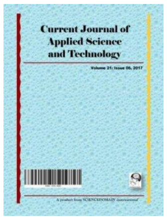

Current Journal of Applied Science and Technology

28(3): 1-12, 2018; Article no.CJAST.42601
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Assessment of Radiological Health Risks from Gamma Radiation Levels in Selected Oil Spill Communities of Bayelsa State, Nigeria

S. I. Ovuomarie-kevin[1], C. P. Ononugbo[2*] and G. O. Avwiri[2]

[1]Institute of Natural Resources Environment and Sustainable Development (INRES), Nigeria.
[2]Department of Physics, University of Port Harcourt, Port Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author GOA designed the study. Author SIO performed the statistical analysis, wrote the protocol and first draft of the manuscript. Author CPO managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2018/42601
Editor(s):
(1) Santiago Silvestre, Associate Professor, Telecommunications Engineering, Universitat Politècnica de Cataluny, Spain.
Reviewers:
(1) Franco Cervellati, SVEB University of Ferrara, Italy.
(2) Ayodele Adeolu Erastus, Federal University of Technology, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/25553

Original Research Article

Received 14th April 2018
Accepted 22nd June 2018
Published 14th July 2018

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 the four communities 0.009±0.001, 0.010±0.002, 0.009±0.002 and 0.010±0.002 mRh^{-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 $mSvy^{-1}$ 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) $x10^{-3}$ 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 $0.29x10^{-3}$ respectively. The calculated dose to organs

**Corresponding author: E-mail: ovuomarie.stella@gmail.com;*

showed that the testes have the highest organ dose of 0.085 $mSvy^{-1}$ while the liver has the lowest organ dose of 0.048 $mSvy^{-1}$. The contour map of Fig. 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 on 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 lifestyle [1]. Radiobiological experiments with cells and cell mechanisms have shown that small amount of radiation with a low dose rate stimulates our defence 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 have 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.

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±0.10 to 22.00± 2.10 μRh^{-1} in the oil field and 9.00±1.00 to 11.00±0.50 μRh^{-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/ Eegbema/Ndoni area of Nigeria, also revealed a mean site radiation level range of 0.014±0.001 to 0.018±0.001 mRh^{-1} while the mean host community radiation levels range from 0.014 ±0.001 to 0.017±0.001 mRh^{-1}. The result showed that 71.7% of the sampling point exceeded the normal background radiation levels of 0.013 mRh^{-1} [6].

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 an 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. The purpose of this work was to assess the background radiation level of the oil spilled communities in Bayelsa state in order to quantify its health risk to exposed individuals. 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.

2. MATERIALS 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° 22′ E and 6° 26′ and latitude 4° 52′N and 4° 57′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 measurement was adopted to enable samples to 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℃ to 50℃ 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 ±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];

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

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.

2.1 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 [9].

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

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

2.2 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]:

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

2.3 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]:

$$AEDE\ (Outdoor)(mSvy^{-1}) = Absorbed\ dose\ rate\ (nGyh^{-1}) \times 8760h \times \frac{0.7Sv}{Gy} \times 0.25 \qquad (4)$$

2.4 Excess Life Cancer Risk (ELCR)

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

$$ELCR = AEDE \times Average\ duration\ of\ life \times Risk\ factor\ Rf \quad (5)$$

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].

2.5 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:

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

Where AEDE is annual effective dose, O is the occupancy factor 0.8 and F is the conversion factor for organ dose from ingestion. Conversion factor (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 and0.68 respectively as obtained from ICRP [28].

3. RESULTS AND DISCUSSION

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 Figs. 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.

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

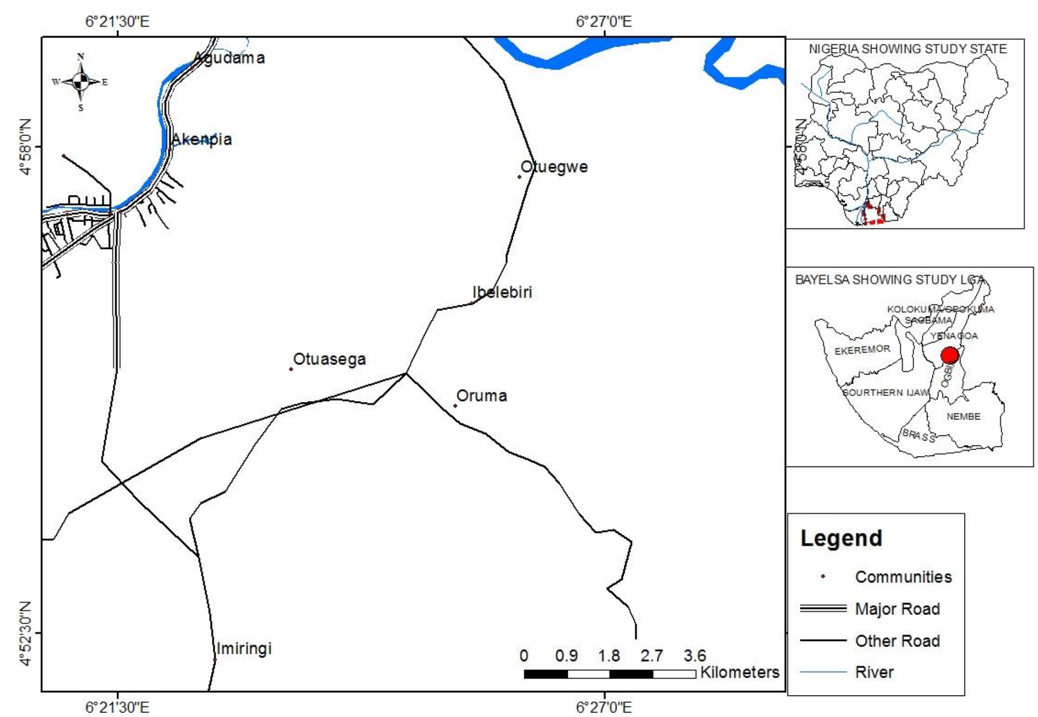

Fig. 1. Map showing the oil spill areas in Bayelsa State

results are presented in Tables 1 to 4. The average sites radiation exposure levels ranges between 0.005 – 0.012 mRh^{-1}(Otuasega), 0.007 – 0.012 mRh^{-1}(Ibelebiri), 0.006 – 0.011 mRh^{-1}(Otuegwe II) and 0.006 – 0.013 mRh^{-1}(Imiringi). The mean values of radiation exposure rate was highest at Ibelebiri and Imiringi oil spill areas (0.010 $\pm$ 0.002) mRh^{-1} while the least value was obtained at Otuasega and Otuegwe II oil spill areas (0.009 $\pm$ 0.001) mRh^{-1}. The value 0.010±0.002 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 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 0.013mRh^{-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})	Equivalent Dose $mSvy^{-1}$	Absorbed dose rate $nGyh^{-1}$	AEDE $mSvy^{-1}$	ELCR x 10^{-3}
1	Otuasega1	N04^{0}55'06.5" E006^{0}23'53.9"	0.008±0.001	0.673	69.60	0.11	0.37
2	Otuasega2	N04^{0}55'06.4" E0062353.7	0.008±0.001	0.673	69.60	0.11	0.37
3	Otuasega3	N04^{0}55'05.6" E0062354.0	0.008±0.002	0.673	69.60	0.11	0.37
4	Otuasega4	N04^{0}55'05.1" E0062353.6	0.011±0.001	0.925	95.70	0.15	0.51
5	Otuasega5	N04^{0}55'04.5" E006^{0}23'54.7"	0.009±0.001	0.757	78.30	0.12	0.42
6	Otuasega6	N04^{0}55'06.8" E006^{0}23'53.5"	0.012±0.001	1.009	104.40	0.16	0.56
7	Otuasega7	N04^{0}55'07.3" E006^{0}23'53.4"	0.012±0.001	1.009	104.40	0.16	0.56
8	Otuasega8	N04^{0}55'06.9" E006^{0}23'54.8"	0.012±0.001	1.009	104.40	0.16	0.56
9	Otuasega9	N04^{0}55'07.3" E006^{0}23'54.9"	0.005±0.003	0.420	43.50	0.07	0.23
10	Otuasega10	N04^{0}55'07.4" E006^{0}23'54.10"	0.011	0.925	95.70	0.15	0.51
	Mean		**0.009±0.001**	**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^{0}56'03.6" E006^{0}25'09.9"	0.008±0.002	0.673	69.60	0.11	0.37
2	Ibelebiri Oil $spill_2$	N04^{0}56'02.4" E006^{0}25'10.5"	0.009±0.001	0.757	78.30	0.12	0.42
3	Ibelebiri Oil $spill_3$	N04^{0}56'03.8" E006^{0}25'11.2"	0.011±0.002	0.925	95.70	0.15	0.51
4	Ibelebiri Oil $spill_4$	N04^{0}56'03.7" E006^{0}25'08.4"	0.011±0.001	0.925	95.70	0.15	0.51
5	Ibelebiri Oil spill5	N04^{0}56'04.4" E006^{0}25'08.3"	0.011±0.003	0.925	95.70	0.15	0.51
6	Ibelebiri Oil spill	N04^{0}56'04.3" E006^{0}25'09.9"	0.012±0.003	1.009	104.40	0.16	0.56
7	Ibelebiri Oil spill	N04^{0}56'05.3" E006^{0}25'09.2"	0.007±0.001	0.589	60.90	0.09	0.33
8	Ibelebiri Oil spill	N04^{0}56'05.7" E006^{0}25'08.9"	0.008±0.002	0.673	69.60	0.11	0.37
9	Ibelebiri Oil spill	N04^{0}56'06.4" E006^{0}25'07.7"	0.011±0.001	0.925	95.70	0.15	0.51
10	Ibelebiri Oil spill	N04^{0}56'07.5" E006^{0}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^{0}57'26.4" E006^{0}26'09.9"	0.010±0.004	0.841	87.00	0.13	0.47
2	Otuegwe 2	N04^{0}57'26.9" E006^{0}26'10.0"	0.006±0.001	0.505	52.20	0.08	0.28
3	Otuegwe 3	N04^{0}57'27.0" E006^{0}26'10.9"	0.007±0.002	0.589	60.90	0.09	0.33
4	Otuegwe 4	N04^{0}57'27.1" E006^{0}26'11.1"	0.007±0.002	0.589	60.90	0.09	0.33
5	Otuegwe 5	N04^{0}57'27.8" E006^{0}26'11.3"	0.007±0.002	0.589	60.90	0.09	0.33
6	Otuegwe 6	N04^{0}57'27.1" E006^{0}26'10.2"	0.008±0.002	0.673	69.60	0.11	0.37
7	Otuegwe 7	N04^{0}57'26.2" E006^{0}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	**0.75**	73.95	0.13	0.40

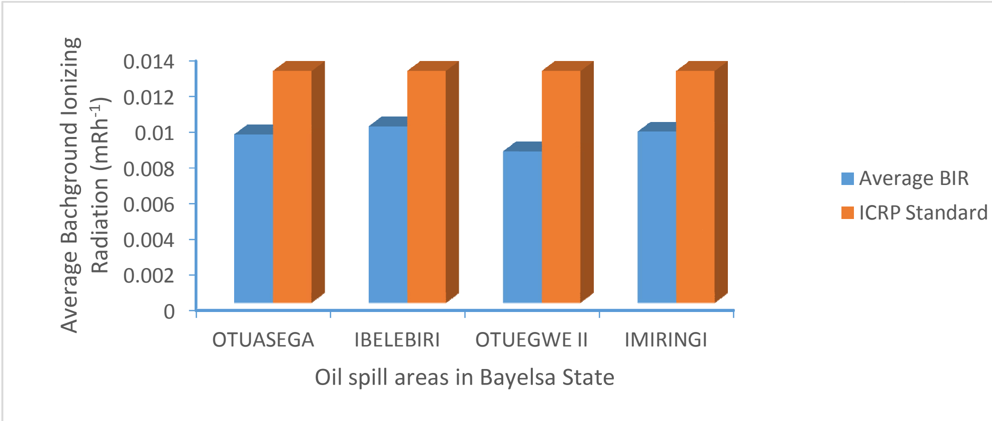

Fig. 2. Comparison of Comparison of measured BIR levels with standard

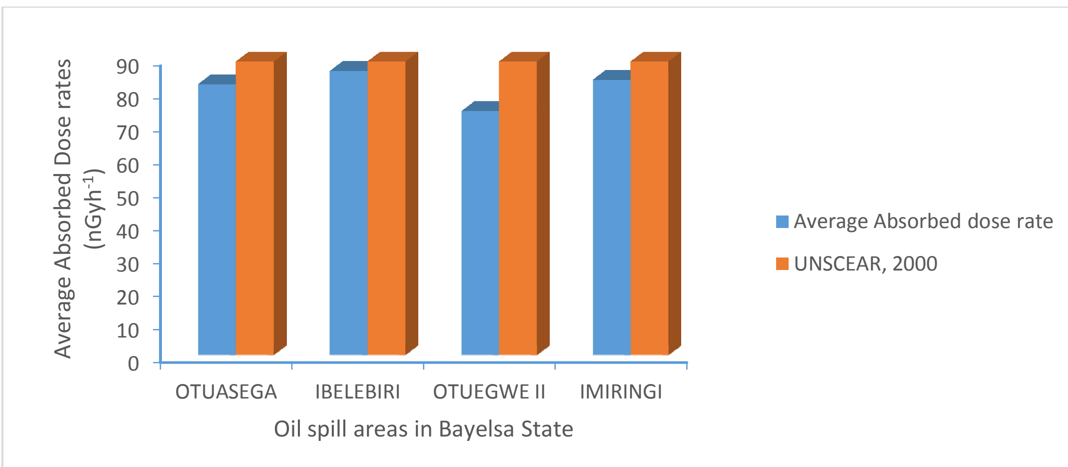

Fig. 3. Comparison of average absorbed dose rate of oil spill areas

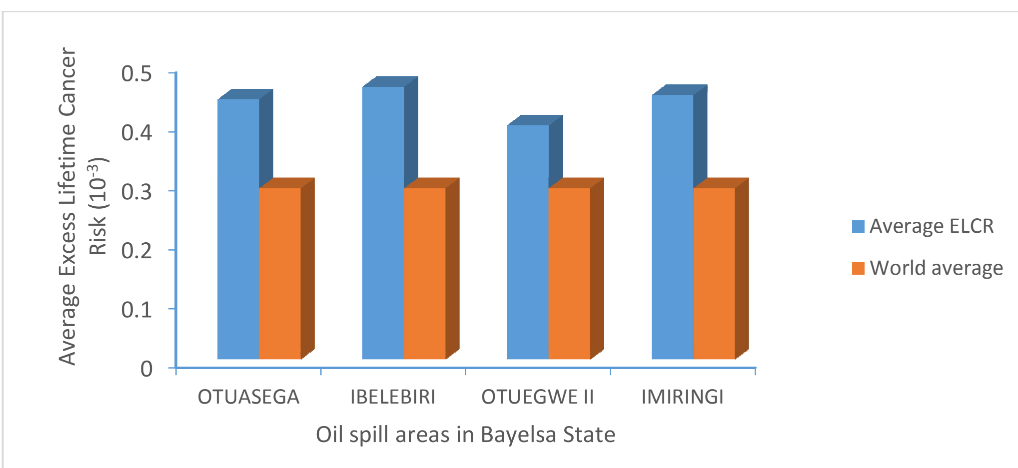

Fig. 4. Comparison of mean ELCR of oil spill with World safe limit value

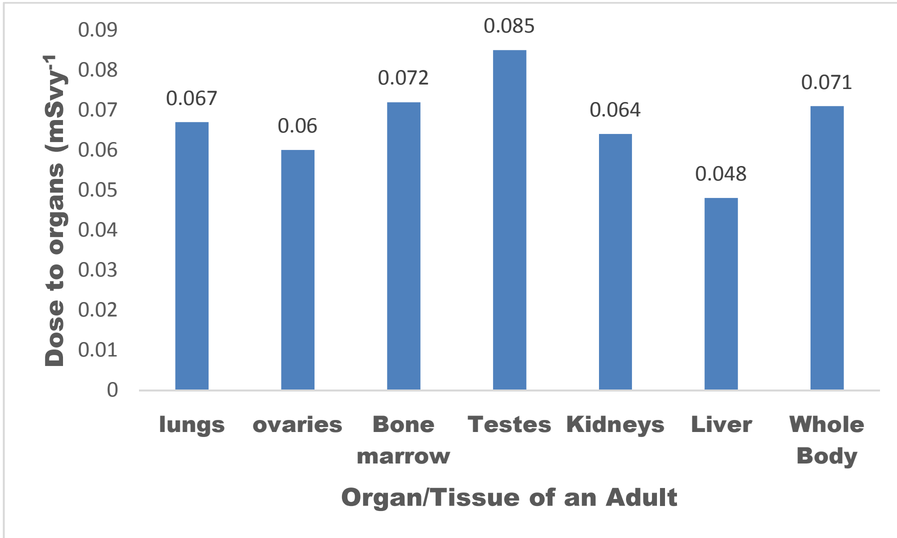

Fig. 5. Annual Effective dose rate ($mSvy^{-1}$) to different organs/tissues

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**

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 for 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 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 Fig. 3.

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 than 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 obtained crude oil spilled areas might not be capable of exerting some acute and long-term adverse health effects.

The value of excess lifetime cancer risk (ELCR) obtained ranges from 0.23 x 10^{-3} to 0.56 x 10^{-3} with an average of 0.44 x 10^{-3} for Otuasega Oil spill site, 0.33 x 10^{-3} to 0.56 x 10^{-3} with an average of 0.46 x 10^{-3} for Ibelebiri Oil spill site while ELCR for Otuegwe II oil spill site range from (0.28 to 0.51) x 10^{-3} with a mean value of 0.40 x 10^{-3} and ELCR for Imiringi oil spill sites ranges from (0.28 to 0.61) x 10^{-3} with a mean value of 0.45 x 10^{-3}. Excess lifetime cancer risks estimated for the entire studied oil spill sites were higher than average world standard of 0.29 x 10^{-3} as shown in Fig. 4. The outcome of this is that individuals exposed to this radiation may not be capable of exerting some acute and long-term

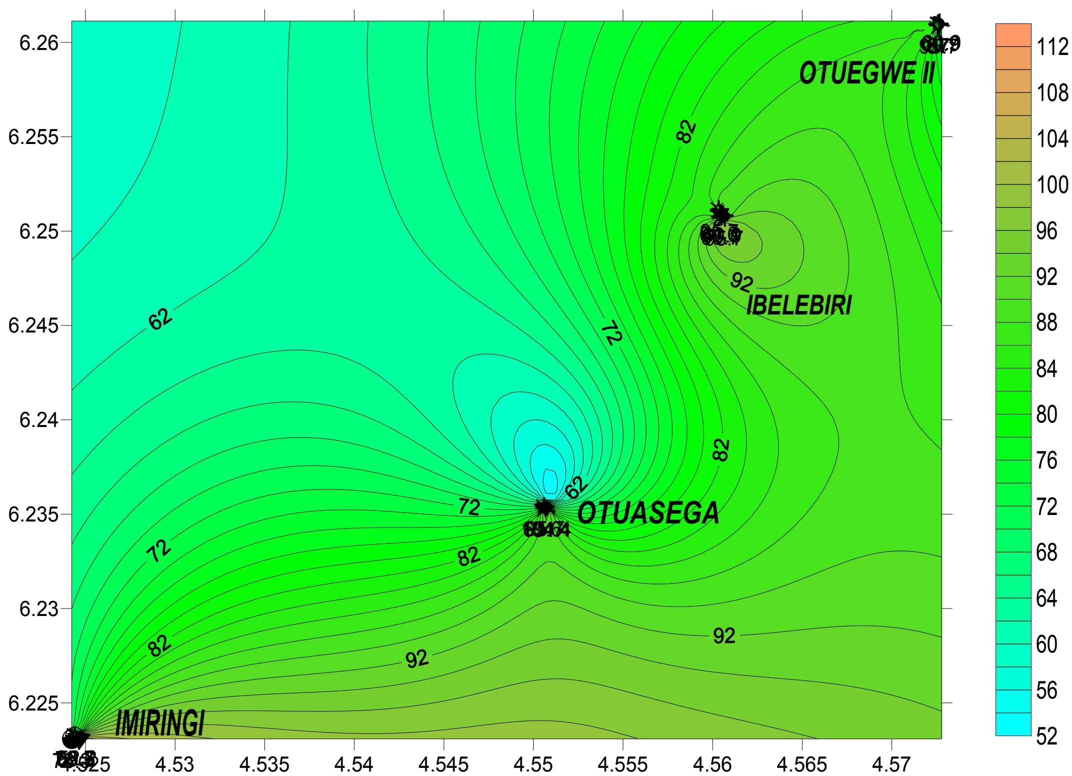

Fig. 6. Contour map of the oil spill sites

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.

The calculated effective dose rates delivered to the different organs are presented in Fig. 5 with numerical values in $mSvy^{-1}$. The model of the annual effective dose to organs estimated the amount of radiation intake by a person which enters and accumulates on 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 lowest dose was found in the liver, with average value of 0.06 $mSvy^{-1}$ as shown in Fig. 5. 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 may be due to different absorption rate and conversion factors [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 Fig. 6. Some communities have sparsely distribution of BIR and some densely distributed.

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. World Health Organization. The World Health Report: 2002: Reducing risks, promoting healthy life. Geneva: World Health Organization. 2003;1–71.
2. Laogun AA, Ajayi NO, Agaja SA. Variation in wellhead gamma radiation levels at the Nigeria Petroleum Development Company Oil Field, Ologbo Edo State, Nigeria. Nigeria Journal Physics. 2006;18(1):135-140.
3. Agbalagba Ezekiel. Assessment of excess lifetime cancer risk from gamma radiation levels in Effurun and Warri city of Delta state, Nigeria. Journal of Talbah University for Science. 2017;11:367-380.
4. Umoren YE, Efe Ohwekevwo E. Influence of crude oil spillage on the γ-radiation status of water and soil in Ogba/Egbema/Ndoni Area, Nigeria. Energy and Environment Research. 2011;3(2).
   Available:http://dx.doi:10.5539/eer.v3n2p45
5. Avwiri GO, Agbalagba EO, Enyinna PI. Terrestrial radiation around oil and gas facilities in Ugheli, Nigeria. Asian Network for Science Information, J. Appl. Sci. 2007;7(11):1543-1546.
6. Ononugbo CP, Avwiri GO, Chad-Umoren YE. Impact of Gas Exploitation on the Environmental Radioactivity of Ogba / Egbema / Ndoni Area, Nigeria. Energy and Environment. 2011;22(8):1017-1028.
   Available:http://dx.doi.org/10.1260/0958-305X.22.8.1017
7. Jibiri NO, Alausa SK, Owofolaju AE, Adeniran A. A terrestrial gamma dose rates and physical-chemical properties of farm soils from ex- tin mining locations in Jos-Plateau, Nigeria. African Journal of Environmental Science and Technology. 2011;5(12):1039-1049.
8. Taskin H, Karavus M, Ay P, Topuzoglu A, Hidiroglu S, Karahan G. Radionuclide concentration in soil and lifetime cancer risk due to the gamma radioactivity in Kirklareli, Turkey. Journal of Environmental Radioactivity. 2009;100:49-53.

9. NPC. National Population Commission, [The Nigeria Census, Federal Government of Nigeria, Abuja; 2006.
10. Ajayi NO, Laogun. Variation of environmental gamma radiation in Benin with vertical height. Nig. J. Space Res. 2006;2:47-54.
11. Avwiri GO, Egieye JF, Ononugbo CP. Radiometric survey of Aluu landfill in Rivers state, Nigeria. Advan. Phys. Theory Appl. 2013;22:24-30.
12. Alagoa EJ. Land and people of Bayelsa State, central Niger Delta, Onyema publications, Port- Harcourt. 1999;167.
13. Diad HM, Noub SA, Hamdy A, El-Fiki. Evaluation of natural radioactivity in a cultivated are a around a fertilizer factory. J. Nucl. Radiat. Phys. 2008;3(1):51-62.
14. Zarie KA, Almagren. Measurement of natural radioactivity and assessment of radioation hazard in soil samples from Tayma area Isotope Radiat Res. 2010; 42(1):1-9.
15. Rafique M, Rahman SU, Basharat M, Aziz W, Ahmad I, Lone KA, Ahmad K, Matiullah. Evaluation of excess life time cancer risk from gamma dose rate in Jhelum valley. Journal of Radiation Research and Applied Sciences. 2014;7:29-35.
16. Ademola JA, Onyema UC. Assessment of natural radionuclides in fly ash produced at Orji River thermal Power Station, Nigeria and the associated radiological impact. Nat. Sci. 2014;6:752–759.
DOI: 10.4236/ns.2014.610075
17. UNSCEAR. Ionizing radiation: Sources and biological effects report to the general assembly with scientific annexes, United Nations Scientific Committee for Effects of Atomic Radiation New York, United Nation. 2000;44-89.
18. Mishra KP. Carcinogenic risk from low dose radiation exposure is overestimated. J Radiat Cancer Res. 2017;8:1-3.
19. Stewart FA, Akleyev AV, Hauer‑Jensen M, Hendry JH, Kleiman NJ, et al. ICRP publication 118: ICRP statement on tissue reactions and early and late effects of radiation in normal tissues and organs – Threshold doses for tissue reactions in a radiation protection context. Ann ICRP. 2012;41:1‑322.
20. Taskin H, Karavus M, Ay P, Topozoglu A, Hindiroglu S, Karahan G. Radionuclide concentrations in soil and life time cancer risk due to gamma radioactivity in Kirklareli, Turkey. Journal of Environmental Radioactivity. 2009;100:49-53.
21. Anekwe UL, Avwiri GO, Agbalagba EO. Assessment of gamma-radiation levels in selected oil spilled areas in Rivers State, Nigeria. Energy Science and Technology. 2013;5(1):33-37.
22. Ebong IDU, Alagoa KD. Estimates of gamma – ray background air exposure at a fertilizer plant. Discovery Innovate. 1992;4: 25-28.
23. Avwiri GO, Ebeniro JO. External environmental radiation in an industrial area of Rivers state. Nig. J. Phys. 1998; 10:105-107.
24. Elena BC, Gracea C. Radiological Impart Assessment on Behalf of Oil/Gas Industry. Journ. Preventive Med. 2004;12(1-2): 16-21.
25. Arogunjo MA, Farai IP, Fuwape IA. Impact of Oil and Gas Industry to the Natural Radioactivity Distribution in the Delta Region of Nigeria. Nig. Journal. Phys. 2004;16:131-136.
26. Akpabio LE, Etuk ES, Essian K. Environmental Radioactive Levels in Ikot Ekpene Nigeria. Nig. Journal. Space. Res. 2005;1:80–87.
27. Laogun AA, Ajayi NO, Agaja SA. Variation in Wellhead Gamma Radiation Levels at the Nigeria Petroleum Development Company Oil Field, Ologbo Edo State, Nigeria. Nigeria. Journal. Physics. 2006;18(1):135-140.
28. Avwiri GO, Agbalagba EO, Enyinna PI. Terrestrial radiation around oil and gas facilities in Ughelli, Nigeria. Asian Network for Science Information. Journal. Applied Sci. 2007;7(11):1543-1546.
29. Agbalagba EO, Avwiri GO, Chad-Umoreh YE. γ-Spectroscopy measurement of natural radioactivity and assessment of radiation hazard indices in soil samples from oil fields environment of Delta State, Nigeria. J Environ Radioact. 2012;109:64-70.
30. Essiett AA, Essien IE, Bede MC. Measurement of Surface Dose Rate of Nuclear Radiation in Coastal Areas of Akwa Ibom State, Nigeria. International Journal of Physics. 2015;3(5):224-229.
DOI: 10.12691/ijp-3-5-5
31. Erees FS, Akozcan S, Parlak Y, Cam S. Assessment of dose rates around Manisa

(Turkey). Radiation and Measurements. 2006;41(5):598-601.
32. Rafique M, Basharat M, Azhar Saeed R, Rahamn S. Effect of geology and altitude on ambient outdoor gamma dose rates in district poonch, Azad Kashmir, Carpathian. Journal of Earth and Environmental Sciences. 2013;8(4):165–173.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/25553