

EVALUATION OF SPECIFIC ACTIVITY CONCENTRATION OF ^{238}U , ^{232}Th AND ^{40}K AND THEIR RADIOLOGICAL IMPACT IN SOIL AND RICE GRAINS FROM SOLID MINERAL MINING SITES IN IKWO LOCAL GOVERNMENT AREA OF EBONYI STATE, NIGERIA.

ABSTRACT

The evaluation of specific activity concentration of ^{238}U , ^{232}Th and ^{40}K in soil and rice grains from solid mineral mining sites in Ikwo local government area of Ebonyi state was carried out using a Digilert-200 Radiation Meter. The radiological impact of the radionuclides was calculated. The average values of radionuclides obtained were 170.53, 9.26 and 8.81 (in Bq/Kg) for ^{40}K , ^{238}U and ^{232}Th respectively in soil samples and 113.77, 5.86 and 7.08 (in Bq/Kg) for ^{40}K , ^{238}U and ^{232}Th respectively in rice grain. These values are below the world permissive value of 400, 35 and 30 (in Bq/Kg) respectively. All the health risk parameters calculated in soil and rice were below world permissive values. For the radionuclides in rice samples, the average annual committed effective doses (in mSv/y) for ages (<1 year), (1 – 7 years), (7 – 12 years), (12 – 17 years) and (>17 years) are 0.37, 0.05, 0.04, 0.03, 0.02 respectively. These results are less than the world permissive value of 1.00 mSv/y. Generally, the study shows that rice consumption was relatively safe radiologically with little contamination which could be attributed to human activities but there is tendency for long term health hazards in future such as cancer due to doses accumulated. It is recommended that various human activities that raise the activity concentration in soil in Ikwo mining area should be reduced. The activity concentration of radionuclides level in the area should be periodically assessed

Key words: activity concentration, health risk parameters, solid mineral mining sites in Ikwo L.G.A.

1.0 INTRODUCTION

Primordial isotopes of ^{226}Ra , ^{238}U , ^{232}Th and ^{40}K are the main sources of external radiation on earth (UNSCEAR, 2000). Man is exposed to radioisotopes from different sources, which can be generated either naturally or through manmade activities like mining. Mining sites and its environs where heavy metal ores are extracted and may be processed have the potential of high radiation emission due to exposure of some certain radioactive substances (Mgbeokwere et al., 2021). The continuous extraction and Processing of Lead / Zinc solid minerals in Ikwo Local Government Area of Ebonyi state enhances the environment radioactivity of the area. The advent of excavation and other human activities coupled with poor environmental management systems have resulted to the release of various forms of toxic, corrosive and radioactive contaminants or pollutants into the environment. When harmful substances are introduced into the system and the environment becomes polluted, it affects man and his environment adversely (Avwiri et al., 2013). Ikwo is a local government area where mining, farming and education are their major occupation. These include lead/zinc mining and cultivation of farm products. Rice is produced mainly in Ikwo Local Government Area of Ebonyi State. Other crops produced in the state are yam, cassava, maize, groundnut, cocoyam, sweet potato, plantain, banana, oil palm and melon. Rice is considered the world's third largest crop, which plays a significant role in human nutrition (Proshad et al., 2019). It is an important source of energy, vitamins, minerals and amino acids for its consumers around the world. Some researchers estimated that rice is supplying almost half of the daily calories of the world population. . One of the critical food for determining the intake of radionuclides by humans is rice, which is the dominant staple food crop in humid tropical countries across the globe (Uchida et al., 2009). Soil is the unconsolidated mineral on the surface of the earth that serves as a natural medium for plant growth (Imran et al., 2010). It is

the main reservoir of plant nutrients and water. These radionuclides, along with essential nutrients, may be absorbed from the soil via plant roots and transported to other parts of the plant. The ubiquitous and persistence nature of natural radionuclides in soil is the starting point of food contamination. It has been investigated that the content of radionuclides in the food chain has a direct linear correlation with that of the soil where they were grown (Ugbede et al.,2021) While it is known that the radionuclides make their way into the soil through natural processes , agricultural practices have continued to make substantial additions to the radionuclides contents of the cultivated soil, thus leading to elevated levels in the soil and consequent transfer to plants. 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(Ugbede et al,2021). The hazard indices are calculated to ascertain the health implication for consumption of such food. The United Nation's advocacy against the consumption of food contaminated with radionuclides has motivated various authors in the field of environmental radioactivity to continuously assess the health impact of radionuclides in various food matrices across the globe. Therefore, the present study is aimed at evaluation of specific activity concentration of ^{238}U , ^{232}Th and ^{40}K and their radiological impact in soil and rice grains from solid mineral mining sites in Ikwo local government area of Ebonyi state, Nigeria.

2.0 THE STUDY AREA

The study area is located in Ikwo Local Government Area of Ebonyi State in South Eastern Nigeria. The area lies within Longitude $8^{\circ}00'E - 8^{\circ}20'E$ and Latitude $6^{\circ}00'N - 6^{\circ}20'N$ (Ande et al.,2016). Ikwo is the largest local government area in Ebonyi State. The nature of activities in the study area includes but not limited to the following; excavation of solid minerals like lead/zinc, salt and limestone , farming of rice,cassava,yam,groundnut and cocoyam.

3.0 MATERIALS AND METHODS

3.1 Sample Collection

Samples were collected in five (5) different farm fields located around the mining area. At each farmland, soil samples and corresponding rice grains samples were collected. Twenty five (25) surface soil samples and twenty five (25) rice grains samples were collected from five different rice farms in Ikwo local government (five soil and five rice samples from each farm). The soil samples were collected using a hand trowel tool to a depth of about 150mm with each spot separated far enough from each other. 5g of soil from each spot was taken from the field. The soil and rice grain samples collected were packaged separately in a cellophane bag well labelled, it was taken to the laboratory for analysis (Ibikunle et al., 2019)

3.2 Sample Preparation

The soil samples and their corresponding rice grain samples were transferred into a polythene bag and taken for preparation at the radiation Physics laboratory, University of Ibadan, Nigeria (Ibikunle et al., 2019). Each soil sample from each spot was mixed thoroughly as a composite sample that is representative of the spot. Extraneous materials like plant materials, roots, pebbles were removed from the soil samples. The samples were then separately dried at 110°C in a temperature controlled oven until there was no detectable change in the mass of the samples. The dried soil samples were thoroughly crushed, grounded and pulverized to powder. The powder was passed through a 2 mm sieve. Due to the limited space of the detector shield only 200g of the soil samples (dry weight) were used for analysis since, this is the quantity it could conveniently take. The samples after weighing were transferred to radon-impermeable cylindrical plastic containers of uniform size (60 mm height by 65 mm diameter) and were sealed for a period of about 30 days. This was done in order to allow for Radon and its short-lived progenies to reach secular radioactive equilibrium prior to gamma

spectroscopy(Ocheje&Tyovenda, 2020).The samples were analysed using NaI (TI) detector (Model No. 80 series, Canberra Inc.) at NNRA, Ibadan Nigeria,(Ugbede et al., 2021). The instrument setting and operational conditions were done in accordance with the manufacturers' specifications. The activity concentration of Uranium ^{238}U , thorium ^{232}Th and potassium ^{40}K was determined using the software. The radiological health risk parameters were calculated from the activity concentration values (Ilemona et al., 2016).

3.3Radiological Hazard Parameters

Radiation models are used to determine the radiological health risk parameters.These parameters are absorbed dose, annual effective dose equivalent and excess life cancer risk, annual gonadal equivalent dose, external hazard index, internal hazard index and representative gamma index.

(i)Absorbed Dose Rate (D)

This is known as the amount of energy that will be impacted by radiation to a unit mass of an irradiated matter. The absorbed dose (D) as a result of gamma radiation in air at 1 m above than ground surface for the even distribution of the radionuclides (^{238}U , ^{232}Th and ^{40}K) Occurring naturally are calculated using the equation by Avwiri et al., (2013);

$$D (\text{nGyh}^{-1}) = 0.427C_{\text{U}} + 0.662C_{\text{Th}} + 0.0432C_{\text{K}} \quad (1)$$

Where C_{U} , C_{Th} and C_{K} are the activity concentrations of ^{238}U , ^{232}Th and ^{40}K respectively.

(ii)Annual Effective Dose Equivalent (AEDE)

The computed absorbed dose rates were used to calculate the Annual Effective Dose Equivalent (AEDE) received by the mining workers or farmers. In calculating AEDE, dose conversion factor of 0.7 Sv/Gy and the occupancy factor for outdoor of 0.25 (6 h out of 24 h)

was used. The occupancy factor for outdoor was calculated based upon interviews with traders. People of the study area spend almost 6 h outdoor due to the nature of their routine. The Annual Effective Dose was estimated using the following relation (Ononugbo&Anakwe, 2020):

$$\text{AEDE (Outdoor) (mSv/y)} = \text{ADR (nGy/h)} \times 8760\text{h} \times 0.7\text{Sv/Gy} \times 0.2 \quad (2)$$

(iii) Excess Life Cancer Risk (ELCR)

The annual effective dose calculated was used to estimate the Excess Lifetime Cancer Risk (ELCR) using Equation:

$$\text{ELCR} = \text{AEDE} \times \text{Average duration of life DL} \times \text{Risk factor RF} \quad (3)$$

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 (Taskin et al., 2009).

(iv) Annual Gonadal 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 (Ugbede et al., 2021). The AGED is given as;

$$\text{AGED (sv/yr)} = 3.09C_u + 4.18C_{Th} + 0.314C_k \quad (4)$$

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

(v) Representative Gamma Index (I_{yr})

This is used to estimate the γ - radiation hazard associated with the natural radionuclide in specific investigated samples, (Avwiri *et al.*, 2012). The representative gamma index is given as.

$$I_{yr} = \frac{C_U}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \quad (5)$$

This gamma index is also used to correlate the annual dose rate due to the excess external gamma radiation caused by superficial materials (Avwiri *et al.*, 2013). 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 1mSv/y, while $I_{yr} \leq 0.5$ is equivalent to annual effective dose less or equal to 0.3mSv.

(vi) Activity Utilization Index

This is the parametric model that enables us determine the dose rates in air of the radionuclides (K, U, Th) from the soil samples. This is given as, (Ugbede, *et al.*, 2021);

$$AUI = \frac{A_u}{50} XF_u + \frac{A_{Th}}{20} XF_{Th} + \frac{A_K}{500} XF_k \quad (6)$$

Where, A_u , A_{Th} and A_k are activity concentration in Bq/kg for ^{234}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 (Sivakumar, *et al.*, 2014). The values of F_u , F_{Th} , and F_k are given as 0.462, 0.604 and 0.041 for uranium, thorium and potassium respectively. Substituting the fractional contributions values, the equation becomes;

$$AUI = \frac{A_u}{50} \times 0.462 + \frac{A_{Th}}{50} \times 0.604 + \frac{A_K}{500} \times 0.041 \quad (7)$$

AUI less than 2 corresponds to an annual effective dose of <0.3 mSv/y which is safe for the environment (Ugbede et al., 2021).

(vii) Annual Committed Effective Dose (ECED)

Committed effective dose is a measure of the total effective dose received over a lifetime (70years) following intake of a radionuclide (internal exposure) (WHO, 2008). In this work, the committed effective dose over one year in crop sample (rice grain) was calculated for different age brackets using the following relation (Darwish et al., 2015).

$$E = IAC \times 365 \quad (8)$$

Where I is the daily crop (rice) consumption in kg per day, A is the activity concentration in Becquerel per kg (Bqkg⁻¹) and C is the dose conversion factor in Sv/Bq.

4.0RESULTS

The specific activity concentration of ⁴⁰K, ²³⁸U and ²³²Th with their radiological health risk parameter in soil and rice are presented in Tables 1 to 10. Tables 11 to 13 are the annual committed effective doses for radionuclides ⁴⁰K, ²³⁸U and ²³²Th respectively for different age brackets. Table 14 is the total annual committed effective dose of the three radionuclides. The graphical comparison of the specific activity concentration of ⁴⁰K, ²³⁸U and ²³²Th in soil and rice respectively with their standard values are presented in Figures 1 to 6.

Table 1: Specific Activity Concentration of ^{40}K , ^{238}U and ^{232}Th in Soil Samples From Farm 1 with their Radiological Health Risk Parameters

S/N	Sample Code	^{40}K (Bq/Kg)	^{238}U (Bq/Kg)	^{232}Th (Bq/Kg)	I_y	AGED (mSv/y)	AUI (uSv/y)	D (nGy/h)	AEDE (mSv/y)	ELCR $\times 10^{-3}$
1	S11	214.37	1.37	5.52	0.23	94.62	0.26	13.50	0.02	0.06
2	S12	163.39	18.6	7.22	0.55	138.96	0.39	19.78	0.02	0.08
3	S13	144.27	3.53	6.03	0.23	81.41	0.22	11.73	0.01	0.05
4	S14	6.56	2.05	8.49	0.13	43.88	0.13	6.78	0.01	0.03
5	S15	138.58	2.36	6.65	0.21	78.60	0.22	11.40	0.01	0.05
AVERAGE		133.43	5.58	6.78	0.27	87.49	0.24	12.64	0.01	0.05
ICRP, 2003		400.00	35.00	30.00	1.00	300.00	1.00	84.00	1.00	0.29

Note : S11 means Soil sample in Farm 1 ,Position 1

Table 2: Specific Activity Concentration of ^{40}K , ^{238}U and ^{232}Th with their Radiological Health Risk Parameters on Soil Samples From Farm 2

S/N	Sample Code	^{40}K (Bq/Kg)	^{238}U (Bq/Kg)	^{232}Th (Bq/Kg)	I_y	AGED (mSv/y)	AUI (uSv/y)	D (nGy/h)	AEDE (mSv/y)	ELCR $\times 10^{-3}$
1	S21	114.85	13.78	6.65	0.42	106.44	0.30	15.25	0.02	0.07
2	S22	214.64	7.55	9.87	0.39	131.98	0.36	19.03	0.02	0.08
3	S23	73.93	6.42	11.17	0.29	89.74	0.25	13.33	0.02	0.06
4	S24	127.53	3.54	10.54	0.26	95.04	0.26	13.99	0.02	0.06
5	S25	174.07	9.13	9.68	0.40	123.33	0.34	17.83	0.02	0.08
AVERAGE		141.00	8.08	9.58	0.35	109.31	0.30	15.89	0.02	0.07
ICRP, 2003		400.00	35.00	30.00	1.00	300.00	1.00	84.00	1.00	0.29

Table 3: Specific Activity Concentration of ^{40}K , ^{238}U and ^{232}Th with their Radiological Health Risk Parameters on Soil Samples From Farm 3

S/N	Sample Code	^{40}K (Bq/Kg)	^{238}U (Bq/Kg)	^{232}Th (Bq/Kg)	I_y	AGED (mSv/y)	AUI (uSv/y)	D (nGy/h)	AEDE (mSv/y)	ELCR $\times 10^{-3}$
1	S31	233.82	8.80	10.21	0.43	143.29	0.40	20.62	0.03	0.09
2	S32	154.97	9.51	12.59	0.42	130.67	0.37	19.09	0.02	0.08
3	S33	286.19	5.1	9.09	0.38	143.62	0.39	20.56	0.03	0.09
4	S34	89.41	14.02	7.34	0.41	102.08	0.29	14.71	0.02	0.06
5	S35	139.57	3.05	9.47	0.25	92.83	0.26	13.60	0.02	0.06
AVERAGE		180.79	8.09	9.74	0.38	122.49	0.34	17.72	0.02	0.08
ICRP, 2003		400.00	35.00	30.00	1.00	300.00	1.00	84.00	1.00	0.29

Table 4: Specific Activity Concentration of ^{40}K , ^{238}U and ^{232}Th with their Radiological Health Risk Parameters on Soil Samples From Farm 4

S/N	Sample Code	^{40}K (Bq/Kg)	^{238}U (Bq/Kg)	^{232}Th (Bq/Kg)	I_y	AGED (mSv/y)	AUI (uSv/y)	D (nGy/h)	AEDE (mSv/y)	ELCR $\times 10^{-3}$
1	S41	257.52	20.37	14.25	0.72	266.17	0.74	37.89	0.05	0.16
2	S42	205.09	13.92	11.93	0.53	157.28	0.44	22.70	0.03	0.10
3	S43	87.87	8.62	10.94	0.34	99.96	0.28	14.72	0.02	0.06
4	S44	224.60	14.13	9.75	0.53	154.94	0.43	22.19	0.03	0.10
5	S45	147.71	10.22	3.68	0.34	93.34	0.26	13.18	0.02	0.06
AVERAGE		184.56	13.45	10.11	0.49	154.34	0.43	22.14	0.03	0.09
ICRP, 2003		400.00	35.00	30.00	1.00	300.00	1.00	84.00	1.00	0.29

Table 5: Specific Activity Concentration of ⁴⁰K, ²³⁸U and ²³²Th with their Radiological Health Risk Parameters on Soil Samples From Farm 5

S/N	Sample Code	40K (Bq/Kg)	238U (Bq/Kg)	232Th (Bq/Kg)	Iy	AGED (mSv/y)	AUI (uSv/y)	D (nGy/h)	AEDE (mSv/y)	ELCR x 10 ⁻³
1	S51	147.02	5.97	6.07	0.28	89.98	0.25	12.92	0.02	0.06
2	S52	173.82	9.94	8.46	0.40	120.66	0.34	17.35	0.02	0.07
3	S53	141.74	4.56	8.07	0.27	92.33	0.26	13.41	0.02	0.06
4	S54	210.57	19.67	7.81	0.61	159.55	0.45	22.66	0.03	0.10
5	S55	191.13	15.29	8.72	0.52	143.71	0.40	20.56	0.02	0.10
AVERAGE		172.86	11.09	7.83	0.42	121.25	0.34	17.38	0.02	0.08
ICRP, 2003		400.00	35.00	30.00	1.00	300.00	1.00	84.00	1.00	0.29

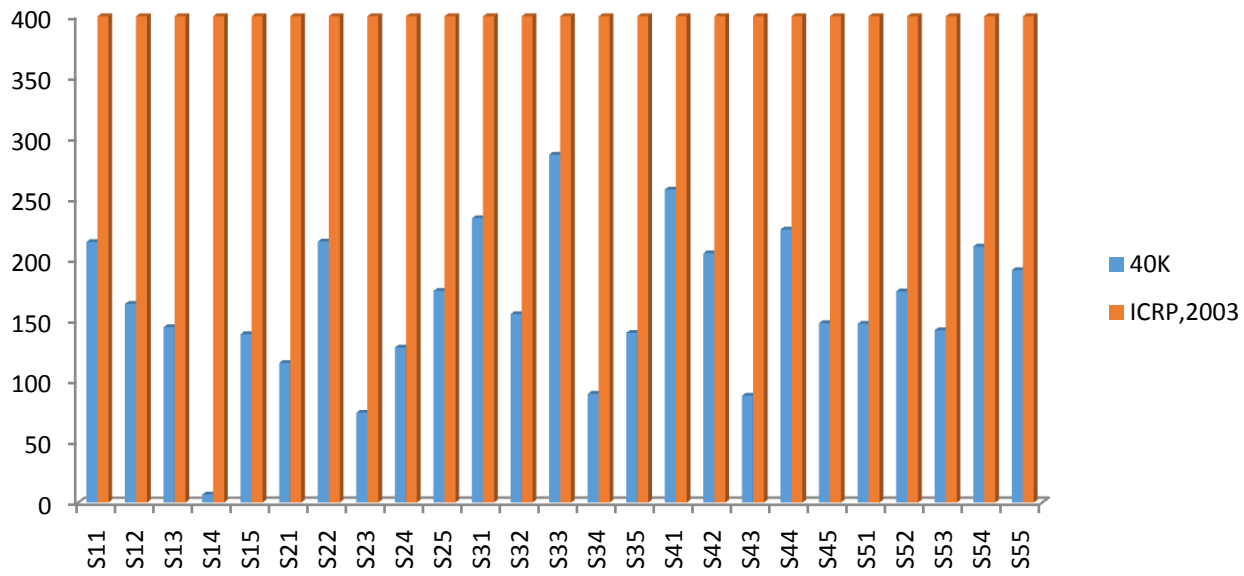


Figure 1: Comparison of Specific Activity Concentration of ^{40}K in Soil with ICRP,2003 value

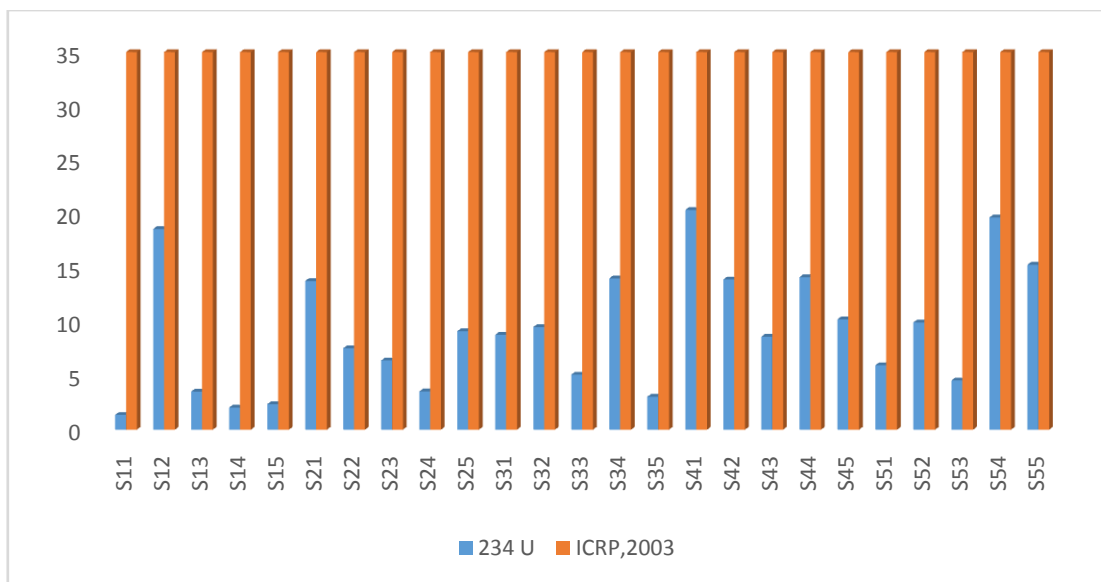


Figure 2: Comparison of Specific Activity Concentration of ^{238}U in Soil with ICRP,2003 Value

UNDER REVIEW

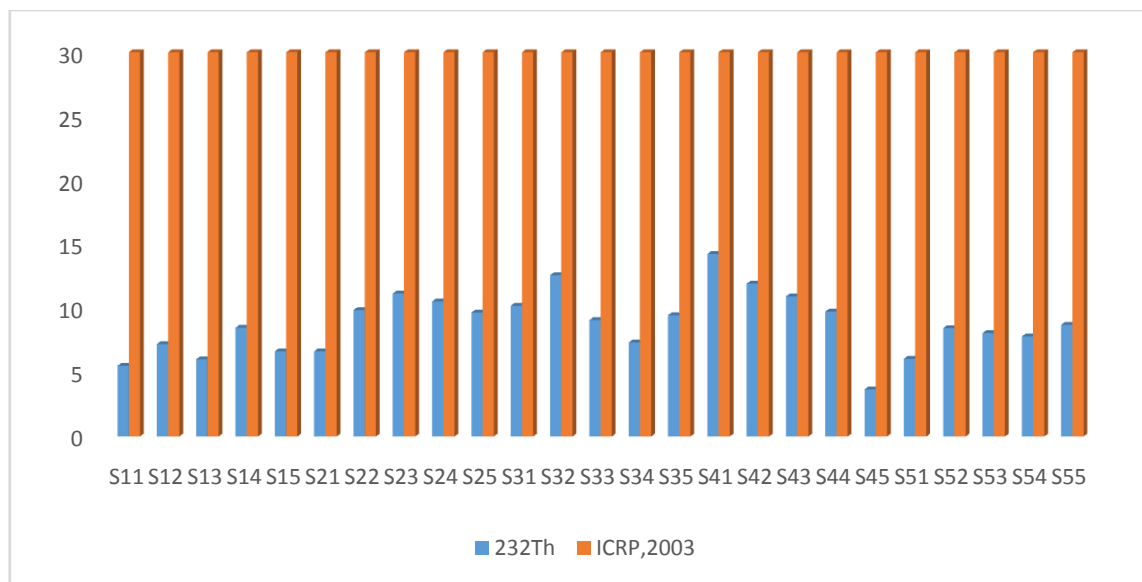


Figure 3: Comparison of Specific Activity Concentration of ^{232}Th in Soil with ICRP, 2003 Value

UNDER REVIEW

Table 6: Specific Activity Concentration of ⁴⁰K, ²³⁸U and ²³²Th with their Radiological Health Risk Parameters on Rice Samples From Farm 1

S/N	Sample code	40k(Bq/Kg)	234U(Bq/Kg)	232Th(Bq/Kg)	AGED(mSv/y)	D(nGy/h)	AEDE(mSv/y)	ELCR x 10 ⁻³
1	R11	12.75	4.24	6.31	43.48	6.54	0.01	0.02
2	R12	86.28	0.00	0.31	28.39	3.93	0.01	0.02
3	R13	27.42	1.27	14.63	73.69	11.41	0.01	0.05
4	R14	53.68	4.09	8.37	64.48	9.61	0.01	0.04
5	R15	133.00	21.70	6.65	136.64	19.42	0.02	0.08
AVERAGE		62.63	6.26	7.25	69.34	10.18	0.01	0.04
ICRP, 2003		400.00	35.00	30.00	300.00	84.00	1.00	0.29

Note : R11 means Rice sample in Farm1,Position1

Table 7: Specific Activity Concentration of ^{40}K , ^{238}U and ^{232}Th with their Radiological Health Risk Parameters on Rice Samples From Farm 2

S/N	Sample code	^{40}K (Bq/Kg)	^{238}U (Bq/Kg)	^{232}Th (Bq/Kg)	AGED(mSv/y)	D(nGy/h)	AEDE(mSv/y)	ELCR x 10^{-3}
1	R21	12.93	0.00	1.26	9.33	1.39	0.00	0.01
2	R22	37.31	5.06	3.27	41.02	5.94	0.01	0.03
3	R23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	R24	36.83	14.6	10.08	98.84	14.50	0.02	0.06
5	R25	177.00	0.00	9.59	95.67	13.99	0.02	0.06
AVERAGE		52.81	3.93	4.84	48.97	7.16	0.01	0.03
ICRP, 2003		400.00	35.00	30.00	300.00	84.00	1.00	0.29

Table 8: Specific Activity Concentration of ⁴⁰K, ²³⁸U and ²³²Th with their Radiological Health Risk Parameters on Rice Samples From Farm 3

S/N	Sample code	40k(Bq/Kg)	234U(Bq/Kg)	232Th(Bq/Kg)	AGED(mSv/y)	D(nGy/h)	AEDE(mSv/y)	ELCR x 10 ⁻³
1	R31	134.80	6.12	8.45	96.56	14.03	0.02	0.06
2	R32	113.40	0.00	10.05	77.63	11.55	0.01	0.05
3	R33	191.60	7.73	10.07	126.15	18.24	0.02	0.08
4	R34	248.00	0.00	11.32	125.19	18.20	0.02	0.08
5	R35	256.70	8.46	8.34	141.61	20.22	0.02	0.09
AVERAGE		188.90	4.46	9.65	113.43	16.45	0.02	0.07
ICRP, 2003		400.00	35	30.00	300.00	84.00	1.00	0.29

Table 9: Specific Activity Concentration of ⁴⁰K, ²³⁸U and ²³²Th with their Radiological Health Risk Parameters on Rice Samples From Farm 4

S/N	Sample code	⁴⁰ K(Bq/Kg)	²³⁴ U(Bq/Kg)	²³² Th(Bq/Kg)	AGED(mSv/y)	D(nGy/h)	AEDE(mSv/y)	ELCR x 10 ⁻³
1	R41	196.80	0.00	7.31	92.33	13.34	0.02	0.06
2	R42	147.70	8.20	10.77	116.72	17.01	0.02	0.07
3	R43	129.20	11.70	5.58	100.01	14.27	0.02	0.06
4	R44	90.46	0.00	8.19	62.64	9.33	0.01	0.04
5	R45	68.96	0.12	3.47	36.53	5.33	0.01	0.02
AVERAGE		126.62	4.00	7.06	81.65	11.85	0.01	0.05
ICRP, 2003		400.00	35.00	30.00	300.00	84.00	1.00	0.29

Table 10: Specific Activity Concentration of ^{40}K , ^{238}U and ^{232}Th with their Radiological Health Risk Parameters on Rice Samples From Farm 5

S/N	Sample code	^{40}K (Bq/Kg)	^{238}U (Bq/Kg)	^{232}Th (Bq/Kg)	AGED(mSv/y)	D(nGy/h)	AEDE(mSv/y)	ELCR x 10^{-3}
1	R51	128.20	21.90	5.44	130.72	18.49	0.02	0.08
2	R52	64.54	0.00	9.21	58.76	8.88	0.01	0.04
3	R53	173.00	13.00	6.88	123.33	17.59	0.02	0.08
4	R54	67.09	9.76	3.25	64.87	9.23	0.01	0.04
5	R55	256.70	8.46	8.34	141.61	20.22	0.02	0.09
AVERAGE		137.91	10.62	6.62	103.86	14.88	0.02	0.06
ICRP, 2003		400.00	35.00	30.00	300.00	84.00	1.00	0.29

Table 11: Annual Committed Effective Dose (mSv/y) Due to (⁴⁰K) of Different Age Bracket from Rice Samples in the Five Farms

S/N	Sample Code	⁴⁰ K (Bq/Kg)	<1yr	1-7yrs	7-12yrs	12-17yrs	>17yrs
1	R11	12.75	0.007	0.002	0.002	0.001	0.001
2	R12	86.28	0.048	0.016	0.010	0.006	0.005
3	R13	0.42	0.015	0.005	0.003	0.002	0.002
4	R14	53.68	0.030	0.010	0.006	0.004	0.003
5	R15	133.00	0.074	0.025	0.016	0.009	0.007
6	R21	12.93	0.007	0.002	0.002	0.001	0.001
7	R22	37.31	0.020	0.007	0.004	0.003	0.002
8	R23	0.00	0.000	0.000	0.000	0.000	0.000
9	R24	36.83	0.021	0.007	0.004	0.002	0.002
10	R25	177.00	0.099	0.034	0.021	0.012	0.010
11	R31	134.80	0.076	0.026	0.016	0.009	0.008
12	R32	113.40	0.064	0.022	0.013	0.008	0.006
13	R33	191.60	0.108	0.037	0.023	0.013	0.011
14	R34	248.00	0.139	0.047	0.029	0.017	0.014
15	R35	256.70	0.144	0.049	0.031	0.018	0.014
16	R41	196.80	0.111	0.037	0.023	0.014	0.011
17	R42	147.70	0.083	0.028	0.017	0.010	0.008
18	R43	129.20	0.072	0.025	0.015	0.009	0.007
19	R44	90.46	0.051	0.017	0.011	0.006	0.005
20	R45	68.96	0.038	0.013	0.008	0.005	0.004
21	R51	128.20	0.072	0.024	0.015	0.009	0.007
22	R52	64.54	0.036	0.012	0.008	0.004	0.004
23	R53	173.00	0.097	0.033	0.020	0.012	0.010
24	R54	67.09	0.038	0.013	0.008	0.005	0.004
25	R55	256.70	0.144	0.049	0.030	0.018	0.014

Table 12: Annual Committed Effective Dose (mSv/y) Due to (^{238}U) of Different Age Bracket from Rice Samples in the Five Farms

S/N	Sample Code	^{238}U (Bq/Kg)	<1yr	1-7yrs	7-12yrs	12-17yrs	>17yrs
1	R11	4.24	0.007	0.003	0.003	0.003	0.002
2	R12	0.00	0.00	0.000	0.000	0.000	0.000
3	R13	1.27	0.002	0.001	0.001	0.001	0.001
4	R14	4.09	0.006	0.003	0.002	0.003	0.002
5	R15	21.70	0.033	0.017	0.014	0.014	0.009
6	R21	0.00	0.000	0.000	0.000	0.000	0.000
7	R22	5.06	0.008	0.004	0.003	0.003	0.002
8	R23	0.00	0.000	0.000	0.000	0.000	0.000
9	R24	14.60	0.022	0.012	0.009	0.010	0.006
10	R25	0.00	0.000	0.000	0.000	0.000	0.000
11	R31	6.12	0.009	0.005	0.004	0.004	0.003
12	R32	0.00	0.000	0.000	0.000	0.000	0.000
13	R33	7.73	0.012	0.006	0.005	0.005	0.003
14	R34	0.00	0.000	0.000	0.000	0.000	0.000
15	R35	8.46	0.013	0.007	0.006	0.006	0.004
16	R41	0.00	0.000	0.000	0.000	0.000	0.000
17	R42	8.20	0.013	0.006	0.005	0.005	0.004
18	R43	11.70	0.018	0.009	0.008	0.008	0.005
19	R44	0.00	0.000	0.000	0.000	0.000	0.000
20	R45	0.12	0.000	9.59E-05	8.06E-05	8.06E-05	5.34E-05
21	R51	21.90	0.033	0.017	0.015	0.015	0.009
22	R52	0.00	0.000	0.000	0.000	0.000	0.000
23	R53	13.00	0.020	0.010	0.009	0.009	0.006
24	R54	9.76	0.015	0.008	0.006	0.006	0.004
25	R55	8.46	0.013	0.007	0.006	0.006	0.004

Table 13: Annual Committed Effective Dose (mSv/y) Due to (²³²Th) of Different Age Bracket from Rice Samples in the Five Farms

S/N	Sample Code	²³² Th (Bq/Kg)	<1yr	1-7yrs	7-12yrs	12-17yrs	>17yrs
1	R11	6.23	0.260	0.019	0.016	0.014	0.013
2	R12	0.31	0.013	0.001	0.001	0.001	0.001
3	R13	14.63	0.611	0.046	0.038	0.033	0.031
4	R14	8.37	0.349	0.026	0.022	0.019	0.017
5	R15	6.65	0.278	0.021	0.017	0.015	0.014
6	R21	1.26	0.053	0.004	0.003	0.003	0.003
7	R22	3.27	0.136	0.010	0.009	0.007	0.007
8	R23	0.00	0.000	0.000	0.000	0.000	0.000
9	R24	10.08	0.421	0.032	0.026	0.023	0.021
10	R25	9.59	0.400	0.030	0.025	0.022	0.020
11	R31	8.45	0.353	0.027	0.022	0.019	0.018
12	R32	10.05	0.419	0.032	0.026	0.023	0.021
13	R33	10.07	0.420	0.032	0.026	0.023	0.021
14	R34	11.32	0.473	0.036	0.029	0.026	0.024
15	R35	8.34	0.348	0.026	0.022	0.019	0.017
16	R41	7.31	0.305	0.023	0.019	0.016	0.015
17	R42	10.77	0.449	0.034	0.028	0.024	0.022
18	R43	5.58	0.233	0.018	0.015	0.013	0.011
19	R44	8.19	0.342	0.026	0.021	0.018	0.017
20	R45	3.47	0.145	0.011	0.009	0.008	0.007
21	R51	5.44	0.227	0.017	0.014	0.012	0.011
22	R52	9.21	0.384	0.029	0.024	0.021	0.019
23	R53	6.88	0.287	0.022	0.018	0.016	0.014
24	R54	3.25	0.136	0.010	0.008	0.007	0.007
25	R55	8.34	0.348	0.026	0.022	0.019	0.017

Table 14: Total Annual Committed Effective Dose (in mSv/y) due to for different age brackets.

S/N	Code	<1yr	1-7yrs	7-12yrs	12-17yrs	above 17yrs
1	R11	0.27	0.03	0.02	0.02	0.02
2	R12	0.06	0.02	0.01	0.01	0.01
3	R13	0.63	0.05	0.04	0.03	0.03
4	R14	0.39	0.04	0.03	0.02	0.02
5	R15	0.39	0.06	0.05	0.04	0.03
6	R21	0.06	0.01	0.01	0.00	0.00
7	R22	0.17	0.02	0.02	0.01	0.01
8	R23	0.00	0.00	0.00	0.00	0.00
9	R24	0.46	0.05	0.04	0.03	0.03
10	R25	0.50	0.06	0.05	0.03	0.03
11	R31	0.44	0.06	0.04	0.03	0.03
12	R32	0.48	0.05	0.04	0.03	0.03
13	R33	0.54	0.07	0.05	0.04	0.03
14	R34	0.61	0.08	0.06	0.04	0.04
15	R35	0.51	0.08	0.06	0.04	0.04
16	R41	0.42	0.06	0.04	0.03	0.03
17	R42	0.55	0.07	0.05	0.04	0.03
18	R43	0.32	0.05	0.04	0.03	0.02
19	R44	0.39	0.04	0.03	0.02	0.02
20	R45	0.18	0.02	0.02	0.01	0.01
21	R51	0.33	0.06	0.04	0.04	0.03
22	R52	0.42	0.04	0.03	0.02	0.02
23	R53	0.40	0.06	0.05	0.04	0.03
24	R54	0.19	0.03	0.02	0.02	0.01
25	R55	0.51	0.08	0.06	0.04	0.04

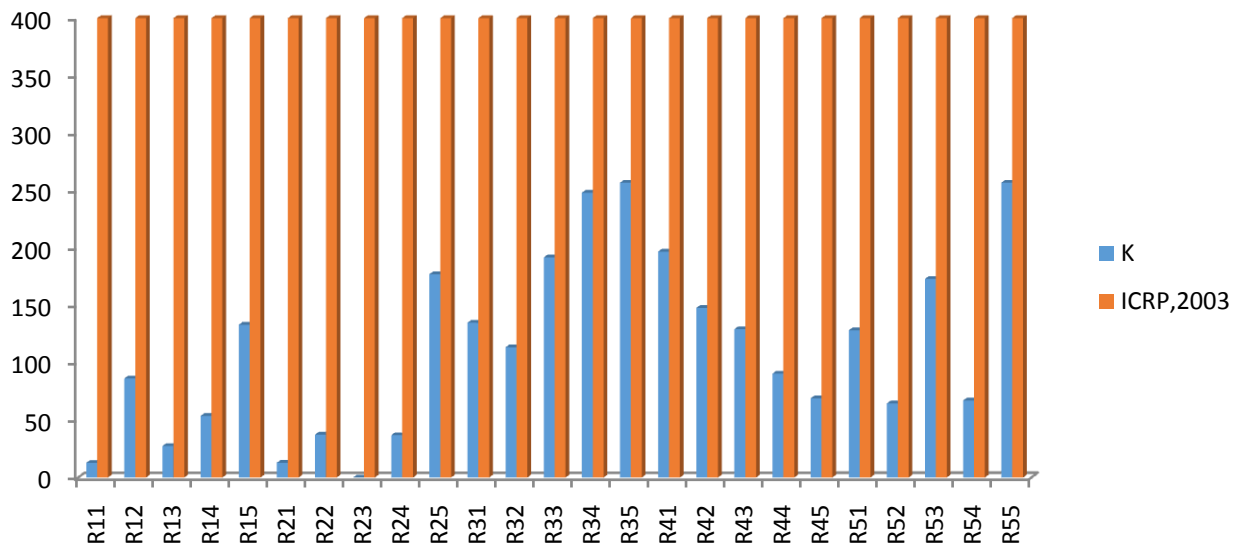


Figure 4: Comparison of Specific Activity Concentration of ^{40}K in Crop with ICRP, 2003 Value

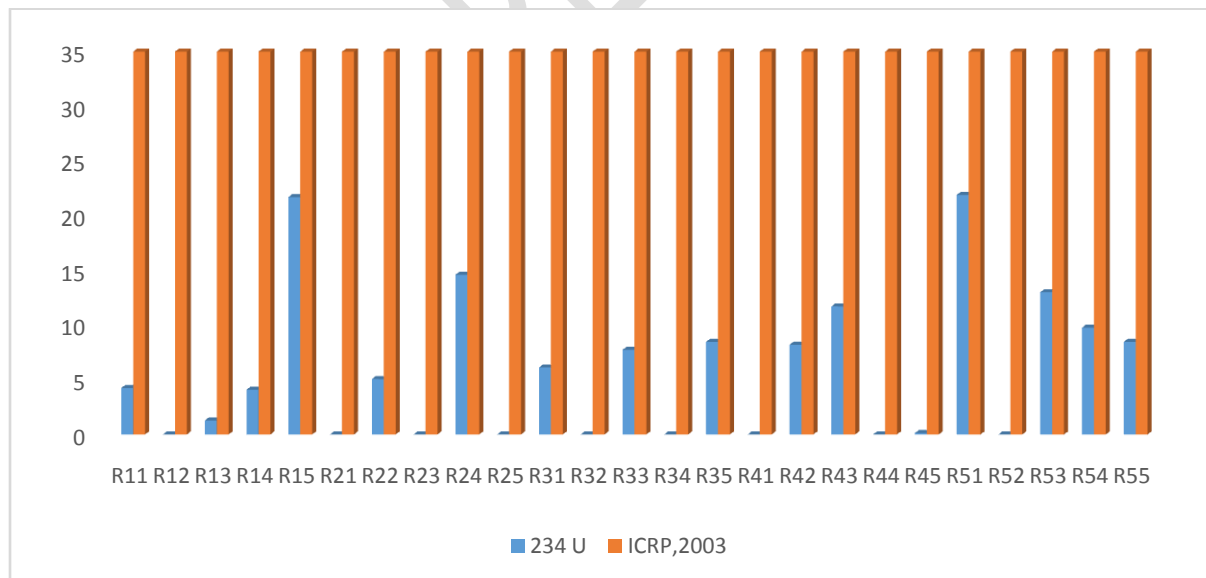


Figure 5: Comparison of Specific Activity Concentration of ^{238}U in Crop with ICRP, 2003 Value

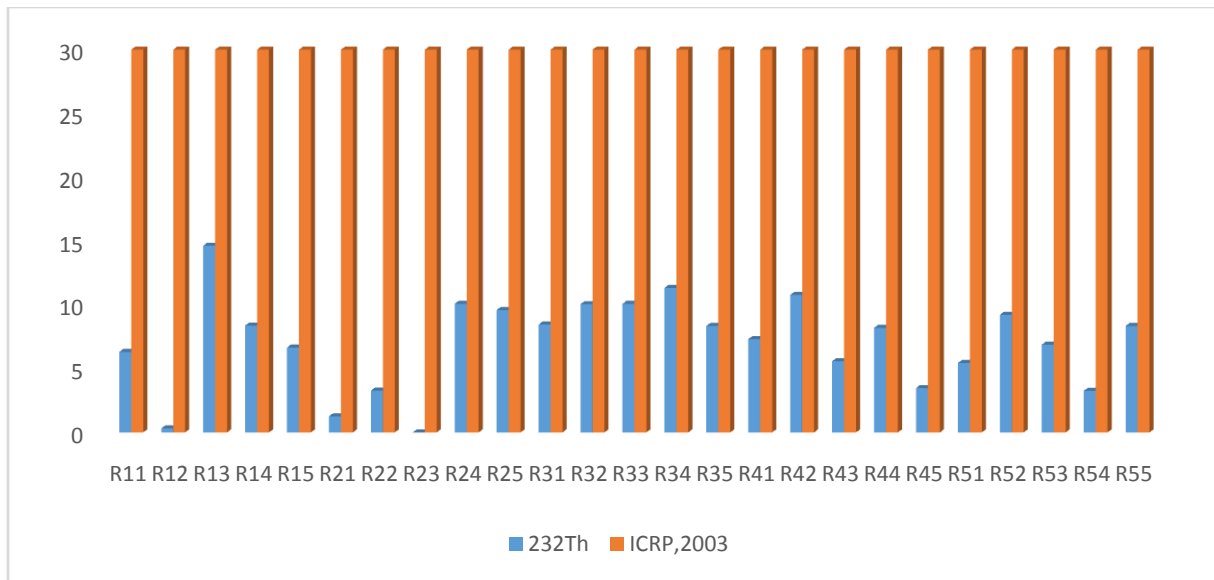


Figure 6: Comparison of Specific Activity Concentration of ^{232}Th in Crop with ICRP, 2003 Value

UNDER PEER REVIEW

5.0 DISCUSSIONS

Special Activity Concentration of ^{40}K , ^{238}U , ^{232}Th in Soil Samples

The specific activity concentration of ^{40}K in soil samples in the five farms ranges from (6.56 – 286.19 Bq/Kg) with an average of 170.53 Bq/Kg, ^{238}U (1.37 –20.37 Bq/Kg) with an average of 9.26 Bq/Kg and ^{232}Th (3.68 -14.25 Bq/Kg) with an average of 8.81 Bq/Kg. These results are below the (ICRP, 2003) values of 400 BqKg⁻¹ Potassium, 35 BqKg⁻¹ Uranium and 30 BqKg⁻¹ Thorium. The result shows that there was no immediate potential risk in Ikwo mining area. This result differ from the results obtained by (Reza & Fatemeh, 2015) in Iran which was higher than the permissive limits, and (Alsaffer et al., 2015; Ocheje&Tyovenda, 2020; Ugbede et al., 2021) in Nigeria with the values of Uranium-238 and Thorium-232 higher than the permissive limit. However, the result is similar to the results obtained by (Ehsan et al., 2019; Avwiri&Agbalagba, 2013) which were below the permissive values. The radiological risk parameters calculated in soil are below their permissive limit. They are the Gamma Index (I_γ) ranges from 0.13 to 0.72 with an average of 0.38 which is less standard value of 1.00 (ICRP, 2003). Annual gonadal Equivalent dose (AGED) ranges from 43.88 to 266.17mSv/y with an average of 118.98 mSv/y which is less than 300 mSv/y, ICRP value. The Activity Utilization Index (AUI) ranges from 0.13 to 0.74 uSv/y with an average of 0.33 uSv/y which is less than the permissive value of 1.00. Absorbed dose (D) ranges from (6.78 -37.89 nGy/h) with an average of 17.15 nGy/h lower than the permissive value of 59 nGy/h, annual effective dose equivalent (AEDE) ranges from (0.01 – 0.05 mSv/y) with an average of 0.02 mSv/y lower than the ICRP permissive value of 1.00 mSv/y, and excess life cancer risk (ELCR x10⁻³) ranges from (0.03 - 0.10) x 10⁻³) which is lower than the ICRP value of 0.29 x10⁻³. The radiological risk parameters were similar to the results by

(Ocheje&Tyovenda, 2020; Ugbede et al., 2021). This shows that it does not have immediate cancer risk but might have long term potential cancer risk.

Special Activity Concentration of ^{40}K , ^{238}U , ^{232}Th in Rice Samples

The specific activity concentration of ^{40}K in rice samples in the five farms as presented in Tables 6 to 10 ranges from (0 – 256.7 Bq/Kg) with an average of 113.77 Bq/Kg, the specific activity concentration of ^{238}U ranges from (0 – 21.9 Bq/Kg) with an average of 5.86 Bq/Kg and that of ^{232}Th ranges from (0 – 14.63 Bq/Kg) with an average of 7.08 Bq/Kg. These results are below the (ICRP, 2003) values of 400 BqKg⁻¹ Potassium, 35 BqKg⁻¹ Uranium and 30 BqKg⁻¹ Thorium. The result shows that there was no immediate potential risk in Ikwo mining area. This result is similar to the results obtained by (Alsaffer et al., 2015; Ibikunle et al., 2019; Ilemona et al., 2016; Ocheje&Tyovenda, 2020 ; Reza & Fatemeh, 2015 &Ugbede et al., 2021) whose results were below the permissive values with no immediate radiological health effect on the consumers. The radiological risk parameters calculated in rice are below their permissive limit. Annual gonadal Equivalent dose (AGED) ranges from 0.00 to 141.61mSv/y with an average of 83.45mSv/y which is less than 300 mSv/y ICRP value. Absorbed dose (D) ranges from (0.00– 20.22 nGy/h) with an average of 12.11n Gy/h which is lower than the permissive value of 59 nGy/h, the annual effective dose equivalent (AEDE) ranges from (0.00 – 0.024 mSv/y) with an average of 0.014 mSv/y lower than the ICRP permissive value of 1.00 mSv/y, and excess life cancer risk (ELCR x10⁻³) ranges from (0.00 - 0.09) x10⁻³ which is lower than the ICRP value of 0.29x10⁻³. The radiological risk parameters were similar to the results by (Ocheje&Tyovenda, 2020; Ugbede et al., 2021). Generally, the study shows that rice consumption was relatively safe radiologically with little contamination which could be attributed to human activities but there is tendency for long term health hazards in future such as cancer due to doses accumulated. The annual

committed effective dose as presented in Table 11 to 13 for each of the radionuclides for different age brackets were calculated as follows: For ^{40}K , the annual committed effective doses for ages (<1 year), (1 – 7 years), (7 – 12 years), (12 – 17 years) and (>17 years) gave (0 – 0.14 mSv/y), (0 – 0.05 mSv/y), (0 – 0.03 mSv/y), (0 – 0.02 mSv/y), and (0 – 0.01 mSv/y) respectively. For ^{232}Th , ages (<1year), (1 – 7years), (7 – 12 years), (12 – 17 years) and (>17 years) gave (0 – 0.611 mSv/y), (0 – 0.046 mSv/y), (0 – 0.038 mSv/y), (0 – 0.003 mSv/y), and (0 – 0.030 mSv/y) respectively. For ^{238}U , ages (<1 year), (1 – 7 years), (7 – 12 years), (12 – 17 years) and (>17 years) gave (0 – 0.034 mSv/y), (9.59E-05 – 0.017 mSv/y), (8.06E-05 – 0.015 mSv/y), (8.06E-05 – 0.015 mSv/y), and (5.34E-05 – 0.009 mSv/y) respectively. For total annual committed effective dose as shown in Table 14, ages (< 1 year), (1 – 7 years), (7 – 12 years), (12 – 17 years) and (>17 years) gave (0 – 0.63 mSv/y) with an average of 0.37, (0 – 0.08 mSv/y) with an average of 0.05, (0 – 0.06 mSv/y) with an average of 0.04, (0 – 0.04 mSv/y) with an average of 0.03, and (0 – 0.04 mSv/y) with an average of 0.02 respectively. These results are less than the world permissive value of 1.00 mSv/y. This result is similar to the result obtained Malaysia by Asaduzzaman et al., (2015). The values signifies no immediate radiological health effect, though additional dose may lead to health risk in future.

6.0 CONCLUSION

Specific activity concentration of ^{238}U , ^{232}Th and ^{40}K in soil and rice grains from solid mineral mining sites in Ikwo local government area of Ebonyi state was carried out using a Digilert-200 Radiation Meter. The radiological impact of the radionuclides was calculated. From the results obtained the values for specific activity concentration for ^{40}K , ^{238}U and ^{232}Th in soil were 170.53 Bq/Kg, 9.23 Bq/Kg and 8.81Bq/Kg respectively while the specific activity concentration of ^{40}K , ^{238}U and ^{232}Th in rice were 113.77 Bq/Kg, 5.86 Bq/Kg and 7.08 Bq/Kg respectively which are

discovered to be lower than world permissive values both for soil and rice. All the radiological health risk parameters are lower than their acceptable safe limits.

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