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Natural Radioactivity of Soil Samples in Near of Al-Jibsa Marsh, Iraq

Amjad H. Ali[1], Abdulhussein A. Alkufi[2] and Ali Abid Abojassim[3]*

[1,2]Education Directorate of Najaf, Ministry of Education, Al-Najaf, Iraq
[3]Department of Physics, Faculty of Sciences, University of Kufa, Al-Najaf-Iraq
[a]amjedlshmry412@gmail.com, [b]abdulhussein.alkufi@gmail.com, [c]ali.alhameedawi@uokufa.edu.iq

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ABSTRACT

This research investigated the natural radioactivity levels of gamma emitters (Uranium-238, Thourium-232, and Potsium-40) and some radiological hazard indices in soil samples obtained from the vicinity of Al-Jibsa Marsh, located in Najaf Governorate. Experiments were conducted using the NaI(Tl) method. The specific activity values of 238U ranged from 14.548 Bq/kg to 266.016 Bq/kg, with an average of 112.332 Bq/kg. For 232Th, the values ranged between 0.812 Bq/kg to 20.720 Bq/kg, with an average of 7.653 Bq/kg. The specific activity values of 40K ranged from 7.975 Bq/kg to 244.992 Bq/kg, with an average of 82.497 Bq/kg. The activity of 235U varied between 0.670 Bq/kg and 12.259 Bq/kg, with an average of 5.177 Bq/kg. Moreover, the average values of some radiological hazard indices such as (Raeq), (Hext), (AD), (ELCR) were 129.628, 0.350, 60.090 nGy/h, and 1.3267×10-3, respectively. When comparing the results of the current study with the global limit according to UNSCEAR, 2008, it is found that the values of uranium-238 in most of the soil samples were high. Therefore, the soil in this area is unsafe and harmful to the people living near this area.

Keywords: natural radioactivity, uranium mine, gamma-ray, NaI(Tl), and Al-Jibsa marsh.

INTRODUCTION

Background radiation has been a continuous companion ever since the Earth was created and life evolved [1]. While some of these radiations originate from space, others come from earthly materials including soil, air, and water [2]. Pollutants include chemicals that may exist naturally but are classified as pollutants when they exceed natural amounts. Exceeding the natural replenishment capacity of ecosystems leads to the contamination of the atmosphere, water bodies, and soil. Natural radiation exposure is the primary component of overall exposure for the majority of individuals and serves as the foundation upon which exposures from artificial sources may occur [1]. The breakdown series of potassium (^{40}K), thorium (^{232}Th), and uranium (^{238}U) could all contribute to this natural radioactivity by producing alpha, beta, and gamma radiations [3]. The surface-level natural radioactivity on Earth varies according to location, with a drop seen in oceanic regions and an increase in locations with rocks rich in radioactive substances. Human exposure to radiation has three components: The surface-level natural radioactivity on Earth varies according to location, with a drop seen in oceanic regions and an increase in locations with rocks rich in radioactive substances. Human exposure to radiation consists of three main components: gamma radiation emitted by radioactive substances on the ground, radiation emitted by radioactive elements present in human tissues due to the consumption of food, and cosmic rays [4]. The main factor influencing the amount of radiation present on a global scale is the concentration of radionuclides in the crust of the earth. Uranium is one of the most important elements in the series of actinides and is found in water, soil and rocks and its concentration in the rocks from 0.5 to 4.7 mg/kg also contains copper ore, phosphate and monazite sand on the proportions of 5-1500 higher [1]. The presence of radioactive isotopes in soil poses a risk of radiation to humans and serves as an indication of the accumulation of radioactive materials in the environment [5]. Studying the distribution, characteristics, and environmental implications of radionuclides is crucial. Therefore, understanding natural radioactivity is crucial for evaluating the related radiation risk, identifying variations in

natural radiation levels, and implementing suitable measures to safeguard human beings. The study of natural radioactivity is significant because radioactive elements may be effective biochemical and geochemical tracers during geological events like earthquakes and volcanic eruptions [4]. Moreover, knowledge of soil radioactivity is crucial for assessing the typical human exposure to natural radiation [3]. Therefore, the assessment of natural radioactivity levels in soil has significant importance for many researchers worldwide, resulting in global attention and extensive national studies [6-10]. The current study aims to evaluate the levels of natural radioactivity and some radiological hazard indices in soil samples near the Al-Jibsa Marsh region using gamma-ray spectroscopy with NaI(Tl) detector.

2. Area Study

In southwestern Iraq, Najaf Governorate is located on the edge of the Western Desert Plateau, about 160 km southwest of Baghdad. It is located at latitude 31059 north and longitude 44019 east. It rises 70 meters above sea level [11]. Al-Jibsa Marsh is located in the Al-Hira district of Al-Manathira District in the Al-Najaf Governorate. As for its location in relation to Al-Hira district, Al-Jibsa Marsh is located at the southwestern end of Al-Hira, as it is located astronomically between the latitude (3148.30) and (3154.30) north, while it is located between the longitude (4419) and (4427) East. The marsh and swamp environments in the area facilitated the formation of reduction conditions, causing the leached uranium to be deposited in two different forms within this layer. One form is uraninite (UO_2), which consists of very fine grains. The other form is absorbed by organic materials and clay minerals, resulting in the formation of a uranium mineralization horizon in the area (U_3O_8) [11].

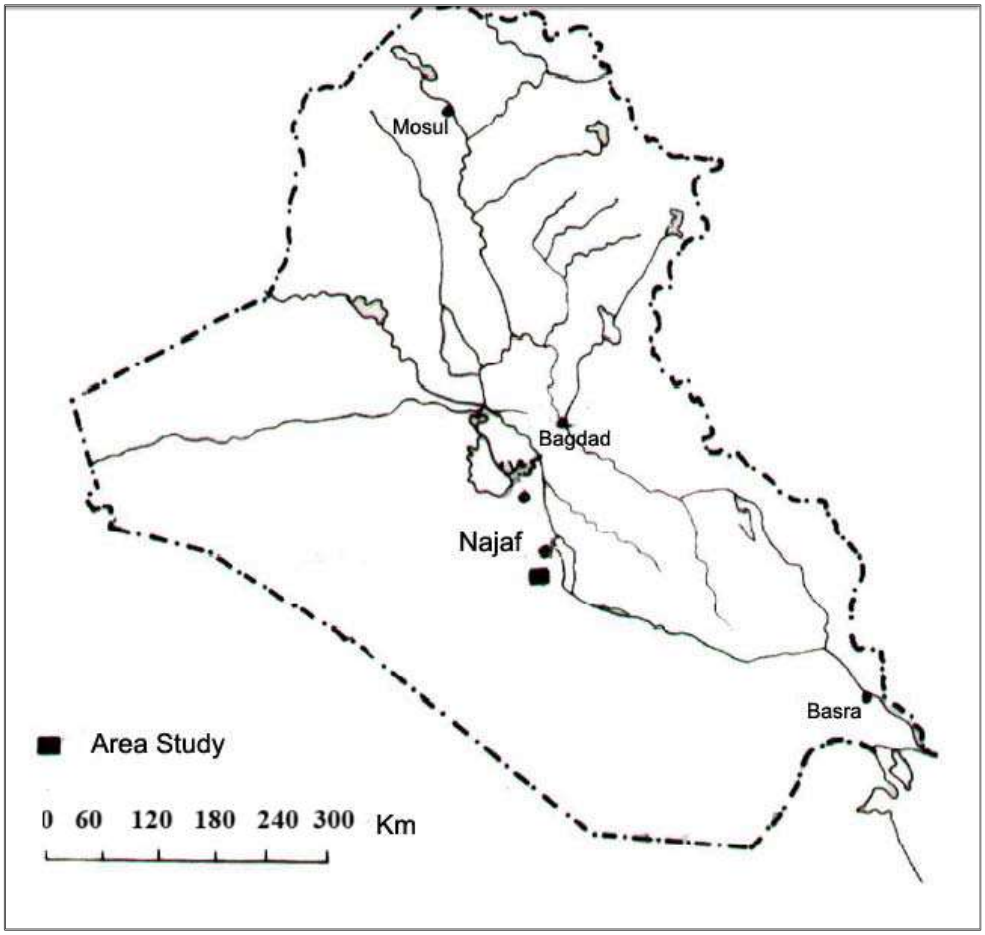

Fig. 1: Area study

3. Materials and methods

3.1. Collection samples

Fourteen soil samples were collected at a depth of (15 cm) in Al-Jibsa Marsh from sites located near the uranium mine in the (Abu-Skhair) in the governorate of Najaf. It used a GIS technical to determine the location

of sampling, which we illustrate in Table 1, to delineate the extent of natural radioactivity ^{238}U,^{232}Th, and ^{40}K in the region.

Table1: Location of soil sample in the present study

Sample code	Coordinates	
	North	East
S1	31.8714241	44.4379825
S2	31.8696601	44.4392283
S3	31.8696595	44.4410967
S4	31.8658667	44.4456665
S5	31.8708941	44.4265578
S6	31.8693947	44.4419282
S7	31.8835933	44.4280122
S9	31.8712471	44.4298817
S10	31.8690422	44.4417210
S11	31.8709832	44.4419291
S12	31.8688654	44.4392279
S13	31.8719657	44.4376018
S14	31.8722458	44.4377306

3.2. Preparation samples

Following the collecting process, every soil sample was stored in a plastic bag and identified based on its specific location. Subsequently, the sample was subjected to solar drying to eliminate any surplus moisture. Subsequently, the materials were pulverized using mechanical means, employing a microsoil grinder mill. The samples were passed through a sieve with a pore size diameter of 0.8mm to achieve homogeneity. Additionally, to ensure that the samples were moisture-free, they were placed in an oven for 5 hours until a consistent weight was reached. Afterward, the samples were placed within 1 L polyethylene plastic Marinelli beakers, guaranteeing a constant volume, to ensure consistent geometric distribution around the Detector. Afterward, the specific net weights were measured and recorded using an extremely accurate digital weighing scale with a precision of ±0.01%. Afterward, the plastic Marinelli beakers were tightly sealed and stored for about one month before being counted. The period was required to establish a condition of secular equilibrium between the radioactive isotope (^{222}Rn) and its parent isotope (^{226}Ra) in the uranium decay chain [9].

3.3. Measurements Sample

The gamma-ray spectrum of a scintillation detector, constructed from a sodium iodide crystal measuring 3"×3", was captured by a multichannel analyzer that was linked to a personal computer. The collected data was then analyzed with the (MAESTRO-32) software. The specimens were positioned on the detector and assessed for a duration of 18000 seconds. The activity of ^{238}U and ^{232}Th was measured using the secular equilibrium method, which relies on the presence of bismuth-214 with an energy of 1764.539 KeV and thallium-208 with an energy of 2614.511 Kev. The activity of the ^{40}K nuclide was measured using a specific energy of 1460.822 KeV [6-9].

The specific activity (A) for ^{238}U, ^{232}Th, and ^{40}K in soil samples of the present study can be calculated by the Eq. [12-14].

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

Where, N_{net} is the net count (area under the specified energy peak after background subtraction.
ε is the efficiency of the detector, Iγ is gamma probability, t is the time (in sec) for the spectrum collected, and m is the sample weight.
The specific activity (A) for ^{235}U can be calculated according to the following Eq. [15].

$$A_{235_U} = \frac{A_U}{21.7} \quad (2)$$

3.4. Radiological hazard indices

The radiological hazard risks, including Radium Equivalent activity (Ra_{eq}), External Hazard Index (H_{ext}), Internal Hazard Index (H_{int}), gamma index (Iγ), Absorbed Dose Rate in Air (AD), Annual Effective Dose (AED), and excess lifetime cancer risk (ELCR), were calculated using the specific activity values of ^{238}U, ^{232}Th, and ^{40}K, according to the equations provided in references [8-14].

$$Ra_{eq}\left(\frac{Bq}{kg}\right) = A_U + 1.43\,A_{Th} + 0.077A_K \quad (3)$$

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (4)$$

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (5)$$

$$I_\gamma = \left(\frac{1}{150}\right)A_U + \left(\frac{1}{100}\right)A_{Th} + \left(\frac{1}{1500}\right)A_K \quad (6)$$

$$AD\left(\frac{nGy}{h}\right) = 0.462\,A_U + 0.604\,A_{Th} + 0.0417A_K \quad (7)$$

$$AED_{outdoor}\left(\frac{mSv}{y}\right) = [D_r(mGy/hr) \times 8760\ hr \times 0.2 \times 0.7Sv/Gy] \times 10^{-6} \quad (8)$$

$$ELCR = AED_{outdoor} \times DL \times RF \quad (9)$$

4. Results and Discussion

The results of the specific activity of (^{238}U, ^{232}Th, ^{40}K., and ^{235}U) in fourteen soil samples collected from different locations near the area of Al-Jibsa marsh at Al-Najaf governorate were shown in Table 2. From Table 2, the values of the specific activity for ^{238}U ranged from 14.548 Bq/kg in sample S_{10} to 266.016 Bq/kg in sample S_9 with an average value of 112.332 Bq/kg. The specific activities of ^{232}Th ranged from 0.812 Bq/kg in sample S_{11} to 20.720 Bq/kg in sample S_7 with an average value of 7.653 Bq/kg. Also, from Table 2, the values of the specific activities for ^{40}K ranged from 7.975 Bq/kg in sample S_5 to 244.992 Bq/kg in sample S_{14}, with an average of 82.497 Bq/kg. The specific activities of ^{235}U ranged from 0.670 Bq/kg in sample S_{11} to 12.259 Bq/kg in sample S_7 with an average value of 7.653 Bq/kg. A comparison of the results of the soil of the study area with the UNSCEAR 2008 report shows that the values of uranium-238 in most samples are greater than the worldwide average (33 Bq/kg) [16], the increase in uranium activity can primarily be attributed to geological factors, such as the presence of radioactive anomalies, as well as physical factors, such as human activities related to drilling, exploration operations, and the transfer of uranium extraction. These factors have resulted in elevated pollution levels in the region [17]. The results of thorium-232 and potassium-40 in all soil samples of the present study were within the worldwide average (45 Bq/kg for ^{232}Tn and 420 for ^{40}K) [16].

Table 2. The results of ^{238}U, ^{232}Th, ^{40}K. and ^{235}U in area of study

Sample Code	Specific Activity (Bq/kg)			
	^{238}U	^{232}Th	^{40}K	^{235}U
S1	65.030	5.852	28.097	4.172
S2	198.837	10.323	92.831	9.163
S3	125.195	7.163	84.017	5.769
S4	152.228	13.932	99.415	7.015
S5	120.873	6.726	7.975	5.570

S6	66.093	3.921	91.127	3.046
S7	20.956	20.720	142.591	0.966
S8	24.012	2.452	115.331	1.107
S9	14.548	1.409	104.413	0.670
S10	266.016	18.848	8.360	12.259
S11	167.926	0.812	9.226	7.739
S12	140.053	4.089	100.219	6.454
S13	140.287	6.653	26.361	6.465
S14	70.593	4.247	244.992	3.253
Min	14.548	0.812	7.975	0.670
Max	266.016	20.720	244.992	12.259
Mean	112.332	7.653	82.497	5.177

The radiological hazard indices Radium Equivalent activity (Ra_{eq}), External Hazard Index (H_{ext}), Internal Hazard Index (H_{int}), gamma index (Iγ), Absorbed Dose Rate in Air (AD), Annual Effective Dose (AED), and excess lifetime cancer risk (ELCR) for the soil samples in the research region are shown in Table 3. The results showed that the highest value of the Ra_{eq} was 293.612 Bq/Kg in Sample S10 and the lowest value was 24.603 Bq/Kg in Sample S9, with an average value was 129.628 Bq/Kg, which falls within the permissible level (370 Bq/kg) [18,19]. Also, Table 3 shows that the values of H_{ex}, H_{in}, and Iγ ranged from 0.066 to 0.793 with an average value of 0.350, from 0.106 to 1.512 with an average value of 0.654. From 0.181 to 1.967 with an average value of 0.880, respectively, The calculated values of the Hex in all samples of the present study were within the worldwide average (1) [20]. In contrast, the results of H_{in} and Iɤ in some samples have values much higher than unity. This gives us a not good indication of the presence of significant radiation risks for some soil samples in the study area, according to the radiation protection report [20]. Also from Table 3, it is found that the AD ranged from 11.950 nGy/h in sample S9 to 134.952 nGy/h in sample S10, with an average value of 60.090 nGy/h. A comparison of the results of AD in the soil of the study area with the UNSCEAR 2000 report shows that the values of AD in most samples are greater than the worldwide average (57 nGy/h) [21]. Moreover, the results values of the AED of outdoor in unit mSv/y ranged from 0.015 to 0.166, with an average of 0.074. In general, the values of AED outdoors in most samples were higher than the worldwide average (0.07 mSv) [22]. The general public's exposure level falls under the recommended threshold of 1 mSv/y [21]. Finally, the results ELCR in the samples of the present study ranged from 0.2736×10^{-3} to 2.9623×10^{-3} with an average value of 0.423×10^{-3} which is higher compared with the world permissible value of 0.29×10^{-3} according to reference [21].

Table 3. The results of Ra_{eq}, H_{ex}. H_{in}, Iγ, AD, $AED_{Outdoor}$, and ELCR in area of study

Code	(Ra_{eq} (Bq/kg)	H_{ex}	H_{in}	Iγ	AD (nGy/h)	$AED_{Outdoor}$ (mSv/y)	ELCR×10^{-3}
S1	75.562	0.204	0.380	0.511	34.850	0.043	0.7778
S2	220.746	0.597	1.134	1.491	102.144	0.125	2.2407
S3	141.907	0.383	0.722	0.962	65.792	0.081	1.4525
S4	179.805	0.486	0.897	1.220	83.127	0.102	1.8262
S5	131.105	0.354	0.681	0.878	60.353	0.074	1.3301
S6	78.717	0.213	0.391	0.541	36.770	0.045	0.8185
S7	61.565	0.166	0.223	0.442	28.495	0.035	0.6409
S8	36.399	0.098	0.163	0.261	17.426	0.021	0.3954
S9	24.603	0.066	0.106	0.181	11.950	0.015	0.2736
S10	293.612	0.793	1.512	1.967	134.952	0.166	2.9623
S11	169.797	0.459	0.913	1.134	78.470	0.096	1.7281
S12	153.617	0.415	0.794	1.041	71.423	0.088	1.5708
S13	151.831	0.410	0.789	1.019	70.043	0.086	1.5478
S14	95.530	0.258	0.449	0.676	45.467	0.056	1.0095
Min	24.603	0.066	0.106	0.181	11.950	0.015	0.2736

Max	293.612	0.793	1.512	1.967	134.952	0.166	2.9623
Mean	129.628	0.350	0.654	0.880	60.090	0.074	1.3267

The mean values of particular activities for all samples were compared with the mean values of local studies and studies conducted in other countries, as shown in Table 4. In the current research, the average value of ^{238}U was higher than that of other nations listed in Table 4, except for Thailand, which had a higher average value compared to the present study. The average values of ^{232}Th and ^{40}K in this research were lower than those of other nations listed in Table 4, except Egypt. Table 4. Comparison of the natural radioactivity in present work with some previous studies

Country	Specific activity average (Bq/kg)			References
	^{238}U	^{232}Th	^{40}K	
India	57	87	143	[23]
Egypt	9.07	5.83	44.81	[24]
Costarica	46	11	140	[25]
Thailand	114	51	230	
Nigeria	30	25	370	
Malaysia	66	82	310	
Iraq (Babylon)	9.60	16.07	308.24	[26]
Iraq (Maysan)	21.19	9.72	667.83	[27]
Iraq (Al-Najaf)	112.332	7.653	82.497	The current study

5. Conclusions

The present research was done to gather fundamental data about the extent of natural radioactivity in the surrounding regions of the Al-Jebsa Marsh in the Najaf Governorate. In light of the study, we deduce that the soil exhibits an uneven distribution of uranium and notable variance in different areas, with average uranium activity above the global average. While, the thorium and potassium activities were within normal levels in the range of the worldwide average, Moreover, according to the results of radiological hazard indices, many samples have radiological hazard indices higher when compared to the global average limit. Therefore, the soil in this area is unsafe and harmful to residents living near this area. Finally, the radioactivity level in the vicinity of Al-Jibsa Marsh, located in Najaf Governorate, has increased due to agricultural activities and plowing in the region. This is further exacerbated by the irrigation process, which involves using groundwater that contains high concentrations of uranium. Consequently, the uranium is redistributed and spread across the surface of the soil.

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