Estimation of Excess Lifetime Cancer Risk and Radiation Hazard Indices in Yunusari, Yobe State, Nigeria

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Abstract

Although mining is crucial, unregulated quarry mining operations may expose people to radiation and pollute the environment, mutually of which could have a negative effect on the host communities. This study used a sodium iodide (NaI) detector to amount the activity concentrations of 226Ra, 232Th, and 40K in soil samples from five mining sites in Yunusari Yobe State. Thirty soil samples were taken using systematic sampling techniques from the five mining areas at a depth of 15 cm and 50 meters apart. These samples were then investigated for activity concentration at Ahmadu Bello University Zaria's Centre for Energy Research and Training (CERT). Calculations were made for the External Hazard Index, Annual Effective Dose Rate, Radium Equivalent Activity, Gamma Absorbed Dose Rate, and Excess Life Cancer Risk. Findings indicate that the average activity concentrations of 226Ra, 232Th, and 40K in soil samples were found to be 108.27 Bq/Kg, 58.99 Bq/Kg, and 287.95 Bq/Kg, respectively, according to the results. With the exception of 40K, which had a value of 287.95Bq/Kg, which is less than the UNSCEAR world standard of 400Bq/Kg, the values of 226Ra and 232Th were all greater than the UNSCEAR world standard of 35Bq/Kg and 30Bq/Kg, respectively. The average Radium Equivalent Activity was 214.090Bq/Kg, which is lower than the world standard of 370Bq/Kg, but the Gamma Absorbed Dose Rate (D) was 97.612nGh-1, which is greater than the 84nGh-1 standard. 0.3200mSv/y, 0.120mSv/y, and 0.300mSv/y were the mean values of the External Hazard Index, Annual Effective Dose Rate, and Excess Life Cancer Risk, respectively, and were below the International System of Radiological Protection's (ICRP) suggested public exposure limit of 1 mSv/y. To sum up dissemination of naturally occurring radionuclides in the soil samples surrounding the research area is displayed in the results. With the exception of 40K, which is lower than the global average, the average activity concentrations of 226Ra, 232Th, and 40K from this investigation are greater than the global average values. As a result, mining operations may present radioactive risks to the host populations.

Keywords: Activity Concentrations, Environmental Pollution, Mining, Radiation Exposure.

Introduction

By-products of industrial processes that are enhanced with radionuclides of natural origin are known as Natural Occurring Radioactive Materials (NORMs). The radionuclides 238U, 232Th, and their progeny, together with 40K, which are present in soils, water, and the Earth's crust, are the main sources of natural radioactivity. The risk of radiation exposure to the human environment is increased by mining and processing minerals, which concentrate naturally occurring radiation levels above background values. In 2019, Ibrahim *et* al. The term "naturally occurring radioactive materials" (NORM) refers to any radionuclide that occurs naturally in the environment. These are the radionuclides 40K, 232Th, and 238U that are found in the earth's crust, together with the by-products of their decay. Both natural and artificial radioactive sources can expose humans to radiation (Yusuf, 2017).

Aim

The aim of this study is to determine the additional lifetime cancer risk and radiation hazard indices in Yunusari, Yobe State, Nigeria.

Objectives

i. To look into the levels of activity soil in samples taken from 40K, 226Ra, and 232Thin mining regions in Yunusari Yobe State.

ii. To calculate the research area's radioactive equivalent, excess life cancer risk, annual effective dose, external hazard indices, and annual effective dosage.

Materials and Procedures

The following supplies and tools were utilised in this investigation: Cutlasses, a shovel, gloves for hands and shoes, a mask, polythene bags that zip-lock, and a GPS

Methods

Research Method

Study Area

Yobe State districts, including Yunusari. The town of Kanamma, located along the Burun Gana River in the northeast of the region, is home to its headquarters. With a population of 125,821 according to the 2006 census, it occupies an area of 3,790 km² and has a northern border with the Republic of Niger. The rainy season, which starts in March or April and ends in October, and the dry season, which starts in November and ends in March or April, are the two main climatic seasons. The primary occupations of the populace are farming and potash mining.

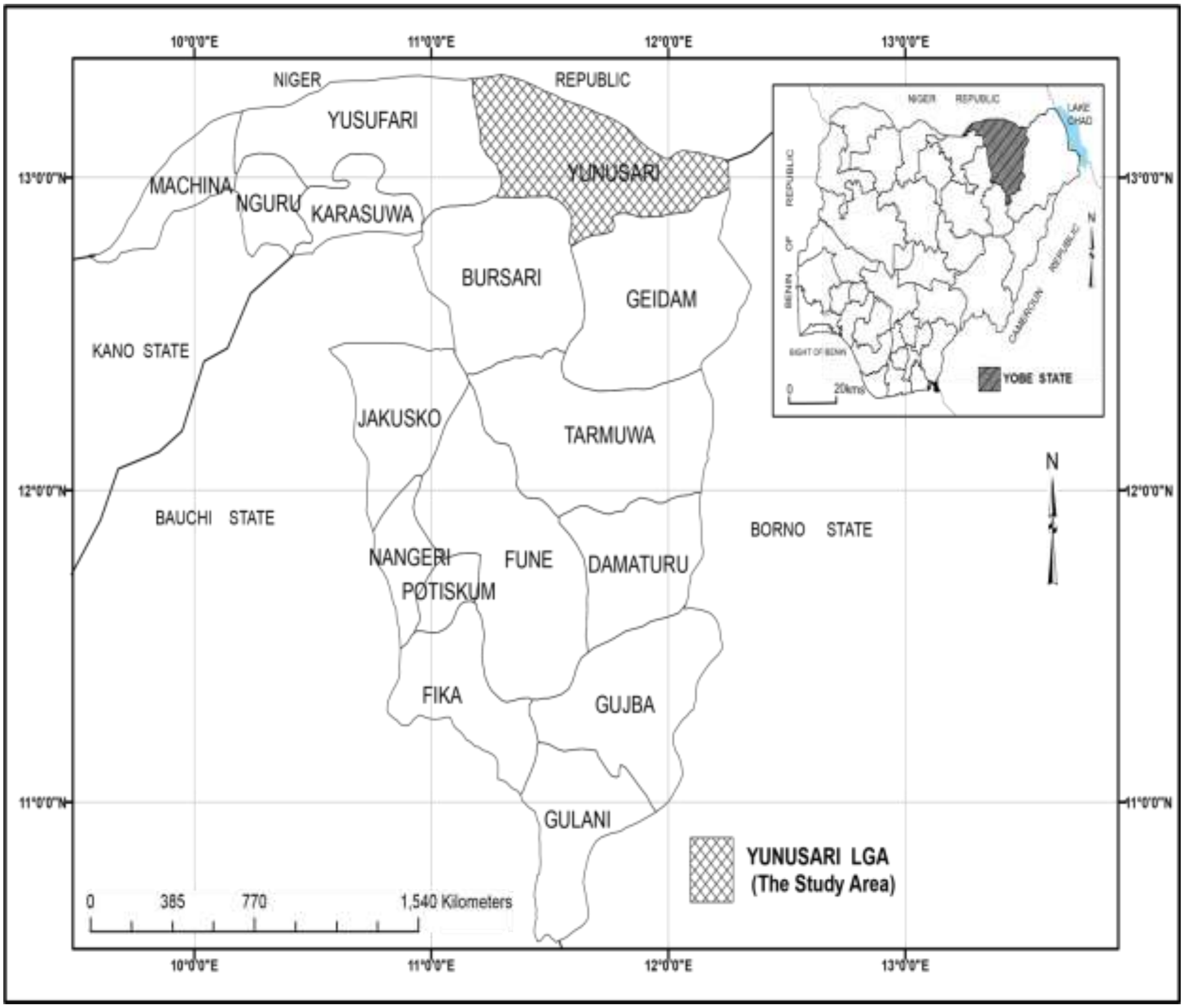

Fig. 1 The research area's map where samples were collected (Yunusari local government area) (Google Search, 2022)

Method of Sample Collection

Thirty (30) samples of soil were gathered from five locations within the mines and the surrounding communities which include; Kanamma, Mosogun, Yunusari Bukarti and Garin Gada.

Six (6) samples were gathered from the five selected sampling locations by systematically mapping the respective coordinates from each sampling point in each location. At 50metres, soil samples were gathered from each sampling points using systematic sampling techniques to achieve statistical sensitivity of sampling and for accurate reference of result. A shovel was used to collect soil 15cm below the surface, every composite soil sample that was gathered weigh about 300g of mass was placed in a well polyethene bag and sealed to avoid cross contamination of the samples during transportation to the laboratory.

Method of Sample Preparation

The soil samples were prepared through a process of open air drying for one week at room temperature to remove moisture. Stony samples were ground into powder form using pestle and mortar and sieved with a wire mesh with holes of thickness 0.5mm to obtain homogeneity of sample size, then package in a well labelled polythene bag. Soil samples 300g were kept in a well labelled sealed polythene bags for four weeks to reach a state of secular balance between ^{226}Ra, ^{232}Th and ^{40}K and their offspring before taking it to the laboratory for analysis at the Centre for Energy Research and Training Ahmadu Bello University Zaria.

Method of Data Collection

Soil samples gathered from five mining sites in Yunusari, Yobe state were analysed to determine the radioactivity concentrations of ^{40}K, ^{232}Th, ^{226}Ra using spectroscopy of Gamma ray with a well calibrated NaI(TI) detector system at the Centre for Energy Research and Training (CERT) Laboratory, Ahmadu Bello University Zaria. The findings are shown in tables below

Method of Data Analysis

The data on radioactivity levels from soil samples will be analysed to determine Gama rate of Dose Absorption, Radium Equivalent Activity, Hazard Indices both Internal and External using the relations below.

Radium Equivalent Activity Assessment

A common radiological index is established in order to reflect the activity levels of natural radio-nuclides (226Ra, 232Th, and 40K) by a single quantity that would account for the radiation dangers associated with NORMs in the soils of the research region. This measure, known as Radium Equivalent (Raeq) Activity (UNSCEAR, 2000), is defined mathematically by equation 1, where ARa, ATh, and AK, which stand for the activity concentrations of 226Ra, 232Th, and 40K, respectively. This presumption only applies to external hazards caused by gamma rays in construction materials. For safe use, it is advised that raw building materials have a maximum Raeq value of less than 370 Bq/kg. Accordingly, the external gamma dosage needs to be below 1.5 $mSvy^{-1}$.

$$Ra_{eq}(Bq/kg) = A_{Ra} + 1.43A_{Th} + 0.077A_K, \quad (1)$$

Assessment of the External Hazard Index

The external hazard index is a commonly used hazard index that reflects external exposure and is employed to evaluate the gamma rays associated with natural radionuclides in building materials. As stated by UNSCEAR (2000), as:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (2)$$

hexadecimal notation was employed, with ARa, ATh, and AK standing for the activity concentrations of 226Ra, 232Th, and 40K, respectively. Apart from the exterior hazard index, the respiratory organs are also at risk from radon and its short-lived by-products.

Calculation of the Absorbed Dose Rate

It is crucial to determine the dose that is absorbed (D) from gamma radiations in air at a height of one metre above the ground in order to evaluate the health hazards connected naturally occurring radionuclides (226Ra, 232Th, and 40K). The computations are performed using the guidelines that UNSCEAR 2000 provides. Other naturally occurring radionuclides were thought to have negligible contributions. Consequently, D is computed in accordance with UNSCEAR

2000, the United Nations Scientific Committee on the Effect of Atomic Radiation.

$D(nGy/h) = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_K,$
(3)

where A_K, A_U and A_{Th} are the activity concentrations (Bq/kg) of ^{40}K, ^{238}U and ^{232}Th present in the soil samples.

0.462, 0.604 and 0.0417 are dose conversion factors of radionuclides (^{238}U, ^{232}Th and ^{40}K) recommended by (UNSCEAR) 2000.

Calculation of the Equivalent Annual Effective Dosage

The UNSCEAR report's suggested outdoor occupancy factor (0.2) and conversion coefficient from absorbed radiation in air to effective dose (0.7 Sv/Gy) received by humans must be considered when estimating the annual effective dose rates. Consequently, the following formula is used to get the yearly effective dosage rate (mSv/yr):

Effective Dose Rate$(mSv/y) = D(nGy/h) \times 8760h/y \times 0.2 \times 0.7Sv/Gy \times 10^{-6}$,
(4)

Calculation of Over Life Cancer Risk

According to ICRP (1990), the Excess Life Cancer Risk (ELCR) is calculated by multiplying the AEDR by the Duration of Life (DL), which is 70 years for children and 50 years for adults, and the low dose background radiation Risk Factor of 5% for public exposure, which is thought to cause a stochastic effect.

ELCR = AEDR x RF x DL
(5)

Results

Table 4.1 presents the values of activity concentration and statistical summary of ^{226}Ra, ^{232}Th and ^{40}K in soil samples collected at different sampling points from five selected mining locations. The results of this investigation indicate that radionuclide activity concentrations in soil samples varied within the research field because of the differences in geological and topographical formations of the study area. The action of ^{226}Ra,^{232}Th and ^{40}K ranges from 82.49Bq/Kg to 140.18Bq/Kg with an average value of 108.27Bq/Kg, 45.17Bq/Kg to 74.78Bq/Kg with an average value of 58.99Bq/Kg, 207.94Bq/Kg to 373.01Bq/Kg with an average value of 287.95Bq/Kg respectively. These findings reveal that's the average of ^{226}Ra,^{232}Th and ^{40}K in soil samples are all above the UNSCEAR's world standard except that of ^{40}K which is less than the world average.

Table 4.1: Action concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples composed at different sampling points from five selected mining locations considered in this study

S/N	Sample ID	Longitude	Latitude	226Ra	232Th	40K
1	KM1	13°05'08"N	12°05'45"E	**131.87**	**45.18**	**352.75**
2	KM2	13°05'23"N	12°05'19"E	**104.67**	**45.33**	**231.77**
3	KM3	13°05'58"N	12°06'28"E	**93.36**	**56.38**	**209.94**
4	KM4	13°05'59"N	12°06'28"E	**99.39**	**72.43**	**285.82**
5	KM5	13°05'39"N	12°06'19"E	**124.64**	**66.68**	**370.01**
6	KM6	13°05'09"N	12°06'14"E	**101.43**	**63.42**	**370.33**
7	MZ1	12°56'00"N	11°50'49"E	**83.09**	**53.47**	**257.78**
8	MZ2	12°56'05"N	11°50'38"E	**82.49**	**54.06**	**261.58**
9	MZ3	12°56'19"N	11°50'26"E	**140.18**	**74.78**	**257.78**
10	MZ4	12°56'03"N	11°50'48"E	**104.95**	**57.60**	**251.07**
11	MZ5	12°56'08"N	11°50'45"E	**114.29**	**70.85**	**247.32**
12	MZ6	12°56'11"N	11°50'42"E	**122.64**	**49.78**	**315.69**
13	MR1	13°06'09"N	11°46'18"E	**130.87**	**44.17**	**350.75**
14	MR2	12°57'44"N	11°57'18"E	**103.78**	**45.44**	**236.77**
15	MR3	12°58'17"N	11°57'38"E	**94.36**	**55.38**	**207.94**
16	MR4	13°00'24"N	12°00'37"E	**98.38**	**73.13**	**275.82**
17	MR5	13°00'28"N	12°00'35"E	**122.68**	**64.88**	**369.01**
18	MR6	13°00'21"N	12°00'33"E	**105.44**	**63.44**	**368.32**
19	BK1	13°05'03"N	11°46'45"E	**86.08**	**61.47**	**258.76**
20	BK2	13°05'19"N	11°46'38"E	**81.49**	**54.06**	**260.55**
21	BK3	13°05'35"N	11°46'29"E	**142.12**	**74.72**	**253.08**
22	BK4	13°05'09"N	11°46'14"E	**103.95**	**56.61**	**245.32**
23	BK5	13°05'01"N	11°46'04"E	**113.28**	**70.23**	**312.69**
24	BK6	13°05'00"N	11°46'05"E	**111.68**	**49.72**	**342.76**
25	GD1	13°02'33"N	11°56'42"E	**123.77**	**46.17**	**233.74**
26	GD2	13°01'07"N	11°55'49"E	**106.56**	**45.55**	**206.94**
27	GD3	13°01'09"N	11°55'13"E	**92.38**	**56.56**	**275.82**
28	GD4	13°01'29"N	11°55'19"E	**98.38**	**73.42**	**373.01**
29	GD5	13°01'38"N	11°55'29"E	**121.66**	**65.68**	**367.53**
30	GD6	13°01'45"N	11°55'29"E	**103.44**	**64.42**	**255.89**
	Max			**140.18**	74.78	**373.01**
	Min			**82.49**	**45.17**	**207.94**
	Average			108.27	58.99	287.95
	World Standard			35	30	400

Where: -

S-KM- Sample at location six for sampling KM

S-MZ- Sample at location six for sampling MZ

S-MR- Sample at location six for sampling MR

S-BK- Sample at location six for sampling BK

S-GD- Sample at location six for sampling GD

Table 4.2 Gamma Absorbed Dose Rate (D), Radium Equivalent Action (Ra_{eq}) and External Hazard indices (HI_{ex}) calculated from the action concentration of ^{226}Ra, ^{232}Th and ^{40}K from soil samples

S/N	Sample ID	D(nGy/h)	Ra_{eq}(Bq/Kg)	HI(ex)(mSv/yr)
1	KM1	102.675	223.639	0.3352
2	KM2	85.239	187.338	0.2736
3	KM3	85.793	190.149	0.2742
4	KM4	101.385	224.973	0.3279
5	KM5	113.029	248.483	0.3688
6	KM6	100.350	220.236	0.3315
7	MZ1	81.252	179.401	0.2649
8	MZ2	81.487	179.937	0.2660
9	MZ3	120.349	266.964	0.3815
10	MZ4	93.571	206.650	0.3007
11	MZ5	105.736	234.649	0.3370
12	MZ6	99.670	218.133	0.3235
13	MR1	101.521	221.041	0.3316
14	MR2	85.099	186.990	0.2736
15	MR3	85.570	189.565	0.2734
16	MR4	101.033	224.194	0.3271
17	MR5	110.995	243.872	0.3617
18	MR6	102.132	224.520	0.3365
19	BK1	87.506	173.906	0.2840
20	BK2	80.983	178.858	0.2644
21	BK3	121.167	268.457	0.3830
22	BK4	92.275	203.791	0.2963
23	BK5	112.195	237.786	0.3481
24	BK6	95.680	209.172	0.3143
25	GD1	94.652	207.791	0.3014
26	GD2	85.227	187.631	0.2714
27	GD3	88.150	194.499	0.2869
28	GD4	105.091	232.092	0.3464
29	GD5	110.946	243.882	0.3624
30	GD6	97.190	215.264	0.3123
	Max.	121.167	268.457	0.3830
	Min.	80.983	173.906	0.2644
	Average	97.612	214.090	0.3200
	Standard	84nGh^{-1}	370BqKg^{-1}	1mSv/yr

D- Gamma Absorbed Dose Rate (nGy/h)

Ra_{eq}- Radium Equivalent Activity (Bq/Kg)

H_{ex} – Hazard Index (mSv/y)

Result of radiological hazard indices for Gamma Absorbed dose rate (D), Radium Equivalent Activity (Ra_{eq}) and External Hazard indices (HI_{ex}) obtained from measured activity concentration of ^{226}Ra ^{232}Th and ^{40}K in soil samples in Table 4.2 above using equations 3.1, 3.2 and 3.3 Demonstrate the worth of Gamma Absorbed Dose Rate (D) ranges from 80.983nGh^{-1} to 121.167nGh^{-1}, with a mean value of 97.612.90nGh^{-1}, Radium Equivalent Action ranges from 173.906Bq/Kg to 268..457Bq/Kg with an average value of 214.090Bq/Kg. External Hazard Index was also computed for the measured action concentrations of ^{226}Ra ^{232}Th and ^{40}K with values ranges from 0.2644mSv/y to 0.3830mSv/y with a mean value of 0.3200msv/y which are below the suggested public dose of 1mSv/y as suggested by ICRP

Table 4.3 Annual Effective Dose Rate (AEDR)

S/N	Sample ID	AEDR(mSv/yr)
1	KM1	0.126
2	KM2	0.105
3	KM3	0.105
4	KM4	0.124
5	KM5	0.139
6	KM6	0.123
7	MZ1	0.100
8	MZ2	0.100
9	MZ3	0.148
10	MZ4	0.115
11	MZ5	0.130
12	MZ6	0.122
13	MR1	0.125
14	MR2	0.105
15	MR3	0.105
16	MR4	0.124
17	MR5	0.136
18	MR6	0.125
19	BK1	0.107
20	BK2	0.100
21	BK3	0.149
22	BK4	0.113
23	BK5	0.138
24	BK6	0.117
25	GD1	0.116
26	GD2	0.105
27	GD3	0.108
28	GD4	0.129
29	GD5	0.136
30	GD6	0.119
	Max.	0.149
	Min.	0.100
	Ave.	0.120
	ICRP Suggested Public Dose Limit	**1mSv/yr**

AEDR – Annual Effective Dose Rate (mSv/y)

Results of radiological hazard index for Annual Effective Dose Rate (AEDR) in mSv/y from Table 4.3 using the value of the Gamma Absorbed Dose Rate (D) in nG/hr range from 0.100mSv/y to 0.149mSv/y, with a mean value of 0.120mSv/y which is display the ICRP suggested public dosage limit of 1mSv

Table 4.4 ELCR – Excess Life Cancer Risk (mSv/y)

S/N	Sample ID	ELCR
1	KM1	0.315
2	KM2	0.263
3	KM3	0.263
4	KM4	0.310
5	KM5	0.345
6	KM6	0.310
7	MZ1	0.250
8	MZ2	0.250
9	MZ3	0.370
10	MZ4	0.288
11	MZ5	0.325
12	MZ6	0.305
13	MR1	0.313
14	MR2	0.263
15	MR3	0.263
16	MR4	0.310
17	MR5	0.340
18	MR6	0.313
19	BK1	0.268
20	BK2	0.250
21	BK3	0.373
22	BK4	0.283
23	BK5	0.345
24	BK6	0.293
25	GD1	0.290
26	GD2	0.263
27	GD3	0.270
28	GD4	0.323
29	GD5	0.340
30	GD6	0.298
	Max.	0.373
	Min.	0.250
	Ave.	0.300
	ICRP Suggested Public Dose Limit	**1mSv/yr**

ELCR – Excess Life Cancer Risk (mSv/y)

Results of radiological hazard index for Excess Life Cancer Risk using Annual Effective Dose Rate (AEDR) from Table 4.4was also computed and the values ranges from 0.250mSv/y to 0.373mSv/y with a mean value of 0.300mSv/y less than the suggested public dose limit of 1mSv/y as suggested by ICR

Discussion

Results from this study shows that radionuclide activity concentrations in soil samples varied within the study area due to the differences in geological and topographical formations of the study area. The activity of ^{226}Ra,^{232}Th and ^{40}K ranges from 82.49Bq/Kg to 140.18Bq/Kg with an average value of 108.27Bq/Kg, 45.17Bq/Kg to 74.78Bq/Kg with an average value of 58.99Bq/Kg, 207.94Bq/Kg to 373.01Bq/Kg with an average value of 287.95Bq/Kg respectively. These findings reveal that the mean of ^{226}Ra,^{232}Th and ^{40}K in soil samples are all above the UNSCEAR's world standard except that of ^{40}K which is less than the world average.

Comparison of the action concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples collected at different sampling points from five selected mining locations in Yunusari Yobe State obtained in the mining sites with published data from similar investigations in Nigeria, Gabon, Egypt, china, japan and India and the UNSCEAR's world average were presented in table 4.9 above. Higher activity concentrations for 226Ra was determined by by Moundxa *et* al., (2018) in Gabon, while that of 232Th was determined by Mbet *et* al., (2019) and that of 40K was determined by Usikalu et al., (2017) and Mbet *et* al., (2018), in Nigeria. The average activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in from this study are higher than the world average (UNSCEAR, 2000b)

Results from the outcome of radiological hazard indices reveal that the values of Gamma Absorbed Dose Rate (D) ranges from 80.983nGh^{-1} to 121.167nGh^{-1}, with a mean value of 97.612nGh^{-1}which is above the world standard of 84nGy/h, Radium Equivalent Activity ranges from 173.906Bq/Kg to 2698.457Bq/Kg with a mean value of 214.090Bq/Kg below the world standard of 370Bq/Kg. External Hazard Index was also computed for the measured activity concentrations of 226Ra 232Th and 40K with values ranges from 0.2644mSv/y to 0.3830mSv/y with a mean value of 0.3200mSv/y which are below the recommended public dose of 1mSv/y as suggested by ICRP. Yearly Effective Dose Rate (AEDR) value ranges from 0.100mSv/y to 0.149mSv/y, with a mean value of 0.120mSv/y for below the suggested public dose limit of 1mSv/y as suggested by ICRP. Additional Life Cancer Risk value ranges from 0.250mSv/y to 0.373mSv/y with a mean value of 0.300mSv/y below the recommended public dose limit of 1mSv/y as suggested by ICRP

Conclusion

The action concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples from five designated mining locations in Yunusari Yobe State was determined using Sodium Iodide (NaI) detector system at the centre for Energy Research and Training (CERT) Laboratory, Ahmadu Bello University Zaria. The distribution of natural radionuclide in the soil samples from the research region is shown in the results. With the exception of 40K, whose average activity concentration is below the global normal, the study's mean activity concentrations for ^{226}Ra, ^{232}Th, and ^{40}K are all greater than the global normal values. Therefore, mining operations could endanger the host communities' radiological safety.

Recommendations

The following are made based on the outcomes of this research

i. Assess the radioactivity concentration throughout the entire Yobe State, including Yunusari Yobe State, in order to determine whether the proper government monitoring agencies should be in charge of regulating all mining activities to advance radiation safety and protection.

ii. Create a database of radioactivity concentration levels near mining sites in Yunusari Yobe State and throughout all of Yobe State for government and academic epidemiological research.

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