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Radiological Hazard Indices and Environmental Impact of Primordial Radionuclides in Iyin Quarry Site and Araromi-Iyin, Southwest, Nigeria

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Abstract

The terrestrial radionuclides content of Araromi-iyin and Iyin quarry site was measured with handheld RS-125 super spec gamma-ray spectrometer using forty sampling points in each of the location of the study area. The purpose of the study is to determine the concentration of ^{238}U, ^{232}Th and ^{40}K in the ambient air and thereby estimate the absorbed dose rate and evaluate the radiological parameters in order to assess the possible radiation risk to the dwellers in the communities. Analysis of the results show that the mean concentrations of ^{238}U, ^{232}Th and ^{40}K were 39.80, 69.62, and 939.0 Bq/kg and 49.28, 112.55, and 1,270 Bq/kg for Araromi-iyin and Iyin quarry site respectively. The mean value of the absorbed dose rate for the two locations were 102.53 nGy/h and 149.43 nGy/h accordingly. The outdoor and indoor effective dose for the two locations were 0.13 & 0.05 mSv/y for Araromi-iyin and 0.13 and 0.68 mSv/y for Iyin quarry site. The external and internal hazard index for Araromi-iyin were 0.73 and 0.83 and Iyin quarry site were 0.83 and 0. 97. The annual gonadal index has the mean value of 0.71 and 1.02 for Araromi-iyin and Iyin quarry site while that of radium equivalents were 205.75 and 300.08 Bq/kg accordingly. The gamma representative indices were 0.79 and 1.15 and excess lifetime cancer risk were 0.36 and 0.52 for Araromi-iyin and Iyin quarry site respectively. The measured radionuclide contents, the effective dose, and the excess lifetime cancer risk were higher than the world limit in both locations. The annual gonadal index and the gamma representative index in Iyin quarry sites were higher than the world limit. The concentration of measured radionuclides and estimated radiological parameters in Iyin quarry site were higher than that of Araromi-iyin. There is need for more scrutiny of Araromi-iyin community while the ongoing mining in the quarry site is impacting the radioactivity level of Iyin quarry site and environs.

Keyword: Radionuclides, Radiological Parameters, Araromi-Iyin, Iyin quarry site

Introduction

Protection of human environs, from the damaging effect of radiation, while still permitting its valuable uses is the major concern of health physics [1]. Environmental science emphasizes the need for human environment to be free from all form of hazard and pollution [2] Environmental monitoring for the prevalence and migration of radioelement protect human being from potential carcinogens, through the pathways of environmental contamination [3]. Environmental contaminants such as physical, chemical and biological or radiological element can be carcinogen, but radiation is a prominent carcinogen [4]. To prevent the release of large volume of long-lived radionuclides which may be carcinogenesis, human environment needs to be constantly monitored to assess the risk of radiation from the natural sources and man- made sources. Environmental protection emphasis on minimizing harm to the natural world from human activities, as well as exposure to radiation. This includes considering the effect of radiation on biota and bio-networks and employing strategies to reduce harm, which involves, developing safe disposal practices for radioactive waste and limiting the release of radioactive substances into the environment. The developed world had various radiation regulatory bodies such as the US Environmental Protection Agency (EPA) that are accountable to set the limit for exposure to ionizing radiation to safeguard the health of member of the public and the environment. They monitor radiation levels and enforce regulations to ensure that sources of ionizing radiation are properly managed to minimize exposure to people and the environment.

Radiation protection is the science of protecting people and the environment from the harmful effects of ionizing radiation [5]. It involves using a combination of technical and administrative measures to reduce exposure to ionizing radiation to as low as reasonably achievable, while still allowing for its beneficial uses. This includes the use of protective clothing, shielding, and limiting the duration of exposure, as well as properly disposing of radioactive materials to prevent contamination. Environmental protection cannot be over emphasized because of the risk of exposure to radiation in the human environment [6]. The radioactivity level of numerous communities in the country had been assessed by environmental researchers [7 ,8, 9,10, 11]. The purpose of this study is to assess the radioactivity level of the communities through the measurement of radionuclides content in the ambient air using RS-125 gamma-ray spectrometer with global positioning system, and consequently evaluate the radiological parameters to determine the possible radiation risk to the residents of the study areas.

Area of Study

The study areas are Araromi-Iyin and Iyin quarry site. The two communities are situated in Irepodun/Ifelodun Local Government Area and each of the community is about 67 Km far from Ado- Ekiti the capital city of Ekiti state. Araromi-Iyin Ekiti is an ancient town in Irepodun/Ifelodun Local Government Area of Ekiti State while Iyin quarry site Iyin-Ekiti is a quarry site in Iyin Ekiti that specializes in mining and crushing of granite stone into smaller particle stone that is used in construction of road and building. The two communities are about 2 km apart. The geology of the study areas consisted of metasediments represented by quartzites in granitic and charnockitic rocks with fine to medium grained granites which usually resulted in lateritic overburden due to weathering. The communities are embedded with crystalline basement rocks of Precambrian age with granitic intrusion and highly deformed metamorphic rocks.

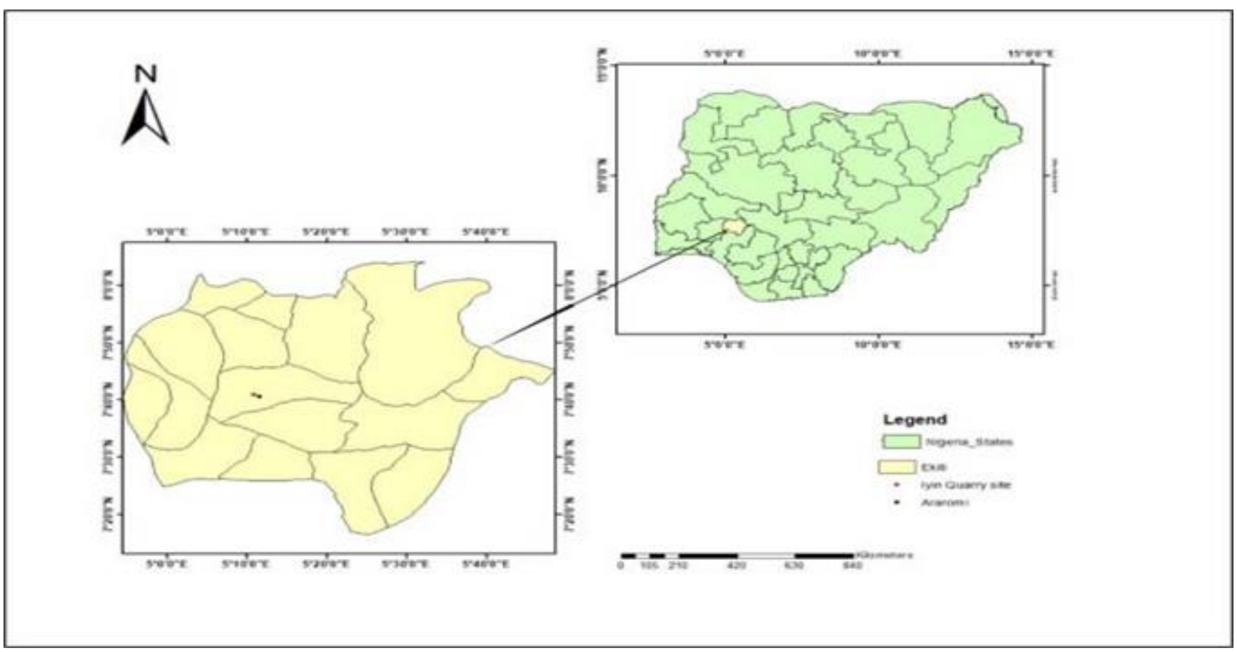


Figure 1: Map showing Study Area

Materials and Methods

The Instruments

RS-125 handheld gamma-ray spectrometer with global positioning coordinates was employed for the measurement of the terrestrial radiation due to ^{238}U,^{232}Th and ^{40}K. RS-125 handheld gamma-ray spectrometer is very versatile in geophysical survey for its ruggedness and ease of operation. The decay series of the primordial radionuclides are made up of radioelement that are very present in human environment. They consisted of radionuclides that yield gamma rays of sufficient energy and intensity that can be measured by the detector. Terrestrial radiation consisted of ^{238}U, ^{232}Th and ^{40}K that exhume from cosmic rays and remain in the natural environment due to their long half-lives. The efficiency and resolution of the detector make it easier to absorbed gamma rays and differentiate between rays of closed energy gap. The instrument measures the concentration of ^{40}K by the detection of 1416 keV that is given off by ^{40}K naturally at a fixed ratio and recorded in percentage. ^{238}U, is determined by the detection of 1765 keV of 214 Bi daughters of ^{238}U, that is emitted and recorded in part per million equivalents of ^{238}U. So also, ^{232}Th is detected by the 2615 keV of 208-Ti, a progeny of ^{232}Th decay series and recorded in part per million equivalents of ^{232}Th. The total count gamma ray is determined by the energy of the source, the volume, efficiency and threshold energy of the detector.

Sampling Procedure

Forty sampling points at different forty locations were covered in each of the community of the study areas. The concentration of the three primordial radionuclides was measured with handheld RS-125 gamma-ray spectrometer. For each of the measurements, the instruments were held at 1 m above the ground level. The background radiation of the primordial radionuclides and the absorbed dose rate was taken three times, and the average value was calculated and recorded. The instrument was allowed to auto-stabilize for 5 minutes after which the concentration of the ^{238}U, ^{232}Th and ^{40}K was taken in the assay mode of the instrument and the average value determined. The sampling time of 90 s was used.

Estimation of Radiological Parameters

The following radiological parameters of interest were evaluated to determine the possible radiation impact to the dwellers of the communities.

Absorbed dose rate is used to find the biochemical change in a specific tissue or organ. It is used to calculate the energy deposited per unit mass in a living tissue when it is exposed to ionizing radiation. It is measured in J/Kg or Rad, or Gray (Gy). This was determined using equation 1

$$DE\ (nGy/h) = 0.462A_U + 0.604A_{Th} + 0.0417A_K$$

ABD is the absorbed dose, A are the concentration of ^{40}K, ^{238}U, and ^{232}Th respectively [12].

Annual committed dose is the dose rate absorbed in an area of exposure in a year. It is used in establishing a threshold limit for risk assessment. It is used by the regulatory body to compare the effect of radiation from different source on human health. The annual committed dose was evaluated using equation 2.

$$ACD\ (mSv/y) = ABD \times T \times F$$

ACD is the annual committed dose rate, *ABD* is the absorbed dose rate, *T* is the duration of time of measurement, which will be taken as 1 year, *F* is the conversion coefficient [13] $ACD_{in}\ (mSv/y) = ABD \times 8760 \times 0.8 \times 0.7 \times 10^{-6}$

$$ACD_{out}\ (mSv/y = ABD \times 8760 \times 0.2 \times 0.7 \times 10^{-6}$$

The excess life-time cancer risk measures the amount of probable cancer risk to the dweller of the community as a result of exposure to ionizing radiation. This was determined using equation 5 $ELTCR$ (mSv/y) $= ABD \times \vartheta \times F$

ELTR is the excess life-time cancer risk, ABD is the absorbed dose, ϑ is the life expectancy which will be taken as 70 years and *F* is the conversion factor and taken as 0.05 Sv^{-1} [14] Dose Equivalent determine the concentration of ionizing radiation to a specific internal organ such as gonads, active bone marrow and the bone surface cells. It was evaluated using equation 6

$$AGDE\ (mSv/y) = 3.09A_U + 4.18A_{Th} + 0.31A_K \quad (6)$$

A_U, A_{Th}, A_K have their usual notation

Radium equivalent measures the amount of gamma ray produced from diverse fusions ^{238}U, ^{232}Th and ^{40}K in the community. It was evaluated using equation 7

$$Ra_{eq}\ (Bq/Kg) = A_U + 1.43A_{Th} + 0.7071A_K \quad (7)$$

The symbols have their usual meaning.

Gamma representative index measures the amount of gamma radiation from the terrestrial radioelement in a sample material. It was determined using equation 8

$$Ra_{eq}\ (Bq/Kg) = A_U + 1.43A_{Th} + 0.07071A_K \leq 1 \quad (8)$$

The symbols have their usual meaning.

Results and Discussion

The result of the three primordial radionuclides measured with handheld RS-125 gamma-ray spectrometer in the two study locations are presented in Table 1 and 2. The analysis of the result revealed that, the concentration of the measured radionuclides in Araromi-Iyin, ranges from 11.11-77.81, 41.41-112.46, 63.4-1439.8 Bq/kg for ^{238}U, ^{232}Th and ^{40}K respectively, with the mean values of 39.80, 69.62 and 939 Bq/kg accordingly. The absorbed dose rate ranges from 76.6-144.2 nGy/h with the mean value of 102.53 nGy/h. The measured radionuclides in Iyin quarry site ranges from 13.59-97.57, 68.61-159.96, 939-1784.1 Bq/kg for ^{238}U, ^{232}Th and ^{40}K with the mean value of 49.28, 112.55, 1270.78 Bq/kg accordingly. The measured absorbed dose ranges from 111.6-201.4 nGy/h with the mean value of 149.43 nGy/h. The estimated mean values of ^{238}U (39.80 and 49.28 Bq/kg) in Araromi-Iyin and Iyin quarry site are more than 35 Bq/kg recommended by radiation regulatory body [15]. The calculated mean values for ^{232}Th are 69.62, 112.55 Bq/kg, which are more than 45 Bq/kg recommended for exposure to ^{232}Th [16] and the concentration of ^{232}Th in Iyin quarry site was more than two times the threshold limit and almost double in comparison to that of Araromi-Iyin. The average values of ^{40}K 939, 1270.78 Bq/kg in Araromi-Iyin and Iyin quarry site were more than 420 Bq/Kg threshold limit, with that of Araromi- Iyin more than two times the reference limit and that of Iyin quarry site more than three times [16]. Consequently, the mean measured absorbed dose in the two communities (102.53, 149.43) nGy/h are more than the allowable limit of 59 nGy/h [14]. The concentration of the three measured radionuclides and the absorbed dose rate are higher in Iyin quarry site than Araromi-Iyin. These shows that the mining activities taking place in Iyin quarry site have resulted in elevating the radioactivity level of the community [17]. Figures 2-4 presents the correlation of the measured radionuclides with the absorbed dose rate.

Empirical analysis of the measured radionuclides with the absorbed dose in Iyin quarry site revealed that the concentrations of the three radionuclides show high correlation with the estimated absorbed dose because the Pearson correlation (R^2) value is very close to unity. This means that all the radionuclides contributed to the radiation in this location with ^{232}Th and ^{40}K, contributing significantly to the radiation burden in the study location as illustrated in Figures 2-4. This prove that the concentrations of ^{232}Th and ^{40}K contribute mostly to the absorbed dose rate in the study location. The absorbed dose rate of the present study is compared with other locations in the world as elucidated in Table 3. It was observed that the absorbed dose rates in this study are higher than what were recorded by [18,19], but comparable with those reported by [20,21,22].

Table 1: Measured Radioelement Content and Absorbed Dose Rate of Araromi-Iyin

Location	LATT	LONG	DR (nGy/h)	DE (nGy/h)	U (Bq/Kg)	Th (Bq/Kg)	K (Bq/Kg)
AR1	7.677535	5.192773	101.8	100.12	34.58	74.70	845.1
AR2	7.677335	5.192085	94.3	94.32	25.94	61.71	1001.6
AR3	7.676813	5.192042	115.2	116.13	24.71	75.52	1314.6
AR4	7.676588	5.192647	98.6	100.57	28.41	57.65	1189.4
AR5	7.676228	5.192002	103.2	102.17	35.82	57.25	1158.1
AR6	7.676075	5.192568	100.3	103.23	41.99	70.64	907.7
AR7	7.675547	5.192273	106.4	102.83	48.17	62.12	970.3
AR8	7.675092	5.191865	115.1	115.71	66.69	57.65	1158.1
AR9	7.674227	5.192162	108.4	111.89	50.64	82.01	845.1
AR10	7.674227	5.192162	100.2	102.46	21.00	90.94	782.5
AR11	7.674058	5.191711	114.7	114.07	53.11	85.67	813.8
AR12	7.673921	5.191375	96.2	96.16	17.29	77.95	876.4
AR13	7.673391	5.190391	100.1	101.29	38.29	66.18	970.3
AR14	7.673691	5.191867	104.3	104.56	25.94	75.11	1032.9
AR15	7.672783	5.192348	102.2	102.21	72.87	51.16	876.4
AR16	7.672348	5.191671	104.6	104.22	29.64	70.24	1064.2
AR17	7.672052	5.192398	93.8	92.78	53.11	57.65	751.2
AR18	7.671958	5.192993	96.6	95.05	40.76	55.22	970.3
AR19	7.672272	5.193721	121.2	122.20	27.17	104.75	970.3
AR20	7.672087	5.194002	144.2	144.81	55.58	112.46	1095.5
AR21	7.672195	5.194478	105.6	107.26	21.00	80.39	1064.2
AR22	7.672853	5.194395	116.5	115.57	11.12	105.15	970.3
AR23	7.673318	5.194548	111.5	112.90	40.76	82.01	970.3
AR24	7.673793	5.194272	102.9	103.29	43.23	73.89	845.1
AR25	7.674683	5.194143	100.4	100.66	59.28	55.62	907.7
AR26	7.674823	5.194825	99.6	100.80	32.11	69.43	970.3
AR27	7.674545	5.195598	104.3	105.83	55.58	51.97	1126.8
AR28	7.675103	5.195513	85.9	84.00	27.17	43.44	1032.9
AR29	7.674763	5.196172	99.1	100.60	21.00	46.69	1439.8

AR30	7.675082	5.196703	120.7	121.99	77.81	67.80	1032.9
AR31	7.675193	5.196195	82.1	82.39	29.64	41.41	1001.6
AR32	7.676675	5.195568	76.6	78.00	22.23	61.31	657.3
AR33	7.676237	5.195555	78.6	80.38	38.29	58.46	594.7
AR34	7.677687	5.196275	95.6	96.41	43.225	71.46	719.9
AR35	7.677322	5.195688	87.1	88.31	51.87	57.65	657.3
AR36	7.676743	5.194982	107.4	108.34	29.64	94.19	782.5
AR37	7.677083	5.193703	115.3	116.10	75.34	62.52	1001.6
AR38	7.677975	5.194112	106.3	107.19	23.47	104.34	657.3
AR39	7.678915	5.194612	101.8	98.92	30.88	67.40	970.3
AR40	7.678505	5.194932	82.6	81.00	66.69	43.04	563.4
MIN			76.6	78.00	11.12	41.41	563.4
MAX			144.2	144.81	77.81	112.46	1439.8
MEAN			102.5	102.92	39.80	69.62	939
World Limit			59.0	59.0	35.0	45.0	420.0

.Table 2: Measured Radioelement Content and Absorbed Dose Rate of Iyin Quarry Site

Location	LATT	LONG	DR (nGy/h)	DE (nGy/h)	U(Bq/Kg)	Th (Bq/Kg)	K(Bq/Kg)
IY1	7.683752	5.182107	151.8	148.13	50.64	122.61	1064.2
IY2	7.683657	5.182127	137.5	138.53	28.41	120.58	1095.5
IY3	7.683611	5.182182	144.1	143.54	69.16	111.65	939
IY4	7.683378	5.182177	132.7	133.28	32.11	120.18	939
IY5	7.683328	5.182242	139.2	138.15	46.93	110.03	1064.2
IY6	7.683187	5.182512	149.4	150.64	45.70	131.54	1032.9
IY7	7.683262	5.182695	130.2	128.49	43.23	99.88	1032.9
IY8	7.683257	5.182911	128	128.01	44.46	102.31	970.3
IY9	7.683345	5.183167	124.2	124.90	56.81	87.70	1001.6
IY10	7.683587	5.183188	141.2	143.03	50.64	116.93	1032.9
IY11	7.683762	5.183382	139.6	138.51	45.70	115.30	1001.6
IY12	7.683962	5.183212	136.2	136.86	25.94	101.91	1377.2

IY13	7.684128	5.183218	130.2	128.20	13.59	90.94	1471.1
1Y14	7.684162	5.183078	137.2	135.11	32.11	105.15	1220.7
IY15	7.684268	5.182417	151.2	150.67	38.29	120.58	1283.3
IY16	7.684348	5.182137	127.2	130.21	69.16	87.70	1001.6
IY17	7.684123	5.181147	120.8	122.39	18.53	102.72	1095.5
IY18	7.683647	5.180367	129.2	126.41	46.93	86.48	1158.1
IY19	7.683408	5.180665	156.2	155.84	62.99	110.43	1314.6
IY20	7.683507	5.180357	166.6	166.60	35.82	144.13	1314.6
IY21	7.683321	5.180173	151.4	152.34	51.87	108.40	1377.2
IY22	7.682915	5.180131	163.7	166.19	54.34	131.54	1314.6
IY23	7.682627	5.179997	152.5	155.71	85.22	97.85	1283.3
IY24	7.682402	5.179985	166.8	166.85	64.22	122.21	1377.2
IY25	7.682272	5.179998	188.2	188.45	34.58	159.96	1596.3
IY26	7.682088	5.180053	200.1	200.74	87.69	144.13	1596.3
IY27	7.681875	5.180543	172.2	174.31	44.46	132.36	1596.3
IY28	7.681663	5.180608	178.9	178.96	13.59	149.41	1752.8
IY29	7.681435	5.180651	178.6	178.11	97.57	97.85	1690.2
IY30	7.681645	5.180972	182.7	181.20	13.59	156.72	1690.2
IY31	7.681795	5.181187	179.7	180.54	49.40	126.67	1784.1
IY32	7.681605	5.181338	192.5	193.40	79.04	132.76	1690.2
IY33	7.681598	5.181682	201.4	202.20	83.98	138.85	1752.8
IY34	7.681742	5.181843	151.2	152.98	54.34	99.88	1502.4
IY35	7.682035	5.181812	117.4	119.32	39.52	88.51	1032.9
IY36	7.682433	5.181778	137.7	137.21	34.58	118.55	1032.9
IY37	7.682741	5.181832	126.8	126.89	60.52	80.39	1126.8
IY38	7.681422	5.180898	121.7	120.69	66.69	71.05	1064.2
IY39	7.680972	5.180561	111.6	107.94	46.93	68.61	1001.6
IY40	7.680881	5.180197	129.4	129.35	51.87	87.70	1158.1
MIN			111.6	107.94	13.59	68.61	939
MAX			201.4	202.20	97.57	159.96	1784.1
MEAN			149.43	149.52	49.28	112.55	1270.78

World Limit	59.0	59.0	35.0	45.0	420.0

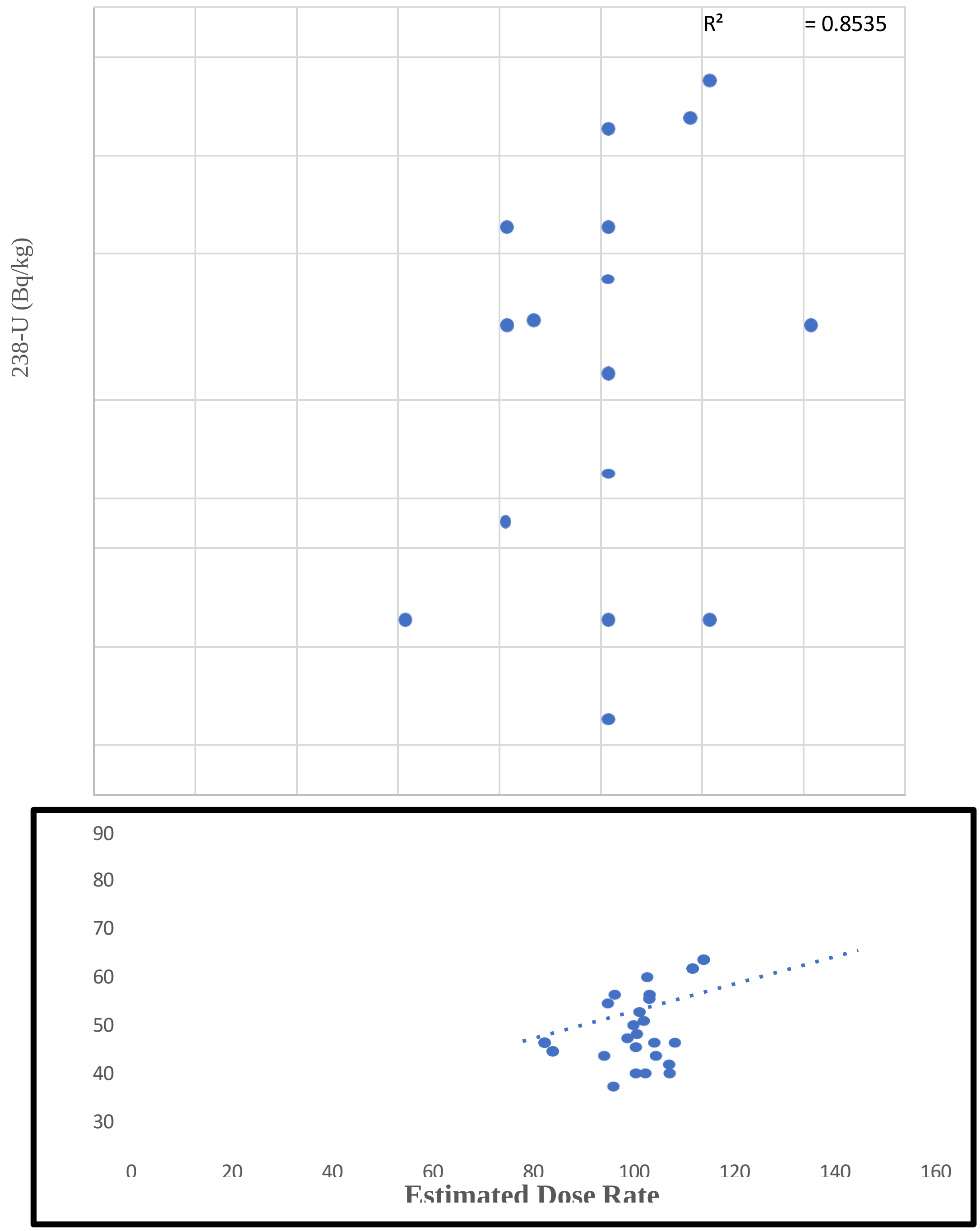


Figure 2: Correlation of ^{238}U with the absorbed dose rate

40-K(Bq/kg)

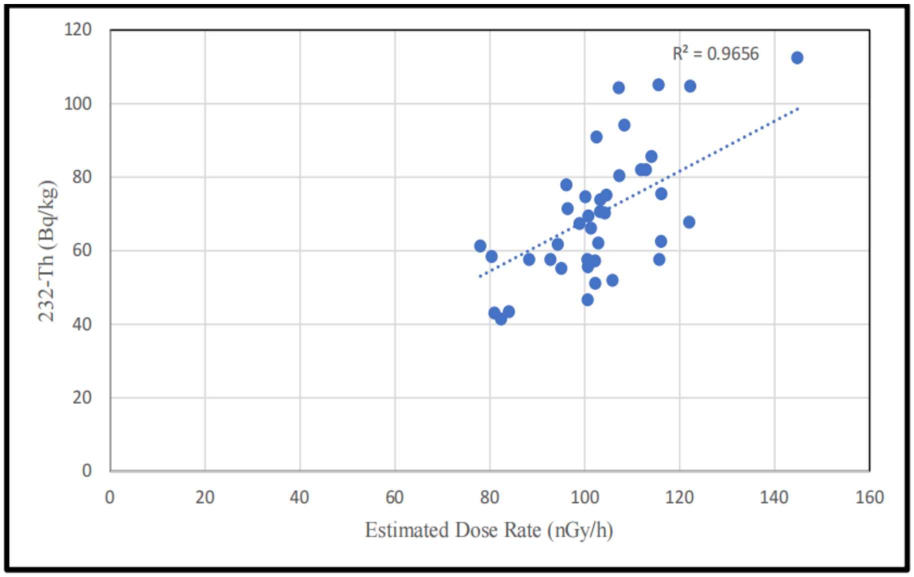
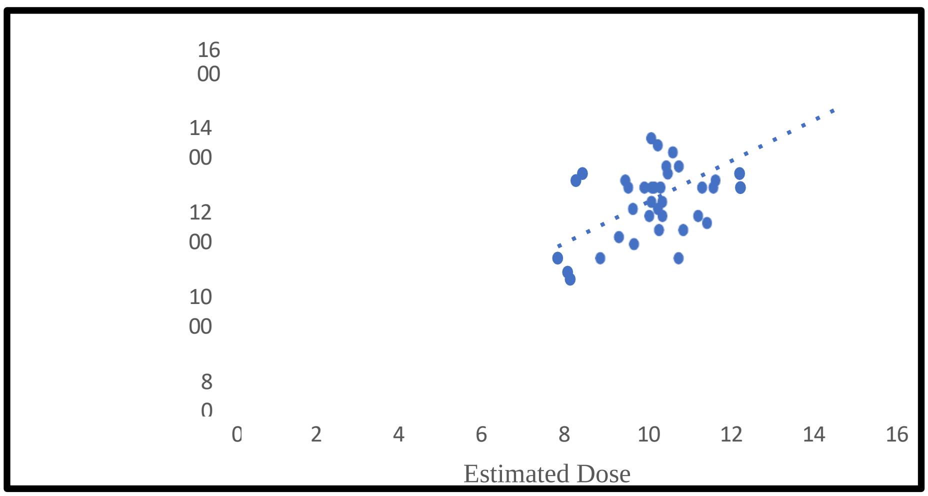


Figure 3: Correlation of ^{232}Th with the absorbed dose rate



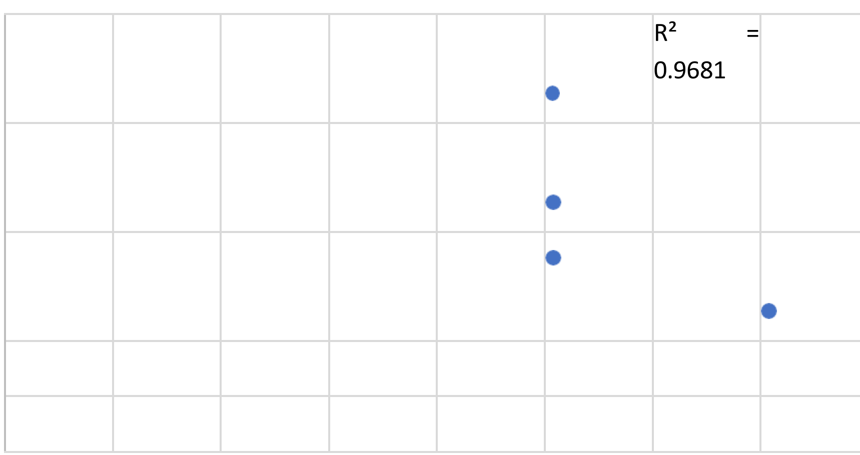


Figure 4: Correlation of ^{40}K with the absorbed dose rate

Table 3: Comparison of the absorbed dose rate of present study with other locations.

Locations	**Absorbed dose rate (nGy/h)**	**References**
Niger-delta, Nigeria	100.00	[23]
Sokoto, Nigeria	114.00	[21]
Manipur, India	86.90	[24]
FCT, Nigeria	105.85	[22]
South-west, Nigeria	84.77	[25]
Tiru region, India	65.70	[26]
Northern Pakistan	60.90	[27]
Agbara, Ogun State, Nigeria	47.22	[20]
Lagos, Nigeria	43.55	[19]
Ekiti State, Nigeria	102.53,149.43	Present Study

Table 4 and 5 depict the estimated radiological parameters for the two locations. The estimated absorbed dose rate ranges between 77.99 and 144.81 nGy/h with the mean of 107.9 nGy/h for Araromi-Iyin and between 102.92 and 202.20 nGy/h with the mean of 149.52 nGy/h for Iyin quarry site. The values of the measured absorbed dose rate and the estimated dose in both communities agree, which signifies the accuracy of the measurement and the instrument used [11]. The outdoor annual effective dose has the minimum value of 0.10 mSv/y and maximum value of 0.18 mSv/y with the mean value of 0.13 mSv/y for Araromi-Iyin while that of Iyin quarry site interspersed between 0.13 and 0.25 mSv/y with the mean value of 0.18 mSv/y. The Outdoor annual effective dose is used to determine the risk of exposure to the primordial radionuclides outside the building while the indoor annual effective dose measured the risk of radiation exposure within the building and the threshold limit for the two parameters are set as 0.07 and 0.41 mSv/y respectively [16]. The indoor annual effective dose ranges between 0.04 and 0.07 mSv/y with the mean value of 0.05 mSv/y for Araromi-Iyin, while that of Iyin quarry site ranges between 0.53 and 0.99 mSv/y with the mean value of 0.73 mSv/y. Both the outdoor and indoor annual effective dose for Iyin quarry site is higher than that of Araromi-Iyin, nevertheless the two locations have the mean values of the two parameters greater than the prescribed value by the radiation regulatory body. The hazard index both external and internal have the average values of 0.57 and 0.68 for Araromi-Iyin and 0.83 and 0.97 for Iyin quarry site. The mean values of hazard indices for the two locations are less than unity, but some locations in Iyin quarry site have their hazard index more than unity with many locations bounded nearer to unity. The annual gonadal equivalent is use to quantify the effect of radiation exposure to some sensitive organs of the body such as the bone marrow, bone surface and gonads. Araromi-Iyin have the values of this parameter spread between 0.53 to 0.985 mSv/y with the mean value of 0.71 mSv/y, while that of Iyin quarry site ranges between 0.75 to 1.39 mSv/y with the average value of 1.02 mSv/y. The permissible limit for this parameter for a safe radiological environment is 1 mSv/y [27]. The radium equivalent delineates the gamma output in terrestrial radiation from the primordial radionuclides with a single index and this must not exceed 370 Bq/kg. The mean value for radium equivalent in Araromi-Iyin was estimated as

205.75 Bq/kg and that of Iyin quarry site also as 300.08 Bq/kg. The values for the two communities are lower than the world limit, the gamma representative index is use to determine the surplus external gamma radiation as a result of superficial material use for construction purposes. The values of this parameter range from 0.43 to 1.30 with the average values of 0.79 in Araromi-Iyin and 0.70 to 1.72 with mean value of 1.15 in Iyin quarry site. The mean value above unity in Iyin quarry site make the materials unsafe for building purposes to avoid the risk of exposure to radiation. The excess lifetime cancer risk estimated for the two communities ranges between 0.27-0.51 mSv/y with the mean value of 0.36 mSv/y in Araromi-Iyin while the Iyin quarry site interspersed between 0.38-0.71 mSv/y with the mean values of 0.52 mSv/y. The value of excess lifetime cancer risk limit should not exceed 0.29 x 10^{-6} mSv/y [14], for a radiologically safe environment. The values recorded in both communities exceeded the set limit, predisposing the dweller of the communities in a lifetime of seventy years to a danger of developing cancer and carcinogenesis diseases. All the radiological parameters evaluated for the two communities exceeded the allowable limit of exposure to radiation except for indoor annual effective dose, gamma representative index in Araromi-Iyin and hazard indices in the two communities. The geology of the study areas that are granitic in nature might be responsible for the high radioactivity level measured in the two communities. However, the mean values of all the-radiological parameters assessed were higher in Iyin quarry site in comparison to Araromi-Iyin community, this revealed that the mining activities taking place in Iyin quarry site has impact on the radioactivity level of the community.

Table 3: Evaluated Radiological Parameter for Araromi-Iyin

Location	DE (nGy/h)	EOUT (mSv/y)	EIN (mSv/y)	HEX	HIN	AGDE mSv/y	RaEQ Bq/kg	Iγ	ELTCR x 10^{-6} (mSv/y)
AR1	100.12	0.123	0.049	0.558	0.651	0.684	201.16	0.770	0.350
AR2	94.32	0.116	0.046	0.517	0.587	0.653	185.01	0.729	0.330
AR3	116.13	0.142	0.057	0.632	0.698	0.805	225.64	0.898	0.406
AR4	100.57	0.123	0.049	0.547	0.623	0.702	194.95	0.779	0.352
AR5	102.17	0.125	0.050	0.559	0.655	0.714	199.57	0.792	0.358
AR6	103.23	0.127	0.051	0.575	0.688	0.71	207.19	0.796	0.361
AR7	102.83	0.126	0.050	0.572	0.702	0.713	205.60	0.795	0.360
AR8	115.71	0.142	0.057	0.644	0.824	0.811	231.02	0.897	0.405

AR9	111.89	0.137	0.055	0.629	0.766	0.765	227.67	0.861	0.392
AR10	102.46	0.126	0.050	0.571	0.627	0.691	206.38	0.786	0.359
AR11	114.07	0.140	0.056	0.643	0.787	0.778	233.15	0.877	0.399
AR12	96.16	0.118	0.047	0.530	0.577	0.655	190.73	0.740	0.337
AR13	101.29	0.124	0.050	0.561	0.664	0.7	201.53	0.782	0.355
AR14	104.56	0.128	0.051	0.575	0.645	0.718	206.38	0.806	0.366
AR15	102.21	0.125	0.050	0.577	0.774	0.714	207.99	0.791	0.358
AR16	104.22	0.128	0.051	0.573	0.653	0.719	205.33	0.805	0.365
AR17	92.78	0.114	0.046	0.522	0.666	0.641	188.66	0.716	0.325
AR18	95.05	0.117	0.047	0.525	0.635	0.661	188.32	0.735	0.333
AR19	122.20	0.150	0.060	0.680	0.753	0.827	245.57	0.938	0.428
AR20	144.81	0.178	0.071	0.812	0.962	0.986	293.86	1.113	0.507
AR21	107.26	0.132	0.053	0.588	0.645	0.735	211.20	0.827	0.375
AR22	115.56	0.142	0.057	0.638	0.668	0.779	230.10	0.886	0.404
AR23	112.90	0.138	0.055	0.629	0.739	0.773	226.64	0.869	0.395
AR24	103.29	0.127	0.051	0.578	0.695	0.708	208.65	0.795	0.362
AR25	100.66	0.123	0.049	0.564	0.724	0.701	203.00	0.778	0.352
AR26	100.80	0.124	0.049	0.557	0.643	0.694	200.00	0.778	0.353
AR27	105.83	0.130	0.052	0.585	0.735	0.743	209.57	0.821	0.370
AR28	84.00	0.103	0.041	0.456	0.529	0.59	162.33	0.652	0.294
AR29	100.59	0.123	0.049	0.536	0.593	0.712	189.57	0.783	0.352
AR30	121.99	0.150	0.060	0.687	0.897	0.848	247.80	0.943	0.427
AR31	82.39	0.101	0.040	0.448	0.528	0.579	159.68	0.640	0.288
AR32	78.00	0.096	0.038	0.433	0.494	0.531	156.38	0.600	0.273
AR33	80.38	0.099	0.039	0.453	0.556	0.549	163.94	0.618	0.281
AR34	96.41	0.118	0.047	0.542	0.659	0.658	196.31	0.741	0.337
AR35	88.31	0.108	0.043	0.499	0.640	0.608	180.79	0.680	0.309

AR36	108.34	0.133	0.053	0.606	0.687	0.731	219.67	0.831	0.379
AR37	116.10	0.142	0.057	0.653	0.857	0.809	235.57	0.898	0.406
AR38	107.19	0.131	0.053	0.603	0.666	0.715	219.15	0.819	0.375
AR39	98.91	0.121	0.049	0.545	0.629	0.681	195.86	0.763	0.346
AR40	81.00	0.099	0.040	0.464	0.644	0.563	168.07	0.625	0.284
MIN	78.00	0.096	0.038	0.433	0.494	0.531	110.17	0.432	0.273
MAX	144.81	0.178	0.071	0.812	0.962	0.986	340.43	1.302	0.507
MEA N	103.31	0.127	0.051	0.574	0.684	0.711	205.75	0.794	0.362
World limit	59.0	0.07	0.41	1.0	1.0	1.0	370.0	1.0	0.29

Table 4: Evaluated Radiological Parameter of Best-stone Solution Quarry site Iyin- Ekiti

Location	**DE (nGy/h)**	**EOUT mSv/y**	**EIN mSv/y**	**HEX**	**HIN**	**AGDE mSv/y**	**RaEQ Bq/kg**	**Iγ**	**ELTCR x 10^{-6} mSv/y**
IY1	148.13	0.182	0.727	0.832	0.968	0.100	301.22	1.137	0.518
IY2	138.53	0.170	0.680	0.770	0.847	0.935	278.30	1.063	0.485
IY3	143.54	0.176	0.704	0.813	1.000	0.975	295.22	1.102	0.502
IY4	133.28	0.163	0.654	0.746	0.833	0.896	270.36	1.021	0.466
IY5	138.15	0.169	0.678	0.773	0.900	0.939	279.52	1.061	0.484
IY6	150.64	0.185	0.739	0.846	0.970	0.102	306.84	1.154	0.527
IY7	128.49	0.158	0.630	0.717	0.834	0.875	259.08	0.988	0.450
IY8	128.01	0.157	0.628	0.717	0.837	0.869	259.38	0.983	0.448
IY9	124.90	0.153	0.613	0.700	0.854	0.856	253.04	0.962	0.437
IY10	143.03	0.175	0.702	0.803	0.940	0.969	290.88	1.098	0.501
IY11	138.51	0.170	0.679	0.777	0.900	0.937	281.40	1.063	0.485
IY12	136.86	0.168	0.671	0.750	0.820	0.938	269.04	1.055	0.479
IY13	128.20	0.157	0.629	0.694	0.730	0.884	247.66	0.990	0.449
IY14	135.11	0.166	0.663	0.747	0.833	0.922	268.80	1.040	0.473
IY15	150.67	0.185	0.739	0.836	0.939	0.103	301.46	1.158	0.527
IY16	130.21	0.160	0.639	0.734	0.921	0.894	265.39	1.003	0.456
IY17	122.39	0.150	0.600	0.674	0.724	0.830	242.87	0.941	0.428
IY18	126.41	0.155	0.620	0.701	0.828	0.870	252.48	0.975	0.442
IY19	155.84	0.191	0.765	0.870	1.040	1.069	313.86	1.200	0.545

IY20	166.60	0.204	0.817	0.927	1.023	1.125	334.88	1.278	0.583
IY21	152.34	0.187	0.747	0.845	0.985	1.045	304.27	1.174	0.533
IY22	166.19	0.204	0.815	0.928	1.075	1.130	335.40	1.277	0.582
IY23	155.71	0.191	0.764	0.875	1.105	1.075	315.88	1.201	0.545
IY24	166.85	0.205	0.818	0.932	1.105	1.141	336.36	1.284	0.584
IY25	188.45	0.231	0.924	1.043	1.136	1.276	376.20	1.447	0.660
IY26	200.74	0.246	0.985	1.125	1.362	1.374	406.67	1.545	0.703
IY27	174.31	0.214	0.855	0.963	1.083	1.191	346.60	1.342	0.610
IY28	178.96	0.219	0.878	0.978	1.015	1.216	351.18	1.377	0.626
IY29	178.11	0.218	0.874	0.993	1.257	1.241	357.00	1.378	0.623
IY30	181.20	0.222	0.889	0.993	1.030	1.227	357.20	1.392	0.634
IY31	180.54	0.221	0.886	0.994	1.127	1.242	356.69	1.393	0.632
IY32	193.40	0.237	0.949	1.078	1.291	1.329	388.40	1.491	0.677
IY33	202.20	0.248	0.992	1.127	1.354	1.390	406.48	1.558	0.708
IY34	152.98	0.188	0.750	0.845	0.992	1.057	303.40	1.181	0.535
IY35	119.32	0.146	0.585	0.663	0.770	0.816	239.12	0.919	0.418
IY36	137.21	0.168	0.673	0.766	0.859	0.926	277.15	1.052	0.480
IY37	126.89	0.156	0.622	0.708	0.872	0.876	255.15	0.979	0.444
IY38	120.69	0.148	0.592	0.676	0.856	0.837	243.54	0.932	0.422
IY39	107.94	0.132	0.530	0.600	0.727	0.746	215.87	0.833	0.378
IY40	129.35	0.159	0.635	0.720	0.860	0.890	259.16	0.997	0.453
MIN	107.94	0.132	0.530	0.600	0.724	0.100	178.10	0.701	0.378
MAX	202.20	0.248	0.992	1.127	1.362	1.390	452.47	1.720	0.708
MEAN	149.52	0.183	0.733	0.832	0.965	0.953	300.08	1.151	0.523
World Limit	59.0	0.07	0.41	1.0	1.0	1.0	370	1.0	0.29

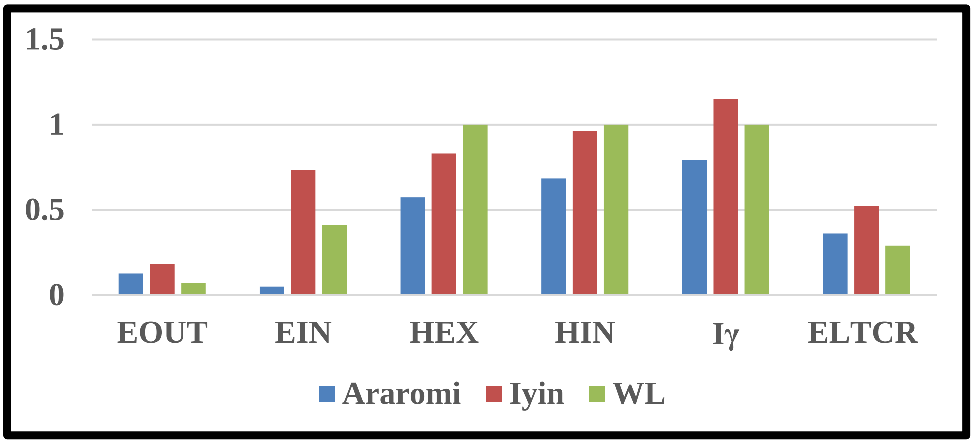


Figure5: Comparison of radiological parameter of the study locations with the world limit

Conclusion

The radionuclides content of Araromi-Iyin community and Iyin quarry site was investigated to determine the possible risk of exposure to ionizing radiation due to the geology and the mining activities ongoing in the communities. The average values of the ^{238}U, ^{232}Th, ^{40}K were 39.80, 69.62,

939.0 Bq/kg for Araromi-Iyin, and 49.28, 112.55, 1,270.78 Bq/kg for Iyin quarry site respectively. The calculated mean radiological parameters for all the measured radionuclides in the two communities were higher than the recommended limit except for the hazard indices and radium equivalent in the two communities, with the annual gonadal dose, gamma representative index and annual indoor effective dose in Araromi-Iyin. Nearly all the estimated radiological parameters were greater in Iyin quarry site than Araromi-Iyin, indicating that the human activities going on in the quarry site have impacted the radioactivity level of the community which may be detrimental to the health of the workers working at the mining site, farmers cultivating the farmland closed to the mining site and the member of the public ingesting the foods and crops from a contaminated farmland.

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References

[1] Siegel, J. A., Brooks, A. L., Fisher, D. R., Zanzonico, P. B., Doss, M., O'Connor, M. K., & Greenspan, B. S. (2019). A critical assessment of the linear no-threshold hypothesis: its validity and applicability for use in risk assessment and radiation protection. *Clinical nuclear medicine*, *44*(7), 521-525.

[2] Adagunodo,T. A., Bayowa, O. G., Ojoawo, A. I., Adewoyin, O. O., Isibor, P. O., Jephthah, E. A., & Anie, N. O. (2022). Investigation of foundation bed's characteristics and environmental safety assessment in some parts of Bayelsa State, south–south Nigeria. *Cogent Engineering*, *9*(1), 2119533.

[3] Balaram, V., Rani, A., & Rathore, D. P. S. (2022). Uranium in groundwater in parts of India and world: A comprehensive review of sources, impact to the environment and human health, analytical techniques, and mitigation technologies. *Geosystems and Geoenvironment*, 100043.

[4] Nakamura,Y., Kubota, J., Nishimura, Y., Nagata, K., Nishimura, M., Daino, K., ... & Imaoka, T. (2022). Brca1L63X/+ rat is a novel model of human BRCA1 deficiency displaying susceptibility to radiation-induced mammary cancer. *Cancer Science*, *113*(10), 3362-3375.

[5] Strand, P., & Larsson, C. M. (2022). Delivering a

framework for the protection of the environment from ionising radiation. In *Radioactive Pollutants* (pp. 131-146). EDP Sciences.

[6] Yusuf, A., Sodiq, A., Giwa, A., Eke, J., Pikuda, O., Eniola, J. O., & Bilad, M. R. (2022). Updated review on microplastics in water, their occurrence, detection, measurement, environmental pollution, and the need for regulatory standards. *Environmental Pollution*, *292*, 118421.

[7] Ekong, G. B., Akpa, T. C., Umaru, I., Akpaowo, M. A., Yusuf, S. D., & Benson, N. U. (2021). Baseline radioactivity and associated radiological hazards in soils around a proposed nuclear power plant facility, South-South Nigeria. *Journal of African Earth Sciences*, *182*, 104289.

[8] Omeje M, Adewoyin Olusegun, O., Joel, E. S., Ikechukwu B, I., Timothy-Terhile Mary, A., Okoro Emeka, E., & Saeed, M. A. (2021). Measurements of seasonal variations of radioactivity distributions in riverine soil sediment of Ado-Odo Ota, South-West Nigeria: probabilistic approach using Monte Carlo. *Radiation Protection Dosimetry*, *193*(2), 76-89.

[9] Esan, D. T., Ajiboye, Y., Obed, R. I., Ojo, J., Adeola, M., & Sridhar, M. K. (2022). Measurement of Natural Radioactivity and Assessment of Radiological Hazard Indices of Soil Over the Lithologic Units in Ile-Ife Area, South-West Nigeria. *Environmental Health Insights*, *16*, 11786302221100041.

[10] Nwodo Victor, K., Nzotta Christian, C., Chiegwu Hyacinth, U., Abubakar Mathew, G., Ezenma Innocent, C., Luntsi, G., & Nwodo Charles, U. (2022). Annual effective dose estimation due to gross alpha and beta activities in groundwater samples from breweries in Nigeria. *IJAR*, *8*(7), 26-32.

[11] Usikalu, M. R., Enemuwe, C. A., Morakinyo, R. O., Orosun, M. M., Adagunodo, T. A., & Achuka,

J. A. (2020). Background Radiation from 238U, 232Th, and 40K in Bells Area and Canaan City, Ota, Nigeria. *Macedonian Journal of Medical Sciences*, *10*(8), 678-684.

[12] Khaleal, F. M., El-Bialy, M. Z., Saleh, G. M., Lasheen, E. S. R., Kamar, M. S., Omar, M. M., & Abdelaal, A. (2023). Assessing environmental and radiological impacts and lithological mapping of beryl-bearing rocks in Egypt using high-resolution sentinel-2 remote sensing images. *Scientific Reports*, *13*(1), 11497

[13] Akingboye, A. S., Ogunyele, A. C., Jimoh, A. T., Adaramoye, O. B., Adeola, A. O., & Ajayi, T. (2021). Radioactivity, radiogenic heat production and environmental radiation risk of the Basement Complex rocks of Akungba-Akoko, southwestern Nigeria: insights from in situ gamma-ray spectrometry. *Environmental Earth Sciences*, *80*, 1-24.

[14] Usikalu, M. R., Morakinyo, R. O., Orosun, M. M., & Achuka, J. A. (2023). Assessment of background radiation in Ojota chemical market, Lagos, Nigeria. *Journal of Hazardous, Toxic, and Radioactive Waste*, *27*(1), 04022041.

[15] Ofomola, O. M., Ugbede, F. O., & Anomohanran, O. (2023). Environmental risk assessment of background radiation, natural radioactivity and toxic elements in rocks and soils of Nkalagu quarry, Southeastern Nigeria. *Journal of Hazardous Materials Advances*, *10*, 100288.

[16] Omeje M, Adewoyin Olusegun, O., Joel, E. S., Ikechukwu B, I., Timothy-Terhile Mary, A., Okoro Emeka, E., & Saeed, M. A. (2021). Measurements of seasonal variations of radioactivity distributions in riverine soil sediment of Ado-Odo Ota, South-West Nigeria: probabilistic approach using Monte Carlo. *Radiation Protection Dosimetry*, *193*(2), 76-89.

[17] Mardonova, M., & Han, Y. S. (2023). Environmental, hydrological, and social impacts of coal and nonmetal minerals mining operations. *Journal of Environmental Management*, *332*, 117387.

[18] Morakinyo, R. O., Usikalu, M. R., & Orosun, M. M. (2022). Evaluation of background radiation of Maryland School complex, Lagos, Nigeria. In *IOP*

Conference Series: Earth and Environmental Science (Vol. 993, No. 1, p. 012015). IOP Publishing.

[19] Usikalu, M. R., Orosun, M. M., Akinwumi, A., Babarimisa, I. O., Arijaje, T. E., & Mohammed, A.

U. (2024). Environmental radioactivity monitoring and radiological impact assessment of Agbara Industrial Area, Ogun State, Nigeria. *Polytechnica*, *7*(2), 9.

[20] Omeje, Maxwell, Muyiwa M. Orosun, Godfrey U. Aimua, Olusegun O. Adewoyin, Soheil Sabri, Hitler Louis, Emmanuel S. Joel (2024) Radioactivity distributions and biohazard assessment of coastal marine environments of niger-delta, Nigeria, *All Earth* 36(1): 1-19.

[21] Saidu, A., Muhammad, S. B., Abubakar, U., Aliyu, J., Bashir, Z. A., Ibrahim, A. M., & Bala, A. (2024). Geological Formation and Soil Type Impact on Terrestrial Gamma Radiation Dose: A Statistical Approach of Dange Shuni (LGA) Sokoto State Nigeria. *CaJoST*, *6*(1), 10-18.

[22] Isa, S., Abuh, R. A., & Godwin, E. (2024). Assessment of Natural Background Radiation Exposure in the Federal Capital Territory of Nigeria. *European Journal of Theoretical and Applied Sciences*, *2*(1), 480-491.

[23] Omeje, M., Usiaka Aimua, G., Oladotun Adewoyin, O., Michael Orosun, M., Sunday Joel, E., Usikalu, M. R., & Anne, O. U. (2023). Dispersion of gamma rates and natural radioelements in the coastal environment of Unomherin community in Niger Delta. Cogent Engineering 10(1), 2204546

[24] Sharma, B. A., Singh, H. S., Singh, S. N., & Singh, T. R. (2024). Assessment of Terrestrial Gamma Radiation Dose Rate and Radioactivity Levels in Eastern Hilly Region of Manipur, India.

[25] Joel, E. S., Omeje, M., Olawole, O. C., Adeyemi, G. A., Akinpelu, A., Embong, Z., & Saeed, M. A. (2021). In-situ assessment of natural terrestrial-radioactivity from Uranium-238 (238U), Thorium-232 (232Th) and Potassium-40 (40K) in coastal urban-environment and its possible health implications. *Scientific reports*, *11*(1), 17555.

[26] Gogoi, P. P., Phukan, S., & Barooah, D. (2024). Terrestrial gamma radiation dose (TGRD) rates and radiological risk assessments in Tiru region of the Naga Schuppen Belt, India. *Atmospheric Pollution Research*, *15*(11), 102294.

[27] Wasim, M., Tariq, A., & Ali, M. (2024). Gamma-radiation levels along the main Karakorum thrust area of Northern Pakistan. *Radiochimica Acta*, *112*(1), 63-71.