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Seasonal measurement and dose assessment of natural radionuclides in sediments of Darbandikhan Lake in Kurdistan-Iraq

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ABSTRACT

A total of 100 sediment samples were collected from Darbandikhan Lake and its different resources (spring, stream, and lake) during the four seasons. Spectrometry analysis of HPGe detector was used for measuring the specific activity. The seasonally measured mean activity concentration of ^{238}U, ^{232}Th and ^{40}K for sediment samples were 11.9 ± 1.0, 7.8 ± 1.0 and 213.4 ± 3.4 Bq/kg in spring; 9.2 ± 1.1, 7.9 ± 1.0 and 205.8 ± 3.0 Bq/kg in summer; 12.7 ± 1.5, 8.2 ± 1.0 and 188.1 ± 3.1 Bq/kg in autumn; 11.9 ± 1.6, 9.1 ± 1.0 and 218.7 ± 3.0 Bq/kg in winter, respectively. The obtained activity concentrations of ^{238}U, ^{232}Th and ^{40}K are all below the recommended values suggested by UNSCEAR (2000) for sediment 35, 30 and 400 Bq/kg, respectively.

The ordinary kriging method was used to draw the contour maps using the surfer digital program.

RESRAD-BUILD simulation code was used to determine the indoor dose, annual dose rate and cancer risks received and exposed to individuals in the dwellings, which show an increase over a period of 50 years. Two scenario descriptions of changing wall thickness and room dimension were, studied and they shows that the indoor dose and cancer risks increase with wall thicknesses until 50 cm and over a period of 50 years, as well as the increase of room size increases the internal dose and cancer risks inside the buildings. From the analyzed results it was concluded that the sediments in the Darbandikhan Lake has no risks when used in building construction.

1. Introduction

According to the source of radiation, there are two types of radiation sources, natural and artificial. The natural radiations also classify into cosmic and terrestrial radiation. All of them cause internal and external exposure to the environments. The ionizing radiations from natural backgrounds are linked to human life and cannot be distinguished and far away from it. The natural background radiation exposure to the human body comes from air, water, plants animals, soil and rocks. Only those radionuclides with long half-life compared with the age of the earth (primordial) and their progenies are one of the main external exposures to the environment creatures (UNSCEAR, 2000).

Everybody is inevitably exposed to natural background radiations which differ from place to place and from time to time in both quantity and quality that depend on the geological and geographical conditions (Henry, 1969).

The principal sources of radiological exposure that monitor interest is due to primordial radionuclides such as ^{238}U, ^{232}Th and ^{40}K, which occur in minerals like zircon and monazites (UNSCEAR, 1993).

Due to the rock erosion and weathering process the radionuclides are carried by soil, streams and rivers, so the lake sediments are considered the main source of radioactivity that contributes the major part to the background level of radioactivity (UNSCEAR, 2000).

Sediments in all water (sea, Lake River and streams) resources considered as the sources of radiation contamination to aquatic organisms. Sedimentary materials, pollutants used as fertilizer increase the radioactivity in soils (Holm and Ballestra, 1989).

Darbandikhan Lake is one of the most important water reservoir resources and the sediments are one of the most important and major mixing materials for building construction in Sulaimany Governorate, so detection and measurement of natural radiation enable one to assess any possible radiological hazard to mankind resulting from the use of such materials.

Some previous natural radioactivity studies have been carried out in sediment samples in different part of the world, Otansev et al. (2016), Abdel-Halim and Saleh (2016), Wang et al. (2016), Patiris et al. (2016), Ravisankar et al. (2015), Ravisankar et al. (2014), Suresh Gandhi et al.

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(2014), and Isinkaye and Emelue (2015).

The aim of the present work is to determine the seasonal measurement of radioactivity due to natural radio nuclides of ^{238}U, ^{232}Th and ^{40}K in Darbandikhan Lake sediments in different seasons. Additionally the simulation RESRAD-BUILD computer code has been used to calculate the internal dose received by the dwellers and cancer risk incidence.

2. Study area

Darbandikhan Lake is one of the major lakes among the three lakes in Kurdistan, northern Iraq, 230 km northeast of Baghdad and 60 km southeast of Sulaimani city on the road to the town of Darbandikhan, at altitude N35°8′41, and longitude E 45°45′18′ with an altitude 450–578 m.

It is fed by two main tributaries: the Tanjero River, which comes and flows in from the north/ northwest, and the Sirwan River, which flows from the east (Iran). The lake covers (according to the year) approximately 7500 ha (Ararat et al., 2008; Evans, 1994).

Many Governorates in Iraq, especially Kurdistan get some benefit from this lake and its water as it is used as a source for drinking water and for irrigation purpose in the agricultural lands around the lake. Darbandikhan Lake is currently at high risk due to Iranian attempts to install dam as well as pollution by putting sewage and municipal wastes from the city of Sulaimani and other near towns and villages.

The environment of the lake is surrounded by hills covered with grass and small shrubs and mountains (including Bashari, Zmnako and Zawally) that are covered in oak forests. The rock filled embankment dam was constructed between 1956 and 1961 for irrigation and power generation.

Water levels decline in summer after the spring melt due to dam release and rise again when winter rains return in the lake fall. The land is used for farming, especially wheat and barley (Evans, 1994).

The latitude, longitude and altitude recorded from the GPS type (GPS72 GARMIN) at each position the geological type and the height from the sea were recorded, as shown in Table 1.

The map of Darbandikhan lake water with their resources is shown in Fig. 1.

3. Materials and methods

3.1. Sample collection and preparation techniques

A total of 100 sediment samples were collected from the Darbandikhan Lake with their resources during the four seasons from May 2014 to February 2015 in which six samples in each season from springs and the rest of the branches, streams and lakes were taken.

The sediment samples were collected at the bottom of the lake, about 3 kg of each sample was kept in a thick plastic bag. The collected samples were brought to the laboratory, the sediment samples were then oven dried at a temperature of 90 °C until achieving a constant weight. The dried samples were pulverized into a fine powder and sieved through a 1 mm homogenized mesh sieve until radioactivity analysis.

The sediment samples were placed in 1 L Marinelli container which fits into the detector, sealed and stored for at least 4 weeks prior to measurement in order to insure that reaching secular equilibrium between the parent and progenies.

3.2. Gamma-ray spectrometry analysis

A high resolution spectrometer was used for the measurement of the gamma energy spectrum of the emitted gamma-rays in the energy range between 50 keV and 2000 keV. The system consists of a p-type high purity germanium (HPGe) detector with an efficiency of 20% and a resolution of 1.8 keV at 1332 keV gamma ray emission of ^{60}Co. It has an operating voltage of +4000 V. During operation the detector is cooled down by 30 L liquid nitrogen at 77 K for the purpose of reducing leakage current and thermal noise, and its warm-up sensor is coupled to the high voltage detector bias supply, ORTEC 659 which is equipped with a remote shutdown feature. The detector was coupled to a preamplifier and an amplifier. The amplifier is an integral part of the low noise system which is providing higher amplification gain and shaping of the signal pulse to obtain the optimum signal with the counting rate. The detector is surrounded by 10 cm lead shield to reduce the background radiation. The energy calibrations were done using the standard radioactive source of ^{137}Cs, ^{60}Co and ^{152}Eu.

Due to the long life of both ^{238}U and ^{232}Th, the concentration was determined from the spectra using the indirect methods. The concentration of ^{238}U was determined from the average concentration of the ^{214}Pb at 352 keV, ^{214}Bi at 609 keV in the samples and ^{232}Th concentration was determined from the average concentration of ^{208}Tl at 583 keV and ^{228}Ac at 911 keV decay products, by this a more accurate radiological concentrations can be obtained. Finally the concentration of 40K was determined directly from 1460KeV peak. The sediment samples were analyzed using gamma ray spectrometry for a counting time 43,200 s. The laboratory background achieved by counting a blank sealed Marinelli beaker for the same time as a sample was running and subtracted from each spectrum.

3.3. Standard source preparation

The IAEA standard samples (S-15) are mixed with SiO_2 in Marinelli beakers and used as reference materials. The uranium and thorium content of S-15 are 85 ppm and 3630 ppm, respectively. A weight of 39.36 g from IAEA S-15 sample was thoroughly mixed with 890 g of SiO_2 in a Marinelli beaker. After mixing with SiO_2, the uranium and thorium concentration are 3.76 ppm and 160 ppm, respectively. Another Marinelli beaker contains 890 g of SiO_2 and provides the background reference for standard samples.

The activity concentration of sediment samples was calculated using the following equation (Wagiran et al., 2005)

$$C_{sample} = \frac{C_{std} \times W_{std} \times N_{samp}}{W_{samp} \times N_{std}} \quad (1)$$

C_{std} and W_{std} are the concentration and weight of the standard, respectively, N_{samp} and N_{std} are the net area of the samples and standard, respectively, W_{samp} is the weight of the samples.

The specific activity of potassium can be calculated using the following equation:

$$A_{sample} = \frac{A_{std} \times W_{std} \times N_{samp}}{W_{samp} \times N_{std}} \quad (2)$$

where A_{sample} is the specific activity of the sample in Bq/kg, Astd (31.45 Bq/g) and W_{std} are the concentration and weight of the standard, respectively, N_{samp} and N_{std} are the net area of the samples and standard respectively, W_{samp} is the weight of the samples.

The uncertainty concentration of the sample was calculated using the following equation (Yussuf et al., 2012)

$$\Delta C_S = C_S \times [\left(\frac{\Delta N_S}{N_S}\right)^2 + \left(\frac{\Delta C_P}{C_P}\right)^2 + \left(\frac{\Delta N_P}{N_P}\right)^2]^{1/2} \quad (3)$$

Where, ΔCs is uncertainty in sample concentration, Ns is standard sample counts, ΔNs is uncertainty in sample counts, Np is standard counts, ΔNp is uncertainty in standard counts, Cp is concentration of standard, ΔCp is uncertainty concentration of standard.

4. Results and discussion

The activity concentration of three naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in sediment samples in the different four