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ORIGINAL PAPER

Evaluation of natural radioactivity levels in soil samples of Al-Hindiya District, Karbala, Iraq

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Abstract. Using a NaI(Tl) detector and the gamma spectrometry technique, 18 soil samples were taken from the Al-Hindiya District in Karbala, Iraq, in order to measure the activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th. The results demonstrated that these radionuclides' activity concentrations in the soil samples varied from 329 to 498 Bq/kg, 18.9 to 28.2 Bq/kg, and 8.2 to 13.1 Bq/kg, respectively. These levels, especially for ^{226}Ra and ^{232}Th, were lower than the global median values published by UNSCEAR (2000) and comparable to those in nearby locations. In order to carry out a more thorough investigation, a sample of dates, water from the Euphrates River, and sandy soil from dredging were also gathered and their inherent radioactivity examined. The sandy soil contained activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th of 271 Bq/kg, 13.1 Bq/kg, and 7.3 Bq/kg, respectively. The values in the water samples were, respectively, 2.13, 0.06, and less than the minimum detectable activity (MDA) in Bq/L. The readings for the date sample were, respectively, 380, 1.5, and MDA Bq/kg. With an average of 41 μSv/y, the outdoor annual effective dose caused by these radionuclides in the soil varied between 34.6 μSv/y and 48.6 μSv/y, which is consistent with values found in the literature and international regulations. Thus, it can be said that the natural radioactivity levels in this area do not pose a threat to the inhabitants.

Keywords: Activity concentration • Dose rate • Gamma spectrometry • Secular equilibrium • Terrestrial radionuclides

Introduction

One of the main natural background radiation sources is soil. For the general public, gamma rays from terrestrial radionuclides such as ^{40}K, ^{226}Ra, and ^{232}Th are a significant source of exposure to natural radioactivity [1–5]. Through paths for ingestion and inhalation, these radionuclides can go from the soil into plants and ultimately into the human body. These radionuclides emit gamma radiation with enough intensity to enable precise concentration measurements using gamma spectrometry methods [6]. Furthermore, because to variations in soil composition and mineral content, soil radioactivity levels range greatly between places. As such, the gamma-ray spectra can be used as distinctive indicators of the type of soil at a particular location [6–10].

Given the recognized health effects of ambient radiation exposure, it is critical to regularly monitor and assess radiation levels. Estimating the amount of radiation that individuals absorb and evaluating possible health hazards require measuring radioactivity levels and figuring out the concentrations of radionuclides in soil. This topic has been the subject of numerous research conducted worldwide, which have also supplied baseline data on natural radioactivity levels in different regions [11–15].

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This study's objective is to determine the activity concentrations of the natural radioisotopes ^{40}K, ^{226}Ra, and ^{232}Th in soil samples that were gathered from the Karbala Governorate's Al-Hindiya District in Iraq. In order to assess the possible radiological risks in the area, the annual effective dose is also computed. It is anticipated that the current investigation will help determine the local population's radiation exposure and offer baseline data on natural radioactivity levels.

Experimental details

Study area

18 soil samples were taken in January 2023 from the Al-Hindiya District, which is about 20 km east of Karbala, Iraq. Two irrigation canals cross the area on either side of the Euphrates River, which runs along its banks. The area under investigation exhibits significant anthropogenic activity, with the majority of the land is used for agriculture, as indicated by the many vegetable crops and date palms. This area's soil is primarily loamy, with roughly 20.5% sand, 37.8% clay, and 41.6% silt [16]. Figure 1 displays the sampling locations' coordinates.

Sample collection, preparations and measurement

All samples whose coordinates are shown in Fig. 1 were obtained from a depth of about 5 cm. Specimens S1, S2, S4, S5, and S13 were collected from

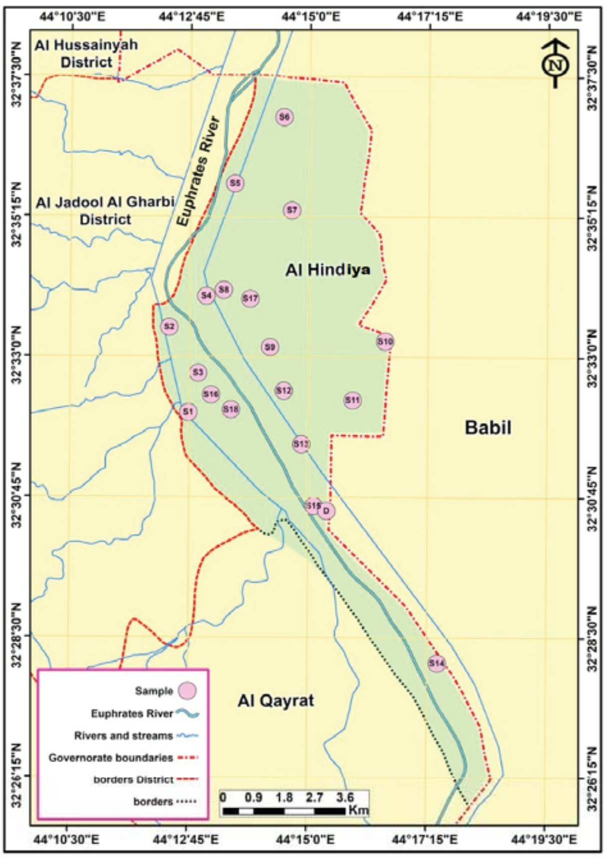

Fig. 1. Al-Hindiya map with samples location.

the zones adjacent to the two irrigation canals. After removing plant roots, leaves, and stones, the soil samples were dried in an oven set to about 100°C. They were then ground into a uniform powder and sieved using a 0.5 mm mesh screen. To allow for the establishment of secular equilibrium between the decay products of the ^{238}U and ^{232}Th series, the homogenized samples were sealed in Marinelli beakers and kept for at least four weeks [17].

Additional samples, such as a sandy soil sample from dredging operations in the Euphrates River at the city center, a water sample from the same river, and dates sample, were gathered in order to perform a thorough survey of the activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th in the study area. The same processing methods used for the original soil samples were applied to the date and sandy soil samples.

Using a NaI(Tl) scintillation detector (Ortec, 3" × 3") with a relative efficiency of 7.4% for the 661.6 keV gamma line of ^{137}Cs, gamma-ray spectrometry was carried out to assess the activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th in the collected soil samples. A counting time of 5 hours was employed to ensure adequate detection sensitivity. The detector was connected to a 1024-channel multichannel analyzer (Ortec DigiBase), and the gamma spectra were analyzed using Maestro-32 software.

To lessen background radiation, a cylindrical lead shield encased the detector. The system was calibrated using standard gamma sources of ^{22}Na, ^{152}Eu, ^{137}Cs, and ^{60}Co. The activity concentrations of ^{226}Ra and ^{232}Th were determined using the 1764 keV gamma-ray peak from ^{214}Bi and the 2614 keV peak from ^{208}Tl, respectively, where ^{214}Bi and ^{208}Tl are in secular equilibrium with ^{238}U and ^{232}Th series. Its distinctive gamma-ray band at 1460.8 keV was used to directly detect the activity concentration of ^{40}K [18]. Each sample's spectrum was subtracted from a background spectrum that was gathered during the same counting period.

Activity and dose assessment

The activity concentration A (Bq/kg) for each soil sample can be calculated according to the relation [19, 20]:

$$A = \frac{N}{I \cdot t \cdot \varepsilon \cdot m} \tag{1}$$

where N is net area under the peak, I is the probability of gamma emission, measurement time t (s), ε is the detector efficiency and m (kg) is the sample mass. Human exposure to external radiation is influenced by the decay of terrestrial radionuclides. The activity concentrations of pertinent radionuclides in the soil can be used to estimate the external gamma dose rate in air, which is expressed in nanograys per hour (nGy/h). The ^{238}U decay series in the samples is thought to have reached secular equilibrium, which means that the uranium-238 activity is roughly equal to the ^{226}Ra activity, i.e. $A_U \cong A_{Ra}$. Yang and Sun [17] reported that the activity ratio of ^{238}U to ^{226}Ra is 0.95 ± 0.16, which supports this assumption. The following relation can be used to determine the external gamma dose rate at a height of 1 m above ground level [17, 21]:

$$D = 0.417A_K + 0.462A_U + 0.604A_{Th} \quad (2)$$

where A_K, A_U, and A_{Th} are the activity concentrations of ^{40}K, ^{238}U and ^{232}Th (Bq/kg) respectively. The annual effective dose rate H (μSv/y) for adults was calculated by the formula [22]

$$H = 1.226D \quad (3)$$

Results and discussion

Table 1 shows the observed activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th in soil samples taken from the Al-Hindiya District in Karbala, Iraq. The average concentration of ^{40}K was 395 Bq/kg, with a range of 329 Bq/kg to 498 Bq/kg. The mean value for ^{226}Ra was 22.2 Bq/kg, with values ranging from 18.9 Bq/kg to 28.2 Bq/kg. The average concentration of ^{232}Th was 11 Bq/kg, with a range of 8.2 Bq/kg in (S12) to 13.1 Bq/kg in (S1). According to UNSCEAR [22], the concentration of ^{40}K in the soil of this area is near the global average value of 420 Bq/kg, with a typical global range of 140–850 Bq/kg. On the other hand, the average activity concentrations of ^{226}Ra and ^{232}Th in the samples under study were lower than the corresponding global average values of 32 Bq/kg and 45 Bq/kg, respectively, as published by UNSCEAR [22].

Table 1. Activity concentrations and annual effective dose rate for soil samples

Sample name	Activity concentration (Bq/kg)			H (mSv/y)
	^{40}K	^{226}Ra	^{232}Th	
S1	396	26.2	13.1	44.8
S2	410	19.9	12.3	41.3
S3	430	22.5	8.5	41.0
S4	372	22.1	11.9	40.3
S5	344	18.9	9.8	35.5
S6	334	19.0	9.2	34.6
S7	388	20.4	12.4	40.6
S8	363	20.5	12.4	39.4
S9	388	23.0	12.7	42.3
S10	361	21.4	10.4	38.3
S11	329	20.0	10.8	36.1
S12	413	20.2	8.2	38.6
S13	389	24.5	10.5	41.5
S14	411	20.2	8.3	38.6
S15	416	23.1	11.7	43.0
S16	488	25.6	12.2	48.5
S17	498	24.8	12.3	48.6
S18	380	28.2	11.7	44.1
Mean	395	22.2	11.02	40.95

The area being studied is located in a sedimentary zone. In general, there is little natural radioactivity in the soil in this area. Since most of the land in this area is used for farming, the application of chemical fertilizers for agricultural purposes is probably responsible for the observed relative rise in radioactivity in some samples.

The sandy soil sample taken from the Euphrates River dredging in the heart of Al-Hindiya had activity concentrations of 271 Bq/kg, 13.1 Bq/kg, and 7.3 Bq/kg for ^{40}K, ^{226}Ra, and ^{232}Th, respectively. These results are similar to the 205.2 Bq/kg, 8.2 Bq/kg, and 7.5 Bq/kg [23] recorded for sediment samples from the Tigris River in Baghdad. Low levels of these radionuclides are found in the riverbed sediments, according to this comparison.

For ^{40}K, ^{226}Ra, and ^{232}Th, the observed radioactive concentrations in the Euphrates River water sample were 2.13, 0.06, and <MDA Bq/L, respectively. Since the 'Zahdi' dates is one of the most widely grown in this region, it was chosen for the date sample. The location D is where this sample was taken. For ^{40}K, ^{226}Ra, and ^{232}Th, the corresponding radioactive concentrations in the date sample were determined to be 380, 1.5, and <MDA Bq/kg. For ^{40}K, ^{226}Ra, and ^{232}Th, the corresponding MDA values were 0.16 Bq/kg, 0.06 Bq/kg, and 0.03 Bq/kg.

According to reports, the average activity concentrations of ^{40}K, ^{238}U, and ^{232}Th in soil in the surrounding areas were 413 Bq/kg, 16 Bq/kg, and 8.45 Bq/kg in Hilla city [24], 375 Bq/kg, 17 Bq/kg, and 9.4 Bq/kg in Baghdad [25], and 319.3 Bq/kg, 11.53 Bq/kg, and 8.7 Bq/kg in the Al-Samawah Desert [26].

As seen in Table 2, the activity concentration of ^{40}K is comparable to these values and compatible with its concentration in other parts of the world. On the other hand, ^{226}Ra and ^{232}Th activity concentrations are lower than those found in the regions indicated in Table 2.

Lastly, the annual effective dose rate data showed an average of 41 μSv/y, with a range of 34.6 μSv/y to 48.6 μSv/y. Values recorded in other local localities,

Table 2. Activity concentrations of soil and corresponding H in some countries

Country	Activity concentrations (Bq/kg)			H (mSv/y)
	^{40}K	^{226}Ra	^{232}Th	
Abha, Saudi Arabia [27]	217.3	39.3	31.5	57.3
Kuwait [28]	385	–	15	40.7
Syria [29]	336	26	24	52
Dehloran, Iran [30]	205.3	292	–	–
Ganos fault, Turkey [31]	445	35	27	–
Guangdong, China [17]	535.8	75.1	101.0	147.2
Spain [32]	578	39	41	49
Present work	395	22.2	11.02	41
World average [22]	400	35	30	70

about 37 μSv/y and 36 μSv/y in Hilla and Baghdad, respectively, are comparable to this average [24, 25]. The effective dose rate (H) values for various nations are shown in Table 2. The average value found in this study, however, is less than the 70 μSv/y outdoor global average that UNSCEAR [22] stated.

Conclusions

In soil samples from the Al-Hindiya District, the activity concentrations of natural radionuclides (^{40}K, ^{226}Ra, and ^{232}Th) are below the world average levels and comparable to those found in other local investigations. Furthermore, these radionuclides produce annual effective dose rate that is below the global average. As a result, both residential and agricultural uses of the soil in this area can be regarded as radiologically safe.

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