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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 Area of Ebonyi State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

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 area of Ebonyi state was carried out using a Digilert-200 Radiation Meter. The radiological impact of the radionuclides was calculated. The average value concentrations of radionuclides obtained were 170.53, 9.26 and 8.81 (in Bq.Kg^{-1}) for ^{40}K, ^{238}U and ^{232}Th respectively in soil samples and 113.77, 5.86 and 7.08 (in Bq.Kg^{-1}) 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^{-1}) 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 mSvy^{-1}) 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

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of 1.00 mSvy^{-1}. Generally, the study shows that the 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 the cancer due to doses accumulation. It is recommended that the various human activities that raise the activity concentration in soil in Ikwo mining area that should be reduced. The activity concentration of radionuclides level in the area should be periodically assessed.

Keywords: Activity concentration; health risk parameters; Ikwo.

1. INTRODUCTION

"Primordial isotopes of ^{226}Ra, ^{238}U, ^{232}Th and ^{40}k are the main sources of external radiation on earth" [1]. "Human is exposed to radioisotopes from different sources, which can be generated either naturally or through manmade activities like mining activities and industrialization. Mining sites and its environs where heavy metal ores are extracted and processed have the potential of high radiation emission due to exposure of some certain radioactive substances" [2,3]. "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 emergence of unearthing of solid minerals 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" [4-6]. "When harmful substances are introduced into the system and the environment becomes polluted, it affects human and his environment adversely" [7]. 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 the mainstay of economy in Ikwo Area of Ebonyi State [3]. "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" [8]. "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" [9]. "Soil is the unconsolidated mineral on the surface of the earth that serves as a natural medium for plant growth" [10]. "It is the main reservoir of plant nutrients and water. These radionuclides, along with essential nutrients, are absorbed from the soil through plant roots and transported to other parts of the plant. The ever-present and incessant nature of natural radionuclides in the 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" [11,12] "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 the soil, but it cannot be used to evaluate the effects of radiation exposure rate of food intake" [12]. 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 the soil and rice grains from solid mineral mining sites in Ikwo area of Ebonyi state, Nigeria.

2. 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 8^0 00'E - $8^0$20'E and Latitude $6^0$00'N - $6^0$20'N [13]. Ikwo is the largest local government area in Ebonyi State. The nature of the activities in the study area include the following; excavation of solid minerals like lead/zinc, salt and limestone, farming of rice, cassava, yam, groundnut and cocoyam.

3. 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 50mm because radionuclides find their way to the crops through their roots [3], 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, all samples were taken to the laboratory for analysis [14].

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 [14]. 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 [3] 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 [15,16,12]. 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 [17]. 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 [3,12]. This was done in order to allow for Radon and its short-lived progenies to reach secular radioactive equilibrium prior to gamma spectroscopy [18]. A 3″×3″ co-axial NaI(TI) detector (Model 802 series, Canberra Inc. USA) available at the environmental radiation laboratory of the National Institute of Radiation Protection and Research (NIRPR), University of Ibadan, Nigeria was used to measure the activity concentrations of ^{232}Th, ^{238}U and ^{40}K in the samples [12]. The background count was determined by counting an empty beaker container having the same dimensions with those carrying the samples. The background spectrum was subtracted from the measured sample spectra to obtain the total net counts. The spectrum acquisition and processing were made possible by coupling the detector output to an ORTEC Multi-Channel Analyzer (MCA) alongside a PC equipped with Genie 2000 evaluation software that matches gamma energies to a library of possible isotopes [12]. The activity concentration values obtained were used to calculate the health risk parameter by using appropriate equations stated below [19].

3.3 Radiological Hazard Parameters

Radiation models(equations) are used to determine the radiological health risk parameters. These parameters are absorbed dose, annual effective dose equivalent and excess life cancer risk, annual gonnadal 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 the ground surface for the even distribution of the radionuclides [18]. Occurring naturally are calculated using the equation by Avwiri et al., [20];

$$D\ (nGyh^{-1}) = 0.427C_U + 0.662C_{Th} + 0.0432C \quad (1)$$

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 $SvGy^{-1}$ 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. Volunteer 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 [21]:

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

(iii) Excess Life Cancer Risk (ELCR)

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

$$ELCR = AEDE \times DL \times RF \quad (3)$$

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 [22].

(iv) 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 [12]. The AGED is given as;

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

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

(v) Representative Gamma Index (Iyr)

This is used to estimate the γ- radiation hazard associated with the natural radionuclide in specific investigated samples, [7]. 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 effective dose rate due to the excess external gamma radiation caused by superficial materials [7]. And it is a tool used to find out materials that might portray health problem when used for construction.

Values of Iyr ≤ 1 is equivalent to an annual effective dose of less than or equal to I mSvy^{-1}, while Iyr ≤ 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, [12];

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

Where, Au, A_{Th} and A_k are activity concentration in Bqkg^{-1} for ^{234}U, ^{232}Th and ^{40}K.

Fu, 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 [23]. The values of Fu 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;

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

AUI less than 2 corresponds to an annual effective dose of < 0.3 mSvy^{-1} which is safe for the environment [12].

(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) [24]. In this study, the committed effective dose over one year in crop sample (rice grain) was calculated for different age brackets using the following relation [25].

$$E = IxA\ x\ C \times 365 \quad (8)$$

Where I is the daily crop (rice) consumption (24.8 kg per day), A is the activity concentration in becquerel per kg (Bqkg^{-1}) and C is the dose conversion factor in S_VBq^{-1}.

4. RESULTS

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

5. DISCUSSION

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

The specific activity concentration of ^{40}K in the soil samples in the five farms ranges from (6.56 – 286.19 BqKg^{-1}) with an average of 170.53 BqKg^{-1}, ^{238}U (1.37 –20.37 BqKg^{-1}) with an average of 9.26 BqKg^{-1} and ^{232}Th (3.68 -14.25 BqKg^{-1}) with an average of 8.81 BqKg^{-1}. These results are below the (ICRP, 2003) values of 400 BqKg^{-1} Potassium, 35 BqKg^{-1} Uranium and 30 BqKg^{-1}

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 ($BqKg^{-1}$)	^{238}U ($BqKg^{1}$)	^{232}Th ($BqKg^{-1}$)	Iy	AGED ($mSvy^{-1}$)	AUI ($uSvy^{-1}$)	D ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR x 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 ($BqKg^{-1}$)	^{238}U ($BqKg^{-1}$)	^{232}Th ($BqKg^{-1}$)	Iy	AGED ($mSvy^{-1}$)	AUI ($uSvy^{-1}$)	D ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR x 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 ($BqKg^{-1}$)	^{238}U ($BqKg^{-1}$)	^{232}Th ($BqKg^{-1}$)	Iy	AGED ($mSvy^{-1}$)	AUI ($uSvy^{-1}$)	D ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR x 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 ($BqKg^{-1}$)	^{238}U ($BqKg^{-1}$)	^{232}Th ($BqKg^{-1}$)	Iy	AGED ($mSvy^{-1}$)	AUI ($uSvy^{-1}$)	D ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR x 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 ^{40}K, ^{238}U and ^{232}Th with their radiological health risk parameters on soil samples from farm 5

S/N	Sample Code	^{40}K ($BqKg^{-1}$)	^{238}U ($BqKg^{-1}$)	^{232}Th ($BqKg^{-1}$)	Iy	AGED ($mSvy^{-1}$)	AUI ($uSvy^{-1}$)	D ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	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**

Table 6. Specific activity concentration of ^{40}K, ^{238}U and ^{232}Th with their radiological health risk parameters on rice samples from farm 1

S/N	Sample code	^{40}k($BqKg^{-1}$)	^{238}U($BqKg^{-1}$)	^{232}Th($BqKg^{-1}$)	AGED ($mSvy^{-1}$)	D($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	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 Farm 1, Position 1

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(BqKg^{-1})	^{238}U(BqKg^{-1})	^{232}Th(BqKg^{-1})	AGED (mSvy^{-1})	D(nGyh^{-1})	AEDE (mSvy^{-1})	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 ^{40}K, ^{238}U and ^{232}Th with their radiological health risk parameters on rice samples from farm 3

S/N	Sample code	^{40}k(BqKg^{-1})	^{238}U(BqKg^{-1})	^{232}Th(BqKg^{-1})	AGED (mSvy^{-1})	D(nGyh^{-1})	AEDE (mSvy^{-1})	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 ^{40}K, ^{238}U and ^{232}Th with their radiological health risk parameters on rice samples from farm 4

S/N	Sample code	^{40}k(BqKg^{-1})	^{238}U(BqKg^{-1})	^{232}Th(BqKg^{-1})	AGED (mSvy^{-1})	D(nGyh^{-1})	AEDE (mSvy^{-1})	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(BqKg^{-1})	^{238}U(BqKg^{-1})	^{232}Th (BqKg^{-1})	AGED (mSvy^{-1})	D(nGyh^{-1})	AEDE (mSvy^{-1})	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 (mSvy^{-1}) Due to (^{40}K) of different age bracket from rice samples in the five farms

S/N	Sample Code	^{40}K (BqKg^{1}	<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

S/N	Sample Code	^{40}K (BqKg^{1}	<1yr	1-7yrs	7-12yrs	12-17yrs	>17yrs
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 (mSvy^{-1}) Due to (^{238}U) of different age bracket from rice samples in the five farms

S/N	Sample Code	^{238}U (BqKg^{-1})	<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 (mSvy^{-1}) Due to (^{232}Th) of different age bracket from rice samples in the five farms

S/N	Sample Code	^{232}Th (BqKg^{-1})	<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 ($mSvy^{-1}$) due to for different age brackets

S/N	Sample 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

Thorium. The result shows that there was no immediate potential risk in Ikwo mining area. This result differ from ^{40}K (331.82 BqKg^{-1}), ^{238}U(52.84 BqKg^{-1}) and ^{232}Th(67.38 BqKg^{-1}) obtained by Ocheje & Tyovenda, [18] and 226Ra(83.85 BqKg^{-1}), ^{40}K(403.76 BqKg^{-1}), and ^{232}Th(108.11 BqKg^{-1}) obtained by Alsaffer et al., (2015) in Nigeria which were higher than the permissive limits of ^{40}K(400 BqKg^{-1}), ^{238}U(35 BqKg^{-1}) and ^{232}Th(30 BqKg^{-1}) . However, the result is similar to the results obtained by [26,27] which were below the permissive values. The radiological risk parameters calculated in soil are below their permissive limit. Gamma Index (Iγ) ranges from 0.13 to 0.72 with an average of 0.38 which is less standard value of 1.00 [28]. Annual gonadal Equivalent dose (AGED) ranges from 43.88 to 266.17 mSvy^{-1} with an average of 118.98 mSvy^{-1} which is less than 300 mSvy^{-1}, ICRP value. The Activity Utilization Index (AUI) ranges from 0.13 to 0.74 uSvy^{-1} with an average of 0.33 uSvy^{-1} which is less than the permissive value of 1.00. Absorbed dose (D) ranges from (6.78 -37.89 nGyh^{-1}) with an average of 17.15 nGyh^{-1} lower than the permissive value of 59 nGyh^{-1}, annual effective dose equivalent (AEDE) ranges from (0.01 – 0.05 mSvy^{-1}) with an average of 0.02 mSvy^{-1} lower than the ICRP permissive value of 1.00 mSvy^{-1}, 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 [18,12]. This shows that it does not have immediate cancer risk but might have long term potential cancer risk.

5.2 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 BqKg^{-1}) with an average of 113.77 BqKg^{-1}, the specific activity concentration of ^{238}U ranges from (0 – 21.9 BqKg^{-1}) with an average of 5.86 BqKg^{-1} and that of ^{232}Th ranges from (0 – 14.63 BqKg^{-1}) with an average of 7.08 BqKg^{-1}. These results are below the results in (ICRP, 2003), the 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 [15,14,19,18] (Reza & Fatemeh, 2015) & [12] 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 141.61 mSvy^{-1} with an average of 83.45mSvy^{-1} which is less than 300 mSvy^{-1} ICRP value. Absorbed dose (D) ranges from (0.00– 20.22 nGyh^{-1}) with an average of 12.11 nGyh^{-1} which is lower than the permissive value of 59 nGyh^{-1}, the annual effective dose equivalent (AEDE) ranges from (0.00 – 0.024 mSvy^{-1}) with an average of 0.014 mSvy^{-1} lower than the ICRP permissive value of 1.00 mSvy^{-1}, 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 [18,12]. 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 Tables 11 to 13 for each of the radionuclides of 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 mSvy^{-1}), (0 – 0.05 mSvy^{-1}), (0 – 0.03 mSvy^{-1}), (0 – 0.02 mSvy^{-1}), and (0 – 0.01 mSvy^{-1}) respectively. For ^{232}Th, ages (<1year), (1 – 7years), (7 – 12 years), (12 – 17 years) and (>17 years) gave (0 – 0.611 mSvy^{-1}), (0 – 0.046 mSvy^{-1}), (0 – 0.038 mSvy^{-1}), (0 – 0.003 mSvy^{-1}), and (0 – 0.030 mSvy^{-1}) 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 mSvy^{-1}) with an average of 0.37, (0 – 0.08 mSvy^{-1}) with an average of 0.05, (0 – 0.06 mSvy^{-1}) with an average of 0.04, (0 – 0.04 mSvy^{-1}) with an average of 0.03, and (0 – 0.04 mSvy^{-1}) with an average of 0.02 respectively. These results are less than the world permissive value of 1.00 mSvy^{-1}. This result is similar to the result obtained from Malaysia by Asaduzzaman et al., [29]. The values signifies no immediate radiological health effect, though additional dose may lead to health risk in the future.

6. 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 values for specific activity concentration for ^{40}K, ^{238}U and ^{232}Th in soil were 170.53 BqKg^{-1}, 9.23 BqKg^{-1} and 8.81 BqKg^{-1} respectively while the activity concentration of ^{40}K, ^{238}U and ^{232}Th in rice were 113.77 BqKg^{-1}, 5.86 BqKg^{-1} and 7.08 BqKg^{-1} respectively, which are lower than their corresponding permissive values of 400BqKg^{-1} , 35 BqKg^{-1} and 30 BqKg^{-1} for soil and rice. All the radiological health risk parameters are lower than their acceptable safe limits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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