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Research Article

Seasonal Variation in the Concentrations of Radionuclides and Radiological Health Assessment of Some Tin Mining Areas of Barkin Ladi Lga of Plateau State Nigeria

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Abstract

Radionuclides are found not only in the earth's crust but also in all of its environments, including soil, water, and the atmosphere. This is as a result of naturally occurring radioactive series of ^{238}U and ^{232}Th. Barkin Ladi Local Government Area is located in the heart of Northern Nigeria and is distinguished by its rough, low terrain. This area serves as the focal point for younger granites and is the primary center of tin and columbite mineralization. Samples were taken in February and July and examined with a gamma-ray spectrometer to evaluate seasonal variation in radionuclide concentrations. The average ranges of radionuclide concentrations are shown by the results In February: ^{40}K (209.9957 ± 0.27 to 271.3964 ± 0.54 Bq/kg), ^{226}Ra (69.3912 ± 0.16 to 98.0745 ± 0.88 Bq/kg), and ^{232}Th (78.0992 ± 0.86 to 97.4741 ± 0.31 Bq/kg). In July: ^{40}K (184.7383 ± 0.36 to 208.0652 ± 0.08 Bq/kg), ^{226}Ra (65.9556 ± 0.40 to 78.4196 ± 0.76 Bq/kg), and ^{232}Th (75.6379 ± 0.98 to 86.4623 ± 0.94 Bq/kg). The results show a decrease in ^{40}K and ^{232}Th concentrations during the wet season compared to the dry season, with an average decrease of 11.40% and 10.30%, respectively. All ^{40}K results were below the recommended limit of 412 Bq/kg, while 226Ra and ^{232}Th results exceeded the world averages of 33 Bq/kg and 45 Bq/kg, respectively. The pH, electrical conductivity (EC), and organic carbon (OC) values ranged from: Dry season: pH (4.20 - 5.81), EC (397.07 - 697), and OC (0.69 - 1.21). Wet season: pH (5.55 - 6.42), EC (302.16 - 489), and OC (0.43 - 0.86). Excess lifetime cancer risk (ELCR) values were highest in locations N (4.3 x 10^{-4}) and F (4.2 x 10^{-4}), indicating elevated cancer risk associated with radiation exposure in these areas. In conclusion, the study reveals that the soil samples in the different locations are polluted with radionuclides ^{226}Ra and ^{232}Th, particularly during the dry season. The results also suggest that people living in the study area may be at risk of developing cancer due to prolonged radiation exposure. Therefore, it is essential to take measures to mitigate radiation exposure and ensure the radiological safety of the area.

Keywords

Radionuclides, Soil, Mining Areas, Cancer

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1. Introduction

Human beings have been impacted by natural radiation from Earth and other sources outside Earth [1, 2]. This exposure is mainly due to cosmic rays, terrestrial and indoor radon [1]. Natural background radiation varies geographically and temporally and is estimated to account for approximately 80 percent of total radiation exposure with an overall average annual individual effective dose of approximately 2.4 mSv [1]. Sources include naturally occurring radioactive elements such as uranium and thorium, their by-products, and cosmic rays [3]. The human body itself contains radioactive elements naturally occurring [2] Exposure to radiation may also be from man-made sources such as medical imaging and radiotherapy [3]. Environmental radioactivity studies are essential in order to monitor human exposure levels [4] although high doses of ionizing radiation may be harmful, exposure to natural is on average around 3 mSv per annum [3].

Natural radioactivity in the soils is mainly due to ^{238}U, ^{232}Th and ^{40}K, as well as man-made radionuclides such as ^{137}Cs, which may occur as a result of nuclear accidents and weapon testing [5, 6]. Studies in different regions have shown that the activity concentrations of these radio-nuclides are above the global average [7, 5] while some areas have normal levels of background radiation [8]. Some variables such as radium equivalent activity, absorbed dose rate, annual effective dose equivalent and the excess risk of cancer over life are calculated for radiological hazard assessment [7, 5]. Although most of these indices are within acceptable limits, they are often much higher than the world average [7]. The presence of these radionuclides in the soil has impact on human health through exposure to gamma rays and inhalation of radon and its compounds.

Natural radioactivity in soil samples is determined primarily by gamma-ray spectrometry [9] to measure concentrations of ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K. These radio-nuclides show a variable distribution depending on the geological formations and chemical properties [10]. High background radiation areas such as Kanyakumari and Odisha in India often have high levels of these radio-nuclides, especially the elements in the thorium series [11, 12]. Activity concentrations these radio-nuclides, especially the elements in the thorium series [11, 12]. Activity concentrations of these radio-nuclides may vary considerably, with 226Ra ranging from less than detection levels to 131 Bq kg-1, 232Th from 9 to 384 Bq/kg^{-1} and 40K from 471 to 1406 Bq kg^{-1} [10] being among the most frequent. These increased lead to increased human exposure, with annual effective radiation doses exceeding the world average of 0.07 mSv in some regions [12]. Radiological indices and multivariate statistical techniques are used for the assessment of potential health hazards and for the understanding of the distribution of radionuclides [11]. The purpose of this study is to assess the seasonal variations in radionuclide concentrations and the impact on radiological health of certain areas of Barkin Ladi Tin Mine in Plateau State of Nigeria.

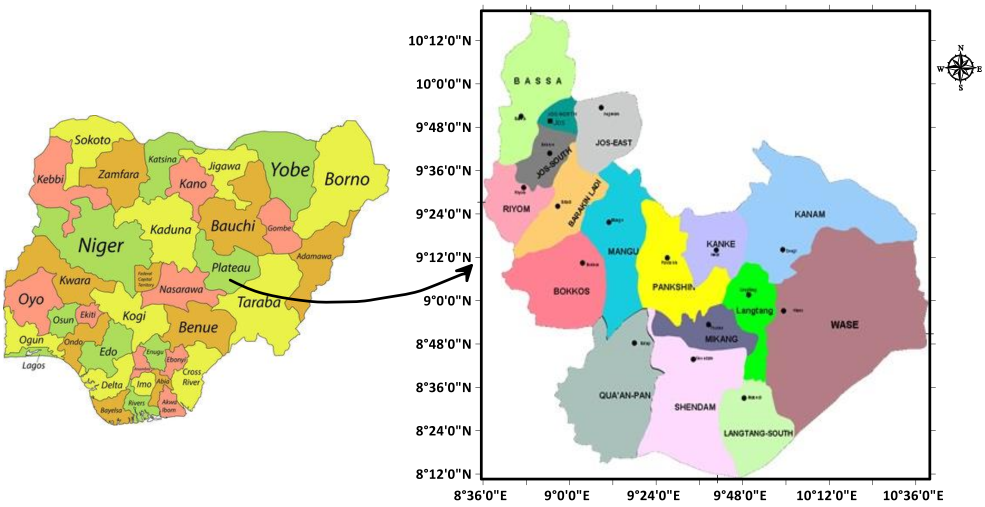
2. Materials and Methods

Materials/Equipment

The materials used in this study are: Canberra Model 727,727R lead shield gamma ray spectrometer with Na (Ti) detector, Gallenham England, Beakers, Mortar and Pestle.

3. Study Area

The study was conducted in Barkin Ladi Local Government Area in Plateau State of Nigeria. Soil samples were taken for radionuclide analysis from Mazat, Bisitchi and Foron communities.



Source: Land, Survey and town planning section Pankshin LGC (2024)

Figure 1. *Map of Nigeria showing Plateau State.*

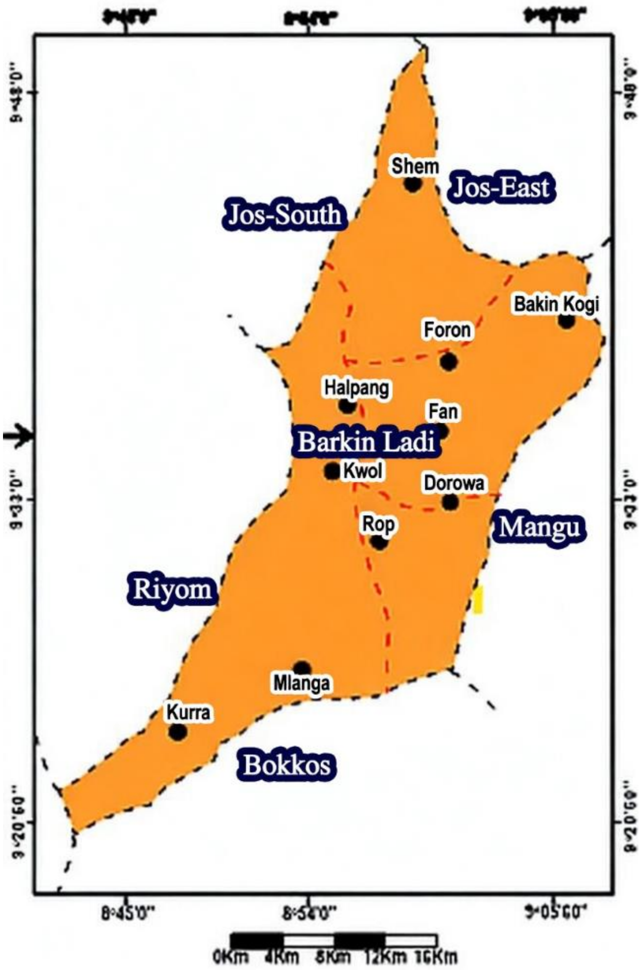


Figure 2. Map of Barkin Ladi Local Government Area.

Source: Land, Survey and town planning section Pankshin LGC (2024)

4. Collection of Samples

Samples were taken from a depth of approximately 15 cm from the surface of the soil using a clean stainless steel spoon, at a distance of 1 m from each sampling point. The samples were mixed together to form a composite after which about one kilogram of each sample was then taken to the laboratory for further preparation and analysis.

5. Sample Preparation and Calibration the Detector

The soil samples were in a very clean polythene bag and labelled to avoid contamination. The samples were sent to the Centre for energy research and training (CERT), Ahmadu Bello University, Zaria. The samples were dried at room temperature until no detectable change in weights was observed. The dried samples were carefully crushed and ground into a powder. The powder was then passed through a sieve of 2 mm thickness. Due to the limited space of the detector shield, only samples weighing 200 g to 300 g (dry-weight) were used for analysis.

In order to prevent escape of 222Radon, the packaging was in each case triple-sealed. The sealing process consisted of rubbing the inner rim of each container lid with Vaseline jelly, filling the gaps in the lid assembly with candle wax to close the gaps between the lid and the container, and sealing the lid assembly with glue masking tape. After weighing, samples were transferred to radon-impermeable cylindrical plastic containers of uniform size (70 mm high by 60 mm wide) and sealed for approximately 30 days. This was done so that radon and its short-lived relatives could reach a secular radioactive balance before gamma spectroscopy. The reference soil was also transferred into the same container of the same material and dimensions as used for the soil sampling. Lead shielded 76 x 76 mm NaI (TI) detector crystal (model number The radioactivity measurements were performed using Canberra Series 703 (Cannons Inc.) Which is connected to a Canberra Series 10 plus multi-channel analyser (MCA) model number 1104) by preamplifier.

A resolution of about 8% at an energy of 662.0 keV (137Cs), is considered sufficient to distinguish the gamma rays of interest in this study. The choice of gamma-ray peaks for measurement was made taking into account the low resolution of the NaI (TI) detector used in this study. This would ensure that the photons emitted by the radionuclide are sufficiently discriminated nly when the probability of their emission and their energy is high enough and the background continuum is low enough. Therefore, 214Bi activity concentration (determined from its 1760 keV - ray peak) was selected as an indicator for 226Ra (238U) in the samples, and 208 Ti daughter radionuclide concentration (determined from its 2615 keV - ray peak) was selected as an indicator for ^{228}Th. Potassium-40 is determined by measuring the 1460 keV radiation emitted by its decomposition.

The soil samples were placed symmetrically on the detector and measured over a period of 29,000 seconds. The net area under the corresponding peaks in the spectrum has been calculated by subtracting the number of Compton scattering peaks and other background sources from the total peak area The calibration of the energy system was carried out with two calibration point sources, ^{137}Cs and ^{60}Co. These were done with an amplifier gain of 72 percent for 661.7 keV Cs-137 and calculated over 30 minutes.

Table 1. Spectral energy windows used in the Analysis.

Isotope	Gamma Energy (keV)	Energy Window (keV)
Ra-226	1764.0	1620-1820
Th-232	2614.5	2480-2820

Isotope	Gamma Energy (keV)	Energy Window (keV)
K- 40	1460.0	1380-1550

6. Radiological Risk Assessment

i. Radium equivalent assessment (Raeq).

Gamma radiation hazard caused by specific radionuclides of ^{226}Ra, ^{232}Th and ^{40}K was calculated using different indices. Ra_{eq} is a weighted sum of activities of the three radionuclides based on the supposition that 370 Bqkg^{-1} ^{226}Ra, 259 Bqkg^{-1} ^{232}Th and 481 Bqkg^{-1} ^{40}K produce the same gamma ray dose rate.

$$\text{Raeq (Bqkg-1)} = \text{CRa} + 1.43\text{CTh} + 0.077\text{C} \qquad (1)$$

where the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K is assumed to be equal to 370 Bqkg^{-1}. In order to maintain annual radiation doses at less than 1.5 mGy^{-1}, the maximum value has to be less than 370 Bqkg^{-1}.

ii Absorbed dose rate in air (D_R).

Following the guidance in [13], the absorbed dose rate of gamma radiation (nGyh^{-1}) in air was determined at 1 m above the ground to ensure a homogeneous distribution of radionuclides. This parameter may be used to evaluate any radiological hazards and exposure to radionuclides in soil; the calculated absorbed dose rate has been calculated by the formula given below [14].

$$\text{DR (nGh}^{-1}) = 0.427\text{CRa} + 0.623\text{CTh} + 0.043\text{CK} \qquad (2)$$

where nGyh^{-1} is the dose ratio for radium ^{226}Ra, thorium ^{232}Th and ^{40}K respectively, and CRa, CTh and CK are the activity concentrations of the active substance (Bqkg^{-1}). The absorbed dose rate indicates the dose absorbed outside from radiation emitted by radionuclides in environmental materials. Determining this rate is a step in the health risk assessment and this parameter is expressed in grey.

iii Annual Effective Dose Rate (AEDR)

This was calculated to assess the effect of absorbed doses on health using a conversion factor (0.7 SvGy^{-1}) to convert the absorbed dose in air to the effective dose in man, with an outdoor occupancy factor (0.2) of 20 percent and 80 percent, respectively, of indoor occupancy [14]. This factor is appropriate to determine the life-cycle in the study area. The annual effective dose ratio (AEDR, in mg^{-1}) received by the population may be expressed as shown in [13].

$$\text{AEDR} = \text{D x 8760 x 0.2 x 0.7 x 10-6} \qquad (3)$$

where AEDR is the annual effective dose ratio (Sv(y)), D is the dose rate of the erythromycin (nGy) and the coefficient of the dose taken in (in) by the adult is 0.7 Sv(v(a).

iv Exterior hazard index Hex

The external hazard index for the samples examined was calculated by the equation defined in [15].

$$\text{Hex CRa (370 + CTh (259 + CK (4810)} \leq 1 \qquad (4)$$

where ^{226}Ra, ^{232}Th and ^{40}K are the active concentrations in Bq (kg) of the active substance. Hex maximum equals the upper limit of Raeq (370Bq/kg.

v Internal hazard index Hin

The Internal Hazard Index (Hin) has been introduced to describe the risk of radon and its short-lived products in soil and is recommended to be less than unity [16, 17].

$$\text{Hin} = \text{CRa (185 + CTh (259) + CK (4810)} \qquad (5)$$

vi Excess Life-Risk of Cancer (ELCR)

The ELCR has been calculated using the equation described in [18].

$$\text{ELCR}= \text{AEDR x L x RF x } 10^{-6} \qquad (6)$$

If AEDR is the annual effective dose, L is the life expectancy taken as 70 years, RF is the risk factor taken as 0.05. The global average value of 0.00027 is given in [19] as a safety measure.

7. Results and Discussion

Table 2. Summary of the result for the analysis of radionuclides ^{40}K, ^{226,} Ra and ^{232}Th sample collected in February.

SAMPLE ID	40K (Bq/kg)	226Ra (Bq/kg)	232Th (Bq/kg)	pH	EC (S/m)	OC (%)
M	209.9957±0.27	76.6219±0.60	81.0756±0.55	4.42	697.00	0.94
N	271.3964±0.54	98.0745±0.88	93.2645±0.43	5.34	465.01	0.69
F	239.5431±0.48	88.8063±0.50	97.4741±0.31	4.98	528.67	0.96
B	219.3265±0.91	73.3100±0.60	89.1831±0.20	5.34	397.07	0.99
C	220.3651±0.16	74.1051±0.60	91.5159±0.79	5.11	567.01	0.73

SAMPLE ID	40K (Bq/kg)	226Ra (Bq/kg)	232Th (Bq/kg)	pH	EC (S/m)	OC (%)
K	203.5607±0.80	69.3912±0.16	78.0992±0.86	5.81	473.09	1.06
L	230.1587±0.75	70.4273±0.36	87.8778±0.67	4.95	625.33	1.21
Control	120.1324±0.01	21.4729±0.02	18.6475±0.11	6.50	123.32	0.21
Permissible Limit	412	33	45			

M= Mazat, N= Narit F = Foron B=Bisitchi, C= Con, K= Kapang, L=Longa

Table 2 shows the activity concentrations ^{40}K, ^{226}Ra and ^{232}Th expressed in Bq/kg and the soil physicochemical characteristics of samples taken from certain mining areas in the Barkin Ladi local government area in the dry season in the State of Plateau. The radioactive content of the samples from different locations varied greatly. ^{40}K concentrations range from 209.9957 ± 0.27 to 271.3964 ± 0.54 Bq/kg, whereas ^{226}Ra concentrations range from 69.0745 ± 0.16 to 98.31 Bq/kg. All values recorded for 40K were below the world average of 420 Bq per/kg, while all values for 226Ra and 232Th were above the world average of 33 Bq per kg and 45 Bq per/kg, [13]. The high concentrations of ^{226}Ra and ^{232}Th may be due to artisanal mining activities occurring in the vicinity of the study sites. The results of this study are similar to those reported in [20, 21]. These findings show that radionuclides are usually released into the environment by various processes, some of which can be linked to mining, processing, transport, erosion of water and wind. The other important factors influencing the distribution and fate of radionuclides in soil are the properties of the specific radionuclide, its chemical form and its reactivity, which control the nature of its retention in the soil and the affinity to certain soil constituents.

The soil's most important characteristic is its pH value, which influences all other soil parameters, therefore, pH is taken into account in the analysis of any soil type. If the pH is below 6, it's acidic soil. If the pH is between 6 and 8.5, it is said to be normal soil, but if it is more than 8.5, it is said to be alkaline soil [22]. The pH of the soil samples from this survey ranged from 4.42 to 5.81, which is lower than the 7.3 to 7.9 reported in one study [23], but similar to that reported in another study [24]. Decreasing pH values increases radionuclide mobility [25].

***Table 3**. Summary of the result for the analysis of radionuclides ^{40}K, ^{226,} Ra and ^{232}Th sample collected in July.*

Sample ID	40k Bq/kg	226Ra Bq/kg	232Th Bq/kg	pH	EC (S/m)	OC %
M	208.0652±0.08	77.3015±0.12	86.4623±0.94	5.81	489.00	0.44
N	217.1815±0.16	78.2199±0.76	76.5933±0.29	6.25	401.01	0.59
F	184.7383±0.36	66.8744±0.48	83.5896±0.94	5.78	396.67	0.66
B	193.5864±0.18	70.5059±0.28	77.0967±0.22	6.31	302.16	0.59
C	204.5062±0.17	65.9556±0.40	69.7874±0.57	6.42	482.11	0.43
K	183.7194±0.23	78.4196±0.76	75.6379±0.98	6.01	388.14	0.86
L	199.6997±0.17	68.5858±0.60	82.1373±0.41	5.55	425.23	0.71
Control	98.5631±0.70	20.4291±0.02	16.6472±0.62	6.90	93.23	0.11
Permissible Limit	412	33	45			

M= Mazat, N= Narit F = Foron B=Bisitchi, C= Con, K= Kapang, L=Longa

Table 3 shows the activity concentrations ^{40}K, ^{226}Ra and ^{232}Th expressed in Bq per kg as well as the soil physicochemical characteristics of the samples taken during the wet season.

Activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th range from 184.7383 ± 0.36 to 208.9556 ± 0.76 Bq kg, and from 78.4196 ± 0.94 to 75.4623 ± 0.08 Bq/kg, respectively. The results show a decrease in concentrations of ^{40}K and ^{232}Th during wet versus dry seasons. This finding is similar to studies performed in India, Bangladesh and Japan, which found increased concentrations of ^{226}Ra, ^{232}Th and ^{40}K activity in sand and rock samples during the dry season and decreased concentrations during the wet season [26-28]. This decrease is attributed to increased precipitation, water flow, mobility of radionuclides and physicochemical properties of the soil. However, contrasting findings were observed in Australia where concentrations of ^{40}K and ^{232}Th did not show significant seasonal variations [29]. Results for ^{226}Ra in M and C show higher concentrations during wet than dry seasons. This finding is similar to the results reported by [30] suggesting that this increase may be related to an increase in water-to-soil ratio. This finding is, however, different from the results reported [31] in Kitui where concentrations were higher during the dry season, which was attributed to an increase in dust in the soil and in the atmosphere. The decrease in concentrations of ^{40}K between seasons was statistically significant ($p<0.041$), while the changes in concentrations of ^{226}Ra and ^{232}Th were not statistically significant.

In general, the smallest percentage decrease in concentration of ^{40}K was observed at sampling point M with a reduction of 0.95 percentage points, whereas the highest reduction was observed at F with a reduction of 22.8 percentage points. Similarly, ^{226}Ra showed the same trend with a reduction of 2.03 percent for M and 24.70 percent for F, whereas 232Th showed the lowest reduction for K, with a reduction of 3.22 percent, and the highest reduction was observed at C sampling site.

Table 4. *The radiological hazard assessment of the study area.*

SAMPLING POINT	Dr (nGh-1)	AEDR (mSvy-1)	Ra eq (Bqkkg)	Hex	Hin	ELCR
M	95.85	0.12	217.01	0.59	0.79	4.1x10-4
N	101.65	0.13	204.30	0.62	0.86	4.3x10-4
F	98.04	0.12	221.98	0.60	0.81	4.2x10-4
B	91.31	0.11	206.55	0.48	0.75	3.9x10-4
C	88.59	0.11	200.72	0.54	0.73	3.8x10-4
K	84.90	0.10	192.04	0.52	0.70	3.6x10-4
L	89.50	0.11	207.03	0.56	0.75	3.9x10-4
CONTROL	24.25	0.03	53.70	0.15	0.20	1.1x10-5
Permissible Limit	60.00	0.50	370.00	< 1	< 1	2.7x10-4

Table 4 summarizes the results of the radiological hazard assessment of the study area. The absorbed dose ratio in air (nGh-1) has been calculated and ranges from 84.90 nGh-1 to 101.65 nGh-1, with a median value of 92.76 nGh-1. This value is above the permitted limit of 60 nGm^{-1} [13]. According to [32], when ionising radiation is delivered throughout the body, the signs and symptoms are collectively called acute radiation syndrome, which can cause certain biological effects such as skin damage, nausea and vomiting, tiredness, hair loss, severe diarrhoea, bone marrow damage, intestinal cell damage, cardiovascular collapse and brain vascular damage.

The annual effective dose ratio (AEDR) was calculated to assess the effect of absorbed doses on health using a conversion factor (0.7SvGy^{-1}) to convert absorbed doses in air to effective doses in man, with an outdoor occupancy factor of 0.2, corresponding to 20 percent and 80 percent, respectively, of the indoor exposure. The AEDR in Table 4 is highest at 0.13 mSvy$^{-1,}$ lowest at 0.10 mSvy-1 and average at 0.11 mSvy-1. These values exceed 14.88 to 22.26 µSvh^{-1} reported by [33] in the artisanal mines of Utan Jos North, 5 - 80 µSvh^{-1} reported in the tin mines of Bukuru, Nigeria, and 6 - 28 µSvh-1 reported [34]. However, all the AEDR values in this study were below the global average indoor terrestrial exposure value of 0.5 mSvy^{-1} [35]. A study in a gold-mining region of Ghana reported a dose ratio of 0.11-0.24 mg-1, comparable to the values achieved in the current study (0.10-0.13 mg^{-1}), [36].

Gamma radiation hazards due to specific radionuclides ^{226}Ra, ^{232}Th and ^{40}K have been calculated using different indices, the Raeq is the weighted sum of the activity of these three radionuclides, based on the assumption that 370 Bq per/kg ^{226}Ra, 259 Bq kg ^{232}Th and 481 Bq/kg ^{40}K produce the same gamma radiation dose [13]. The results obtained in this study show values ranging from 221.98 Bq per kg to 217.01 Bq per kg, with an average value of 207.09 Bq per kg, which is consistent with the results in [37]. Another study by [38] in the uranium mining region of Australia reported a range of radio-equivalent activity of 100-400 Bq per kg, which is higher than the values obtained in this study of 192-221 Bq per kg. It was also found that it was below the maximum permitted limit of 370 Bq per kg, equivalent to 1 mSvvy-1 for safety purposes [13].

The external and internal hazard index indices (Hex and Hin) have been calculated from the concentration activity of the soil samples. This was introduced to describe the risk of radon and its short-lived products in soil and it is recommended that the radon level is less than unity [38]. All the external hazard index (Hex) values are less than 1, indicating that the exposure level is within acceptable limits. However, the internal hazard index (Hin) is higher than Hex indicating that there is a potential health risk from inhalation of radioactive materials.

The Excess Life Risk (ELR) refers to the probability of developing cancer over a lifetime at a given exposure level, calculated ELCR data in Table 4 show that the ELCR is highest in N (4.3 x 10^{-4}) and F (4.2 x 10^{-4}) exposure zones. A study [39] in the coal mining sector of China reported an excess lifetime cancer risk (ELCR) ranging from 1.3 to 2.5 times 10-4, comparable to the results of the 3.6 to 4.3 times 10-4 study. ELCR values in the study area are generally high compared to the world average value of 2.7x10^{-4} as reported in the International Committee on the Progress of Research (ICPR, 1991).

8. Summary

This study examined the activity concentration of radionuclides (^{40}K, ^{226}Ra, and ^{232}Th) in soil samples collected from Tin mining areas in Barkin Ladi Local Government Area, Plateau State, Nigeria. The samples were collected during both dry and wet seasons. The results exhibited variations in radionuclide concentration between seasons and among different sampling locations. The concentration of ^{40}K and ^{232}Th reduced during the wet season, while ^{226}Ra showed an increase in some.

9. Conclusion

The study concludes that the concentration of radionuclides in soil exhibit significant variation between seasons and among different locations. The decrease in ^{40}K and ^{232}Th concentrations during the wet season may be attributed to increased rainfall and water movement, which may result in radionuclide mobility. The increase in ^{226}Ra concentration in some locations during the wet season may be associated with enhanced soil-to-water transfer. The study emphasizes the significance of examining seasonality. It is therefore established, that the soil samples in the different locations are contaminated, with radionuclides ^{226}Ra and ^{232}Th especially during the dry season, and also people living around the study area may be at risk of cancer as a result of an accumulation of radiation dose over time, hence the area may be considered radiologically hazardous. It is therefore essential to take measures to mitigate radiation exposure so as to ensure safety of the area.

Abbreviations

Dr	Absorbed Dose Rate in Air
AEDR	Annual Effective Dose Rate
Raeq	Radium Equivalent
Hex	External Hazard Index
Hin	Internal Hazard Index
ELCR	Excess Life Time Cancer Risk
EC	Electrical Conductivity
Ra	Radium
Th	Thorium
K	Potassium
OC	Organic Carbon

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Author Contributions

Sati Lubis: Conceptualization, Methodology, Validation

Ogori Boniface Otokpa: Investigation, Formal analysis, Supervision

Bakji Gomerep: Data curation, Writing – review & editing

Goshit Wubaknenkat Christopher: Visualization, Writing – original draft

Conflicts of Interest

Authors have declared that no conflicting interests that exist between the researchers during the research work.

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