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Characterization of Radiation dose and Excess Lifetime Cancer Risk Due to Natural Radionuclides in soils from Some Cities in Southwestern Nigeria

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Abstract

Activity concentrations of natural radionuclides and artificial radio caesium have been determined in soil samples from thirty-six locations in Southwestern Nigeria. The samples were analysed for radioactivity using the co-axial type Hyper-Pure Germanium (HPGe) detector (CANBERRA, U.S.). The mean activity concentrations of ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs were ^{477}.69 Bq kg^{-1}, 52.05 Bq kg^{-1}, 85.84 Bq kg^{-1} and 1.60 Bq kg^{-1}, respectively. The radium equivalent concentration and the external and internal hazard indices were estimated to range from 28.47 to 701.53 Bq kg-1, 0.08 to 1.89, and 0.10 to 2.33, with mean values of 210.57 Bq kg^{-1}, 0.57, and 0.71, respectively. The mean absorbed dose and the mean annual outdoor effective dose equivalent in soil samples were 95.40 nGy h^{-1} and 0.117 mSv y^{-1} respectively. The mean annual effective dose equivalent for the study area is higher than the world average (0.07 mSv y^{-1}) and international permissible standards of 0.1 mSv y^{-1} recommended by World Health Organization (WHO). The excess lifetime cancer risk (ECLR) ranged from 5.32 x 10^{-5} to 1.36 x 10^{-3}, with a mean of 4.10 x 10^{-4}. This value is higher than the world average of 2.9 x 10^{-4} reported by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Some levels of radiation cancer risk were noticed in some parts of the study area. The result showed that ELCR due to natural radiation sources is a function of environmental geology.

Keywords: Soil; Radioactivity; Hazard Index; Cancer Risk; Mortality

Introduction

The radioactive decay of some primordial radionuclides in the families of the non-series 40K and the radionuclides belonging to the 238U and the 232Th series give rise to the terrestrial gamma radiation. The [1]. report presents the radionuclide concentrations in the soils from various countries of the world. The values of activity concentrations of 232Th, 238U, and 40K in the soils, as reported in the literature for different countries of the world, varies in the range of 0.05 - 360 Bq kg^{-1}, 2.0 - 1000 Bq kg^{-1}, and 4.0 - 3200 Bq kg^{-1}, with corresponding worldwide average values of 45 Bq kg-1, 33 Bq kg^{-1}, and 412 Bq kg^{-1}, respectively (UNSCEAR, 2008). The worldwide average outdoor terrestrial gamma absorbed dose rate in the air from gamma radiation is 54 nGy h^{-1}, and the relative contributions of 232Th, 238U, and 40K to this dose is about 37%, 32% and 31% respectively [1]. The worldwide average value of radiation dose to human beings from natural sources of radiation is estimated to be 2.45 mSv y^{-1} [2]. The ingestion dose to man from terrestrial sources is 0.310 mSv y^{-1} worldwide [2].

There are regions that were referred to as the high background radiation area (HBRA) in the world where the outdoor terrestrial radiation exceeds substantially from the normal range due to the enrichment of certain radioactive minerals [1]. Several countries like China, Iran, Germany, USA, Brazil, and India have reported the existence of high background radiation areas [1]. The world highest levels of natural radiation have been reported in some areas in Ramsar with extraordinary radon level [3-5]. The radiation data obtained from HBRA in Ramsar recorded an effective dose of 260 mSv y^{-1} This value is several times higher than the ICRP-recommended radiation dose limits for radiation workers, and over 200 times greater than normal background levels [2]. Naturally occurring radioactive materials have been concentrated or exposed to the accessible environment as a result of human activities such as manufacturing, mineral extraction, or water processing. Uranium and thorium as well as 40K are present in higher concentrations in coal [6]. Coal mining as well as burning of coal in thermal power stations, releases uranium and thorium into the environment mainly through the escaping fly-ash. This is a well-known example of Technologically-Enhanced, Naturally-Occurring Radioactive Materials TENORM. It is estimated that about 4,000 tons of uranium and 8,000 tons of thorium are distributed globally along with their daughter products solely due to coal combustion [7].

The phosphate fertiliser industry is a major generator of TENORM. Uranium concentrations in phosphate rock range

from 500 Bq kg^{-1} to 7000 Bq kg^{-1}, and radium concentrations are about 700 Bq kg^{-1} to 3000 Bq kg^{-1} [8]. Phosphate rock is mined for the production of phosphoric acid, majority of which is used in agricultural fertiliser. These radionuclides are redistributed to the environment in the course of industrial processing, use of fertilisers, effluent discharges, and the utilisation of by-products and waste material for other purposes [9]. Radiation exposure can cause cancer in any living tissue, but high-dose whole-body external exposure is mostly associated with leukemia [10]. reflecting the high radiosensitivity of bone marrow. Internal exposures is a major cause of cancer in the organs where the radioactive material concentrates, so that radon predominantly causes lung cancer, iodine-131 is most likely to cause thyroid cancer [11-13]. The rate of breast cancer incidences is reportedly higher in developing countries as compared with other parts of the world [14]. The linear dose-response model suggests that any increase in dose, no matter how small, results in an increase in risk of cancer. The linear no-threshold model (LNT) hypothesis is accepted by the International Commission on Radiological Protection (ICRP) and regulators around the world [15]. This model estimated that about 1% of the world population develop cancer as a result of natural background radiation at some point in their lifetime. Who reported that 13% of deaths in 2008 are attributed to cancer, so that background radiation could be a small contributor [16].

Radiation exposure is responsible for about 10% of invasive cancers. This includes ionizing radiation and non-ionizing radiation [17]. Exposure to ionizing radiation is linearly proportional to the future incidence of cancer, particularly leukemia. The mechanism by which this occurs is well understood, but quantitative models predicting the level of risk remain controversial. The most widely accepted model reveals that the incidence of cancers due to ionizing radiation increases linearly with effective radiation dose at a rate of 5.5% per Sievert [18]. Since the linear model is universal, natural background radiation is the most hazardous source of radiation to general public health. It is assumed that long-term exposure to radiation has some risks of causing cancer. The implication is that every individual has a risk of getting cancer at a time in his lifetime. Report from Surveillance, Epidemiology, and End Results (SEER) Cancer Statistics Review, which was presented by the National Cancer institute showed that American men have a 44% lifetime risk of cancer, while their women have a 38% lifetime risk. Long-time exposure to cancer-causing materials resulted in additional risk that someone might have cancer in a lifetime.

Research Methodology

Collection of Samples

36 soil samples were collected from 36 locations from the six States in the South-Western Nigeria. The soil were collected after the top soil has been removed to rid it of extraneous objects in accordance with IAEA recommendation (IAEA, 1989). The soil samples collected were packaged in a cellophane bag, well labelled and taken to the laboratory for processing before preparation for activity concentration analysis.

Sample Site Selection

Figure 1: Map of Southwestern Nigeria.

The decision about the sample site was sponsored by an objective to cover a wide range of study area in the South-Western part of the country (Figure 1). which is an important part of the country because of the high population density, coupled with various Industrial and agricultural activities going on in the study area. Also for the purpose of the determination of fallout Caesium-137 concentration which has to be over a wide area so as to give it a wider view of evaluation in estimating the impact and aftereffect of the nuclear accident in some eastern part of the world over our immediate environment. The environment of the study area ranges from the mangrove swamps to the tropical rainforest in a low elevation along the coast. The tropical monsoon climate is found in the southern part of the country. This climate is influenced by the monsoons originating from the South Atlantic Ocean, which is brought into the country by the (maritime tropical) MT airmass, a warm moist sea to land seasonal wind. Its warmth and high humidity give it a strong tendency to ascend and produce copious rainfall, which is a result of the condensation of water vapour in the rapidly rising air [19].

The tropical monsoon climate has a very small temperature range. The temperature ranges are almost constant throughout the year. The southern part of Nigeria experiences heavy and abundant rainfall with storm. These storms are usually convectional in nature due to the regions proximity, to the equatorial belt. The annual rainfall received in this region is very high, usually above the 2,000 mm (78.7 in) rainfall totals giving for tropical rainforest climates worldwide. The southern region of Nigeria experiences a double rainfall maximum characterised by two high rainfall peaks, with a short dry season and a longer dry season falling between and after each peaks. The first rainy season begins around March and last to the end of July with a peak in June, this rainy season is followed by a short dry break in August known as the August break which is a short dry season lasting for two to three weeks in August. This break is broken by the short rainy season starting around early September

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and lasting to Mid-October with a peak period at the end of September. The ending of the short rainy season in October is followed by long dry season. This period starts from late October and lasts till early March with peak dry conditions between early December and late February.

Processing of Soil Samples and Preparation for Geometry

The soil samples collected from the field were brought to the laboratory. The samples were processed following the standard procedure [20,21]. The soil samples were first sieved with 2 mm mesh screen to obtain a fine textured sample, which were then oven dried at about 110°C to a constant weight to remove all moisture content in it. The soil samples were weighed before and after the oven drying to obtain the fresh and dry weight of the samples. Each of the dried soil samples were then stored in a 250 ml plastic geometry bottle, weighed, labelled and kept for 30 days to attain secular equilibrium between parent and daughters for radon detection before radiation counting in the hyper pure Germanium detector.

Determination of Activity Concentration of Radionuclides

The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the samples were determined using the gamma spectrometry system employing a 38% relative efficiency p-type low background HPGe detector having an energy resolution of 2.1 keV at 1.33 MeV (CANBERRA, USA). The spectrum was acquired and analyzed using a 16 K multichannel analyzer (Multiport, CANBERRA) and GENIE-2000 software. The detector efficiency calibration was performed using the IAEA quality assurance reference materials: RG U-238, RG Th-232, RG K-40, and SOIL-6 procured from IAEA. The standard materials and samples were collected in containers of uniform size and type so that detection geometry remained the same. The samples were counted long enough to reduce the counting error. The ^{226}Ra activity was evaluated from the weighted mean of the activities of three photopeaks of ^{214}Bi (609.3, 1129.3, and 1764.5 keV) after applying the Compton corrections. In the case of ^{232}Th, one photopeak of ^{228}Ac (911.2 keV) and two photopeak's of ^{208}Tl (583.1 and 2614.5 keV) were used in the same way. The activity of ^{40}K was derived from the 1460.8 keV gamma line of this isotope [21]. The minimum detection levels (MDL) for the above detecting system were 0.62 Bq kg^{-1}, 2.46 Bq kg^{-1}, and 1.42 Bq kg^{-1}, respectively for ^{226}Ra, ^{232}Th, and ^{40}K for a counting time of 60,000 s and a sample weight of 300 g [22,23].

Radium Equivalent Concentration and Hazard Indices

Radium Equivalent Concentration (R_{aeq}) The radium equivalent is an index used to describe the gamma output from different mixtures of Uranium (i.e. ^{226}Ra), ^{232}Th and ^{40}K in a material. From the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, the radium equivalent was calculated using the equation [24].

$$Ra_{eq}=A_{Ra}+1.43A_{Th}+0.077A_{K} \quad 3$$

External and Internal Hazard Indices (H_{ex}) and (H_{in}) The concept of external hazard index (H_{ex}) was used to assess the potential health risk associated with human and gamma radiation emitted by the radionuclides while the internal hazard index (H_{in}) was used to determine the internal exposure of living cell to radon and its products (UNSCEAR, 2000). These indices were determined by the equations [25-27].

$$H_{ex}=A_{Ra}/370+A_{Th}/259+A_{K}/4810 \quad 4$$

$$H_{in}=A_{Ra}/185+A_{Th}/259+A_{K}/4810 \quad 5$$

Data Analysis and Dose Calculation

Absorbed Dose Rate in Air (ADRA or D) The total absorbed dose rate in air, D (nGyh^{-1}) due to a partial evaluation of the radiological hazard posed by the exposure to these estimated radioactivity concentrations at 1 m above the ground containing the naturally occurring radionuclide was calculated using [1].

$$D\ (nGyh^{-1})=0.042A_{K}+0.462A_{U}+0.604A_{Th} \quad 6$$

Where A_K,A_U, and A_{Th} are the specific activity concentration in Bq kg^{-1} of ^{40}K, ^{238}U and ^{232}Th respectively in the soil sample and 0.042, 0.462 and 0.604 (nGyh^{-1} per Bq kg^{-1}) are the concentration-to-dose conversion factors.

Annual Effective Dose Equivalent (AEDE) h^{-1} Using an outdoor occupancy factor (OF) of 0.20 and the Dose Conversion Factor (DCF) of 0.70 SvGy^{-1} [28]. the Annual Effective Dose Equivalent (AEDE) from the calculated outdoor terrestrial gamma radiation at 1 m above the ground were calculated using the relation:

$$AEDE\ (\mu Svy^{-1})=ADRA\times DCF\times OF\times T \quad 7$$

where T is 8760 h. The excess lifetime cancer risks which deals with the probability of developing cancer over a lifetime at a given exposure level was also calculated. It was presented as a value representing the number of cancers expected in a given number of people on exposure to a carcinogen at a given dose. It is worth noting that an increase in the ELCR causes a proportionate increase in the rate at which an individual can get cancer of the breast, prostate or even blood. Excess lifetime cancer risk (ELCR) was estimated using the equation [29].

$$ELCR = AEDE \times DL \times RF\times 10^{-3} \quad 8$$

where AEDE is the annual effective dose equivalent, DL is the average duration of life (estimated to 70 years), and RF is the Risk Factor (Sv^{-1}), i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for public [29].

Results and Discussion

The activity concentrations of natural and artificial radionuclides has been measured in soils collected from different locations in the South-Western Nigeria. The evaluation of radioactivity was performed in order to estimate the absorbed dose and cancer risk probability due to continuous exposure to ionising radiation as a result of ingestion and inhalation of radionuclides from environmental samples collected from the

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study area. The tables and graphical representations of the data were provided in the respective sections. The result obtained in this study were compared across location of different activities and geology. The result were also analysed and compared with result from different literatures available, maximum permissible standards and the world average as appropriate. A summary of the activity concentration of primordial radionuclides and artificial cesium in the soil samples were presented in the (Tables 1). The results of various measurements are presented and discussed in the following sections.

Table 1: Activity Concentration of Natural Radionuclides in Soil.

State	Location	Soil type	Activity concentration (bq kg^{-1})			
			K-40	RA-226	TH-232	CS-137
LA	Badagry	Sandy Loamy (S/L)	95.77	10.58	13.54	BDL
	Iyana ipaja	S/L	200.38	36.75	56.80	BDL
	Ojota	Loamy (L)	235.49	22.67	40.09	BDL
	V. Island	Sandy (S)	165.07	20.27	24.35	BDL
	Epe	Loamy Clay (L/C)	76.87	31.18	46.33	1.27
	Festac	S	BDL	8.53	13.95	BDL
	Ikeja	L/C	142.70	27.34	61.31	BDL
OG	Abeokuta	L/C	533.28	58.05	194.23	1.37
	Ayetoro	S/C	50.05	26.61	53.49	BDL
	Ijebu-ode	S/C	43.27	64.95	47.31	0.89
	Ilaro	L	23.96	29.01	28.72	BDL
	Shagamu	S/C	175.44	40.87	80.69	BDL
OY	Ibadan	L	330.11	61.13	101.37	BDL
	Igboho	L	1545.07	160.37	295.24	BDL
	Iseyin	L	177.85	46.77	60.06	1.57
	Ogbomoso	Clay (C)	641.20	95.29	71.66	2.15
	Eruwa	S/L	1210.15	52.34	262.55	BDL
	Igbeti	L	1020.68	39.06	54.69	1.06
	Oyo	S	305.05	26.79	23.98	BDL
	Shaki	L/C	2723.22	59.62	52.95	BDL
OS	Ikire	S/L	462.44	59.34	99.78	BDL
	Ila	L/C	162.18	78.49	158.79	1.87
	Osogbo	S	374.33	65.07	48.88	BDL
	Owu	C	29.52	24.35	19.41	3.53
	Ife	S	249.44	57.33	59.31	BDL
	Ilesa	L/C	401.12	65.46	69.87	0.90
	Iwo	S/L	388.60	47.02	48.56	BDL
OD	Akungba	C	258.42	89.07	165.14	BDL
	Akure	L	638.08	49.20	114.68	1.23
	Ondo	C	392.92	63.56	59.13	BDL
	Idanre	S/C	935.84	71.68	116.14	BDL
	Okitipupa	L	15.97	24.71	42.94	1.75
EK	Ado	L	886.86	46.58	67.68	BDL
	Ido	L/C	1004.27	73.40	239.65	1.66
	Ikere	C	587.41	58.85	124.73	BDL
	Ikole	L/C	236.28	81.62	72.50	BDL
	Mean		477.69	52.05	85.84	1.60
	Range		15.97-2723.22	8.33-160.37	13.54-295.24	0.89-3.53

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Activity Concentration of Natural Radionuclides and Artificial Caesium in Soil

The activity concentration of ^{40}K, ^{226}Ra, ^{232}Th and ^{137}Cs in the soil ranges from 15.97 - 2723.22 Bq kg^{-1}, 8.33 - 160.37 Bq kg^{-1}, 13.54 - 295.24 Bq kg^{-1} and 0.89 - 3.53 Bq kg^{-1} with the corresponding mean values of 477.69 Bq kg^{-1}, 52.05 Bq kg^{-1}, 85.84 Bq kg^{-1} and 1.60 Bq kg^{-1} respectively as shown in (Figure 2). The distribution of ^{40}K activity concentration in the soil has a wide range across the study area. The highest activity concentration of natural radionuclides in soil was obtained in the result from Igboho in Oyo State, this area is characterised by a rocky geology. The study revealed a highly non-uniform distribution of this radionuclides in the region with activity concentration in the soil varying significantly within a small area, which is due to the geological variability of the area. The activity concentration of natural radionuclides in the study area was comparable with the world average value of 440 Bq kg^{-1} for ^{40}K as reported by McAulay and Moran (1988) and 412, 32 and 45 Bq kg^{-1} for ^{40}K, ^{226}Ra, ^{232}Th respectively as reported by [51]. The activity concentration of ^{137}Cs was low and varied within a narrow range. This radionuclide is of the fallout origin, and its concentration in a region depends largely on the local meteorological conditions, amount of rainfall, and the soil properties [30]. Large variations in the activity of ^{137}Cs in a small region is not expected since its original fallout (due to weapon testing in the 1950s-60s and the Chernobyl accident) was influenced by the meteorological conditions, which does not vary within a small region. It is also known that there is no fresh input of ^{137}Cs to the environment.

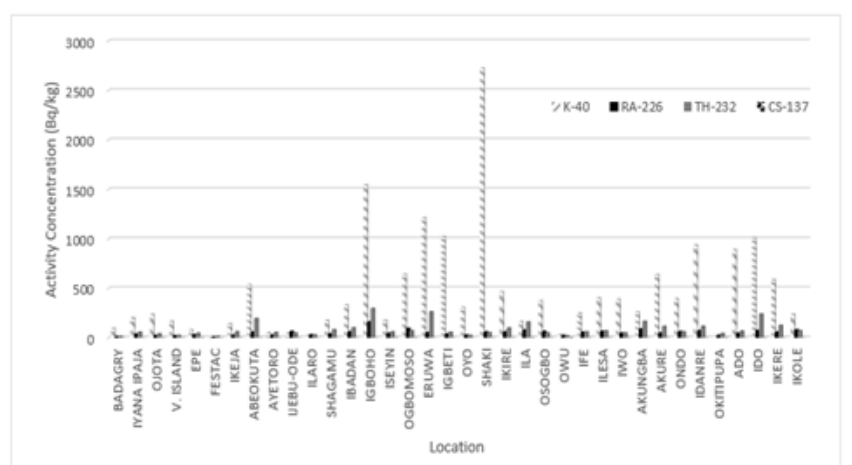

Figure 2: Activity Concentration of Natural Radionuclides in Soil from Different Locations.

Radium Equivalent Activity (Ra_{eq})

Table 2: Comparison of Activity Concentration of Radionuclides in the Soil with Literature Values.

Activity (Bq kg^{-1})		Region	Reference
Present study	Literature values		
^{40}K			
15.97-2723.22 (477.69*)	400	All India Average	UNSCEAR [1].
	33.5-1085.7	Botswana	Murthy and Karunakara [22].
	64-3017 (915)	Kenya	Otwoma et al. [24].
	751.2	China	Lu et al. [32].
	4-3200 (412)	World Average	UNSCEAR [1].
^{226}Ra			
8.33- 160.37 (52.05*)	32	All India Average	UNSCEAR [1].
	17-1447 (195)	Kenya	Otwoma et al. [24].
	22-104	Jordan	Al-Jundi et al. [52].
	6.1–97.4 (41.8)	Botswana	Murthy and Karunakara [22].
	40	China	Lu et al. [32].
	0.5-1000 (32)	Worldwide	UNSCEAR [1].
^{232}Th			
13.54–295.24 (85.84*)	64	All India Average	UNSCEAR [1].
	23-1369 (409)	Kenya	Otwoma et al. [24].

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	21-103	Jordan	Al-Jundi et al. [52].
	59.6	China	Lu et al. [32]
	7.4–110.0 (41.8)	Botswana	Murthy and Karunakara [22].
	0.05-360 (45)	Worldwide	UNSCEAR [1].
^{137}Cs			
0.89-3.53 (1.60*)	7.2-314	Greece	Papaefthymiou et al. [36].
	0.74	Baltic coast	Luksiene et al. [56].
	7.5-576.0	Jordan	Al-Hamarneh et al. [52].
	2.5-21.0 (12.0)	Aomori, Japan	Tsukada et al. [28].
	40.2-293.0	Bohemia	Holgye and Maly [55].
	16.46	Turkey	Belivermis [54].
	1.82-413.25	Montenegro	Nevenka et al.
	1.02-39.6 (5.9)	Taiwan	Wang et al. [14].

Radium equivalent (Ra_{eq}) activity is a common index used to compare the specific activities of materials containing ^{226}Ra, ^{232}Th, and ^{40}K by a single quantity, which takes into account the radiation hazards associated with these primordial radionuclides [31]. The activity index provides a useful guideline in regulating the safety standard for dwellings (Table 2). The radium equivalent activity represents a weighted sum of activities of the above-mentioned natural radionuclides and is based on the estimation that 1 Bq kg^{-1} of ^{226}Ra, 0.7 Bq kg^{-1} of ^{232}Th, and 13 Bq kg^{-1} of ^{40}K produce the same radiation dose rates. The details for the calculation of radium equivalent activity were presented in equation. 3 and the summary of the results of these calculations were presented in (Table 3). The radium equivalent activity for the study area ranged from 28.47 to 701.53 Bq kg^{-1}, with the corresponding mean values of 210.57 Bq kg^{-1}. The soil samples from some of the locations, specifically Igboho and Abeokuta, showed radium equivalent activity above the recommended limit of 370 Bq kg^{-1} [2]. However, the overall mean values were below this recommended limit. The values of radium equivalent activity obtained in the present study were higher when compared to the values reported for some other countries, which were in the range of 164.7 to 199.1 Bq kg^{-1} for China [32]. 19.3 to 413.3 Bq kg^{-1} for Yemen [33] and 29.57 to 71.85 Bq kg^{-1} for Egypt [34].

External and Internal Hazard Indices (H_{ex} and H_{in})

Many radionuclides occur naturally in terrestrial soils and rocks and upon decay. These radionuclides produce an external radiation field to which all human beings are exposed. The external hazard index (H_{ex}) is defined in equation 4. The value of this index must be less than unity for the radiation hazard to be negligible [27]. Hex equal to unity corresponds to the upper limit of Raeq (370 Bq kg^{-1} [27]. The internal hazard index is the internal exposure due to 222Rn and its short lived decay products. The internal hazard index (H_{in}) is defined in equation 5. The summary of the estimation of external hazard index (H_{ex}) and internal hazard index (H_{in}) are presented in (Table 3). The external hazard index ranged from 0.08 to 1.89, with the mean value of 0.57. The internal hazard index ranged from 0.10 to 2.33, with the mean value of 0.71. The general value of H_{ex} and H_{in} must be less than 1 [24]. However, for the soil samples collected from some cities (Igboho and Abeokuta), this indices were greater than 1 which is an indication that in these locations, the activity concentrations of ^{40}K, ^{232}Th, and ^{226}Ra were higher than recommended value for environmental safety. The highest values of H_{ex} (1.89) and H_{in} (2.33) were recorded at Igboho in Oyo State and the activity concentrations of ^{232}Th, ^{226}Ra, and ^{40}K were also high at this location. The high values of the external and internal hazard indices observed is attributable to the higher concentrations of ^{232}Th, ^{226}Ra, and ^{40}K in the study area due to the rocky nature of its local geology and soil constituents [35].

Gamma Absorbed Dose Rates Due to Primordial Radionuclides

From the results of the activity concentrations of ^{40}K, ^{232}Th, and ^{226}Ra in the soils, the gamma absorbed dose rates in the air was computed by using the dose conversion coefficients ; 0.0417 nGy h^{-1}, 0.604 nGy h^{-1}, and 0.462 nGy h^{-1} per Bq kg^{-1}, respectively for ^{40}K, ^{232}Th, and ^{226}Ra [36]. The summary of these dose estimations are presented in (Table 3). It presents the total absorbed dose due to the primordial radionuclides, and this ranged from 12.36 to 317.31 nGy h^{-1} with a mean value of 95.40 nGy h^{-1}. This value is higher than the worldwide average value of 54 nGy h^{-1} [19].

The Annual Outdoor Effective Dose Equivalent

The mean annual outdoor effective dose equivalent given in [1,2]. due to terrestrial sources (^{40}K, ^{226}Ra, and ^{232}Th) were found to be 0.1170 mSv y^{-1}. The result of outdoor annual effective dose equivalent is also presented in the With the corresponding worldwide average value of 0.0725 mSv y^{-1} [1]. It can be observed that the mean annual outdoor effective dose equivalent for the study area is higher than world average and higher than 0.1 mSv y^{-1} maximum permissible limit recommended by WHO [36]. but lower than 1 mSv y^{-1} maximum permissible limit recommended by NCRP [37-39]. This indicates that there are higher risks of radiation cancer in some locations in the study area where there are higher effective dose than what was recommended for human

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safety. This could be because of the prevalence of rocks and their associated constituents of quartz and feldspar in the formation of these locations coupled with high agricultural activity and the use of soils enhancement fertilizers.

Table 3: Radium Equivalent (Ra_{eq}), External (H_{ex}), Internal (H_{in}) Hazard Index, Absorbed Dose Rate in Air, Annual Effective Dose Equivalent and Excess Lifetime Cancer Risk.

State	Location	H_{ex}	H_{in}	Ra_{eq} (bq kg^{-1})	Absorbed dose rate ($ngyh^{-1}$)	Annual effective dose equivalent ($msvy^{-1}$)	Excess lifetime cancer risk
LA	Badagry	0.10	0.13	37.30	17.08	0.0210	0.0000735
	Iyana ipaja	0.36	0.46	133.40	59.70	0.0732	0.0002562
	Ojota	0.27	0.33	98.13	44.58	0.0547	0.0001915
	V. Island	0.18	0.24	67.79	31.00	0.0380	0.0001330
	Epe	0.28	0.36	103.34	45.61	0.0559	0.0001957
	Festac	0.08	0.10	28.47	12.36	0.0152	0.0000532
	Ikeja	0.34	0.41	125.99	55.65	0.0683	0.0002391
OG	Abeokuta	1.02	1.17	376.86	166.53	0.2042	0.0007147
	Ayetoro	0.29	0.36	106.95	46.70	0.0573	0.0002006
	Ijebu-ode	0.37	0.54	135.92	60.39	0.0741	0.0002594
	Ilaro	0.19	0.27	71.92	31.75	0.0389	0.0001362
	Shagamu	0.46	0.57	169.77	74.99	0.0920	0.0003220
OY	Ibadan	0.63	0.79	231.51	103.33	0.1267	0.0004435
	Igboho	1.89	2.33	701.53	317.31	0.3891	0.0013619
	Iseyin	0.40	0.52	146.34	65.35	0.0801	0.0002804
	Ogbomoso	0.67	0.93	247.13	114.23	0.1401	0.0004904
	Eruwa	1.41	1.55	520.96	233.59	0.2865	0.0010028
	Igbeti	0.53	0.63	195.85	93.94	0.1152	0.0004032
	Oyo	0.23	0.30	84.56	39.67	0.0487	0.0001705
	Shaki	0.93	1.09	345.02	173.90	0.2133	0.0007466
OS	Ikire	0.64	0.80	237.62	107.10	0.1313	0.0004596
	Ila	0.86	1.07	318.05	138.98	0.1704	0.0005964
	Osogbo	0.44	0.62	163.78	75.30	0.0924	0.0003234
	Owu	0.15	0.21	54.38	24.21	0.0297	0.0001040
	Ife	0.44	0.59	161.34	72.78	0.0893	0.0003126
	Ilesa	0.53	0.71	196.25	89.29	0.1095	0.0003833
	Iwo	0.40	0.52	146.38	67.37	0.0826	0.0002891
OD	Akungba	0.93	1.17	345.11	151.75	0.1861	0.0006514
	Akure	0.71	0.84	262.31	118.79	0.1457	0.0005100
	Ondo	0.48	0.65	178.37	81.58	0.1000	0.0003500
	Idanre	0.84	1.03	309.81	142.57	0.1748	0.0006118
	Okitipupa	0.24	0.30	87.33	38.02	0.0466	0.0001631
EK	Ado	0.57	0.70	211.65	99.65	0.1222	0.0004277
	Ido	1.33	1.53	493.43	220.84	0.2708	0.0009478
	Ikere	0.76	0.92	282.44	127.19	0.1560	0.0005460
	Ikole	0.55	0.77	203.48	91.42	0.1121	0.0003924
	Mean	0.57	0.71	210.57	95.40	0.1170	0.0004095
	Range	0.08-1.89	0.10-2.33	28.47-701.53	12.36-317.31	0.0152-0.3891	0.0000532-0.0013619

The Excess Lifetime Cancer Risk

The excess lifetime cancer risk (ELCR) for outdoor exposure, which deals with the risk of developing cancer over a period of time due to the ionizing radiation emitted by the radionuclides in the study area was calculated using equation 8. The excess lifetime cancer risk (ECLR) ranged from 7.35×10^{-5} to 1.36×10^{-3}, with a mean of 4.10×10^{-4}. This value is higher than the world average of 2.9×10^{-4} [40]. The samples having higher (ELCR) were collected from parts of the study area with high rocky geology.

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WHO reports that cancer is the second commonest cause of mortality after cardiovascular diseases and that the burden of cancer in Nigeria is appreciable with about 100,000 new cancer cases being reported in the country each year [41,42]. Awodele [43] conducted a desk review of the level of occurrence and pattern of distribution of different cancer types in over a 5 year period (2005-2009) and reported that the level of occurrence and pattern of distribution of different cancer types in the two major functional cancer registries in south-western Nigeria (Lagos and Ibadan cancer registries) was significant. Out of 5094 cancer patients registered between 2005 and 2009 in both Lagos (60%) and Ibadan (40%) cancer registries. Breast cancer accounted for the majority of cases (20.2%), followed by cervical cancer (7.9 %), fibroid (4.4%), liver (4.4%), stomach (4.3%), brain (3.9%), pancreas (3.8%), prostate (3.3%), lung (3.0%) and cancer of the kidney (0.7%) [42]. linked the high proportion of cancers found in Lagos cancer registries than Ibadan cancer registries to the high population density in Lagos and some other environmental factors. The cancer epidemiological report in Africa related the 667,000 incident cases and 518,000 deaths in 2008 to the higher radioactivity in the area.

The areas which are more prone to the excessive lifetime cancer risk were observed in the study area. This is the South Western part and the most densely populated area of Nigeria which is the most populated African country. The result of ECLR obtained from the study area (0.41×10^{-3}), compared favourably with the result of ELCR obtained from different parts of the world: These results ELCR as a result of radioactivity in soils from Kerala, Indian, Kirklareli, Turkey, Tulkarem Province-Palestine, Azad Kashmir, Pakistan 1.7×10^{-3}, 0.50×10^{3}, 0.17×10^{-3} and 0.54×10^{-3} respectively, the results of ELCR as a results of radioactivity in sediments from Karnataka & Tamilnadu, India and Northern Pakistan were 0.20×10^{-3} and 0.37×10^{-3} [44-48]. all these results rom other parts of the world [45]. has linked numerous cancer deaths annually reported from the Northern Pakistan to the high excess lifetime cancer risk factor in the area. WHO has reported that Nigeria has the highest cancer death in Africa and the South Western Nigeria is the most susceptible area because of the dense population and the rocky geology which has enhanced the activity concentration level in the area [49].

Conclusion

Radiation dose and excess lifetime cancer risk assessment has been carried out for soil from some location in the South-Western Nigeria to evaluate the impact level across the area. The results has been successfully presented to reflect the environmental condition and the vulnerability of the study area. From the results of analysis, it was obtained that the highest radioactivity level in soils for all the natural radionuclides were in area with rocky geology, and the rocks of the area are mainly of sedimentary origin [50]. The mean value for ^{40}K in the study area compared favourably with the earth's crustal mean of 400 Bq kg^{-1} [2]. and it is higher than the world average of 412 Bq kg^{-1} [1]. This can be attributed to the fact that some locations in the study area are highly rocky in nature, The values of radium equivalent activity obtained in the present study were higher when compared to the values reported for some other countries, The high values of the external and internal hazard indices observed is attributable to the higher concentrations of ^{232}Th, ^{226}Ra, and ^{40}K in the study area due to its environmental geology.

The summary of the absorbed dose estimations showed that the value is higher than the worldwide average value of 54 nGy h^{-1} [51]. The mean annual outdoor effective dose equivalent for the study area is higher than world average and higher than 0.1 mSv y^{-1} maximum permissible limit recommended by WHO [51] but lower than 1 mSv y^{-1} maximum permissible limit recommended by NCRP [39]. The excess lifetime cancer risk is higher than the world average of 2.9×10^{-4} [52-56]. The samples having higher (ELCR) were collected from parts of the study area with high rocky geology [57,58]. Numerous cancer deaths annually reported in Nigeria, most especially in the South West has been linked to the high excess lifetime cancer risk factor which is the product of the environmental radioactivity in the study area.

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