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INVESTIGATION OF NATURAL RADIOACTIVITY IN SOIL OF SELECTED HOSPITALS IN IMO STATE, NIGERIA

*Ibeabuchi E. Okwor, Chidi E. Akulor and Udoka M. Ukewuihe

Department of Physics, Federal University of Technology, P. M. B. 1526, Owerri, Imo State, Nigeria

*Corresponding Author Email Address: okworibeabuchi@gmail.com Phone: +234 (0) 803 319 8021

ABSTRACT
We measured the terrestrial activity contents, radiation doses; hazard indices and excessive lifetime cancer risk (ELCR) from primordial radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in 50 soil samples collected from the five selected hospitals within Imo State, Nigeria. Radioactivity measurements were carried out by the method of gamma-ray spectrometry with thallium doped sodium iodide [NaI(Tl)] detector. The mean activity values obtained for the radionuclides ^{226}Ra, ^{232}Th and ^{40}K (respectively) in Federal Medical Centre, Owerri (FMC); General Hospital, Umuguma, Owerri West, (GHW); Neuroscience Hospital, Ohaji Egbema (NHO); St. Joseph Hospital, Okigwe (SJH); Imo State University Teaching Hospital, Orlu (IMSUTH) are: 20.56±4.73, 14.96±3.42 and 105.65±31.40 Bqkg^{-1}; 11.77±3.03, 17.45±4.20 and 63.67±18.44 Bqkg^{-1}; 17.97±4.65,10.02±2.18 and 190.43±42.83 Bqkg^{-1}; 11.36±3.71, 17.39±4.46 and 76.29±25.08 Bqkg^{-1}; and 11.84±3.64, 4.89±2.25 and 165.18±58.41 Bqkg^{-1} respectively. These values were below the worldwide average values: 32 Bqkg^{-1} for ^{226}Ra, 45 Bqkg^{-1} for ^{232}Th, and 412 Bqkg^{-1} for ^{40}K as documented by UNSCEAR (2000). ^{40}K recorded the highest mean activity compared to ^{226}Ra and ^{232}Th in the studied soil samples. Radium equivalent activity (Ra_{eq}), absorbed gamma dose rate (D_r), annual effective dose equivalent (AEDE), external hazard index (H_{ex}), gamma representative index (I_{Yr}) and annual gonadal dose equivalent (AGDE), were calculated to quantify the radiation risk to the public from exposure to ^{226}Ra, ^{232}Th and ^{40}K in the studied samples. In addition, excess lifetime cancer risk (ELCR) was also accessed. The mean computed values of the excess lifetime cancer risk for FMC, GHW, NHO, SJH and IMSUTH are 0.08±0.03, 0.09±0.15, 0.10±0.2, 0.10±0.03 and 0.07±0.02 respectively. The mean values of these hazard parameters were within the acceptable safety limits provided for human safety and environmental protection.

Keywords: Primordial radionuclides, Soils, Activity concentration, Radiation doses, Hazard indices, Excess lifetime cancer risk

INTRODUCTION
Living organisms are continuously exposed to a wide range of ionizing radiations from naturally occurring radioactive materials (NORMS) and radionuclides generated from human activities known as artificial radionuclides (El Samad *et al*, 2013). The levels of radioactivity can be used to assess public dose rates and radioactive contamination, hence predicting changes in environmental radioactivity caused by nuclear accidents, industrial activities and other human activities (UNSCEAR, 2000).
^{40}K, ^{238}U, and ^{232}Th (their decay products inclusive) are important natural radioactive elements that contribute to a large part of the radiation dose received by humans. They are encountered in terrestrial strata (soil or rocks) and water bodies (ocean, sea, lakes, etc.), and can easily be accumulated into the food chain through these terrestrial strata. Artificial radionuclides are from nuclear accidents, nuclear weapon tests, radionuclide generators, etc.
Radiation exposure can either come from radioactive materials existing on the ground, suspended in the air, or attached to clothes or the surface of the body (external exposure) or internal exposure due to inhalation, ingestion, percutaneous absorption, wound contamination and injection (Jibiri & Okeyode, 2012; Ngachin *et al*., 2007). The internal radiation exposure, affecting the respiratory track is due mainly to radon and its decay products (Polonium-218, Polonium-214, Lead-82, etc.) which emanate from soil, sediment and building materials (Hameed *et al*, 2014). Long-term exposures to radioactivity and inhalation of radionuclides have serious health effects such as chronic lung cancer and leukemia (Abiodun *et al*, 2019).

Due to the hazard associated with exposure to these radionuclides and inhalation of the short-lived decay products of radon, international bodies and governmental organization such as International Commission on Radiological Protection (ICRP), and Environmental Protection Agency (EPA) have adopted strong measures to minimizing such exposures (Augustine *et al*., 2014).

Location, Physiography and Geology of Study Area
Imo State, South-eastern Nigeria lies within Latitudes 4^0 45^{1}N and 7^0 15^{1}N and longitude 6^{0}50^{1}E and 7^{0}25^{1}E, within an area of about 5,100sqkm, with estimated population of 5.4 million (Imo State Ministry of Land and Survey, 2010).
The study area is characterized by gently undulating topography with average elevation of 229.50 m above sea level within the tropical humid region. The climatic condition common to the equatorial belt of Southeastern Nigeria is sub-divided into wet and dry seasons with mean annual temperature of 28°C. The rainy season starts from April to October with heavy downpours in June/July, while the remaining months are always dry with little or no rain (Ojo, 1997).
The geological setting of Imo State is a complex geological environment with several natural resources (Akaolisa & Selemo, 2009), profitable flora (Vanguard, Nigeria, 2015).
The selected hospitals include: Federal Medical Centre, (FMC), Owerri; General Hospital, Umuguma, Owerri West, (GHW); Imo State University Teaching Hospital, (IMSUTH), Orlu; Neuroscience Hospital, Ohaji Egbema (NHO); and St. Joseph Hospital, Okigwe (SJH).

MATERIALS AND METHODS
Materials and Equipment
The materials and equipment used in this study were:
Na(Tl) Gamma Ray Detector, Hand trowel, Spring balance, Polyethylene bags, Local mortar and pestle, 2 mm sieve, Sample containers, and Adhesive tapes.

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Collection of Soil Samples

A total of ten soil samples weighing 2000g each were collected from different locations of each of the five hospitals at a depth of 0-10cm, using hand trowel, spring balance, measuring tape, adhesive tapes and polyethylene bags.

Preparation of Soil Samples

The soil samples were dried in an enclosure at a room temperature for 4 days. The drying was to remove any available moisture content. After drying, the samples were crushed using local mortar, and sieved with a mesh of 2.0 mm aperture. This helped to remove any lumps, gravels and organic materials that may be present in the soil samples. The homogenized samples were weighed, and a mass of 200 g of each of the samples were fed into empty containers and labeled.
Thereafter, the fine labeled samples were transported to the National Institute of Radiation and Protection Research (NIRPR), University of Ibadan, Nigeria, for Laboratory analysis.

Gamma Counting

At the research laboratory in NIRPR, each fine sample was transferred into a soil Marinelli beaker and sealed completely for about 30 days to attain secular radioactive equilibrium between ^{226}Ra and its short-lived daughter products (Veiga *et al*., 2006). After the period, the samples were analyzed with high resolution gamma-spectrometry system equipped with Sodium Iodide (NaI) detector coupled with computer-based processor and computer system. The detector was connected to an Uninterrupted Power Supply for 36,000s while identification and quantitative analysis of radionuclides was carried out using standard efficiency calibration.

The gamma spectrometer has a resolution of 8% efficiency at energy of 0.662 MeV (^{137}Cs), which is capable of differentiating the gamma ray energies of radionuclides used for the measurement. The photons emitted by the samples were sufficiently discriminated when their emission probability and their energy were high enough and the surrounding background continuum was low enough.
The photo-peak energy of 1.460 MeV was used to identify ^{40}K, 1.760 MeV for ^{226}Ra and 2.614 MeV for the measurement of ^{232}Th. Each sealed soil sample was placed symmetrically on top of the detector and counted for a period of 36,000 s. The net area under the corresponding peaks in the energy spectrum was computed by subtracting counts due to Compton scattering of higher peaks and other background sources from the total area of the peaks. From the net area, the activity concentrations in the samples were obtained using the expression as proposed by Olomo *et al*., 1994; Akinloye & Olomo, 2000.

$$C(Bqkg^{-1}) = \frac{C_n}{\varepsilon P_\gamma M_s} \quad (1)$$

Where:
C is the activity concentration of the radionuclide in the sample in Bqkg^{-1}.
C_n is the count rate under the corresponding peak.
ε is the detector efficiency at the specific gamma-ray energy.
P_γ is the absolute transition probability of the specific gamma ray
M_s is the mass of the sample (kg).

Radium Equivalent Activity (Ra_{eq})

To access the gamma radiation hazards to human associated with the use of the soil samples, radium equivalent activity was calculated. It is expressed mathematically according to (UNSCEAR, 2000).

$$Ra_{eq}\,(Bqkg^{-1}) = A_{Ra} + 1.43A_{Th} + 0.077A_k \quad (2)$$

Where A_{Ra}, A_{th} and A_k are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively in Bqkg^{-1}.

Absorbed Dose Rate (D_r)

The average absorbed dose rate in air 1m above the ground surface were estimated from the results of the activity concentration of the radionuclide determined. The corresponding values relative to the different types of soil samples are calculated using the relation given in (UNSCEAR, 2000).

$$D_r(nGyh^{-1}) = 0.462A_{Ra} + 0.604A_{th} + 0.0417A_k \quad (3)$$

Where D_r is the dose rate (nGyh^{-1}) at 1m above the ground due to ^{226}Ra, ^{232}Th, and ^{40}K in the soil samples. A_{Ra}, A_{Th}, and A_k are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1} respectively Bqkg^{-1}.

Annual Gonadal Dose Equivalent (AGDE)

The Annual Gonadal Dose Equivalents (AGDE μSvy^{-1}) for the occupants of the study area due to the specific activities of ^{226}Ra, ^{232}Th and ^{40}K was calculated using equation (4) proposed by (Arafa, 2004) as:

$$AGED\,(\mu Svy^{-1}) = 3.09A_{Ra} + 4.18A_{Th} + 0.314A_k \quad (4)$$

Where A_{Ra}, A_{Th} and A_k are the activity concentrations of ^{226}Ra, ^{232}Ra and ^{40}K respectively in Bqkg^{-1}

Annual Effective Dose Equivalent (AEDE)

Exposure risk to any individual due to absorbed dose rate is estimated in term of the annual effective dose equivalent (AEDE). AEDE was calculated by applying the conversion factors of 0.70SvGy^{-1}, which converts absorbed dose rate in the air to effective dose and the outdoor occupancy factor 0.2. AEDE in outdoor air, measured in mSvy^{-1} was calculated using equation (5) as proposed by (Amanjeet *et al*., 2017; Lu *et al*., 2012)

$$AEDE\,(mSvy^{-1}) = D_r \times 1.21 \times 10^{-3} \quad (5)$$

External Hazard Index

The external hazard index (H_{ex}) is derived from the same expression of Ra_{eq} with the supposition that its maximum value corresponds to the upper limit of Ra_{eq}, 370 Bqkg^{-1}. It represents the hazard incurred due to external exposure to radiation from ^{226}Ra, ^{232}Th and ^{40}K in the studied soil samples. It was calculated from the equation 6 (UNSCEAR, 2000).

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Ra}}{239} + \frac{A_{Ra}}{4810} \le 1 \quad (6)$$

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Where H_{ex} is the external hazard index and A_{Ra}, A_{Th} and A_K are the activity concentration activity of ^{226}Ra, ^{232}Th and ^{40}K, respectively in $Bqkg^{-1}$.

Gamma Index

Gamma activity concentration index ($I\gamma_r$) is derived for identifying whether a dose standard is met (EC, 1999) and it is estimated from equation 7.

$$I_{\gamma r} = \frac{A_{Ra}}{150} + \frac{A_{Ra}}{100} + \frac{A_{Ra}}{1500} \leq 1 \quad (7)$$

Where $I_{\gamma r}$ is the gamma activity concentration index and A_{Ra}, A_{Th} and A_k are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively in $Bqkg^{-1}$.

Excess Lifetime Cancer Risk (ELCR)

Excess lifetime cancer risk is a parameter that measures the probability of cancer risk to any population due to radiation exposure. It is expressed as a number representing the number of additional cancers expected in a given number of people exposed to a carcinogen at a specific dose. It was calculated based on the estimated annual effective dose.

Equation 8 was used to calculate ELCR as provided by International Commission on Radiological Protection (ICRP) publication 60 (Taskin *et al*, 2009; Emelue, Jibiri & Eke, 2014).

$$ELCR = (AED \times D_L \times R_F) \times 10^{-3} \quad (8)$$

Where:
AED is the annual effective dose
D_L is the average period life span assumed to be 70 years.
R_F is the fatal risk factor per Sievert ($0.05Sv^{-1}$) for the public.

RESULTS AND DISCUSSION

The activity concentrations of primordial radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) have been carried out in this study. The mean activity concentrations of radionuclides in soil samples are 20.56±4.73 $Bqkg^{-1}$, 14.96±3.42 $Bqkg^{-1}$ and 105.65±31.40 $Bqkg^{-1}$ for ^{226}Ra, ^{232}Th, and ^{40}K respectively, as obtained from the FMC; 11.77±3.03 $Bqkg^{-1}$, 17.45±4.20 $Bqkg^{-1}$ and 63.67±18.44 $Bqkg^{-1}$ for ^{226}Ra, ^{232}Th, and ^{40}K, respectively as obtained from GHW; 17.97±4.65 $Bqkg^{-1}$, 10.02±2.18 $Bqkg^{-1}$ and 190.43±42.83 $Bqkg^{-1}$ for ^{226}Ra, ^{232}Th, and ^{40}K respectively, as obtained from NHO; 11.36±3.71 $Bqkg^{-1}$,17.39±4.46 $Bqkg^{-1}$,and 76.29±25.08 $Bqkg^{-1}$ for ^{226}Ra, ^{232}Th, and ^{40}K respectively, as obtained from SJH and 11.84±3.64 $Bqkg^{-1}$, 4.89±2.25 $Bqkg^{-1}$ and 165.18±58.41 $Bqkg^{-1}$for ^{226}Ra, ^{232}Th, and ^{40}K, respectively as obtained from IMSUTH. These values are comparable to other similar research conducted by Eke *et al.*(2015) on soil samples at the Federal University of Technology, Owerri, which revealed the mean activity concentrations of 90.18 $Bqkg^{-1}$, 17.88 $Bqkg^{-1}$ and 22.82 $Bqkg^{-1}$ for ^{40}K, $^{226}Ra$and ^{232}Th, respectively.

Similarly, the study conducted by Egunyinka *et al.* (2009) on evaluating primordial radionuclides in the topsoil of the University of Ibadan showed the activity concentrations 261.37±192.17, 50.01±29.00 and 84.66±37.88 $Bqkg^{-1}$ for ^{40}K, ^{226}Ra and ^{232}Th respectively. Their results are comparable to the findings in the present study. The results indicate that the distributions of activity concentrations of primordial radionuclides in the studied areas are not uniform. The non-uniformity may be partly due to the geochemical, chemical, mineralogical and physical properties of the terrestrial soil since the establishment of the hospitals. The present research work revealed that ^{40}K contributes a significant amount to the total radioactivity of soil in the studied areas. The high value of ^{40}K could be due to potash feldspar minerals present in soil samples of the studied locations (Eke *et al*, 2015). Moreover, the activity concentration of ^{40}K from the present study is found to be higher than those of ^{226}Ra and ^{232}Th, which corroborates with the findings of similar studies within Nigeria.

The average absorbed dose estimated for soil samples from the present study due to primordial radionuclides were 22.94±4.77 $nGyh^{-1}$for FMC; 20.77± 9.41 $nGyh^{-1}$ for GHW; 22.29±3.98 $nGyh^{-1}$for NHO; 21.27±9.32 $nGyh^{-1}$for SJH and 15.31±4.50 $nGyh^{-1}$ for IMSUTH. These values are below the average world value of 59 $nGyh^{-1}$ for an outdoor absorbed dose as reported in UNSCEAR (2000), indicating that the soil samples within the studied areas are free of radiological threat and they are within the normal background environment. The comparison of the absorbed dose obtained from the two institutions with existing literature indicates that the present values are less than the average value of 32.17 $nGyh^{-1}$ in Niger Delta, Nigeria (Avwiri & Ononugbo, 2012) and 38.7±5.0 $nGyh^{-1}$ in Agbara, Ogun State, Nigeria (Gbadamosi, 2017).

The computed mean values of Annual Gonadal Dose Equivalent (AGDE) were 159.23±33.10 μSvy^{-1} for FMC; 129.86±30.80 μSvy^{-1} for GHW; 155.73±27.77 μSvy^{-1} for NHO; 131.74±35.82 μSvy^{-1} for SJH; and 108.94±32.24 $\mu Svy^{-1}$for IMSUTH. These values are below the World average value of 300 μSvy^{-1} (UNSCEAR 2000) report.

Other radiological parameters such as annual effective dose, external hazard index and gamma index have their average values 0.03±0.01 $mSvy^{-1}$, 0.14±0.03, 0.36±0.08, respectively, for FMC. Annual effective dose, external hazard index and gamma index obtained from GHW have their average values of 0.02±0.01 $mSvy^{-1}$, 0.11±0.03, 0.29±0.07, respectively. Similarly, effective dose, external hazard index and gamma index obtained from NHO have their average values of 0.03±0.01 $mSvy^{-1}$, 0.13±0.02, 0.35±0.06. Also, in SJH, the annual effective dose, external hazard index and gamma index have their average values 0.03±0.01 $mSvy^{-1}$, 0.12±0.03, 0.30±0.08, respectively. Also, annual effective dose, external hazard index and gamma index obtained from IMSUTH have their average values of 0.09±0.03 $mSvy^{-1}$, 0.12±0.03, 0.23±0.08, respectively. The values obtained from annual effective dose, external hazard index and gamma index are below the recommended safety limit based on UNSCEAR (2000) report.

Evaluation of Excess Lifetime Cancer Risk (ELCR) revealed that radiation levels from ^{226}Ra, ^{232}Th and ^{40}K in the studied soil are unlikely to cause cancer. The computed ELCR ranged from 0.07 to 0.14 with a mean of 0.08±0.03 for soil samples from FMC; 0.04 to 0.18 with a mean of 0.09±0.15 for soil samples from GHW; 0.07 to 0.11 with a mean of 0.10±0.2 for soil samples from NHO; 0.04 to 0.18 with a mean of 0.10±0.03 for soil samples from SJH; while ELCR for soil samples in IMSUTH ranged from 0.04 to 0.11 with a mean of 0.07±0.02. The estimated ELCR from the study locations are less than the average world value of 0.290 × 10^{-3} as reported by (UNSCEAR, 2000 & Taskin *et al*, 2009), indicating the probability of developing radiation-induced cancer from exposure from soil samples over a lifetime exposure of 70 years is low.

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Conclusion

The radioactivity concentrations ^{226}Ra, ^{232}Th, and ^{40}K in soil samples taken from the five selected hospitals in Imo State, Nigeria, as investigated using gamma ray spectrometer, showed that there are low level activities in the studied locations. The mean activity concentrations obtained in the present study fall within the respective recommended worldwide average of 32 $Bqkg^{-1}$, 45 $Bqkg^{-1}$ and 412 $Bqkg^{-1}$ for ^{226}Ra, ^{232}Th and ^{40}K respectively (UNSCEAR, 2000). The average radiation doses obtained from the sampled locations are less than the recommended worldwide average values 51 $nGyh^{-1}$, 70 μSvy^{-1} and 300 μSvy^{-1} for Annual Dose Rate, Annual Effective Dose Equivalent and Annual Gonadal Dose Equivalent respectively.

Also, the radiation hazard indices obtained from the studied soil samples were below the safety limit of unity set by United Nations Scientific Committee on the Effects of Atomic Radiation for radiation protection. This reveals that the studied regions are relatively safe for human outdoors activities.

In addition, The estimated ELCR from the study locations are less than the average world value of 0.290×10^{-3} as reported by (UNSCEAR, 2000 & Taskin *et al*, 2009), indicating the probability of developing radiation-induced cancer from exposure from soil samples over a lifetime exposure of 70 years is low. Thus, in accordance to my findings, the soil of the study areas does not expose the residents, patients or workers in the area to any health challenge. It is therefore necessarily advised to periodically conduct investigations of natural radiation, and artificial radiation from monitoring the region for human health, as this will help to keep the possible radiation hazards As Low As Reasonably Achievable (ALARA).

Table I Showing the Activity Concentrations of ^{226}Ra, ^{232}Th and ^{40}K, Radiation Doses, Radiation Hazard Indices and Excess Lifetime Cancer Risk of soil samples from Federal Medical Centre, Owerri, Imo State, Nigeria.

	Activity Concentration ($Bqkg^{-1}$)				Radiation Doses			Radiation Hazard Index (≤ 1)		Excess Lifetime Cancer Risk
SAMPLECODES	**^{226}Ra**	**^{232}Th**	**^{40}K**	**Ra_{eq}**	**D_r ($nGyh^{-1}$)**	**AEDE ($mSvy^{-1}$)**	**AGDE (μSvy^{-1})**	**H_{ex}**	**$I_{\gamma r}$**	**ELCR (10^{-3})**
FMC 01	28.50	22.12	172.00	73.38	33.70	0.04	234.54	0.20	0.53	0.14
FMC 02	20.20	15.20	117.87	51.01	23.43	0.03	162.97	0.14	0.37	0.11
FMC 03	26.00	14.00	83.40	52.44	23.95	0.03	165.05	0.14	0.37	0.11
FMC 04	16.05	12.92	104.73	42.60	19.59	0.02	136.49	0.12	0.31	0.07
FMC 05	24.80	12.70	86.73	49.64	22.75	0.03	156.95	0.13	0.35	0.11
FMC 06	15.80	11.00	69.10	36.85	16.83	0.02	116.50	0.10	0.26	0.07
FMC 07	**16.40**	**14.40**	**83.67**	**43.44**	**19.76**	**0.02**	**137.14**	**0.12**	**0.31**	**0.07**
FMC 08	16.00	14.74	87.10	43.79	19.93	0.02	138.40	0.12	0.31	0.07
FMC 09	18.70	12.80	141.50	47.90	22.27	0.03	155.72	0.13	0.35	0.11
FMC 10	23.10	19.74	110.40	59.83	27.20	0.03	188.56	0.16	0.43	0.11
Min.	**15.80**	**11.00**	**69.10**	**36.85**	**16.38**	**0.02**	**116.50**	**0.10**	**0.26**	**0.07**
Max.	**28.50**	**22.12**	**172.00**	**73.38**	**33.70**	**0.04**	**234.54**	**0.20**	**0.53**	**0.14**
Mean ±SD	**20.56 ±4.73**	**14.96 ±3.42**	**105.65 ±31.40**	**50.09 ±10.35**	**22.94 ±4.77**	**0.03 ±0.01**	**159.23 ±33.10**	**0.14 ±0.03**	**0.36 ±0.08**	**0.08 ±0.03**

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Table II Showing the Activity Concentrations of ^{226}Ra, ^{232}Th and ^{40}K, Radiation Doses, Radiation Hazard Indices and Excess Lifetime Cancer Risk of soil samples from General Hospital, Owerri West, Imo State, Nigeria.

	Activity Concentration ($Bqkg^{-1}$)				Radiation Doses			Radiation Hazard Index (≤ 1)		Excess Lifetime Cancer Risk
SAMPLE CODES	**^{226}Ra**	**^{232}Th**	**^{40}K**	**Ra_{eq}**	**D_r ($nGyh^{-1}$)**	**AEDE ($mSvy^{-1}$)**	**AGDE (μSvy^{-1})**	**H_{ex}**	**I_{Yr}**	**ELCR 10^{-3}**
GHW 01	13.26	18.63	88.44	46.71	21.07	0.03	146.62	0.13	0.33	0.11
GHW 02	13.93	21.45	70.45	50.03	44.50	0.05	160.47	0.14	0.35	0.18
GHW 03	10.05	19.48	64.96	42.91	19.12	0.02	132.88	0.12	0.31	0.07
GHW 04	10.98	12.98	65.97	34.62	15.65	0.02	108.90	0.09	0.23	0.07
GHW 05	15.09	20.78	84.80	51.34	23.06	0.03	160.12	0.14	0.37	0.11
GHW 06	10.83	18.88	65.07	42.84	19.12	0.02	132.83	0.12	0.30	0.07
GHW 07	14.53	16.94	71.88	44.29	19.94	0.02	138.28	0.12	0.31	0.07
GHW 08	12.68	19.21	54.60	44.35	19.73	0.02	136.62	0.12	0.31	0.07
GHW 09	04.59	07.48	25.74	17.27	06.97	0.01	53.53	0.05	0.12	0.04
GHW 10	11.74	18.65	44.79	41.86	18.56	0.02	128.30	0.11	0.30	0.07
Min.	**04.59**	**07.48**	**24.74**	**17.27**	**06.97**	**0.01**	**53.53**	**0.05**	**0.12**	**0.04**
Max.	**15.09**	**21.45**	**88.44**	**51.34**	**44.50**	**0.05**	**160.47**	**0.14**	**0.37**	**0.18**
Mean ±SD	**11.77 ±3.03**	**17.45 ±4.20**	**63.67 ±18.44**	**41.56 ±9.72**	**20.77 ±9.41**	**0.02 ±0.01**	**129.86 ±30.80**	**0.11 ±0.03**	**0.29 ±0.07**	**0.09 ±0.15**

Table III Showing the Activity Concentrations of ^{226}Ra, ^{232}Th and ^{40}K, Radiation Doses, Radiation Hazard Indices and Excess Lifetime Cancer Risk of soil samples from Neuroscience Hospital, Ohaji Egbema, Owerri, Imo State, Nigeria

	Activity Concentration ($Bqkg^{-1}$)				Radiation Doses			Radiation Hazard Index (≤ 1)		Excess Lifetime Cancer Risk
SAMPLE CODES	**^{226}Ra**	**^{232}Th**	**^{40}K**	**Ra_{eq}**	**D_r ($nGyh^{-1}$)**	**AEDE ($mSvy^{-1}$)**	**AGDE (μSvy^{-1})**	**H_{ex}**	**I_{Yr}**	**ELCR 10^{-3}**
NHO 01	24.00	11.22	225.00	44.03	27.25	0.03	191.71	0.16	0.42	0.11
NHO 02	09.96	05.85	172.38	21.38	15.32	0.02	109.34	0.09	0.24	0.07
NHO 03	17.50	06.81	129.73	29.53	17.61	0.02	123.28	0.10	0.27	0.07
NHO 04	14.80	09.40	213.81	31.74	21.43	0.03	152.16	0.12	0.34	0.11
NHO 05	20.66	10.24	257.10	39.85	26.45	0.03	187.37	0.15	0.41	0.11
NHO 06	14.78	10.04	140.98	31.63	18.77	0.02	131.91	0.11	0.29	0.07
NHO 07	23.52	10.70	203.10	42.42	25.80	0.03	181.18	0.15	0.40	0.11
NHO 08	21.08	11.12	185.10	39.26	24.17	0.03	169.74	0.14	0.38	0.11
NHO 09	13.31	12.80	231.11	35.71	23.52	0.03	152.75	0.13	0.37	0.11

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NHO 10	20.05	11.98	145.94	39.77	22.59	0.03	157.86	0.13	0.35	0.11
Min.	**09.96**	**05.85**	**129.73**	**21.38**	**15.32**	**0.02**	**109.34**	**0.09**	**0.24**	**0.07**
Max.	**24.00**	**12.80**	**225.00**	**44.03**	**27.25**	**0.03**	**187.37**	**0.16**	**0.42**	**0.11**
Mean ±SD	**17.97 ±4.65**	**10.02 ±2.18**	**190.43 ±42.83**	**35.53 ±6.96**	**22.29 ±3.98**	**0.03 ±0.01**	**155.73 ±27.77**	**0.13 ±0.02**	**0.35 ±0.06**	**0.10 ±0.20**

Table IV Showing the Activity Concentrations of ^{226}Ra, ^{232}Th and ^{40}K, Radiation Doses, Radiation Hazard Indices and Excess Lifetime Cancer Risk of soil samples from St. Joseph Hospital, Okigwe, Imo State, Nigeria.

	Activity Concentration (Bqkg^{-1})				**Radiation Doses**			**Radiation Hazard Index (≤ 1)**		**Excess Lifetime Cancer Risk**
SAMPLE CODES	**^{226}Ra**	**^{232}Th**	**^{40}K**	**Ra_{eq}**	**D_r (nGyh^{-1})**	**AEDE (mSvy^{-1})**	**AGDE (μSvy^{-1})**	**H_{ex}**	**$I_{\gamma r}$**	**ELCR 10^{-3}**
SJH 01	14.25	19.63	86.45	48.98	22.05	0.03	153.23	0.13	0.35	0.11
SJH 02	14.35	23.21	97.47	55.05	24.71	0.03	171.96	0.15	0.39	0.11
SJH 03	04.59	08.49	26.74	18.79	08.36	0.01	58.07	0.05	0.13	0.04
SJH 04	06.52	13.44	55.46	30.01	13.44	0.02	93.74	0.08	0.22	0.07
SJH 05	12.29	20.64	80.06	47.97	21.48	0.03	149.39	0.13	0.34	0.11
SJH 06	13.68	20.29	97.97	50.24	22.66	0.03	157.85	0.14	0.36	0.11
SJH 07	14.34	19.08	66.48	46.74	20.92	0.03	144.94	0.13	0.33	0.11
SJH 08	12.17	18.44	114.07	47.32	21.52	0.03	150.50	0.13	0.34	0.11
SJH 09	07.44	12.68	75.74	31.33	14.22	0.02	99.57	0.09	0.23	0.07
SJH 10	13.95	18.04	62.45	44.56	43.38	0.05	138.12	0.12	0.32	0.18
Min.	**04.59**	**08.49**	**26.74**	**18.79**	**08.36**	**0.01**	**58.07**	**0.05**	**0.13**	**0.04**
Max.	**14.35**	**19.63**	**114.07**	**55.05**	**43.38**	**0.05**	**157.85**	**0.15**	**0.39**	**0.18**
Mean ±SD	**11.36 ±3.71**	**17.39 ±4.46**	**76.29 ±25.08**	**42.11 ±11.43**	**21.27 ±9.32**	**0.03 ±0.01**	**131.74 ±35.82**	**0.12 ±0.03**	**0.30 ±0.08**	**0.10 ±0.03**

Table V Showing the Activity Concentrations of ^{226}Ra, ^{232}Th and ^{40}K, Radiation Doses, Radiation Hazard Indices and Excess Lifetime Cancer Risk of soil samples from Imo State University Teaching Hospital, Orlu, Imo State, Nigeria.

	Activity Concentration (Bqkg^{-1})				**Radiation Doses**			**Radiation Hazard Index (≤ 1)**		**Excess Lifetime Cancer Risk**
SAMPLE CODES	**^{226}Ra**	**^{232}Th**	**^{40}K**	**Ra_{eq}**	**D_r (nGyh^{-1})**	**AEDE (mSvy^{-1})**	**AGDE (μSvy^{-1})**	**H_{ex}**	**$I_{\gamma r}$**	**ELCR 10^{-3}**
IMSUTH 01	08.68	03.12	109.54	21.58	10.46	0.01	74.26	0.06	0.16	0.04
IMSUTH 02	10.49	02.73	117.46	23.44	11.39	0.01	80.71	0.06	0.18	0.04
IMSUTH 03	09.46	03.59	128.64	24.50	11.90	0.02	84.63	0.07	0.19	0.07

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IMSUTH 04	13.20	03.03	131.75	27.68	13.42	0.02	94.82	0.08	0.13	0.07
IMSUTH 05	09.94	02.84	114.68	22.83	11.09	0.01	79.58	0.06	0.17	0.04
IMSUTH 06	09.30	09.78	289.13	45.55	22.26	0.03	160.45	0.12	0.35	0.11
IMSUTH 07	20.90	06.34	211.99	46.29	22.33	0.03	157.65	0.13	0.34	0.11
IMSUTH 08	10.60	05.94	195.89	34.18	16.65	0.02	119.09	0.09	0.26	0.07
IMSUTH 09	11.50	05.80	146.75	31.09	14.94	0.02	105.59	0.08	0.23	0.07
IMSUTH 10	14.30	05.69	205.99	38.30	18.63	0.02	132.65	0.10	0.29	0.07
Min.	**08.68**	**02.73**	**109.54**	**21.58**	**10.46**	**0.01**	**74.26**	**0.06**	**0.16**	**0.04**
Max.	**14.30**	**09.78**	**289.13**	**38.30**	**22.33**	**0.03**	**160.45**	**0.10**	**0.35**	**0.11**
Mean ±SD	**11.84 ±3.64**	**04.89 ±2.25**	**165.18 ±58.41**	**31.54 ±9.26**	**15.31 ±4.50**	**0.02 ±0.01**	**108.94 ±32.24**	**0.09 ±0.03**	**0.23 ±0.08**	**0.07 ±0.02**

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