International Journal of Oil, Gas and Coal Engineering
2026, Vol. 14, No. 5, pp. 108–116
https://doi.org/10.11648/j.ogce.20261405.11

Research Article

Assessment of Radiation Exposure Rate and Excess Lifetime Cancer Risk in Oil-Producing Communities of Edo State, Nigeria

Igbinake Osakpamwan, Mgbemere Chimmuanya James*, Avwiri Gregory Onomakere, Ononugbo Chinyere Philomena

Department of Physics, University of Port Harcourt, Choba, Nigeria

Abstract

The exposure of humans and other living matters in the environment to ionizing radiation is traceable to natural and artificial activities such as oil and gas exploration. This study presents the result of assessment of ionizing radiation exposure and excess lifetime cancer risk in oil producing communities of Edo state Nigeria. An *In-situ* measurement of radiation exposure rate was done using well calibrated radiation detector (Radalert-100). From the ionizing radiation exposure rate, the absorbed dose, annual effective dose and excess lifetime cancer risk were calculated by standard methods. Results showed that the outdoor mean absorbed dose rates due to the ionizing radiation exposure rate in the various communities of the four LGAs, estimated were 137.837 $nGyh^{-1}$, 98.457 $nGyh^{-1}$, 92.83 $nGyh^{-1}$, 75.95 $nGyh^{-1}$, 78.76 $nGyh^{-1}$, 118.15 $nGyh^{-1}$, 73.13 $nGyh^{-1}$ and118.15 $nGyh^{-1}$ respectively for Ohamaha, Ologbo, Obaretin, River A, River B, EDSPADEC, Gelegele Town, and Flow Station. The obtained values for absorbed dose rate and excess lifetime cancer risk (ELCR) in Ohamaha, Ologbo, Obaretin, EDSPADEC and Flow station, are higher than the world average value of 89 $nGyh^{-1}$ (UNSCEAR, 2000) 0.29×10^{-3} respectively. The study concluded that the chance of the workers and those living around such locations to be exposed to cancer overtime in these communities is high due to the high value of ionizing radiation exposure rate and high values of excess lifetime cancer risk obtained in this study which is attributed to oil exploration activities within the study area. Hence, the implication is that there are possibilities of stochastic effects on the exposed individuals.

Keywords

Exposure, *In-situ,* Exploration, Radiation, Value

1. Introduction

Humans and other living matter in the environment are continuously exposed to ionizing radiation that stem from both natural and man-made sources. The principal origins of ionizing radiation exposure are natural sources. The main constituents of natural radiation are cosmic rays and gamma ray emitters in soils, building materials, water, food and air. Varieties of human activities like oil exploration and exploitation, mining and milling natural resources may result in Technically Enhanced Naturally Occurring Radioactive Materials

*Correspondence: Mgbemere Chimmuanya James (jamesmgbemere@gmail.com)

Received: 25 November 2025; **Accepted:** 9 January 2026; **Published:** 20 September 2026

(TENORMs) in the products and by-products of those activities [2]. The presence of radioactive materials and radiation generators could be harmful to humans and the environment. High level of background ionizing radiation due to activity concentrations of NORMs may increase risk of cancer and genetic effects in the population [24]. The evaluation of ionizing radiation exposure rate due to background ionizing radiation levels is, therefore, very desirable, especially in communities where oil prospecting is prevalent [10]. External background ionizing radiation (BIR) exposure can come from three major pathways namely; terrestrial radiation (primordial), cosmic radiation (cosmogenic) and man-made radiation (anthropogenic). In public health management of radiation emergencies, one of the essential components of integrated assessment is to quickly and accurately assess and categorize the exposure pathways. [22]

Natural radioactivity is associated with natural sources such as uranium deposits in oil and natural gas fields. Generally, Oil exploration is known to have great impact on the environment due to the presence of natural radionuclides in crude oil [13]

More than 80% of the worldwide environmental radiation is from natural sources which are widespread in the earth environment [33]. There exist radiation in various geological formations such as earth crust, rocks, soils, plants, water and air [31]. However, environmental radiation exposure to man is caused by the presence of primordial radionuclides such as 232Th, 238U, 235U, and 40K in the earth's crust and atmospheric cosmic rays' interaction [32]. Radiation is often time used to refer to ionizing radiation, defined as the emission of energy or rays, wave motion or streams of particles such as electrons or photons or a mixture of them. It can also be defined as the emitted energy that travels as electromagnetic waves. Hence, radiation describes energy in motion, which radiate from its source. Ionizing radiation has a higher frequency and shorter wavelength than non-ionizing radiation, and can be a serious health hazard. Exposure to ionizing radiation can cause burns, radiation sickness, cancer and genetic damage [17]. Ionizing radiation is a form of radiation that has enough energy to ionize biologic molecules i.e. remove electrons from atoms or molecules when it passes through or collides with some materials.

The background ionizing radiation level due to ionizing radiation exposure of selected oil spill communities of Delta State, Nigeria, has shown to have mean values of absorbed dose, annual effective dose and excess lifetime cancer risk values that exceeded their recommended safe values [6].

2. Materials and Methods

2.1. The Study Area

Edo state is one of the states in the Niger Delta region, located in the South-South geopolitical zone of the Federal Republic of Nigeria. The study areas are located in the Southern part of Edo State, Nigeria and bounded to the south by the Delta state. The area spans across four (4) local government areas, Ikpoba Okha, Ovia Northeast, Egor and Oredo L.G.A.

Ikpoba Okha L.G.A. was splited into six locations (Oredo flow station, Modular Refinery/LPG terminal, Obaretin forest reserve, Ohen Primary School, Ologbo market and Ologbo river), while Ovia North East was split into four locations (Gelegele Gbene town, EDSOGPADEC quarters, Gelegele river and Flow station). While for Egor and Oredo L.G.As only background ionizing radiation samples were collected.

The choice of the sampling locations is birthed from the Oil and Gas exploration activities going on the area with the intention of assessing how its influences and impact on the human, environmental and economic activities of the area.

The exploration of oil and gas in the Niger Delta region remains a major source of environmental degradation, causing deterioration of the environment through depletion of resources such as air, water and soil, the destruction of the ecosystems, habitat destruction and pollution which results in considerable change in the environment [3].

Those communities, apart from being the oil producing communities, are inhabited mainly by farmers, fishers and traders. They subsist mainly by raising livestock, fishing and being involved in other types of agriculture. They are rural population, with diet based mainly on the consumption of rice, yam, cassava, plantain, cocoyam, meat and fish.

The Oil producing communities in Edo state are Iguemokhua, Ologbo, Obayantor, Obagie, Uroho, Iyanomo N' Iyekorhionmwon, Ajoki, Oben and Obozogbe Nugu, Ikobi, Iguelaba, Orogho, Gelegele, Ughoton and Iwevbo across three L.G.A Ikpoba okha, Ovia N.E. and Orhiomwon.

The ethnic Nationalities that live in the study area includes; Bini, Urhobo and Ijaws. The major economic activities of these people are fishing, farming, hunting and trading [1]. The study area is endowed with abundant natural resources in agriculture and forestry.

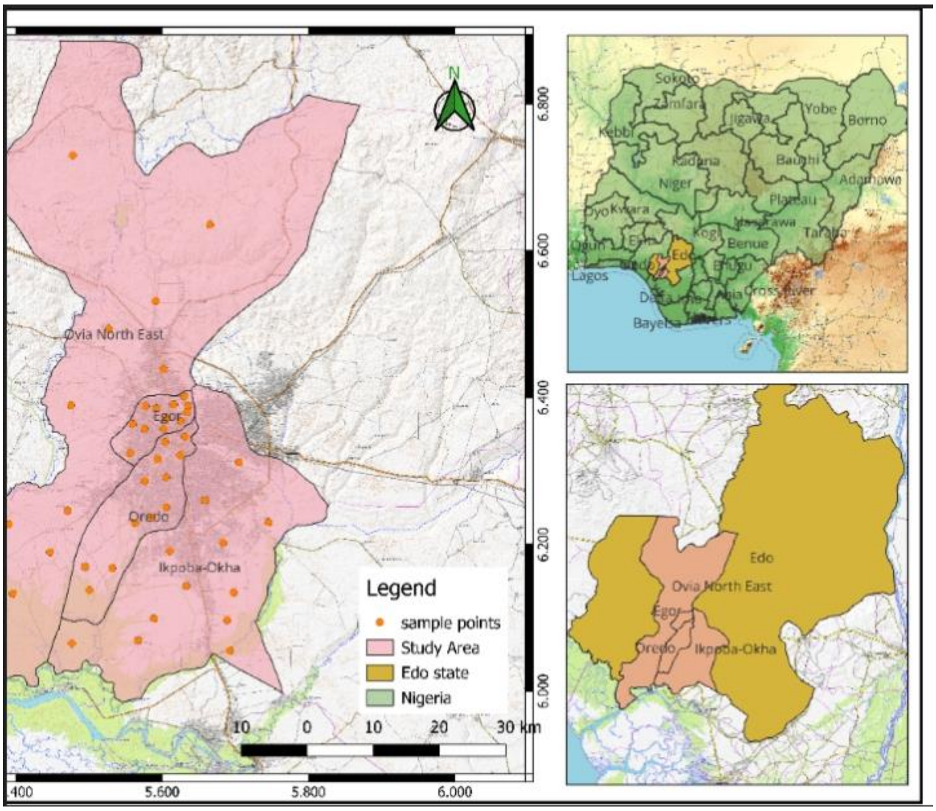

Figure 1. Map of Edo State showing the Study Area.

2.2. Method of Data Collection

The handheld digital Radiation Detector, Radalert-100 with up-to-date calibration was used for background ionizing radiation exposure rate measurement. Global Positioning System (GPS) was also employed to ascertain the coordinate of the locations of sample collection. The digital radiation monitor contains a Geiger Muller tube capable of detecting and measuring alpha, gamma as well as low beta radiation.

3. Radiation Hazard Indices

3.1. Absorbed Dose (D)

Air-absorbed dose D, is the radiation energy absorbed or deposited per unit mass on matter. The outdoor exposure rate in μRh^{-1} is converted into absorbed dose rate using the conversion factor expressed in equation (1) [28].

$$1\ \mu R/h = 8.7\ nGy\ h^{-1} \quad (1)$$

3.2. Annual Effective Dose Equivalent (AEDE)

The Annual effective Dose Equivalent is calculated using the absorbed dose, dose conversion factor of 0.7 Sv/Gy and the occupancy factor for outdoor of 0.25 (6 hours of 24 hours). The annual effective dose is estimated using equation (2) [25].

$$AEDE(mSv/y) = D(nGy/h) \times 0.7 \times 0.25 \quad (2)$$

3.3. Excess Lifetime Cancer Risk (ELCR)

This quantity is used to describe the potential carcinogenic effects that are characterized by estimating the probability of cancer incidence in a population of individuals for a specified lifetime from projected intakes and exposures [29].

$$ECLR = AED\ X\ DL\ X\ RF \quad (3)$$

Where: AED is Annual Effective Dose in msv, DL = Average lifespan (70 years)

RF = fatal cancer risk per sievert (Sv^{-1}) = 0.05.

4. Result

Table 1. Radiation Exposure Rate and Associated Radiological Parameters of Oil Producing Communities in Edo State.

S/N	Sampling Location	Sampling Code	GPS Reading	Exposure Rate (mRh^{-1})	Absorbed Dose ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR ($\times 10^{-3}$)
1	Ohamaha	Ohh	6°4'12"N 5°36'26"E	0.017	143.46	0.18	0.50
2	Ohamaha 2	OHt	6°4'50"N 5°34'17"E	0.017	143.46	0.18	0.50
3	Ohamaha 3	OHT	6°4"10"N 5°34'0"E	0.015	126.59	0.16	0.44
4	Ologbo	OLN	6°4'53"N 5°40'15"E	0.013	109.71	0.13	0.36
5	Ologbo 2	OLt	6°4'0"N 5°38'0"E	0.013	109.71	0.13	0.36
6	Ologbo 3	OLT	6°5'15"N 5°37'11"E	0.009	75.95	0.09	0.25
7	Obaretin 1	Obt	6°5'0"N 5°40'50"E	0.013	109.71	0.13	0.36
8	Obaretin 2	OBt	6°5'50"N 5°40'52"E	0.013	109.71	0.13	0.36
9	Obaretin 3	OBT	6°4'46"N 5°39'12"E	0.009	75.95	0.09	0.25
10	Ologbo River	OLr	6°3'43"N 5°39'08"E	0.009	75.95	0.09	0.25
11	Ologbo River 2	OLR	6°2'10"N 5°40'16"E	0.009	75.95	0.09	0.25
12	Ologbo River 3	OLgR	6°3'45"N 5°39'0"E	0.009	75.95	0.09	0.25
13	EDSPADEC	EDP 1	6°10'44"N 5°20'46"E	0.015	126.59	0.16	0.44
14	EDSPADEC-2	EDP 2	6°10'24"N 5°22'52"E	0.015	126.59	0.16	0.44
15	EDSPADEC-3	EDP-3	6°10'56"N 5°21'37"E	0.012	101.27	0.12	0.33
16	Gelegele Town	GLT-1	6°6'57"N 5°20'41"E	0.009	75.951	0.09	0.24
17	Gelegele Twn-2	GLT-2	6°6'37"N 5°20'10"E	0.01	84.39	0.10	0.28
18	Gelegele Twn-3	GLT-3	6°7'15"N 5°20'32"E	0.007	59.073	0.07	0.20
19	Flow station-1	FS-1	6°10'12"N 5°21'36"E	0.015	126.59	0.16	0.44
20	Flow station-2	FS-2	6°10'19"N 5°21'51"E	0.015	126.59	0.16	0.44
21	Flow station-3	FS-3	6°10'56"N 5°21'49"E	0.012	101.27	0.12	0.33

S/N	Sampling Location	Sampling Code	GPS Reading	Exposure Rate (mRh^{-1})	Absorbed Dose ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR ($\times 10^{-3}$)
22	Gelegele Rv-1	GLR-1	6°9'36"N 5°20'43"E	0.01	84.39	0.10	0.28
23	Gelegele Rv-2	GLR-2	6°9'42"N 5°20'57"E	0.01	84.39	0.10	0.28
24	Gelegele Rv-3	GLR-3	6°8'55"N 5°20'12"E	0.008	67.512	0.08	0.22
	Mean			0.011833	99.86275	0.12125	0.335416
		STD		0.00299	25.21599	0.033791	0.092735

Table 2. *Mean Radiation Exposure Rate and Associated Radiological Parameters in Oil Producing Communities in Edo State.*

S/N	Sampling Area	Sampling Code	Exposure Rate (mRh^{-1})	Absorbed Dose ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR ($\times 10^{-3}$)
1	Ohamaha	OHM	0.016	137.837	0.174	0.609
2	Ologbo	OLB	0.012	98.457	0.117	0.4095
3	Obaretin	ORN	0.011	92.83	0.117	0.4095
4	River A	RVO	0.009	75.95	0.090	0.315
5	EDSPADEC	EDP	0.014	118.15	0.147	0.5145
6	Gelegele Town	GLW	0.009	73.13	0.087	0.3045
7	Flow Station	FST	0.014	118.15	0.147	0.5145
8	River B	RVG	0.009	78.76	0.094	0.329
	Mean		0.01175	99.158	0.121625	0.4256875
		STD	0.002712	23.574	0.0317037	0.11096

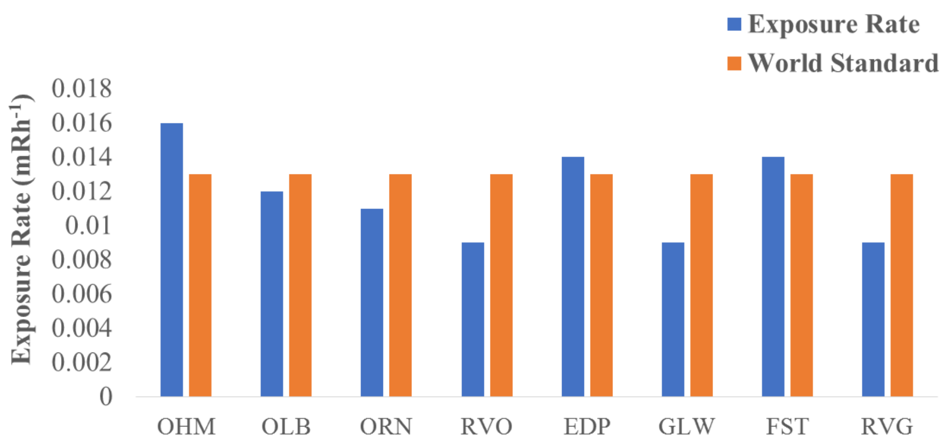

Figure 2. *Comparison of exposure rate with world standard.*

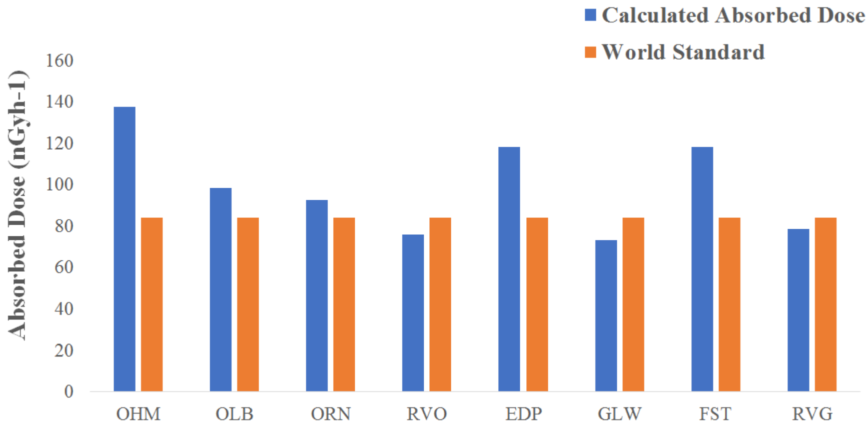

Figure 3. Comparison of estimated absorbed dose with world standard.

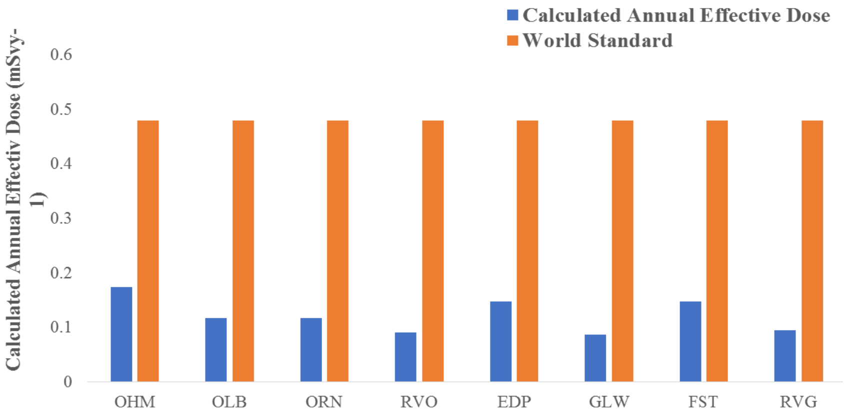

Figure 4. Comparison of calculated annual effective dose with world standard.

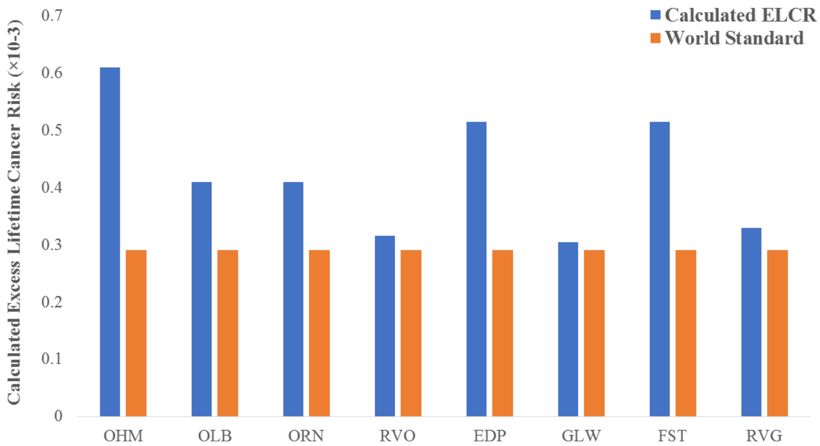

Figure 5. Comparison of excess lifetime cancer risk with world standard.

5. Discussion

The result of the radiation exposure rate values measured in Ologbo ranged between 0.009 to 0.017 $mRhr^{-1}$ with a mean value of 0.012$mRhr^{-1}$. While the exposure rate at Obaretin varies from 0.008 to 0.015 $mRhr^{-1}$ with a mean value of 0.011 mRhr-^{1}, for Ohamaha a value of 0.016 $mRhr^{-1}$ and for EDSPADEC with a value of 0.014 $mRhr^{-1}$. The values of exposure rates from Gelegele Town, Flow Station and River B, are (0.009, 0.014 and 0.009) $mRhr^{-1}$ respectively. Hence, the values of ionizing radiation exposure rate in less than 50% of the study area are below the ICRP standard value of 0.013$mRhr^{-1}$ [20]. However, the standard deviation (0.00271 $mRhr^{-1}$) of the radiation exposure rate is below the world standard value.

In addition, all the mean exposure rates from the studied communities within the four LGAs are like that reported by [5, 11] in selected oil spill Communities of Bayelsa State and by [4] in selected oil spilled areas within Rivers State. But the values are by far lower when compared to that reported by [8] while profiling the hydrocarbon belt of Nigeria. However, the values were found to be higher when compared with the average exposure rate value of 0.0065 mRh^{-1} obtained [19], to the population of Caspian coastal provinces in North Iran. They are also higher than the values of 7.00 and 29.00 mRh^{-1} obtained [26] for coastal (oil producing) communities in Ndokwa East, Delta State, Nigeria.

Thus, the ionizing radiation exposure rate of the entire oil producing communities ranges between 0.004 mRh^{-1} to 0.017 mRh^{-1}, and this is similar to the average background ionizing radiation (BIR) value of 0.008-0.015 mRh^{-1} as reported. More than 50% of radiation exposure rates from the study area was found to be lower than the world average, unlike the values of 0.0156 $mRh\text{-}^{1}$ measured [9] from coastal (oil producing) communities in Burutu L.G.A, of Delta State.

The mean absorbed dose rates due to the ionizing radiation exposure rate in the various communities of the four LGAs were 137.837 $nGyh^{-1}$, 98.457 $nGyh^{-1}$, 92.83 $nGyh^{-1}$, 75.95 $nGyh^{-1}$, 78.76 $nGyh^{-1}$, 118.15 $nGyh^{-1}$, 73.13 $nGyh^{-1}$ and118.15 $nGyh^{-1}$ respectively for Ohamaha, Ologbo, Obaretin, River A, River B, EDSPADEC, Gelegele Town, and Flow Station.

The obtained values for absorbed dose rate in Ohamaha, Ologbo, Obaretin, EDSPADEC and Flow Station were higher than the world average value of 89 $nGyh^{-1}$ [30], this could be due to the presence of Oil and Gas in these areas, while River A, River B and Gelegele Town recorded lower values as the areas have lower Oil exploration activities. The mean absorbed dose rates in two of the studied areas (Ikpoba-okha and Ovia N.E) were higher when compared with values obtained by Abomoosa and Minab in oil producing Hormozgan province Southeast of Iran [12] and also above the mean value of 69.63 nGy/h in oil fields and wells environments. However, values of mean absorbed dose rates in all the LGAs are lower than the value of 810.84 $nGyh^{-1}$ obtained by [23] for the ADR measurement in a selected region of AL-Qizwini Najaf in Iraq.

The mean annual effective dose equivalent recorded in the study area has values that are lower than the worldwide average of 0.48 $mSvy^{-1}$ set by [16-18, 21, 31], but similar to the results obtained from selected oil spill communities of Bayelsa State, Nigeria and that reported by [3] in Effurun and Warri of Delta State. However, the values are lower than the ICRP safe limit of 1.0 $mSvy^{-1}$ for outdoor annual dose environment. These results indicate minimal possible radiological contamination of the sampled sites [14].

The estimated mean Excess Lifetime Cancer Risk (ELCR) across the study areas revealed notable spatial variability. Specifically, the ELCR values obtained for Ohamaha, Ologbo, Obaretin, EDSPADEC, and Flow Station exceeded the internationally recommended average threshold value of 0.29×10^{-3} proposed by [27, 28]. Exceedance of this benchmark indicates that individuals residing in or working around these communities are subject to a heightened probability of cancer incidence over their lifetime, attributable to chronic exposure to carcinogenic contaminants [7]. This finding underscores the potential public health implications of sustained industrial activity in these communities and highlights the necessity for targeted environmental management and occupational health interventions. Thus, the ELCR values recorded in all the locations were higher than the global average, suggesting comparatively higher cancer risk profiles. These results are consistent with the findings [15], who reported sub-threshold ELCR values in selected oil-host communities within Okoroma/Tereke South, Bayelsa State, Nigeria. Such congruence suggests that while elevated risks are evident in certain oil-producing regions from this study, others may remain within acceptable world limits, possibly reflecting differences in pollutant dispersion, industrial intensity, or local environmental conditions.

When placed in a broader international context, the ELCR values from the Nigerian sites, even those exceeding the global average, than those reported [8] in the Hormozgan and Sistan-Baluchistan provinces of Southeast Iran. In those regions, higher mean ELCR values were attributed to extensive industrial operations and elevated background ionizing radiation, which collectively exacerbate cancer risk. This comparative perspective demonstrates that although localized risks in Nigerian oil-producing communities warrant concern, they are not as severe as those documented in certain highly industrialized or geologically vulnerable regions. Hence the value of the standard deviation of calculated excess lifetime cancer risk from the study area due to the annual effective dose is 0.087, and this value is higher than the world average value.

6. Conclusion

The relative high value of ionizing radiation exposure rate obtained in this study can be attributed to oil exploration activities within the study area.

The background ionizing radiation exposure rate of the oil producing communities in Edo State, Nigeria is higher than the recommended world average value of 0.013 $mRhr\text{-}^{1}$. The absorbed dose in more than 50% of the study area is higher than the recommended world average value, but the annual effective dose values due to the exposure to background ionizing radiation in the study area are within the recommended world average value. The Excess Lifetime Cancer Risk due to the annual effective dose equivalent in all the study areas is relatively higher than the world exposure average value of 0.29×10^{-3}. The implication is that there is a probability of stochastic effect (cancer risk) on the exposed individuals.

Abbreviations

UNSCEAR	United Nations Scientific Committee on the Effects of Atomic radiation
ELCR	Excess Lifetime Cancer risk

ICRP International Commission on Radiological Protection

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Adedokun, M. B., Aweda, M. A., Maleka, P. P., Obed, R. I., Ogungbemi, K. I., & Ibitoye, Z. A. (2020). Natural radioactivity contents in commonly consumed leafy vegetables cultivated through surface water irrigation in Lagos State, Nigeria. Journal of Radiation Research and Applied Sciences, 12(1), 147-156

[2] Ademola, J. A., & Ademonehin, S. (2019). Radioactivity concentrations and dose assessment for bitumen and soil samples around a bituminous deposit in Ondo State, Nigeria. Radioprotection, 45(3), 359-368.

[3] Agbalagba, O. E. (2017). Assessment of excess lifetime cancer risk from gamma radiation levels in Effurun and Warri city of Delta State, Nigeria. Journal of Taibah University for Science, 11(3), 367-380.

[4] Agbalagba, E. O., & Meindinyo, R. K. (2010). Radiological impact of oil spilled environment: a case study of the Eriemu Well 13 and 19 oil spillage in Ughelli region of Delta State, Nigeria. Indian Journal of Science and Technology, 2, 1001-1005

[5] Akintunde, Z. A., Olawoore, T. O., Atilola, O. S., & Ojo, A. O. (2021). Evaluation of indoor and outdoor background ionizing radiation of selected residential buildings in Ibarapa Central Oyo state. Trailblazer International Journal of Educational Research, 2(1), 158-163.

[6] Alzahrani, J. S., Almuqrin, A., Alghamdi, H., Albarzan, B., Khandaker, M. U., & Sayyed, M. I. (2022). Radiological monitoring in some coastal regions of the Saudi Arabian Gulf close to the Iranian Bushehr nuclear plant. Mar. Pollut. Bull. 175: 113146.

[7] Avwiri, G. O. (2011). Radiation: The Good, The Bad, and The Ugly in Our Environment. An Inaugural Lecture Series 79, University of Port-Harcourt, Port Harcourt, p. 8.

[8] Avwiri, G. O., & Agbalagba, E. O. (2012). Studies on the Radiological Impact of Oil and Gas Activities in Oil Mineral Lease 30 (Oml30) Oil Fields in Delta State, Nigeria. Journal of Petroleum & J Environmental Biotechnology, 3(2), 115.

[9] Avwiri, G. O., & Esi, E. O. (2015). Survey of background ionization radiation level in Burutu L. G. A, coastal area of Delta State, Nigeria. Journal of Applied Physical Science International, 2(2), 72-78.

[10] Avwiri, G. O., Nte, F. U., and Olarewaju, A. I. (2013a). Terrestrial radiation level in selected asphalt plants in Port Harcourt, Nigeria. Scientia Africana. 12(1).

[11] Azionu C. K., Avwiri O. G., & Ononugbo, P. C. (2019). Occupational Hazards from BIR in Selected Crude Oil Production Pipes Storage Locations in Niger Delta Region of Nigeria. Current Journal of Applied Science and Technology, 37(2), 1-12.

[12] Bagheri, M., Fouladi, M. R., & Abedi-Firouzjah, R. (2020). An Investigation of Natural Background Radiation and Health Risk Assessment in Kohgiluyeh and Boyer-Ahmad Province, Iran. Annals of Military and Health Sciences Research, 18(4).

[13] Darko, E. O., Kpeglo, D. O., Akaho, E. H. K., Scandorf, C., Adu, P. A. S., Faanu, A., Abankwah, E., Lawluui, H., & Awudu, A. R. (2011). Radiation Doses and Hazards from processing of crude oil at Terna Oil Refinery in Ghana. Radiation Protection Dosimetry, 15(4), 1-11.

[14] Derin, M. T., Vijayagopal, P., Venkatraman, B., Chaubey, R. C., & Gopinathan, A. (2012). Radionuclides and radiation indices of high background radiation area in Chavara-Neendakara placer deposits (Kerala, India). PLoS One; 7: e50468.

[15] Farai, I. P., & Jibri, N. N. (2000). Baseline studies of terrestrial outdoor gamma dose rate levels in Nigeria. Radiation Protection Dosimetry, 88(3), 247-254.

[16] IAEA, (1989). Guide Book of the Fallout of Radioactivity Monitoring in the Environment and Food Programme. Technical Report Series, 295, International Atomic Energy Agency, Vienna.

[17] IAEA, (1990). Nuclear technique in the exploration and exploitation of energy and mineral resources. Proceedings series, International Atomic Energy Agency, Vienna.

[18] IAEA, (2003). Radiation Protection and the Management of radioactive waste in the oil and gas industry. IAEA-Safety reports series 34, Vienna.

[19] ICRP International Commission on Radiological Protection (1990). Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. Pergamon Press, Oxford.

[20] ICRP International Commission on Radiological Protection (2003). Dose Coefficient for inake of radionuclides by workers. Publication 68.

[21] ICRP International Commission on Radiological Protection (2012). Compendium of Dose coefficients based on ICRP publication 60. ICRP publication 119, Ann. ICRP 41(suppl.)

[22] Isinkaye, M. O., Jibiri. N. N., Bamidele. S. I. & Najam. L. A., (2018). Evaluation of Radiological Hazards due to natural radioactivity in bituminous soils from tar-sand belt of southwest Nigeria using HpGe-Detector. *International Journal of Radiation Research*, 16(3), 351-362.

[23] Mohammed, R. S., & Ahmed, R. S. (2017). Estimation of excess lifetime cancer risk and radiation hazard indices in southern Iraq. Environmental Earth Science, 76, 303

[24] NNR. (2013). National Nuclear Regulator RG-002 Safety Assessment to Radiation Hazards to Members of the Public from NORM Activities. NNR, Pretoria, South Africa.

[25] Ononugbo, C. P., & Bubu, A. A. (2017). Evaluation of Excess Lifetime Cancer Risk from Gamma Dose Rates in Coastal Areas of Bonny Island, Rivers State, Nigeria. Advances in Physics Theories and Applications, 63, 10-15.

[26] Ononugbo, C. P., & Nte, F. U. (2017). Measurement of Outdoor Ambient Radiation and Evaluation of Radiological Risks of Coastal Communities in Ndokwa East, Delta State, Nigeria. Advances in Research, 9(6), 1-11.

[27] Rafique, M., Saeed, U. R., Muhammad, B., Wajid, A., Iftikhar, A., Khursheed, A. L., & Khalil, A. M. (2014). Evaluation of excess lifetime cancer risk from gamma dose rates in Jhelum valley. Journal of Radiation Research and Applied Sciences, 7, 29-35.

[28] Rahman, M. M. A., Islam, A. T. A., Kamal, M. B., & Chowdbury, M. I. B. (2012). Radiation hazards due to terrestrial radionuclides at the coastal area of Ship Breaking Industries. Science Journal of Physics, 2, 1-6.

[29] Smith, K. P., Blunt, D. L., Williams, G. P., & Tebes, C. L. (2000). Radiological Dose Assessment Related to Management of Naturally Occurring Radioactive Materials (NORMs) Generated by the Petroleum Industry. Environmental Assessment Division, US Department of Energy, Office of Policy, Argonne, Illinois 60439.

[30] Ugbede, F. O. (2018). Measurement of Background Ionizing Radiation Exposure Levels in Selected Farms in Communities of Ishielu LGA, Ebonyi State, Nigeria. Journal of Applied Sciences and Environmental Management, 22(9), 1427-1432.

[31] UNSCEAR. (2000). United Nations Scientific Committee on the Effects of Atomic Radiation. Sources, Effects and Risks of Ionizing Radiation. Report to the General Assembly with Annex B. New York: United Nations.

[32] UNSCEAR. (2016). Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation. Report to the General Assembly.

[33] World Health Organization. (2016). Ionizing radiation, health effects and protective measures.