Estimating the health risks of environmental radiation in soil samples from the National Hospital for Oncology and Hematology in Najaf Al-Ashraf

By Ahmed Alshewered

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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"×3") was done to determine the activities concentration of ^{226}Ra, ^{232}Th and ^{40}K 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 (Ra_{eq}) value was (46.372 Bq.kg^{-1}). Raeq 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 (26.481nGy.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 x 10^{-3}). This number short of the globally accepted level of (2.9 x 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).

Keywords: variogram , Radioactivity, Risk Assessment, Middle Euphrates, Gonadal Dose

1.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]. 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]. Because early dentists and radiologists were exposed to radioactive components, empirical and epidemiological data have shown that radioactive elements have the potential to induce skin cancer. Leukemia was reported to have been contracted by survivors of the Hiroshima atomic bombing who were exposed to radiation above 100 rem [5]. Ionizing radiation can harm biological cells in two ways: temporarily and permanently. The short-term exposure to radiation may result in radioactive side effects, although long-term effects may not manifest for many years [6]. The ways in which ionizing radiation interacts 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 radiation exposure such that the effects are no longer as severe [7]. Exposure of humans to naturally occurring radionuclides can originate from both natural and man-made sources. Large-scale exposure is significant from a health physics standpoint as it indicates a higher degree of danger [8]. Studies show that about 80% of these ionizing radiations are caused by natural background radiation from sources like cosmic rays, radon gases, and terrestrial radionuclides. Terrestrial radionuclides are made up of series radionuclides of thorium (232Th), uranium-radium (238U-226Ra), and non-series radionuclide of potassium (40K) [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 226Ra, 232Th, and 40K was below an internationally recommended standards [10]. Researchers on Iraq's Ya-Hussain road (Najaf/Karbala) calculated the values of 226Ra, 232Th and 40K 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 226Ra, 232Th and 40K 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 (Tl) 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 40K. 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 goal of the project is to measure the activity amounts of radionuclides in soil samples. These measurements will be used to assess health risks in terms of excess lifetime cancer risks, gamma representative levels indexes, absorbed dose rates in air, annual gonadal doses equivalent, and absorbed dose rates relative to air.

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

Thirteen different locations were chosen at a depth of 20 to 50 cm to gather soil samples from the MECC in Najaf using purposeful random sampling. To remove moisture, samples are pounded and dried at 120 ^{O}C in an oven. Each sample was then homogenized and sieved to a size of 200 mesh. Afterwards, weigh 1 kg and transfer to a Marinelli beaker. Then sealed for 30 days to allow ^{226}Ra, ^{232}Th and their corresponding offspring to reach radioactive secular equilibrium [14].

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.-12I12/3, coupled with a multi-channel analyzer (MCA) (ORTEC -Digi Base) with a range of 4096 channels connected to an ADC (Analog to Digital Convertor) unit, Lead shielding is applied to the detector to reduce background radiation, and (MAESTRO-32) software was used to directly send the spectral data to the lab PC. The configuration and geometry of the samples were preserved during the study as they were counted for thirty thousand seconds in a predictable manner.

Calculations

Risk Assessment of Radionuclides

Depending on the specific radioactivity(A_i) [11], was computed 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 in the risk assessment process.

Radium Equivalent Activity (Ra_{eq})

To achieve consistency with regard to radiation exposure, the distribution of natural radioactivity in soil must be improved ,the radium equivalent activity Ra_{eq} is used(15),It is the weighted sum of ^{226}Ra, ^{232}Th and ^{40}K Activity concentrations can be computed using equation 1 with the assumption that 370 $Bq.kg^{-1}$ [16].

$$Ra_{eq} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad [1]$$

which is equivalent to

$$Ra_{eq} = A_{Ra} + 1.43 A_{Th} + 0.077 A_K \quad [2]$$

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

Absorbed Dose Rate in Air (DR)

The rate of dosage absorption is influenced by the particular activity of ^{226}Ra, ^{232}Th and ^{40}K the soil under the presumption that there are minimal amounts of other radioactive isotopes. Given that these radionuclides contribute very little to the overall background radiation output [18]. Equation 3's relation was used to determine the absorbed dosage rate.

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

Annual Effective Dose Equivalent (AEDE)

The unit of measurement for the annual effective dose equivalent was $mSv.\ y^{-1}$. Equation 4 was used to compute the amount of radioactivity that the general public is exposed to in soil.

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

The conversion factor from absorbed dose to effective dose is 0.7 $SvGy^{-1}$, and D is the absorbed dose rate expressed in nGy h^{-1}. The outdoor occupancy factor is represented by 0.2. [19], the time for a year is 8760 hours, with a conversion factor of 10-6.

Annual Gonadal Dose Equivalent (AGED)

The gonads are regarded as organs of interest for dosimetry purposes, per UNSCEAR (2010). These are the main reproductive organs: the female ovaries and the male testes [20], Due to their extreme radiosensitivity, the International Commission for Radiation Protection has placed special emphasis on these members. Reducing the gonadal dose for the general public is imperative and all efforts should be made [21]. The production of red blood cells in the bone marrow is also known to be impacted by elevated AGED levels. Leukemia, a blood cancer that frequently results in death, may result from this. Interest-worthy additional organs include the thyroid, lungs, liver, colon, and bladder [22,23], The annual gonadal dose equivalent AGED $Sv.y^{-1}$ can be calculated by using the formula in equation 5 [24]:

$$AGED\ (\mu Sv.y^{-1}) = 3.09A_{Ra} + 4.19A_{Th} + 0.314A_K \quad [5]$$

Representative Level Index (RLI)

The following formula can be used to compute the gamma radioactivity Representative Level Index associated with naturally occurring radioactive compounds [25]:

$$RLI = \frac{1}{150}A_{Ra} + \frac{1}{100}A_{Th} + \frac{1}{1500}A_K \quad [6]$$

External Hazard Index (H_{ex})

The overall gamma dose that humans receive is influenced by a variety of radionuclides; hence, the hazard index is employed to assess radiological dangers as a single quantity. Equation 7 was used to calculate the External Hazards Index (26), The Hex must be less than one for radiological reasons in order to maintain low radiation exposure hazards [16].

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad [7]$$

Excess Lifetime Cancer Risk (ELCR)

The chance that a person will get cancer at a given dose during their lifetime is determined by using equation 8, which is the excess lifetime cancer risk (ELCR) for outdoor exposure.

ELCR=AEDE×DL×RF [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 (^{226}Ra, ^{232}Th, and ^{40}K) activity concentrations in the dumpsite are presented in Table 2, also the air DR's absorbed dose rate and radium equivalent activity (Raeq). The specific activity in($Bq.kg^{-1}$) of (^{226}Ra, ^{232}Th and ^{40}K) were 8.889±0.878, ranging from 0 to 39.2 ±1.22, while the for ^{232}Th the average was 6.810±0.446 ranging from 0.9±0.33 to 19.56±0.64 and ^{40}K average 360.288±3.753 ranging from 117.46±2.47 to 746.69±5.1, respectively. 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) $Bq.kg^{-1}$, respectively [22].

The values of Ra_{eq} from the soil varying from 17.141 to 124.667 $Bq.kg^{-1}$ with an average of 46.72 $Bq.kg^{-1}$. The estimated values of Ra_{eq} were below than the 370 $Bq.kg^{-1}$ globally acceptable threshold (28). The result of the outdoor absorbed dose rate ranged from 5.797 to 72.929 $nGy.h^{-1}$ with an average of 26.481 $nGy.h^{-1}$. This value was found lower than the internationally acceptable value of 59 $nGy.h^{-1}$. Because of radium equivalent includes the effect of the three radioactive nuclei studied, so we took into account its statistical relationship with the site coordinates of soil samples in the study as in figure 3 ,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 figures (2,3) and Table 4 [22].

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

Table 2. Activity concentrations ^{226}Ra, ^{232}Th and ^{40}K, 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**

(^{226}Ra, ^{232}Th and ^{40}K) = activity specifice of (raduim,thoruim and potassiom) respectively in ($Bq.kg^{-1}$) unit
SD= Standard Deviation; Req= Radium Equivalent Activity ($Bq.kg^{-1}$); (DR)= Absorbed Dose Rate in Air ($nGy.h^{-1}$)

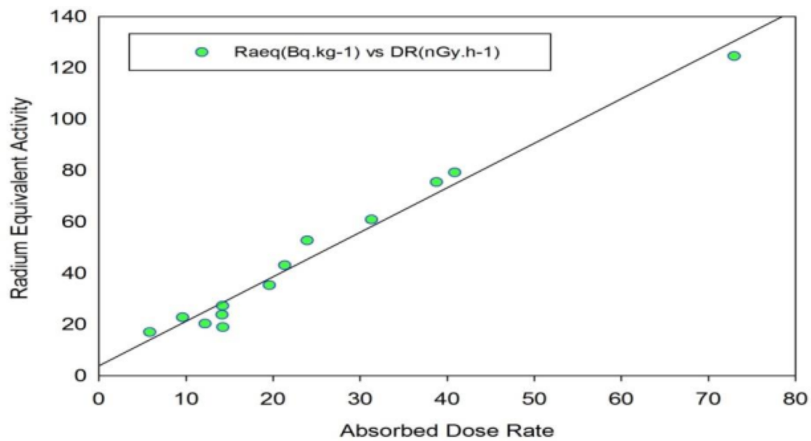

Figure1. The absorbed dose rate relationship with radium equivalent activity

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 ($\mu Sv.y^{-1}$)**	**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

EDE ($mSv.y^{-1}$), RLI, AGED ($\mu Sv.y^{-1}$), H_{ex} and ELCR = Excess Lifetime Cancer Risk, Annual Gonadal Dose Equivalent, Representative Level Index, Annual Effective Dose Equivalent, and External Hazard Index, in that order.

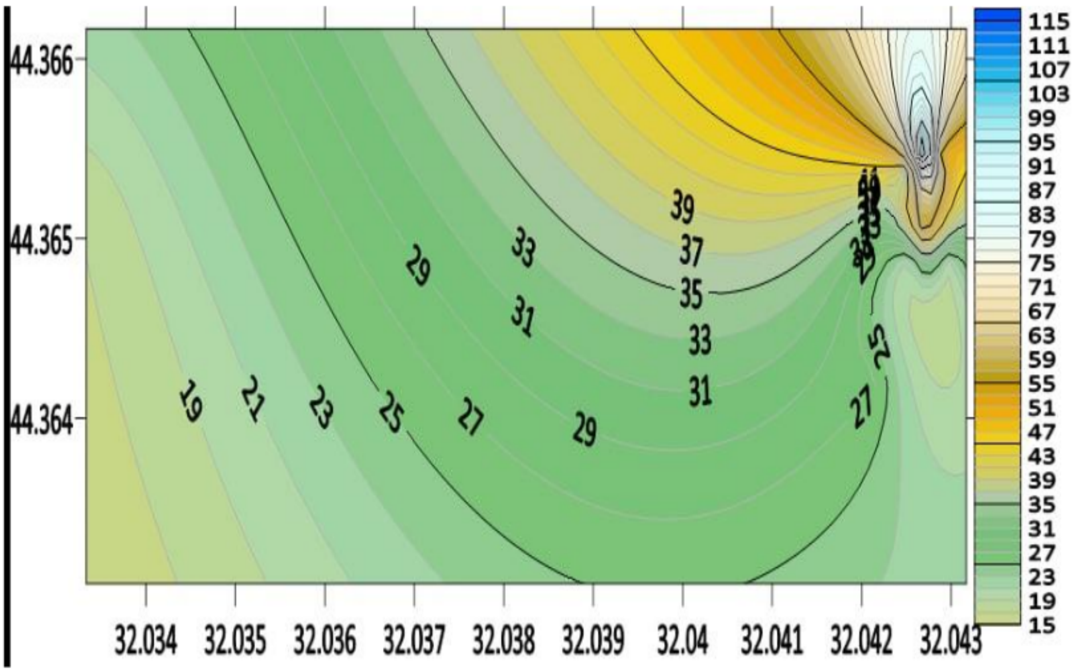

Figure2. Radioactive map of radium equivalent (R_{eq})

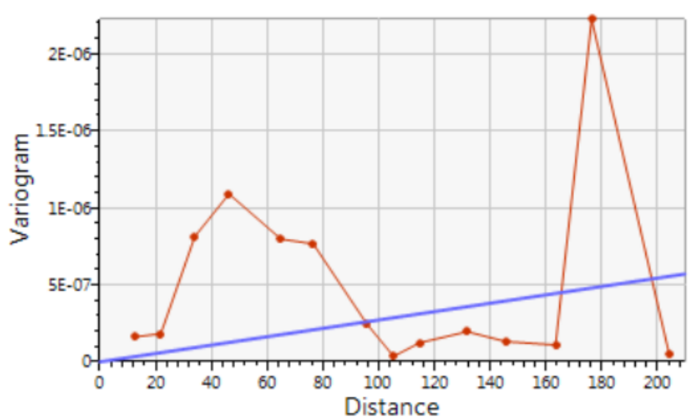

Figure 3. Variance between R_{eq} and locations of the studied soil samples

Table 4. The statistical relationship of R_{eq} with the site coordinates of the studied soil samples

Statically information	X (Latitude)	Y (longitude)	Z (R_{eq})
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

Table 3 displays the findings of calculations made for soil sample yearly 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 ranged from 0.0681 to 0.469 $mSv.y^{-1}$, was determined to be 0.180 $mSv.y^{-1}$, which was less than the global average of 0.48 mSv [13].

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

However, the representative level index RLI was discovered to be within the range of 0.138 to 0.955, with an average value of 0.351. It is evident that the RLI values acquired in this study did not surpass the crucial value of unity [30].

The external hazard index Hex readings ranged from 0.046 to 0.336, with an average of 0.119. All of the Hex values were below unity, which is the highest number that UNSCEAR [26] permits, indicating that the soil is safe for the population in the research region. The analyzed result was determined to be lower than the world critical value of 2.9 x 10-3. The excess lifetime cancer risk (ECLR) ranged from 0.238 x 10^{-3} to 1.645 x 10^{-3}, with a mean of 0.605 x 10^{-3} [31], It was found that there the absorbed dose and the corresponding concentration have a linear relationship (Ra_{eq}) as in figure 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 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 Figure 2 and we note the radioactive variation of the studied sites due to the different nature of the soil.

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 R_{aeq} 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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Ethical Approval

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

Disclaimer

None

Conflict of interest

There are no disclosed conflicts of interest.

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