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Radiological Health Risks due to Exposure to Gamma Radiation in Okoroma/Tereke, south Bayelsa State

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Abstract

The radiological health risks due to exposure to gamma radiation in some selected communities in Okoroma/Tereke in the southern part of Bayelsa State, Nigeria was estimated from the radiation exposure rate measured using radiation models. The radiation exposure rate measurements was carried out using well calibrated digilert-200 and Geological Positioning System (Garmin GPS MAP 76S) with a view of evaluating radiological health hazard fallout of oil and gas activities in these areas. The results of measured Background Ionizing Radiation (BIR) levels exposure rate and the calculated health hazards in the entire study area are presented in this text. The mean annual effective dose equivalent (AEDE) calculated for the study area was 0.33 $mSvy^{-1}$ and 0.32 $mSvy^{-1}$, while the mean excess lifetime cancer risk (ELCR) was $0.83 x 10^{-3}$and $0.81 x 10^{-3}$ respectively. The calculated ELCR values indicates that there is chances of developing cancer by residents and oil and gas workers in the study area is high. The dose received by organs was highest in the testes with a value of 0.22$mSvy^{-1}$, while the liver had the lowest dose value of 0.12 $mSvy^{-1}$. The effective dose for adult organs investigated can cause any health related problem or can damage the organs from the present exposure rate. The computed mean equivalent dose rate values across the entire study areas was 2.037 $mSvy^{-1}$ and 2.088 $mSvy^{-1}$. The results of this work was compared with both control and recommended safe values.

Keywords: Okoroma/Tereke (O/T) Obama, Radiation, Digilert-200, ELCR, Effective dose rate, AEDE, oil and gas fields and Communities

1. Introduction

Naturally Occurring Radioactive Material (NORM) are by nature form part of the earth environmental system. They result in significant fractions of the background radiation in which all humans are exposed. Radioactive material is produced as a waste product from the oil and gas industry and generally referred to as 'technologically enhanced naturally occurring radioactive materials' (TENORM**)** [1, 33]

Okoroma/Tereke communities and its environment are constantly surrounded by radioactive emissions as a result of oil and gas exploration activities over the years which have degraded the environment. During drilling operations in the region, radionuclides of the ^{238}U decay series (notably ^{226}Ra, ^{210}Pb and ^{210}Po) that are present in processed waters can be precipitated as scales and sludge in pipeline work, pumps, valves and drilling equipment. All these radionuclides emit ionizing radiation which is harmful to human health and environment. These Radionuclide's, along with other minerals that are dissolved in the brine, precipitate (separate and settle) out forming various wastes at the surface [1, 33]. Exploration has also resulted in various environmental problems such as oil spills, radioactive waste which have had a major impact on Okoroma/Tereke communities and the ecosystem of the oil-producing areas [2]

Radiation cannot be avoided completely because is present everywhere on the earth and in atmosphere. Studies on health effects have shown that the exposure of humans to background ionizing radiation (BIR) may cause challenging detrimental health effects to individuals, environment and members of the public. Studies carried out by researchers have shown that causes of cancer and mental disorder in offspring is as a result of exposure to ionizing radiation during pregnancy. A strong correlation between radiation exposure and health hazards among the populace and industrial workers in a given environment was reported by Agbalagba [3]. The practices of radiation protection have been developed to ensure that human exposure to radiation is guided by the principle of ALARA (As Low as Reasonably Achievable) [4]

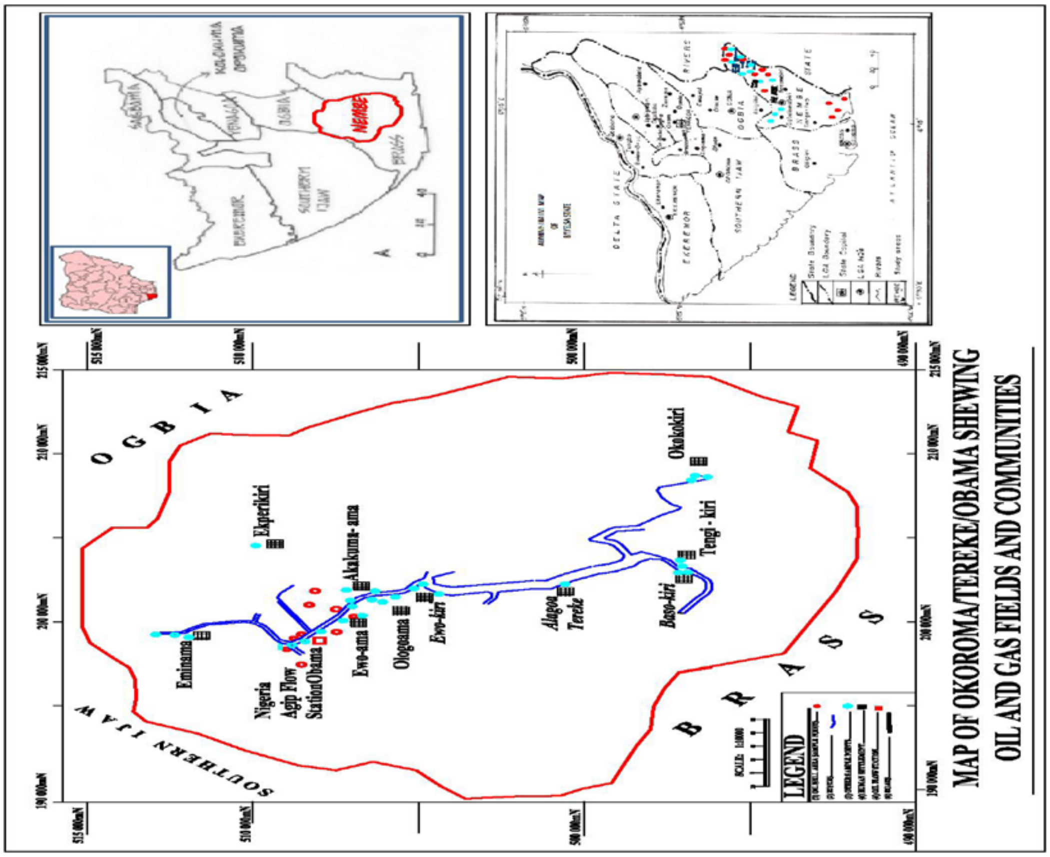
Several studies have been carryout by many researchers on background ionizing radiation (BIR) levels assessment in most part of world which shows low and high BIR levels. According to

Agbalagba [5] who carryout GIS mapping of impact of industrial activities on the terrestrial background ionizing radiation levels of Ughelli metropolis and its Environs and he reported a high radiation levels which was attributed to the industrial nature of the area. Avwiri studied terrestrial radiation around oil and gas facilities in Ughelli region of Nigeria and he reported that average exposure value ranging from 12.00 ± 0.1 μRh^{-1} (5.33 ± 0.35 μSv/wk) to 22.00 ± 2.1μRh^{-1} (9.79 ± 0.16 μSv/wk) in the oil field and 09.00 ± 1.0 to 11.00 ± 0.5 μRh^{-1} in the host communities, which is an indication of elevation above the normal background radiation level [6]. Akpabio studied the terrestrial radiation levels in Ikot-Ekpene, south Nigeria, and reported that the radioactivity levels in the area are generally low [7]. Termizi-Ramli studied effective dose from natural background radiation in Keffi and Akwanga towns, central Nigeria and reported low radiation levels that are within recommended safe limits for the areas [4]. In Pakistan, Rafique evaluated the excess life time cancer risk (ELCR) from measured ionizing radiation levels in a living environment and reported a mean ELCR indoor value of 1.629×10^{-3} and outdoor value of 1.629×10^{-3} , with the indoor value found to be greater than the world average value of 780 $\mu Gy.y^{-1}$[8] . Agbalagba studied assessment of excess lifetime cancer risk from gamma radiation levels in Effurun, Warri city of Delta State and documented mean BIR exposure value of 0.022±0.006 mRh^{-1} which was higher than world average value of 0.013mRh^{-1}[3]. In Chihuahua City, Mexico, Luevano-Gurrola observed high outdoor gamma dose rates ranging from 113 to 310 $nGyh^{-1}$[9]. Exposure to high levels of gamma radiation are detrimental to human health and causes a number of harmful effects in human such as cancer of various types and mutation. When gamma radiation passes through human biological cells and tissues, it will cause both excitation and ionization thereby altering the structure of the cells and tissues (10, 20]. This research work shall aimed to evaluate radiological health indices such as equivalent dose rate, Annual effective dose equivalent (AEDE), Excess lifetime cancer risk (ELCR) and Annual gonadal equivalent dose (AGED).

2. Materials and methods

2.1 Study area

The study areas covers some selected Okoroma/Tereke (O/T) oil and gas communities in the south of Bayelsa State, Nigeria. The geographical location of the area is highly blessed with oil and gas activities and has been considered as regional development centers in the State. They are predominately dominated by both Ogbia and Nembe speaking people and has its headquarters at Ologoama which lies between latitudes 4 degree 37 minutes 26 seconds N and 6 degree 16 minutes 62 seconds E. Exploitation and exploration of oil and gas activities in this region has been quite heavy for the past decades and have affected the livelihood of the people. The impact of oil and gas activities have dire consequences on the environment and cause severe health challenges. Nigerian Agip Oil Company (NAOC/ENI) is the major oil company operating in this area for the past forty (40) years. The environmental formations comprises of islands and muddy dry land which interspersed with thick forestry in the southern part of the region. The study area



covers the following communities which includes Akakuama, Ewoama, Tereke, Basokiri, Tengikiri, Ewokriri, Eminama Ekperikiri, Ologoama, and Alagoa-Tereke, communities etc [11]. Fig. 1 shows some selected Okoroama/Tereke communities and Agip Obama dominated Oil and Gas fields.

Fig. 1 shows some selected Okoroama/Tereke communities and Agip Obama dominated Oil and Gas fields.

2.2 Materials

A functional Monitoring Instrument (Survey Meter) (Digilert-200 and Inspector 1000 Nuclear Radiation Monitors) were used for this work as well as Geographical Positioning System (GPS).

The Digilert-200 and Inspector 1000 are health and safety instrument which contains a Geiger Muller tube that can detect Alpha, Beta, Gamma and X-rays. GPS was used to determine the sample point in latitude and longitude across the study area and it was also used for mapping of the area [12, 13].

The institute of Radiation Protection and Research, Ibadan use Cs-137 source of specific energy to calibrate the two survey meters which were set to measured exposure in micro Sievert per hour ($\mu Svhr^{-1}$) and milli Roentgen per hour ($mRhr^{-1}$). The time of measurement was between the hours of 1300 and 1600 hours interval. This is because the monitoring instrument has maximum environmental response to radiation within the aforementioned hours stated above. The counts detected by the instrument varies as a result of natural fluctuation of radioactivity [12, 13].The measured results were used to calculate radiological health indices such as Annual effective dose equivalent (AEDE), Excess Lifetime Cancer Risk (ELCR), Equivalent Dose Rate, effective dose rate to different organs and tissues and Annual Gonadal Equivalent Dose (AGED).

3. Radiological Health Indices

3.1 **Equivalent Dose Rate**

Equivalent dose accounts for biological effects per unit dose, therefore, to determine the equivalent dose rate over one year period, we used the recommendation made by National Council on Radiation Protection (NCRP) as stated in the equation 1 [14,21,31].

$$1mRh^{-1} = \frac{0.96x24x365}{100} mSvy^{-1} \tag{1}$$

3.2 **Annual Effective Dose Equivalent (AEDE)**

The annual effective dose equivalent is used for assessment of outdoor radiation protection to quantify whole-body absorbed dose per year by applying dose conversion factor of 0.7 Sv/Gy. AEDE is usually used to assess potential for long-term effects which might occur during dose absorption in the future. The AEDE can be determine by using equation 2

$$\text{AEDE (outdoor) } (mSvy^{-1}) = \text{Absorbed dose (D) } (nGyh^{-1}) \text{ x } 8760 \text{ x } \frac{0.7Sv}{Gy}\ x\ 0.25 \tag{2}$$

Where D is the absorbed dose rate in nGyh-1, 8760 is the total hours in a year with occupancy factor of 0.2 for outdoor exposure. [3, 15].

3.3 **Excess Lifetime Cancer Risk (ELCR)**

The Excess Lifetime Cancer Risk (ELCR) can be defined as the probability of developing cancer due to exposure to carcinogens. This is calculated using equation 3.

$$\text{ELCR = AEDE X Average duration of life (DL) X Risk factor (RF)} \tag{3}$$

Where AEDE, DL and RF are the annual effective dose equivalent, duration of life (70 years) and the risk factor (Sv^{-1}) respectively. For low dose background radiations which are considered to produce stochastic effects, ICRP 60 uses 0.05 for the public [3, 21].

3.4 **Effective dose rate D_{organ} in $mSvy^{-1}$ to different organs and tissues**

The effect dose rate for different organs and tissues are calculated using equation 4 [16, 27].

$$D_{organ}\ (mSvy\text{-}1) = O \times AEDE \times F \tag{4}$$

Where AEDE is the annual effective, O is the Occupancy factor 0.8 and F is the conversion factor for organ dose from ingestion. Conversion factor (F) values for lungs, ovaries, bone marrow, testes, kidney, liver and whole body are 0.64, 0.58, 0.69, 0.82, 0.62, 0.46 and 0.68 respectively as obtained from ICRP [17,20].

3.5 **Annual Gonadal Equivalent Dose (AGED)**

The Annual Gonadal Equivalent Dose can be defined as the measure of activity concentration in reproductive organs such as testes or ovary due to intake of particular type of radiation. The most sensitive parts of the human body to radiation exposure are bone marrow, gonads and the bone surface cells and are usually considered as organs of interest [18, 19]. It has been known that an increased in AGED causes destruction of red blood cells which can be replaced by white blood cells and also affect the bone marrow. This resulting problem can lead to blood cancer known as leukemia and is very fatal. The annual gonadal equivalent dose (AGED) for members of the public can be calculated using equation 5 [19, 20].

$$AGED = \frac{AEDE}{Radiation\ \ weighting\ \ factor\ \ (We) x\ Tissues\ \ Weighting\ \ factor\ \ (Wt)} \tag{5}$$

4. **Results**

The estimated results of the radiation exposure rates of Okoroma/Tereke (O/T) Obama Oil and Gas fields and the host communities, southern Bayelsa as well as the assessment of radiological health risks parameters due to exposure to gamma radiation are presented in Tables 1-2, Figures 2-6 shows Comparison of average Equivalent Dose of Okoroma/Tereke (O/T) Obama Oil and Gas Fields and host Communities with ICRP, 2003 standard, Comparison of Average ELCR of Host Communities and Oil and Gas Fields Areas with world average and Organ Dose Distributions in Okoroma /Tereke Obama Oil and Gas workers/Communities.

Table 1. The Measured Radiological Health Risks Parameters of Selected Okoroama / Tereke (O/T) Obama Oil and Gas Communities

S/n	Okoroama/ Tereke Communities	Geographical Positions	Average Exposure (mRh^{-1})	AEDE ($mSvy^{-1}$)	ELCR ($X10^{-3}$)	Equivalent dose rate ($mSvy^{-1}$)	AGED $mSvy^{-1}$
1	Alagoa-tereke	04°35504N 06°16905E	0.018±0.002	0.240	0.600	1.514	0.048
2	Ologoama	04°37267N 06°16620E	0.029±0.001	0.387	0.967	2.439	0.077
3	Farm-Ologoama	04°37094N 06°16537E	0.026±0.002	0.347	0.867	2.186	0.069
4	Eminama	04°38459N 06°16872E	0.019±0.001	0.253	0.634	1.598	0.051
5	Ewokiri	04°36472N 06°16541E	0.022±0.003	0.293	0.734	1.850	0.059
6	Basokiri	04°34283N 06°17683E	0.023±0.003	0.307	0.767	1.934	0.061
7	Akakumama	04°37276N 06°16362E	0.029±0.002	0.387	0.967	2.439	0.077
8	Ewoama	04°37267N 06°16304E	0.027±0.001	0.360	0.900	2.271	0.072
9	Tengi-tereke	04°34262N 06°17137E	0.025±0.002	0.333	0.834	2.102	0.067
	mean		**0.024±0.002**	**0.323**	**0.808**	**2.037**	**0.065**

Table 2. The Measured Radiological Health Risks Parameters of Selected Sites of Okoroma/Tereke Obama Oil and Gas Fields

S/n	Okoroama/ Tereke Communities	Geographical Positions	Average Exposure (mRh^{-1})	AEDE ($mSvy^{-1}$)	ELCR ($X10^{-3}$)	Equivalent dose rate ($mSvy^{-1}$)	AGED $mSvy^{-1}$
1	NASO1	04°37522N 06°15522E	0.028±0.002	0.373	0.933	2.355	0.075
2	OW1	04°37347N 06°26600E	0.025±0.004	0.333	0.834	2.102	0.067
3	OW2	04°37314N 06°16040E	0.027±0.003	0.360	0.900	2.271	0.072
4	OW3	04°37336N 06°16359E	0.026±0.003	0.347	0.867	2.187	0.069
5	OW4	04°37258N 06°16196E	0.028±0.001	0.373	0.934	2.355	0.075

6	OW5	04°37504N 06°16317E	0.025±0.002	0.333	0.834	2.102	0.067
7	OW6	04°37471N 06°16468E	0.027±0.003	0.360	0.900	2.271	0.072
8	OW7	04°37547N 06°15580E	0.018±0.001	0.240	0.600	1.513	0.048
9	OW8	04°37581N 06°15550E	0.022±0.003	0.293	0.734	1.850	0.059
10	OW9	04°38249N 06°15438E	0.025±0.003	0.333	0.834	2.102	0.067
11	OW10	04°37543N 06°15274E	0.021±0.002	0.280	0.700	1.766	0.056
12	NV028	04°37170N 06°16577E	0.026±0.002	0.346	0.867	2.187	0.069
	Mean		**0.024±0.002**	**0.331**	**0.828**	**2.088**	**0.066**

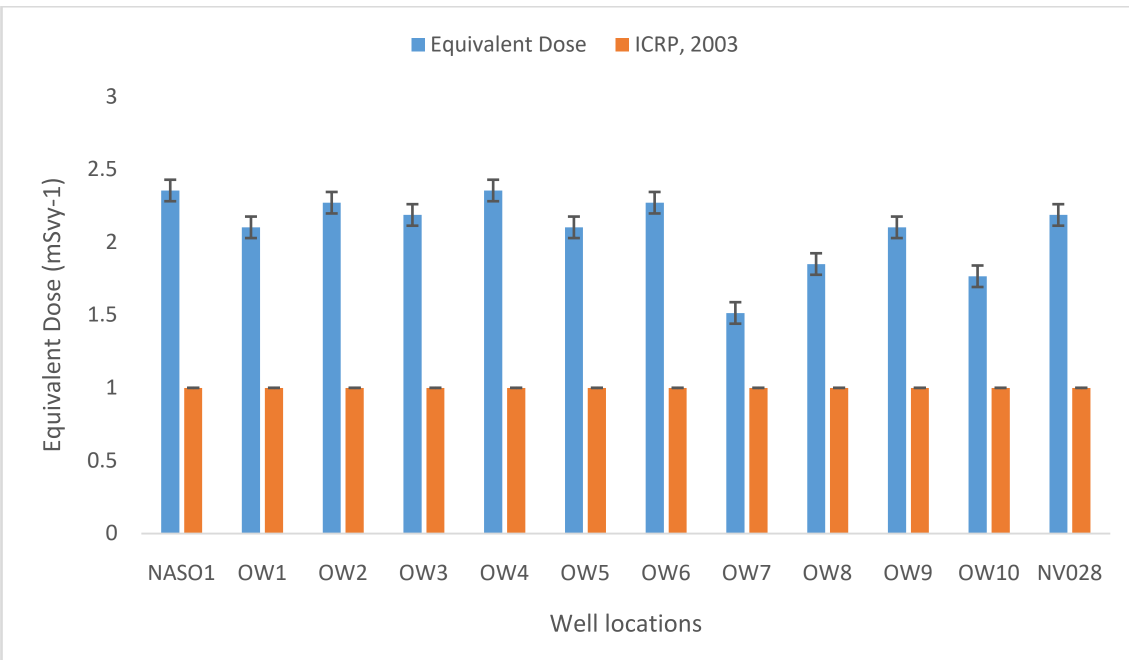


Fig 2. Comparison of average Equivalent Dose of Okoroma/tereke Obama Oil and Gas Fields with ICRP, 2003 standard

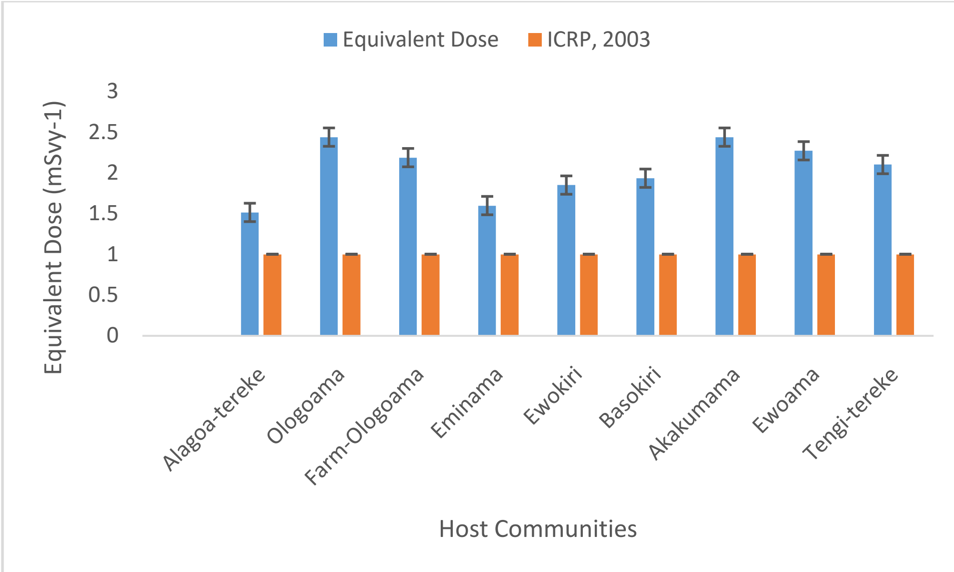


Fig 3. Comparison of average Equivalent Dose of Okoroma/tereke host Communities with ICRP, 2003 Standard

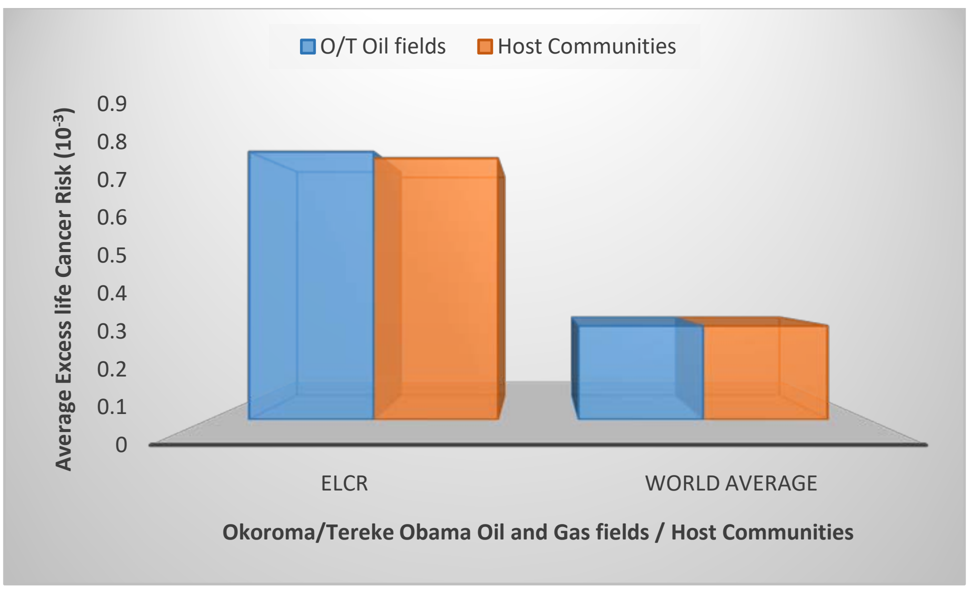


Fig 4. Comparison of Average ELCR of Host Communities and Oil and Gas Fields Areas with world average.

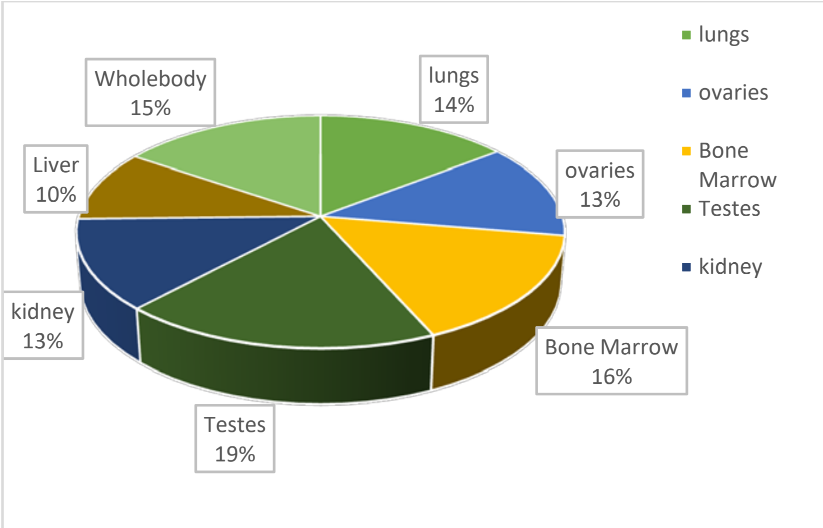


Fig 5. Organ Dose Distributions in Okoroma /Tereke Obama Oil and Gas Communities

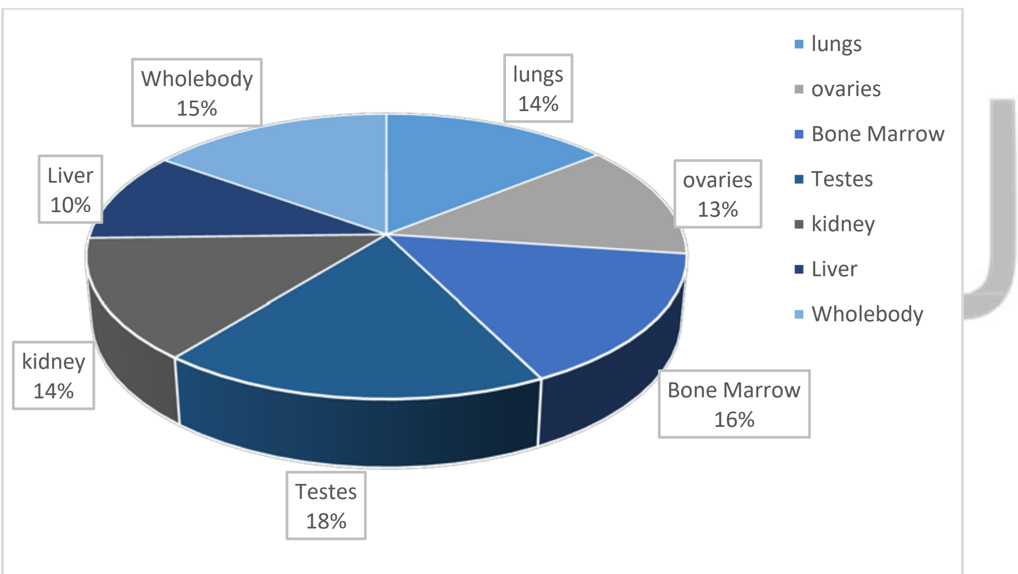


Fig 6. Organ Dose Distributions in Okoroma/Tereke Obama Oil and Gas Workers

4.2 Discussions

The computed equivalent dose rate across the entire study areas of Oil and Gas fields and host Communities ranges from 1.514 $mSvy^{-1}$ to 2.439 $mSvy^{-1}$with a mean value of 2.037 $mSvy^{-1}$ and 1.514 $mSvy^{-1}$ to 2.355 $mSvy^{-1}$ with a mean value of 2.088 $mSvy^{-1}$ respectively. Results showed that average value of Equivalent dose is higher than the recommended permissible limit of 1.0 $mSvy^{-1}$ for the general public and also were quite above the recommended occupational permissible limit of 1.5 $mSvy^{-1}$ by [21, 22]. These results agree quite well with previous findings of an Oil and Gas environment and may be attributed to release of radioactive waste and oil spillage during exploitation, exploration and drilling operations over time.

The estimated values of Excess Life Cancer Risk (ELCR) for the study areas of Oil and Gas fields and the host Communities ranges from 0.60×10^{-3} to 0.93×10^{-3} with a mean value of 0.83×10^{-3} and 0.60×10^{-3} to 0.97×10^{-3} with a mean value of 0.81×10^{-3} respectively (Table 1-2). The ELCR values obtained in this study were higher compared to the mean value of 0.6 ± 0.2 μSvy^{-1} reported by Agbalagba [13] at active coal mines sites and environs, Enugu state. The values obtained in the study area were still higher compared to the values reported by Rafique [23] in Muzaffarabad, by clouvas [24] in Greece, by Al Mugren [25] in Al- Rakkah, Saudi Arabia and by [8] in Poonch, Turkey. However, average value of ELCR obtained in the current study area is higher than the world average standard of 0.29×10^{-3} [26] as shown in Fig 4. In this regards, individual exposed to this radiation may likely contact cancer due to ionization of tissues and Organs. These adverse health effects is due to contamination of the drilling waste and Oil spillage which have occurred over time and spread through different path ways to the environment as a result of Oil and Gas production operations / activities [3,15].

The mean values of Annual Effective Dose Equivalent (AEDE) of Okoroma/Tereke (O/T) Obama Oil and Gas fields and Host Communities ranges from 0.24 $mSvy^{-1}$ to 0.37 $mSvy^{-1}$ with a mean value of 0.33 $mSvy^{-1}$ and 0.24 $mSvy^{-1}$ to 0.38 $mSvy^{-1}$ with a mean value of 0.32 $mSvy^{-1}$ respectively. The values obtained in this study are higher than previously reported values of 0.19, 0.15 and 0.20 $mSvy^{-1}$ by Agbalagba [3]. Also, these values were still higher compared to the values 0.135$mSvy^{-1}$ and 0.363$mSvy^{-1}$ reported by Eshiemomoh at Solid mineral mining sites, Edo- North, Nigeria [27]. The values of the current study area is higher compared to the values obtained at Bayelsa state oil spill areas reported by Ovuomarie-kevin [21]. However, AEDE of the study areas of Okoroma/Tereke Obama Oil and Gas fields and Host Communities are lower compared to the global world average of 1.0$mSvy^{-1}$ for outdoor environment. The reference levels used by ICRP, 2003 is between 1$mSvy^{-1}$ and 20 $mSvy^{-1}$ in the area of radiation protection. The values obtained in this study area compared to the reference levels of ICRP may not cause biological health effect, acute effect of radiation to the workers and members of the public, although due to long term exposure might likely have adverse health challenges [18, 20].

The estimated results of the Annual Gonadal Dose Equivalent (AGDE) due to gamma radiation are presented in Table 1 and 2. The values obtained ranged from 0.048 to 0.077 mSv/yr with a mean value of 0.0 mSv/yr 65 for host communities and 0.048 to 0.075 mSv/yr with a mean value of 0.066 mSv/yr for Okoroma/Tereke Obama oil and gas fields. The AGDE values for all the samples collected are below the world average value of 0.3 mSv/yr [10]. These results are also within the range of AGDE, between 0.0013 and 4.46 mSv/yr (estimated from activity concentration) reported for naturally occurring radionuclides from produced waters in the oil and gas industry [35]. Despite the fact that the measured values of AGDE were lower than the world average, the inhabitants may still likely have adverse health impacts due to continuous usage of water consumption from their surroundings rivers as a result of the drilling operations and other economic activities.

The effective dose rates delivery to different Organs of the body were calculated with numerical values of $mSvy^{-1}$ and dose distributions are presented in Fig 5-6. The amount of radiation intake to individual who works in the Oil and Gas fields and those that live with this facilities (host communities) may have accumulated doses in their various body organs and tissues. The model of annual effective dose to organs were used to examine radiation intake of seven tissues and organs [3]. The result shows that testes received the highest doses with average value of $0.22mSvy^{-1}$ which make up about 18/19% in the entire study areas of Oil and Gas fields and host Communities while the lowest dose found to be liver with an average value of 0.12 $mSvy^{-1}$ which makes up 10% in the study areas.

Previous studies at Bunker and Okpara mining sites environment in Enugu state were reported by Agbalagba [5] which shows that the testes received the highest dose with average values of 0.11 $mSvy^{-1}$ while the liver received the lowest average values of 0.06 $mSvy^{-1}$. Also, the mean values of doses obtained in the current study is higher than the values reported at Bayelsa oil spill sites areas by Ovuomarie-kevin [21]. However, these results stated that the estimated doses to the different organs were compared to that of international tolerable limit dose intake to the body organ of 1.0mSv annually and it shows that the values obtained were lower. What causes the high doses to testes and low doses to liver may be as a result of the different absorption rate and conversion factors [13].

5. Conclusion

The assessment of radiological health risk parameters due to exposure to gamma radiation were calculated across the entire study areas of Okoroma/Tereke (O/T) Obama Oil and Gas fields and the host communities, South Bayelsa State. The following conclusions were reported from the study:

1) The computed equivalent dose rate across the entire study areas of Oil and Gas fields and host Communities is higher than the recommended permissible limit of 1.0 $mSvy^{-1}$ for the general public.
2) The calculated values of Excess Life Cancer Risk (ELCR) for the study areas of Oil and Gas Fields and the host Communities are higher than the world average standard of $0.29x10^{-3}$ for exposure. The residents living in this areas might likely incurred developing cancer over time.
3) The Annual Effective Dose Equivalent (AEDE) for the study area were estimated and it shows that Oil and Gas fields and Host Communities are lower than the global world average of $1.0mSvy^{-1}$ for outdoor environment.
4) The estimated results of the Annual Gonadal Dose Equivalent (AGDE) due to gamma radiation for the entire study area were lower than the world average standard value of 0.3 mSv/yr.
5) The effective dose rates delivery to different Organs of the body were calculated and results of the study areas were compared with that of international tolerable limits of dose to body organs of $1mSvy^{-1}$ and it shows that the value obtained was lower.

Competing Interest

Authors have declared that no competing interest exist

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