

ASSESSMENT OF RADIOLOGICAL HEALTH RISKS FROM GAMMA RADIATION LEVELS IN SELECTED OIL SPILL COMMUNITIES OF BAYELSA STATE, NIGERIA

Abstract

Measurement of terrestrial background ionizing radiation of oil spilled communities of Bayelsa State, Nigeria was carried out using well calibrated radalert-100 and 200 meters and a Global Positioning System (Garmin 765). The average exposure rate of four the four communities 0.009 ± 0.001 , 0.010 ± 0.002 , 0.009 ± 0.002 and 0.010 ± 0.002 mR h^{-1} respectively. The mean of absorbed dose rates estimated in Otuasega, Ibelebiri, Imiringi and Otuegwe are 82.17, 86.13, 73.95 and 83.52 nGy/hr respectively. Estimated values of the annual effective dose equivalent (AEDE) for outdoor exposures 0.13 mSv/yr was obtained in Otuasega, and Ibelebiri while at Imiringi AEDE was 0.15 mSv^{-1} and 0.11 mSv/yr was obtained in Otuegwe II respectively. The mean excess lifetime cancer risk calculated for the oil spill values are (0.44, 0.46, 0.40 and 0.45) $\times 10^{-3}$ respectively. The obtained values for background ionizing radiation in Ibelebiri and Imiringi oil spill sites was below the recommended standard limits by ICRP while the absorbed dose (D) and AEDE calculated in the entire oil spill sites are within safe values but the excess lifetime cancer risk (ELCR) estimated were higher than their world permissible values of 0.29×10^{-3} respectively. The calculated dose to organs showed that the testes have the highest organ dose of 0.085 mSv^{-1} while the liver has the lowest organ dose of 0.048 mSv^{-1} . The contour map of figure 5 showed low level of BIR sparsely distributed and also the result showed that the oil spilled had little or no impact on the background radiation of the area.

Keywords: *Oil spill, Radalert - (100 and 200), background ionizing radiation, absorbed dose rate, excess lifetime cancer risk and effective dose.*

1. Introduction

Ionizing radiation can neither be seen nor felt. It is therefore a challenge just to know whether it is present or not [1]. There are radioactive isotopes in our bodies, houses, air, water, in the ground and we are also exposed to radiation from outer space. The United Nations Committee in the effect of Atomic Radiation [2] has shown the distribution of radiation sources around the world and doses to the public. Humans are exposed to natural radiation from the cradle to grave and the accumulated lifetime dose depends upon where they live as well as their life style [1]. Radiobiological experiments with cells and cell mechanisms has shown that small amount of radiation with a low dose rate stimulates our defense mechanisms. Human activities especially industrial activities which includes gas flaring in the oil gathering centres, crude oil spills in the oil and gas installations, spills of imported toxic chemicals and radionuclide materials for geological mapping, x-ray welding and well logging and other industrial activities tend to increase the background ionizing radiation levels of the community or city [3].

Exposure to background radiation, which is present everywhere on the earth and in the atmosphere may also add to radiation exposure levels that may cause detrimental health effects to residents. Researches has shown that exposure to ionizing radiation can cause cancer and mental retardation in children whom their mothers were exposed to radiation during pregnancy. The long term exposure to background radiation and high doses of radionuclide like thorium through inhalation and ingestion from dust sediments has severe health effects such as chronic lung diseases and bone cancer [4]. Agbalagba [3] also reported a strong correlation between radiation exposure and health hazards among the populace and industrial workers in a given environment.

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Background ionization radiation can be considered to be a form of environmental contamination, especially when it exceeds safe occupational and public limits. External background ionizing radiation comes from three major sources: terrestrial radiation, cosmic radiation and anthropogenic radiation. In this study, we are concerned with the terrestrial gamma BIR levels in four oil spilled communities of Bayelsa State, which may be a combination of all three sources of BIR. A study of the terrestrial radiation levels around oil and gas facilities in the Ugheli region of Nigeria reported an average value range of 12.00 ± 0.1 to $22.00 \pm 2.1 \mu\text{Rh}^{-1}$ in the oil field and 9.00 ± 1.0 to $11.00 \pm 0.5 \mu\text{Rh}^{-1}$ in the surrounding communities [5]. They concluded that although the radiation values are within the levels established by international standards and are consistent with other reported values in the country, the BIR levels in the area exceeded normal background levels. Further study on the impact of gas exploitation on the environmental radioactivity of Ogba/Egbema/Ndoni area of Nigeria, also revealed a mean site radiation level range of 0.014 ± 0.001 to $0.018 \pm 0.001 \text{ mRh}^{-1}$ while the mean host community radiation levels range from 0.014 ± 0.001 to $0.017 \pm 0.001 \text{ mRh}^{-1}$. The result showed that 71.7 % of the sampling point exceeded the normal background radiation levels of 0.013 mRh^{-1} [6].

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Kolo-creek in Ogbia local Government Area of Bayelsa State is one of the ancient settlements where oil exploration activities are highest. Due to oil exploration activities in the area, there are influx of people in the area and rapid development of the area. The growing number of residents and industrial activities and inadequate data on the BIR levels in the study area necessitated this research work. Additionally no known gamma radiation level measurements have been reported for the study area. Hence, the result of this work may serve as baseline data for background radiation levels in this area.

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76 2. Material and Methods

This study was conducted between November 2017 and May 2018, which represented the seasons transition (dry-to-wet) period. The area lies within longitude $6^{\circ} 22' \text{ E}$ and $6^{\circ} 26'$ and latitude $4^{\circ} 52' \text{ N}$ and $4^{\circ} 57' \text{ N}$. The oil spilled communities (study area) are Otuegwe, Imiringi, Otuasega and Ibelebiri. Measurements were made in strategic oil spilled areas mostly fishing ponds and residential areas. An in-situ approach of background ionizing radiation

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measurement was adopted to enable samples maintain their original environmental characteristics.

A well calibrated Rad-monitor, Digilert-200 and Radalert -100 nuclear radiation monitoring meter (S.E. International Incorporation, Summer Town, USA), containing a Geiger-Muller tube capable of detecting alpha, beta, gamma and X-rays was used within the temperature range of -10°C to 50°C and a geographical positioning system (GPS) was used to measure the precise location of sampling. The Geiger-muller tube generates a pulse current each time radiation passes through the tube and causes ionization [7]. Each pulse is electronically detected and registered as a count. The radiation meters were calibrated with a ^{137}Cs source of specific energy and set to measure exposures rate in milli Roentgen per hour (mRhr^{-1}). The meter has an accuracy of $\pm 15\%$. The tube of the radiation monitoring meter was raised to a standard height of 1.0 m above the ground[8,9], with its window facing the suspected source while the GPS reading was taken at that spot. Measurements were taken within the hours necessary since exposure rate meter has a peak response to environmental radiation within these hours, then the background radiation level was recorded. In order to ensure quality assurance the provisions taken include: Two measuring instruments was deplored to field and standardization of the measuring instruments before use was done, multiplicity of measurement for each sample point ($n = 4$ for radiation measurements for each sample point). The switch (knob) was turned to return the meter to zero after each measurement.

The generated data were converted to absorbed dose rate nGy h^{-1} using the relation for the external exposure rate by [10];

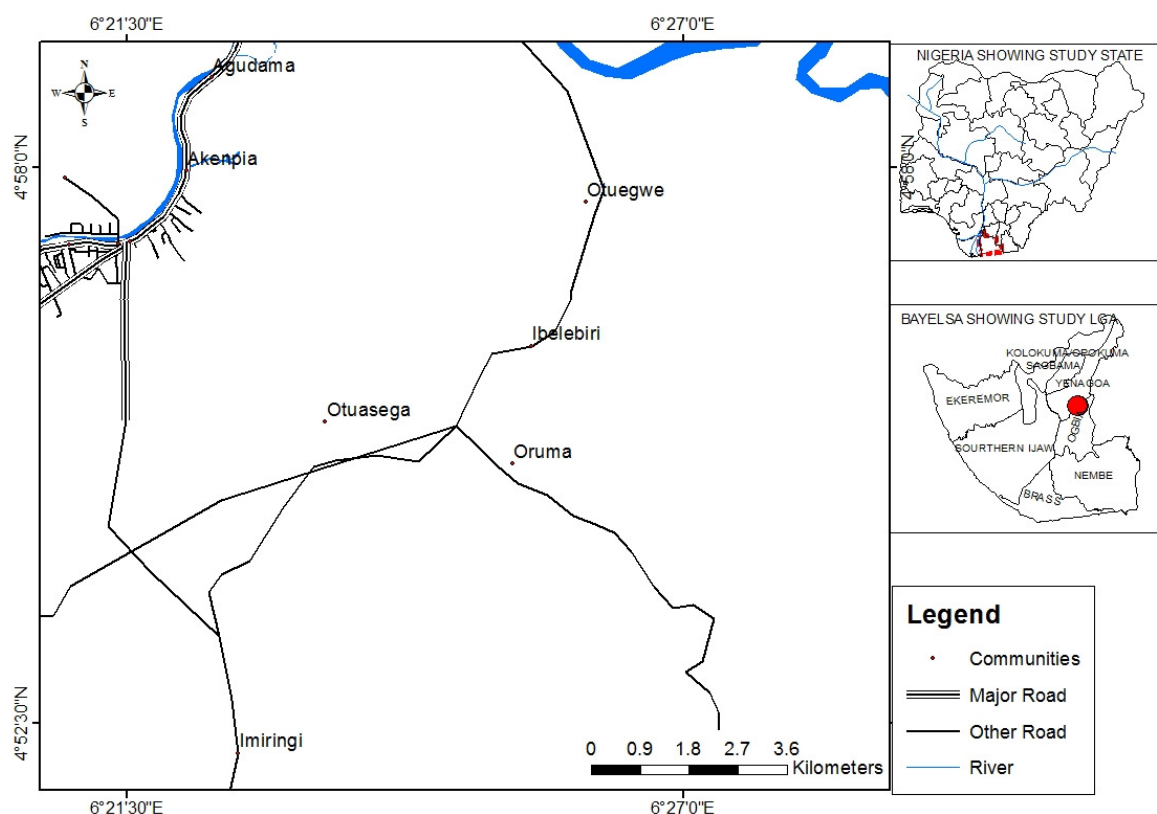
$$1\mu\text{R/h} = 8.7\text{ nGy/h} = 8.7 \times 10^{-3}\mu\text{Gy}/(1/8760\text{ y}) \quad 1$$

3.0 Results and Discussions

3.1 Results

3.1.1 Discussion of results

The results for the measured BIR exposure levels and the calculated radiological health risks for the four communities: Otuasega, Ibelebiri, OtuegweII and Imiringi oil spill sites are presented in Tables 1-4 and Figures 2 and 3 show the comparison of excess lifetime cancer risk with average world standard value for Otuasega, Ibelebiri, Otuegwe II and Imiringi oil spill sites respectively. Analyses using different known radiation health hazard indices are used in radiation studies to arrive at a more reliable assessment of the health risks to an irradiated person [11, 12]. To assess the radiation hazards associated with the gamma radiation levels in oil spill communities of Bayelsa state, the following radiation hazard indices were used: equivalent dose, absorbed dose rate, annual effective dose rate, excess lifetime cancer risk and effective dose to different organs.



Map. 1: Map showing the oil spill areas in Bayelsa State

3.1.1.1 Background ionizing radiation (BIR) exposure levels.

The terrestrial radiation level and radiation parameters of the four oil spill sites (Otuasega, Ibelebiri, Otuegwe II and Imiringi) of Bayelsa State and its surrounding area was determined with two well-calibrated radiation meters and the results are presented in Tables 1 to 4. The average sites radiation exposure levels ranges between $0.005 - 0.012 \text{ mRh}^{-1}$ (Otuasega), $0.007 - 0.012 \text{ mRh}^{-1}$ (Ibelebiri), $0.006 - 0.011 \text{ mRh}^{-1}$ (Otuegwe II) and $0.006 - 0.013 \text{ mRh}^{-1}$ (Imiringi). The mean values of radiation exposure rate was highest at Ibelebiri and Imiringi oil spill areas ($0.010 \pm 0.002 \text{ mRh}^{-1}$) while the least value was obtained at Otuasega and Otuegwe II oil spill areas ($0.009 \pm 0.001 \text{ mRh}^{-1}$). The value $0.010 \pm 0.002 \text{ mRh}^{-1}$ was recorded in Ibelebiri and Imiringi this shows 33% deviation from the value obtained in host community (0.005 mRh^{-1}) while Otuasega and Otuegwe II oil spill sites where least value was obtained, shows 36% deviation from the host community value respectively. The mean value obtained in Ibelebiri and Imiringi oil spill sites is slightly lower compared to the ICRP standard of 0.013 mRh^{-1} for normal background ionizing radiation. The mean values obtained in Otuasega and Otuegwe II oil spill sites were below compared to the ICRP standard of 0.013 mRh^{-1} for normal background ionizing radiation. Figure 2 shows the comparison of the measured values in the sample location with the normal background level. The least value obtained are at Otuasega and Otuegwe II oil spill sites with 18 % below the ICRP, BIR standard of 0.013 mRh^{-1} . The variation in the reading for different oil spill sites may be as a

result of inconsistency in the quantity of crude oil spilled. This consistency of the average values of the exposure rate obtained in all the sites could be credited to the crude oil spilled on the areas as well from the same geological formation bearing the crude. It might be from the same oil reservoir such that they are polluted equally from the underlying rock. The variation in the exposure rates between oil spilled sites and the control fields could be due to impact of the crude oil spillages associated with the activities on the facilities or ill-maintained or sabotaged pipelines which have caused the elevation of the BIR levels of these areas. The average exposure rate of the four oil spill sites in Bayelsa State were found to be lower than the range of values (0.018-0.020 mR/hr) obtained in oil spill from Omoda vandalised oil pipeline areas, Rivers state by Anekwe and others, [13] whose mean 0.019 ± 0.006 mR/hr. The overall results showed that in all the four study sites, the exposure rates are in agreement with the values reported by [14, 15, 16, 17]. Also these values reported are in agreement with some previously reported results in similar environment [18, 19, 20, 21], thus confirming the sources of these elevated values to the oil spills. High absorbed dose rates were obtained in all the mineral deposition fields these may be due to crude oil spillage which may be rich in radioactive bearing materials.

Table 1: The mean radiation exposure rate and estimated radiation risk parameters of Otuasega oil spill site

S/ N	Location	Geographical positions	Average Exposure rate (mRh ⁻¹)	Equivalen t Dose mSvy ⁻¹	Absorbe d dose rate nGyh ⁻¹	AED E mSvy ⁻¹	ELC R x 10 ⁻³
1	Otuasega1	N04°55'06.5" E006°23'53.9"	0.008±0.00 1	0.673	69.60	0.11	0.37
2	Otuasega2	N04°55'06.4" E006°23'53.7"	0.008±0.00 1	0.673	69.60	0.11	0.37
3	Otuasega3	N04°55'05.6" E006°23'54.0"	0.008±0.00 2	0.673	69.60	0.11	0.37
4	Otuasega4	N04°55'05.1" E006°23'53.6"	0.011±0.00 1	0.925	95.70	0.15	0.51
5	Otuasega5	N04°55'04.5" E006°23'54.7"	0.009±0.00 1	0.757	78.30	0.12	0.42
6	Otuasega6	N04°55'06.8" E006°23'53.5"	0.012±0.00 1	1.009	104.40	0.16	0.56
7	Otuasega7	N04°55'07.3" E006°23'53.4"	0.012±0.00 1	1.009	104.40	0.16	0.56
8	Otuasega8	N04°55'06.9" E006°23'54.8"	0.012±0.00 1	1.009	104.40	0.16	0.56
9	Otuasega9	N04°55'07.3" E006°23'54.9"	0.005±0.00 3	0.420	43.50	0.07	0.23
10	Otuasega10	N04°55'07.4" E006°23'54.10"	0.011	0.925	95.70	0.15	0.51
	Mean		0.009±0.00 1	0.807	82.17	0.13	0.44

Table 2: The mean radiation exposure rate and estimated radiation risk parameters of Ibelebiri oil spill site

S/N	Location	Geographical positions	Average Exposure rate (mRh ⁻¹)	Equivalent Dose mSvy ⁻¹	Absorbed dose rate nGyh ⁻¹	AEDE mSvy ⁻¹	ELCR x 10 ⁻³
1	Ibelebiri Oil spill ₁	N04°56'03.6" E006°25'09.9"	0.008±0.002	0.673	69.60	0.11	0.37
2	Ibelebiri Oil spill ₂	N04°56'02.4" E006°25'10.5"	0.009±0.001	0.757	78.30	0.12	0.42
3	Ibelebiri Oil spill ₃	N04°56'03.8" E006°25'11.2"	0.011±0.002	0.925	95.70	0.15	0.51
4	Ibelebiri Oil spill ₄	N04°56'03.7" E006°25'08.4"	0.011±0.001	0.925	95.70	0.15	0.51
5	Ibelebiri Oil spill ₅	N04°56'04.4" E006°25'08.3"	0.011±0.003	0.925	95.70	0.15	0.51
6	Ibelebiri Oil spill	N04°56'04.3" E006°25'09.9"	0.012±0.003	1.009	104.40	0.16	0.56
7	Ibelebiri Oil spill	N04°56'05.3" E006°25'09.2"	0.007±0.001	0.589	60.90	0.09	0.33
8	Ibelebiri Oil spill	N04°56'05.7" E006°25'08.9"	0.008±0.002	0.673	69.60	0.11	0.37
9	Ibelebiri Oil spill	N04°56'06.4" E006°25'07.7"	0.011±0.001	0.925	95.70	0.15	0.51
10	Ibelebiri Oil spill	N04°56'07.5" E006°25'06.6"	0.011±0.001	0.925	95.70	0.15	0.51
		Mean value	0.010±0.002	0.833	73.95	0.11	0.40

Table 3: The mean radiation exposure rate and estimated radiation risk parameters of Otuegwe II oil spill site

S/N	Location	Geographical positions	Average Exposure rate (mRh ⁻¹)	Equivalent Dose mSvy ⁻¹	Absorbed dose rate nGyh ⁻¹	AEDE mSvy ⁻¹	ELCR x 10 ⁻³
1	Otuegwe 1	N04°57'26.4" E006°26'09.9"	0.010±0.004	0.841	87.00	0.13	0.47
2	Otuegwe 2	N04°57'26.9" E006°26'10.0"	0.006±0.001	0.505	52.20	0.08	0.28
3	Otuegwe 3	N04°57'27.0" E006°26'10.9"	0.007±0.002	0.589	60.90	0.09	0.33
4	Otuegwe 4	N04°57'27.1" E006°26'11.1"	0.007±0.002	0.589	60.90	0.09	0.33
5	Otuegwe 5	N04°57'27.8" E006°26'11.3"	0.007±0.002	0.589	60.90	0.09	0.33
6	Otuegwe 6	N04°57'27.1" E006°26'10.2"	0.008±0.002	0.673	69.60	0.11	0.37
7	Otuegwe 7	N04°57'26.2" E006°26'09.5"	0.011±0.002	0.925	95.70	0.15	0.51

8	Otuegwe 8	N04 ⁰ 57'26.3" E006 ⁰ 26'09.2"	0.009±0.002	0.757	78.30	0.12	0.42
9	Otuegwe 9	N04 ⁰ 57'25.7" E006 ⁰ 26'09.4"	0.010±0.002	0.841	87.00	0.13	0.47
10	Otuegwe 10	N04 ⁰ 57'25.1" E006 ⁰ 26'08.9"	0.010±0.002	0.841	87.00	0.13	0.47
	Mean		0.009±0.002	0.7i5	73.95	0.13	0.40

Table 4: The mean radiation exposure rate and estimated radiation risk parameters of Imiringi oil spill site

S/N	Location	Geographical positions	Average Exposure rate (mRh ⁻¹)	Equivalent Dose mSvy ⁻¹	Absorbed dose rate nGyh ⁻¹	AEDE mSvy ⁻¹	ELCR x 10 ⁻³
1	Imiringi 1	N04 ⁰ 52'45.4" E006 ⁰ 22'32.4"	0.006±0.001	0.505	52.20	0.08	0.28
2	Imiringi 2	N04 ⁰ 52'45.4" E006 ⁰ 22'32.0"	0.009±0.002	0.757	78.30	0.12	0.42
3	Imiringi 3	N04 ⁰ 52'44.7" E006 ⁰ 22'31.9"	0.008±0.002	0.673	69.60	0.11	0.37
4	Imiringi 4	N04 ⁰ 52'44.6" E006 ⁰ 22'32.2"	0.011±0.003	0.925	95.70	0.15	0.51
5	Imiringi 5	N04 ⁰ 52'43.9" E006 ⁰ 22'32.0"	0.009±0.003	0.757	78.30	0.12	0.42
6	Imiringi 6	N04 ⁰ 52'42.5" E006 ⁰ 22'31.8"	0.009±0.001	0.757	78.30	0.12	0.42
7	Imiringi 7	N04 ⁰ 52'42.3" E006 ⁰ 22'30.9"	0.009±0.001	0.757	78.30	0.12	0.42
8	Imiringi 8	N04 ⁰ 52'43.8" E006 ⁰ 22'31.3"	0.011±0.002	0.925	95.70	0.15	0.51
9	Imiringi 9	N04 ⁰ 52'44.5" E006 ⁰ 22'32.4"	0.011±0.004	0.925	95.70	0.15	0.51
10	Imiringi 10	N04 ⁰ 52'46.0" E006 ⁰ 22'31.7"	0.013±0.001	1.093	113.10	0.17	0.61
	Mean		0.010±0.002	0.807	95.70	0.15	0.51

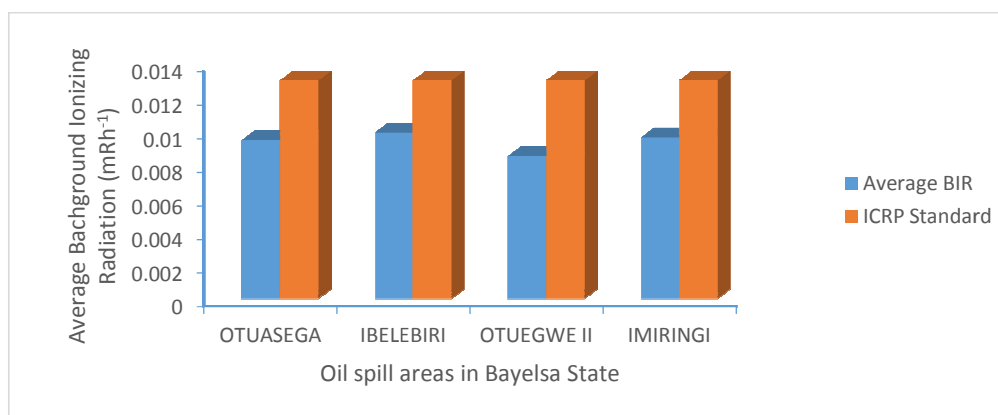


Fig. 1: Comparison of measured BIR levels with standard

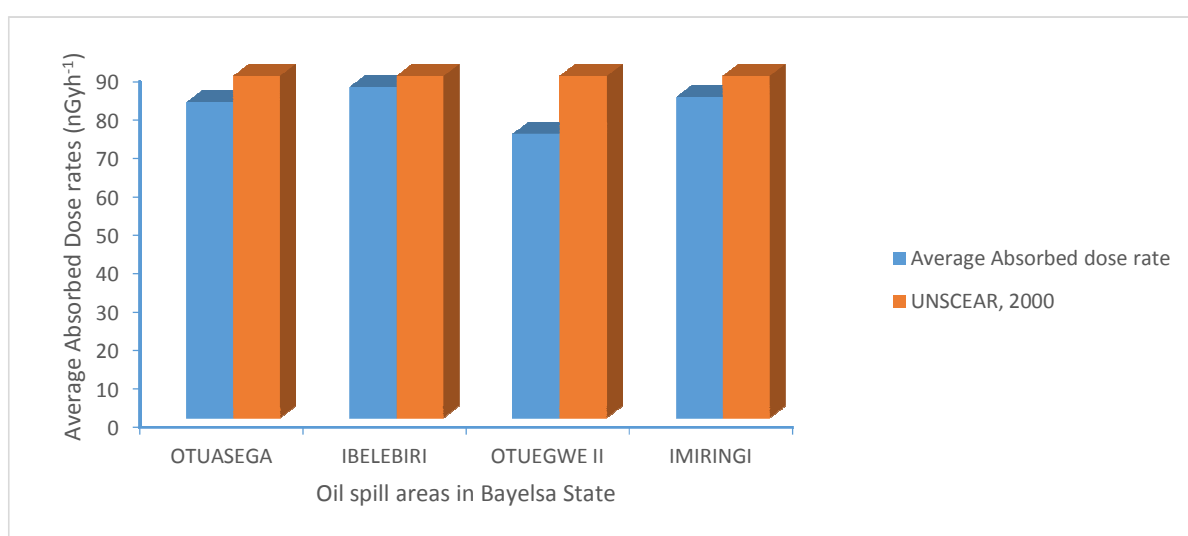


Fig. 2: Comparison of average absorbed dose rate of oil spill areas

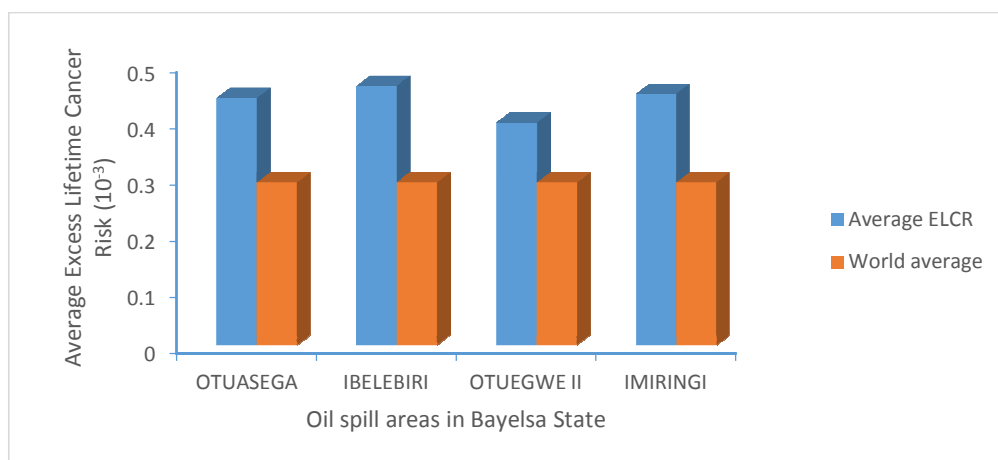


Fig. 3: Comparison of mean ELCR of oil spill with World safe limit value

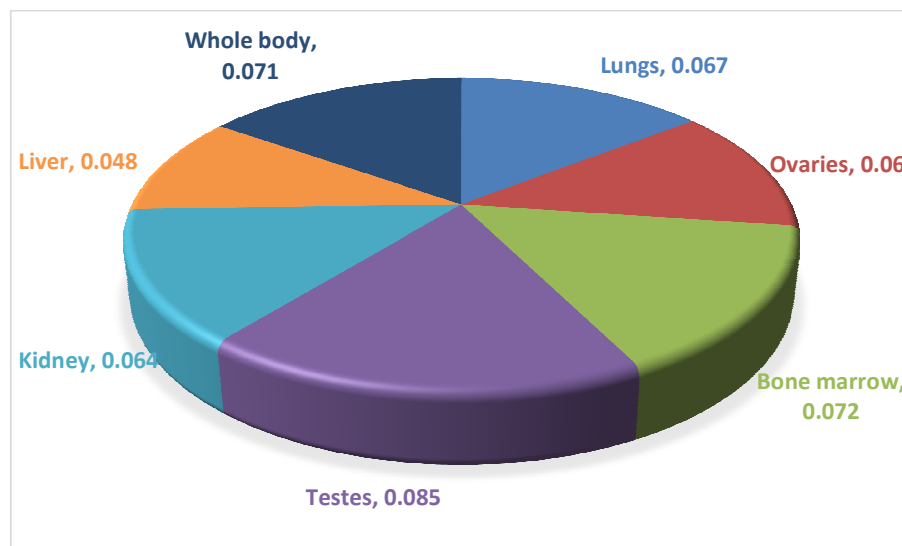


Fig. 4: Annual Effective dose (mSvy⁻¹) to adult body organs

3.1.1.2 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 [9].

$$1 \text{ mRh}^{-1} = \frac{0.96 \times 24 \times 365}{100} \text{ mSvy}^{-1} \quad 2$$

The results of the calculated whole body equivalent dose rate are presented in Table 1-4. The results obtained indicate mean values of

3.1.2 Absorbed dose rate

The data obtained for the external exposure rate in μRh^{-1} were also converted into absorbed dose rates nGyh^{-1} using the conversion factor [22]:

$$1 \mu\text{Rh}^{-1} = 8.7 \text{ nGyh}^{-1} = \frac{8.7 \times 10^{-3}}{\left(\frac{1}{8760\text{y}}\right)} = 76.212 \mu\text{Gyy}^{-1} = 76.212 \mu\text{Gyy}^{-1} \quad 3$$

The result of the gamma radiation absorbed dose rates for the four communities are presented in Table 1-4. The absorbed dose of radiation estimated in the Otuasega oil spill site ranges from 43.50-104.40 nGyh^{-1} with mean value of 82.17 nGyh^{-1} and Ibelebiri oil spill site ranges from 60.90 – 104.40 nGyh^{-1} with mean value of 86.13 nGyh^{-1} while the absorbed dose rate at the Otuegwe II oil spill site ranges from 52.20 – 95.70 nGyh^{-1} with mean value of 73.95 nGyh^{-1} while the absorbed dose rate for Imiringi oil spill site ranges from 52.20 – 113.10 nGyh^{-1} with mean value of 83.52 nGyh^{-1} . The values reported for Ibelebiri oil spill site and Imiringi oil spill site are higher than those reported Otuegwe II and Otuasega oil spill sites. The mean outdoor gamma dose rate measured at Otuasega (82.17 nGyh^{-1}), Ibelebiri

(86.13 nGyh⁻¹), Otuegwe II (73.95 nGyh⁻¹) and Imiringi (83.52 nGyh⁻¹) were higher than the values previously reported in Delta State (54.6 nGyh⁻¹) [23]. Also the mean outdoor gamma dose rate measured for this study are higher than the values previously reported in Akwa-Ibom covering Eastern Obolo, Ibeno and Ikot Abasi [24] (20.37 nGyh⁻¹) respectively. The measured outdoor gamma dose rates are also within the values reported in Turkey (78.3-135.7 nGyh⁻¹) [25] and lesser than the value reported in poonch district (102 nGyh⁻¹) [26] which are non-oil spilled sites. The high absorbed dose rate in these sites could be due to high impact of the crude oil spilled over time. The absorbed doses estimated are slightly less than the world permissible value of 89.0 nGyh⁻¹ as shown in Figure 3

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 residents living in the study area. In calculating AEDE, dose conversion factor of 0.7 Sv/Gy and the occupancy factor for outdoor of 0.25 (6 hours out of 24 hours) was used. The occupancy factor for outdoor was calculated based upon interviews with peoples of the area. People of the study area spend almost 6 hours outdoor due to the nature of their routine. The annual effective dose was estimated using the following relation [13]:

$$AEDE (Outdoor)(mSvy^{-1}) = Absorbed\ dose\ rate\ (nGyh^{-1}) \times 8760h \times \frac{0.7Sv}{Gy} \times 0.25$$

The Annual Effective Dose Equivalent for Otuasega, Ibelebiri, Otuegwe II and Imiringi oil spill sites of Bayelsa State ranges from 0.07 to 0.16 mSvy⁻¹, 0.09 to 0.16 mSvy⁻¹, 0.08 to 0.17 mSvy⁻¹ and 0.08 to 0.17 mSvy⁻¹ respectively. The annual effective doses estimated in the four oil spill sites of Bayelsa State (Otuasega, Ibelebiri, Otuegwe II and Imiringi) were higher than the results obtained in Akwa-Ibom [24] (0.02 mSvy⁻¹) and higher than the results in the control sites. The annual effective dose estimated in control sites are lower compared to the value obtained in Akwa-Ibom [24]. The annual effective doses in all the oil spill sites were lower than world average of 0.48 mSvy⁻¹. This implies that the level of doses from the presence and quantity of these constituents of crude oil spill might not be capable of exerting some acute and long-term adverse health effects.

3.1.4 Excess Life Cancer Risk (ELCR)

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

$$ELCR = AEDE \times Average\ duration\ of\ life \times Risk\ factor\ Rf$$

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 [12, 13]. The value of ELCR obtained ranges from 0.23×10^{-3} to 0.56×10^{-3} with an average of 0.44×10^{-3} for Otusega Oil spill site, 0.33×10^{-3} to 0.56×10^{-3} with an average of 0.46×10^{-3} for Ibelebiri Oil spill site while ELCR for Otuegwe II oil spill site range from $(0.28 \text{ to } 0.51) \times 10^{-3}$ with a mean value of 0.40×10^{-3} and ELCR Imiringi oil spill sites ranges from $(0.28 \text{ to } 0.61) \times 10^{-3}$ with a mean value of 0.45×10^{-3} .

Excess lifetime cancer risks estimated for the entire studied oil spill sites were higher than average world standard of 0.29×10^{-3} as shown in Figure 4. The outcome of this is that individuals exposed to this radiation be capable of exerting some acute and long-term adverse health effects because of ionization of tissues. The radiation contamination caused by crude oil spill in the Niger delta region is often so widespread that the surface water [27] and crops grown in the impacted environment [28] are seen to be contaminated.

3.1.3 Effective Dose Rate D_{organ} in mSvy^{-1} to different organs and tissues

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

$$D_{\text{organ}} (\text{mSvy}^{-1}) = O \times \text{AEDE} \times F \quad 6$$

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 Figure 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 and 0.68 respectively as obtained from ICRP [28]. 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 [3]. Seven organs and tissues were examined and the results show that the testes received the highest dose, with average values of 0.085 mSvy^{-1} while the dose was found to be lowest in the liver, with average value of 0.06 mSvy^{-1} . This result compares very well with the result obtained by Agbalagba, [3] but these results show that the calculated doses to the different organs studied are all below the international tolerable limits on dose to body organs of 1.0 mSvy^{-1} . The relatively higher dose to the tests and low dose intake to the liver is due to different absorption rate [29]. This result shows that exposure to BIR levels in the oil spilled communities of Bayelsa contributes insignificant radiation dose to these organs in adult. The distribution of the BIR levels of the studied area was represented by the contour plot of figure 5. Some communities have sparsely distribution of BIR and some densely distributed.

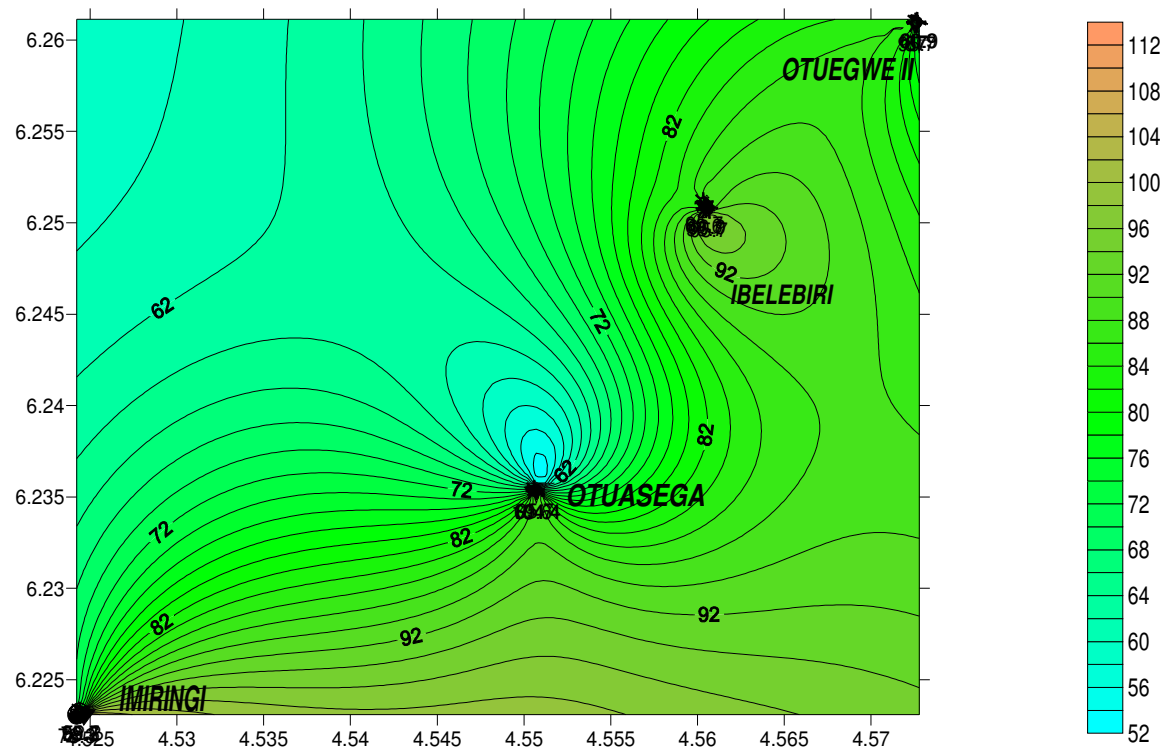


Fig. 5: Contour map of the oil spill sites

4. Conclusion

The measurement of terrestrial background ionizing radiation levels due to oil spill in some communities (Otuasega, Ibelebiri, Otuegwe II and Imiringi) of Bayelsa State have been carried out. The following conclusions were drawn from the study.

- The study revealed that the background ionizing radiation levels of the four communities are below the normal BIR levels, therefore has not been impacted by the oil spills.
- The estimated absorbed dose rates (D), equivalent dose rate and annual effective dose are within the safe value.
- The ELCR calculated revealed that the chance of contracting cancer for residents of the study area who will spend all of their lives in the village is low and the effective doses from the current exposure rate to the adult organs investigated are insignificant.

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