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ARTICLE

Fertility Cancer and Hereditary Risks in Soil Sample of Nasarawa, Nasarawa State, Nigeria

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ABSTRACT

A survey of Fertility Cancer and Hereditary Risks in Soil Sample of Nasarawa was carried out. This study assessed the level of Fertility Cancer and Hereditary Risks from the naturally occurring radionuclides; ^{232}Th, ^{226}Ra and ^{40}K. 12 soil samples collected from the respective part of the Nasarawa were analyzed using the gamma-ray spectrometry NaI (Tl) detector system. The mean concentration for ^{40}K was 645.29 ± 07.32 Bq/kg, for ^{226}Ra was 28.43 ± 4.8422 Bq/Kg and for ^{232}Th was 66.84 ± 2.0201 Bq/Kg. The average effective dose due to the ingestion was 0.36±0.1 μSv/y which was approximately 1000 times lower than the world average effective dose. Radium equivalent activity Ra_{eq} (Bq/kg), alpha index and total cancer risk were found to be 161.44±8.08 Bq/kg, 0.142±0.02 and (0.21±0.05) $\times 10^{-5}$ respectively. UNSCEAR/ USEPA stipulated that; radium equivalent activity, alpha index, effective dose and total cancer risk should not exceed the limit of 370 Bq/kg, unity, 300 μSv/y and 1 $\times 10^{-4}$ respectively. Hence the values obtained in this work were within the acceptable limits. This implies that the ingestion or inhalation of soil is not associated with any radiological risk of concern.

1. Introduction

The natural terrestrial γ-radiation dose rate is important to the average dose rate received by the world's population [1,2].

Estimation of radiation dose distribution is important in assessing the health risk to a population and serve as the reference in documenting changes to environmental radioactivity in soil due to anthropogenic activities [2].

Human beings are exposed outdoors to the natural terrestrial radiation that originates predominantly from the upper 50cm of the soil [3].

Only radioactivity with half-lives comparable with the age of the earth or their corresponding decay products

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existing in terrestrial material such as ^{232}Th, ^{226}Ra and ^{40}K are of great interest. Since these radionuclides are not uniformly distributed, the knowledge of their distribution in soil and sediments plays an important role in radiation protection and measurement [4].

Gamma radiation from these represents the main external source of irradiation to the human body and the concentrations of these radionuclides in soil are determined by the radioactivity of the rock and nature of the process of the formation of the soils [5,6].

Therefore, radionuclides in soil generate a significant component of the background radiation exposure to the population [7].

The aim of this work is to measure the specific activity of the naturally occurring radionuclides (^{40}K, ^{226}Ra and ^{232}Th) in different types of soils from Nasarawa in Nasarawa State using Sodium Iodide-Thalium Gamma Spectroscopy System.

The objective of this work will be accomplished through the following types of measurement: Radionuclide Activity Concentrations in surface soil, Radium Equivalent Activity, Annual Effective Doses, Alpha Index (I_α) and Cancer and hereditary risks of the studied area.

The area of toxic and water pollutants has been the subject of interest and concern for many years. The assessment of impact on human health aids major decisions on control of population by Federal, State and Local Governments. This will be an outcome of this study. This study shall identify the areas, and the level of radiation present in the areas, which is Nasarawa, Nasarawa State, Nigeria. Radioactive material can remain dangerous for long periods, which requires radioprotection measures in order to protect the health of the workers and the public in general.

The primary parameter that determines the environmental health effects of radioactive particles and their concentration, decay rate and chemical composition. These parameters, however, are spatially and temporally variable. The identification and quantification of natural radioactivity represent demanding analytical challenges. This study shall outline the study perspectives on the properties and interactions of natural radioactivity and their effects on environmental and human health. At the end of the study, there would be a multi – disciplinary benefits and applications. The study shall serve as an academic reference material and can contribute significantly to knowledge especially as regard to health and environment.

This work focused only on some selected mining areas of Nasarawa in Nasarawa State, Nigeria. The work will give detailed information on natural radioactivity concentration in the study area, as well as discussing the protective measures that must be taken to regulate or prevent people from high dose of radiation.

2. Methodology

2.1 Soil Samples Collection

Four sample locations were chosen from all over Nasarawa in Nasarawa State, Nigeria, to conduct the radiometry study. Three samples were collected from each sample area to make twelve samples of soil. The samples were collected at 0.5 m depth level from the surface of the soil. From each area, as stated earlier, three samples were collected. Firstly, from the mining spot, secondly from a distance of 100 m away from the mining spot, and thirdly, from the river area within the mining spot. The collected samples were then sealed in a labeled polythene bags and enclose into one sack for easiest transportation from the mining or sample point to the house.

2.2 Soil Sample Preparation

The collected samples (soil) brought into the laboratory are left open (since it is wet) for a minimum of 24 hours to dry under ambient temperature. They were grounded using mortar and pestle and allowed to pass through 5 mm-mesh sieve to remove larger object and make it fine powder. The samples were packed to fill a cylindrical plastic container of height 7 cm by 6 cm diameter. This satisfied the selected optimal sample container height. Each container accommodated approximately 300 g of sample. They were carefully sealed (using Vaseline, candle wax and masking tape) to prevent radon escape and then stored for a minimum of 24 days. This is to allow radium attain equilibrium with the daughters.

2.3 Soil Sample Analysis

Gamma-ray spectrometry technique was employed in the spectral collection of the prepared sample using the higher energy region of the gamma-lines. This consists of a 7.62 cm by 7.62 cm NaI (Tl) detector housed in a 6 cm thick lead shield and lined with cadmium and copper sheets. The shield assisted in reduction of the background radiation. The samples were mounted on the detector surface and each counted for 29,000 seconds in producible sample-detector geometry. The configuration and geometry was maintained through the analog. A computer based Multichannel Analyzer (MCA) Maestro programme from ortec was used for data acquisition and analysis of gamma spectra. The 1764 KeV gamma-line of ^{214}Bi was used for ^{238}U in the assessment of the activity concentration of

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^{226}Ra while 2614.5 KeV gamma-line of ^{208}Tl was used for ^{232}Th. The single 1460 KeV gamma-line of ^{40}K was used in its content evaluation. All the obtained raw data were converted to conventional units using calibration factors to determine the activity concentration of ^{40}K, ^{226}Ra and ^{232}Th as presented in Table 1:

Table 1. Energy Calibration for Quantitative Spectra Analysis

Isotopes	$\times 10^{-3}$ (cps/ppm)	$\times 10^{-4}$ (cps/Bq/kg)	Conversion factors (Bq/kg (ppm))	Ppm	Bq/kg
^{40}K	0.026	6.431	0.032	454.54	14.54
^{226}Ra	10.500	8.632	12.200	0.320	3.84
^{232}Th	3.612	8.768	4.120	2.27	9.08

The net number of counts under each photo peak of interest was then background subtracted using the time correct spectrum taken using the blank container. The activity concentration was calculated using Equation 1 [8,9].

$$\text{Activity (Ra, Th and K)} = \frac{count\ rate\ (cpm) for\ Ra,\ Th,\ K}{count\ rate\ (cpm) for\ Ra,\ Th,\ K} \quad (1)$$

2.4 Assessment of Radiation Hazards Associated with the Ingestion of Soil

2.4.1 Radium Equivalent Activity (Ra_{eq})

To represent the activity levels of Ra-226, Th-232 and K-40 by a single quantity, which takes into account the radiation hazards associated with them, a common radiological index called Radium equivalent activity was used. This parameter was calculated using Equation 2 [10,11] based on the assumption that 10 Bq/kg of Ra-226, 7 Bq/kg of Th-232 and 130 Bq/kg of K-40 produce equal gamma dose.

$$R_{eq}\ (Bq/Kg) = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (2)$$

Where C_{Ra}, C_{Th} and C_K are the activity concentrations of Ra-226, Th-232 and K-40 respectively.

2.4.2 Annual Effective Dose from Ingestion

From the activity concentration of Ra-226, Th-232 and K-40 in the soil samples, the annual effective dose due to the ingestion of soil in humans was estimated using Equation 3 [12,13]

$$E = (U_{Ra}C_{Ra} + U_{Th}C_{Th} + U_kC_k)\ M \quad (3)$$

Where, M is the annual average quantity of soil ingested per person in Nigeria which was adopted as 9.13 kg/capital/year [14]. C is the specific activity concentration of radionuclides in soil determined in this work, and U refers to the effective dose coefficients measured for the radionuclides (Sv/Bq) for different age groups for the ingestion of natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K with values of 4.50×10^{-8}, 2.30×10^{-7} and 6.20×10^{-9} respectively [12-15].

2.4.3 Alpha Index

Alpha Index (I_α) is used to estimate the hazards that could arise from the ingestion of soil. this index is computed using Equation 4 [16-18]. For radiation protection purposes, the value of alpha index must not exceed the limit of unity. The maximum value of I_α equal to unity corresponds to the upper limit of radium equivalent activity 370 Bq.kg^{-1}.

$$I_\alpha = \frac{Cra}{200\left(\frac{Bq}{kg}\right)} \quad (4)$$

2.4.4 Fertility Cancer and Hereditary Risks

The cancer and hereditary risks due to low doses without threshold dose known as stochastic effects were estimated using Equation 5 and 6 respectively based on ICRP, 2007 cancer risk assessment methodology. The lifetime risks (70 years) of fatal cancer were based on the hypothesis of linearity of dose and effect without any threshold. The nominal risk coefficients for low doses as adopted from ICRP based on data for cancer incidence weighted for lethality and life impairment were 5.5×10^{-2} and 0.2×10^{-2} for cancer and hereditary risks, respectively, these values were derived by [19].

Fatality cancer risk = Total AED (Sv) × Cancer Nominal Risk Factor (5)

Hereditary risk = total AED Sv × hereditary nominal risk factor (6)

3. Results and Discussion

The spectra of twelve surface soil samples surrounding the Culombite mine have been analyzed. The specific activity of ^{40}K, ^{226}Ra, ^{232}Th.

Table 2 presents the activity concentration of the naturally occurring radioactive materials in twelve (12) different soil samples. ^{226}Ra had the lowest activity concentration in each sample compared to ^{232}Th and ^{40}K, while ^{40}K had the highest activity concentration in all the samples except "NW3 A" which has lower concentration analyzed as expected since Potassium is an important nutrient for man and is naturally available in abundance. The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in the twelve (12) different soil samples, varied widely and had an average ± error values of 28.43 ± 5.28 Bq/kg, 66.84 ± 2.02 Bq/kg and 645.29 ± 7.32 Bq/kg respectively. NW3 C was found to have the highest activity concentration of 1026.13 ± 7.62 Bq/kg for ^{40}K while NW2 B was found to have the lowest activity concentration of 268.27 ± 4.51 Bq/kg for ^{40}K. Activity concentration of ^{226}Ra was found to be high-

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est (54.58 ± 8.23 Bq/kg) in NW4 B and lowest (6.49 ± 1.27 Bq/kg) in NW2 A. It was observed that NW4 B had the highest activity concentration values of 83.12±0.46 Bq/kg and the lowest of 42.65±5.25 Bq/kg for ^{232}Th.

Table 2. Specific Activity of the NORMs in the Analyzed Samples

Sample codes	k-40 (Bq/kg)	Ra-226 (Bq/kg)	Th-232 (Bq/kg)
NW1 A	0569.98±09.95	19.35±02.32	79.93±1.03
NW1 B	0536.39±08.55	24.91±00.12	67.50±0.11
NW1 C	0530.48±09.49	33.60±07.02	63.06±1.37
NW2 A	0239.04±05.60	06.49±01.27	52.79±1.77
NW2 B	0268.27±04.51	20.63±05.33	42.65±5.25
NW2 C	0646.19±05.91	35.46±10.78	78.45±4.10
NW3 A	048.52±03.58	44.96±03.71	73.32±0.46
NW3 B	0570.30±06.53	33.60±06.61	65.34±4.79
NW3 C	1026.13±07.62	18.31±00.48	62.71±1.61
NW4 A	0537.48±11.20	37.89±07.88	71.38±2.28
NW4 B	0283.83±08.40	54.58±08.23	83.12±0.46
NW4 C	0551.01±06.53	11.36±09.62	61.80±1.03
Range	268.27-1026.13	6.49-54.58	42.65-83.12
Average	0645.29±07.32	28.43±05.28	66.84±2.02

The radiological parameters associated with the ingestion and inhalation of naturally occurring radioactive materials in soil samples are presented in Table 3. Considering the annual average quantity of soil ingested or inhaled per person in Nigeria as 14 kg/year [20], the average annual effective dose due to the ingestion of soil in humans was estimated at 0.36±0.1μSv/y which was far (approximately 1000 times) lower than the world average annual committed effective dose of 300 μSv/y for ingestion of natural radionuclides provided in [20]. At the present average soil ingestion or inhalation rate of 9.13 kg/year in Nigeria [20], the annual effective dose is far below the acceptable limit, however, people mining in the sample area may have higher ingestion or inhalation rates than that reported by [20]. Consequently, it is important to predict the threshold ingestion or inhalation rate above which the average annual effective dose will exceed the acceptable threshold of 300 μSv/y. Figure 1 presents the average annual effective dose as a function of ingestion or inhalation rates. From the figure it could be observed that for ingestion or inhalation rates between 0 and 40 kg/yr, the AED is within the acceptable limit, therefore the threshold ingestion or inhalation rate is 40 kg/yr and any value slightly higher than the threshold values is prone to significant radiological health risk. In order to safeguard the members of pubic from the radiological hazards associated with the soil ingestion or inhalation, radium equivalent activity Ra_{eq} (Bq/kg), alpha index and total cancer risk were estimated and found to be 161.44±8.08 Bq/kg, 0.142±0.02 and (0.21±0.05) $\times 10^{-5}$ respectively. UNSCEAR stipulated that; radium equivalent activity should not exceed 370 Bq/kg and alpha index should not exceed the limit of unity, annual effective dose due to ingestion or inhalation of naturally occurring radioactive materials in soil, medicinal plants and food should not exceed 300 μSv/y [20], hence the values obtained in this work were within the acceptable limits. Similarly, USEPA stated that the maximum acceptable total cancer risk should not exceed 1 $\times 10^{-4}$, since all the cancer risks obtained in this work were by far (approximately 100 times) less than the acceptable threshold, it implies that the ingestion or inhalation of soil is not associated with any radiological risk of concern. The fatality cancer risk for almost all the samples were found to be approximately 30 to 40 times the hereditary cancer risks. Of all the samples analyzed, NW2 C had the highest radium equivalent activity, annual effective dose due to ingestion and total cancer risk values of 197.40 Bq/kg, 2.20×10^{-4} μSv/y and 1.20×10^{-5} respectively while NW2 A had the lowest values of 100.39 Bq/kg for radium equivalent activity, NW2 B had the lowest values of 1.1×10^{-4} μSv/y and 0.63×10^{-5} for annual effective dose due to ingestion or inhalation and total cancer risk respectively. Ingestion or inhalation of NW4 B was found to be associated with the highest alpha index of 0.273, while ingestion or inhalation of NW2 A was found to have the least values of 0.032 for alpha index. Due to the lack of published literature on the radiological levels of soil samples, the activity concentration of natural radionuclides obtained in this work were compared with that obtained for soil and medicinal plants in and outside Nigeria in Figure 2. It is pertinent to note that; the activity concentration of ^{226}Ra reported in this work was greater than that which was reported in soil [18-20], while that of ^{232}Th and ^{40}K were lower than that reported by [16-19] respectively.

Table 3. Radiological Implications of the Ingestion or Inhalation Soil Samples.

Sample Code	Ra_{eq} (Bq/kg)	I_α	$E \times 10^{-4}$ (μSv/yr)	Cancer Risk		
				Fatality $\times 10^{-5}$	Hereditary $\times 10^{-7}$	Total $\times 10^{-5}$
NW1A	177.54	0.097	2.00	1.10	4.00	1.10
NW1B	162.74	0.125	1.90	1.00	3.80	1.00
NW1C	164.62	0.168	1.80	0.99	3.60	1.00
NW2A	100.39	0.032	1.30	0.72	2.60	0.75
NW2B	102.27	0.103	1.10	0.61	2.20	0.63
NW2C	197.40	0.177	2.20	1.20	4.40	1.20
NW3A	153.54	0.225	1.80	0.99	3.60	1.00
NW3B	170.95	0.168	1.80	0.99	3.60	1.00
NW3C	189.00	0.092	1.90	1.00	3.80	1.00
NW4A	181.35	0.189	1.90	1.00	3.80	1.00
NW4B	195.30	0.273	2.10	1.20	4.20	1.20
NW4C	142.16	0.057	1.60	0.88	3.20	0.91
Range	100.39-197.4	0.032-0.273	1.1-2.2	0.61-1.20	2.2-4.4	0.63-1.20
Mean	161.44±8.08	0.142±0.02	0.36±0.1	0.20±0.05	0.72±0.2	0.21±0.05

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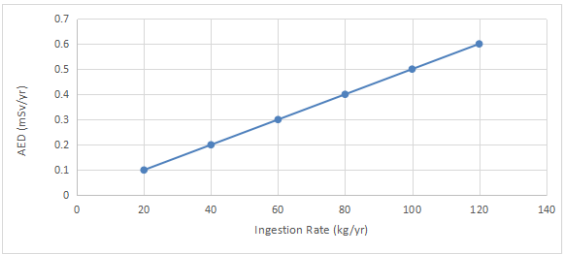

Figure 1. Annual effective dose (AED) due to Soil Ingestion or Inhalation.

It is important to predict the threshold ingestion or inhalation rate above which the average annual effective dose will exceed the acceptable threshold of 300 µSv/yr. Figure 1 presents the average annual effective dose as a function of ingestion or inhalation rates. From the figure it could be observed that for ingestion or inhalation rates between 0 and 40 kg/yr, the AED is within the acceptable limit, therefore the threshold ingestion or inhalation rate is 40 kg/yr and any value slightly higher than the threshold values is prone to significant radiological health risk.

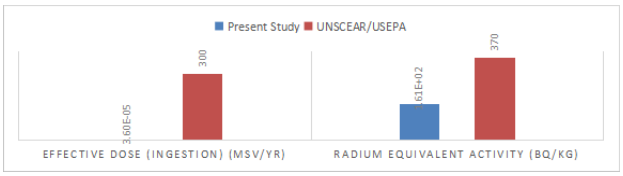

Figure 2. Annual effective dose (AED) and Radium Equivalent Activity (Ra_{eq}) due to Soil Ingestion or Inhalation.

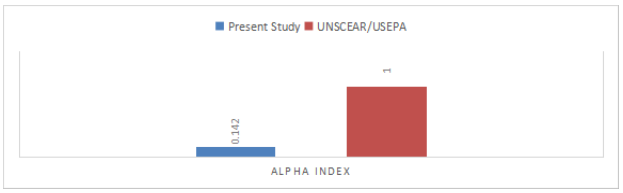

Figure 3. Alpha Index (I_α) due to Soil Ingestion or Inhalation.

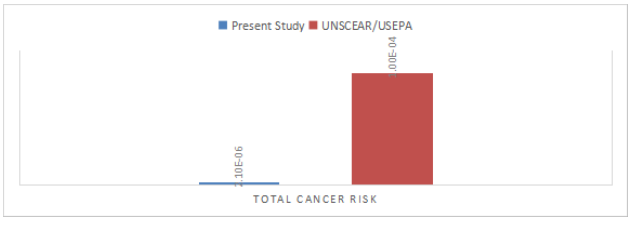

Figure 4. Total Cancer Risk due to Soil Ingestion or Inhalation.

4. Conclusions

At the present average Soil Ingestion or Inhalation rate of 14.4 kg/y in Nigeria, the average annual effective dose due to the Soil Ingestion or Inhalation in humans was approximately 1000 times lower than the world average annual committed effective dose of 300 µSv/yr for ingestion of natural radionuclides provided in UNSCEAR 2000 report. It was established that for Ingestion or Inhalation rates between 0 and 40 kg/y, the AED is within the acceptable limit, therefore the threshold Ingestion or Inhalation rate is 40 kg/y and any value slightly higher than the threshold values will be associated with a significant radiological health risk. The radium equivalent activity (Ra_{eq}) and alpha index were far lower than their UNSCEAR acceptable thresholds of 370 Bq/kg and 1 respectively. Furthermore, the total cancer risk due to fatality and hereditary effects that may arise from Ingestion or Inhalation was approximately 100 times less than the USEPA acceptable threshold of 1×10^{-4}. Among all the soil varieties analyzed, NW2 C had the highest radium equivalent activity (Ra_{eq}), annual effective dose due to ingestion and total cancer risk values while NW2 A had the lowest values of these parameters. Therefore, the present Ingestion or Inhalation rate of soil in the area poses no radiological risk to the population.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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