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Full Length Research Article

RISK ASSESSMENT OF EXCESS LIFETIME CANCER RISK (ELCR) IN FEDERAL MEDICAL CENTER, OWERRI, IMO STATE, NIGERIA

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ABSTRACT
Excess Lifetime Cancer Risks, Activity Concentrations, Radium equivalent activity (Ra_{eq}), absorbed gamma dose rate (D_r), annual effective dose equivalent (AEDE), external hazard index (H_{ex}), and annual gonadal dose equivalent (AGDE), were measured and evaluated from primordial radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in 10 Soil samples collected from Federal Medical Center (FMC), Owerri, Imo State, Nigeria. Radioactivity measurements were carried out by the method of gamma-ray spectroscopy with a Thallium-doped Sodium Iodide [NaI (Tl)] detector. The mean activity values obtained for the radionuclides ^{226}Ra, ^{232}Th, and ^{40}K in Federal Medical Centre (FMC), Owerri are: 20.56 ± 4.73, 14.96 ± 3.42, and 105.65 ± 31.40 $Bqkg^{-1}$, 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. ^{40}K recorded the highest mean activity compared to ^{226}Ra and ^{232}Th in the studied soil samples, as shown in the table below. The mean computed values of the Excess Lifetime Cancer Risk are $0.08 \times 10^{-3} \pm 0.03$. The mean values of these hazard parameters were within the acceptable safe limits provided for human safety and environmental protection. This simply means that the Excess Lifetime Cancer Risk is insignificant or minimal from the studied samples.

Keywords: Excess lifetime cancer risk, Na (Tl) gamma ray detector, Primordial radionuclides, Hazard index, Soils, Activity concentrations

INTRODUCTION

Excess Lifetime Cancer Risk assessment in hospitals involves the lifetime risk of developing cancer due to radiation exposure among the staff members and patients within the facility. Cancer is a large group of diseases that can start in almost any organ or tissue of the body when abnormal cells grow uncontrollably, go beyond their usual boundaries to invade adjoining parts of the body and/or spread to other organs. The latter process is called metastasizing and is a major cause of death from cancer. A neoplasm and malignant tumour are other common names for cancer (WHO, 2010). According to the Global Cancer Observatory (GLOBOCAN) in 2021, Nigeria had 124,815 new cases in total in 2020, of which 51,398 were males, with prostate cancer being the most prevalent (29.8%) and 73,417 were females, with breast cancer being the most common type at 38.7%, followed by cervical cancer at 16.4% (Omosun*et al*., 2022). Also, an estimated 78,889 people died from cancer, 34,200 being men and 44,699 being women (Omosun et *al*., 2022). As of 2022, Nigeria recorded 269,109 cases of cancer within 5 years (2018–2022), with the total number of new cases and deaths of cancer in the year 2022 estimated to be 127,763 and 79,542, respectively.

Every living being is constantly exposed to natural radiation arising from the environment. Cosmic rays and naturally occurring radioactive elements account for the majority of natural radiation on Earth and within the human body. Radon (^{222}Rn) is one of the most abundant sources of naturally occurring radiation. It is an odorless, colorless, and noble gas with a half-life of 3.82 days. ^{222}Rn is generated through the radioactive decay of radium (^{226}Ra) in rocks and soils and escapes to the atmosphere and underground water. Therefore, the inhalation of ^{222}Rn and its daughters is the major internal source of radiation.

Ingestion exposure to ^{222}Rn is likewise possible by drinking water; however, the dose and risk of exposure are minimal (WHO, Geneva, 2010). Long-term exposures to radioactivity, Ionizing radiation, and inhalation of radionuclides have serious health effects such as chronic lung cancer and leukemia (Qureshi *et al*., 2014). Due to the hazards associated with exposure to these radionuclides and inhalation of the short-lived decay products of radon, International bodies and governmental organizations such as the International Commission on Radiological Protection (ICRP), and the Environmental Protection Agency (EPA) have adopted strong measures to minimize such exposures (Augustine *et al*., 2014). Considering natural radioactivity in Nigeria, different research in living and working environments has been conducted over the years. In recent times, radionuclides such as ^{40}K, ^{232}Th, and ^{226}Ra have been analyzed in the soil samples from various parts of the country. Radioactive decay is a highly exoergic, statistically random, first-order process that occurs with a small amount of mass being converted to energy. Since it is a first-order process, each radioactive species is characterized by its own half-life, the length of time in which an initially very large number of such nuclei will have decayed to only half the original number.

MATERIALS AND METHODS

Location, Physiography, and Geology of the Study Area

The geological setting of Imo State, an area in South-eastern Nigeria, is a complex geological environment. The State has several natural resources, including Crude Oil, Natural Gas, Lead, Calcium Carbonate, Solar and Wind Power, and Zinc (Akaolisa & Selemo 2009). Imo State, Southeastern 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 5,100 sq km, with an 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 subdivided into wet and dry seasons with a mean annual temperature of 28°C. The rainy season starts from April to October with heavy downpours in June and July, while the remaining months are always dry with little or no rain (Ojo, 1997). The vegetation in the study area consisted of coastal lowlands to

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the east of the Niger River. Most of the State's original tropical rain forest vegetation has been replaced by more open areas of oil-palm bush. There are over 163 oil wells at over 12 different locations in the State (Vanguard, Nigeria, 2015). The main petroleum companies operating in the state are Addax Petroleum, Chevron Corporation, Royal Dutch Shell, and Agip.

Materials and Sample Collections

The materials used include a Na (TI) gamma ray detector, a spring balance, measuring tape, local mortar and pestle, 2.00 mm sieve, sample containers, and adhesive tapes. A total of ten (10) soil samples weighing 2000 g each were randomly collected at locations of the hospital at a depth of 0-10 cm, using an auger, spring balance, measuring tape, adhesive tapes, and polyethylene bags. The soil samples were carefully marked and labeled for easy identification.

Sample Preparation

The soil samples were dried in an enclosure at room temperature for 6 days. This was meant to remove any available moisture in the soil samples. After drying, the samples were crushed using local mortar and sieved with a mesh of 2.0 mm aperture. The crushing and sieving helped to remove organic materials, gravel, pieces of stone, and lumps present in the samples.

Afterward, the homogenized samples were weighed, and a mass of 200 g of each of the samples was fed into empty containers that had been previously certified to be non-radioactive and non-contaminated. The sample containers were of uniform size (7 cm and 6cm diameter). The sample containers were hermetically sealed with adhesive tapes (AERB, 2003).

Spectroscopy Analysis

Thereafter, the samples were sent to the National Institute of Radiation Protection and Research (NIRPR) for gamma spectroscopy. At the laboratory, the sealed samples were left for a period of 30 days. This was done before gamma spectroscopy, to allow the short-lived radionuclide to attain secular radioactive equilibrium (Veiga et *al*., 2006). Each sealed soil sample was placed symmetrically on top of the detector and counted for a period of 36,000 s (10 hours). the counting was done during this period so as to achieve a minimum counting error. 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.

Measurement of Radioactivity

The gamma spectrometer has a resolution of 8% efficiency at an energy of 0.662 MeV (^{137}Cs), which is capable of differentiating the gamma ray energies of radionuclides used for the measurement. 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. The standard reference soil sample used for efficiency calibration was from Rocketdyne Laboratories, California, USA, traceable to a mixed standard gamma source (Ref No 48722-356) by Analytic Inc., Atlanta, GA, USA.

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).

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

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

Radium Equivalent Activity (Ra_{eq})

To assess the gamma radiation hazards to humans associated with the use of the soil samples, radium equivalent activity was calculated. This gives a single index that describes the gamma output from different mixtures of ^{238}U, ^{232}Th, and ^{40}K in the soil samples. Radium equivalent activity (Ra_{eq}) is expressed mathematically according to (UNSCEAR, 2000).

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

Where A_{Ra}, A_{th}, and $A_k$are 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 was estimated from the results of the activity concentration of the radionuclide determined. The corresponding values relative to the different types of soil samples were calculated using the relation given in Equations (UNSCEAR, 2000).

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

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. The absorbed dose rate expresses the received dose in the open air due to the radiation emitted from radionuclide concentrations in environmental materials.

Annual Gonadal Dose Equivalent (AGDE)

According to reference (UNSCEAR, 1988), the gonads, the active bone marrow, and the bone surface cells are considered as the organs of interest. Therefore, 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 were calculated using the Equation proposed by Arafa (2004) as:

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

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 terms of the annual effective dose equivalent (AEDE). AEDE was calculated by applying the conversion factors of 0.70 $SvGy^{-1}$, which converts absorbed dose rate in the air to effective dose, and the outdoor occupancy factor of 0.2. AEDE in outdoor air, measured in $mSvy^{-1}$, was calculated using the equation:

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

External Hazard Index

The external hazard index (H_{ex}) is derived from the same expression of R_{aeq} with the supposition that its maximum value

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corresponds to the upper limit of R_{aeq}, 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 (UNSCEAR, 2000).

$$H_{ex} = \frac{A_{R\alpha}}{370} + \frac{A_{R\alpha}}{239} + \frac{A_{R\alpha}}{4810} \leq 1 \quad \ldots\ldots\ldots (6)$$

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

$$ELCR = (AED \times D_L \times R_F) \times 10^{-3} \quad \ldots\ldots\ldots (7)$$

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

Table 1. 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 Center, Owerri, Imo State, Nigeria.

	Activity Concentrations (Bqkg^{-1})				Radiation Doses			Radiation Hazard Index (≤ 1)		Excess Lifetime Cancer Risk
SAMPLE CODES	^{226}Ra	^{232}Th	^{40}K	Ra_{eq}	D_r (nGy h^{-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	**20.56**	**14.96**	**105.65**	**50.09**	**22.94**	**0.03**	**159.23**	**0.14**	**0.36**	**0.08**
S . D	**4.73**	**3.42**	**31.40**	**10.35**	**4.77**	**0.01**	**33.10**	**0.03**	**0.08**	**0.03**
World Average	32	45	412	370	51	70	300	≤ 1	≤ 1	0.29
S . D	Standard deviation for average values									

RESULTS AND DISCUSSION

The activity concentrations of primordial radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) have been carried out in this study as shown in Table 1. 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, These values are comparable to a similar study 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 non-uniformity may be partly due to the geochemical, chemical, mineralogical, and physical properties of the terrestrial soil since the establishment of the hospital. The present research work revealed that ^{40}K contributes a significant amount to the total radioactivity of the soil the studied areas.
The average absorbed dose estimated for soil samples from the present study due to primordial radionuclides was: 22.94 ± 4.77 nGyh^{-1} in the hospital.
The computed mean values of Annual Gonadal Dose Equivalent (AGDE) were 159.23 ± 33.10 μSvy^{-1} in the studied samples. 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. The values obtained from annual effective dose, external hazard index, and gamma index are below the recommended safe limit based on the UNSCEAR (2000) report.
The computed ELCR ranged from 0.07 × 10^{-3} to 0.14 × 10^{-3} with a mean of 0.08 × 10^{-3} ± 0.03. The estimated ELCR from the analyzed locations is 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.

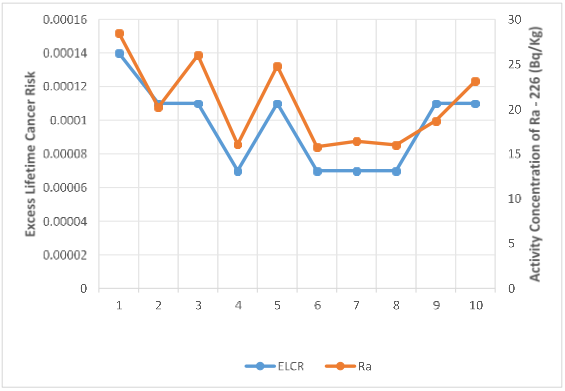

Figure 1. Activity Concentration of Ra - 226 Versus Excess Lifetime Cancer Risk

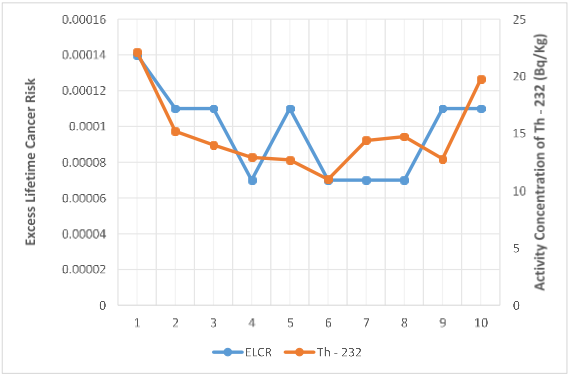

Figure 2. Activity Concentration of Th - 232 Versus Excess Lifetime Cancer Risk

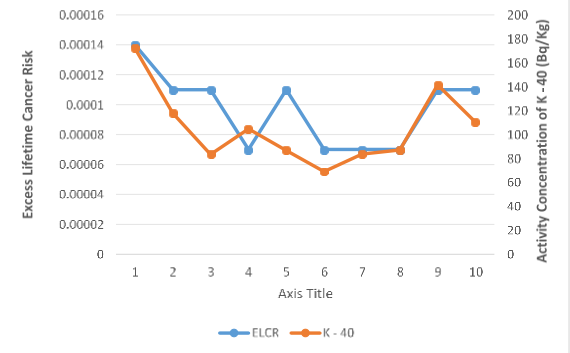

Figure 3. Activity Concentration of K - 40 Versus Excess Lifetime Cancer Risk

Conclusion

The activity concentrations ^{226}Ra, ^{232}Th, and ^{40}K in soil samples taken from the Federal Medical Center (FMC), Owerri, Imo State, Nigeria, as investigated using a 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 $\mu Svy^{-1,}$ 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 the United Nations Scientific Committee on the Effects of Atomic Radiation for radiation protection.

In addition, the estimated ELCR from the study locations is 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 to soil samples over a lifetime exposure of 70 years is low. Thus, in accordance with my findings, the soil of the study areas does not expose the residents, patients, or workers in the area to any health challenge. This study can be considered a useful resource for further studies on natural radioactivity mapping.

Recommendation

It is recommended that similar studies should periodically be conducted on natural radiation in the region, as this will help to keep the possible radiation hazards As Low As Reasonably Achievable (ALARA).

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