

Estimating the Health Risks of Environmental Radiation in Soil Samples from the National Hospital for Oncology and Hematology in Najaf Al-Ashraf

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ABSTRACT

Human activities like the radioactive sources usage in radiotherapy for cancer tend to negatively impact the environment. Some radioactive sources are associated with pharmaceutical preparations with high levels of natural radioactivity. This is what occurs in all oncology treatment centers. Therefore, the study's objective was to examine the health risk posed by naturally occurring radiation from Middle Euphrates center (MECC) cancer and the area close to it. In this work, gamma spectrometric analysis NaI(Tl) of (3"X3") was done to determine the activities concentration of ²²⁶Ra, ²³²Th and ⁴⁰K in 13 soil samples. The average specific activity of these nuclei in Bq.kg⁻¹ were (8.889 ± 0.878, 6.810 ± 0.446, and 360.288 ± 3.753), respectively. Thus, the average (R_{eq}) value was (46.372 Bq.kg⁻¹). R_{eq} readings were discovered to be lower in every sample than the global value of 370 Bq.kg⁻¹. The average values for (AEDE) were reported as being (0.180 mSv.y⁻¹), which is smaller than (0.48 mSv), the global average. The absorbed doses rate was found to be (26.481 nGy.h⁻¹). The Annual Gonadal Dose Equivalent (AGED) was determined to be (161.456 Sv.y⁻¹), which is lower than the global average of 300 (Sv.y⁻¹), and the External Hazard Index Hex was found to be (0.119), all of which had average values that were less than unity. The excess lifetime cancer risk (ECLR) had an average value of (0.605 × 10⁻³). This number short of the globally accepted level of (2.9 × 10⁻³). The study's findings indicate that there were no health risks associated with the natural radioactivity of the region (found in soil samples).

Key words: variogram, radioactivity, risk assessment, Middle Euphrates, Gonadal Dose

INTRODUCTION

Numerous investigations were conducted on this topic following the 1896 discovery of radioactivity (1). A significant aspect of human life is radiation and radioactivity, which is the statistical and natural process by which unstable parent nuclei release energy to transform into more stable daughter nuclei (2).

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Beta, alpha, and gamma rays are examples of nuclear particles or waves that are emitted as a result of the energy produced during the transformation process. Ionizing radiation is the term used to describe these discharges (3). The scientific community began debating the radioactively hazardous nature of ionizing radiation as early as 1920–1930. Ionizing radiations are dangerous to biological tissues because they produce charge when they enter biological materials (4). Empirical and epidemiological data have indicated that radioactive materials have carcinogenic tendencies for skin cancer, that widespread among early dentists and radiologists because of the exposure to radio-active components. According to reports, peoples survived from the Hiroshima atomic explosion exposed to radiation above 100 rem, which caused them to get leukemia (5). There are two types of ionizing radiation damage to biological cells: short- and long-term. The short-term exposure to radiation may result in radioactive side effects, although long-term effects may not manifest for many years (6). The interactions of ionizing radiation with cell during exposure and tissues after exposure may lead to changes in chromosomal layout and mitotic processes, which may eventually cause the creation of malignant cells, depending on the severity. This ionizing radiation can cause short-term or permanent harm. Damaged cells and tissues may occasionally be able to recovered from the effect of radiation exposure that it is less severe (7). Human exposures to naturally occur radionuclides can come from both man-made and natural sources. Large-scale exposure is significant from a health physics standpoint as it indicates a higher degree of danger (8). According to studies, natural background radiation from sources such cosmic rays, radon gases and terrestrial radionuclides accounts for around 80% of these ionizing radiations. Both with non-series radionuclide of potassium (^{40}K), series radionuclides of uranium-radium (^{238}U - ^{226}Ra) and thorium (^{232}Th) make up terrestrial radionuclides (9). Trash disposal is one example of a man-made activity that might raise ionizing radiation levels. The ecosystem and public health are negatively impacted by these actions. They contaminate water supplies, wildlife, plants, soil, and air. Soil serves as one of the primary reservoirs for these naturally occurring radionuclides. The radioactivity of soil samples taken from several locations in Iraq was tested using an iodide sodium system triggered by thallium 3. The results indicated that the radioactivity for ^{226}Ra , ^{232}Th , and ^{40}K was below an internationally recommended standards (10). Researchers on Iraq's Ya-Hussain road (Najaf/ Karbala) calculated the values of ^{226}Ra , ^{232}Th and

^{40}K as well as their radiological dangers, yearly effective dosage, and lifetime cancer risk (ELCR) by a NaI(Tl) gamma-ray spectrophotometer detector. The findings demonstrated which the quantities were below the global average, proving the safety of the region and the absence of radiation in the samples (11). The specific activities of ^{226}Ra , ^{232}Th and ^{40}K was calculated from a soil of Al Rahmah, Najaf, Iraq, using a gamma-ray spectrometer systems NaI (TI) detectors. Additionally, indicators of internal and external hazards, internal and external absorbed doses, and radium equivalent activity were calculated, along with the annual total effective doses and lifetime cancer risks (ELCR) that were beneath internationally recommended limits (12).

Using a NaI (TI) detectors to evaluated the activities values in soils samples taken at random from the heart of Al-Diwaniyah, Iraq, to determined that the average values were ^{238}U , ^{232}Th and ^{40}K . Findings demonstrated that activity concentrations on average were lower than the level published by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (13).

The work is aimed at carry out measurements of the activity amounts for radionuclides from the soil samples, then used to carrying out health risks assessment in term of radium equivalent activities, gamma representative levels indexes, external hazard indexes, absorbed doses rates in air, annual gonadal doses equivalent, the annual effective doses equivalent and excess lifetime cancer risks.

MATERIAL AND METHODS

Study Area

Middle Euphrates Oncology Center is a free governmental institution that provides medical services to patients. According to *table 1*, which displays the coordinates of the samples under study, it is situated in the city's center.

Collection and Preparation of Samples

Purposive random sampling used to collected soils samples from the MECC in Najaf at a depth of 20–50 cm from thirteen distinct places. Samples pound and dried in an oven at 120 OC to eliminate moisture. Then, each sample homogenized and sieved to 200-mesh size. Then weighing 1 kg and put into a marinelli beaker. Then sealed for 30 days to allow ^{226}Ra , ^{232}Th and their corresponding offspring to reach radioactive secular equilibrium (14).

Table 1 - Latitude and longitude of the studied locations

ID	Latitude	Longitude	Altitude (m)	H.A. (m)
EU-01	32° 2' 34.6682" N	44° 21' 53.5756" E	37	9
EU-02	32° 2' 33.1031" N	44° 21' 47.0780" E	11	19
EU-03	32° 2' 35.2660" N	44° 21' 53.2213" E	34	19
EU-04	32° 2' 35.4080" N	44° 21' 53.4942" E	32	18
EU-05	32° 2' 34.6583" N	44° 21' 51.1665" E	1	19
EU-06	32° 2' 31.7962" N	44° 21' 55.7485" E	31	50
EU-07	32° 2' 33.7394" N	44° 21' 55.3244" E	31	12
EU-08	32° 2' 33.0637" N	44° 21' 58.2026" E	30	34
EU-09	32° 2' 33.9252" N	44° 21' 54.2556" E	57	19
EU-10	32° 2' 33.7178" N	44° 21' 54.6682" E	56	23
EU-11	32° 2' 32.9003" N	44° 21' 56.3508" E	30	32
EU-12	32° 2' 32.7890" N	44° 21' 55.7705" E	31	22
EU-13	32° 2' 34.3252" N	44° 21' 54.3182" E	57	20

H.A.(m) = high of altitude

Gamma-ray Spectrometry

The radioactivity measured by a NaI(Tl) system, which consist of a scintillation detectors NaI(Tl) with a 3" x 3" crystal dimension, provided by Alpha Spectra, Inc. 12112/3, coupled with a multichannel analyzer (MCA) (ORTEC Digi Base) with a range of 4096 chan nels connected to an ADC (Analog to Digital Convertor) unit, To prevent background radiation, the detector is covered with lead shielding. The spectral data was directly transmitted to the lab's PC using the MAESTRO32 program. The configuration and geometry of the samples were maintained throughout the examination, and they were counted for 30,000 seconds in a consistent manner.

Calculations

Risk assessment of radionuclides

Depending on the specific radioactivity(Ai) (11), was determined Radium equivalent activity (Raeq), annual effective dose equivalent (AEDE), absorbed dose rate (DR), annual gonadal dose equivalent (AGED), representative level index (RLI), external hazard index (Hex), and excess lifetime cancer risk (ELCR) were the radiological metrics used to estimate risk.

Radium equivalent activity (Raeq)

The radium equivalent activity Raeq is utilized in order to increase the distribution of natural radioactivity in soil and attain uniformity with respect to radiation exposure (15). It is the weighted sum of the activity concentrations of ⁴⁰K, ²³²Th, and ²²⁶Ra,

assuming 370 Bq.kg⁻¹. It can be calculated using equation 1 (16).

$$R_{aeq} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \quad (1)$$

which is equivalent to

$$R_{aeq} = A_{Ra} + 1.43 A_{Th} + 0.077 A_K \quad (2)$$

(A_{Ra}, A_{Th} and A_K) are the specific activity in (Bq.kg⁻¹) of ²²⁶Ra, ²³²Th, and ⁴⁰K, respectively (17).

Absorbed dose rate in Air (DR)

The rate of dosage absorption is influenced by the particular activity of ²²⁶Ra, ²³²Th and ⁴⁰K in soil with the presumption that other radioactive isotopes are insignificant, as their contributions to the overall background radiation contribution are quite minimal (18).

Equation 3's relation was used to determine the absorbed dosage rate.

$$DR(nG.h^{-1}) = 0.462 A_{Ra} + 0.604 A_{Th} + 0.0417 A_K \quad (3)$$

Annual effective dose equivalent (AEDE)

For the annual effective dose equivalent, mSv. y⁻¹ was the unit of measurement. The dose that soil radioactivity concentrations provide to the general public was calculated using equation 4.

$$AEDE(mSv.y^{-1}) = D(nGy.h^{-1}) \times 8760 (h) \times 0.2 \times 0.7 (Sv.Gy^{-1}) \times 10^{-6} \quad (4)$$

D is the absorbed dose rate, measured in nGy h⁻¹, and the conversion factor between the absorbed dose and effective dose is 0.7 SvGy⁻¹, 0.2 stands for the outdoor occupancy factor (19), and the time for a year is 8760 hours, and the conversion factor is 10⁻⁶.

Annual Gonadal Dose equivalent (AGED)

The gonads are regarded as organs of interest for dosimetry purposes, per UNSCEAR (2010). The male testes and the female ovaries are the main reproductive organs (20), Due to their high radio sensitivity, the International Commission for Radiation Protection placed special emphasis on these members, stating that every attempt should be made to lower the gonadal dose to the general public (21). It is also known that the bone marrow, which makes red blood cells, is impacted by elevated AGED levels. This can result in leukemia, a blood cancer that is frequently fatal. The thyroid, lungs, liver, colon, and bladder are further noteworthy organs (22,23), equation 5 is used to calculate the annual gonadal dose equivalent AGED in μSv.y⁻¹ (24):

$$\text{AGED } (\mu\text{Sv}\cdot\text{y}^{-1}) = 3.09 A_{\text{Ra}} + 4.19 A_{\text{Th}} + 0.314 A_{\text{K}} \quad (5)$$

Representative level index (RLI)

The gamma radioactivity RLI connected with natural radioactive substances and can be calculated using the formula below (25):

$$\text{RLI} = 1/150 A_{\text{Ra}} + 1/100 A_{\text{Th}} + 1/1500 A_{\text{K}} \quad (6)$$

External Hazard Index (Hex)

The hazard index is used to measure radiological dangers as a single quantity because different radionuclides contribute to the overall gamma dose that humans receive. Equation 7's relation was used to calculate the External Hazards Index (26), The Hex must be less than one for radiological purposes in order to minimize the risk of radiation exposure (16).

$$H_{\text{ex}} = A_{\text{Ra}}/370 + A_{\text{Th}}/259 + A_{\text{K}}/4810 \leq 1 \quad (7)$$

Excess Lifetime Cancer Risk (ELCR)

Using equation 8, the chance that a person will get cancer over their lifetime at a particular exposure is determined by the excess lifetime cancer risk (ELCR) for outdoor exposure.

$$\text{ELCR} = \text{AEDE} \times \text{DL} \times \text{RF} \quad (8)$$

where DL and RF stand for life expectancy (70 years) and risk factor, respectively Sv⁻¹. For public use, Global Agency for Radiological Protection (ICRP) used a stochastic impact value of 0.05 (27).

Statistical Analysis

The surfer (version 23) program was used for the purpose of drawing radioactive maps between the variables that were calculated with the above-mentioned equations, and this version was also used for the purpose of calculating all the statistical variables of the R_{aeq}(Bq/kg) as Minimum, Maximum, Mean, Median, Variance, Standard Deviation, Mean Difference, Standard Error.

RESULT AND DISCUSSION

Analysis of the soil's (²²⁶Ra, ²³²Th, and ⁴⁰K) activity concentrations in the dumpsite are presented in table 2, also R_{aeq} (radium equivalent activity) and DR (absorbed dose rate) in air. The specific activity in (Bq.kg⁻¹) of (²²⁶Ra, ²³²Th and ⁴⁰K) were 8.889 ± 0.878, ranging from 0 to 39.2 ± 1.22, while the for ²³²Th the average was 6.810 ± 0.446 ranging from 0.9 ± 0.33 to 19.56 ± 0.64 and ⁴⁰K average 360.288 ± 3.753 ranging

Table 2 - Activity concentrations ²²⁶Ra, ²³²Th and ⁴⁰K, radium equivalent activity R_{eq} and absorbed dose rate DR from Soil samples

ID	Activity Concentrations Bq.kg ⁻¹						(Req) Bq.kg ⁻¹	(DR) (nGy.h ⁻¹)
	²²⁶ Ra	SD	²³² Th	SD	⁴⁰ K	SD		
EU-01	5.29	1.03	2.16	0.34	156.27	3	20.415	12.157
EU-02	1.78	0.9	4.85	0.33	184.13	2.83	22.898	9.577
EU-03	4.64	1.22	1.66	0.43	219.4	3	23.911	14.099
EU-04	8.73	0.88	0.9	0.34	117.46	2.47	19.064	14.204
EU-05	4.21	1.22	3.71	0.34	232.16	3.18	27.389	14.171
EU-06	39.2	0.94	19.56	0.38	746.69	4.03	124.667	72.929
EU-07	8.41	0.9	5.22	0.34	253.65	3.08	35.407	19.538
EU-08	12.89	1.12	11.49	0.64	649.82	5.06	79.358	40.836
EU-09	5.71	1.12	6.17	0.56	604.01	5.1	61.035	31.269
EU-10	5.89	0.81	6.66	0.52	360.46	4.13	43.168	21.305
EU-11	15.84	1.12	13.56	0.57	523.84	4.77	75.567	38.729
EU-12	2.97	0.7	8.1	0.57	496.84	4.75	52.810	23.884
EU-13	DL<	0	4.5	0.36	139.02	3.33	17.141	5.797
Minimum	0	0	0.9	0.33	117.46	2.47	17.141	5.797
Maximum	39.2	1.22	19.56	0.64	746.69	5.1	124.667	72.929
Average	8.889	0.878	6.8107	0.446	360.2884	3.753	46.372	26.481
Worldwide average (13)	35		30		400		370	59

(²²⁶Ra, ²³²Th and ⁴⁰K) = activity specific of (radium, thorium and potassium) respectively in (Bq.kg⁻¹) unit
SD = Standard Deviation; Req = Radium Equivalent Activity (Bq.kg⁻¹); (DR) = Absorbed Dose Rate in Air (nGy.h⁻¹)

from 117.46 ± 2.47 to 746.69 ± 5.1 . It is clear that the specific activity of (^{226}Ra , ^{232}Th and ^{40}K) were below the critical values of (35, 30 and 400) Bq.kg^{-1} (22).

With an average of 46.72 Bq.kg^{-1} , the soil's Raeq readings range from 17.141 to $124.667 \text{ Bq.kg}^{-1}$. The predicted Raeq values fell below the 370 Bq.kg^{-1} global tolerable limit (28). The average outdoor absorbed dose rate was $26.481 \text{ nGy.h}^{-1}$, with a range of 5.797 to $72.929 \text{ nGy.h}^{-1}$. This value was determined to be less than the 59 nGy.h^{-1} globally accepted standard. Because of radium equivalent includes the effect of the three radio active nuclei studied, so we took into account its statistical relationship with the site coordinates of soil samples in the study as in *fig. 1*, area also the variation of data points in relation to distance it says that along this trend, data points that are close together show a low degree of variance while points that are farther away show a higher degree of variance, within a certain range, the differences between the points will become more or less constant as shown in *fig. 2*, 3 and *table 4* (22).

Table 3 displays the findings of the calculations for the soil samples' annual effective dose equivalent (AEDE), representative level index, annual gonadal dose equivalent (AGED), external hazard index (Hex), and excess lifetime cancer risk (ELCR). The average value of the AEDE, which ranges from 0.0681 to 0.469 mSv.y^{-1} , was 0.180 mSv.y^{-1} , which was less than the global average of 0.48 mSv (13).

The average annual gonadal dose equivalent AGED value was $161.456 \mu\text{Sv.y}^{-1}$, which was lower than the global average of $300 \mu\text{Sv.y}^{-1}$. The values ranged from 62.466 to $437.356 \mu\text{Sv.y}^{-1}$ (29).

However, the representative level index RLI was determined to be between 0.138 and 0.955, with an average value of 0.351. It is evident that the RLI values obtained in this investigation did not surpass the crucial value of unity (30).

With an average of 0.119 and a range of 0.046 to 0.336, the external hazard index Hex findings demonstrated that all of the values were below unity, the highest value allowed by UNSCEAR (26), indicating that the soil in the research region was safe for human habitation. With a mean of 0.605×10^{-3} , the excess lifetime cancer risk ECLR varied between 0.238×10^{-3} and 1.645×10^{-3} , which was below the world critical threshold of 2.9×10^{-3} (31), It was found that there the absorbed dose and the corresponding concentration have a linear relationship (Raeq) as in *fig. 1*.

Perhaps the reason for the fact that the values of the radiation parameters are very low compared to what is permitted globally is due to the continuous change in

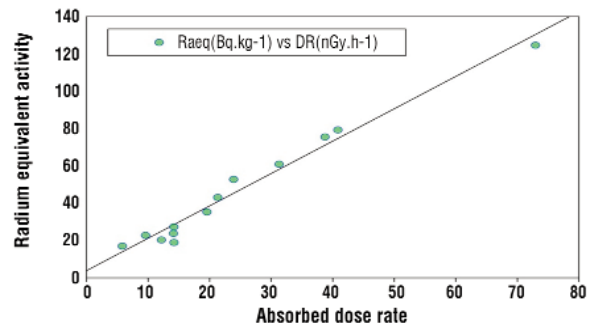


Figure 1 - The absorbed dose rate relationship with radium equivalent activity

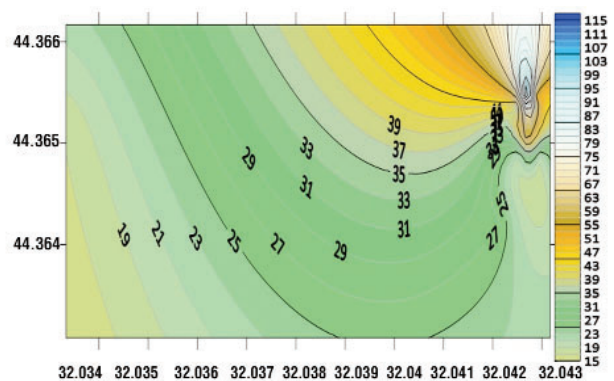


Figure 2 - Radioactive map of radium equivalent (Req)

the building and floor of the building. Statistical parameters were also calculated for the effectiveness of the radium equivalent activity and a radiological map was drawn between latitude and longitude, and this variable shown in *fig. 2* and we note the radioactive variation of the studied sites due to the different nature of the soil.

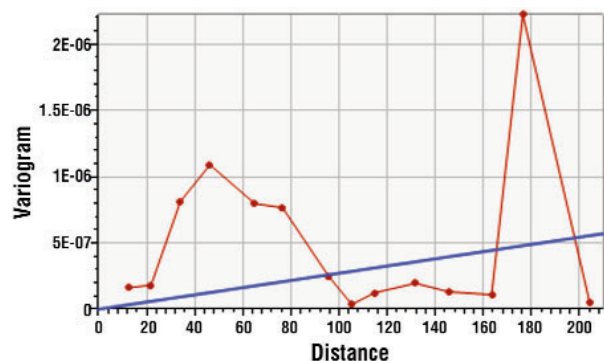


Figure 3 - Variance between Raeq and locations of the studied soil samples

Table 3 - Annual effective dose equivalent, representative level index, the annual gonadal dose equivalent, external hazard index and excess lifetime cancer risk in soil samples

ID	AEDE (mSv.y ⁻¹)	RLI Bq.kg ⁻¹	AGED (μSv.y ⁻¹)	Hex	ELCR x 10 ⁻³
EU-01	0.079	0.161	74.455	0.055	0.277
EU-02	0.090	0.183	83.605	0.061	0.316
EU-03	0.095	0.194	90.181	0.064	0.333
EU-04	0.071	0.146	67.628	0.051	0.25
EU-05	0.108	0.22	101.408	0.073	0.379
EU-06	0.469	0.955	437.356	0.336	1.645
EU-07	0.136	0.277	127.458	0.095	0.478
EU-08	0.312	0.634	291.908	0.214	1.093
EU-09	0.247	0.502	233.075	0.164	0.865
EU-10	0.170	0.346	159.221	0.116	0.597
EU-11	0.290	0.59	270.116	0.204	1.018
EU-12	0.212	0.432	199.046	0.142	0.745
EU-13	0.068	0.138	62.466	0.046	0.238
Minimum	0.068	0.138	62.466	0.046	0.238
Maximum	0.469	0.955	437.356	0.336	1.645
Average	0.180	0.351	161.456	0.119	0.605
World wide average (13)	0.48	1	300	1	2.9

AEDE (mSv.y⁻¹), RLI, AGED (μSv.y⁻¹), Hex and ELCR = Annual Effective Dose Equivalent, Representative Level Index, Annual Gonadal Dose Equivalent, External Hazard Index and Excess Lifetime Cancer Risk respectively.

CONCLUSIONS

The potential health concerns associated with naturally existing radioactivity in soil samples were investigated using a gamma spectrophotometer. It was discovered that the particular activities of ²²⁶Ra, ²³²Th, ⁴⁰K, and Raeq were less than the globally recognized values. It was discovered that the mean AEDE and AGED values were below the global critical values. The respondents in the study region did not exhibit any substantial radiological interest, as indicated by the mean values of the hex index and RLI, which were less than unity. The average lifetime cancer risk (ELCR) value was determined to be less than the 2.9 × 10⁻³ global average, indicating that normal radioactivity in the vicinity of the soil samples did not pose a health danger.

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Conflict of Interest

There are no disclosed conflicts of interest.

Table 4 - The statistical relationship of Req with the site coordinates of the studied soil samples

Statically information	X (latitude)	Y (longitude)	Z (Req)
Minimum	32.033	44.363	17.141
Maximum	32.043	44.366	124.667
Mean	32.041	44.365	46.372
Median	32.042	44.365	35.407
Variance	6.831	5.698	1012.291
Standard Deviation	0.002	0.0007	31.816
Mean Difference	0.001	0.0008	34.749
Standard Error	0.0007	0.0002	8.824

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Ethical Approval

The local ethics committee gave its approval to the study protocol.

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