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Measurement and Mapping of Natural Radioactivity in Al-Musayyab District , (Iraq)

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Abstract : The present study aims to measure the natural radioactivity of background radiation (dose rate) and gamma ray emitters (uranium U^{238}, thorium Th^{232}, and potassium K^{40}) in soil samples collected from Al-Musayyab district in Babil province. 10 soil and rock samples were collected from different areas of Al-Musayyab district at a depth of 10 cm using a multi-channel gamma ray spectrometer (3×3).. The results showed (U^{238}, Th^{232}, K^{40}) and radium equivalent, absorbed dose, gamma rays, and internal and external hazard coefficients. The results were plotted and distributed using the GIS technology (Arc Gls. 10.71) in order to lay the foundation for a more comprehensive study, aiming to draw geological maps of the area and characterize Natural radiation levels in other environments.

INTRODUCTION

Energy in the form of heat or light is called radiation. It is defined by wavelength and frequency, with radio waves occurring at the lowest frequencies and microwaves and infrared waves at the highest. The highest frequencies are where ionizing radiation occurs. Ionization is the process by which a neutral atom or molecule is changed into an electrically charged component. The quantity of protons and electrons in an atom determines whether an ion is positively or negatively charged. The breakdown of an unstable isotope results in the production of ionizing radiation. There are various ways in which these isotopes can degrade. In a stable, light atom, the neutron-to-proton ratio is roughly one. Heavy elements can raise this ratio to roughly 1.5. There are unstable nuclei because of an imbalance in this ratio [1].

All common forms of rock and soil contain isotopes, including radionuclides like ^{238}U and ^{232}Th. Moreover, a decay chain is created when these radionuclides break down into other radioactive nuclides. Radionuclides from the environment, both man-made and natural, can enter the human body by eating and inhalation. Therefore, among the numerous studies pertaining to naturally occurring isotopes, it is essential to investigate these radionuclides in each environmental compartment (atmosphere, hydrosphere, lithosphere, and biosphere) globally and to assess the possible risks to human health [2,3].natural isotopes are radionuclides that naturally occur in the environment. Numerous sources contribute to the majority of the radiation that is characterized as ionizing and found on the surface of the earth, which creates the radiation that envelops us. The presence of radioactive isotopes second, bismuth, lead, astatine, radon, polonium, protactinium, radium, and francium is due to the decay of natural radionuclides ^{232}Th, ^{235}U, and ^{238}U, which is the cause of natural radioactivity Because of the short half-life of these uranium and thorium nuclei [4,5].

MATERIALS AND METHODS

Study OF area

Al-Musayyib is an Iraqi city and district center in Babil Governorate in the Middle Euphrates region of Iraq. Its population in 2003 was estimated at about 100,000 people. The city is located on the banks of the Euphrates River, which divides it in half between the cities of Baghdad, Karbala and Hillah. The city includes one of the main power plants in Iraq. Its longitude is 44.29 and its latitude is 32.77.. 10 soil samples were collected at a depth of 10 cm in 2024 from different places in of Al-Musayyib City Figure(1) shows a map Al-Musayyib of Babylon Governorate in Iraq[6,7].

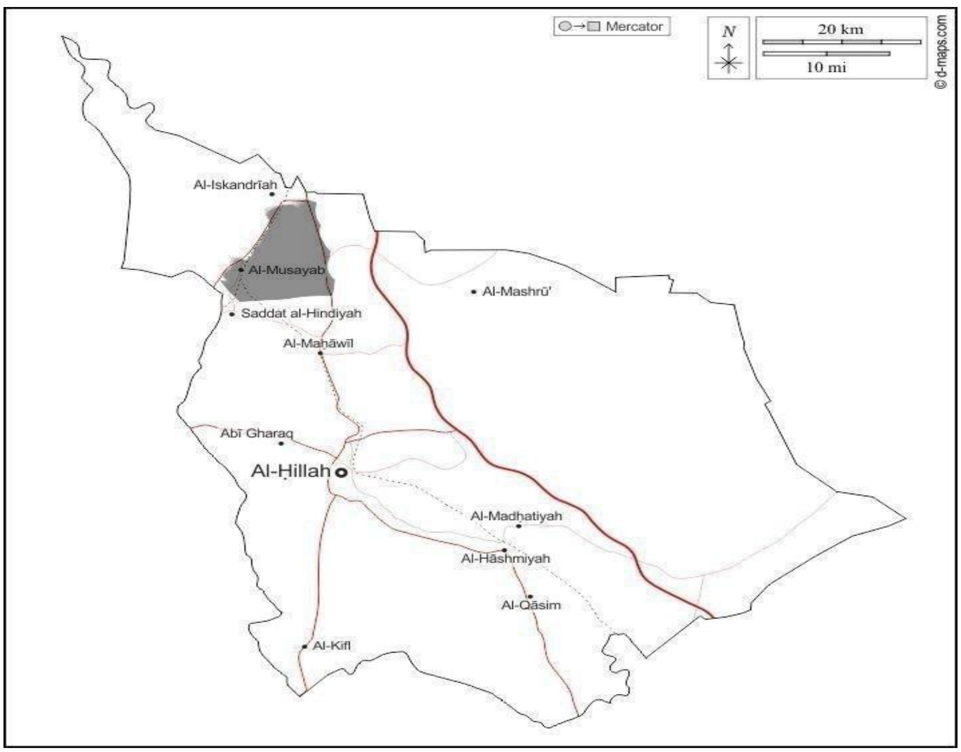

Figure (1) shows Al-Musayyab district in Babylon explains

SAMPLE COLLECTION AND PREPARATION

In order to determine the concentrations of radionuclides in soil samples in of Al-Musayyib City in Babylon Governorate in Iraq, 10 samples were collected and the location of each sample was determined using a GPS device. Table No. (1) shows the names of the areas from which the soil samples were taken, These samples were collected from 20/9/2024 to 27/9/2024. The concentrations of (U, Th, and K) in soil samples were measured using a gamma spectrometer NaI(TI). Figure (2) shows the gamma spectrometer. These samples were dried by exposing them to sunlight for two days to ensure that they were completely dried because the presence of moisture affects the true weight value of the sample and thus affects the value of the specific effectiveness. After that, they were crushed by a mill to obtain a fine powder and sieved using a manual sieve network. Finally, they were placed in a plastic box for thirty days to obtain a secular balance of radionuclides. Figure (2) shows the gamma spectrometer.

Figure (2) shows Gamma ray spectroscopy

In this work, the environmental radioactivity in the soil samples was measured with the Gamma-ray spectroscopy technique by NaI(Tl) type of (3"x3") crystal dimension, supplied by (Alpha Spectra, Inc.-12112/3), coupled with a multi-channel analyzer (MCA) (ORTEC-Digi Base) with range of 4096 channel joined with ADC (Analog to Digital Convertor) unit, through interface. The spectroscopic measurements and analysis were performed via the (MAESTRO-32) software into the PC of the laboratory[8], A crystal of NaI(TI) is a widely used scintillation detector due to their relatively efficiency greater than germanium detectors and, besides, works under room temperature circumstance (i.e. without the use of liquid nitrogen as in germanium detectors). Thallium-doped sodium iodide (NaI(TI)) scintillator, which is present as an impurity in the crystal structure of NaI (TI) detector, transforms the energy absorbed in the crystal to Light [9].When a gamma ray from a radioactive sample enters the crystal, some combination of three physical processes can happen, photo effect of an electron that absorbs all of the gamma's energy, Compton scattering of the gamma ray photon off electrons in the crystal and pair-production of an electron-positron pair[10]. The electrons produced by these interactions will lose all its energy by causing excitation in the crystal which upon de-excitation produces light[11]. as shown in figure(3)

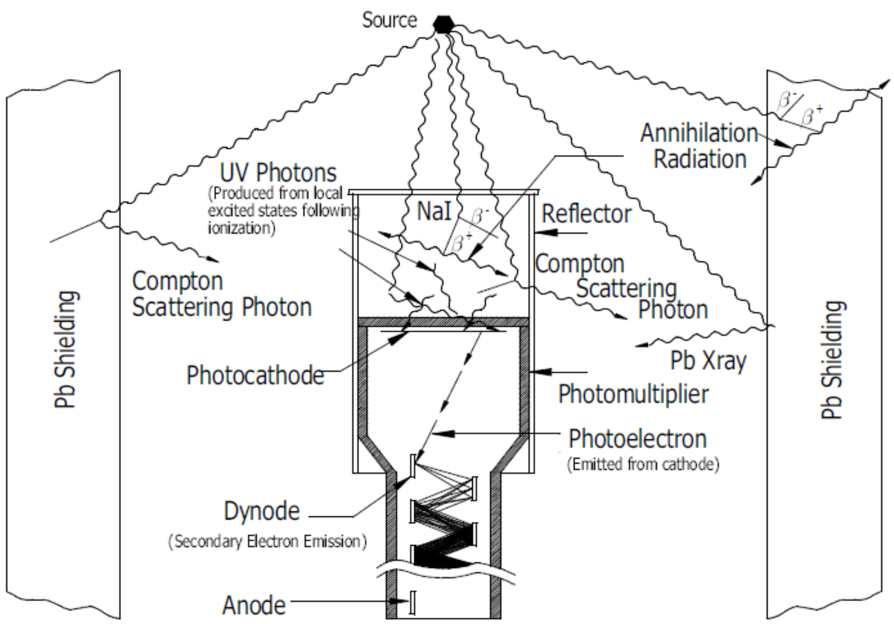

Figure (3) showing the NaI device

Table (1) shows the sample code, location, and coordinates.

Sample code	Name of samples	Coordinates	
M1	Teachers' District 2	32°77'28.1"N	44°28'82.8"E
M2	Station Street	32°77'85.9"N	44°29'49.2"E
M3	Carpet neighborhood	32°78'65.4"N	44°29'77.8"E
M4	Umm Al Baneen neighborhood	32°78'23.5"N	44°29′85.4" E
M5	Awlad Muslim Gas Station	32°78'22.4"N	44°30'02.8"E
M6	Teachers' District 1	32°78'38.3"N	44°30'10.0"E

M7	Al-Musayyab Electricity Department	32°78'53.7"N	44°29'26.6"E
M8	Al Zahra Hospital	32°79'40.0"N	44°29'63.5"E
M9	Muslim Sons Shrine	32°78'66.9"N	44°31'14.3"E
M10	Musayyib River	32°78'29.7"N	44°35'90.1"E

CALCULATION

Using the Nal(Tl) detector and a computer program, these samples were placed inside this detector to identify the radionuclides according to their energy in the spectrum. The size of one sample is (1 kg) and the time is (12600 seconds). Then the net area of each radionuclide is calculated, and after that the specific activity is calculated through equation No (1).

Equation 1 to extract the radioactivity [12].

$$A_s\left(\frac{Bq}{Kg}\right) = \frac{c_n}{\varepsilon \times I_\gamma \times T \times m} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Eq . 2 was used to calculate the radium equivalent [12].

$$Raeq(Bq/kg) = Au + 1.43\ A\ th + 0.077A\ k \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Eq. 3 was used to calculate the absorbed dose in air [12] .

$$Dy = 0.462\ Au + o.604\ Ath\ + 1.43\ A\ th + 0.0417A\ k \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where Au is the uranium activity, Ath is the thorium activity, and Ak is the potassium activity, all measured in Bq/kg.

The following equations yield The annual Effective Dose Equivalent (AEDE), as well as the external and internal hazard indices for the analyzed samples [12] .

$$AEDE\ out = D \times 10^{-6} \times 8760 \times 0.7 \times 0.2 \quad \ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$AEDE\ in = D \times 10^{-6} \times 8760 \times 0.7 \times 0.8 \quad \ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$Hex = \frac{Au}{370} + \frac{Ath}{259} + \frac{Ak}{4810} \quad \leq 1 \quad \ldots\ldots\ldots\ldots\ldots \quad (6)$$

$$Hin = \frac{Au}{185} + \frac{Ath}{259} + \frac{Ak}{4810} \quad \leq 1 \quad \ldots\ldots\ldots\ldots\ldots \quad (7)$$

$$Iy = \frac{Au}{150} + \frac{Ath}{100} + \frac{Ak}{1500} \quad \ldots\ldots\ldots\ldots\ldots \quad (8)$$

RESULTS

Table (2) and (3) show the results of the of radioactive activities that are determined in soil samples taken from Al-Musayyib district in the city of Babylon, located north of Babylon Governorate in Iraq, The size of the sample is (10 cm) and a volume of (1 kg), and they are analyzed using the sodium iodide detector NaI(Tl), Table (2) shows the effectiveness of activities (U^{238}, Th^{232} and K^{40}), Table No. (3) shows the values of radium equivalent, absorbed dose, gamma rays, and internal and external risk factors.

Table(2) The specific activity of gamma emitters (U, Th, and K) in soil samples is shown.

Samples	A_K	A_{TH}	A_U
M1	278.668 ± 0.628	30.697 ± 0.097	15.982 ± 0.072
M2	318.981 ± 0.672	21.586 ± 0.081	14.114 ± 0.067
M3	297.537 ± 0.649	21.120 ± 0.080	13.237 ± 0.065
M4	162.133 ± 0.479	18.467 ± 0.075	16.120 ± 0.072
M5	298.011 ± 0.650	24.754 ± 0.087	23.108 ± 0.086
M6	350.486 ± 0.705	18.836 ± 0.076	12.130 ± 0.062
M7	229.682 ± 0.570	18.025 ± 0.074	12.776 ± 0.064
M8	244.893 ± 0.589	13.850 ± 0.065	13.122 ± 0.065
M9	246.553 ± 0.591	16.675 ± 0.071	13.007 ± 0.065
M10	238.355 ± 0.581	26.301 ± 0.089	20.248 ± 0.081
The average	266.529	21.031	15.384
Worldwide(11)	400	30	35

Table(3) Radionuclide (U, Th, and K) radiation characteristics in soil samples from Al-Hashimiyah District, Iraq

Sample	Ra_{eq}(Bq/Kg)	H_{ex}	H_{in}	I_α	D(nGy/h)	$AEDE_{out}$ $(\frac{\mu Sv}{h})$	$AEDE_{in}$ $(\frac{\mu Sv}{h})$
M1	81.337	0.219	0.262	0.599	37.545	0.041	0.165
M2	69.544	0.187	0.225	0.522	32.860	0.033	0.134
M3	66.349	0.179	0.214	0.497	31.279	0.028	0.114
M4	55.013	0.148	0.192	0.400	25.363	0.023	0.131
M5	81.454	0.219	0.282	0.600	38.596	0.031	0.124
M6	66.053	0.178	0.211	0.502	31.569	0.038	0.152
M7	56.238	0.151	0.186	0.418	26.368	0.030	0.123
M8	51.785	0.139	0.175	0.389	24.640	0.032	0.129
M9	55.836	0.150	0.185	0.417	26.362	0.030	0.121
M10	76.213	0.205	0.260	0.556	35.180	0.033	0.132
The average	65.98	0.17	0.21	0.49	30.97	0.03	0.13
Worldwide(11)	370	≤ 1	≤ 1	1	59	0.08	0.42

DISCUSSION

Tables (2) and (3) show the results of the for 10 from soil samples radioactivity detected in Al- Al-Musayyib district in Babylon city (Iraq), where it is found that the radioactivity of potassium Ak is the lowest value(162.133 ± 0.479) in sample No. (M4) and the highest value is (350.486 ± 0.705) in sample No. (M6) and the average is (266.529). It is found that the values of the specific activity in the soil samples fall within the internationally permitted limits (400 Bq / kg) [13]. Figure (4) shows the results of the samples in Musayyib district. As for the values of the effectiveness of thorium Ath, the lowest value is (13.850 ± 0.065) in sample (M8) and the highest value is(30.697 ± 0.097) in sample (1). As for the rate of thorium, it is (21.031), and these results are within the internationally permitted values (30 Bq / kg) [13]. Tables (2) shows the results of the samples in Musayyib district. As for the effectiveness of uranium, the lowest value is (12.130 ± 0.026) in sample No. (M6) and it is The highest value (20.248 ± 0.081) is in sample (M10) and the average is (15.384). These values are less than the internationally permitted values (35 Bq/kg) [13] As shown in Table (2). (IDW) This program has been used for mapping and is called spatial interpodulation Interpolation of Weight A technique used in GIS to estimate values at unmeasured locations based on known values at surrounding locations. It is based on the assumption that points closer to the target location have a greater influence on the estimated value than points further away. ArcGIS : One of the most popular commercial GIS software, developed by Esri. It provides advanced tools for analyzing spatial data, creating maps, and managing geographic data. It is used in many fields such as urban planning, resource management, and the environment. The IDW method is widely used in GIS applications, such as estimating pollution levels, rainfall distribution, or soil properties in areas where direct measured data is lacking. The method is simple and easy to apply, but it assumes that the spatial effect decreases regularly with distance, which may not be accurate in all cases. To improve the accuracy of interpolation using IDW, some parameters can be modified, such as the Power, which controls how much distance affects the weight. Increasing the Power value makes the spatial effect decrease more rapidly with distance, giving greater weight to closer points. It is also important to determine the appropriate search radius and number of points used in the interpolation process to ensure the accuracy of the results. Using too many points or a wide search range may result in the inclusion of irrelevant points, reducing the accuracy of the estimate. The IDW method is suitable for areas with a uniform distribution of measured data, but may be less accurate in areas with irregular distribution or when there are sudden changes in spatial values. In such cases, other interpolation methods, such as kriging, may be more appropriate.In short, inverse distance weight interpolation is a powerful tool in GIS for estimating values at unmeasured locations, taking into account the limitations and assumptions associated with this method to ensure the accuracy of the results[14,15]..

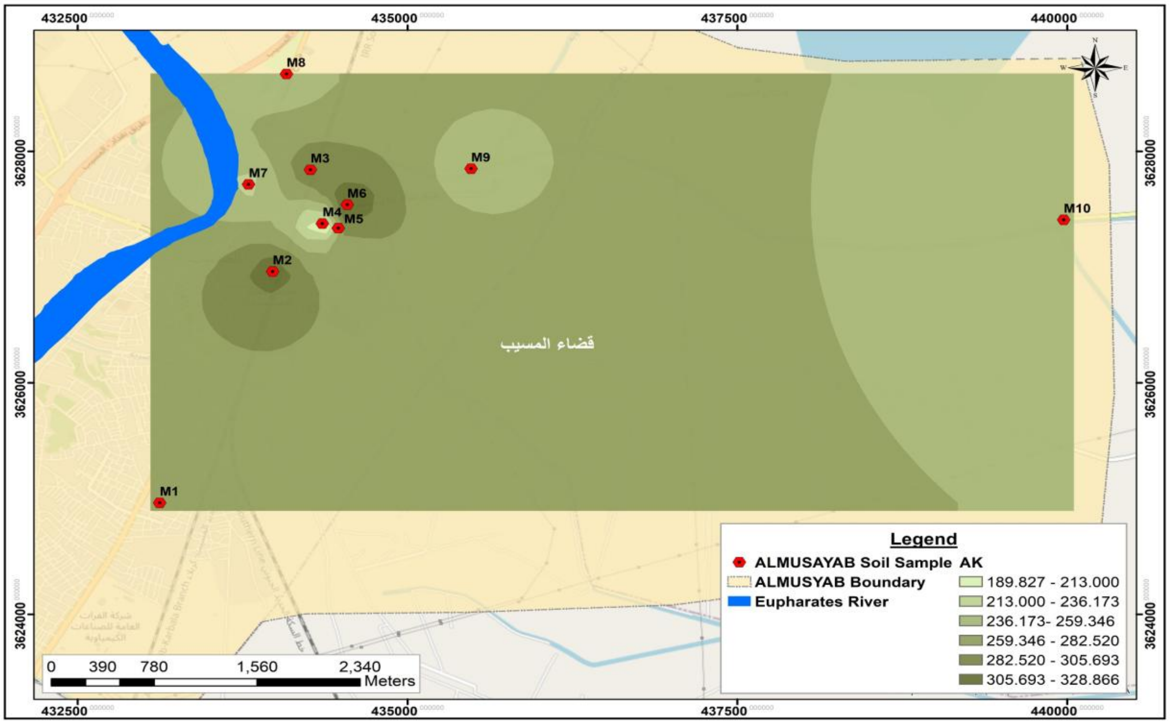

Figure (4) Corroborative map of (Ak)values for Musayyib district

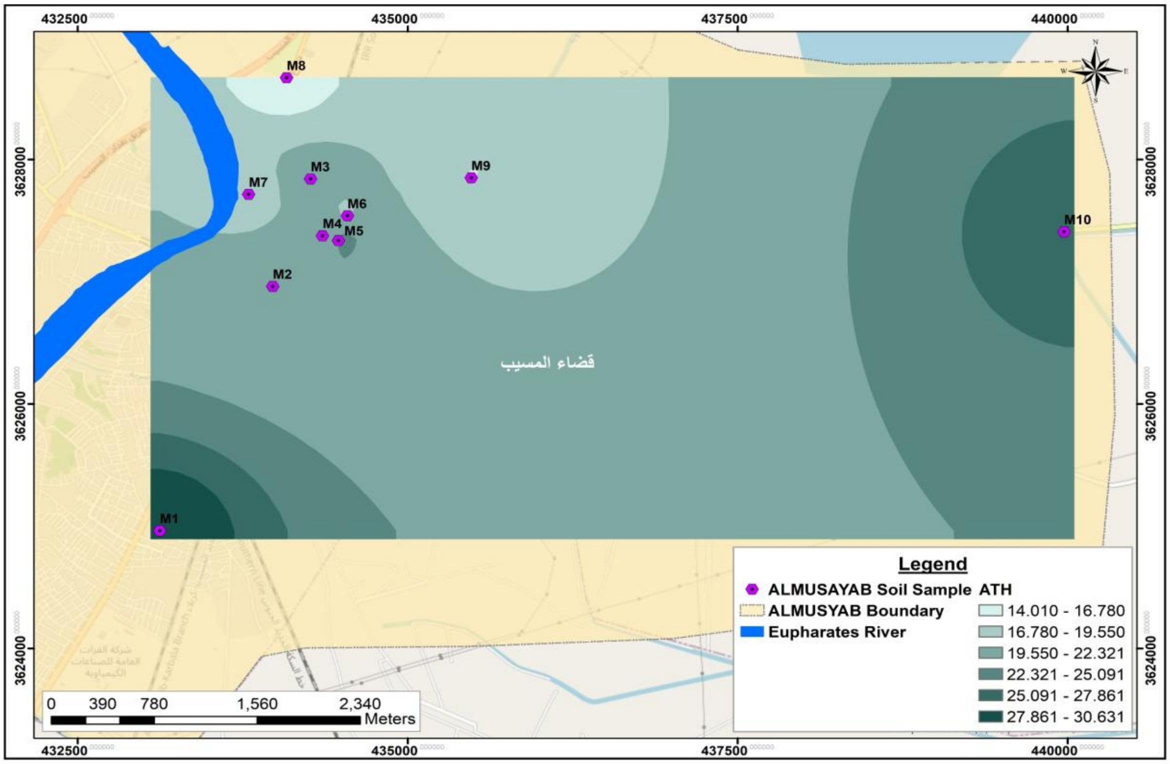

Figure (5) Corroborative map of(Ath) values for Musayyib district

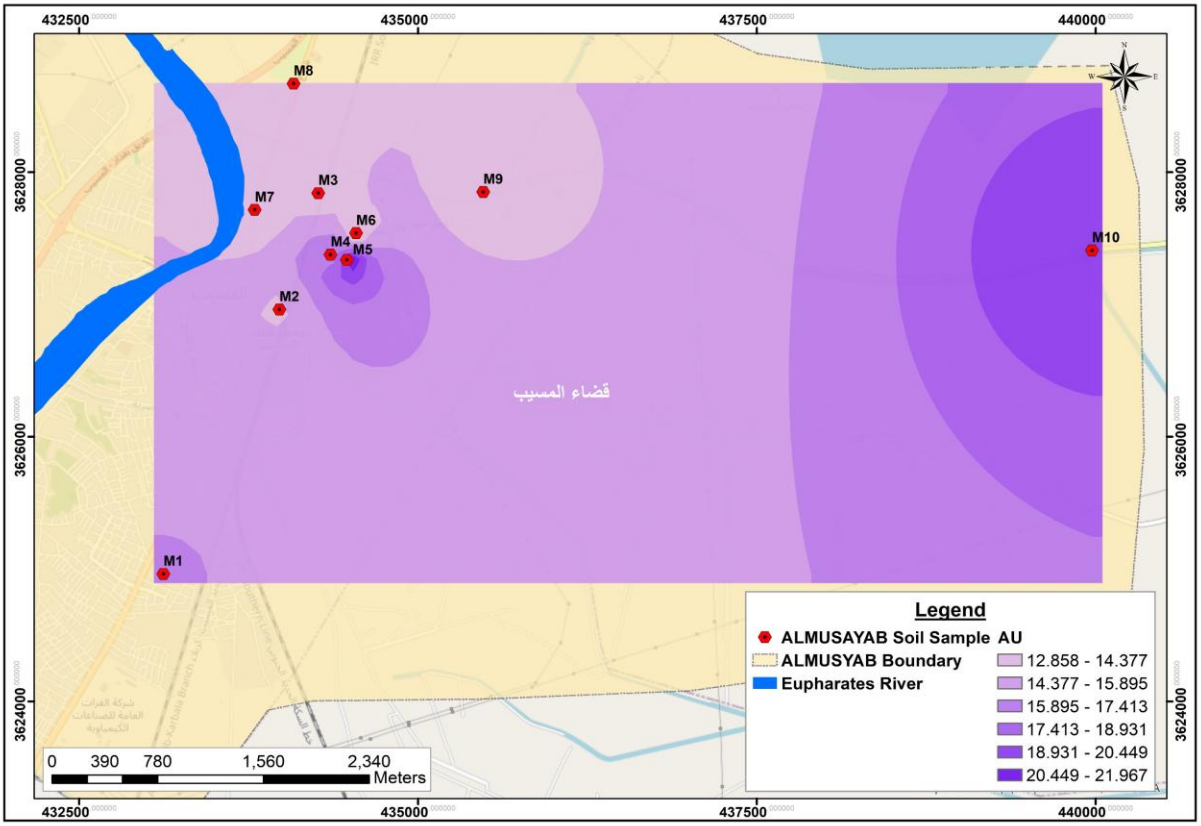

Figure (6) Corroborative map of (Au) values for Musayyib distric

Table (3) shows that the activity levels of radium equivalent (Ra) in soil samples ranged from (51.78 to 81.45 Bq/Kg), falling below the allowed limit of (370 Bq/Kg) [13] As shown in Figure (7). The equations above determined the exterior and internal hazard indicators, as well as gamma rays, for soil samples taken. The value of (Hex) ranged from (0.139 to 0.219), while the value of (Hin) ranged from (0.175 to 0.282), all of which are within the UNSCEAR safety level's maximum value. The annual effective dose values for $AEDE_{out}$ ranged from (0.023 to 0.0.165)(μsv / h) ,for $AEDE_{in}$ from (0.114 to 0.165) (μsv / h) , and for absorbed dose from (24.640 to 38.569 nGy/h) As shown in Figure (8) It is within the permissible limits (55 nGy/h) [13] The gamma ray measurements are from (0.389 to 0.600) which is within the permissible limits.

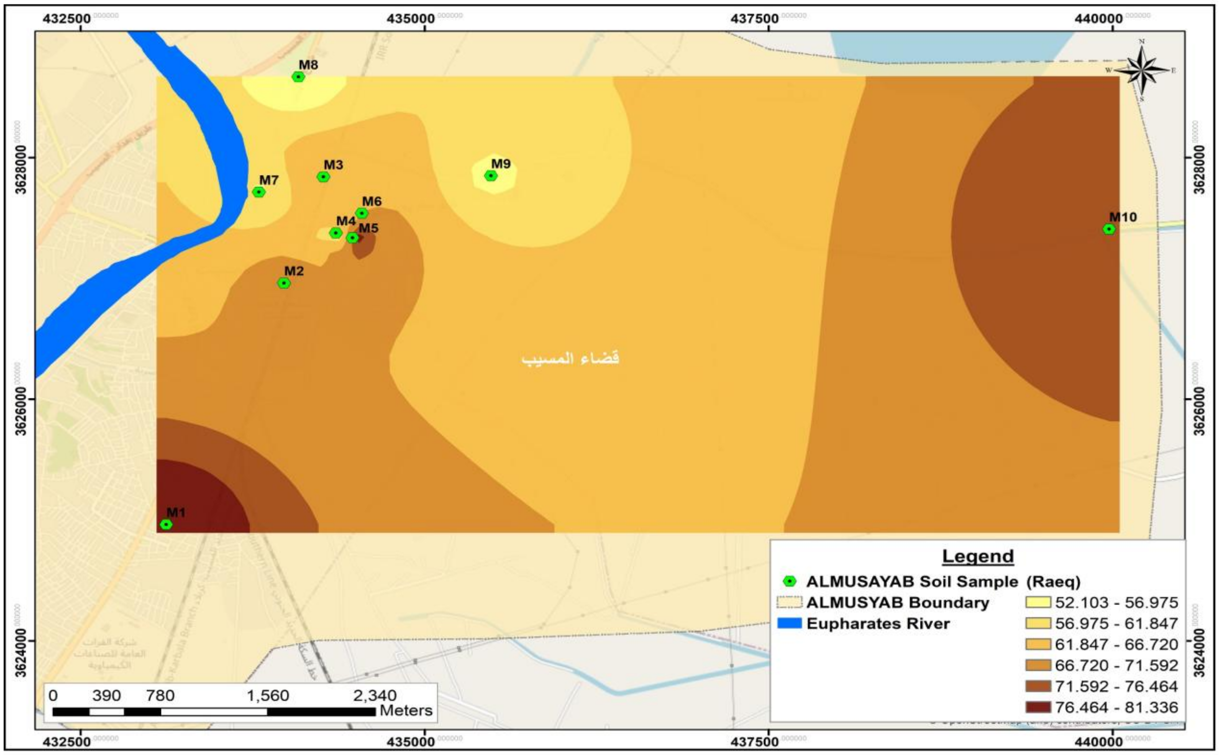

Figure (7) Correlation map of the radium equivalent (Ra) values for Musayyib District

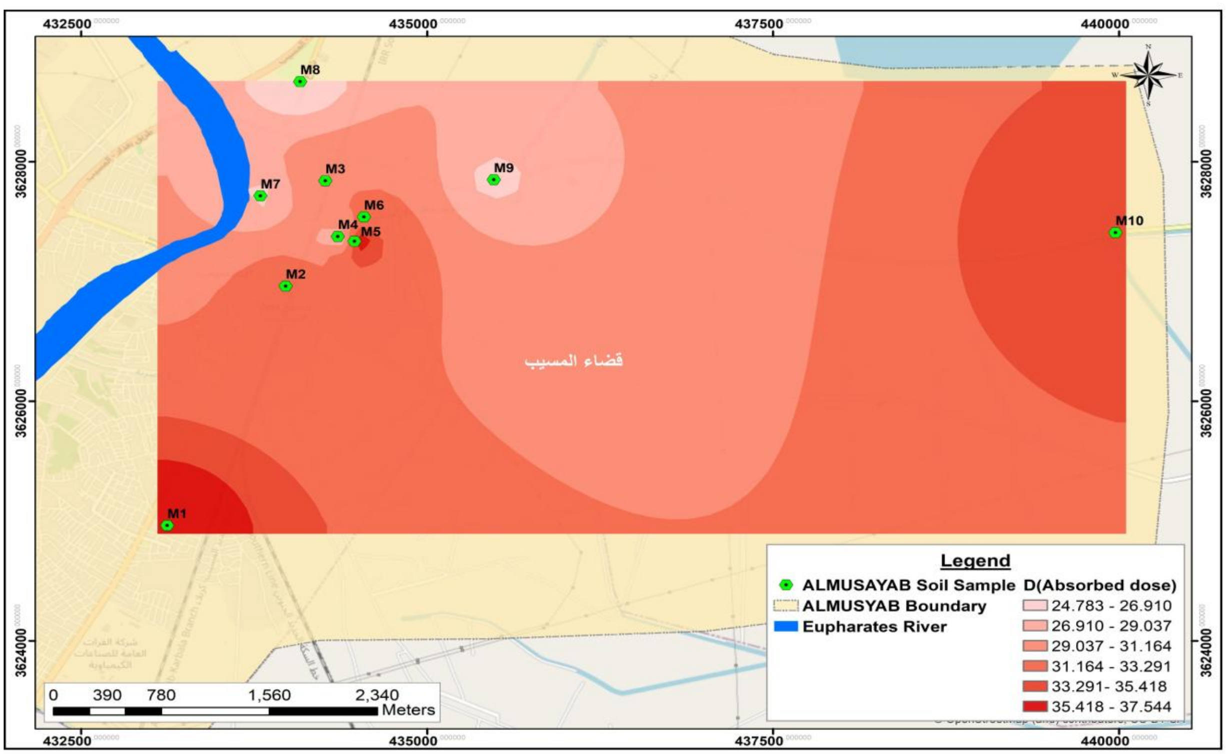

Figure (8) Corroborative map of D(Absorbed dose) values for Musayyib distr

Table (4) Comparison of the specific activity concentrations of natural radionuclides in units (Bq/kg) in soil samples in the current study with other studies.

Location	U-238	Th-232	K-40	Reference
Karbala / Iraq	30.96 ± 5.86	67.09 ± 2.9	271.2 ± 170	[16]
(Basra) /Iraq	11.9	41.1	499.2	[17]
Qadisiyah Governorate Center / Iraq	1.91	20.55	262.43	[18]
Najaf / Iraq	23.59	12.10	60.68	[19]
Al-Qadisiyah Governorate Districts / Iraq	3.82	29.84	421.15	[18]
Worldwide	25	25	302.3	[20]
Present study	15.384	21.031	266.529	

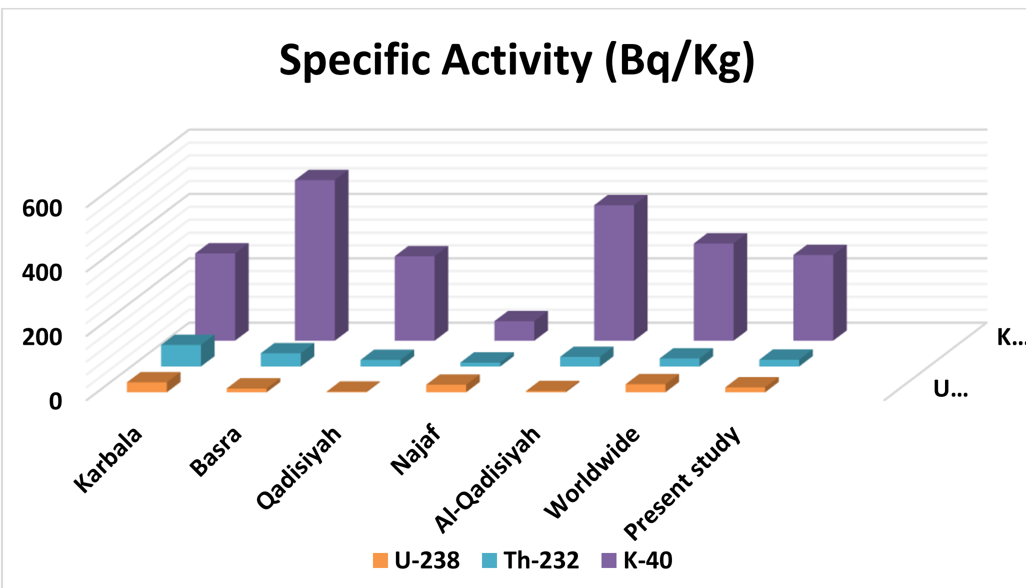

Figure (9) Comparison of the concentration of specific activity in soil samples in the current study with other studies.

CONCLUSION

In light of these results obtained, it was concluded that the values of nuclear radioactivity of isotopes (U^{238}, Th^{232}, K^{40}) were distributed in varying proportions in Al-Musayyab district in Babil governorate, due to the geological nature of the rocks that contain them. The rates of radioactivity of (U^{238}, Th^{232}, K^{40}) in this study were within the internationally permitted limits and therefore they are safe and do not pose a radiation hazard. However, I recommend that the competent authorities, such as the Ministry of Environment, the Ministry of Health and the local government, in order to preserve the environment and public health from the risks of radiation. Radionuclides risks When the concentrations of these radionuclides exceed the internationally permitted levels, they pose risks to human health. Therefore, it is necessary to measure the concentration continuously in order to preserve public health.

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