Assessment of natural radioactivity and hazards in selected Najaf Sea soil samples

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Abstract. The present work evaluates the natural radioactivity of soils from the Najaf Sea area by determining the activity concentrations of U-238, Th-232, and K-40. A total of twenty soil samples were collected from different locations, prepared under laboratory conditions, and examined using a NaI(Tl) gamma-ray spectrometry system. The measured activity of U-238 varied from 21 to 33 Bq/kg, with a mean value of 26.9 Bq/kg, while Th-232 ranged between 15 and 28 Bq/kg, with an average of 21.2 Bq/kg. The highest activity values were recorded for K-40, which ranged from 260 to 420 Bq/kg and had a mean concentration of 332 Bq/kg. The obtained data were compared with internationally accepted reference levels, and no exceedance was observed. The spatial differences between the samples are mainly associated with the geological structure, sediment composition, and mineral content of the area. The results indicate that the investigated soils reflect normal natural background radiation and do not represent a considerable radiological hazard. The data may therefore serve as a reference basis for subsequent environmental radiation surveys in the Najaf Sea region.

1 Introduction

Natural radionuclides are permanent components of the Earth's crust and represent one of the main sources of background ionizing radiation. Among them, U-238, Th-232, and K-40 are of particular importance because they are widely distributed in rocks, sediments, and soils and may contribute to human exposure through external gamma radiation and, in some cases, through inhalation or ingestion pathways. Their activity levels are not uniform and are determined by the origin of parent rocks, mineralogical composition, soil-forming processes, weathering intensity, and local environmental conditions [1].

Soil radioactivity studies are especially relevant in regions where sediment transport, wind erosion, and arid climatic conditions affect the redistribution of mineral particles. In

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such environments, radionuclides may be unevenly distributed as a result of natural accumulation in fine-grained sediments or mineral-rich deposits. These processes are characteristic of many Middle Eastern landscapes, including central and southern Iraq, where dry climatic conditions and complex geomorphology influence the structure and composition of surface soils [2].

The Najaf Sea area represents a distinctive geological depression in central-southern Iraq. Historically, this area was periodically influenced by the Euphrates River, and large parts of the depression were covered by water. The former flooded zone extended over a considerable distance, which explains the traditional designation of the region as the Najaf Sea. Long-term sedimentation, evaporation, and subsequent exposure of deposits formed heterogeneous soil conditions across the area. Such geological history may affect the content and spatial distribution of natural radionuclides in the soil matrix [3].

Radiological characterization of this region is required for several reasons. First, the Najaf Sea area has environmental and agricultural importance. Second, the growing interest in land use and development requires reliable baseline data on the radiation status of local soils. Third, measurements of natural radionuclides provide a basis for distinguishing normal background radiation from possible future contamination. For this purpose, activity concentrations of U-238, Th-232, and K-40 should be measured and compared with recognized reference values and safety criteria [4].

The distribution of radionuclides in soils is commonly affected by clay content, grain size, organic matter, carbonate fractions, and the presence of heavy minerals. Uranium and thorium are often retained in fine particles and resistant mineral phases, whereas potassium activity is mainly related to K-bearing minerals such as feldspar and mica. Consequently, even within one geographical area, measurable differences can occur between sampling points without indicating anthropogenic pollution.

This study aims to determine the activity concentrations of U-238, Th-232, and K-40 in soil samples collected from selected locations in the Najaf Sea area and to assess whether the measured levels correspond to normal natural background conditions. Sampling sites were identified by GPS, and their distribution was mapped using GIS techniques. This approach allowed the sampling network to represent the investigated area and supported the interpretation of radionuclide variability. The geographic position of the sampling points is shown in Figure 1.

Fig. 1. Map of the study area.

2 Materials and methods

Twenty surface soil samples were obtained from selected points in the Najaf Sea area, Najaf Governorate, Iraq. The sampling points were distributed across the investigated territory to reflect the spatial variability of the local soil cover. Their coordinates were recorded using GPS to ensure accurate location control and to support further spatial interpretation.

At each site, the upper soil layer was sampled from a depth of approximately 5–10 cm. Before collection, coarse stones, roots, plant residues, and visible organic impurities were removed. About 1 kg of soil was taken from each point and placed in clean polyethylene bags. The samples were then transported to the laboratory for preparation and gamma spectrometric analysis.

Laboratory preparation included drying, homogenization, sieving, and sealing. First, the samples were air-dried and then placed in an oven at 105 °C to remove residual moisture. The dried material was crushed and thoroughly mixed to obtain a representative fraction. After that, the soil was passed through a 2 mm sieve to achieve uniform particle size. The prepared samples were transferred into Marinelli beakers, tightly sealed, and stored for about four weeks. This period was necessary to establish radioactive equilibrium between U-238, Th-232, and their short-lived decay products.

The activity concentrations of U-238, Th-232, and K-40 were determined using a gamma-ray spectrometry system based on a thallium-activated sodium iodide detector, NaI(Tl). This type of detector is frequently used in environmental radioactivity measurements because it is reliable, relatively inexpensive, and suitable for routine laboratory monitoring [5, 6].

The operating principle of the detector is based on scintillation. Gamma photons interacting with the NaI(Tl) crystal generate light pulses proportional to the deposited energy. These pulses are converted into electrical signals by a photomultiplier tube, amplified, and processed by a multichannel analyzer to produce the gamma spectrum. Before sample measurements, the system was calibrated for energy and efficiency using standard radioactive sources.

Each soil sample was counted for 10,000–20,000 seconds to improve counting statistics and reduce uncertainty. The activity concentrations were calculated from the net areas of the selected gamma-ray photopeaks. The main components of the system included the NaI(Tl) crystal, photomultiplier tube, high-voltage supply, preamplifier, amplifier, and multichannel analyzer. Although high-purity germanium detectors offer better energy resolution, NaI(Tl) systems remain practical for routine environmental surveys due to their operational simplicity and lower cost [7].

Fig. 2. NaI(Tl) detection system.

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The specific activities of the radionuclides U-238, Th-232 and K-40 were calculated using the following:

$$A\left(\frac{Bq}{kg}\right) = \frac{N}{I_\gamma\, \varepsilon\, M\, T} \tag{1}$$

N is the net area under the photopeak, Iγ corresponds to the probability of gamma emission, ε is the detector efficiency, M is a sample mass and T is a measurement time

3 Results and discussion

The measured activity concentrations of U-238, Th-232, and K-40 in the soil samples are presented in Table 1. The activity of U-238 ranged from 21 to 33 Bq/kg, whereas Th-232 varied from 15 to 28 Bq/kg. K-40 showed considerably higher values, ranging from 260 to 420 Bq/kg. The mean concentrations were 26.9 Bq/kg for U-238, 21.2 Bq/kg for Th-232, and 332 Bq/kg for K-40. The obtained values were compared with international reference levels commonly used for environmental radiation assessment. The reference values are 33 Bq/kg for U-238, 45 Bq/kg for Th-232, and 420 Bq/kg for K-40. The comparison shows that the measured concentrations did not exceed these limits. This confirms that the investigated soils are characterized by normal natural radioactivity and do not show signs of abnormal radionuclide enrichment [8].

The variability observed among the sampling points can be explained by natural differences in the composition of local sediments. Soil texture, mineral assemblage, grain-size distribution, and the proportion of clay and carbonate fractions can all influence radionuclide retention. K-40 activity was higher than that of U-238 and Th-232 because potassium is a major constituent of many common rock-forming minerals. In particular, feldspar and mica may contribute to increased K-40 levels in sedimentary and alluvial soils [9]. The slightly elevated U-238 and Th-232 values in several samples may be related to the presence of finer particles or mineral phases capable of adsorbing and retaining these radionuclides. Nevertheless, the recorded differences are limited and remain within the natural background range. Therefore, they should be interpreted as a result of geological and sedimentological variability rather than human-induced contamination [10].

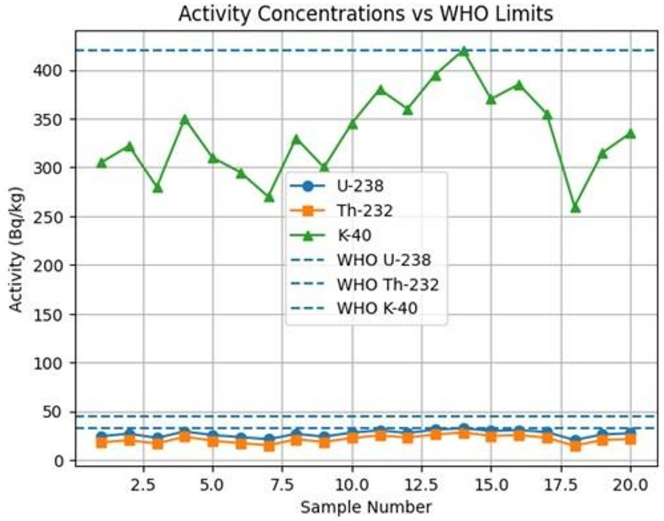

Fig. 3. Activity concentrations of U-238, Th-232, and K-40 compared with WHO limits.

Table 1. Level of U-238, Th-232, and K-40 in soil samples from the Najaf Sea area (Bq/kg).

Sample	U-238	Th-232	K-40
1	24.5	18.2	305
2	27.1	20.5	322
3	22.8	16.9	280
4	29.3	24.1	350
5	25.7	19.8	310
6	23.6	17.5	295
7	21.4	15.2	270
8	26.9	21.3	330
9	24.1	18.7	300
10	28.2	22.6	345
11	30.5	25.4	380
12	27.8	23.1	360
13	31.2	26.3	395
14	32.7	28.4	420
15	29.9	24.9	370
16	30.8	25.7	385
17	28.7	22.9	355
18	20.6	14.8	260
19	26.3	20.7	315
20	27.5	21.5	335
Average Activity (Bq/kg)	**26.9**	**21.2**	**332**
WHO	**33**	**45**	**420**

The overall pattern of the results indicates that the Najaf Sea soils do not present a significant radiological concern for the local population. The activity concentrations are comparable with those reported for natural soils in similar arid and semi-arid regions. The data also demonstrate that the selected sampling network adequately reflects the general radiation status of the investigated area. Thus, the Najaf Sea region can be considered radiologically safe with respect to the measured natural radionuclides.

4 Conclusions

The study determined the activity concentrations of U-238, Th-232, and K-40 in twenty soil samples from the Najaf Sea area. The average values were 26.9 Bq/kg for U-238, 21.2 Bq/kg for Th-232, and 332 Bq/kg for K-40. All measured concentrations were below the corresponding international reference levels. The differences between individual samples are mainly associated with the natural geological and mineralogical characteristics of the area. No evidence of anthropogenic radioactive contamination was identified. The obtained results indicate that the investigated soils correspond to normal background radiation conditions and do not pose a significant radiological hazard.

The presented data may be used as baseline information for future environmental monitoring, comparative radioactivity studies, and land-use assessment in the Najaf Sea region.

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