Original Research Article

RADIOLOGICAL ASSESSMENT OF BACKGROUND IONIZING RADIATION EXPOSURE RATES FROM SOLID MINERAL MINING SITES IN IKWO LOCAL GOVERNMENT AREA OF EBONYI STATE, NIGERIA.

ABSTRACT

A study to assess the radiological background ionizing radiation exposure dose rates from solid mineral mining sites in Ikwo Local Government Area of Ebonyi State was carried out outdoor Background Ionizing Radiation (BIR) levels in Emene Industrial Layout of Enugu State, Nigeria has been conducted. An in-situ measurement of BIR exposure rate in mRh^{-1} ~~-1~~ for 30 locations was done using a well calibrated Dd igilert -200 nuclear radiation meter (S.E international, INC.) at an elevation of 1.0 m above ground level with a geographical positioning system (GPS) for geographical location. The measured BIR exposure rates were used to evaluate the radiological health hazards and radiation effective doses to different body organs using well established radiological relations. The obtained values were compared with recommended permissible limits to ascertain the radiological health status of the environment. The mean values of BIR exposure levels (0.02 mRh-1), absorbed dose rates (185.39 ηGyh^{-1}) and excess lifetime cancer risk (1.00 ×10^{-3}) are higher than their recommended safe limits of 0.013 mRh~~-1~~ $^{-1}$, 84.0 ηGyh^{-1} ~~-1~~, 0.29×10^{-3} respectively as recommended by ICRP and UNSCEAR. The mean annual effective dose equivalent (0.20 mSvy^{-1}) is within recommended permissible limits of 1.00 mSvy^{-1} for general public exposure. Also, the effective doses to different body organs are all below the recommended limits of 1.0 mSvy^{-1}-1 . Generally, the study shows that Ikwo solid mineral mining areas are radiologically contaminated due to land excavation and mining activities taking place.

However, the contamination does not constitute any immediate radiological health effect on resident of the area but there is the potential for long-term health hazards in the future such as cancer due to accumulated doses.

Key words: BIR exposure level, effective dose, solid minerals, mining sites,in Ikwo L.G.A.

1.0 INTRODUCTION

The continuous land excavation,extraction and pProcessing of Lead /Zinc solid minerals in Ikwo Local Government Area of Ebonyi state enhances the environment radioactivity of the area. The advent of Excavation and other human activities coupled with poor environmental management systems have resulted to the release of various forms of toxic, corrosive and radioactive contaminants or pollutants into the environment. When harmful substances are introduced into the system and the environment becomes polluted, it affects man and his environment adversely (Avwiri et al., 2013).

The negative health impact of human activities in the environment has been an issue of discussion in contemporary times. Radiation has been found in everyday activities in many forms and intensities, and has been determined to be harmful. Human health is harmed by high radiation levels and doses.Ionizing radiation is a type of high- energy particle with a strong high penetrating powerDirect ionizing radiadiation such as $\alpha^{2+}, \beta^{-}, \beta^{+}$and indirect-ionizing radiations such asγ rays have high ionizing and penetrating ability respectively .When such radiation passes through a biological cell, it induces excitation as well as ionization, causing the cell's structure to change (Emelue et al., 2014). Cancer, cataracts, gene mutation, disintegration of bones and blood cells, and death are just a few of the negative consequences (Ogola et al., 2016). Because of the fatal consequences of ionizing radiation, it is common practice to monitor and assess exposure levels and limit ionizing radiation exposure as low as reasonably achievable, called the ALARA principle (Ilugo et al.,2021). Estimating ionizing radiation exposure is a major priority for regulatory agencies and radiation protection scientists, as well as for all of humanity. It is critical to understand background radiation since it will aid in determining the likely source and effects on human (Sadiq & Agba, 2011). Research data available on BIR levels assessment in some locationsshow regions of low and high BIR levels. Mgbeokwere et al., (2021) reported high radiation levels around solid mineral mining sites in Ishiagu of Ebonyi state due to extraction of Lead/zinc ores. Fedrick (2019) reported higher BIR than the recommended limits in Nkalagu-Ezillo rice farm of Ebonyi state. Agbalagba (2017) documented mean BIR exposure value of 0.022±0.006 mRh^{-1} ~~-1~~in industrial zone of Warri city.Ilugo et al.,(2021) reported higher BIR in the radiological assessment of BIR exposure rate at selected basements and excavation sites in Delta state.Ugbede(2018) measured the background ionizing radiation exposure level in selected in communities of Ishielu LGA,Ebonyi state, Nigeria.The BIR measured at Okpoto and Nteze are in tendem with recommended value of 0.013mR/h. Akpabio et al. (2005) also studied the environmental radioactive levels in Ikot– Ekpene and reported that the radioactivity levels in the area is generally low ranging. High radiation levels and doses are detrimental to human health. It has been observed globally in recent literatures to be increasing, which many have attributed to geological formation of the environment, as well as human and industrial activities in those towns (Osimobi et al., 2015). Evaluation of health related risk from exposure to background ionizing radiation is of immense importance because it will give the radiological status of the area and residents which serves as a radiation safety monitoring tool.

The result of this work will also serve as baseline data for the background radiation levels in the study area.

2.0 THE STUDY AREA

The study area is located in Ikwo Local Government Area of Ebonyi State in South Eastern Nigeria. The area lies within Longitude 8^0 00’E - $8^0$20’E and Latitude $6^0$00’N - $6^0$20’N (Ande et al.,2016).Ikwo is the largest local government area in Ebonyi State.The nature of activities in the study area includes but not limited to the following; excavation of solid minerals like lead/zinc, salt and limestone, farming of rice,cassava,yam,groundnut and cocoyam.

Insert map of study area

3.0 MATERIALS AND METHODS

Fifty sampling points were carefully marked out for BIR exposure measurement which covers the locations of the five farms around the mining area. Each of the sampling point was assigned a code (AF1 to AF5) for easy referencing. An in-situ approach of measurement with the standard practice of raising the detector tube 1.0 m above ground level with its window facing the point under investigation was adopted to enable sample points maintain their original environmental characteristics (Agbalagba et al., 2016).An in-situ sampling and measurements was done with the help of a well calibrated Ddigilert -200 nuclear radiation meter (S.E international, INC.). The radiation meter contains a Geiger-Muller detector tube capable of detecting alpha down to 2.5 MeV with 80% detection efficiency and can also detect beta at 150 KeV with 75% detection efficiency. Digilert 200 is capable of detecting gamma and X-rays down to 10 KeVv through the window, 40 KevV minimum through the case within the temperature range of -10°cCto 50°Vc. The effective dose readings were taken in milli Roentgen per hour (mR/hr) directly from the display screen of the radiation meter. The results were then converted to micro-Sievert per hour (μSv/hr) and then finally converted to micro-Sievert per year (μSv/yr). A geographical position system (GPS) was used to take the precise positions of the sampling points.

Radiological Hazard Parameters

The mean background ionizing radiation exposure rate obtained were quantitatively used to assess the radiation health impact to farmers in the immediate environments by performing a number of radiological health indices calculations such as absorbed dose rate, annual effective dose equivalent and excess lifetime cancer risk.~~using the necessary relations given by (Agbalagba, 2017).~~

Absorbed dose rate

The exposure dose rates in (μR/h) obtained in the study areas were converted into absorbed dose rate (nGy/h) using the conversion factor (Ilugo*et al.*, 2021):

$$1\mu R/h = 8.7\ nGy/h = 8.7\ x\ 10^{-3}\mu Gy/(1/8760)yr = 76.212nGyy^{-1} \quad 13.1$$

~~The mean background ionizing radiation exposure rate obtained were quantitatively used to assess the radiation health impact to farmers in the immediate environments by performing a number of radiological health indices calculations such as absorbed dose rate, annual effective dose equivalent and excess lifetime cancer risk using the necessary relations given by (Agbalagba, 2017).~~

~~3.1 Radiological Hazard Parameters~~

Formatted: Space Before: Auto, After: Auto

~~Radiation models are used to determine the radiological health risk parameters such as absorbed dose, annual effective dose equivalent and excess life cancer risk .~~

3.1.1 Equivalent Dose Rate

To estimate the whole body equivalent dose rate over a period of one year, we used the National Council on Radiation Protection and Measurement's recommendation (Ononugbo et al., 2011):

1mR/h = (0.96x24x365)/100 mSv/y

3.1.2 Absorbed dose rate

The exposure dose rates in (μR/h) obtained in the study areas were converted into absorbed dose rate (nGy/h) using the conversion factor (UNSCEAR,2000):

1μR/h = 8.7nGy/h = 8.7x10-3μGy/(1/8760)y = 76.212μGy/ythis equation is repeated, please delete

3.1.3 Annual Effective Dose Equivalent (AEDE)

The computed absorbed dose rates were used to calculate the Annual Effective Dose Equivalent (AEDE) received by the mining workers or farmers. In calculating AEDE, dose conversion factor of 0.7 Sv/Gy and the occupancy factor for outdoor of 0.25 (6 h out of 24 h) was used. The occupancy factor for outdoor was calculated based upon interviews with traders. People of the study area spend almost 6 h outdoor due to the nature of their routine. The Annual Effective Dose was estimated using the following relation (Ononugbo&Anakwe, 2020):

$$\text{AEDE (Outdoor) (mSv/y)} = \text{ADR (nGy/h)} \times 8760\text{h} \times 0.7\text{Sv/Gy} \times 0.25 \quad 3.6$$

Where ADR is Absorbed Dose Rate.

3.1.4 Excess Life Cancer Risk (ELCR)

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

ELCR = AEDE x Average duration of life (DL) x Risk factor (RF).......

Where AEDE is the Annual Effective Dose Equivalent,

DL is average Duration of Life (70years), and

RF is the Risk Factor i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public (Taskin et al., 2009).

3.2 Effective Dose Rate (D~~organ~~$_{organ}$) in mSvy^{-1} to Different Organs/ Tissues

The effective dose rate to a particular organ was ~~canbe~~ calculated using the relations:

Dorgan (mSvy^{-1}) = O x AEDE 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. The calculated effective dose rates delivered to the different organs are presented in Fig. 4, with the F values for lungs, ovaries, bone marrow, testes, kidneys, liver and whole body being 0.64, 0.58, 0.69, 0.82, 0.62, 0.46 and0.68 respectively (Ovuomarie-kevin et al.,2018).

4.0 RESULTS

The results for the in-situ measurement of the exposure rate with their associated health risk parameters for the five farms around solid mineral mining sites in Ikwo Local Government Area are presented in Tables 1-5. Figs. 1to~~and~~ 4 show the comparison of the measured exposure rates, calculated absorbed doses , annual effective dose equivalent and excess life cancer risk of the sampled area (Around Farm1 to Farm 5) with their international standards respectively. Fig.5 represents the graph of the effective dose rates for to different organs/tissues

Table 1 :Radiation Exposure Rate of Farm 1 and its Radiological Risk Analysis

S/N	Sampling Point	Geographical Coordinate	Average Radiation Exposure Rate (mR/h)	Absorbed Dose (nGy/hr)	AEDE (mSv/y)	ELCR(10^{-3})
1	AF11	N06^{0}10'15.4 E008^{0}08'23.0	0.019	165.30	0.25	0.89
2	AF12	N06^{0}10'16.9 E008^{0}08'29.6	0.019	165.30	0.25	0.89
3	AF13	N06^{0}10'19.9 E008^{0}08'29.5	0.011	95.70	0.15	0.51
4	AF14	N06^{0}10'19.6 E008^{0}08'29.6	0.013	113.10	0.17	0.61
5	AF15	N06^{0}10'10.0 E008^{0}08'30.0	0.027	234.90	0.36	1.26
6	AF16	N06^{0}10'10.0 E008^{0}08'35.0	0.015	130.50	0.20	0.70
7	AF17	N008^{0}10'22.9 E008^{0}08'31.1	0.024	208.80	0.32	1.12
8.	AF18	N008^{0}10'22.5 E008^{0}08'31.0	0.017	147.90	0.23	0.79
	Average		**0.02**	**157.67**	**0.24**	**0.85**

Table 2 :Radiation Exposure Rate of FARM 2 and its Radiological Risk Analysis

S/No	Sampling Point	Geographical Coordinate	Average Radiation Exposure Rate (mR/h)	Absorbed Dose (nGy/hr)	AEDE (mSv/y)	ELCR (10^{-3})
1	AF21	N06^{0}10'21.7 E008^{0}08'29.5	0.017	147.90	0.23	0.79
2	AF22	N06^{0}10'23.5 E008^{0}10'29.3	0.017	147.90	0.23	0.79
3	AF23	N06^{0}10'22.3 E008^{0}10'30.6	0.019	165.3	0.25	0.89
4	AF24	N06^{0}10'21.1 E008^{0}08'31.7	0.011	95.7	0.15	0.51
5	AF25	N06^{0}10'19.2 E008^{0}08'33.0	0.017	147.9	0.23	0.79
6	AF26	N06^{0}10'24.8 E008^{0}10'31.6	0.015	130.5	0.20	0.70
7	AF27	N06^{0}10'22.3 E008^{0}08'32.9	0.022	191.4	0.29	1.03
8	AF28	N06^{0}10'15.0 E008^{0}08'25.0	0.022	191.4	0.29	1.03
	Average		**0.0175**	**152.25**	**0.23**	**0.82**

The numbers should be at least two decimal place

Table 3: Radiation Exposure Rate of FARM 3 and its Radiological Risk Analysis

S/N	Sampling Point	Geographical Coordinate	Average Radiation Exposure Rate (mR/h)	Absorbed Dose (nGy/hr)	AEDE (mSv/y)	ELCR (10^{-3})
1	AF31	N06^{0}09’96.0 E008^{0}09’16.5	0.022	191.40	0.29	1.03
2	AF32	N06^{0}09’95.0 E008^{0}09’15.0	0.024	208.80	0.32	1.12
3	AF33	N06^{0}09’90.4 E008^{0}09’17.1	0.021	182.70	0.28	0.98
4	AF34	N06^{0}09’90.2 E008^{0}09’17.0	0.017	147.9	0.23	0.79
5	AF35	N06^{0}09’90.1 E008^{0}09’16.0	0.025	217.5	0.33	1.16
6	AF36	N06^{0}09’90.0 E008^{0}09’15.0	0.032	278.4	0.43	1.49
7	AF37	N06^{0}09’90.12 E008^{0}09’15.5	0.023	204.45	0.31	1.10
	Average		**0.023**	**204.45**	**0.31**	**1.10**

The numbers should be at least two decimal place

Table 4: Radiation Exposure Rate of FARM 4 and its Radiological Risk Analysis

S/N	Sampling Point	Geographical Coordinate	Average Radiation Exposure Rate (mR/h)	Absorbed Dose (nGy/hr)	AEDE (mSv/y)	ELCR (10-3)
1	AF41	N06^{0}09'80.0 E008^{0}09'15.0	0.018	156.6	0.24	0.84
2	AF42	N06^{0}09'95.0 E008^{0}09'20.0	0.019	165.3	0.25	0.89
3	AF43	N06^{0}09'94.5 E008^{0}09'20.9	0.021	182.7	0.28	0.98
4	AF44	N06^{0}09'90.5 E008^{0}09'44.6	0.024	208.8	0.32	1.12
5	AF45	N06^{0}09'85.0 E008^{0}09'45.0	0.004	34.8	0.05	0.19
6	AF46	N06^{0}09'81.4 E008^{0}09'44.7	0.015	130.5	0.20	0.70
7	AF47	N06^{0}09'80.8 E008^{0}09'45.3	0.017	147.9	0.23	0.79
8	AF48	N06^{0}09'80.5 E008^{0}09'45.4	0.021	182.7	0.28	0.98
	Average		**0.02**	**151.16**	**0.23**	**0.81**

Table 5: Radiation Exposure Rate of FARM 5 and its Radiological Risk Analysis

S/N	Sampling Point	Geographical Coordinate	Average Radiation Exposure Rate (mR/h)	Absorbed Dose (nGy/hr)	AEDE (mSv/y)	ELCR (10-3)
1	AF51	N06^{0}10’48.0 E008^{0}08’18.9	0.026	226.2	0.35	1.21
2	AF52	N06^{0}10’48.5 E008^{0}08’19.0	0.029	252.3	0.39	1.35
3	AF53	N06^{0}10’49.0 E008^{0}08’19.5	0.03	261	0.40	1.40
4	AF54	N06^{0}10’49.5 E008^{0}08’19.9	0.035	304.5	0.47	1.63
5	AF55	N06^{0}10’49.7 E008^{0}08’20.0	0.026	226.2	0.35	1.21
6	AF56	N06^{0}10’49.2 E008^{0}08’20.1	0.029	252.3	0.39	1.35
7	AF57	N06^{0}10’50.2 E008^{0}08’20.9	0.03	261	0.40	1.40
8	AF58	N06^{0}10’51.3 E008^{0}08’22.5	0.035	304.5	0.47	,1.63
9	AF59	N06^{0}10’52.7 E008^{0}08’21.3	0.031	269.7	0.41	1.45
10	AF510	N06^{0}10’53.3 E008^{0}08’23.2	0.026	226.2	0.35	1.21
11	AF511	N06^{0}10’54.2 E008^{0}08’23.9	0.029	252.3	0.39	1.35
12	AF512	N06^{0}10’55.0 E008^{0}08’25.9	0.032	278.4	0.43	1.49
13	AF513	N06^{0}10’55.8 E008^{0}08’27.7	0.036	313.2	0.48	1.68
14	AF514	N06^{0}10’56.4 E008^{0}08’28.9	0.034	295.8	0.45	1.59
15	AF515	N06^{0}10’57.3 E008^{0}08’30.8	0.028	243.6	0.37	1.31
16	AF516	N06^{0}10’58.1 E008^{0}08’32.9	0.027	234.9	0.36	1.26
17	AF517	N06^{0}10’56.8 E008^{0}08’32.4	0.029	252.3	0.39	1.35
18	AF518	N06^{0}10’54.7 E008^{0}08’31.6	0.031	269.7	0.41	1.45
19	AF519	N06^{0}10’53.0 E008^{0}08’30.8	0.028	243.6	0.37	1.31
	AVERAGE		**0.03**	**261.46**	**0.40**	**1.40**

The same corrections for tables 1-5

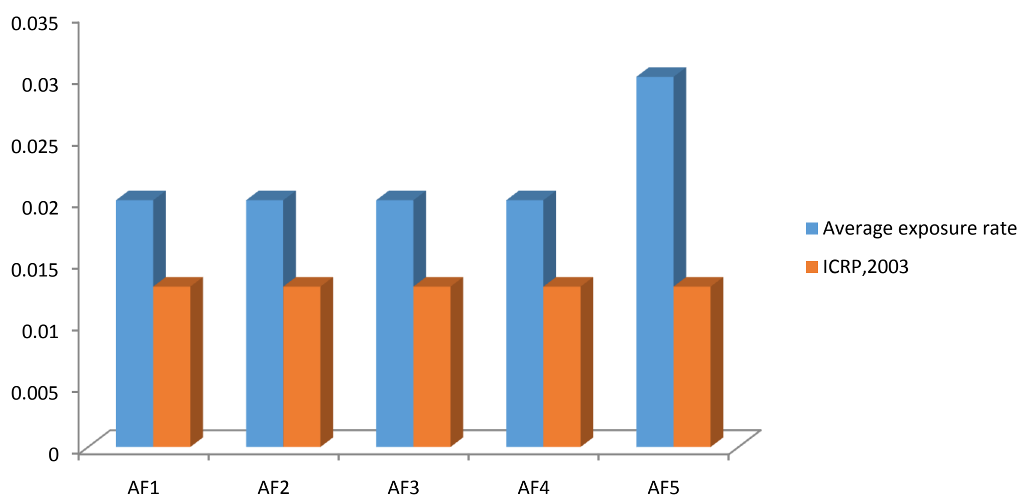

Fig 1: Comparison of Exposure rate in Soil with ICRP, 2003 Standard Value

Label the Y- axis e.g Average exposure rate (mR/h)

Label the X-axis e.g Location

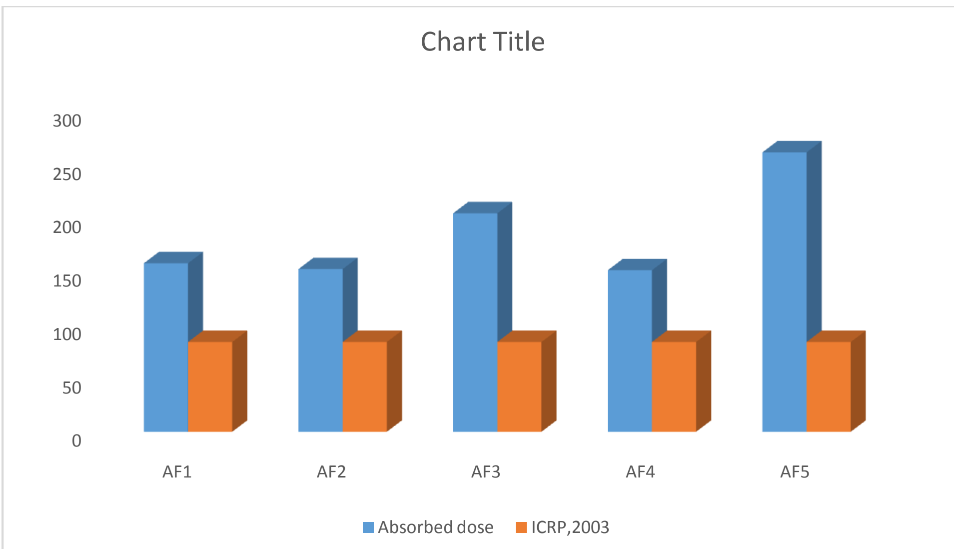

Fig 2: Comparison of Absorbed dose rate in Soil with ICRP, 2003 Standard Value

Label the Y- axis e.g Average exposure rate (mR/h)

Label the X-axis e.g Location

Remove chart title

It's a good scientific practice to always indicate the SD/Errors in your values

Formatted: Left

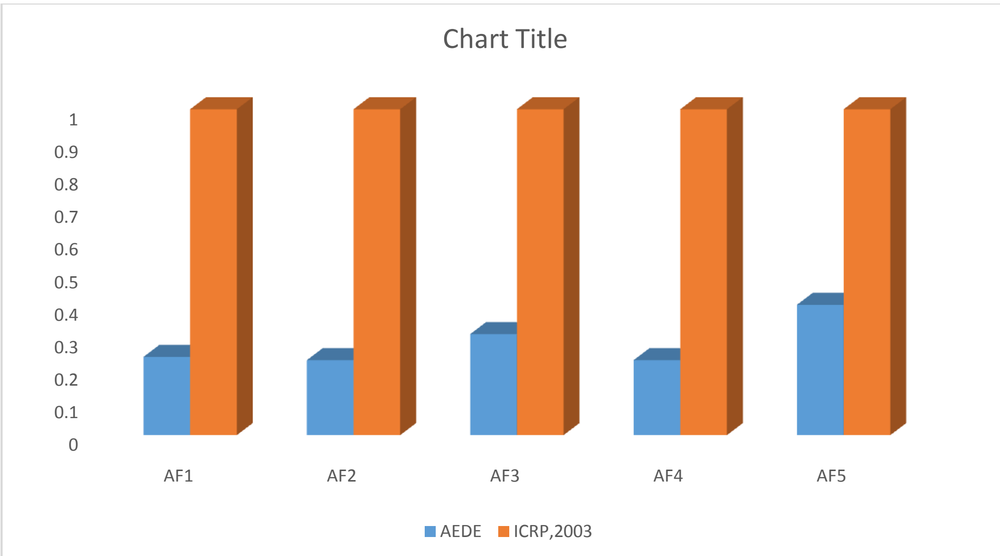

Fig 3: Comparison of AEDE in Soil with ICRP, 2003 Standard Value

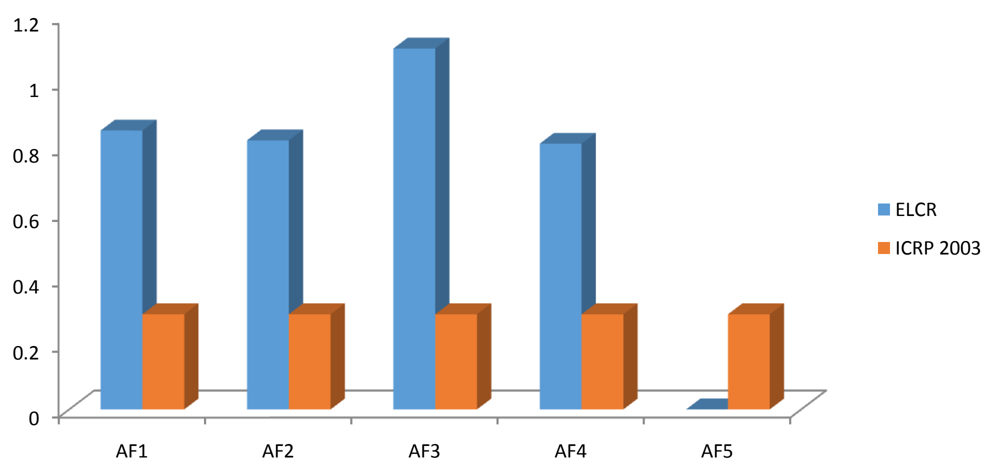

Fig 4: Comparison of Excess Life Cancer Risk in Soil with ICRP, 2003 Standard Value

Label the Y- axise.g ELCR x10^{-3}

Label the X-axis e.g Location

Remove chart title

It's a good scientific practice to always indicate the SD/Errors in your values

Formatted: Superscript

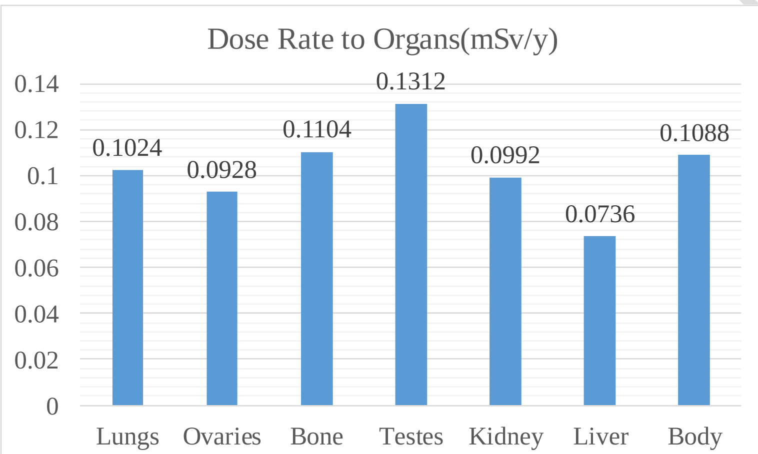

Fig 5: Effective Dose Rate(in mSv/y) to Different Organs/Tissues

Label the Y- axise.g Dose Rate to Organs (mSv/y)

Label the X-axis e.gOrgans

Remove chart title

It's a good scientific practice to always indicate the SD/Errors in your values

5.0 DISCUSSION

The average exposure rate, absorbed dose rate, annual effective dose equivalent and the excess life cancer risk from the in-situ measurement of the five farms are~~as follows~~as indicated ~~seen~~in Tables 1 to 5.

The outdoor background exposure rate measured ranges from 0.02 to 0.03 mRh^{-1} with mean value of 0.02 mRh^{-1}. The mean background exposure rate for the environment studied exceeded the permissible recommended limit of 0.013 mRh^{-1}. The high exposure rate level in some area is attributed to the geological formation, geophysical characterization and manmade activities that contribute to the overall radiation level such as continuous land excavation in search of solid mineral and abandonment of used mining pits. The high outdoor background levels indicates that the environment is radiologically unhealthy and contaminated for the general public. The mean exposure result can be liken to the result of ~~to the resultsof~~(Ugbede, 2018; Fedrick, 2019). However, the result is different from the one obtained by (Ayua et al., 2017) where the value is slightly lower than the world standard value. The range of calculated absorbed dose rate value is between 151.16 $nGyh^{-1}$ and 261.46 $nGyh^{-1}$ with observed mean value of 185.39 $nGyh^{-1}$. The mean absorbed dose rate is higher than the recorded world weighted average of 59.00 $nGyh^{-1}$ (Agbalagba, et al., 2016) and recommended safe limit of 84.0 $nGyh^{-1}$ (Agbalagba et al., 2016; Ononugbo&Mgbemere, 2016) for outdoor exposure. These dose rates result indicate contamination of the environment by radiation. Although the health effect to the residents of the locality may not be immediate, b~~ut~~ however there is the potential for long-term health hazards in the future due to the doses accumulated. The mean absorbed dose rate from this study is higher than 126.15 ±5.10 $nGyh^{-1}$ dose rates earlier reported by (Ugbede& Benson 2018) in Emene Industrial Layout of Enugu State, Nigeria and 132.16±24.36 $nGyh^{-1}$ for Ughelli metropolis in Delta State Nigeria by (Agbalagba et al., 2016). The Annual effective dose equivalent (AEDE) ranges between 0.23 mSvy^{-1} and 0.40 mSvy^{-1} with mean value of 0.20 mSvy^{-1}. This is higher than world average value of 0.07 mSvy^{-1} (Agbalagba et al., 2016) but lower than recommended permissible limits of 1.00 mSvy^{-1} for the general public (Agbalagba et al., 2016). The AEDE from the present study are similar to those reported by (Ononugbo&Mgbemere, 2016; Ugbede& Benson, 2018).

The calculated values of ELCR ranges from 0.18×10^{-3} to 1.40×10^{-3}with mean value of 1.00 ×10^{-3}. This mean value is higher than the world average value of 0.29×10^{-3}. The lifetime cancer risk is quite high and the possibilities of cancer development by residents who wish to spend all their life time in the area is imminent. The ELCR values in this study is higher than those reported by (Ugbede, 2018; Idris et al., 2021).

The calculated effective dose rates delivered to the different organs in the adult body are presented in Fig. 5. It was shown that the testes recorded the highest dose of 0.13mSvy^{-1} while the liver recorded the least value with average value of 0.07 mSvy^{-1} . These results indicate that the estimated doses to the different organs are all below the international tolerance limits on dose to body organs of 1.0 mSvy^{-1} . The relatively higher dose to the testes and low dose intake to the liver is justified by the food nutrient absorption rate (Ovuomarie-kevin et al.,2018). This result shows that exposure to background ionizing radiation levels in all the sample from solidmineral mining area in Ikwo LGA contribute insignificantly to the radiation dose to these organs in adults.

6. CONCLUSION

Radiological assessment of background ionizing radiation exposure dose rates from solid mineral mining sites in Ikwo local government area of Ebonyi state was carried out using a Digilert-200

Radiation Meter. From the results obtained the BIR exposure rate of 0.02mR/h for the mining sites exceeded the recommended permissible limit of 0.013 mR/hr. The mean absorbed dose rate of 185.39nGy/h is greater than the recommended permissible limit of 84nGy/h. Theresults indicate contamination and radiologically enhanced environment by radiation.This may be due to continuous excavation of land and mining of Lead/Zinc solid mineralwhich enhances the environment radioactivity of the area. The excess lifetime cancer risk calculated revealed that the chance of contracting cancer for residents of the study area is high and the effective doses to the adult organs calculated are less than the permissive limit and insignificant in all the organs except the testes and bone marrow. However, to keep the radiation level under control, authorized government organizations and radiation protection bodies must conduct regular check and periodic monitoring in the area.

REFERENCES

Ononugbo, C. P., Avwiri, G. O., & Chad-Umoren, Y. E. (2011). Impact of gas exploitation on the environmental radioactivity of Ogba/Egbema/Ndoni Area, Nigeria. *Energy and Environment, 22*(8), 1017-1028.

Agbalagba, E.O., Avwiri, G.O., &Ononugbo, C .P. (2016). GIS mapping of impact of industrial activities on the terrestrial background ionizing radiation levels of Ughelli metropolis and its Environs, Nigeria. *Environmental Earth Science* 75:1425 DOI 10.1007/s12665-016- 6216-y

Agbalagba, O .E. (2017). Assessment of excess lifetime cancer risk from gamma radiation levels in Effurun and Warri city of Delta state, Nigeria. *Journal of Taibah University for Science, 11*(3),367-380.

Akpabio, L. E., Etuk, E. S., &Essian, K.(2005). Environmental radioactive levels in IkotEkpene Nigeria. *Nigerian Journal of Space Research* 1,80–87.

Emelue, H .U.,Jibiri, N .N.,& Eke, B .C. (2014). Excess lifetime cancer risk due to gamma radiation in and around Warri refining and petrochemical company in Niger Delta, Nigeria. *British Journal of Medicine and Medical Research*, *4*(13),2590-2598.

Ogola, P .E., Arika, W .M., Nyamai, D .W., Osano, K .O., &Rachuonyo, H .O. (2016). Determination of background ionizing radiations in selected buildings in Nairobi County, Kenya. *Journal of Nuclear Medical Radiation*, *7*, 289. 20.

Osimobi, J. C., Agbalagba, E. O., Avwiri, G. O., &Ononugbo, C. P. (2015). GIS mapping and background ionizing radiation (BIR) assessment of solid mineral mining sites in Enugu State. OALib 2:e1979. http://dx.doi. org/10.4236/oalib.110197

Taskin, H., Karavus, M., Topuzoglu, P .A., Hindiroglu, S.,& Karahan, G. (2009).Radionuclide concentrations in soil and life time cancer risk due to gamma radioactivity in Kirklareli, Turkey. *Journal of Environmental Radioactivity*, *100*, 49-53.

Ande, O. T., Ojo, O. A., Adeyolanu, O. D., Are, S. K., Adelana, A., Adetayo, A. A.,& Oluwatosin, G. (2016). Digital soil mapping and morphogenetic characterization of soils of Ebonyi formation in South-Eastern Nigeria. *Journal of Earth Science Research*, *5*(11), 1-9.

Avwiri, G. O., Osimobi, J. C., &Agbalagba, E. O. (2013). Evaluation of natural occurring radionuclide variation with lithology depth profile of Udi and Ezeagu Local Government

Areas of Enugu State, Nigeria. *International Journal of Engineering and Applied Sciences*, *4* (3), 234-239.

Ayua, J., Tyovenda, A. A., &Igyuse, I. S. (2017). Determination of ionizing radiation exposure levels within four local mining sites selected from Sardauna local government area of Taraba State, Nigeria. *International Journal of Physics*,*5*(5), 157-161.

Fedrick, O. U. (2019). In-situ assessment of terrestrial background gamma radiation exposure and dose levels in Nkalagu-Ezillo Rice farm, Ebonyi State, Nigeria. *Science and Technology Journal*, *4(*1), 62-68.

Idris, M. M., Rahmat, S. T., Musa, M., Muhammed, A. K., Isah, S. H., Aisha, B., & Umar, S. A.(2021). Outdoor background radiation level and radiological hazards assessment in Lafia metropolis, Nasarawa State, Nigeria. *Aseana Journal Of Science And Education*, *1*(1), 27-35

Mgbeokwere, C., Ononugbo, C. P., & Bubu, A. (2021). Teresterial background ionizing radiation around lead/zinc mining site in Ishiagu, Ebonyi State, Nigeria. *Asian Journal of Physical and Chemical Sciences*, *9*(4),1-13.

Ononugbo, C. P., &Anakwe, U. (2020). Background gamma radiation in Nigeria market environment. *American Journal of Environmental Science*,*16*(3), 48-54.

Ononugbo, C. P., &Mgbemere, C. J. (2016). Dose rate and annual effective dose assessment of terrestrial gamma radiation in Notre fertilizer plant, Onne, Rivers State, Nigeria. *International Journal of Emergence Research Management and Technology*, *5*(9),30–35.

Sadiq, A.A., & Agba, E.H. (2011). Background radiation in Akwanga, Nigeria. *FactaUniversitatisSeries:working and living environmental protection*,*8*(1), 7-11.

Ugbede, F.O. (2018). Measurement of background ironizing radiation exposure levels in selected farms in communities of Ishielu L.G.A, Ebonyi State, Nigeria. *Journal of Applied Science and Management*, *22*(9),1427-1432.

Ugbede, F.O., & Benson, I. D. (2018). Assessment of outdoor radiation levels and radiological health hazards in Emene Industrial layout of Enugu State, Nigeria. *International Journal of Physical Science,13*(20),265–272.

United Nations Scientific Committee on the Effects of Atomic Radiation(UNSCEAR,2000). Sources, Effects and Risk of Ionizing Radiation.United Nations 2000; New York. http://www.unscear.org/unscear/publications/2000_2.html

Ovuomarie-kelvin, S. I.,Ononugbo, C. P., &Avwiri, G. O. (2018).Evaluation of health risks from exposure to low level ionizing radiation in some oil spilled communities of Rivers State,Nigeria. Journal of Scientific Research and Reports, 19(5), 1-11.

Use the same format for the line spacing in your references. Some are indented while others are not