Current Journal of Applied Science and Technology

38(3): 1-10, 2019; Article no.CJAST.52234
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Evaluation of Background Ionizing Radiation Level of Selected Oil Spill Communities of Delta State, Nigeria

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Authors' contributions

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

Article Information

DOI: 10.9734/CJAST/2019/v38i330362
Editor(s):
(1) Dr. João Miguel Dias, Associate Professor, Habilitation in Department of Physics, CESAM, University of Aveiro, Portugal.
Reviewers:
(1) Sokari, Sylvester Akinabie, Captain Elechi Amadi Polytechnic, Nigeria.
(2) Carpinelli Assunta, Italy.
(3) R. D. Mavunda, University of Johannesburg, South Africa.
(4) Paola Taydé Vázquez Villegas, Instituto Tecnológico Superior de Cintalapa, Chiapas, México.
Complete Peer review History: https://sdiarticle4.com/review-history/52234

Original Research Article

Received 11 August 2019
Accepted 20 October 2019
Published 01 November 2019

ABSTRACT

Study of the terrestrial Background Ionizing Radiation levels of selected Oil Spill Communities of Delta State, Nigeria have been carried out using Digilert 200 and Radalert 100 nuclear radiation monitor and a geographical positioning system (Garmin GPSMAP 76S). The exposure rates of the five communities ranges from 0.016 to 0.030 mRhr^{-1} at Jones Creek, 0.014 to 0.034 mRhr^{-1} at Opuwade Community, 0.015 to 0.037 mRhr^{-1} at Okpare community, 0.007 to 0.029 mRhr^{-1} at OtuJeremi community and 0.011to 0.040 mRhr^{-1} at Otor-Edo community. The obtained mean exposures rates were higher than ICRP standard limit of 0.013 mRhr^{-1}. The absorbed dose rates calculated ranged from 139.2 to 261 nGyh^{-1} (Jones Creek), 121.8 to 259.8 nGyh^{-1} (Opuwade Community), 130.5 to 321.9 nGyh^{-1} (Okpare community), 60.9 to 252.3 nGyh^{-1} (OtuJeremi community) and 95.9 to 348 nGyh^{-1} (Otor-Edo community). The estimated annual effective dose

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equivalent varies from 0.21 to 0.40 $\mathrm{mSvy^{-1}}$, 0.19 to 0.45 $\mathrm{mSvy^{-1}}$, 0.20 to 0.49 $\mathrm{mSvy^{-1}}$, 0.09 to 0.39 $\mathrm{mSvy^{-1}}$ and 0.15 to 0.53 $\mathrm{mSvy^{-1}}$ for Jones Creek, Opuwade Community, Okpare community, Otu Jeremi community and Otor-Edo community respectively while the excess lifetime cancer risk calculated for Jones Creek varies from (0.75 to 1.40) x 10^{-3}, Opuwade community (0.65 to 1.59)×10^{-3}, Okpare community (0.70 to 1.73) x 10^{-3}, OtuJeremi community (0.33 to 1.35)×10^{-3} and Otor-Edo community (0.51 to 1.87)×10^{-3}. All the mean values of absorbed dose, annual effective dose and excess lifetime cancer risk exceeded their recommended safe values. The results obtained in this work may not constitute any immediate health risk to the residents of the selected oil spill communities but long term exposure in the area may lead to detrimental health risks.

Keywords: Evaluation; community; background; exposure; Okpare; absorbed dose.

1. INTRODUCTION

Nigeria is blessed with a huge deposit of oil resources in the Niger Delta with an estimated crude oil reserves of approximately 22.5 billion barrels [1]. Advances in industrial development and human living standards, the demand for energy throughout the world is ever increasing [2]. World's economy is highly dependent on crude oil for energy production and its widespread use has led to enormous release of crude oil and its constituents into the environment [3].

The exploitation of crude oil and gas may bring economic benefits to a country, but its activities are destructive to the environment even at the safest and best operating practices unsafe acts may include the redistribution of naturally occurring radioactive materials (NORM) which are within the earth and brought to the surface during the processes [4].

Humans are continuously exposed to natural radioactivity which is widespread in the earth environment and exists in various geological formations such as earth crust, rocks, soils, plants, water and air [5, 6]. The level of terrestrial sources of natural radioactivity changes according to the geological structure of the area, geographic location, radiochemical state, and the distribution of radionuclides on Earth [7]. The external background ionizing radiation comes from three major pathways namely terrestrial radiation, cosmic radiation and man-made radiation [4]. Background ionizing radiation could be considered as environmental contamination especially when it exceeds safe occupational and public limits [8].The global average effective dose due to natural background radiation is 2.4 mSv/y, one third of which is due to external exposure and two thirds to internal exposure [9].

Aliyu and Ramli [10], reported that nearly 80% of the annual effective dose attributed to radiation exposure originates from background ionizing radiation, which is predominantly produced by cosmogenic and primordial radionuclides. Areas of high background ionizing radiations are Kerala (India), Guarapari (Brazil), Yangjiang (China), and Ramsar (Iran), a northern coastal city in Iran and radon prone areas receive radiation doses that are higher than the doses in the normal background radiation areas (NBRAs).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, skin erythema and mental retardation in children whom their mothers were exposed to radiation during pregnancy [11, 12]. Ovuomarie-kevin, et al. [11], evaluated health risks from exposure to low levels of ionizing radiation in some oil spilled communities of Rivers State, Nigeria and concluded that the chance of contracting cancer by residents of the study is low and the effective dose from present exposure rate to the adult organs investigated was insignificant.

The Niger Delta ecosystem contains one of the highest concentrations of biodiversity on the planet and supports abundant flora and fauna. Its arable terrain and water resources can sustain a wide variety of crops, lumbar and agricultural trees and more species of freshwater fisheries than any other wetland in West Africa [4]. Exploration has also resulted in various environmental problems such as oil spills, which have had a major impact on the Niger Delta ecosystem of the oil-producing areas [1]. Delta State is a part of the Niger Delta and is classified as containing the world's third largest wetland, with the most extensive freshwater swamp forest and rich biological diversity [13].The area is one of the highest in oil and gas production onshore of Niger Delta with about 172 oil wells with 10 flow stations and 14 flare stack sites. The area is criss-cross with network of pipelines carrying oil or gas to the flow stations from the various oil and gas wells [13, 14]. There is need to measure the main source of exposure to ionizing radiation in developing countries [9] and some studies have reported elevated BIR levels in some locations of Delta State. Hence the aim of this study is to measure the background ionizing radiation levels of oil spill communities of Delta state in order to evaluate the radiological health risk posed to residents.

2. MATERIALS AND METHODS

2.1 Study Area

The study locations are situated in Delta State, one of the 36 states of Nigeria. The study area lies within latitude 5º18” N and 5º86” N and longitude 5º33”E and. 6º40 E”, South-west of Niger Delta region of Nigeria [13]. This study was conducted in September, 2018. The measurements were made within the oil spill sites of Jones Creek, Opuwade Community, Okpare community, OtuJeremi community and Otor-Edo community of Delta State (Fig. 1).

2.2 Method

The *in-situ* measurements of Background Ionizing radiation were done using two well calibrated nuclear monitors; Digilert 200 and Radalert 100 (S.E. International Incorporation, Summer Town, USA) with the ability of measuring alpha, beta, gamma and x-ray radiation within the temperature range of -10ºC to 50ºC were used to measure background ionizing radiation of selected Oil spill sites. A geographical positioning system (Garmin GPSMAP 76S) was used to measure the precise longitude and latitude of sampling point. The Geiger-Muller tube generates a pulse current each time radiation passes through the tube and causes ionization. Each pulse is electronically detected and registered as a count. The radiation monitors were calibrated with a 137Cs source of specific energy at National Institute of Radiation Protection and Research, University of Ibadan and set to measure exposures rate in milli Roentgen per hour (mRhr^{-1}).

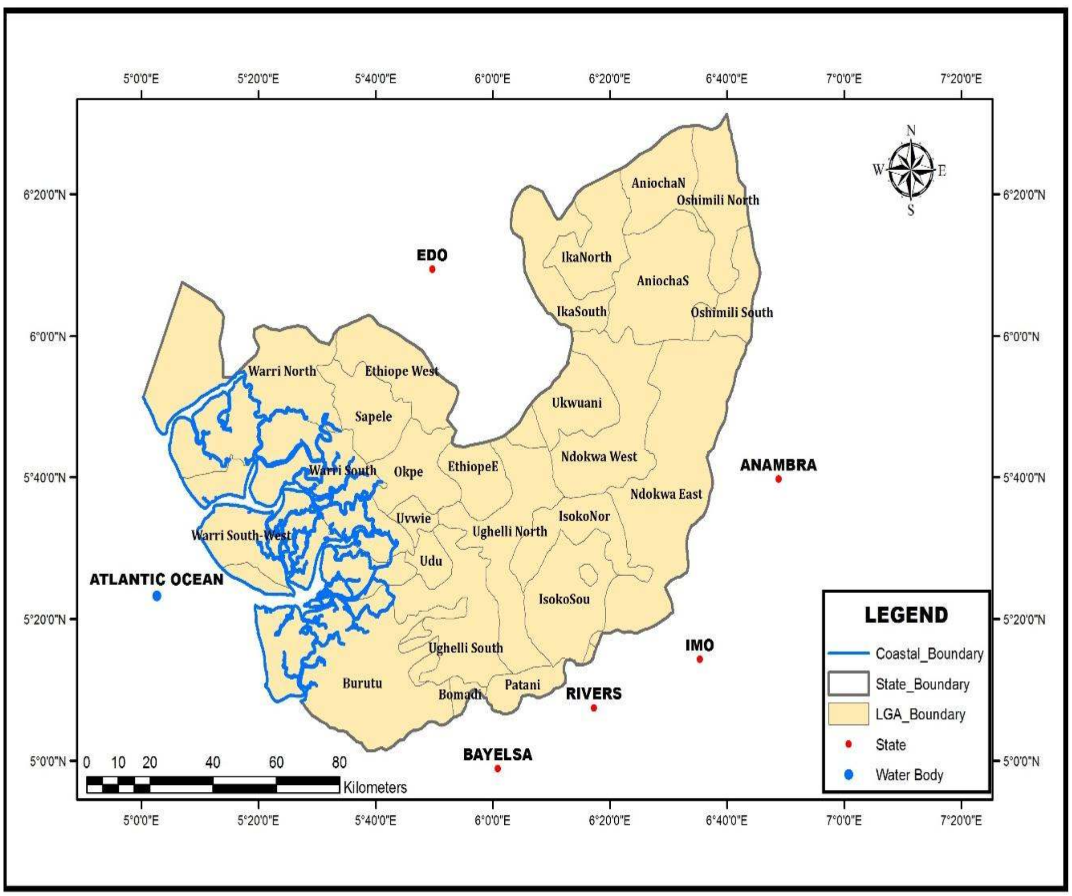

Fig. 1. Map of the study area

Readings were obtained between the hours of 1300 and 1600 since the exposure rate meter has a maximum response to environmental radiation within these hours [1]. The radiation exposure reading in all the Oil Spill sites were converted to absorbed dose using the conversion factor shown in equation 1, [15].

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

2.2.1 Absorbed dose

It is defined as is the measure of the amount of energy (radionuclides) deposited by ionization radiation in the human body for a given period [16]. The exposure rates were converted to absorbed dose rate using the conversion factor [17].

$$1\mu Rh^{-1} = 8.7\ nGyh^{-1} = 8.7 \times 10^{-3} /(\frac{1}{8760y}), \quad (2)$$

$$1\mu Rh^{-1} = 76.212\ \mu Gyy^{-1}$$

2.2.2 Annual Effective Dose Equivalent (AEDE)

The calculated absorbed dose rates were used to analyse the annual effective dose equivalent (AEDE) received by residents living in the study areas. Dose conversion factor of 0.7 Sv/Gy recommended by UNSCEAR for the conversion coefficient from the absorbed dose in air to the effective dose received by adults [18] and an occupancy factor of 0.25 for outdoor exposure was used Ola [15]. The annual effective dose equivalent was estimated using Equation 3.

$$\text{AEDE (outdoor)}(mSvy^{-1}) = \text{Absorbed dose}(nGyh^{-1}) \times 8760 \times 0.7 Sv/Gy \times 0.25 \quad (3)$$

2.2.3 Excess Life time 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 [19]. This study is based on the traditional worldwide radiation protection standards for late (stochastic) effects which are based on the LNT hypothesis. This is the probability of residents and workers in the various communities developing cancer. It was determined using Equation 4.

ELCR=AEDE ×Average duration of life (DL) × Risk factor (RF) (4)

Where AEDE, DL and RF is the annual effective dose equivalent, duration of life (70 years) and the risk factor (Sv^{-1}), fatal cancer risk per Sievert. For low dose background radiations which are considered to produce stochastic effects, ICRP 60 uses 0.05 for the public [20].

3. RESULTS AND DISCUSSION

Tables 1-5 show the *in-situ* exposure rates and the estimated radiological parameters of the various spill communities in Delta State. Figs. 2 and 3 show the comparison of estimated exposure rates and excess life cancer risk of the sampled communities respectively.

The results of the radiation exposure rate measured at Jones creek as presented in Table 1 show that the values ranged from 0.016 to 0.030 $mRhr^{-1}$ with a mean value of 0.022 $mRhr^{-1}$ while the exposure rate at Opuwade community and Opure community varies from 0.014 to 0.034 $mRhr^{-1}$with a mean value of 0.022 $mRhr^{-1}$ and 0.015 to 0.037 $mRhr^{-1}$ with a mean value of 0.023 $mRhr^{-1}$ respectively. The radiation exposure rate measured at OutJeremi and OtorEdo community varies from 0.007 to 0.029 $mRhr^{-1}$with a mean value of 0.019 $mRhr^{-1}$ and 0.011 to 0.040 $mRhr^{-1}$ with a mean value of 0.020 $mRhr^{-1}$ respectively. The mean values from the five communities studied exceeded ICRP standard of 0.013 $mRhr^{-1}$ [20]. This shows that the background ionizing radiation levels of those communities in Delta State are elevated and agrees with the results obtained in Effurun and Warri, Delta State, Nigeria by Agbalagba, [18]. This higher values obtained in these studied communities are mainly due to anthropogenic activities in the area and oil spill from oil pipelines. The es mean values from the current study were higher when compared with the results from coastal communities in Ndokwa East, Delta State, Nigeria [17], with similar geological ecosystem.

The mean absorbed dose rates estimated from the exposure rates of five communities were 193.3 $nGyh^{-1}$ for Jones creek, 194.3 $nGyh^{-1}$ for

Opuwade community, 203.0 nGyh^{-1} for Okpure community, 168.2 nGyh^{-1} for OtuJeremi community and 175.6 nGyh^{-1} for Otor-Edo community. These obtained values were higher than world permissible value of 89 nGyh^{-1} and higher than the mean values obtained from solid mineral mining sites at Benue State, Nigeria [15]. The mean annual effective dose equivalent recorded in the oil spill sites of Jones creek, Opuwade community, Okpure community, OtuJeremi community and Otor-Edo community 0.30, 0.30, 0.31, 0.26 and 0.27 mSvy^{-1} respectively. The obtained average values of the annual effective dose equivalent were lower than the world average of 0.48 mSvy^{-1} and higher than the values obtained from Ughelli North local government area, Delta State, Nigeria by Agbalagba, et al. [21] and the results obtained from selected oil spill communities of Bayelsa State, Nigeria [22]. These results indicate the possible radiological contamination of the sampled sites.

Table 1. Mean radiation exposure rate and estimated risk parameters of jones creek

s/n	Location	Geographical coordinates	Av.exposure rate (mRh^{-1})	Absorbed dose $\mathrm{nGy/hr}$	AEDE (mSv/yr)	ELCR X 10^{-3}
1	Ajapawei. Q.	N05º29' 41.7" E005º42'16.2"	0.024±0.001	208.8	0.32	1.12
2	Jones Street	N05º29' 22.3" E005º42'02.8"	0.028±0.003	243.6	0.37	1.31
3	Osowarei compound	N05º29'39.4" E005º42'21.8"	0.016±0.002	139.2	0.21	0.75
4	Kolokuwei .Q.	N05º29' 49.1" E005º42'38.7"	0.03±0.021	261.0	0.40	1.40
5	Opokuma	N05º29' 44.6" E005º42'26.2"	0.022±0.001	191.4	0.29	1.03
6	Main Jetty	N05º29' 05.9" E005º42' 1.4"	0.017±0.001	147.9	0.23	0.79
7	Pere Compound	N05º29' 19.8" E005º42'39.9"	0.019±0.002	165.3	0.25	0.89
8	Community Health Center	N05º29' 26.0" E005º42'27.5"	0.024±0.002	208.8	0.32	1.12
9	Ekogbene	N05º29' 52.0" E005º42'07.9"	0.02±0.001	174.0	0.27	0.93
10	Unity Hall	N05º29' 38.6" E00 º42' 0.4"	0.013±0.005	113.1	0.17	0.61
	MEAN		**0.022±0.004**	**193.3±41.4**	**0.30±0.06**	**1.04±0.22**

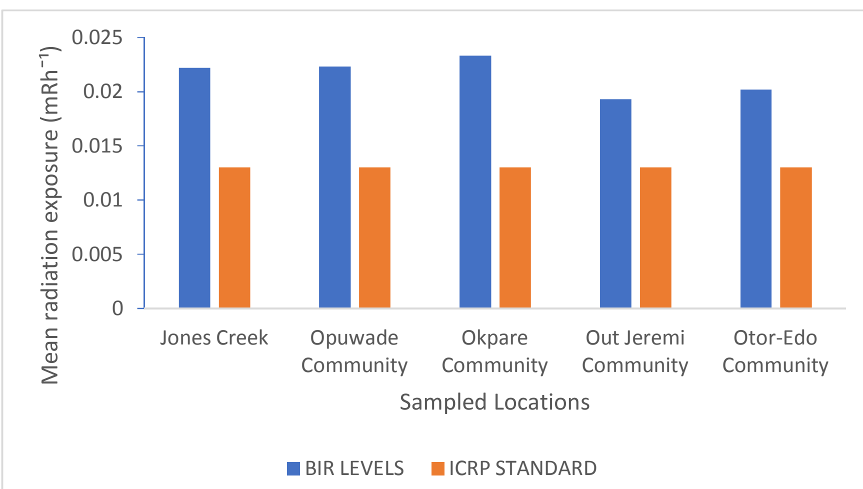

Fig. 2. Comparison of measured exposure rate with ICRP Standard

Table 2. Mean radiation exposure rate and estimated risk parameters of opuwade community

s/n	Location	Geographical coordinates	Av. Exposure Rate (mRh^{-1})	Absorbed dose$\mathrm{Gy/hr}$	AEDE (mSv/yr)	ELCR $\mathrm{X}10^{-3}$
1	Ode Quarter	N05º36'03.9" E005º19'34.3"	0.024±0.002	208.8	0.32	1.12
2	Eguregu Quarter	N05º36 21.4" E005º19'52.8"	0.026±0.001	226.2	0.35	1.21
3	Ebima Quarter	N05º36 63.3" E005º19'44.0"	0.019±0.002	165.3	0.25	0.89
4	Eguregu	N05º36 57.5" E005º19'38.3"	0.016±0.001	139.2	0.21	0.75
5	Odeweri	N05º36 51.2" E005º19'32.6"	0.034±0.008	295.8	0.45	1.59
6	Jetty	N05º36 42.7" E005º19' 6.1"	0.014±0.004	121.8	0.19	0.65
7	Chairman Compound	N05º36 36.5" E005º19'51.9"	0.018±0.002	156.6	0.24	0.84
8	Tamigbe Quarter	N05º36 28.4" E005º19'31.9"	0.028±0.007	243.6	0.37	1.31
9	Edumaweri	N05º36 06.7" E005º19'29.6"	0.022±0.003	191.4	0.29	1.03
10	Town Hall	N05º36 15.0" E005º19'07.4"	0.014±0.001	121.8	0.19	0.65
	Mean		**0.022±0.003**	**194.3±55.4**	**0.30±0.08**	**1.04±0.30**

Table 3. Mean radiation exposure rate and estimated risk parameters of okpare community

S/N	Location	Geographical coordinates	Av. Exposure Rate (mRh^{-1})	Absorbed dose (nGyh^{-1})	AEDE (mSvyr^{-1})	ELCR X 10^{-3}
1	Okpaki Street	N05º27'42.7" E005º44'09.4"	0.022±0.001	191.4	0.29	1.03
2	Adawe	N05º27' 39.6" E005º44'21.8"	0.03±0.019	261.0	0.40	1.40
3	Adawel Water Side	N05º27' 40.9" E005º44'16.2"	0.019±0.002	165.3	0.25	0.89
4	Obare	N05º27' 38.5" E005º44'38.1"	0.015±0.001	130.5	0.20	0.70
5	Gorde Street	N05º27'36.8" E005º44'26.9"	0.018±0.001	156.6	0.24	0.84
6	Market	N05º27' 34.6" 7E005º44'581.0"	0.023±0.004	200.1	0.31	1.07
7	Main Jetty	N05º27'0.028" E005º44' 31.7"	0.028±0.011	243.6	0.37	1.31
8	Barrack	N05º27' 37.5" E005º44' 19.3"	0.018±0.001	156.6	0.24	0.84
9	Edjeba	N05º27' 42.3" E005º44' 47.1"	0.037±0.004	321.9	0.49	1.73
10	Town Hall	N05º27' 33.2" E005º44' 00.5"	0.012±0.005	104.4	0.16	0.56
	MEAN		**0.023±0.005**	**203±61.5**	**0.31±0.09**	**1.09±0.33**

Table 4. Mean radiation exposure rate and estimated risk parameters of otujeremi community

S/N	Location	Geographical coordinates	Av.Exposure Rate $mRhr^{-1}$	Absorbed dose $nGyh^{-1}$	AEDE ($mSvy^{-1}$)	ELCR X 10^{-3}
1	Secretarial	N05º25'27.7" E005º52'42.6"	0.023±0.001	200.1	0.31	1.07
2	Ovies Palace	N05º25' 33.6" E005º52'35.7"	0.029±0.01	252.3	0.39	1.35
3	Okwagbe Road	N05º25' 46.1" E005º52'34.6"	0.022±0.003	191.4	0.29	1.03
4	Ukpedri	N05º25' 54.6" E005º52'33.7"	0.022±0.005	191.4	0.29	1.03
5	Primary School Ughievieri M	N05º25' 59.3" E005º2'34.0"	0.019±0.002	165.3	0.25	0.89
6	Uwvie Street	N05º25'00.49" E005º52'42.8"	0.016±0.001	139.2	0.21	0.75
7	Uwvie Street II	N05º25' 58.1" E005º52'45.8"	0.007±0.003	60.9	0.09	0.33
8	Jeremi Junction	N05º25' 17.1" E005º52'36.1"	0.018±0.001	156.6	0.24	0.84
9	Oyibo Street	N05º25'17.0" E005º52'12.5"	0.021±0.004	182.7	0.28	0.98
10	Osita Avenue	N05º25' 22.6" E005º52'31.1"	0.018±0.003	156.6	0.24	0.84
11	Otor-udu/Jeremi Junction	N05º25' 47.6" E005º52'19.6"	0.018±0.001	156.6	0.24	0.84
12	Nigerian Gas Company	N05º25' 52.6" E005º52'23.4"	0.019±0.003	165.3	0.25	0.89
13	Baptist Church (Good Shepherd)	N05º25' 11.9" E005º52'41.1"	0.013±0.003	113.1	0.17	0.61
	MEAN		**0.019±0.003**	**168.2±44.9**	**0.26±0.07**	**0.90±0.24**

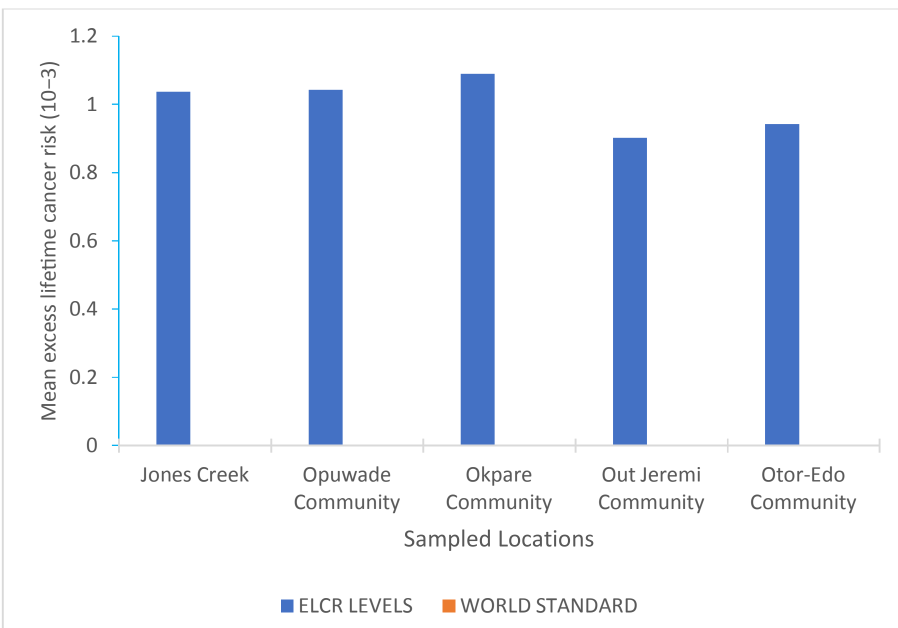

Fig. 3. Comparison of mean ELCR of mineral deposition with ICRP permissible limit

Table 5. Mean radiation exposure rate and estimated risk parameters of otor-edo community

S/N	Location	Geographical coordinates	AVE. BIR value mRhr^{-1}	Absorbed dose $\mathrm{nGy/hr}$	AEDE (mSv/yr)	ELCR X 10^{-3}
1	Odowogba	N05º28' 16.4" E005º54'14.4"	0.011±0.001	95.7	0.15	0.51
2	Odowogba II	N05º25' 16.1" E005º52'11.4"	0.016±0.002	139.2	0.21	0.75
3	Ighovo	N05º25' 18.7" E005º52'08.5"	0.014±0.004	121.8	0.19	0.65
4	Odogba	N05º25' 15.1" E005º52'18.3"	0.011±0.004	95.7	0.15	0.51
5	Agbabi Compound	N05º25' 13.0" E005º52'25.6"	0.013±0.001	113.1	0.17	0.61
6	Ekogbowe I	N05º25' 11.9" E005º52'26.7"	0.018±0.002	156.6	0.24	0.84
7	Ekogbowe II	N05º25' 12.1" E005º52'31.9"	0.028±0.003	243.6	0.37	1.31
8	Ekogbowe III	N05º25' 11.4" E005º52'35.0"	0.016±0.004	139.2	0.21	0.75
9	Ogoro Street	N05º25'08.9" E005º52'39.7"	0.04±0.028	348	0.53	1.87
10	Akpovire Compound	N05º25' 11.5" E005º52'24.4"	0.035±0.007	304.5	0.47	1.63
11	Echugba	N05º25' 15.3" E005º52'23.6"	0.02±0.003	174	0.27	0.93
12	Ikpessu Compound	N05º25' 16.6" E005º52'21.9"	0.011±0.001	95.7	0.15	0.51
	MEAN		**0.020±0.005**	**175.6±85.8**	**0.27±0.13**	**0.94±0.46**

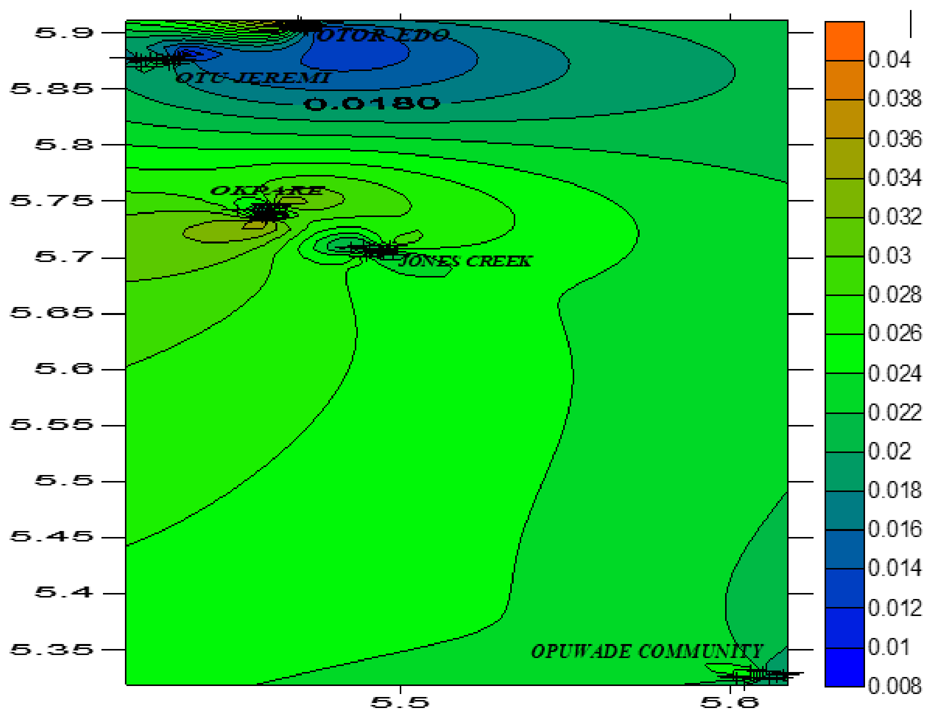

Fig. 4. Radiation contour map of Oil spill locations

The estimated mean excess lifetime cancer risk (ELCR) for the various oil spill communities are higher than the world standard of 0.29×10^{-3} which implies that chance of contacting cancer overtime by residents of these communities is probable. The current results of this study are higher than values obtained from some oil spilled communities of River State, Nigeria [11]. Fig. 4 represents the radiation contour of the oil spilled communities. The relative spacing of the contour lines indicates the relative slope of the surface and the distribution of radiation exposure rates of high value of 0.034 mR/h and above in the areas bounded by latitudes N05º25'08.9" to N05º 36' 63.3" and longitudes E005º 52' 39.7" to E005º 19' 44.0"and these areas include Opuwade community, Jones Creek, Out-Jeremi, Okpare and Otor-Edo of the oil spill communities. These areas are characterized with steady undulating zones of the oil spill communities in light to dark green areas on the contour plot with elevated radiation exposure rates of 0.018 to 0.030 mR/h in Opuwade community and Jones Creek. Radiation exposure (0.020 to 0.022 mR/h) in gradual slope areas of Opuwade community and Jones Creek were slightly high and were within the elevated zones. The saddle area of the contour map for the oil spill communities were Otor-Edo and few part of Otu-Jeremi in the light to dark blue coloured areas with radiation exposure rates between 0.008 to 0.013 mR/h, these areas have low radiation exposure. Hilly regions was observed in Okpare community of the oil spill communities in orange colour zones with most elevated radiation exposure rate 0.036 mR/h, this shows the higher the elevation the higher the background radiation exposure.

4. CONCLUSION

The study of the terrestrial Background Ionizing Radiation levels of Oil Spill Communities of Jones Creek, Opuwade Community, Okpare community, OtuJeremi community and Otor-Edo community in Delta State, Nigeria have been carried out in order to estimate the radiological health risk parameters. The following conclusion were deduced from the present study.

1. The average value of the background ionizing radiation levels of the communities were higher than the ICRP permissible value.
2. The computed absorbed dose rate in all oil spilled communities were higher than the world standard value.
3. The calculated mean annual effective dose equivalent rate (AEDE) in all oil spilled communities were lower than the world permissible value but similar to recorded values from other environments.
4. The estimated excess lifetime cancer risk (ELCR) values are higher than world standard and there could be probability of developing cancer over time for residents of the study areas.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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