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Assessment of natural radioactivity and radiological risk of sediment samples in Karacaören II dam Lake, Isparta/Turkey

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Abstract

This research aimed to assess natural radioactivity levels in lake sediment of Karacaören II Dam. In this study sediment samples were collected from 12 station of lake in May, 2016. The natural radionuclides 226Ra, 232Th and 40K were measured with a coaxial HPGe detector (Canberra, GC 1519 model) of 15% relative efficiency and a resolution of 1.9 keV at the 1332 keV gamma of 60Co. In order to assess the radiological hazards resulting from natural radioactivity, radium equivalent activities (Raeq), absorber dose rate (D), internal (Hin) and external (Hex) hazard index, annual effective dose rate (AED) and Excess life time cancer risk (ELCR) were calculated and compared with recommended values of international organizations.

Keywords: Karacaören II Dam Lake, Sediment, Natural Radioactivity, Absorber Dose Rate.

1. INTRODUCTION

Karacaören II Dam Lake (FIG. 1), which is situated on Aksu stream within the boundaries of Isparta and Burdur, is built for irrigation and energy production. In this reservoir, there are various types of aquatic creatures and are aquaculture cages for kinds of carp and perch. Recently, Karacaören II dam has become more of an issue from the point of a water supply for Antalya. The pollution of water sources is one of the most serious problems in today's world. The safe water reserve must not contain any harmful bacteria, toxic materials and chemicals, and radioactive residue etc. Radioactivity in water may have a very high background level depending on the geology of the environment. Radioactivity in water may come from the decay products of naturally occurring radionuclides such as Uranium and Thorium.

The contribution of radiation from sediment to human exposure can either be the whole body due to external radiation originating directly from primordial radionuclides present in sediment or internal due to inhalation. The internal exposure to radiation, affecting the respiratory tract, is due mainly to radon and it's decay products which emanate from the soil, sediment, and building materials [1].

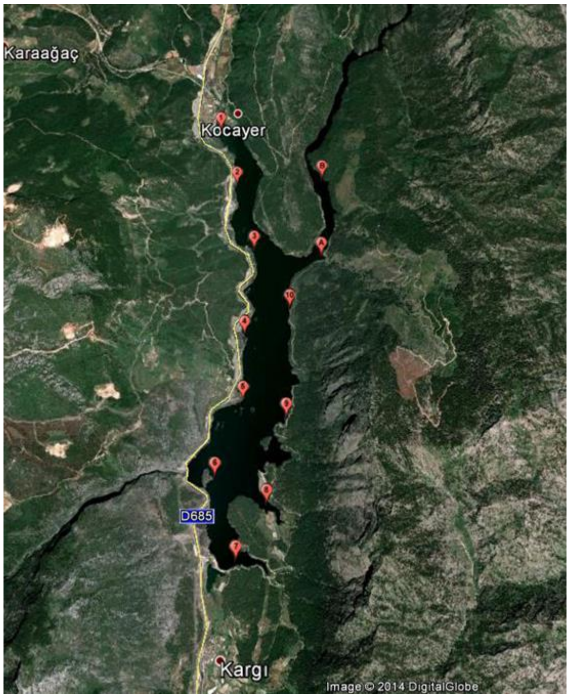


FIG 1. Location of Karcaören II Lake Dam with sample point (*from Google Earth*)

2. EXPERIMENTAL PRECEDURE

In this study sediment samples were collected from 12 stations of the lake in May 2016. The details of sediment including depths and sampling points (using a GPS, Garmin eTrex10 model) are given in Table I. Each the lake sediment sample of 0.5–1 kg was collected from the lake coast using a Van Veen grab sampler (FIG. 2a) at the predetermined locations; these were packed in a nylon made of non-radioactive material and were sealed and labeled to avoid mixing and contamination (FIG. 2b). Each sediment sample was homogenized, dried in a temperature-controlled furnace at 105 °C for 24 h to remove moisture and sieved through a 400 mesh. About 120 g of each sample was sealed in gas-tight, radon impermeable, cylindrical polyethylene plastic containers (5.5 cm diameter and 5 cm height) for gamma activity analysis [2].

TABLE I. Location, geographical coordinates of sediment samples

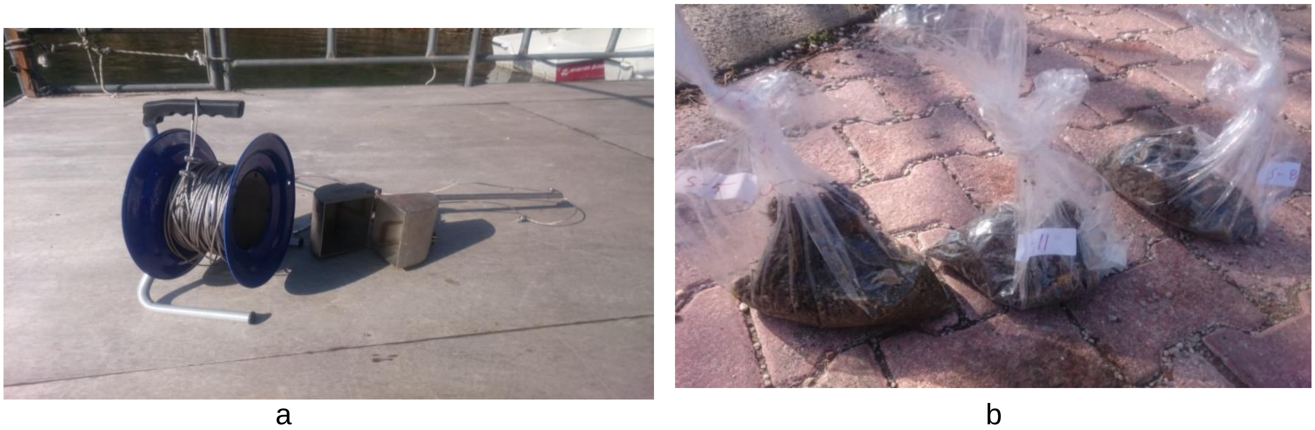
Point	Latitute	Longitude
1	37°20'17.18"K	30°48'38.43"D
2	37°19'57.47"K	30°48'46.08"D
3	37°19'35.50"K	30°48'53.95"D
4	37°19'7.07"K	30°48'51.59"D
5	37°18'46.29"K	30°48'51.91"D
6	37°18'22.71"K	30°48'42.59"D
7	37°17'57.85"K	30°48'51.89"D
8	37°18'14.49"K	30°49'21.37"D
9	37°18'40.79"K	30°49'80.82"D
10	37°18'33.76"K	30°49'31.32"D
11	37°18'36.72"K	30°49'62.32"D
12	37°19'59.69"K	30°49'20.32"D

The natural radionuclides ^{226}Ra, ^{232}Th, and ^{40}K were measured with a coaxial HPGe detector (Canberra, GC 1519 model) of 15% relative efficiency and a resolution of 1.9 keV at the 1332 keV gamma of ^{60}Co. The detector was shielded in a 10 cm thick lead well internally lined with 2 mm Cu foils. The spectrum analysis was performed using computer software Genie 2000 (FIG. 3). As an example, a gamma-ray spectrum of a sample taken from one of the sediment samples belonging to the A1 station recorded with the HPGe detector is presented in Figure. 4.

The specific activities of these samples were in accordance with their certified values within errors in the order of 3%–7%. The gamma energy lines of 351.9 keV (^{214}Pb) and 609.3 keV (^{214}Bi) were used to represent the ^{226}Ra series, while 911.1 keV (^{228}Ac) and 583.1 keV (^{208}Tl) were used to represent the ^{232}Th series. ^{40}K was investigated using gamma lines at 1460.8 keV [3]. The activity values were given in Bq kg−1 in dry weight for sediment samples. The activity concentrations for the ^{226}Ra, ^{232}Th, and ^{40}K in the measured samples were computed using the following equation:

$$C = \frac{N}{\varepsilon \cdot P_{\gamma} \cdot t \cdot m} (Bqkg^{-1}) \tag{1}$$

where N is the net counting rate of the gamma ray, ε is the photo peak efficiency of the detector used, P_γ is the absolute transition of gamma decay, t is the counting time in seconds and m is the mass of the sample in kilograms.



a b

FIG. 2. Sample collection and transportation

FIG. 3. Canberra GC 1519 model HPGe detector

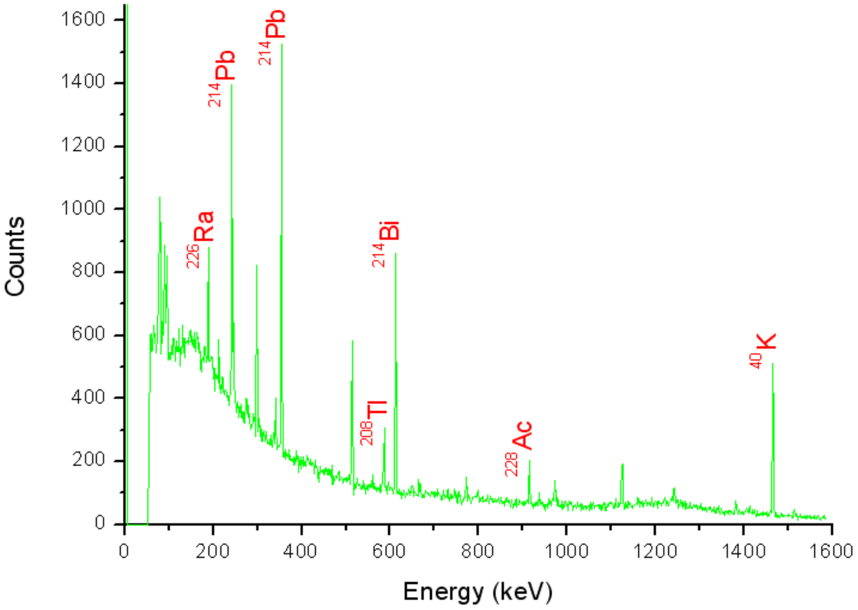


FIG.4. Gamma-ray spectrum of a sample taken from A1 station

3. RESULT AND DISCUSSION

The ^{226}Ra, ^{232}Th and ^{40}K radioactivity values of sediment samples taken from Karacaören Dam Lake in May 2016 are shown in Table 2 and also these values were compared with the values of UNSCEAR (2000) and the other authors [4,5]. The mean radioactivity concentrations of ^{226}Ra, ^{232}Th and ^{40}K are 79.59, 72.42 and 812.37 Bq kg^{-1}, respectively. The concentrations in the study area were higher than those of the other studies. There is an excess of marble and granite mines in the region [6]. The rock groups where uranium, thorium, radium and radon are rich are metamorphic rocks, granite type rocks, sediments containing organic matter, sandstones and carbonate sedimentary rocks. The presence of uranium and thorium in magmatic rocks is closely related to the change in uranium and thorium concentrations at the origin of the magma and magmatic crystallization. The content of uranium and thorium in magmatic rocks decreases from acidic rocks to basic rocks [7]. The presence of this structure near the reservoir lake in the lake sediment may cause high activity values. In addition, When look at the natural and radioactivity values taken from TAEK in Turkey [8] (TCRA, 2013), the studied region has the bigger activity values than other regions.

3.1 Radiological Parameters

The main objective of measuring radioactivity is to make an estimate of radiation dose likely to be delivered externally to the general public [9]. To assess the radiological risk of the lake sediments, it is useful to calculate the different radiological indices such as;

- Radium equivalent activities (Ra_{eq}),
- Absorbed dose rate (D),
- Internal (H_{in}) and external (H_{ex}) hazard index,
- Annual effective dose rate (AED) and
- Excess lifetime cancer risk ($ELCR$)

3.1.1 Radium equivalent activities (Ra_{eq})

The radium equivalent concept allows a single index or number to describe the gamma output from different mixtures of uranium, thorium, and potassium in the sediments sampled from different locations. It is a widely used hazard index and is calculated using the following equation [10].

$$Ra_{eq}=A_{Ra}+1.43\times A_{Th}+0.077\times A_{K} \qquad (2)$$

where, A_{Ra} A_{Th} and A_{K} (in Bq kg^{-1}) are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K, respectively (Table 2). In Table 3, the values of radium equivalent summarized. These values varied from 209.41 to 324.85 Bq kg^{-1}. The mean Ra_{eq} values of 245.70 Bq kg^{-1}. Maximum allowed radium equivalent activity value is 370 Bq kg^{-1} [11] .

3.1.2 Absorber dose rate (D)

The contribution of natural radionuclides to the absorbed dose rate in air (D) depends on the natural specific activity concentration of ^{226}Ra, ^{232}Th and ^{40}K. The major part of the gamma radiation comes from terrestrial radionuclides. There is a direct relation between terrestrial gamma radiation and radionuclide concentrations. If a radionuclide activity is known then its exposure dose rate in air at 1m above the ground can be calculated using the formula suggested by [11-12] UNSCEAR.

$$D(\mathrm{nGyh}^{-1})=0.427\times A_{Ra}+0.662\times A_{Th}+0.0432\times A_{K} \qquad (3)$$

where A_{Ra}, A_{Th} and A_{K} (in Bq kg^{-1}) are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K, respectively (Table 2).

3.1.3 Internal (H_{in}) and external (H_{ex}) hazard index

The internal and external hazard index is a criterion for index radiation hazard. For the safe use of materials in the construction of dwellings the following criterion was proposed by [13].

$$H_{in}=A_{Ra}/159+A_{Th}/259+A_{K}/4810\leq 1 \qquad (4)$$
$$H_{ex}=A_{Ra}/370+A_{Th}/259+A_{K}/4810\leq 1 \qquad (5)$$

where, A_{Ra} A_{Th} and A_{K} (in Bq kg^{-1}) are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K, respectively (Table 2). In Table 3, the values of hazard index were given. These values varied from 0.566 to 0.877 for external index and from 0.758 to 0.957 for the internal index. The values of indices should be ≤1. All value of hazard index are below the criterion values.

3.1.4 Annual effective dose rate (AED)

The calculated absorbed dose rate was also converted into an annual effective dose;

$$AED(\mu SV/year)=D(nGy/h)\times 8760(h/year)\times 0.2\times 0.7(Sv/Gy)\times 10^{-3} \qquad (6)$$

where 0.2 is outdoor occupancy factor, 0.7 (Sv/Gy) is the conversion coefficient of the dose absorbed in the air [10]

3.1.5 Excess life time cancer risk ($ELCR$)

Excess lifetime cancer risk (ELCR) was estimated using the equation [14];

$$ELCR = D(\text{nGy/h}) \times DL \times RF \tag{7}$$

where D is the absorbed dose rate, DL is the duration of life (approximately 78 years) and RF is the risk factor (Sv^{-1}), which reflects the fatal cancer risk per sievert. For stochastic effects, ICRP 60 uses a value of 0.05 for the public [15].

TABLE II. Activity Concentration of Lake Sediment samples

Activity concentration (Bq kg^{-1}, dw)			
No	**^{232}Th**	**^{226}Ra**	**^{40}K**
1	65.99	69.63	637.77
2	87.79	74.53	731.3
3	72.60	72.25	804.5
4	63.17	79.25	701.32
5	52.10	83.31	670.04
6	106.55	53.55	728.76
7	73.59	83.9	922.59
8	69.52	84.63	723.61
9	70.79	91.15	868.77
10	55.81	65.88	849.81
11	87.82	103.58	1242.64
12	63.38	93.37	867.41
Mean	**72.42**	**79.58**	**812.37**
Altınkaya Dam Lake[a]	27.7	19.5	460
Dernebt Dam Lake[a]	25.5	18.8	365
Deriner Dam Lake[b]	13.9	15.8	551.5
Borçka Dam Lake[b]	12.5	3.7	473.8
Muratlı Dam Lake[b]	30.0	14.4	491.7
Worldwide[c]	35	30	400

[a][4], [b][5], [c][10]

TABLE III. Radiological Hazards Parameters calculated using Activity Concentration of Lake Sediment samples

Radiological hazards parameters						
No	Ra_{eq}	D (nGyh^{-1})	AED (μSV/year)	H_{ex}	H_{in}	ELCR $\times 10^{-3}$
1	213.10	98.62	121	0.576	0.764	0.466
2	256.38	118.1	144.7	0.692	0.894	0.557
3	238.01	110.8	135.9	0.643	0.838	0.523
4	223.58	104.0	127.6	0.604	0.818	0.491
5	209.41	97.89	120.1	0.566	0.791	0.462
6	262.03	119.5	146.5	0.708	0.852	0.564
7	260.17	121.7	149.2	0.703	0.929	0.575
8	239.76	111.3	136.5	0.648	0.876	0.525
9	259.27	121.1	148.5	0.702	0.947	0.572
10	211.12	99.58	122.1	0.570	0.748	0.472
11	324.85	152.7	187.3	0.877	0.957	0.721
12	250.79	117.6	144.2	0.677	0.931	0.555
Worldwide[c]	**370**	57	70	≤1	≤1	0.29

5. ACKNOWLEDGEMENTS

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