RISK ASSESSMENT OF OUTDOOR GAMMA RADIATION IN SOME COASTAL COMMUNITIES OF DELTA STATE, NIGERIA

Abstract:

An assessment of background ionization radiation and associated health risk in some coastal communities of Delta State, Nigeria was carried out using a well calibrated portable radiation detector (Radalert-200) and GPS (Garmin GPS 72H) for the measurement of the geographical locations. The study covers Abiteye and Anotech Jetty water ways with nine notable communities assessed, where marine transportation and equipment haulage are predominant. The exposure rates ranged from 0.011 to 0.019 mRh^{-1} with overall mean value of 0.015 ± 0.002 mRh^{-1}. The computed absorbed dose rates ranged from 95.70 to 165.30 $nGyh^{-1}$ with overall mean value of 132.46 ± 19.05 $nGyh^{-1}$. The estimated overall mean annual effective dose equivalent (AEDE) for the studied communities was 0.203 ± 0.03 $mSvy^{-1}$, while the overall mean excess lifetime cancer risk (ELCR) was $(0.710 \pm 0.10) \times 10^{-3}$. The dose received by organs was highest in the testes (18%), while the liver had the lowest dose values (10%). Among all the estimated risk parameters, only the overall mean AEDE was found to be below the safe world recommended standard value while others were higher than their respective safe world average values. Hence the exposure may not constitute any immediate health risk to the resident of the study area.

Keywords: Excess Life Cancer Risk, Background Ionizing Radiation, Radalert-200, Exposure Rate, Absorbed dose

1. Introduction

The exposure of human beings to natural radiation, are mainly due to natural radionuclides decay of ^{238}U (^{226}Ra) series, ^{232}Th series and ^{40}K present in the earth's crust, in air, water, building materials, the human body and food [1]. Background radiation originates from a variety of sources, both natural and artificial. These include both cosmic radiation and environmental radioactivity from naturally occurring radioactive materials (such as radon and radium), as well as man-made medical X-ray, fallout from nuclear weapons testing and nuclear accidents. Naturally occurring radionuclides are present in the Earth crust; however, their distribution is not homogeneous. The associated gamma radiation emitted from these radionuclides in external exposures depend on the geological and geographical conditions and vary between regions in the world [2].

Humans are exposed to naturally radiation in their environment with or without their consent; and the exposure to natural background radiation is an unpreventable event on earth. Atomic radiation has no boundaries; and the injuries and clinical symptoms induced by exposure to ionizing radiation include; direct chromosomal transformation, indirect free-radical formation, radiation cataractogenesis, cancer induction, bone necrosis and so on [3]. The practice has been to ensure that human exposure to radiation is as low as reasonably achievable, commonly known as the ALARA principle. In order to assure radiation protection of the population, it is important to map the potential exposure for workers and the general public.

However, there are high background radiation area (HBRA) regions in the world where the terrestrial outdoor radiation exceeds substantially from the normal range due to the enrichment of certain minerals that are radioactive [1,3]. Several countries like Iran, Germany, China, USA, Brazil, and India have reported the existence of high background radiation areas [4]. The highest levels of natural radiation in the world have been reported in some areas in Ramsar with extraordinary radon level [4]. The data of radiation level obtained from HBRA in Ramsar recorded an effective dose of 260 $mSvy^{-1}$. This value is far higher than the International Commission on Radiation Protection (ICRP) recommended radiation dose limits for radiation workers, and over 200 times greater than normal background levels for members of the public.

In Nigeria, several studies have been carried out in different areas to determine the natural radiation level in some location. For instance, it is reported by Termizi *et al*., [3] that the mean annual effective dose equivalent due to outdoor exposure to radiation in Keffi and Akwanga of Nasarawa State-Nigeria, ranged from 0.25 mSv/y and 0.31mSv/y respectively, which are below the world in recommended dose limit of 1 mSv/y. Also, a study done nationwide to determine the terrestrial radiation in Nigeria indicates that the mean annual effective dose equivalent is 0.27mSv/y [5]. Hence, this present study aimed at assessment of environmental gamma doses in some coastal communities around the jetty areas of Delta State-Nigeria, for the estimation of the annual effective dose equivalent (AEDE) and excess lifetime cancer risk (ELCR) to individual's resident in the area.

2. Materials and Methods

2.1 Study Area

The study area covers nine coastal communities in Warri, Delta State-Nigeria and are within and around two major jetties in the coastal areas; Abiteye and Anotech Jetty water ways where marine transportation and equipment haulage is predominant. Communities within Abiteye water ways include: Benikuru, Okpelama, Okerenkuku, Oporosa. While Communities within Anotech Jetty include: Enerhe, Opette, Okpaka, Sedico and Ovwian as shown in Figure 1. Warri sits on the bank of warri river which joined Forcados River and Escravos River through jones creek in the lower Niger Delta region of Nigeria. The city has a modern seaport which serves as the cargo transit point between the Niger River and the Atlantic Ocean for import and export. It is geographically located at latitudes 5.30687 – 5.560285 N and between longitudes 5.47272 – 5.708444 E. The area lies parallel to the coastline sediments region and basement of another Atlantic coastal region of Escravos, Forcados and Warri River. Other surface features include vegetation, sediment’s structure and soil textures, which formed the characteristic of the environments in the coastal regions.

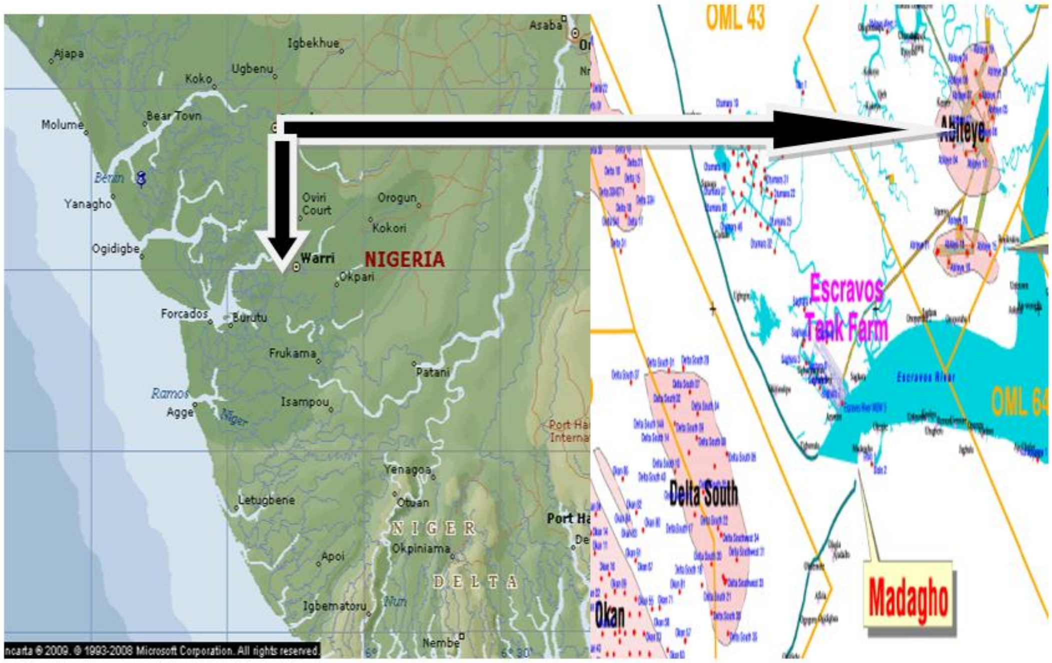

Figure 1: Map of the study Area

2.2 Method

An *in-situ* measurement of the radiation exposure dose rates was carried out at 1 meter above the ground using Radalert-200 gamma detector coated with 2.0 cm x 2.0 cm NaI crystal. Readings were obtained between the hours of 1300 and 1600 since the exposure rate meter has a maximum response to environmental radiation within these hours [6]. The instrument was mostly suitable for the detection of dose exposure and naturally occurring radionuclides, with higher degree of accuracy and probable errors of about ± 5%. Radalert-200 is a rugged solution for monitoring both ambient and elevated levels of ionizing radiation in a challenging environment. It detects and measures alpha, beta, gamma and x-radiation. Data is displayed in choices of counts per minutes (CPM), micro-sivert per hour (μSv/hr), mili-roentgen per hour (mR/h) or in accumulated counts. It has a digital, easy to read backlit display, a red count light and a beeper that sounds with each count detected. Data measured were used to estimate the radiological health risks of exposed individuals in the area.

3. Radiological Health Risk Parameters

3.1 Absorbed Dose of Radiation

Absorbed dose is a measure of the energy deposited in a medium by ionizing radiation per unit mass. The absorbed dose is used to assess the potential for any biochemical changes in specific tissues. It quantifies the radiation energy that might be absorbed by a potentially exposed individual. It is measured as Joules per kilogram and represented by the equivalent SI unit, Gray (Gy) or rad. The data obtained for the external background ionization radiation exposure rate in mRh^{-1} were also converted into absorbed dose rates $nGyh^{-1}$ using the conversion factor shown in equation 1 [7].

$$1\ \mu Rh^{-1} = 8.7 nGyh^{-1} = \frac{8.7 \times 10^{-3}}{(1/6760y)}\ \mu Gy^{-1} = 76.212 \mu Gyy^{-1} \qquad (1)$$

3.2 Equivalent Dose Rate.

To estimate the whole-body equivalent dose rate over a period of one year, the National Council on Radiation Protection and Measurement’s recommended equation was used [8]:

$$1mRh^{-1} = \frac{0.96 \times 24 \times 365}{100} mSvy^{-1} \qquad (2)$$

3.3 Annual Effective Dose Equivalent (AEDE)

Annual effective dose is the tissue-weighted sum of the equivalent doses in all specified tissues and organs of the human body and it represents the stochastic health risk to the whole body which is the probability of cancer induction and genetic effects due to low levels of ionizing radiation. It takes into account the type of radiation and the nature of each organ or tissue being irradiated. In calculating the annual effective dose equivalent (AEDE) outdoor, a dose conversion factor of 0.7 Sv/Gy was used as recommended by the United Nations Scientific Committee on the Effect of Atomic Radiation UNSCEAR [9], while an occupancy factor of 0.2 was also used as shown in equations 3.

$$AEDE_{(Outdoor)}\ (mSvy^{-1}) = D_{(air)}\ (nGyh^{-1}) \times 8760\ h \times 0.7\ Sv/Gy \times 0.2\ x10^{-6} \qquad (3)$$

3.4 Excess Lifetime Cancer Risk (ELCR)

Excess lifetime cancer risk (ELCR) is defined as the probability of developing cancer as a result of exposure to a specific carcinogen. Excess lifetime cancer risk (ELCR) was calculated using equation 4 [10]:

$$ELCR\ (mSvy^{-1}) = AEDE \times DL \times RF \qquad (4)$$

where AEDE, DL and RF are the annual effective dose equivalent, duration of life (70 years) and fatal cancer risk factor (Sv^{-1}) respectively. For low-dose background radiation which is considered to produce stochastic effects, ICRP-60 uses a fatal cancer risk factor value of 0.05 (Sv^{-1}) for public exposure [7].

3.5 The Effective Dose Rate (D_{organ}) in mSvy^{-1} to Different Body Organs and Tissues

The effective dose rate to a particular organ can be calculated using the relationship below [11.12]:

$$D_{\text{organ}}\ (\text{mSvy}^{-1}) = O\times\text{AEDE}\times F \qquad (5)$$

where AEDE is the annual effective dose equivalent, *O* is the occupancy factor (0.8) and *F* is the conversion factor for organ ingestion. The F values for lungs, ovaries, bone marrow, testes, kidneys, liver and whole body are 0.64, 0.58, 0.69, 0.82, 0.62, 0.46 and 0.68 respectively as obtained from the ICRP. The model of the annual effective dose to organs estimates the amount of radiation intake by a person that enters and accumulates in various body organs and tissues [13].

4. Results and Discussion

Tables 1 to 2 show the *in-situ* exposure rates and the estimated radiological parameters of the various communities in the study area. Figures 2 to 5 show the estimated exposure rates, and excess lifetime cancer risk of the sampled communities. The Effective Organ Dose (D_{organ}) Distribution in mSvy^{-1} to different organs and tissues of residents in the communities are shown in Figures 6 and 7.

Table 1: Exposure Rate and Health Risk Parameters around Anotech Communities

S/N	Sample Points	GPS Reading	Exposure Rate (mRh^{-1})	Absorbed Dose (nGyh^{-1})	Equivalent dose (mSvy^{-1})	AEDE (mSvy^{-1})	ELCR X 10^{-3}
1.	Enerhe$_1$	N05^{0}31′.687″ E005^{0}47′.271″	0.014	121.8	1.161	0.187	0.654
2.	Enerhe$_2$	N05^{0}31′.654″ E005^{0}47′.261″	0.014	121.8	1.161	0.187	0.654
3.	Enerhe$_3$	N05^{0}31′.682″ E005^{0}47′.241″	0.019	165.3	1.576	0.253	0.887
4.	Enerhe$_4$	N05^{0}31′.680″ E005^{0}47′.273″	0.014	121.8	1.161	0.187	0.654
5.	Opette$_1$	N05^{0}31.696 E005^{0}47′.297″	0.013	113.1	1.078	0.173	0.607
6.	Opette$_2$	N05^{0}31′.693″ E005^{0}47′.397″	0.015	130.5	1.244	0.200	0.700
7.	Opette$_3$	N05^{0}31′.698″	0.012	104.4	0.995	0.16	0.56

		E005^{0}47′.299″					
8.	Opette$_4$	N05^{0}31′.793″ E005^{0}47′.396″	0.015	130.5	1.244	0.200	0.700
9.	Okpaka$_1$	N05^{0}31′.687″ E005^{0}47′.274″	0.014	121.8	1.161	0.187	0.654
10.	Okpaka$_2$	N05^{0}31′.685″ E005^{0}47′.273″	0.018	156.6	1.493	0.240	0.840
11.	Okpaka$_3$	N05^{0}31′.689″ E005^{0}47′.282″	0.017	147.9	1.410	0.227	0.794
12.	Okpaka$_4$	N05^{0}31′.688″ E005^{0}47′.276″	0.014	121.8	1.161	0.187	0.654
13.	Sedico$_1$	N05^{0}31′.640″ E005^{0}47′.330″	0.017	147.9	1.410	0.227	0.794
14.	Sedico$_2$	N05^{0}31′.640″ E005^{0}47′.330″	0.019	165.3	1.576	0.253	0.887
15.	Sedico$_3$	N05^{0}31′.640″ E005^{0}47′.330″	0.018	156.6	1.492	0.24	0.84
16.	Sedico$_4$	N05^{0}31′.640″ E005^{0}47′.330″	0.016	139.2	1.327	0.213	0.747
17.	Ovwian$_1$	N05^{0}31′.669″ E005^{0}47′.296″	0.014	121.8	1.161	0.187	0.654
18.	Ovwian$_2$	N05^{0}31′.669″ E005^{0}47′.296″	0.016	139.2	1.327	0.213	0.747
19.	Ovwian$_3$	N05^{0}31′.669″ E005^{0}47′.296″	0.019	165.3	1.576	0.253	0.887
20.	Ovwian$_4$	N05^{0}31′.669″ E005^{0}47′.296″	0.013	113.1	1.078	0.173	0.607
	Mean Value		**0.016 ± 0.002**	**135.3 ± 19.2**	**1.290 ± 0.184**	**0.207±0.029**	**0.726±0.103**

Table 2: Radiation Exposure Rate of Some Communities around Abiteye Communities

S/N	Sample Points	GPS Reading	Exposure Rate (mRh^{-1})	Absorbed Dose (nGyh^{-1})	Equivalent dose (mSvy^{-1})	AEDE (mSvy^{-1})	ELCR x 10^{-3}
1.	Benikuru$_1$	N05030.700’ E005044.848’	0.013	113.1	1.078	0.173	0.607
2.	Benikuru$_2$	N05030.684’ E005044.823’	0.014	121.8	1.161	0.187	0.654
3.	Benikur$_3$	N05030.679’	0.016	139.2	1.327	0.213	0.747

		E005044.809’					
4.	Benikuru$_4$	N05030.675’ E005044.809’	0.015	130.5	1.244	0.200	0.700
5.	Benikuru$_5$	N05030.666’ E005044.812’	0.017	147.9	1.410	0.227	0.794
6.	Okpelema$_1$	N05030.671’ E005044.793’	0.013	113.1	1.078	0.173	0.607
7.	Okpelema$_2$	N05030.668’ E005044.794’	0.012	104.4	0.995	0.160	0.560
8.	Okpelema$_3$	N05030.684’ E005044.806’	0.014	121.8	1.161	0.187	0.654
9.	Okpelema$_4$	N05030.691’ E005044.808’	0.016	139.2	1.327	0.213	0.747
10.	Okpelema$_5$	N05030.862’ E005044.702’	0.018	156.6	1.493	0.24	0.84
11.	Okerenkuku$_1$	N05030.702’ E005044.789’	0.019	165.3	1.576	0.253	0.887
12.	Okerenkuku$_2$	N05030.696’ E005044.777’	0.018	156.6	1.493	0.240	0.840
13.	Okerenkuku$_3$	N05030.692’ E005044.773’	0.017	147.9	1.410	0.227	0.794
14.	Okerenkuku$_4$	N05030.707’ E005044.779’	0.015	130.5	1.244	0.200	0.700
15.	Okerenkuku$_5$	N05030.709’ E005044.776’	0.014	121.8	1.161	0.187	0.654
16.	Oporosa$_1$	N05030.771’ E005044.760’	0.015	130.5	1.244	0.200	0.700
17.	Oporosa$_2$	N05030.794’ E005044.752’	0.015	130.5	1.244	0.200	0.700

18.	Oporosa$_3$	N05030.706’ E005044.705’	0.012	104.4	0.995	0.160	0.560
19.	Oporosa$_4$	N05030.719’ E005044.740’	0.011	95.7	0.912	0.147	0.513
20.	Oporosa$_5$	N05030.722’ E005^{0}44.750’	0.014	121.8	1.161	0.187	0.654
Mean Value			**0.015 ± 0.002**	**129.6 ± 18.9**	**1.236 ± 0.180**	**1.199 ± 0.029**	**0.696 ± 0.102**

The radiation exposure rates measured around Anotech communities ranged from 0.012 to 0.019 mRh^{-1}, with a mean value of 0.016 ± 0.002 mRh^{-1}. Enerhe, Opette and Okpaka communities have the highest exposure rate values of 0.019 mRh^{-1} which exceeded the recommended permissible limit of 0.013 mRh^{-1} [14, 15, 16]. The result indicates that 53.3% of the sample points exceeded the permissible BIR level for the general public, these could be attributed to the presence of petroleum products, chemicals and construction materials like asphalt, granites, cement which have been recognized to contain some radioactive elements [16]. While the variation and high exposure rate level is attributed to the different industrial activities carried out in the different sampling locations and their geophysical characterization. The high BIR levels as represented in figure 2, are suggestive indication that the environment is radiologically contaminated. Though the dose rate at these levels may not constitute any immediate health hazards to the residents of the locality, there is the potential for long-term health hazards in the future

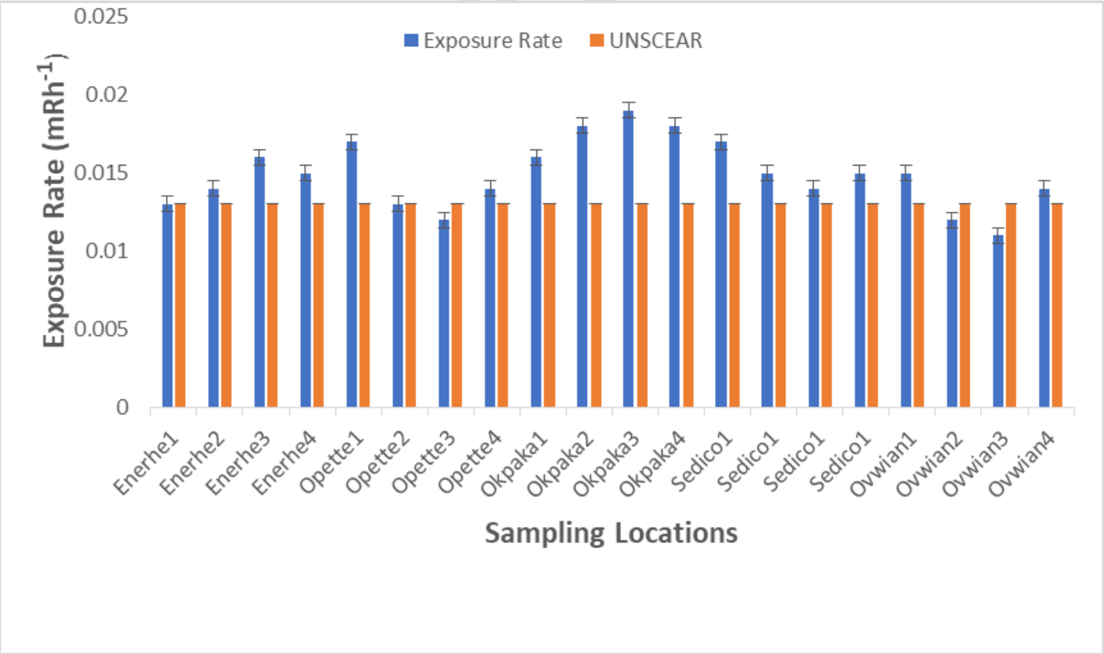

Figure 2: Comparison of Radiation Exposure Rate in Anotech Communities with UNSCEAR, 2008

In Abiteye communities, the measured exposure rate ranged from 0.011 to 0.019 mRh^{-1}, with the highest value of 0.019 mRh^{-1} observed in Okerenkuku community. This could be due to dredging activities and loading of products within the community. Oprosa-4 community recorded the lowest value of exposure rate, with a value of 0.011 mRh^{-1}, the community is located further away from the jetty and no industrial activities within it. However, the mean exposure level of 0.015 ± 0.002 µRh^{-1} recorded in Abiteye communities is lower than 0.018±0.004 mRh^{-1} value observed by Osimobi *et al*., [16] in solid mineral mining sites of Enugu State, Nigeria, but higher than the value measured by Ononugbo and Mgbemere [8] in a fertilizer company within Onne, Rivers State, Nigeria which ranged between 11.73 and 14.95 µRh^{-1}. Comparison of the exposure rates in Abiteye communities with the world standard is shown in figure 3.

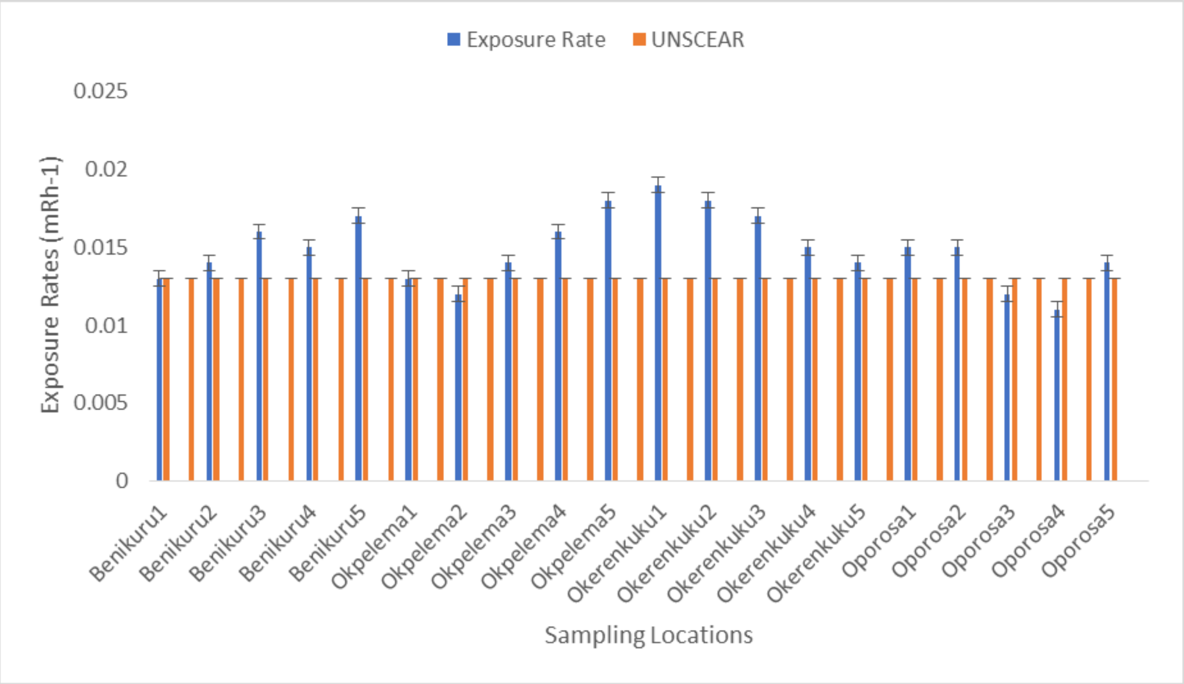

Figure 3: Comparison of Radiation Exposure Rate in Abiteye Communities with UNSCEAR, 2008

The estimated absorbed dose rate in Anotech communities' range between 104.4 and 165.3 nGyh^{-1} with a mean value of 135.3 ± 19.2 nGyh^{-1}, while that in Aiteye communities range from 95.7 to 165.3 nGyh^{-1} with a mean value of 129.6 ± 18.9 nGyh^{-1}. These dose rates are far higher than the recorded world weighted average of 59.00 nGyh^{-1} [13,17] and the recommended safe limit of 84.0 nGyh^{-1} [19] for outdoor exposure. The mean dose rates are higher than the values 97.44±20.42, 124.41±33.21, 97.44±12.17, 99.18±21.78 and 119.19±17.90 nGyh^{-1} earlier reported by Benson and Ugbede [4] in populated motor packs environment of Enugu city, but lower than the value of 141.30±31.31 $nGyh^{-1}$ reported by Agbalagba [13] for Warri city in Delta State, Nigeria.

Values of absorbed dose were used to estimate the Annual Effective Dose Equivalent (AEDE), in Anotech communities, AEDE range from 0.995 to 0.253 $mSvy^{-1}$ with a mean value of 0.207±0.029 $mSvy^{-1}$, while the range was 0.147 to 0.253 $mSvy^{-1}$ with mean value of 1.199 ± 0.029 $mSvy^{-1}$ in Abiteye communities. The mean AEDE values are similar to those reported by Ononugbo and Mgbemere in fertilizer producing area in Onne River State [8], higher than the world average value of 0.07 $mSvy^{-1}$ [13] but within ICRP and UNSCEAR recommended permissible limits of 1.00 $mSvy^{-1}$ for the general public [14, 18]. This could be an implication that the studied communities are radiologically contaminated due to the industrial activities (loading and off- loading of oil and gas products) taking place in the area. However, the contamination does not constitute any immediate radiological health effect on residents of the area.

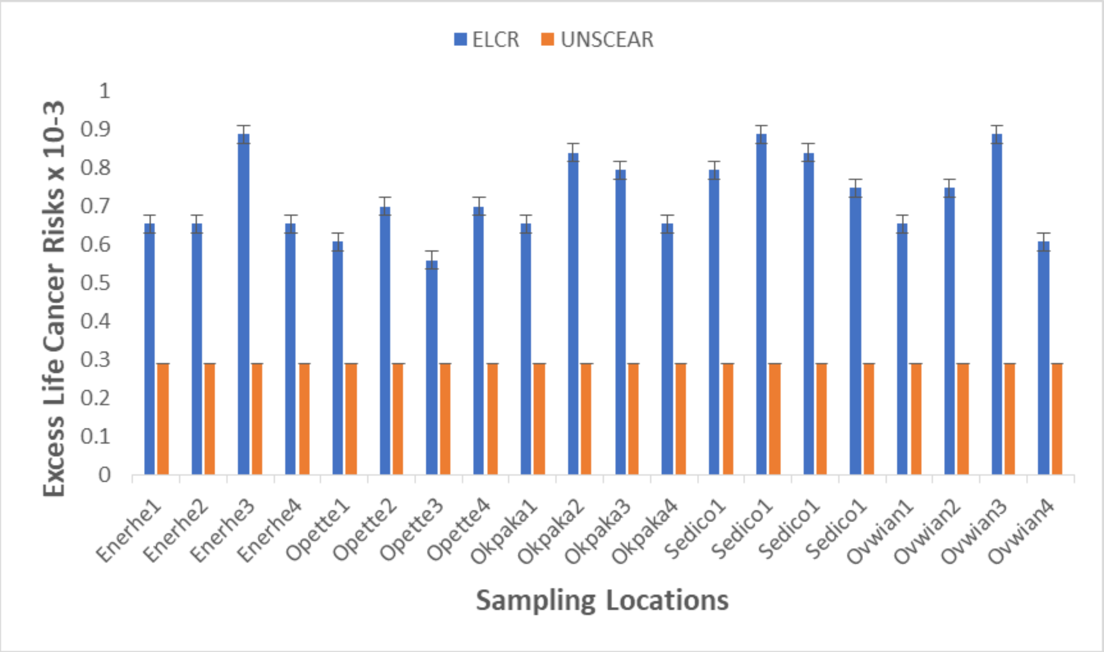

Figure 4: Comparison of Average ELCR in Anotech Communities with World Safe Limit Value

The estimated values of ELCR in Anotech and Abiteya communities are shown in figure 4 and 5 respectively. The ELCR range from 0.56×10^{-3} to 0.887×10^{-3} with a mean value of $0.726\pm0.103 \times 10^{-3}$ in Anotech communities, while the values around Abiteye communities range from 0.513×10^{-3} to 0.887×10^{-3} with a mean value of $0.696 \pm 0.102 \times 10^{-3}$. The highest ELCR value obtained $(0.887 \pm 0.013) \times10^{-3}$ is approximately 94.6% higher than the world average value of 0.29×10^{-3}. This high value for excess lifetime cancer risk indicates that there exist the possibilities of cancer development by residents who wish to spend all their life time in the area. The ELCR values report in this study are within the range of those reported by Agbalagba [13] in industrial areas of

Warri Nigeria but higher than those for those reported by Avwiri *et al*., [19] in Okposi Okwu Salt Lake and Uburu Salt Lake environments of Ebonyi State, Nigeria.

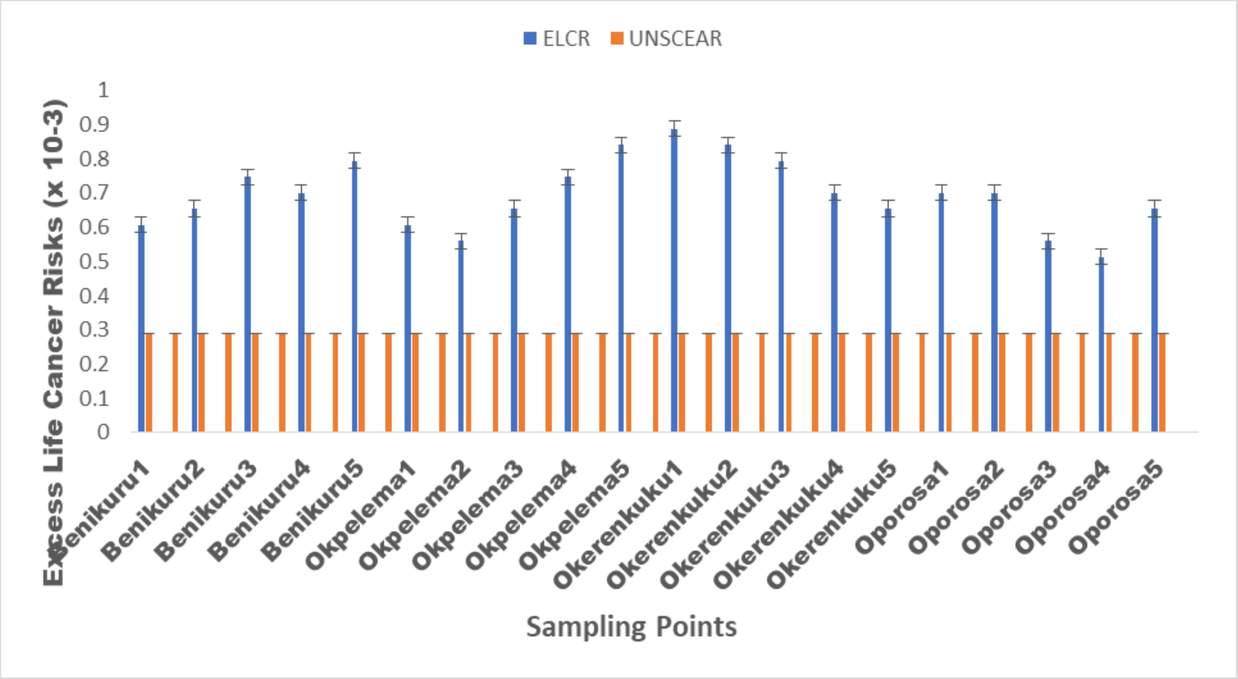

Figure 5: Comparison of Average ELCR in Abiteye Communities with World Safe Limit Value

The calculated effective dose rates delivered to the different organs in the adult body are shown in figures 6 and 7, for Anotech and Abiteye communities respectively. It was shown that the testes recorded the highest dose of 18 % while the liver recorded the least value of 10%. These results indicate that the estimated doses to the different organs are 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 justifiable from the radioactivity distribution pattern [20, 21, 22]. This result shows that exposure to background ionizing radiation levels in all the studied communities contributes insignificantly to the radiation dose to these organs in adults.

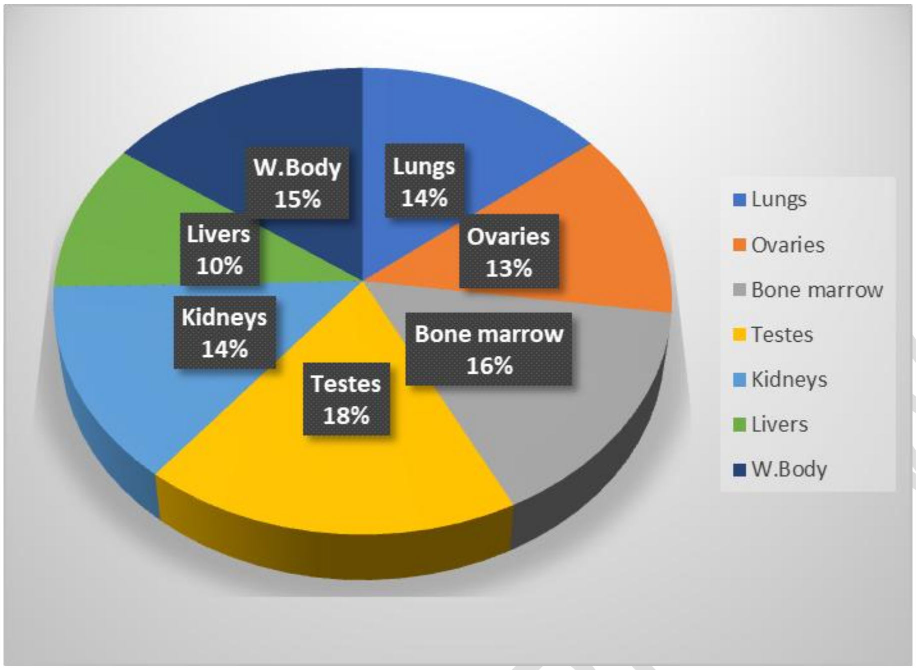

Figure 6: Effective Dose Rate to different organs / tissues of individuals around Anotech Communities

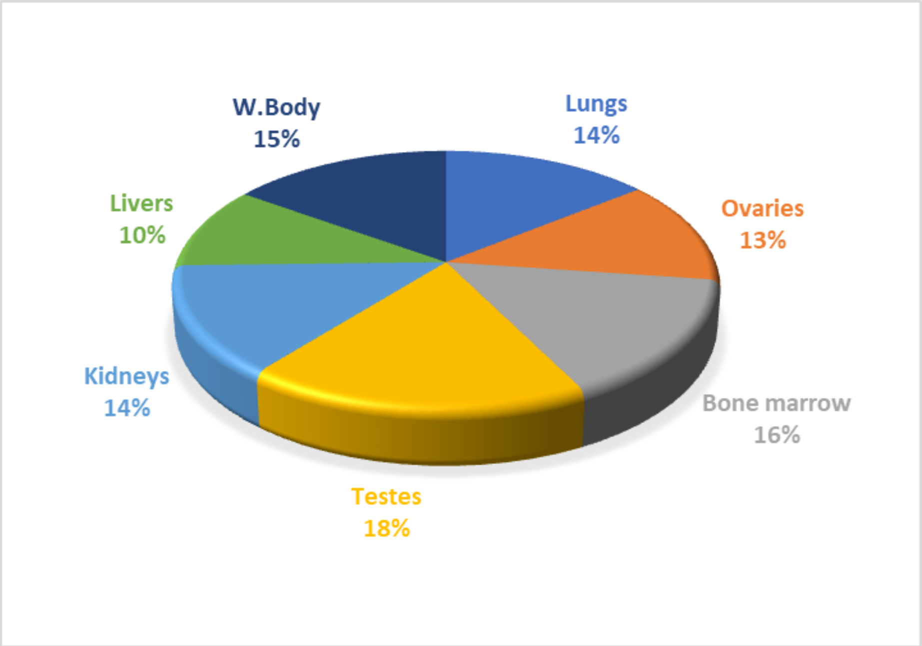

Figure 7: Effective Dose Rate to different organs / tissues of individuals around Abiteye Communities

Conclusion

Risk assessment of outdoor gamma radiation in some coastal communities of Delta State, Nigeria has been carried out. The radiation level investigated in this study are within the world average values reported by ICRP and UNSCEAR, though with little variations in some communities. Generally, the study shows that the communities around the two jetties are relatively safe radiologically, with little contamination which could be attributed to the geological formation and partly due to human activity in the area. However, the contamination will not pose any immediate radiological health effect on resident of the area but there is tendency for a long-term health hazard such as cancer due to doses accumulated over a long period of time. The results from this study also provides a baseline information for research purposes on the activities within the study areas as they relate exposure of the population to ionizing radiation.

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