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Evaluation of Health Risks from Exposure to Low Levels of Ionizing Radiation in Some Oil Spilled Communities of Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author GOA designed the study. Author SIOK performed the statistical analysis, wrote the protocol and wrote the 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.

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ABSTRACT

Background: Oil spillage is often an unintended release of crude oil into the environment as a result of human activity. Crude oil spills in the oil and gas installations, radionuclide material used for geological mapping, well logging and other related activities can also increase the background ionizing radiation. Long term exposure to this low level radiation can lead to many health related risks.
Aim: The aim of this study is to evaluate the health risk from exposure to low levels of background ionizing radiation in some oil spilled communities of Rivers State.
Method: An in-situ measurement of radiation exposure rate of Bon-ngia, Bolte-kpan, Te-oo-goo and Nupene communities were done using well calibrated radalert-50 and 100 meters, a Global Positioning System (Garmin 765) and radiation models.
Results: The mean background radiation exposure rate of Bon-ngia, Bolte-kpan, Te-oo-goo and Nupene are 0.0110±0.005, 0.0132±0.002, 0.0103±0.003 and 0.0113±0.003 mRh^{-1} respectively. The mean of absorbed dose rates, annual effective dose equivalent (AEDE), are within their

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permissible safe values while the mean excess lifetime cancer risk calculated were slightly higher than the safe value. The estimated dose to organs showed that the testes have the highest organ dose of 0.11 $mSvy^{-1}$ while the liver has the lowest organ dose of 0.06 $mSvy^{-1}$. The radiation contour maps of the study area presented the distribution of radiation within the spilled communities. The estimated excess lifetime cancer risk values indicates that the chance of contracting cancer for residents of the study is low and the effective dose from present exposure rate to the adult organs investigated is insignificant.

Keywords: Radalert – 200; background; radiation; health risk; exposure and effective dose.

1. INTRODUCTION

Petroleum exploration and production in the Niger Delta region of Nigeria by the petroleum sector has substantially improved the nation's economy over the past decades [1]. However, activities associated with petroleum exploration, development and production operations may have local detrimental and significant impacts on the environment. Although there are other potential anthropogenic sources of pollution, some of the major consequences such as air pollution, global climate change and oil spills in the Niger Delta may be regional or global in scale [1,2]. In Nigeria apart from medical exposure, the petroleum industry is the largest importer and user of radioactive sources, covering both upstream and downstream operations [3]. Natural radioactivity has been present in the coastal environment since the formation of the earth [4]. Hydrocarbon exploration and production activities have the potential to increase the risk of radiation exposure to the environment and humans by concentrating the quantities of naturally occurring radiation beyond normal background levels [5]. Once present in the environment, these radionuclides are available for uptake by plants, fishes and animals and so make their way into the food chain. Plants, fishes and animals in the marine environment accumulate radionuclide to concentration greater than those of the ambient [6]. Foland et al. [7] reported that human activities, that have led to the depletion of the ozone layer, increased the cosmic rays reaching the earth's surface thereby affecting the background radiation. Kuroda [8] reported that the background radiation levels are from a combination of terrestrial (^{40}K, ^{232}Th, ^{226Ra}). He reported that the level is fairly constant over the world, being 0. 008-0.015 mR h^{-1}. But Brazil, India and China have higher background ionizing radiation, primarily due to the high concentrations of radioactive minerals (Monozite) in the soil [9]. Avwiri and Ebeniro [10] studied the external environmental radiation in an industrial area of Rivers State. They reported an average value of 0.014 mRh^{-1}. The results indicated significant elevation from the standard background radiation of O.Ol3 mRh^{-1}.

Naturally Occurring Radioactive Materials (NORMs) exist in soil, sediment, water, plants, animals, human, coal, lignite, petroleum, phosphate ores, geothermal wastes, waste waters in small but varying amounts almost everywhere [11,12]. Excessive exposure of residents and workers of the nearby coastal communities to ionizing radiation could result to health side effects such as lung cancer, eye cataracts, and skin erythema [13]. Human beings are exposed to external radiation and radiation from the naturally occurring radionuclide in their immediate surroundings and also to internal radiation from food, water and air they consume [14]. Evaluation of health related risk from exposure to background ionizing radiation is of immense importance because it will give the radiological status of the area and residents which serves as a radiation safety monitoring tool. The result of this work will also serve as baseline data for the background radiation levels in this area. The high risk associated with oil spill and the high cost of remediation as the case of Ogoni Land [15] which is typical scenario of oil spillage and its consequence have necessitate this research work. The absorbed dose, equivalent dose rate, the annual effective dose equivalent rate (AEDE) and the excess life time cancer risk (ELCR) were estimated from the measured gamma exposure rates of the spilled communities.

2. MATERIALS AND METHODS

This study was conducted in March-April 2018. The area lies within longitude 6°50′E and 6°57′E and latitude 4°45′N and 4°60′N. Four communities: Bon-ngia, Bolte-kpan, Te-oo-goo and Nupene where oil spillage occurred in recent times were selected for this study.

Measurement were made in strategic areas of the oil spilled area. An in-*situ* approach of background ionizing radiation measurement was adopted to enable samples to maintain their original environmental characteristics [16]. *A 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 within the temperature range of -10°C and 50°C and a geographical positioning system (GPS) was used to measure the precise location of sampling. The meter's sensitivity is 3500CPM/ (mR^{-1}) relative to Cs-137 and its maximum alpha and beta efficiencies are 18% and 33%, respectively [17]. The Geiger-Muller tube generates a pulse current each time radiation passes through the tube and causes ionization [18]. Each pulse is electronically detected and registered as a count.

The tube of the radiation monitoring meter was raised to a standard height of 1.0 mm above the ground with its window facing the spilled area while the GPS was taken at that spot. The measurements were carried out by positioning the radiation meter at the targeted sample located at varying distance from the oil spill sites established by Geographical Positioning System (GPS). Measurements were repeated for six times at each sampling site. Reading were obtained between 1300 and 1600 h because the radiation meter has a maximum response to environmental radiation within these hours according to the NCRP [19]. 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 = 6 for radiation measurements for each sample point). The switch (knob) was turned to return the meter to zero after each measurement [20].

3. RADIOLOGICAL PARAMETERS

3.1 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 [9,21].

$$1\ mRh^{-1} = \frac{0.96 \ x\ 24\ x\ 365}{100}\ mSvy^{-1} \quad (1)$$

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

3.2 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]:

$$1\ \mu Rh^{-1} = 8.7\ nGyh^{-1} = \frac{8.7\ x\ 10^{-3}}{(\frac{1}{8760y})} = 76.212\ \mu Gyy^{-1} = 76.212\ \mu Gyy^{-1} \quad (2)$$

3.3 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]:

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

3.4 Excess Life Cancer Risk (ELCR)

The probabilities of contacting cancer by the oil workers and residents of the study area who will spend all their life time in this environment can be estimated using the Excess Lifetime Cancer Risk (ELCR) even in the absence of outbreak radioactive components. The Linear No Threshold (LNT) hypothesis extrapolation from evidence-supported, high-dose effects to low-dose responses claims that all acute ionizing radiation exposures down to zero are harmful. The harm is proportional to dose and is cumulative throughout life, regardless of how low the dose rate is [22]. This study is based on the traditional worldwide radiation protection standards for late (stochastic) effects which are based on the LNT hypothesis [23]. The annual effective dose calculated was used to estimate the Excess Lifetime Cancer Risk (ELCR) is calculated using equation (3).

$$ELCR = AEDE \times Average\ duration\ of\ life \times Risk\ factor\ Rf \quad (3)$$

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 [24,22].

3.5 Effective Dose Rate D_{organ} in $mSvy^{-1}$ to Different Organs/ Tissues

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

$$D_{organ}\,(mSvy^{-1}) = O \times AEDE \times F \quad (4)$$

Where AEDE is annual effective dose, O is the occupancy factor 0.8 and F is the conversion factor for organ dose from ingestion. The calculated effective dose rates delivered to the different organs are presented in Fig. 4, with the F values for lungs, ovaries, bone marrow, testes, kidneys, liver and whole body being 0.64, 0.58, 0.69, 0.82, 0.62, 0.46 and0.68 respectively 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].

4. RESULTS

The results for the *in-situ* measurement of the exposure rate with their associated health risk parameters for oil spilled communities in Rivers State (Bon-ngia, Bolte-kpan, Nupene and Te-oo-goo) are presented in Tables 1-4. Figs. 2 and 3 show the comparison of the measured exposure rates and calculated absorbed doses of the sampled communities (Bon-ngia, Bolte-kpan, Nupene and Te-oo-goo) with their international standards respectively.

Table 1. The mean radiation exposure rate and estimated radiation risk parameters of Bon-Ngia 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	Bon-Ngia 1	N04^{0}38'24.0 E007^{0}14'43.0""	0.012±0.001	1.009	104.4	0.16	0.56
2	Bon-Ngia 2	N04^{0}38'23.7" E007^{0}14'42.5""	0.011±0.002	0.925	95.7	0.15	0.51
3	Bon-Ngia 3	N04^{0}38'24.3 E007^{0}14'41.6"	0.016±0.003	1.346	139.2	0.21	0.75
4	Bon-Ngia 4	N04^{0}38'21.6" E007^{0}14'43.0"	0.009±0.004	0.757	78.3	0.12	0.42
5	Bon-Ngia 5	N04^{0}38'19.8"" E007^{0}14'43.7"	0.009±0.003	0.757	78.3	0.12	0.42
6	Bon-Ngia 6	N04^{0}38'19.6" E007^{0}14'44.1"	0.012±0.001	1.009	104.4	0.16	0.56
7	Bon-Ngia 7	E007^{0}14'44.1" E007^{0}14'44.1"	0.013±0.001	1.093	113.1	0.17	0.61
8	Bon-Ngia 8	N04^{0}38'21.2" E007^{0}14'43.7""	0.009±0.002	0.757	78.3	0.12	0.42
9	Bon-Ngia 9	N04^{0}38'24.2" E007^{0}14'44.1"	0.009±0.003	0.757	78.3	0.12	0.42
10	Bon-Ngia 10	N04^{0}38'26.0" E007^{0}14'42.5	0.010±0.005	0.841	87.0	0.13	0.47
	Mean		0.0110±0.005	0.924	114.84	0.18	0.62

Table 2. The mean radiation exposure rate and estimated radiation risk parameters of Bolte-Kpan oil spill

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	Bolte-Kpan 1	N04^{0}38'30.5" E007^{0}14'21.2"	0.012±0.004	1.009	104.40	0.16	0.56
2	Bolte-Kpan 2	N04^{0}38'30.1" E007^{0}14'20.6"	0.010±0.003	0.841	87.00	0.13	0.47
3	Bolte-Kpan 3	N04^{0}38'30.0" E007^{0}14'20.3"	0.011±0.001	0.925	95.70	0.15	0.51
4	Bolte-Kpan 4	N04^{0}38'30.3" E007^{0}14'19.7"	0.012±0.001	1.009	104.40	0.16	0.56
5	Bolte-Kpan 5	N04^{0}38'31.2" E007^{0}14'19.7"	0.015±0.002	1.261	130.50	0.20	0.70
6	Bolte-Kpan 6	N04^{0}38'31.6" E007^{0}14'19.7"	0.016±0.003	1.346	139.20	0.21	0.75
7	Bolte-Kpan 7	N04^{0}38'31.2" E007^{0}14'23.0"	0.014±0.003	1.177	121.80	0.19	0.65
8	Bolte-Kpan 8	N04^{0}38'31.1" E007^{0}14'23.8"	0.019±0.001	1.598	165.30	0.25	0.89
9	Bolte-Kpan 9	N04^{0}38'30.8" E007^{0}14'24.1"	0.012±0.002	1.009	104.40	0.16	0.56
10	Bolte-Kpan 10	N04^{0}38'30.6" E007^{0}14'25.1"	0.011±0.004	0.925	95.70	0.15	0.51
	Mean		**0.013±0.002**	**1.118**	**114.84**	**0.18**	**0.62**

Table 3. The mean radiation exposure rate and estimated radiation risk parameters of Te-oo-goo 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	Te-oo-goo 1	N04^{0}38'24.7" E007^{0}14'12.9"	0.015±0.004	1.261	130.5	0.20	0.70
2	Te-oo-goo 2	N04^{0}38'24.0" E007^{0}14'13.5"	0.011±0.002	0.925	95.7	0.15	0.51
3	Te-oo-goo 3	N04^{0}38'24.2" E007^{0}14'13.0"	0.012±0.002	1.009	104.4	0.16	0.56
4	Te-oo-goo 4	N04^{0}38'24.4" E007^{0}14'13.7"	0.011±0.002	0.925	95.7	0.15	0.51
5	Te-oo-goo 5	N04^{0}38'24.4" E007^{0}14'14.1"	0.007±0.003	0.589	60.9	0.09	0.33
6	Te-oo-goo 6	N04^{0}38'24.6" E007^{0}14'15.2"	0.011±0.003	0.925	95.7	0.15	0.51
7	Te-oo-goo 7	N04^{0}38'25.6" E007^{0}14'14.6"	0.005±0.001	0.420	43.5	0.07	0.23
8	Te-oo-goo 8	N04^{0}38'26.0" E007^{0}14'14.4"	0.011±0.002	0.925	95.7	0.15	0.51
9	Te-oo-goo 9	N04^{0}38'26.9" E007^{0}14'15.6"	0.008±0.004	0.673	69.6	0.11	0.37
10	Te-oo-goo 10	N04^{0}38'27.7" E007^{0}14'16.4"	0.012±0.003	1.009	104.4	0.16	0.56
	Mean		**0.010±0.003**	**0.967**	**89.61**	**0.14**	**0.48**

Table 4. The mean radiation exposure rate and estimated radiation risk parameters of the Nupene 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	Nupene 1	N04^{0}38'33.3" E007^{0}14'13.1"	0.011±0.005	0.925	95.70	0.15	0.51
2	Nupene 2	N04^{0}38'34.1" E007^{0}14'12.5"	0.014±0.004	1.177	121.80	0.19	0.65
3	Nupene 3	N04^{0}38'35.0" E007^{0}14'12.1"	0.008±0.002	0.673	69.60	0.11	0.37
4	Nupene 4	N04^{0}38'35.6" E007^{0}14'12.1"	0.010±0.003	0.841	87.00	0.13	0.47
5	Nupene 5	N04^{0}38'35.5" E007^{0}14'11.7"	0.015±0.003	1.261	130.50	0.20	0.70
6	Nupene 6	N04^{0}38'35.9" E007^{0}14'12.5"	0.009±0.003	0.757	78.30	0.12	0.42
7	Nupene 7	N04^{0}38'36.0" E007^{0}14'12.4"	0.010±0.002	0.841	87.00	0.13	0.47
8	Nupene 8	N04^{0}38'35.0" E007^{0}14'13.5"	0.013±0.002	1.093	113.10	0.17	0.61
9	Nupene 9	N04^{0}38'34.4" E007^{0}14'13.0"	0.011±0.003	0.925	95.70	0.15	0.51
10	Nupene 10	N04^{0}38'33.3" E007^{0}14'13.1"	0.012±0.002	1.009	104.40	0.16	0.56
	Mean		**0.011±0.003**	**0.950**	**98.31**	**0.15**	**0.53**

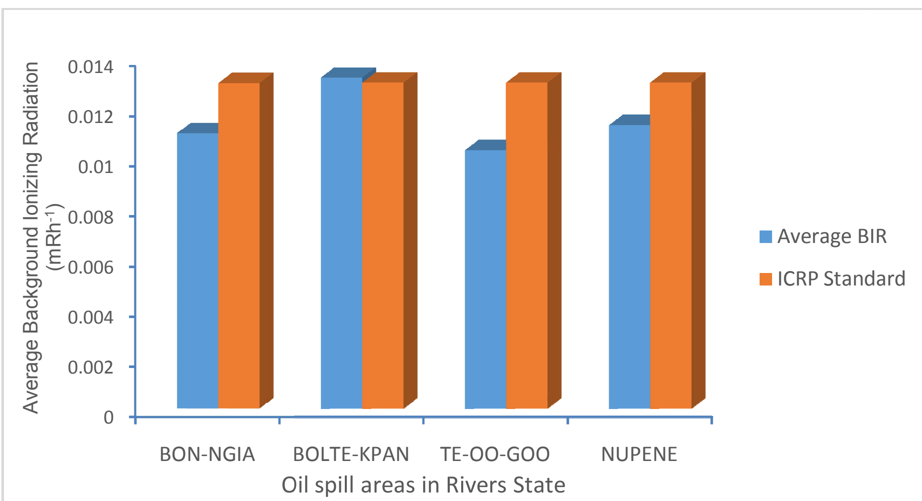

Fig. 2. Comparison of measured exposure rate with ICRP standard

5. DISCUSSION

The terrestrial radiation level and radiation parameters of the four oil spill sites (Bon-ngia, Bolte-kpan, Tee-oo-goo and Nupene) of Rivers State with the uncertainty measurement and its environs was determined with two well-calibrated radiation meters and the results are presented in Tables 1 to 4. The average sites radiation exposure levels of Bon-ngia ranges between 0.009 to 0.016 mRh^{-1} with mean value of 0.011±0.003 while for Bolte-kpan it ranges from 0.010 to 0.019 mRh^{-1} with mean value of 0.013±0.002. The exposure rate for Tee-oo-goo and Nupene communities ranges from 0.005 to 0.015 mRh^{-1} with mean value of 0.010±0.003

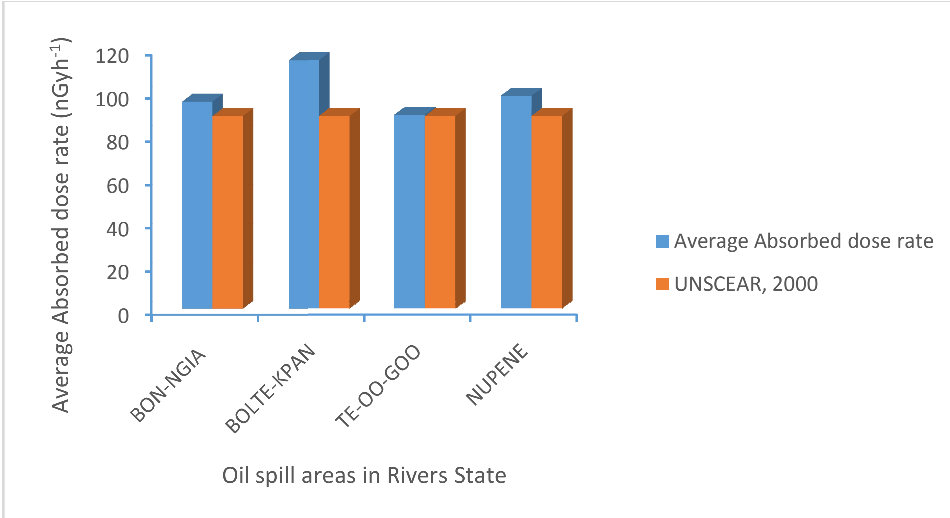

Fig. 3. Comparison of average absorbed dose rate of oil spill areas

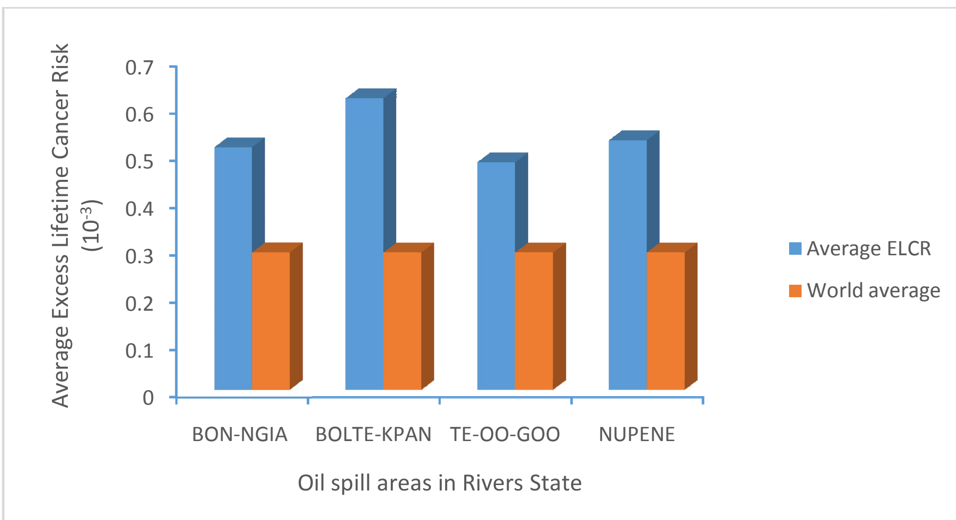

Fig. 4. Comparison of mean ELCR of oil spill with World safe limit value

and 0.008 to 0.015 mRh^{-1} with mean value of 0.011±0.003 mRh^{-1} respectively. The mean values of radiation exposure rate were highest at Bolte-kpan which may be due to higher concentration of the oil contaminant in the area while the least value was obtained at Tee-oo-goo oil spill areas which could be the result of the cleaning exercise done in this community. The mean value obtained in all the communities are within the safe values stipulated by ICRP [24]. Fig. 2 shows the comparison of the measured exposure rates with the normal background level. The least value obtained at Tee-oo-goo shows a 12% below the ICRP standard of 0.013mRh^{-1}. The slight variation in the exposure rates for different oil spilled sites may be as a result of environmental factors and skeletal clean up exercise in some parts. 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 as 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 on the background ionizing radiation levels of these areas.

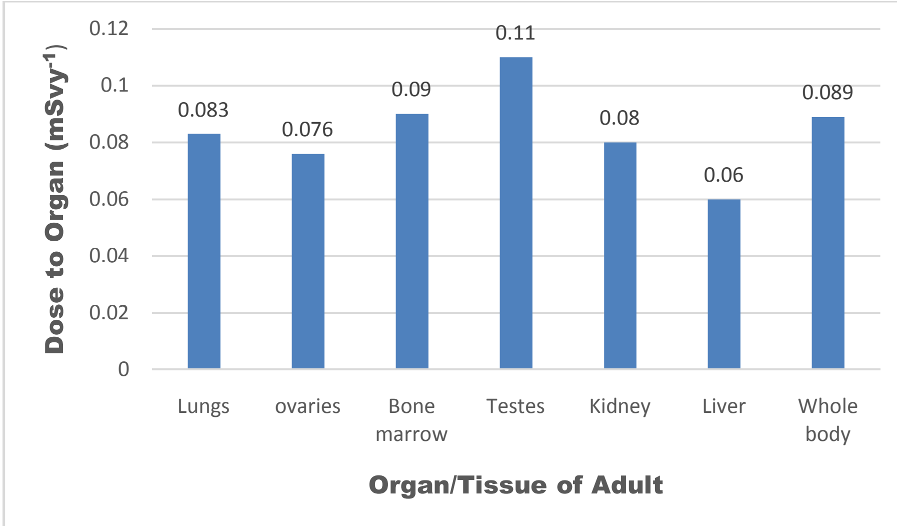

Fig. 5. Effective dose rate to different organs / tissues

The average exposure rate of the four oil spill sites were found to be lesser than the range of values obtained in Omoda vandalised oil pipeline areas, Rivers state by Anekwe et al. [25]. The overall results showed that in all the four study sites, the exposure rates are in agreement with the values reported by [10, 26, 27,28]. Also these values reported are in agreement with some previously reported results in similar environment [29-32], thus confirming the sources of these elevated values to the oil spills. The absorbed dose of radiation estimated in the Bon-ngia oil spill site ranges from 78.30 to 113.10 $nGyh^{-1}$ with mean value of 95.70 $nGyh^{-1}$ and Bolte-kpan oil spill site ranges from 87.00 to 165.30 $nGyh^{-1}$ with mean value of 114.84 $nGyh^{-1}$ while the absorbed dose rate at the Tee-oo-goo oil spill site ranges from 43.50 to 130.50 $nGyh^{-1}$ with mean value of 89.61 $nGyh^{-1}$ while the absorbed dose rate for Nupene oil spill site ranges from 69.60 to 130.50 $nGyh^{-1}$ with mean value of 98.31 $nGyh^{-1}$. The absorbed dose values obtained in Bolte-kpan oil spill site and Nupene oil spill site are higher than those obtained at Bon-ngia and Tee-oo-goo oil spill sites. This could be the effect of the rough cleaning excise performed in Bon-gia and Tee-oo-goo communities.

The mean outdoor gamma dose rate measured at Bon-ngia, Bolte-kpan, Tee-oo-goo and Nupene were higher than the values previously reported in Delta State (54.6 $nGyh^{-1}$) [32]. 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 (20.37 $nGyh^{-1}$) respectively [33]. The measured outdoor gamma dose rates are also within the values reported in Turkey (78.3-135.7 $nGyh^{-1}$) [34] and in poonch district (102 $nGyh^{-1}$) [35] 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 higher than the world permissible value of 89.0 $nGyh^{-1}$ as shown in Fig. 3. The annual effective doses estimated in the four oil spill sites of Rivers State (Bon-ngia, Bolte-kpan, Tee-oo-goo and Nupene) were higher than the results obtained in Akwa-Ibom [33] (0.02 $mSvy^{-1}$) and higher than the results in the control sites.

The annual effective doses in all the oil spill sites were lower than world average of 0.48 $mSvy^{-1}$. This implies that oil spillage in the area have not impacted on the background radiation level of the sampled communities. Excess lifetime cancer risks estimated for the entire studied oil spill sites were slightly higher than average world standard of 0.29 x 10^{-3} as shown in Fig. 4. The calculated effective dose rates delivered to the different organs in the adult body are presented in Fig. 5. It was shown that the testes recorded the highest dose of 0.11 $mSvy^{-1}$ while the liver recorded the least value with average value of 0.06 $mSvy^{-1}$. These results indicate that the estimated doses to the different organs are all below the international tolerance limits on dose to body organs of 1.0 $mSvy^{-1}$. The relatively higher dose to the testes and low dose intake to the liver is justified

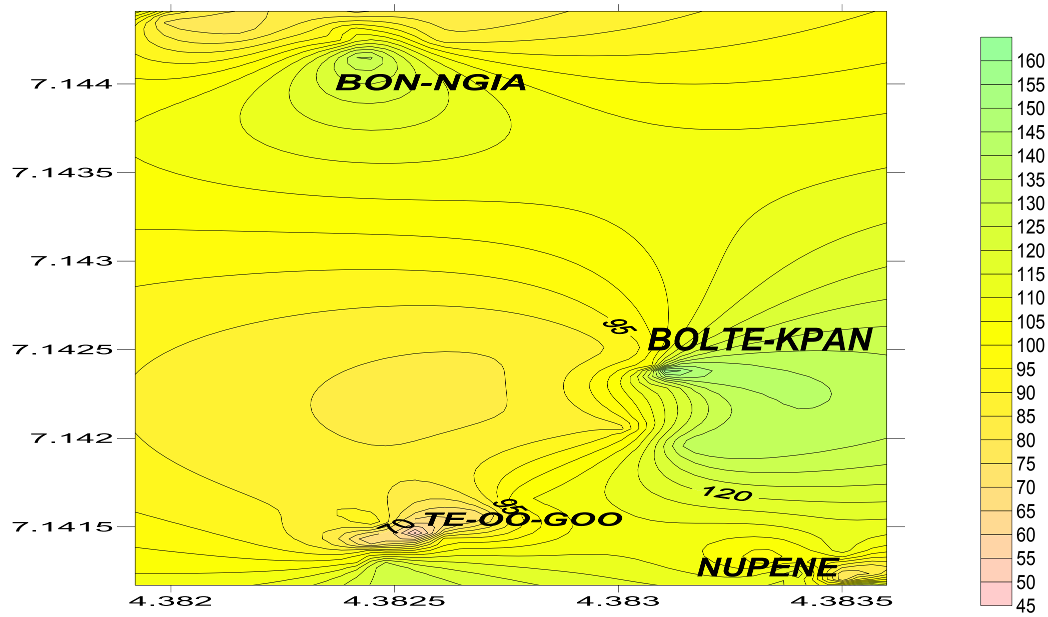

Fig. 6. Radiation contour map of the oil spill sites

by the food nutrient absorption rate [35,36]. This result shows that exposure to background ionizing radiation levels in all the sample oil spilled communities contributes insignificantly to the radiation dose to these organs in adults.

Fig. 6 represents the radiation contour of the oil spilled communities. The relative spacing of the contour lines indicates the relative slope of the surface. Fig. 6 shows the distribution of absorbed dose rate of high value of 140 nGyhr^{-1} and above in the areas bounded by latitudes 4º.382′ to 4º.3835′ and longitudes 7º.1415′ to 7º.1440′ and the areas include Bon-ngia, Bolte-kpan, Tee-oo-goo and Nupene of the oil spill sites. These areas are characterized with steady hilly zones of the oil spill sites in light green with elevated absorbed dose rates of 120 to 140 nGyhr^{-1} in Bon-ngia and Bolte-kpan while lowland distribution areas of the oil spill sites are yellow colored with absorbed dose rate of 75 to 100 nGyhr^{-1} in Tee-oo-goo and Nupene.

6. CONCLUSION

The terrestrial radiation exposure dose rate of oil spill communities (Bon-ngia, Bolte-kpan, Tee-oo-goo and Nupene) of Rivers State has been measured and health risk parameters estimated using appropriate radiation models.

All the health risk parameters evaluated are within their safe values except the excess lifetime cancer risk which was slightly higher than the world permissible level. The result showed that the oil spillage in the sampled communities did not have any impact on the background radiation level of the area.

The excess lifetime cancer risk calculated revealed that the chance of contracting cancer for residents of the study area who will spend all of their lives in those communities is low and the effective doses to the adult organs calculated are insignificant in all the organs except the testes. Though the oil spillage in the communities sample did not enhance the level of background ionizing radiation level, it might affect other environmental media.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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