Research Article / Review Article FUPRE JOURNAL 8(1): 79-88(2024)

FUPRE Journal

of

Scientific and Industrial Research

ISSN: 2579-1184(Print) ISSN: 2578-1129 (Online)

http://fupre.edu.ng/journal

Evaluation of radiological hazard Indices and Excess Lifetime Cancer Risk in Ishiagu Quarry Site, Ebonyi State, Nigeria

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ARTICLE INFO

Received: x/x/2023
Accepted: x/x/2023

Keywords

Cancer, Exposure rates, Quarry site, Radiologically

ABSTRACT

A radiometric survey of background ionizing radiation (BIR), estimate the excess lifetime cancer risk and its radiological hazard indices in Ishiagu quarry site in Ebonyi State were carried out, using a nuclear radiation monitor (Radalert 200) and a geographical positioning system (GPS) for location coordinate. The measured average exposure rates and its equivalent dose rate ranged from 0.0138mRh^{-1} (1.1605mSvy^{-1}) to 0.0172mRh^{-1} (1.4465mSvy^{-1}) with mean value of 0.0156mRh^{-1} (1.3087mSvy^{-1}). The calculated mean outdoor absorbed dose rate for each area ranged from 119.71 nGyh^{-1}in the Pit Area 1 to 155.21nGyh^{-1}in the Crush Area 2, with a mean value of 135.44nGyh^{-1}. The estimated mean annual effective dose equivalent (AEDE) rate for each area ranged from 0.1835 mSvy^{-1} to 0.2379 mSvy^{-1}, with a mean value of 0.2076 mSvy^{-1}, while the mean excess lifetime cancer risk (ELCR) for each area ranged from 0.6056 to 0.7852, with a mean value of 0.6852. The mean BIR values obtained and all the calculated radiological hazard indices were all higher than the world average permissible limit as stipulated by the International Commission on radiological Protection in the entire Quarry site. The calculated dose to organs/tissues of the quarry workers and residents ranged from the lowest organ dose of 0.076404mSvy^{-1} (10%) liver to the highest organ dose of 0.136199mSvy^{-1} (18%) testes. However, these values indicates that the Ishiagu Quarry site may not be radiologically healthy for both workers and individuals living in the area as possible chance of contracting cancer of both workers and residents is insignificant.

1. INTRODUCTION

External exposure of natural environmental radioactivity can be due to radiation from geological formation of the earth crust, that is been brought to the surface of the earth through blasting and crushing of granite rocks in quarrying sites (UNSCEAR, 2000). This granite rocks that are being use for constructions and as building materials contained naturally occurring radioactive materials such as uranium thorium and potassium (Shiva *et al.,* 2008; Odunaike *et al.,* 2008). Quarrying process is an open process which has led to both dust and noise generation on site. However, the radionuclides contained in the granite rocks give out ionizing radiation during the process to the quarry sites and its environment in form of dust, thereby subjecting the quarry workers and the people

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living in the immediate surroundings to radiation exposure. The radiological health effect of ionizing radiation that could have affected both quarry workers and the environment has necessitated this research work.

The quarry site studied is located at Ishiagu town in Ivo Local Government Area in Ebonyi State, Nigeria. The area is rich in igneous intrusion rocks and sedimentary rocks. Ishiagu lies within latitudes 5^0.52'–6^0.00' North of the equator and Longitude 7^0.30'-7^0.35' East of the prime meridian. Ishiagu area is shaly terrain of 85-100m above sea level and has few low hills (Ezepue, 1984).

2. MATERIALS AND METHOD

A Global Positioning System (GPS) receiver was used to determine the geographical coordinates of the sampling points. Radiation Monitors (Nuclear Radiation Monitor (Radalert 100) and Nuclear Radiation Monitor (Digilert): both detectors are for alpha, beta, gamma and X-radiation detection. The meter uses 9V battery. The radiation exposure rate measurement was carried out using a survey meter device as described above, this meter record dose rate in micro sievert per hour (mR/hr). Twenty-five readings were taken altogether from five sampling locations, Ishiagu quarry site in Ebonyi state. The detector was placed about one meter above ground level for effective detection, the detector was switched on to absorb radiation for a few seconds and the highest stable point was recorded. The procedure was repeated at each location and three readings in ($mRhr^1$) were recorded at each location in which an average value in ($mRhr^1$) was determined. This was converted to absorbed dose rate in nano Garay per hour ($nGyhr^1$) using the conversion factor. Figure 1: showed Nuclear Radiation Monitors and Global Positioning System.

Figure 1: Nuclear Radiation Monitors and Global Positioning System

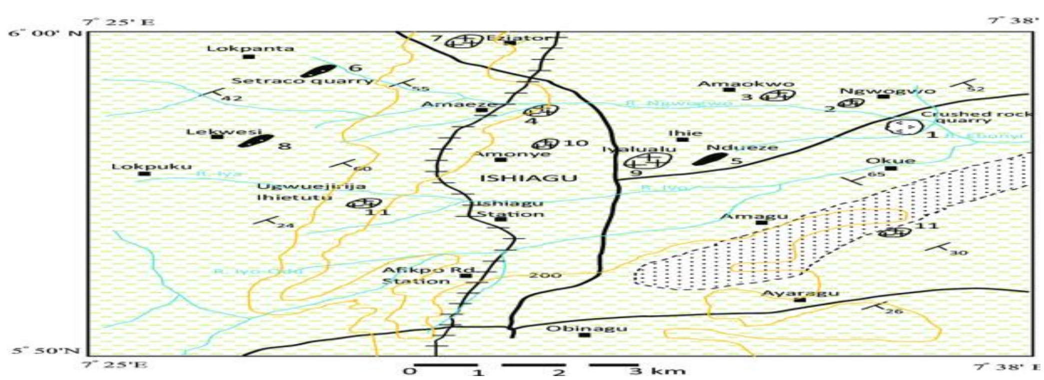

Fig 2. Map showing the study area (Mgbeokwere et al., 2021)

2.1.Theory And Calculation

Absorbed Dose Rate

Data obtained for the external exposure rate in mR/h was converted into absorbed dose rate nGy/h using the conversion factor;

$1\mu Rh^{-1} = 8.7nGyh^{-1} = \frac{8.7 X 10^{-3}\ \mu Gy}{\left(1/_{8760y}\right)} = 76.212\mu Gy^{-1}$

The readings are presented in terms of $nGyh^{-1}$.

Equivalent Dose Rate

The equivalent dose rate of the entire body for a year is approximately calculated using the

National Council on Radiation Protection and Measurement's recommendation (Ovuomarie et al, 2018).

$1mRh^{-1} = \frac{(0.96 \text{ x } 24 \text{ x } 365)}{100} mSvy^{-1}$

The Annual Effective Dose Equivalent (AEDE)

Measured absorbed gamma dose rates were used to calculate the annual effective dose equivalent (AEDE) received by people of the surveyed area. For calculating AEDE we have used dose conversion factor of 0.7 Sv/Gy and the occupancy factor for outdoor was 0.25 (6/24) respectively. Occupancy factor for indoor and outdoor situations were calculated based upon interviews with peoples of the study area. Peoples of study area spent almost 6 h in outdoor and 18 h in indoor environment.

The annual effective dose is determined using the equations below:

AEDE (Outdoor) (mSv/y) = Absorbed dose rate (nGy/h) x 8760h x 0.7Sv/Gy x 0.25

In the UNSCEAR 1993 report the Committee used 0.7 Sv/Gy for the conversion coefficient from absorbed dose in air to effective dose received by adults.

Excess Lifetime Cancer Risk (ELCR)

Based upon calculated values of AEDE, Excess Lifetime Cancer Risk (ELCR) is calculated using the expression below:

Excess lifetime cancer risk = AEDE x Average duration of life (DL) x Risk factor (RF)

where AEDE, DL and RF is the annual effective dose equivalent, duration of life (70 years) and risk factor (Sv^1), fatal cancer risk per sievert. For low dose background radiations which are considered to produce stochastic effects, ICRP 60 uses values of 0.05 for the public exposure (Taskin, et al., 2009).

Effective Dose Rate Dorgan in mSvy-1 to Different Organs/ Tissues

The effective dose rate to a particular organ can be calculated using the relations:

$D_{organ}\ (mSvy^{-1}) = O \text{ x } AEDE \text{ x } F$

Where AEDE is annual effective dose, O is the occupancy factor 0.8 and F is the conversion factor for organ dose from ingestion

3. RESULTS AND DISCUSSIONS

3.1 Insitu Measurement Result of Ionization Radiation

The results of *insitu* background ionizing radiation levels measurement of the mine fields and host communities are presentation in Tables 1 to 5. Monitoring of external exposure (Workplace and individual) by active or passive means is carried out with devices calibrated in terms of the operational quantities. Estimation of the equivalent dose rate received by the whole body with the National Council of Radiation Protection and Measurement (NCRP, 1993) was computed.

Table 1 Measured the Background ionizing Radiation exposure rate of Administration Area

S/No	Locations	1st	2nd	3rd	4th	Average (mR/hr)
1	No5° 57.063' E0.07°34.541'	0.007	0.006	0.008	0.01	0.0078
2	No 5° 57.043' E007° 34.562'	0.014	0.015	0.012	0.013	0.0136
3	No 5° 57.017' E007°34.582'	0.01	0.017	0.031	0.02	0.02
4	No 5° 57.659' E007°34.584'	0.015	0.014	0.02	0.018	0.0166
5	No 5° 57.095' E007°34.542'	0.015	0.011	0.016	0.015	0.0142
MEAN VALUE		0.0122	0.0126	0.0174	0.0152	0.01444

Table 2 Measured the Background ionizing Radiation exposure rate of Crush Area 1

S/No	Locations	1st	2nd	3rd	4th	Average (mR/hr)
11	No 5° 57.062' E007° 34.835'	0.016	0.016	0.012	0.014	0.0146
12	No 5° 57.043' E007° 34.849'	0.014	0.015	0.017	0.018	0.0166
13	No 5° 57.014' E007° 34.843'	0.015	0.019	0.041	0.026	0.0242
14	No 5° 57.027' E007° 34.817'	0.014	0.014	0.014	0.013	0.0136
15	No 5° 57.051' E007° 34.803'	0.010	0.012	0.029	0.020	0.0172
MEAN VALUE		0.0138	0.0152	0.0226	0.0182	0.01724

Table 3 Measured the Background ionizing Radiation exposure rate of Crush Area 2

S/No	Locations	1st	2nd	3rd	4th	Average (mR/hr)
1	No 5° 57. 017' E007°34.733'	0.017	0.019	0.020	0.023	0.0206
2	No 5° 57.004' E007°34.774'	0.016	0.016	0.010	0.016	0.0154
3	No 5° 56.990' E007° 34.738'	0.013	0.019	0.022	0.021	0.019
4	No 5° 56.961' E007° 34.704'	0.012	0.017	0.031	0.020	0.0196
5	No 5° 56.978' E007° 34.662'	0.012	0.012	0.020	0.015	0.0146
MEAN VALUE		0.014	0.0166	0.0206	0.019	0.01784

Table 4 Measured the Background ionizing Radiation exposure rate of Pit Area 1

S/No	Locations	1st	2nd	3rd	4th	Average (mR/hr)
1	No 5° 57. 050' E007° 34.607'	0.007	0.007	0.016	0.018	0.0124
2	No 5° 57.108' E007° 34.593'	0.012	0.011	0.012	0.019	0.0134
3	No 5° 57.036' E007° 34.686'	0.011	0.010	0.015	0.013	0.013
4	No 5° 57.049' E007° 34.773'	0.011	0.010	0.015	0.013	0.013
5	No 5° 57.187' E007° 34.837'	0.018	0.011	0.022	0.019	0.017
MEAN VALUE		0.0118	0.0098	0.016	0.0164	0.01376

Table 5 Measured the Background ionizing Radiation exposure rate of Pit Area 2

S/No	Locations	1st	2nd	3rd	4th	Average (mR/hr)
16	No 5° 57.335' E007° 3.803'	0.008	0.016	0.011	0.014	0.0124
17	No 5° 57.330' E007° 34.746'	0.017	0.009	0.014	0.012	0.0126
18	No 5° 57.225' E007 34.733'	0.021	0.019	0.017	0.019	0.0194
19	No 5° 57.253' E007° 34.864'	0.016	0.013	0.016	0.017	0.0156
20	No 5° 57.294' E007° 34.819'	0.010	0.010	0.013	0.015	0.0128
MEAN VALUE		0.0144	0.0134	0.0142	0.0154	0.01456

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Table 6 Average Background ionizing Radiation exposure rate and calculated hazard indices of Administration Area

S/N	Geographical location	Average BIR levels (mR/h)	Equivalent dose rate (mSv/y)	Absorbed dose rate (ηGy/h)	Annual effective dose equivalent (mSv/y)	Excess lifetime cancer risk (x 10^{-3})
1	No5° 57.063' E0.07°34.541'	0.0078	0.6556	67.86	0.1040	0.3433
2	No 5° 57.043' E007° 34.562'	0.0136	1.1437	118.32	0.1814	0.5986
3	No 5° 57.017' E007°34.582'	0.0200	1.6819	174.00	0.2667	0.8802
4	No 5° 57.659' E007°34.584'	0.0166	1.3960	144.42	0.2214	0.7306
5	No 5° 57.095' E007°34.542'	0.0142	1.1942	123.54	0.1894	0.6250
MEAN VALUE		0.0144	1.2120	125.63	0.1926	0.6355

Table 7 Average Background ionizing Radiation exposure rate and calculated hazard indices of Crush Area 1

S/N	Geographical location	Average BIR levels (mR/h)	Equivalent dose rate (mSv/y)	Absorbed dose rate (ηGy/h)	Annual effective dose equivalent (mSv/y)	Excess lifetime cancer risk (x 10^{-3})
1	No 5° 57.062' E007° 34.835'	0.0146	1.2278	127.02	0.1947	0.6426
2	No 5° 57.043' E007° 34.849'	0.0166	1.3960	144.42	0.2214	0.7306
3	No 5° 57.014' E007° 34.843'	0.0242	2.0351	210.54	0.3226	1.0651
4	No 5° 57.027' E007° 34.817'	0.0136	1.1437	118.32	0.1814	0.5986
5	No 5° 57.051' E007° 34.803'	0.0172	1.4465	149.64	0.2294	0.7570
MEAN VALUE		0.0172	1.4465	149.99	0.2299	0.7588

Table 8 Average Background ionizing Radiation exposure rate and calculated hazard indices Crush Area 2

S/N	Geographical location	Average BIR levels (mR/h)	Equivalent dose rate (mSv/y)	Absorbed dose rate (ηGy/h)	Annual effective dose equivalent (mSv/y)	Excess lifetime cancer risk (x 10^{-3})
1	No 5° 57. 017' E007°34.733'	0.0206	1.7324	179.22	0.2747	0.9067
2	No 5° 57.004' E007°34.774'	0.0154	1.2951	133.98	0.2054	0.6778
3	No 5° 56.990' E007° 34.738'	0.0190	1.5978	165.30	0.2534	0.8362
4	No 5° 56.961' E007° 34.704'	0.0196	1.6483	170.52	0.2614	0.8626
5	No 5° 56.978' E007° 34.662'	0.0146	1.2278	127.02	0.1947	0.6426
MEAN VALUE		0.0178	1.4969	155.21	0.2379	0.7852

Table 9 Average Background ionizing Radiation exposure rate and calculated hazard indices of Pit Area 1

S/N	Geographical location	Average BIR levels (mR/h)	Equivalent dose rate (mSv/y)	Absorbed dose rate (ηGy/h)	Annual effective dose equivalent (mSv/y)	Excess lifetime cancer risk (x 10^{-3})
1	No 5° 57. 050' E007° 34.607'	0.0124	1.0428	107.88	0.1654	0.5458
2	No 5° 57.108' E007° 34.593'	0.0134	1.1269	116.58	0.1787	0.5898
3	No 5° 57.036' E007° 34.686'	0.0130	1.0933	113.10	0.1734	0.5722
4	No 5° 57.049' E007° 34.773'	0.0130	1.0933	113.10	0.1734	0.5722
5	No 5° 57.187' E007° 34.837'	0.0170	1.4296	147.90	0.2267	0.7482
MEAN VALUE		0.0138	1.1605	119.71	0.1835	0.6056

Table 10: Average Background ionizing Radiation exposure rate and calculated hazard indices of Pit Area 2

S/N	Geographical location	Average BIR levels (mR/h)	Equivalent dose rate (mSv/y)	Absorbed dose rate (ηGy/h)	Annual effective dose equivalent (mSv/y)	Excess lifetime cancer risk (x 10^{-3})
1	No 5° 57.335' E007° 3.803'	0.0124	1.0428	127.02	0.1947	0.6426
2	No 5° 57.330' E007° 34.746'	0.0126	1.0596	109.62	0.1680	0.5546
3	No 5° 57.225' E007 34.733'	0.0194	1.6315	168.78	0.2587	0.8538
4	No 5° 57.253' E007° 34.864'	0.0156	1.3119	135.72	0.2081	0.6866
5	No 5° 57.294' E007° 34.819'	0.0128	1.0764	111.36	0.1707	0.5634
MEAN VALUE		0.0146	1.2278	126.67	0.1942	0.6408

Table 11 Mean summary of both Background ionizing Radiation exposure rate and the calculated hazard indices in Ishiagu Quarry Site

S/No	Location	Average BIR levels (mR/h)	Equivalent dose rate (mSv/y)	Absorbed dose rate (ηGy/h)	Annual effective dose equivalent (mSv/y)	Excess lifetime cancer risk (x 10^{-3})
1	Administration Area	0.0144	1.2120	125.63	0.1926	0.6355
2	Crush Area 1	0.0172	1.4465	149.99	0.2299	0.7588
3	Crush Area 2	0.0178	1.4969	155.21	0.2379	0.7852
4	Pit Area 1	0.0138	1.1605	119.71	0.1835	0.6056
5	Pit Area 2	0.0146	1.2278	126.67	0.1942	0.6408
6	Mean	0.0156	1.3087	135.44	0.2076	0.6852
7	World Average Limits	0.013	1.00	59.00	0.07	0.29

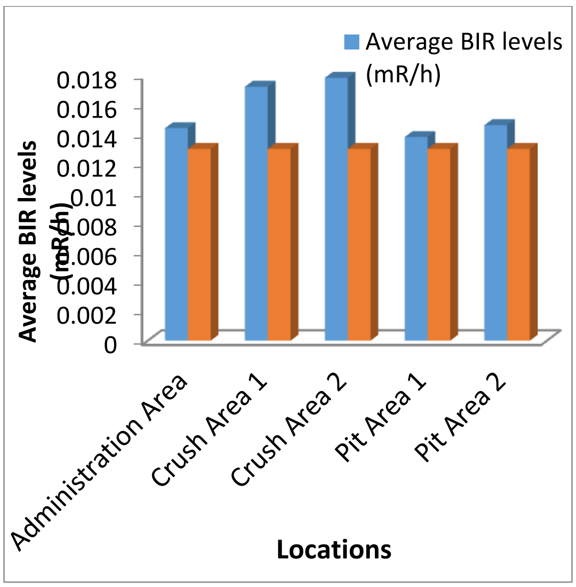

Fig. 2: Comparison of Average BIR levels (mR/h) with World Average limit.

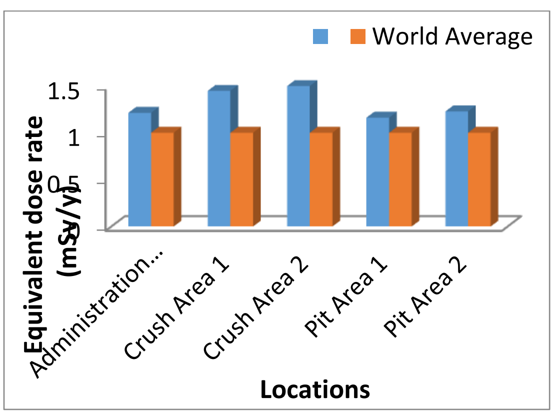

Fig. 3: Comparison of Equivalent dose rate (mSv/y) with World Average limit.

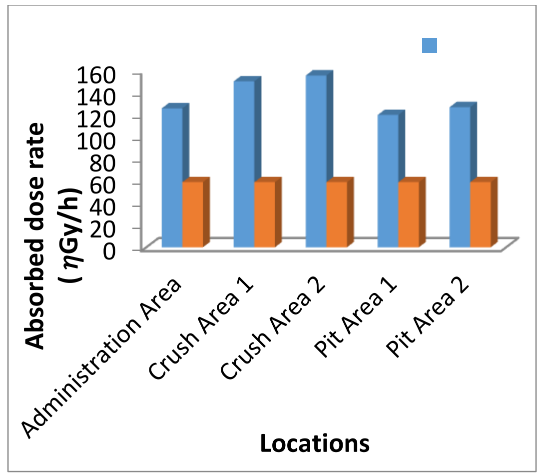

Fig. 4: Comparison of Absorbed dose rate (ηGy/h) with World Average limit.

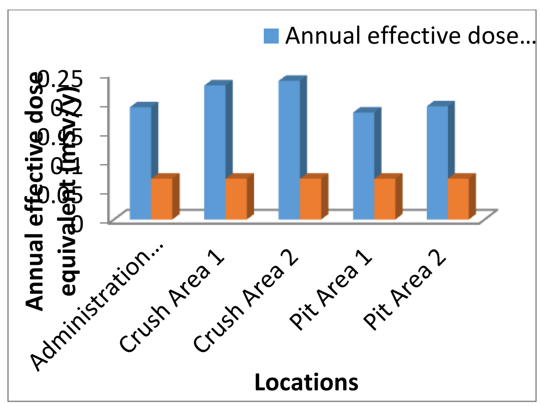

Fig. 5: Comparison of Annual effective dose equivalent (mSv/y) with World Average limit.

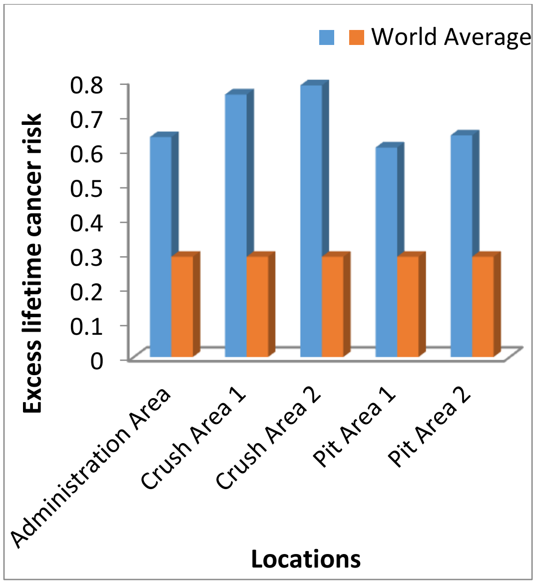

Fig. 6: Comparison of Excess lifetime cancer risk with World Average limit.

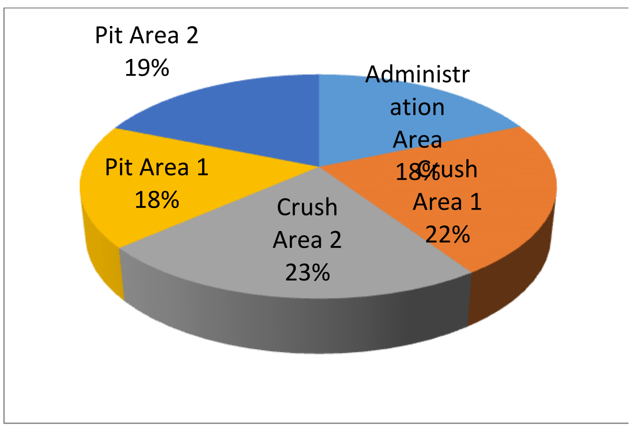

Fig. 7: Pie chart showing percentage contribution of various area of the quarry site.

Table 12: Dose rate to different organs/Tissues of the body due to Background Ionizing Radiation

S/No	Organs/Tissues	Effective dose rate to Organs/ Tissues ($mSvy^{-1}$)
1	Lungs	0.106301
2	Ovaries	0.096336
3	Bone marrow	0.114606
4	Testes	0.136199
5	Kidneys	0.102980
6	Liver	0.076404
7	Whole body	0.112945

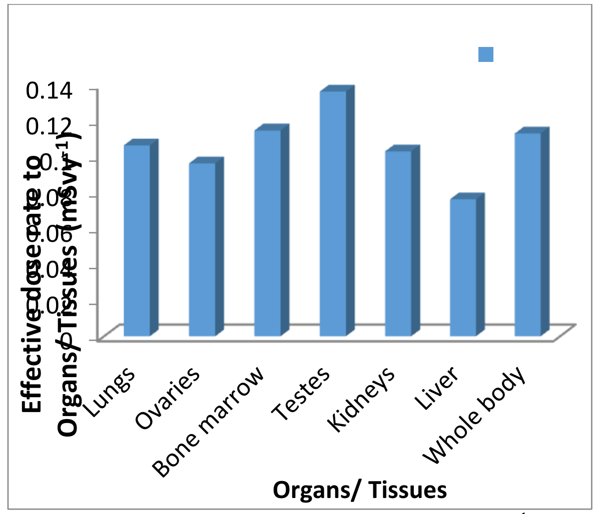

Fig. 8: Effective dose rate to Organs/ Tissues ($mSvy^{-1}$)

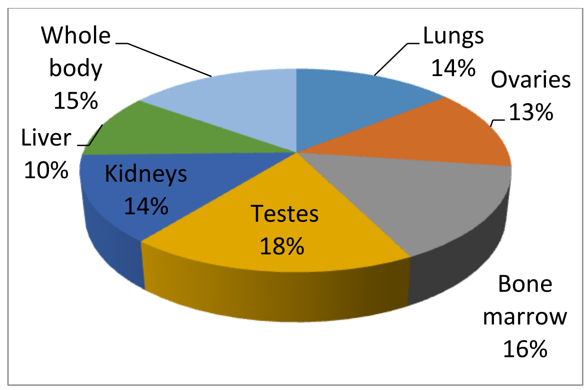

Fig. 9: Pie chart showing percentage contribution of various Organs/ Tissues

3.2 Discussion of Results

Tables 1 to 10 showed the background ionizing radiation rate and equivalent dose rate level of The Ishiagu quarry site. Table 11 shows that the average background ionization radiation exposure dose rate ranged from minimum value of 0.0138 $mRhr^{-1}$ at the pit area 1 to maximum value of 0.0178 $mRhr^{-1}$ at crush area 2. The mean values of 0.0156 obtained from all the locations when compared with the world average value of 0.013 $mRhr^{-1}$ (UNSCEAR, 2000) are slightly greater than the standard world average. The high mean values of measured background ionizing radiation in the location can be attributed to the exploitation activities currently going on in the area. It also indicates high concentration of radiation in aggregate that is in abundance in this environment.

The absorbed dose measured ranged from 119.71 nGyh $^{-1}$ to 155.21 nGyhr^{-1} with mean value of 135.44 nGyh^{-1} which is higher than the world weighted average of 59.00 nGyh^{-1}.The location that recorded the highest exposure rate, absorbed dose, annual effective dose and excess lifetime cancer risk, is crush area 2. The continuous land excavation may account to high radiation level recorded in the area.

The annual effective dose (AEDE) measured ranged from 0.1835 to 0.2379 mSvyr^{-1} with mean value of 0.2076 mSvy^{-1}. This is higher than the world weight value of 0.07 mSvy^{-1}. The ELCR measured ranged from 0.6056 x 10^{-3} to 0.7852 x 10^{-3} with mean value of 0.68 x 10^{-3} which is higher when compared with the world standard value of 0.29 x 10^{-3}. The values of the radiation hazard parameters were highest for Crush area 2 and lowest for Pit area 1. The Crush areas are found to have the highest exposure rate this may be due to quarry activities carried out there. These high values are due to high concentration of radiation content of the bedrock (Igneous rock) in the quarry site.
The excess lifetime cancer risk estimated from the annual effective dose in all the location exceeded the world weighted average of 0.29 x 10^{-3}. Therefore, the probability of developing extra cancer due to exposure to natural radioactivity in this quarry site is significant. This suggests further investigation of other environmental media such as soil, water and crops from this area of study.

The calculated dose to organs/tissues of the quarry workers and residents ranged from the lowest organ dose of 0.076404 mSvy^{-1} (10%) liver to the highest organ dose of 0.136199 mSvy^{-1} (18%) testis. However, these values indicates that the Ishiagu Quarry site may not be radiologically healthy for both workers and individuals living in the area as possible chance of contracting cancer in the future is evident.

In comparison with several radiological studies, for instance a study by Enyinna and Onwuka, 2014, elevated levels of natural background radiations were reported in this area of study. Echeweozo and Ugbede, 2020 had an estimated mean annual effective dose (AED) and excess lifetime cancer risk (ELCR) are 0.26±0.03 mSv/y and 0.92×10^{-3} respectively at the excavated section and 0.32±0.02 mSv/y and 1.10×10^{-3} at the quarry section which was well above the outdoor worldwide average value of 0.07 mSv/y. The study by Ruth et al, 2020 for levels of ionizing radiation on some selected quarry sites in Kenya indicated that 89% of the sampled quarries had radiation emissions above the ICRP and WHO standard.

The rise in degree of ionizing radiation may be as a result of quarrying activities which raises the natural background radiation levels by letting out a buried materials containing naturally occurring radioactive materials onto the surface of the environment (EPA, 2014; Ruhm et al, 2019).

4. CONCLUSION

Excavation activities has contributed immensely to the national economy of any many developed and developing countries like Nigeria, of the world. However, the great danger posed by these activities and the potential health risk to workers on site and neighborhood communities deserve urgent attention. The present study has shown that the BIR dose levels of the investigated quarry site has been found to be high compared to values from other studies and world recommended value (0.013mR/hr). The mean absorbed dose was high compared to the world recommended value. However, it has been observed that no matter the level obtained, all levels of ionizing radiation are hazardous to human health. Therefore, there is a need for a comprehensive radiological study of the quarry sites and the level of radiation exposure of the inhabitants.

The fear of serious health hazards arising from the exposure of radiation emanating from this quarry operation should not be entertained. However, focus should be on the proper management of the radiation emissions into the resident to be a low as reasonably achievable to prevent radiation induced diseases.

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