ASSESSMENT OF ACTIVITY CONCENTRATION OF RADIONUCLIDES IN SOIL AND CASSAVA FOOD CROP FROM SOLID MINERAL MINING SITE IN ISHIAGU, IVO L.G.A OF EBONYI STATE, NIGERIA

ABSTRACT

The assessment of activity of concentration of radionuclides in soil and food crops from solid mineral mining sites at Ishiagu, in Ivo L.G.A of Ebonyi State was carried out using the necessary measuring instruments. Samples of soil and cassava crop collected from around the mining sites. The samples were analysed using gamma ray spectrometry. The average activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples were 12.37,16.08, and 144.29 $Bqkg^{-1}$ while those for cassava were 2.81, 16.80, and 205.41 $Bqkg^{-1}$. The soil/plant radionuclide transfer ratio estimated are 0.62, 2.43 and 2.51 for ^{226}Ra, ^{232}Th and ^{40}K, respectively. All the radiological risk parameters estimated are relatively low. The result of this work showed that the obtained results for all samples were lower than the international accepted limit. Hence, from radiological health standpoint, the obtained values of effective doses may not pose significant threat to both human and the environment.

Keywords: Gamma Spectrometer, NaI(IT) detector, Radionuclides, Excess Lifetime Cancer Risk, Annual Gonadal Equivalent Dose.

INTRODUCTION

Generally speaking, man is exposed to radioisotopes from different sources, which can be generated either naturally or through man-made activities like mining [1]. Mining sites and its environs where heavy metal ores are extracted and may be processed has the potential of high radiation emission due to exposure of some certain radioactive substances. When harmful substances are introduced into the system and the environment becomes polluted, it affects man and his environment adversely [2]. When man eats foods from crops that are cultivated in an environment with high radionuclides concentration, it exposes man to radionuclide radiation [7]. Therefore, it is very important to have the knowledge of radionuclide radiation levels in food crops, which can help in determining the dosage received by man through food intake. The major ways radiation energy enter into the body are [14] by inhalation which has to do with the respiratory tracts. When the air in contaminated with radionuclide and is breathed in by people around, it goes into the respiratory and this cause inflammation and cancer of the lungs. It can also enter by Ingestion which concerned with the indirect absorption by consuming a

contaminated food or water. The effect is experienced mainly by destroying the digestive system. By Skin Absorption which the effects on the skin may include dermatitis corrosion, erythema, and sensitization and in severe cases could lead to skin cancer. When wounds are opened, the cells are exposed to air and if the air in that environment is contaminated with radionuclide, the wound will be affected and thus could lead to damage of the white blood cells. It is possible to determine the level of food crops contamination through the magnitude of radioactivity in soil, but it cannot be used to evaluate the effects of radiation exposure rate of food intake. The harzard indices are calculated to ascertain the health implication for consumption of such food. The rate at which these food are consumed and the amount of radionuclide content in these food crops determines the exposure rate. The danger related to the consumption of radionuclides in the body is equivalent to the sum of the dose delivered by radioisotopes while occupying different organs of the body. Usually, it is presumed that stochastic effects take place linearly with dose and in general the annual effective dose quantities are used to explain those risks when lengthened exposure in a person from a single consumption of a radioisotope is being weighed. Frequent mining activities of lead/zinc in Ishiagu exposes the people working in the site and people living around the area to great health danger. Crops like rice, cassava and maize are grown around there. These crops are harvested and consumed annually by the people, hence the need to ascertain the activity concentration of radioisotopes in the soil, determine soil to crop uptake and thereby ascertain the health effect on the people's contribute to the health and safety awareness of the people living in the area, contribute to research reservoir and to serve as radiation baseline of the area for future references

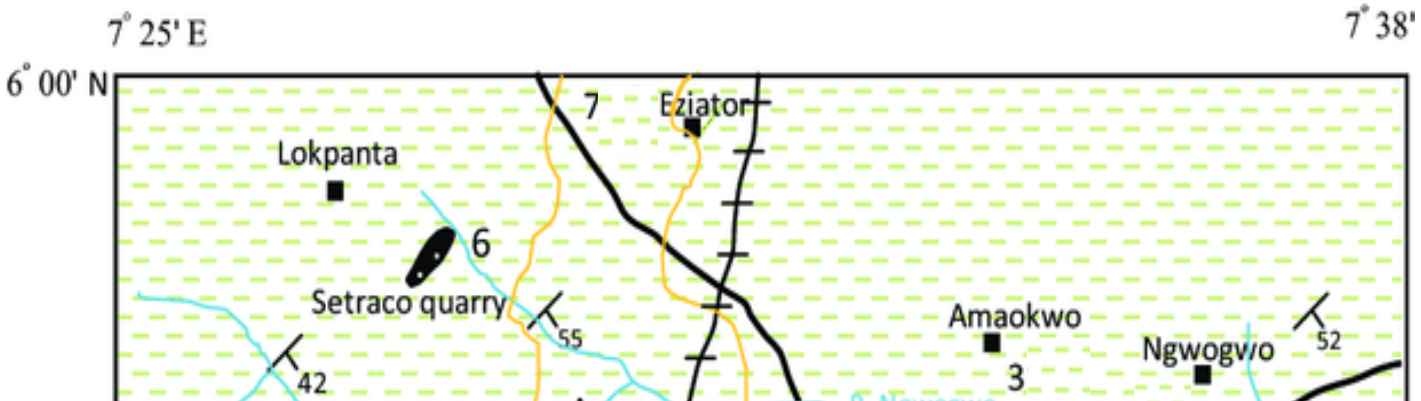

Figure 1: Map showing the study area [5]

MATERIALS AND METHODS

Study Area

Ishiagu village is situated in Ivo LGA of Ebonyi State. It is found between latitude 5°54' – 5°59' N and longitudes 7°30' – 7°35' E[8]. The area coverage 25 sq.km, is located in the south-west part of the Abakaliki Basin, in Eastern part of Nigeria and is comprised of a low-lying sedimentary terrain with some encroachment on different occurrences [8]. The Pb-Zn deposits in Ishiagu area appear to be the southern limit of mineralization in the Benue Trough and the Pb-Zn mineralized zone extends over a distance of 500 km in a narrow belt from Isiagu in the lower Benue Trough to Zurek in the upper Benue Trough, likewise the extent of igneous intrusions in the Benue Trough. Majority of the geologic and topographic features of the area align in the NW-SE direction, and conform to orientation of the folds from the Santonianorogenic deformation. Geologic model of Pb-Zn mineralization in Ishiagu. The sediments of lead/zinc in Ishiagu constitute the basic part of Benue Trough sedimentary basin development and the policies for exploring them must consider the relevant geological model. The Isiagu lead/zinc mineralization is credited to geological model formed on the geotectonic environment, the method of development and fluid inclusion features[5].

Samples collection and preparation

In order to assess the activity concentration of radionuclides in soil and food crops from solid mineral mining site in Ishiagu, Ebonyi State, global position system(GPS) was used for coordinate measurement and detector for analysis.

Fifteen (15) surface soil samples and fifteen (15) cassava roots were collected from the mining site for study. Specimens were taken 5cm below the surface because radionuclides find their way to the crops through their roots. The samples were placed inside labeled bags and sealed, processed and grinded and then transported to the laboratory for further processes. Soil and cassava were collected for analysis from 15 locations. (SND stands for sand while CAS stands

for cassava). The soil and cassava samples were later sealed in a well labeled black polythene bag to avoid cross contamination. The collected soil and cassava specimens were subjected to test in the Physics laboratory at Federal University of Agriculture, Abeokuta for specific activity concentration measurement.

Fifteen (15) samples of soil and cassava each were subjected to spectrometric analysis using sodium iodide NaI (TI) spectrometer.

The soil and cassava samples were prepared for gamma analysis by drying overnight in the electric oven at 115^{0C}. The samples were mechanically crushed and sieved through 0.8mm mesh sieve. The sieved portion of the sample was transferred into a 100ml Marinelli beaker for gamma spectrometry and sealed for four weeks to attain secular equilibrium between the uliradium contents of the samples and their decay product before analysis using the NaI (TI) gamma spectrometer. The NaI(TI) is a 2″×2″ Sodium iodide detector coupled to an ORTEC 456 digiBase multichannel analyzer (MCA). The digiBase is connected to a computer with a USB cable. Accumulation and analysis of the gamma-ray spectrum were carried out with the computer using the ORTEC Mestro Software. The counting (accumulation) time was 10800 seconds. The detector was installed in a 15cm thick cylindrical lead shield to reduce influence of background radiation.

The standard materials from the International Atomic Energy Agency (IAEA) were used for calibration. From the counting spectra, the activity concentrations of radium ^{226}Ra, thorium ^{232}Th and potassium ^{40}K was determined using the software [14].

Activity concentrations and radiological hazard parameter calculation

1. Effective Dose

Effective dose (that is the quantity of radiation dose) is the tissue-weighted sum of the equivalent doses in all specified tissues and organs of the body and represents the stochastic health risk, which is the probability of cancer induction and genetic effects of ionizing radiation delivered to those body parts. It takes into account the type of radiation and the nature of each organ or tissue being irradiated over a period of l year. This was calculated from the Alpha activity result.

The effective dose is given as[15]

$$DR_w = A_w \, x \, IR_w \, x \, 1DF \qquad (1)$$

Where;

DR_w is the effective dose (mSv),

A_w = activity ($Bq1^{-1}$)

IRw =intake of water for person in 1year (adult =730 liters) (infant =200 liters)

IDF = ingestion effective dose equivalent weighting factors $3.58x10^{-7}SvBq^{-1}$ [15].

These parameters are Radium equivalent activity, annual gonnadal equivalent dose, external hazard index, internal hazard index, representative gamma index, excess lifetime cancer exposure rate and the radiogenic heat production.

2. Radium Equivalent Activity

Radium equivalent (Ra compare the specific activities of materials containing by a quantity and responsible for the dangers that are linked with the measured radionuclide [3]. The index is very profitable in controlling safe allowable standards.

The radium equivalent activity equals a weighted sum of activities of natural radionuclides (Uranium, Thorium, Potassium) and is based on the estimation that l Bq/kg of ^{226}Ra, 0.7Bq/kg of ^{232}Th, and l3BqIkg of ^{40}K produce the same radiation dose rates.

The radium equivalent activity index is given below as [4];

$$\mathbf{Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_k} \quad \textbf{(2)}$$

Where; C_{Ra}, C_{Th}, C_K, are the radioactivity concentration in Bq/Kg of ^{238}U, ^{232}Th, and ^{40}K.

Every material whose Ra_{eq} concentration exceeds 37Bq/kg is strongly advised not to be used [9].

3. Annual Gonnadal Equivalent Dose (AGED)

Protecting the organs of the gonads, the bone marrow and the bone surface cells is of key importance to the radiation community [13]. The AGED is given as;

$$\mathbf{AGED\ (Sv/yr) = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_K} \quad \textbf{(3)}$$

Where C_{Ra}, C_{Th}, and C_K are the radioactivity concentration of ^{238}U, ^{232}Th, and ^{40}K.

4. External Hazard Index

Most radioisotopes naturally exist in terrestrial soils and rocks and upon decay, man is exposed to their environmental radiation field effect. In terms of the dose, the major primordial radioisotopes are ^{238}U, ^{232}Th, and ^{40}K [1].

The external hazard index (H_{ex}) can be calculated as [4].

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad \textbf{(4)}$$

Where C_{Ra}, C_{Th}, C_k are the radioactivity concentrations in Bq/Kg of ^{238}U, ^{232}Th, and ^{40}K respectively. The result obtained from the index must be lower than one for the radiation hazard to be insignificant. [4].

When the index is equivalent to one, it represents the upper limit of Raeq (370Bq/Kg) [4].

5. Internal Hazard Index'l

The internal hazard index (H_{in}) is calculated as [4].

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad \textbf{(5)}$$

H_{in} should be lower than one for the radiation hazard to be insignificant. Internal exposure to randon are extremely dangerous, this can lead to respiratory diseases like asthma and cancer.

6. Representative Gamma Index (l_{yr})

This is used to estimate the γ- radiation hazard associated with the natural radionuclide in specific investigated samples, [1]. The representative gamma index is given as .

$$H_{yr} = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \quad \textbf{(6)}$$

This gamma index is also used to correlate the annual dose rate due to the excess external gamma radiation caused by superficial materials [1]. This is a tool used to find out materials that might portray health problem when used for construction.

Values of $I_{yr} \leq 1$ is equivalent to an annual effective dose of less than or equal to lmSv, while $I_{yr} \leq 0.5$ is equivalent to annual effective dose less or equal to 0.3mSv [12].

7. Excess Lifetime Cancer Risk (ELCR)

This deals with the probability of developing cancer over a lifetime at a given exposure level. It is presented as a value representing the number of extra cancers expected in a given number of people on exposure to a carcinogen at a given dose. Excess lifetime cancer risk (ELCR) is given as [11].

ELCR=AEDE x DL x RF **(7)**

Where AEDE is the Annual Effective Dose Equivalent,

DL is average Duration of Life (70years), and

RF is the Risk Factor i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public [11].

8. Annual Effective Dose Equivalent (AEDE) For Outdoor

The annual effective dose equivalent received outdoor by a member is given as, [1]

AEDE (Outdoor) (μSv/y) = ADR (nGy/h) x 8760h x 0.7Sv/Gy x 0.2 x 10^{-3} **(8)**

This hazard index keeps control on the effects of radiation on reproductive organs.

9. Activity Utilization Index

This is the parametric model that enables us determine the dose rates in air of the radionuclides (K, Ra, Th) from the soil samples. This is given as, [10];

$$AUI = \frac{A_u}{50} XFu + \frac{A_{Th}}{20} XF_{Th} + \frac{A_K}{500} XF_k \quad \textbf{(9)}$$

Where, A_u, A_{Th} and A_k are activity concentration in Bq/kg for ^{238}U, ^{232}Th and ^{40}K.

F_u, F_{Th}, and F_k are the fractional contributions to the total dose rate in air due to gamma radiation from the actual concentrations of these radionuclides, [10]. The values of F_uF_{Th}, and F_x are given as 0.462, 0.604 and 0.041 for uranium, thorium and potassium respectively. Substituting the fractional contributions values, the equation becomes;

$$AUI = \frac{A_u}{50} X\ 0.462 + \frac{A_{Th}}{50} X\ 0.604 + \frac{A_K}{500} X\ 0.041 \quad \textbf{(10)}$$

AUI less than 2 corresponds to an annual effective dose of <0.3 mSv/y which is safe for the environment [10].

Estimation of soil-to-plant transfer factor (TF)

IAEA has already approved a procedure mapped out for protocol developed by the Working Group of International Union of Radio ecologists for standardizing the rooting depth to describe soil to plant transfer factor. A generally acceptable soil layer was accepted in this work. For grass, this soil depth value is 10 cm and for all other crops (including fruit trees) it is assumed as 20 cm. Using [6] guidelines, the soil-to-plant transfer factor TF was estimated as:

$$TF = \frac{C_p}{C_a} \quad \textbf{(11)}$$

where C p = radionuclide concentration in plant (Bqkg^{-1}) and Ca = radionuclide concentration in soil (Bqkg^{-1}) .

RESULTS

The results of the activity concentrations of radionuclides ^{40}K, ^{226}Ra and ^{232}Th in soil are presented in Table 1. While the comparison of the calculated radiation hazard indices with standards are presented in Table 4. The soil/plant transfer ratio is presented in Table 5.

Table 1. Radionuclide Concentration on Soil

		Activity concentration (BqKg^{-1})		
S/N	**Location**	**^{40}K**	**^{226}Ra**	**^{232}Th**
1	SND1	447.27	12.59	7.38
2	SND2	30.57	22.72	30.57
3	SND3	378.12	3.18	26.13
4	SND4	34.21	BDL	29.35
5	SND5	70.60	16.47	16.91
6	SND6	125.19	2.61	17.22
7	SND7	185.24	4.78	13.32
8	SND8	113.28	9.12	16.06
9	SND9	66.96	20.70	14.47
10	SND10	190.70	19.11	6.77
11	SND11	48.77	8.39	11.11
12	SND12	68.78	24.17	13.01
13	SND13	161.58	9.97	19.66
14	SND14	88.80	6.22	15.15
15	SND15	154.31	3.18	4.03
	Mean	144.29	12.37	16.08
	UNSCEAR (2000)	400	35	30

BDL = Below Detectable Level

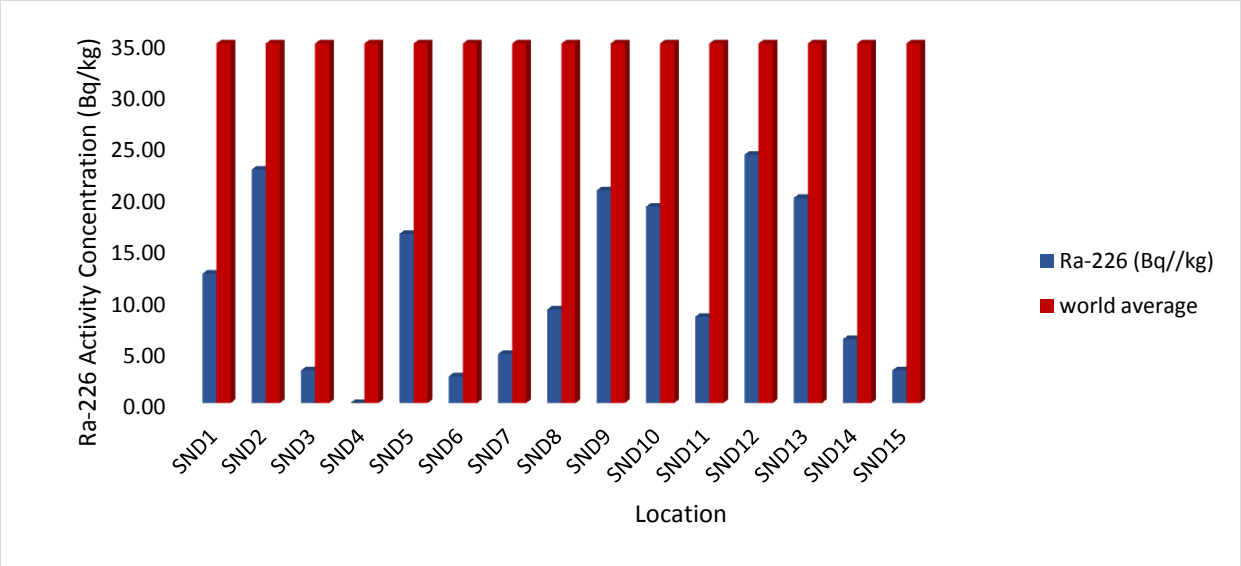

Fig. 2. Radionuclide Concentration on Soil

Table 2. Radionuclide concentration in Cassava

		Activity concentration ($BqKg^{-1}$)		
S/N	**Location**	**^{40}K**	**^{226}Ra**	**^{232}Th**
1	CAS1	411.10	BDL	24.61
2	CAS 2	131.41	15.98	20.14
3	CAS 3	255.72	BDL	39.87
4	CAS 4	161.01	BDL	19.53
5	CAS 5	140.29	BDL	BDL
6	CAS 6	159.53	BDL	23.19
7	CAS 7	78.14	BDL	BDL
8	CAS 8	184.69	BDL	6.22
9	CAS 9	499.89	11.68	32.34
10	CAS 10	138.81	BDL	39.46
11	CAS 11	424.42	BDL	4.27
12	CAS 12	121.05	14.44	0.81
13	CAS 13	124.01	BDL	BDL
14	CAS 14	137.33	BDL	BDL
15	CAS 15	109.21	BDL	41.50
	Mean	205.41	2.81	16.80

BDL = Below Detectable Level

Table 4. Hazard Indices

Location	Raeq (Bq/Kg)	Iγ ($mSvy^{-1}$)	Hex ($mSvy^{-1}$)	Hin ($mSvy^{-1}$)	D ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	Gonadal (μSvy^{-1})	ELCR x 10^{-3}	AUI ($mSvy^{-1}$)
SND1	492.27	0.46	0.16	0.19	29.05	0.04	0.21	0.09	0.56
SND2	76.64	0.48	0.19	0.25	30.76	0.04	0.21	0.09	0.60
SND3	444.61	0.53	0.19	0.20	33.47	0.04	0.24	0.10	0.65
SND4	78.82	0.32	0.12	0.12	19.65	0.02	0.13	0.06	0.38
SND5	100.22	0.33	0.12	0.17	21.06	0.03	0.14	0.06	0.41
SND6	159.45	0.27	0.10	0.11	17.11	0.02	0.12	0.05	0.33
SND7	218.55	0.29	0.10	0.12	18.20	0.02	0.13	0.06	0.35
SND8	144.97	0.30	0.11	0.13	18.91	0.02	0.13	0.06	0.37
SND9	92.81	0.33	0.13	0.18	21.34	0.03	0.15	0.07	0.42
SND10	215.06	0.32	0.12	0.17	20.98	0.03	0.15	0.06	0.41
SND11	68.41	0.20	0.08	0.10	12.81	0.02	0.09	0.04	0.25
SND12	92.69	0.34	0.13	0.20	22.12	0.03	0.15	0.07	0.44
SND13	202.13	0.44	0.16	0.22	28.17	0.03	0.19	0.09	0.55
SND14	117.30	0.25	0.09	0.11	15.98	0.02	0.11	0.05	0.31
SND15	171.95	0.16	0.06	0.06	10.41	0.01	0.08	0.03	0.20
Mean	178.39	0.33	0.12	0.15	21.34	0.03	0.15	0.07	0.42
UNSCEAR (2000)	370	1	1	1	60	1	0.30	0.29	1

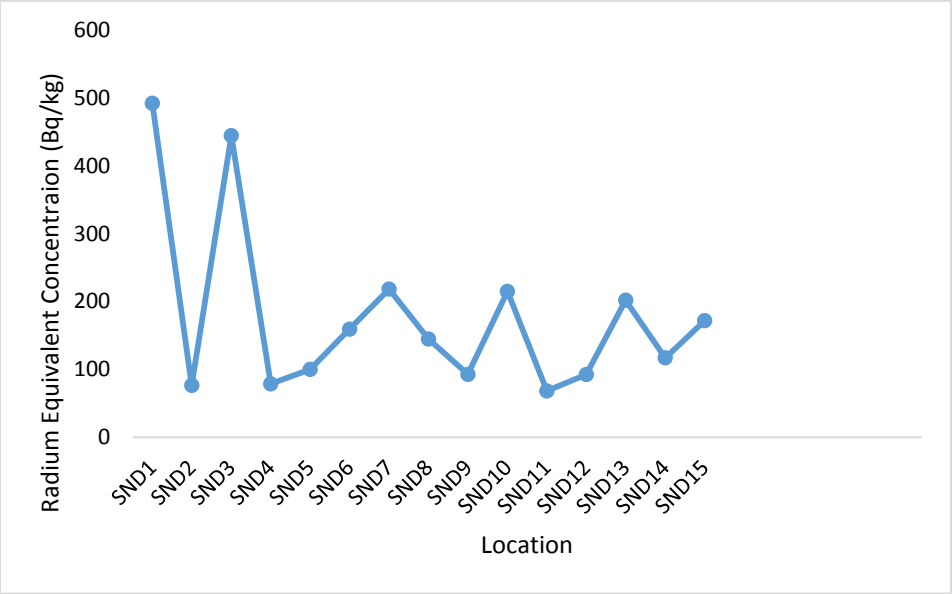

Fig. 3. Comparison of Radium Equivalent concentration in with all the location.

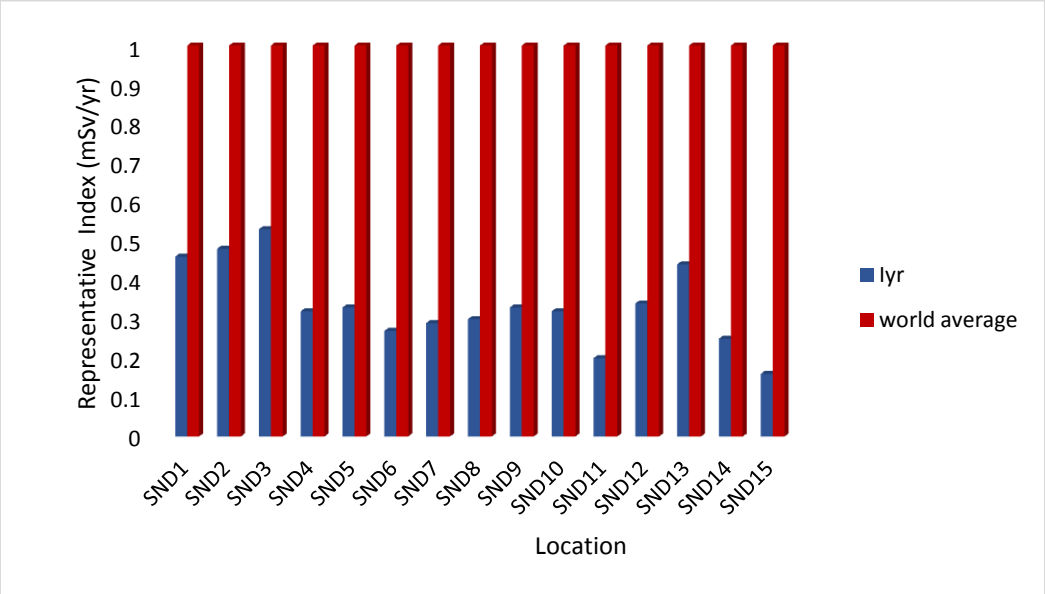

Fig. 4. Comparison of Gamma index in Soil with world average in all the locations.

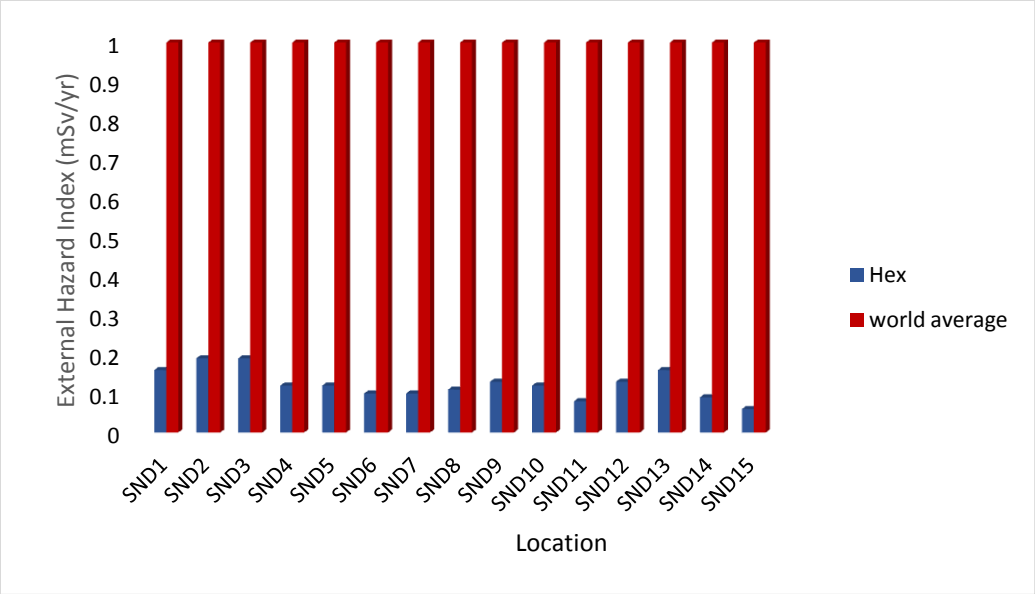

Fig. 5. Comparison of external hazard index in Soil with world average in all the locations.

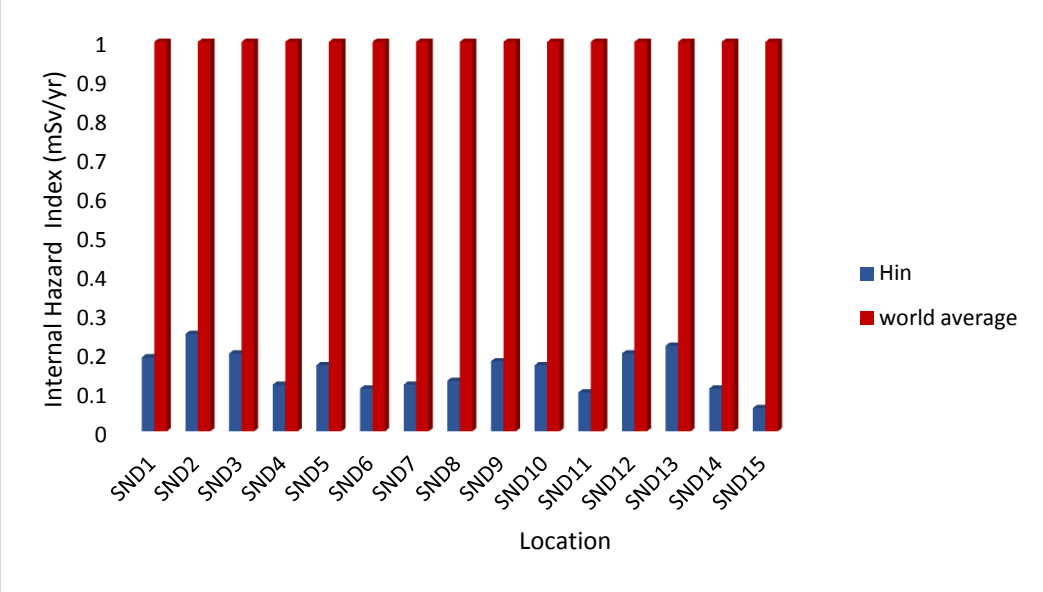

Fig. 6. Comparison of internal hazard index in Soil with world average in all the locations.

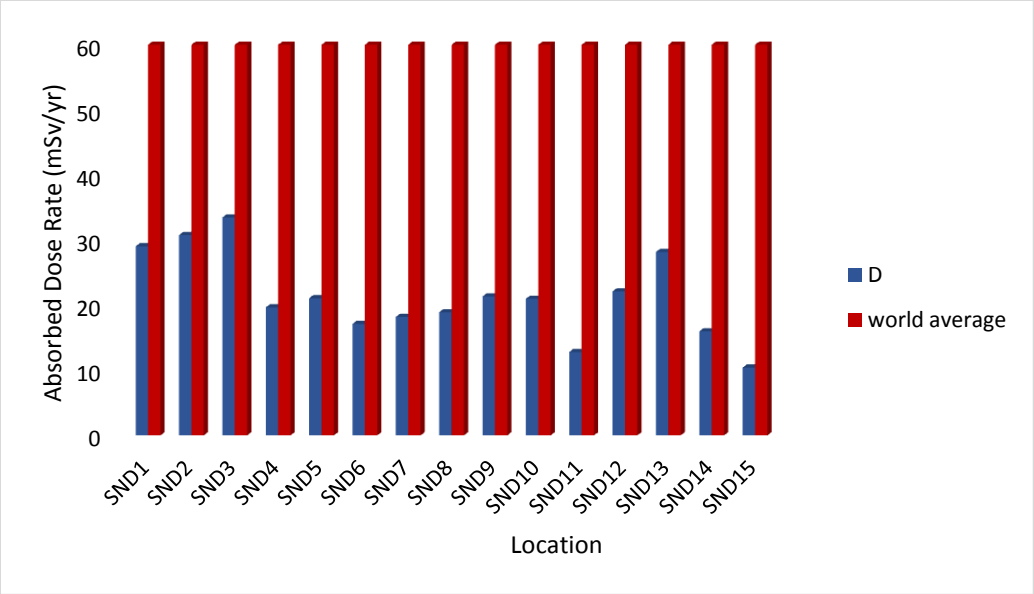

Fig. 7. Comparison of Absorbed Dose Rate in Soil with world average in all the locations.

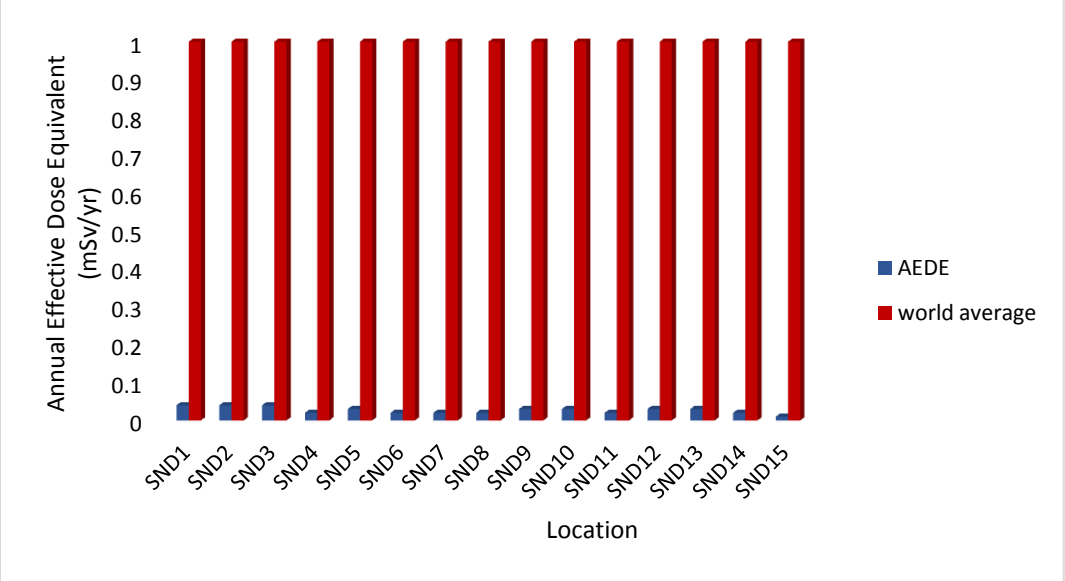

Fig.8 Comparison of Annual effective dose equivalent in Soil with world average in all the locations.

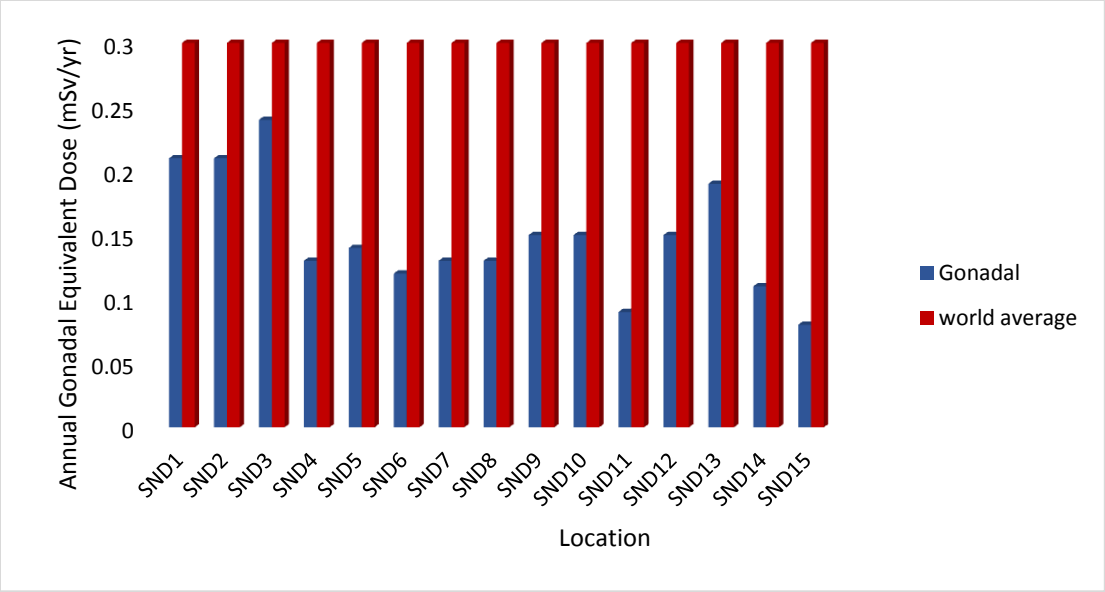

Fig. 9. Comparison of annual gonadal equivalent dose in Soil with world average in all the locations.

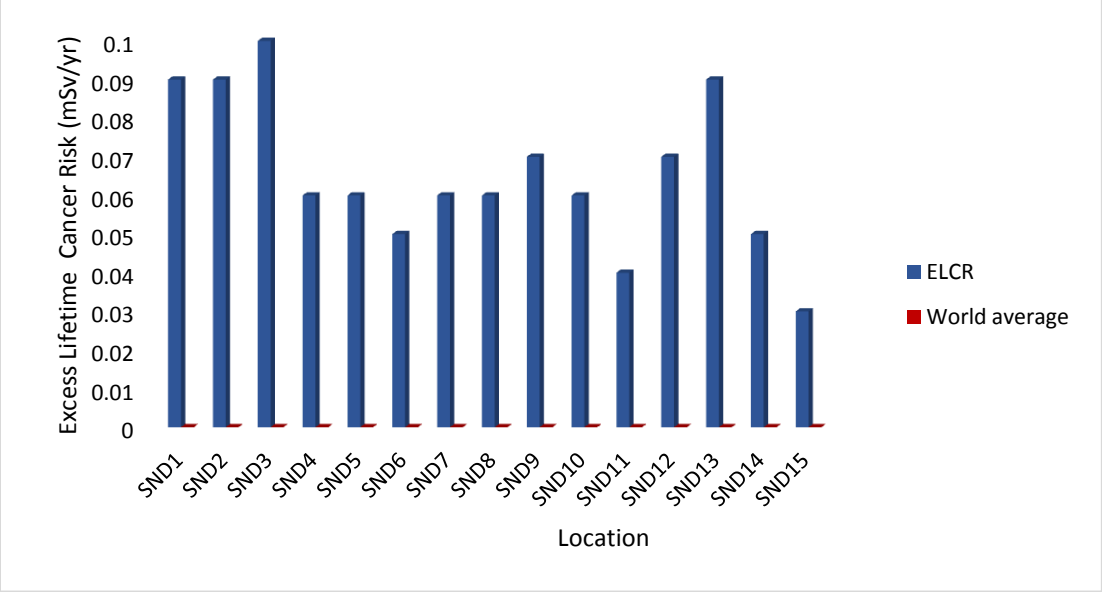

Fig.10. Comparison of excess life cancer risk in Soil with world average in all the locations.

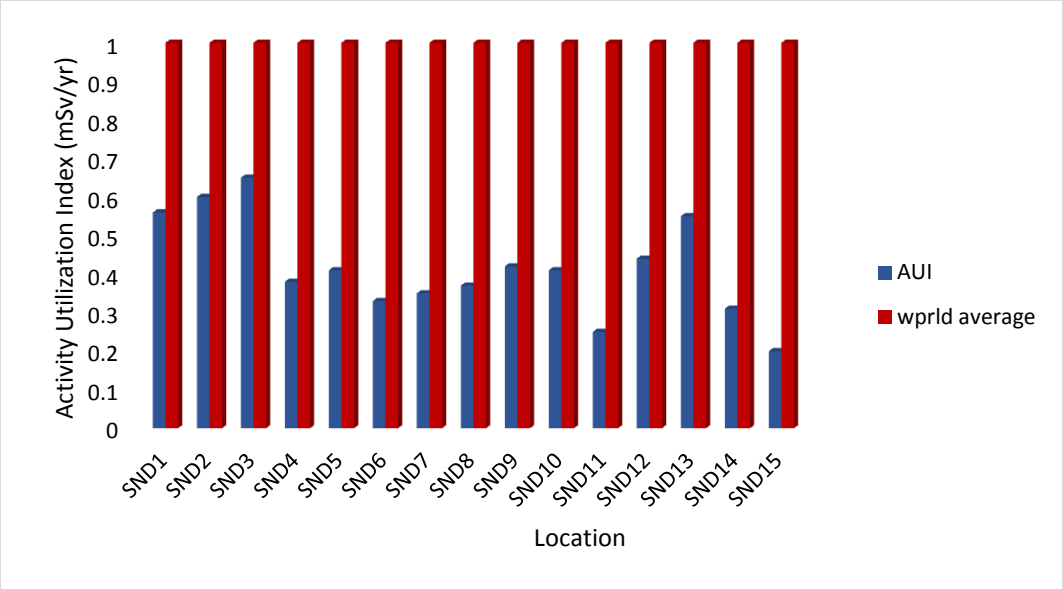

Fig. 11 Comparison of Activity utilization index in Soil with world average in all the location.

Table 5: Soil /plant transfer ratio

Location	Plant	T/F (^{40}K)	T/F (^{226}Ra)	T/F (^{232}Th)
SND1	CAS1	0.92	BDL	3.33
SND2	CAS2	4.30	0.703086	0.66
SND3	CAS3	0.68	BDL	1.53
SND4	CAS4	4.71	BDL	0.67
SND5	CAS5	1.99	BDL	BDL
SND6	CAS6	1.27	BDL	1.35
SND7	CAS7	0.42	BDL	BDL
SND8	CAS8	1.63	BDL	0.39
SND9	CAS9	7.47	0.564095	2.24
SND10	CAS10	0.73	BDL	5.83
SND11	CAS11	8.70nhb	BDL	0.38
SND12	CAS12	1.76	0.597429	0.06
SND13	CAS13	0.77	BDL	BDL
SND14	CAS14	1.55	BDL	BDL
SND15	CAS15	0.71	BDL	10.30
AVERAGE		**2.51**	**0.62**	**2.43**

BDL = Below Detectable Level

Discussion

The mean activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in soil from the studied area are 144.29 $Bqkg^{-1}$, 12.37 $Bqkg^{-1}$ and 16.08 $Bqkg^{-1}$ respectively. The largest contribution of the overall activity concentration in soil comes mainly from ^{40}K. The obtained mean values in soil of ^{40}K, ^{226}Ra and ^{232}Th, when compared with standard value limit of Thorium (30 $Bqkg^{-1}$), Radium (35 $Bqkg^{-1}$) and Potassium (400 $Bqkg^{-1}$) [14] is below the standard limit.

Leonid and Najat (2014), carried out a research on Minjingu phosphate mining area, in Tanzania, and determined the radionuclide present in maize and Mung Beans. They discovered that the activity concentration of ^{226}Ra ,^{228}Th and ^{40}K in these food products using spectrometry. The average level of radioisotope present in the food specimen were calculated to be 21.01 Bq/Kg(mung beans), 25.6 Bq/Kg (maize) for ^{226}Ra , 62.6 Bq/kg (mung beans), 72.9 Bq/kg (maize) for ^{228}Th and 542.9 Bq/kg (mung beans), 434.6 Bq/kg (maize) for ^{40}K. The radionuclide content of the maize and mung beans from Minjingu area and that of Bukombe zone in Geita Region both in Tanzania were compared, and the results shows that the radioactivity of the specimen in Minjingu area were higher. The sum of annual effective dose of 2.003 ± 0.044 mSv/year for intake of ^{226}Ra and ^{228}Th by adults was determined. This result is greater than the annual dose limit of 1 mSv/year approved by the International Commission on Radiological Protection (ICRP) for the public. To this effect, it can be summarized that minjingu populace might face health challenge due to high level of radiation dose from these crops.

The representative index, external hazard index, internal hazard index and annual effective dose equivalent AEDE (outdoor) in soil samples are calculated. The obtained results are as shown in Table 4. When compared with [13] standard of allowable limit of 1.0 $mSvy^{-1}$ for soil, it is observed that the obtained results for all samples are lower than the international accepted limit.

Hence, from radiological health standpoint, the obtained values of effective doses may not pose significant threat to both human and the environment.

Conclusion

The assessment of activity concentration of radionuclides in soil and food crops from solid mineral mining sites in Ishiagu, Ebonyi State, Nigeria has been carried out

The soil to plant average transfer ratio calculated of ^{40}K, ^{226}Ra and ^{232}Th were 2.5, 0.6 and 2.43 respectively. The transfer ratio in ^{40}K was higher in majority of the location samples than the ones obtained from ^{226}Ra and ^{232}Th. This result may not be unconnected with the fact that ^{40}K have accumulated from the soil through the root uptake over a long time.

The analysis of activity concentration of radionuclides presence in soil was also carried out. The radionuclides identified in the soil are ^{226}Ra, ^{232}Th and ^{40}K. The radiation hazard indices were obtained from the measured radionuclide concentration and the results in all showed that the activity concentration were lower than the world average. The values were 12.37, 16.08 and 144.29 for are ^{226}Ra, ^{232}Th and ^{40}K respectively as against 35, 30 and 400 world average [14].

Competing Interests Disclaimer

Authors have declared that no competing interest exist. The product used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and the producers of the products because we do not intend to use these products as an avenue for any litigation but for advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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