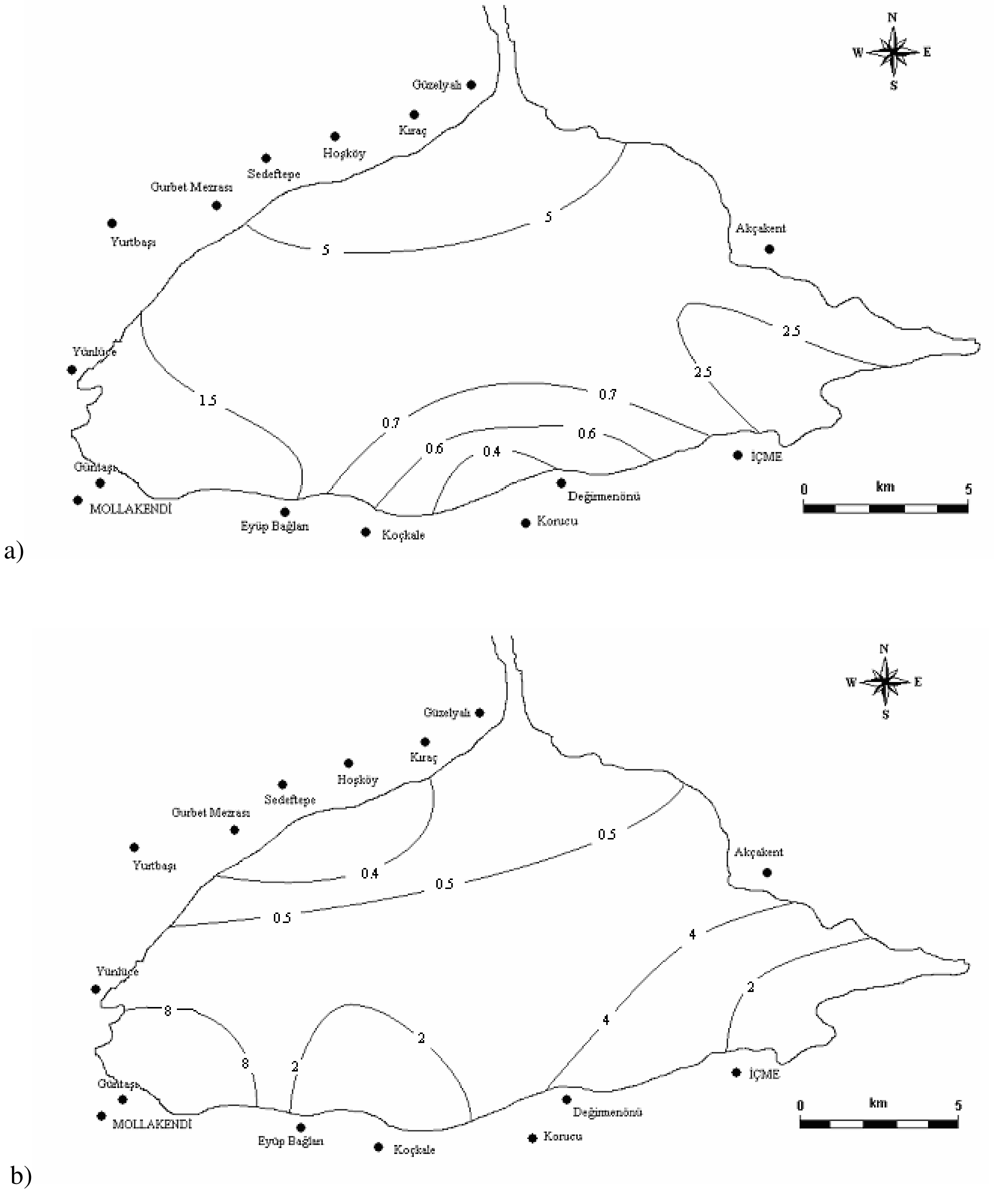


Fig. 7. Map of iso-curves of ^{137}Cs concentration (in Bq·kg^{-1}) of deep sediment samples in spring (a); in autumn (b)

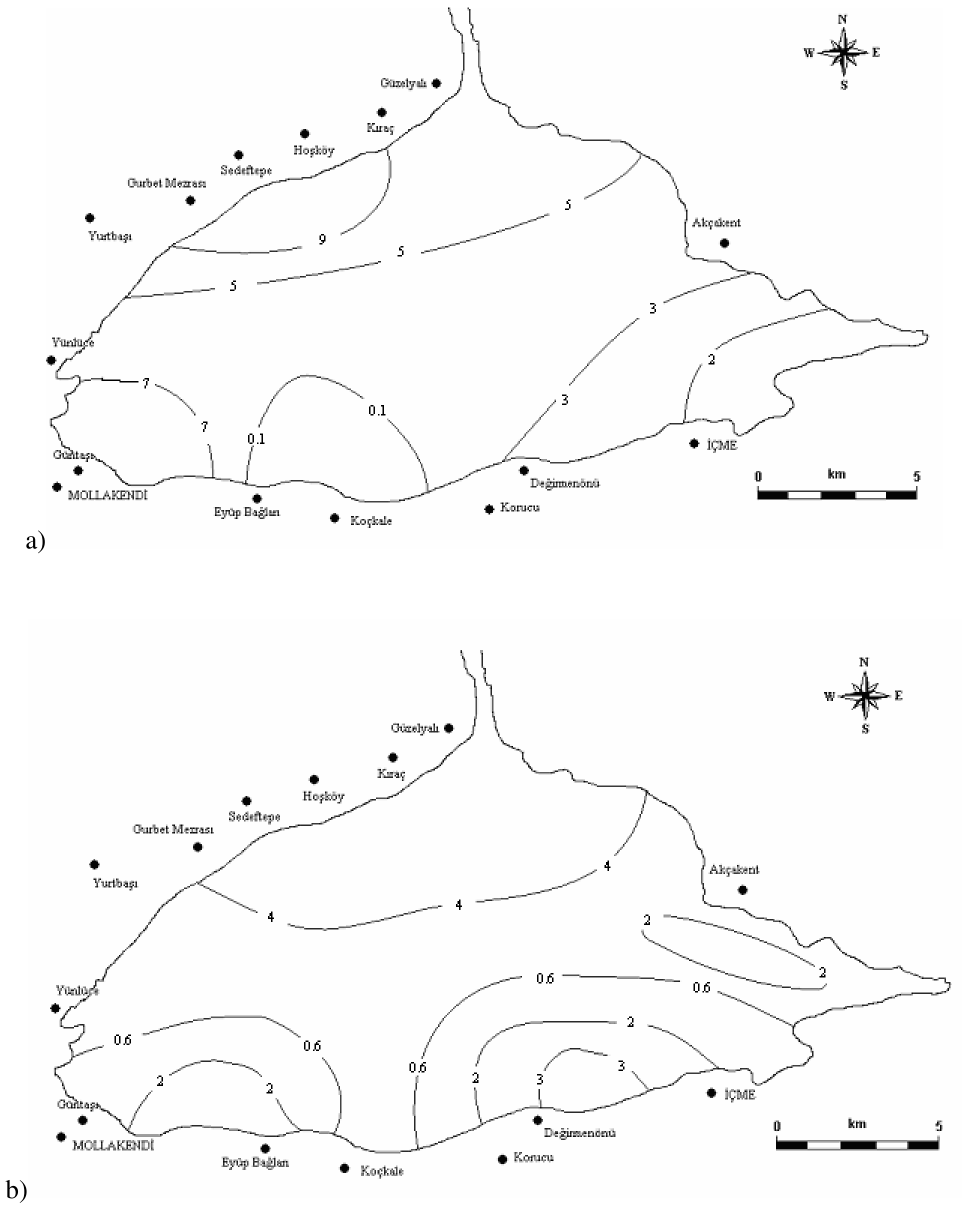


Fig. 8. Map of iso-curves of ^{90}Sr concentration (in Bq·kg^{-1}) of deep sediment samples in spring (a); in autumn (b)

Conclusions

The distance between Chernobyl and Samsun, Trabzon and Ankara is 1210 km, 1375 km and 1210 km, respectively; however, the distance between Chernobyl and the research field, Keban (Uluova), is 1560 km. ^{137}Cs and ^{90}Sr concentrations were determined at the Keban Dam Lake in the Uluova region, 19 years after the Chernobyl accident (1986). In South-eastern Europe, the impact of the explosion in Chernobyl was felt mainly between 3 and 5 May. Peak fallout values were recorded during that period in Turkey, Yugoslavia, Italy, Greece and Albania.[3]

The ^{137}Cs concentration in deep sediment samples was less than that in surface water even if no ^{137}Cs was found in some regions. ^{137}Cs and ^{90}Sr concentrations were determined in the deep sediment samples taken in spring and found to be almost equal.

The gross alpha-activity and ^{137}Cs concentration values of the water analyzed in spring were higher than the concentrations determined in the deep sediment samples taken from the same locations. Moreover, the ^{137}Cs and ^{90}Sr concentrations in the water samples taken in spring were higher than in the deep sediment samples from the same locations. This is in agreement with other results.[2,9] According to a research performed for the Japan Sea, the ^{90}Sr concentration of the surface water varied between 0.0011 and 0.0016 Bq/l, while that in surface water was between 0.0016 and 0.0020 Bq/l.[2] These results agreed those of ours, as well (Fig. 3a, 3b, 4a, 4b).

It can be concluded that the activity concentration in the lake water increases as it rises from the bottom upwards to the surface.

Uranium isotopes are dominant gross alpha-emitters. Uranium isotopes, especially ^{238}U, exists mainly in surface water. It was observed that in deep waters uranium flows from the bottom to the surface. Therefore, the concentration of ^{238}U and of natural uranium isotopes in the surface water is higher than in the bottom water of the lake.[15]

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