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RESEARCH ARTICLE

RADIATION RISK ASSESSMENT IN MINING SITE OF PAAGO, ISEYIN LOCAL GOVT, OYO STATE, SOUTHWESTERN NIGERIA

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ABSTRACT

The hazards of being over-exposed to ionizing radiation at various mining sites are of great concern to environmental scientists. This study aims to measure the activity concentrations of ^{40}K, ^{238}U, and ^{232}Th radionuclides at various mining sites of Paago, Iseyin local Government, Oyo state, Southwestern Nigeria using a well calibrated HPGe detector. Twenty (20) soil samples were obtained, analyzed, and compared with the WHO recommended standard. The results obtained indicate that ^{40}K, ^{238}U, and ^{232}Th values ranging from 58.40 to 950.41Bqkg^{-1}, 5.57 to 24.22Bqkg^{-1}, and 4.1 to 25.93Bqkg^{-1}. The gamma absorbed dose rate in the soil samples ranged from 6.85nGyh^{-1} to 45.73nGyh^{-1}, with mean absorbed dose rate lower than the WHO recommended average value of 59nGh^{-1}. The annual effective dose rates in the air varied from 14.26 to 19.74μ Svyr^{-1} with an average value of 17.99 μSvy^{-1}, while the highest and lowest values of radium equivalent in the soil were 113.68Bqkg^{-1} and 21.62Bqkg^{-1}. These findings shows that the external and internal hazard indices obtained were less than unity and the means activity concentration of the three radionuclides was lower than the world average recommended value indicating that the study areas pose no significant radiological threat to the populaces, and the crops are safe for consumption.

KEYWORDS

Radionuclides, effective dose rate, gamma absorbed dose rate, mining sites, Paago

1. INTRODUCTION

Radioactivity occurs when unstable nuclei spontaneously disintegrate and emit nuclear particles and energy to attain stability (Abojassim et al., 2019). The nuclear particles emitted in the process of radioactivity include heavily charged α-particles (^4_2He) and the light β-particles ($^0_{+1}e$) or ($^0_{-1}e$) together with neutral and lighter particles called neutrinos (Ahosan et al., 2018). The natural sources of radioactivity are either terrestrial (primordial radionuclides) or extra-terrestrial (cosmic rays). About 85% of the natural background radiation exposure to the environment comes from primordial sources that are known to constitute (Ahosan et al., 2018; Thomas et al., 2019). All the radionuclides found in nature are classified into three sprimordial-formed before the creation of the earth; cosmogonic formed as a result of cosmic ray interactions; artificial radionuclides–formed due to human activities (Adagunodo et al., 2019). The natural gamma radiation, especially from the series ^{232}Th and ^{238}U radionuclides and their decay products; and the non-serial ^{40}K radionuclides represent the main external source of radiation exposure to the environment (Dauer et al., 2010; Aluko, 2019). The soil retains radioisotopes (radionuclides) in varying amounts and acts as the major source of continuous exposure of man to either internal or external ionizing radiation (Ibrahim et al., 2013; Bawallah et al., 2021). The knowledge of radionuclide distribution and radiation levels in to the environment is important for assessing the effects of radiation exposure due to both terrestrial and cosmogonic sources (Orosun et al., 2020a). Artificial or man-made radioactivity is emitted by nuclear power plants, industrial plants, and research facilities (Orosun et al., 2016). According to (Ilugbo et al 2018; Adebiyi et al., 2018; Alabi et al., 2019) soil may be contaminated through mine tailings, application of fertilizers, and disposal of metal wastes, gasoline, and paints, wastewater irrigation, pesticides, spillage of petrochemicals (EC 2000, Al-Alawy et al., 2018; Orosun et al., 2020b, Paulnah et al., 2021). Sterility, making reproduction impossible and stunted growth, and cancer can be as a result of Radiation (Ahmad et al., 2015; Orosun et al., 2017). Nigeria is well endowed with vast land including arable vegetation for agriculture and mineral resources (Al-Jundi et al., 2003; Almayahi et al., 2012; Adewoyin et al., 2022). These can likely lead to health hazards for the mechanics, automobile owners, and others; especially when the pollution is ignored or not given attention (Singh et al., 2005). The need for accurate information on the levels of radiation within the auto mechanic sites and lacks of data on the radiation level of the study area lays credence to this research work (Tufail et al., 2006). Therefore, it is necessary to monitor the radiation exposure and determine the health effects as well as the potential impacts on the environment (Adewoyin et al., 2019). The activity concentration of the radioactive elements which include ^{238}U, ^{232}Th, and ^{40}K depends on the soil type, mineral content, geological features, and geological condition of an area. Human activity such as mining may contribute to the distributions and levels of radioactivity in the soils of any mining area thereby posing more radiological health hazard to people that use the soil (Boukhenfouf and Boucenna, 2011; Adagunodo et al., 2019). Therefore, radionuclide's activity concentrations and the risks associated with miners and farmer's exposure to these radioactive elements should be monitored. The research aims to assess the radiation risk of the activity concentrations of the natural radionuclides in the soils from Paago mining sites; in Iseyin Local Government Oyo State, Southwest Nigeria. Also to estimate radiation doses and hazards that may emanate from using the soil around the study area by measuring the activity concentrations of ^{238}U,^{40}K, and ^{232}Th in the soil samples from the study area, Calculate the gamma exposure dose levels to the environment of the study area and Compare the result with the world standard recommendation and make relevant Recommendations

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2. The Study Area and Geological Setting

Paago mining site is located in Iseyin Local Government in Oyo State covering or lies between latitude: 7°57'0"N to 8°4'30"N and longitude: 3°30'0"E to 3°40'0"E (figure 1a). The study location can be easily accessed through major and minor road and footpath in an area where there are neither major nor minor road. The study location is situated at Iseyin Central, Southwestern Nigeria, with average elevation of about 266 m above the ground level. The climatic variation of the study area exhibits by averagely high temperature (Orosun et al., 2019). The investigated area lies within the basement complex region of Nigeria comprises quartzites, slightly migmatised to unmigmatised metasedimentary schists, migmatitic and granitic gneisses, and metaigneous rocks; gabbroic, charnockitic, and dioritic rocks (Rahaman, 1976). The investigated area is predominantly dominated by migmatite (Figure 2). The migmatite occur as low-lying outcrops and contained dark coloured bands (melanosome), described as *early gneiss* and *mafic-ultramafic bands* and streaks of leucotomies (Rahaman, 1976) as *granitic or felsic components*, which is indicative of anatexis (Odusanya and Amadi, 1989).

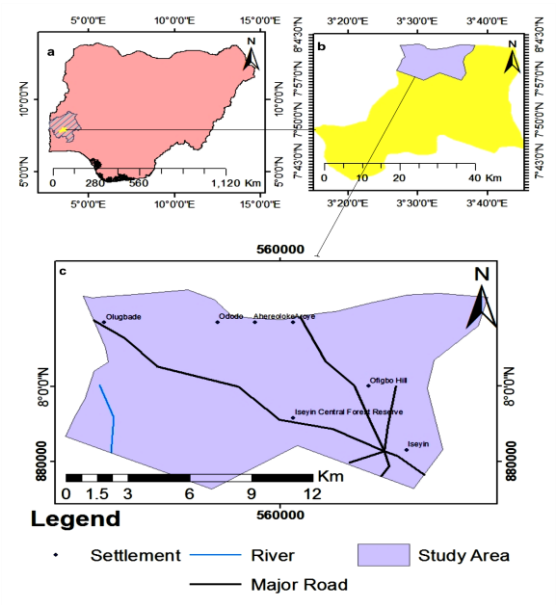

Figure 1: Map showing mining site in Paago village Iseyin Central Local Government

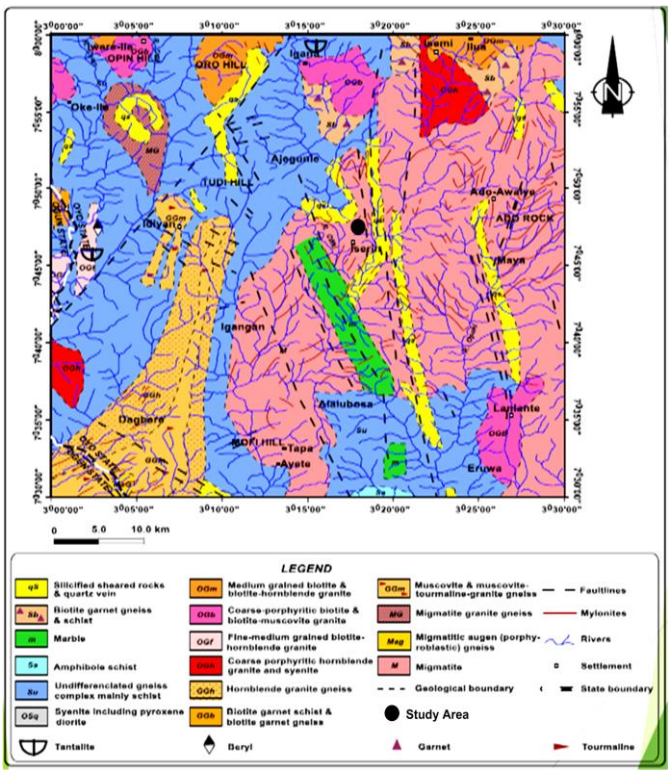

Figure 2: Map of Iseying Local Govt. Indicating the Study Area

3. Methodology

A total of twenty (20) sampling grids of 3 by 4 m^2 each were mapped within each mining pitch locations (ESS1 to ESS20) were randomly taken for the analysis (Figure 3a). This was carried out to assess the radiation risks of mining site's exposure to natural radioactivity in Paago village Iseyin Central Local Government, Oyo State Nigeria. In each pitch, soil samples were collected (Figure 3b). The samples were then thoroughly mixed, packed in polythene bags, and labeled to form a representative sample. The procedure was repeated for all the pitches in each of the mining sites considered for this research. The soil-garbage samples were oven dried at a steady temperature of 110^0C for 6 hours to remove all the moisture and to ensure a constant mass for all the samples. The oven dried samples were pulverized, sieved with a 2mm sieve to attain the same matrix, each sample was packed into a plastic sock and it was taken to IITA Laboratory in Ibadan where Inductively Coupled Plasma Mass Spectrometry (ICP-MS) was used to determine the concentrations. Then 200g each of the samples were weighed, packed into a clean and radon-impermeable plastic container of uniform size and sealed for a period of about 30 days to allow for secular equilibrium between ^{226}Ra and ^{228}Ra and their respective gaseous progenies prior to gamma spectroscopy. The standard reference soil sample was also packed into a container of the same geometric configuration to determine the background radiation. Equation (1) was used to determine the activity concentration and the count rate under the photo peak (Obaseki et al., 2015).

$$C = \frac{C_n}{\varepsilon I_\gamma m_s} \quad (1)$$

where C is the activity concentration of the radionuclide in the sample ($Bqkg^{-1}$); C_n is the count rate under the photo peak, ε is the detector efficiency at the specific γ-ray energy, I_γ is the absolute transition probability of specific γ-ray and M_s is the mass of the sample (kg). With the aid of the Quantum MCA software, the activity concentration of each sample was obtained.

3.1 Radiological Assessments of the Soil Samples

Each soil sample was crushed, pulverized, and homogenized. The sample was then dried and sieved with a < 0.16mm mesh-size before dried in an electric temperature-controlled furnace at 110^{0c} temperature for 4 hours to remove moisture (if any). 200g of each of the dried samples was carefully weighed using an electronic balance with a sensitivity of 0.01mg into a gas-tight radon Impermeable, cylindrical polyethylene container of 2cm uniform base diameter and sealed. The container was substantially fit to sit on the 2cm x 2cm NaI(TI) detector used for the study. The analysis was carried out at the International Institute of Tropical and Agricultural which is one of the International Geochemical Laboratories for Geoscientists. The concentrations of radionuclides (^{238}U and ^{232}Th) and potassium (^{40}K) presence in the samples was determined using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). 0,05ppm, 0,1ppm, and 0,01% are the detection limit of ICP-MS for ^{238}U, ^{232}Th and ^{40}K. Percent (%) and parts per million (ppm) was assign to the concentrations of potassium, uranium and thorium in each soil sample. The radionuclide dispersions in the area were reveal from the obtained results and used for further hazards evaluation.

3.2 Outdoor Annual Effective Dose

Annual effective dose is used to assess potential long term effects that might occur in future due to exposure of the rocks samples by the public. To measure the annual effective doses, both indoors and outdoors, considerations must be made for the conversion coefficient from absorbed dose in air to effective dose and the indoor and outdoor occupancy factors respectively. Hence, the annual indoor and outdoor effective doses ($mSvyr^{-1}$) are given by (UNSCEAR, 2000)

$$E_D = D_R n G h^{-1} \times 8760h \times 0.2 \times 0.7 \times 10^{-3} \quad (2)$$

where E_D is the effective dose, D_R is the dose rate in air, 8760 is the time in an hour for one year, 0.2 is the outdoor occupancy factor, and 0.7 is the indoor occupancy factor (UNSCEAR, 2000).

3.3 Outdoor Absorbed Dose Rate

The quantity of absorbed dose is the amount of energy per unit mass absorbed by irradiated object. Absorbed dose is the energy responsible for damage in living organism.

$$DR(nGy/h) = 0.462A_{Ra} + 0.604A_{Ra} + 0.0417A_K \quad (3)$$

where D_R is the absorbed dose rate in $nGyh^{-1}$, A_{Ra}, A_{Th}, and A_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K, respectively. However,

annual effective dose AED (mSvy^{-1}) to the public due to absorbed dose rate in the air can be calculated by converting the total absorbed dose in (nGyh^{-1}) using 0.7 SvGy^{-1} as the conversion factor (CF) and multiplying by occupancy factor (OF) using equation 4.

$$AED = D_R + 0.2x24x365x0.7 \quad (4)$$

where D_R is the dose rate, 0.7 SvGy^{-1} is the conversion factor (UNSCEAR, 2008) for absorbed dose in the air to an external effective dose, and 0.2 represents the outdoor occupancy factor.

3.4 Radium Equivalent Activity (Ra_{eq})

The radium equivalent activity (Ra_{eq}) is used as a common index to compare the specific activities of samples. It provides a useful guideline in regulating the safety standards on radiation protection for the general public and is obtained as the sum of the weighted activities. The radium equivalent was calculated through the use equation 5.

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (5)$$

where C_{Ra}, C_{Th}, and C_K are the activity concentrations (Bqkg^{-1}) of ^{226}Ra, ^{232}Th, and ^{40}K, respectively.

3.5 External Radiation Hazard Index (H_{ex})

External hazard index (H_{ex}) is used to measure the external hazard due to the emitted natural gamma radiation. The external hazard index, H_{ex} estimates the potential radiological hazard posed by the different rock samples for the external gamma dose of materials to 1.5 mGy/year. It is another criterion to assess the suitability of material. A safety criterion for materials used for building construction is that $Hex \leq 1$ (UNSCEAR, 2000). The external hazard index is also calculated using equation 6.

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (6)$$

where C_{Ra}, C_{Th}, C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively.

3.6 Internal Radiation Hazard Index (H_{in})

In addition to the external hazard index, there is also a threat to the respiratory organs due to ^{222}Rn, the gaseous short-lived decay product of ^{226}Ra. The internal hazard index (Hin) is defined generally to reduce the maximum permissible concentration of ^{226}Ra to half the value appropriate for external exposure alone (Maxwell et al., 2013). Internal exposure to radon and its progeny products is quantified by estimating the internal hazard index using the model by (Avwiri and Alao, 2013): It is calculated using equation 7.

$$H_{in} = \frac{C_{RA}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (7)$$

Where C_{RA}, C_{TH}, and C_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K respectively. If the maximum concentration of ^{226}Ra is one-half that of the normal acceptable limit, then H_{in} will be less than one. For safety precautions in the use of materials in the construction of dwellings, the criterion demands that $H_{in} \leq 1$.

3.7 Representative Gamma Index (I_γ)

The gamma index (I_γ) is used as a screening tool for identifying materials that might be a threat to human health. The representative gamma index (Iγ) was used to estimate the level of γ - radiation hazard associated with the natural radionuclides in specific investigated samples. It is calculated using equation 8.

$$I_\gamma = \frac{C_{RA}}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \quad (8)$$

Where C_{Ra}, C_{Th}, and C_K, are the activity concentrations (Bqkg^{-1}) of ^{226}Ra, ^{232}Th, and ^{40}k respectively.

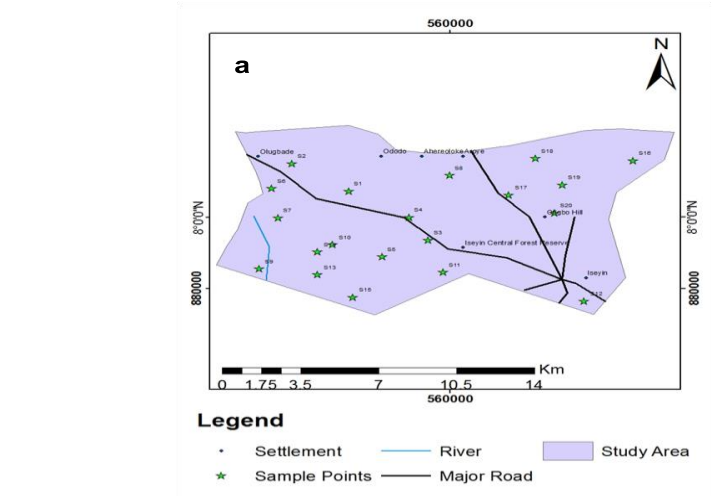

Figure 3: (a) Map of the Study Area Showing Sample Point (b). Pictorial View of the Mining Sites

4. Results and Discussion

4.1 Activity Concentration Natural Radionuclides in the Soil Samples

The natural activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K have been determined from the soil samples collected from mining sites and the results are presented in Table 1. The detection limits (DL) of 21.3Bqkg^{-1}, 9.1Bqkg^{-1} and 4.9Bqkg^{-1} for ^{40}K, ^{226}Ra, and ^{232}Th were also obtained. The values that were lower than the detection limits in the present study were considered as Below Detection Limit (BDL) of the detector. In one-half of the Detection Limits (DL), the DL value was considered for calculating the mean activity concentration and other radiological assessments whenever the concentration of any radionuclide was below the detection level, (Cevik et al., 2008).

Table 1: Range and Mean Activity Concentrations of Radionuclides In Soil Samples From the Study Areas

S/N	Sample Name	^{40}K (Bq/kg)	^{238}U (Bq/kg)	^{232}Th (Bq/kg)
1	SAMPLE NO 1 ESS 1	567.558	3.667	0.802
2	SAMPLE NO 2 ESS 2	333.461	2.154	0.471
3	SAMPLE NO 3 ESS 3	605.555	3.912	0.856
4	SAMPLE NO 4 ESS 4	414.815	2.680	0.586
5	SAMPLE NO 5 ESS 5	317.366	2.050	0.449
6	SAMPLE NO 6 ESS 6	523.002	3.379	0.739
7	SAMPLE NO 7 ESS 7	277.083	1.790	0.392
8	SAMPLE NO 8 ESS 8	459.429	2.968	0.649
9	SAMPLE NO 9 ESS 9	303.075	1.958	0.428
10	SAMPLE NO 10 ESS 10	478.503	3.092	0.676
11	SAMPLE NO 11 ESS 11	190.326	1.230	0.269
12	SAMPLE NO 12 ESS 12	356.254	2.302	0.504
13	SAMPLE NO 13 ESS 13	287.126	1.855	0.406
14	SAMPLE NO 14 ESS 14	529.207	3.419	0.748
15	SAMPLE NO 15 ESS 15	595.626	3.848	0.842
16	SAMPLE NO 16 ESS 16	483.518	3.124	0.684
17	SAMPLE NO 17 ESS 17	523.700	3.384	0.740
18	SAMPLE NO 18 ESS 18	353.649	2.285	0.500
19	SAMPLE NO 19 ESS 19	286.114	1.849	0.404
20	SAMPLE NO 20 ESS 20	313.335	2.024	0.443

4.2 Absorbed Dose Rate and Annual Effective Dose

Table 2: Range and Mean of Absorbed Dose and Annual Effective Dose Rates in Soil Samples from the Study Areas

Sampling Points	^{40}K(Bq\kg)	^{238}U(Bq\kg)	^{232}Th(Bq/kg)	Absorbed dose (nGyh^{-1})	Collective effective dose (µSvy^{-1})
SAMPLE NO 1	567.558	3.667	0.802	11.41	11.62
SAMPLE NO 2	333.461	2.154	0.471	17.09	20.10
SAMPLE NO 3	605.555	3.912	0.856	11.08	12.29
SAMPLE NO 4	414.815	2.680	0.586	13.03	14.24
SAMPLE NO 5	317.366	2.050	0.449	19.38	20.59
SAMPLE NO 6	523.002	3.379	0.739	14.89	16.10
SAMPLE NO 7	277.083	1.790	0.392	9.72	10.93
SAMPLE NO 8	459.429	2.968	0.649	13.48	14.69
SAMPLE NO 9	303.075	1.958	0.428	10.36	11.57
SAMPLE NO 10	478.503	3.092	0.676	5.64	6.85
SAMPLE NO 11	190.326	1.230	0.269	12.21	13.42
SAMPLE NO 12	356.254	2.302	0.504	8.16	9.37
SAMPLE NO 13	287.126	1.855	0.406	43.60	44.81
SAMPLE NO 14	529.207	3.419	0.748	31.02	32.23
SAMPLE NO 15	595.626	3.848	0.842	44.12	50.73
SAMPLE NO 16	483.518	3.124	0.684	39.40	40.65
SAMPLE NO 17	523.700	3.384	0.740	31.48	32.69
SAMPLE NO 18	353.649	2.285	0.500	18.72	19.93
SAMPLE NO 19	286.114	1.849	0.404	11.88	13.09
SAMPLE NO 20	313.335	2.024	0.443	11.49	12.70

The results of the absorbed dose rate and Annual effective dose of soil samples from the study area are represented in Table 2.

4.3 Radiological Assessments Due to the Radionuclides in Soil Samples

Radiological hazard indices which include radium equivalent activity, internal radiation hazard index, external radiation hazard index, and representative gamma index are presented in table 3. The errors in the mean values are the standard deviations that spread across the measured values obtained for the samples.

Table 3: The Range and Meano Radium Equivalent, Internal, External Hazard and Gamma Representative Indices in Soil Samples from the Study Areas

Samples	Iγ	Hin	Hex	Rae	ED
SAMPLE NO 1 ESS 1	0.41	0.14	1.66	48.52	771.85
SAMPLE NO 2 ESS 2	0.24	0.08	0.97	28.51	759.02
SAMPLE NO 3 ESS 3	0.44	0.15	1.77	51.76	773.93
SAMPLE NO 4 ESS 4	0.30	0.10	1.21	35.46	763.48
SAMPLE NO 5 ESS 5	0.23	0.08	0.93	27.13	758.14
SAMPLE NO 6 ESS 6	0.38	0.13	1.53	44.71	769.41
SAMPLE NO 7 ESS 7	0.20	0.07	0.81	23.69	755.93
SAMPLE NO 8 ESS 8	0.33	0.11	1.34	39.27	765.92
SAMPLE NO 9 ESS 9	0.22	0.08	0.88	25.91	757.35
SAMPLE NO 10 ESS 10	0.35	0.12	1.40	40.90	766.97
SAMPLE NO 11 ESS 11	0.14	0.05	0.56	16.27	751.18
SAMPLE NO 12 ESS 12	0.26	0.09	1.04	30.45	760.27
SAMPLE NO 13 ESS 13	0.21	0.07	0.84	24.54	756.48
SAMPLE NO 14 ESS 14	0.38	0.13	1.54	45.24	769.75
SAMPLE NO 15 ESS 15	0.43	0.15	1.74	50.92	773.39
SAMPLE NO 16 ESS 16	0.35	0.12	1.41	41.33	767.24
SAMPLE NO 17 ESS 17	0.38	0.13	1.53	44.77	769.45
SAMPLE NO 18 ESS 18	0.26	0.09	1.03	30.23	760.13
SAMPLE NO 19 ESS 19	0.21	0.07	0.83	24.46	756.43
SAMPLE NO 20 ESS 20	0.23	0.08	0.91	26.78	757.92

5. Discussion

5.1 Activity Concentration

The measured activity concentrations of ^{40}K, ^{238}U, and ^{232}Th ranged from 190.326 to 605.555Bqkg^{-1}, 1.790 to 3.912Bqkg^{-1}, and 0.269 to 0.802Bqkg^{-1} (Figure 4). The average value of ^{40}K, ^{238}U, and ^{232}Th were 440.446±19.07Bqkg^{-1}, 2.846±3.11Bqkg^{-1}, and 0.623±3.10Bqkg^{-1}. The results showed that ^{40}K has the highest activity concentration of 605.555±1.1Bqkg^{-1} which is almost the world average of 420Bq/kg^{-1}, while ^{232}Th has the least activity concentration of 0.269±0.1Bqkg^{-1}. The value of ^{40}K indicates that the soil was not as a result of the natural weathering of the earth's crust rock but as a result of decay, accumulation, and sedimentation of materials. However, the mean value of activity concentration obtained for ^{238}U was 8.58 ± 4.1Bqkg^{-1} which is lower than the world average value. The highest value of ^{238}U in the soil sample is 3.848Bqkg^{-1}. While the lowest concentration for both ^{232}Th and ^{226}Ra radionuclides in soil were 1.849 and 0.269Bqkg^{-1} respectively. The variation that occurs in the value obtained from soil may be a result of several factors such as the latitude of the area, and geographical soil formation of the study area. The results from the present study areas were compared with other research works. Mean concentration of the primordial radionuclides in the study area compared to similar studies. The mean activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th in El-Taher and Makhluf, 2010 were 157.1Bq/kg, 15.2Bq/kg, and 26.9Bq/kg, these values were higher than the result obtained in the present study except for ^{40}K. The results of IAEA 1989 were higher than the results obtained in the present study except for ^{226}Ra which is three times higher.

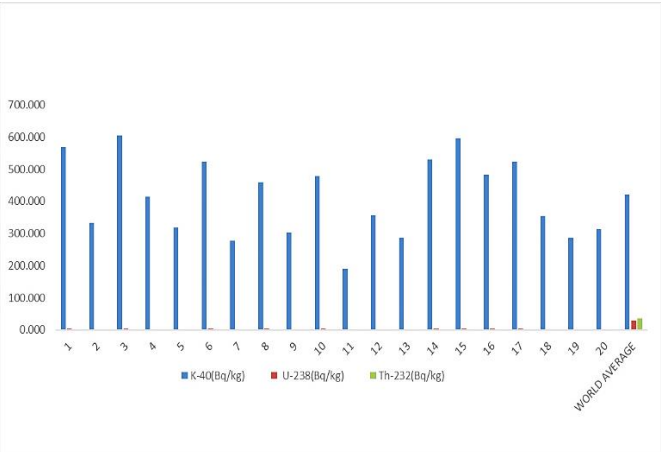

Figure 4: Mean activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th radionuclides in soil samples

5.2 Absorbed and Effective Doses in Soil from the Study Area

The gamma absorbed dose rate presented in Table 2 ranged from 6.85nGyh^{-1} to 45.73nGyh^{-1}, however, the average absorbed dose rate in the samples was 11.18±2.35nGyh^{-1}. The mean absorbed dose rate in this study is lower than the world recommended average value of 59nGh^{-1}. The results obtained in this study are similar to the value obtained and lower than the value obtained by (Atolagbe et al., 2017; Farai et al., 2001; Lawal et al., 2016). The values of the annual effective dose computed for the soil sample in this study were lower than the standard dose criterion of 0.3mSv^{-1}. Therefore, from the radiological point of view, the use of soil from the study areas do not pose a significant health hazard and is considered to be safe for the artisans whose workshop are situated in the study areas.

5.3 Radiological Hazard Indices

Radiological hazard indices include radium equivalent, external and internal hazard index, and representative gamma index (I_γ). Radium equivalent is an index that gives the sum of gamma radiation from^{40}K, ^{226}Ra, and ^{232}Th radionuclides in a sample. The maximum value of radium equivalent for building materials must be less than the limit value of 370 Bqkg^{-129} to keep the external and internal doses below 1 mSvy^{-1}. Table 3 presents the values of calculated hazard indices, the value of radium equivalent ranging from 21.62Bqkg^{-1} to 113.68Bqkg^{-1} in the soil. The values of radium equivalent obtained in the present study were below the recommended value of 370 Bqkg^{-1} (Figure 5). In addition, all the values obtained for external and internal hazard indices were less than unity except in two locations where the value shows little deviation from unity, the results show that radiation hazard associated with the soil within study areas would pose negligible health impact.

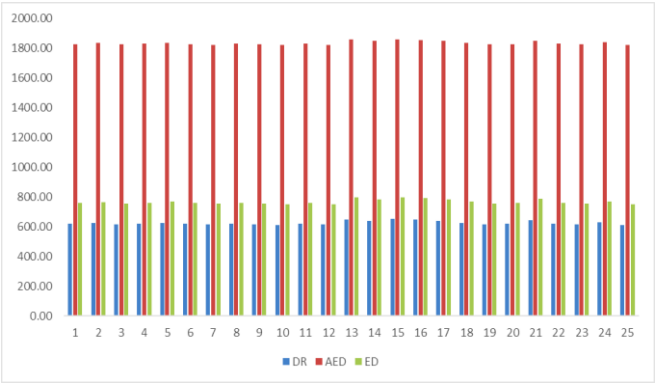

Figure 5: Absorbed and Effective Doses in Soil from the Study Area

6. Conclusion

In this present study, measurements of the activity concentrations of ^{40}K, ^{238}U, and ^{232}Th radionuclides have been carried out at various mining sites of paago village, Iseyin Local Government, Oyo state, Southwestern Nigeria using a well-calibrated HPGe detector. Twenty (20) soil samples were analyzed and the results showed that ^{40}K, ^{238}U, and ^{232}Th ranged from 58.40 to 950.41Bqkg^{-1}, 5.57 to 24.22Bqkg^{-1} and 4.1 to 25.93Bqkg^{-1}. The means activity concentration of the three radionuclides was lower than the world average value. The values of the gamma absorbed dose rate in the soil samples ranged from 6.85nGyh^{-1} to 45.73nGyh^{-1}. The mean absorbed dose rate in the present study is lower than the world-recommended average value of 59nGh^{-1}. The annual effective dose rates in the air varied from 14.26 to 19.74μ Svyr^{-1} with an average value of 17.99 μSvy^{-1}. The highest and lowest values of radium equivalent in the soil was 113.68Bqkg^{-1} and 21.62Bqkg^{-1}. However, all the values obtained for external and internal hazard indices were less than unity. The values of the Gamma absorbed dose rate in the soil samples ranges from 11.62 to 16.08 nGyh^{-1} with a mean value of 14.60nGy-1. The annual effective dose rates in the air varied from 14.26 to 19.74μ Svyr^{-1} with an average value of 17.99 μSvy^{-1}. This results obtained in this study pose no significant radiological threat to the populace when compared with other published value and world recommended standard. It indicates that any physical activity, oil drop, disturbance, and instability of the land may not necessarily affect the concentration of primordial radionuclides from the study area. The effects that high amounts of radioactive elements in the soil can have a deadly effects on human health. The assessment of the radiological impact due to natural radionuclides on the population is important in monitoring population exposure, providing data on radiation levels to make policy-relevant to radiation protection. Based on the findings of this present study, the Government should do more to raise

public awareness of the effects of ionizing radiation. The data obtained are important both for assessing the risk to human health as well as environmental monitoring.

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