Journal of Asian Scientific Research
ISSN(e): 2223-1331
ISSN(p): 2226-5724
DOI: 10.55493/5003.v13i1.4728
Vol. 13, No. 1, 45-53.

URL: www.aessweb.com

Radiological impact assessment due to background ionizing radiation around palm oil processing mills in southwestern Nigeria

Olusegun Yemi Omogunloye[1+]
Abiola Olawale Ilori[2]
Olamiposi Isaac Abolade[3]

[1,2,3]*Department of Physical Sciences, Olusegun Agagu University of Science and Technology, Ondo State, Nigeria.*
[1]*Email: olusegunomogunloye@gmail.com*
[2]*Email: iloriabiola99@gmail.com*
[3]*Email: isaacolamipo@gmail.com*


(+ Corresponding author)

Article History
Received: 25 November 2022
Revised: 19 January 2023
Accepted: 31 January 2023
Published: 17 February 2023

Keywords
Background Ionizing radiation
Effective dose
Excess lifetime cancer risk
Geiger muller counter
Palm oil processing mills
Radiation dose exposure rate.

ABSTRACT

This study assesses palm oil processing mills' background ionizing radiation exposure rate and is radiological health hazards in various communities within Southwestern Nigeria. At the height of 1.0 m, a digital Geiger Muller counter measured the radiation exposure rate in forty-three selected palm oil processing mills. The recorded background radiation exposure rates during non-working hours were below the recommended acceptable limit, while the background radiation exposure rates during the working hours were higher than $0.013\ mR.h^{-1}$, the recommended permissible limit provided by the International Commission on Radiological Protection. During the working hours of the palm oil processing mills, the estimated absorbed dose rates and excess lifetime cancer risks were all greater than the recommended acceptable safety limits. The estimated values of the effective dose irradiated to various body organs and tissues due to radiation exposure and inhalation in the designated palm oil processing mills during their working and non-working hours were lower than the allowable global limit of $1.00\ mSv.y^{-1}$. This study showed that the study area is radiologically polluted; nevertheless, the pollution may not produce any immediate radiation hazards to the residents of the area.

Contribution/ Originality: The study aims to assess the background ionizing radiation exposure rate and radiological health hazards due to activities at forty-three selected palm oil processing mills within Southwestern Nigeria using a digital Geiger Muller counter. The results showed that the study locations are minimally radiologically polluted.

1. INTRODUCTION

For the past few years, the various governments of the Southwestern States in Nigeria, through their various Agencies and Ministries of Agriculture, have embarked on massive sensitization of their citizenry on the importance of going back to using agricultural means as a panacea to solving the present economic hardship faced by people [1]. These sensitizations resulted from the Nigerian government's economic dependence on crude oil while neglecting other sectors [2, 3]. The Southwestern States in Nigeria have taken to the farming and processing of palm oil as a significant source of their income. The weather and climatic conditions of Southwestern Nigeria favour the cultivation and growth of palm oil (*Elaeis guineensis*), a native plant in West Africa that eventually leads to increasing rates at which oil palm is cultivated and commercially cultivated processed in Nigeria [4, 5]. The massive increment in the rate at which people are going into oil palm cultivation and processing in Southwestern Nigeria, combined with inadequate environmental management schemes, brings about the discharge of several radioactive waste products or pollutants into the environment [6, 7]. These concerns raise severe environmental problems due to air emissions generated during oil palm production [8]. Contamination and degradation of the environment are global concerns due to their harmful health effects [9-11]. When background ionizing radiation (BIR) exposure levels significantly exceed permissible occupational and public limits, environmental contamination may be considered [12]. Oil palm productions often provide enhanced earnings for small and commercial scale producers than other revenue sources, thereby contributing to rural economies and the overall economy of producing countries through its linkages. Nowadays, palm oil has become the most significant source of vegetable oil globally since it overtaken the soybean oil in 2006, while the corresponding third and fourth positions are rapeseed oil and sunflower oil [13, 14]. Palm oil is used to meet the growing demand for vegetable oil worldwide [15]. Background ionizing radiation was initially present in human surroundings because natural terrestrial radionuclide and extraterrestrial cosmic radiation sources had been enhanced over the years due to various human activities, especially in industrialized areas. These enhanced radiation levels in the human environment expose them to acute radiological hazards [16, 17].

Hence, this study aims to evaluate the radiological hazard indices due to background ionizing radiation around selected palm oil processing mills in Southwest Nigeria and ascertain the level of radiation exposure safety within the study area. This study will help establish radiological reference data and assist in observing possible future changes resulting from radiological contamination in the study area.

2. MATERIALS AND METHODS

2.1. Study Area

The study areas are selected in Ere-Ekiti (EE), Igbotako (ITK), Iju-Odo (IO), Ode–Aye (OA), and Erinje (ERN), Southwestern Nigeria. The area falls in the Bitumen Belt of Ondo State, Southwestern Nigeria, predominantly populated by the Ikales of Yoruba extraction. The landscape is regionally gradually undulating southward; topographic altitudes vary from about 84 m above sea level in the Northern part, with a gradual slope to a relative sea-level swamp flat in the coastal area to the South. Ominla, Oluwa, Akeun, Ufara, Otu, Oha, and Oni are just a few perennial streams and rivers that flow through the area. At the same time, lagoons, coastal creeks, canals, and several tributaries to the vast River Oluwa characterize the Southern part.

The average annual temperature is between 24 and 27 ^0C, and the mean annual rainfall is over 2500 mm [18]. An array of exploitable economic mineral resources such as Coal, Kaolin, Bitumen, Oil and Gas, Dimension Stones, and Glass Sand are present [10, 19]. The study area is significant from an economic and environmental point of view because the weather and climatic conditions favour the farming and growing of oil palm (*Elaesis guineensis*). Residents of these areas are primarily farmers. Their main cash crops are oil palm, kola nut, cocoa, and rubber. Their staple foods include baked cassava (traditionally known as Pupuru), yam, yam flour, cassava flakes (garri), and vegetables.

2.2. Instrumentation

This research was carried out with a digital GQ-500 Geiger Muller Counter (GMC), a measuring tape, and a Germin eTrex 10 Geographical Positioning System (GPS) device. The radiation level measured is indicated by audible and visual cues built into the instrument. Geiger tubes are installed in the digital GMC to detect the radiation level of an environment. The number of pulses per second measures the intensity of the radiation field. When radiations pass through the GQ GMC-500 Geiger tube, electrical pulses are generated, which the central processing unit (CPU) interprets as counts. Count per minute (CPM) is the basic count rate unit. The CPM count rate represents the amount of radiation present and can be transformed into other radioactivity units of $\mu Sv.h^{-1}$ or $mR.h^{-1}$, typical radiation measurement units [20].

2.3. Measurement of the Radiation Exposure Rate (R_{ER})

The radiation exposure rates (measured in $mR.h^{-1}$) in forty-three (43) selected palm oil processing mills were measured in the study area. Measurements were carried out when palm oil processing activities were ongoing (working hours) and when not ongoing (non-working hours). The palm oil processing activities are bunch sterilization, bunch threshing, steaming/cooking of palm fruits, fruit digestion, pulp pressing, palm oil extraction, palm nut/fibre separation, and palm oil packing. The working hours span from 7.30 a.m. to 6.30 p.m., while the non-working hours span from 7.00 p.m. to 6.30 a.m. When turned on, the radiation exposure rate in each location was measured by positioning the Geiger Muller Counter at the height of 1.0 m. The radiation exposure rates displayed were recorded using the Geiger Muller Counter in mRh^{-1}. Four readings were taken for each measurement point, and the mean was determined and recorded. The device was placed one meter above the ground level with the help of a meter rule, and the GPS locations of the point of measurement were also recorded using the GPS device.

2.4. Assessment of Radiological Health Hazard Indices

The following are the various radiological health hazard indices employed in assessing the radiological safety condition of the studied areas.

2.4.1. Absorbed Dose Rate (D)

This is vital in radiological impact assessments because it evaluates the irradiated matter's doses per unit time. To avoid any radiation health hazards, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) set the maximum acceptable value of 84.00 $nGy.h^{-1}$ for the entire public [9]. To convert the radiation exposure rate in $mR.h^{-1}$ to the absorbed dose rate in the air (D) measured in $nGy.h^{-1}$, Equation 1 was used [21].

$$D(nGy.h^{-1}) = 8700 \times Y(mR.h^{-1}) \quad (1)$$

Where Y is the measured radiation exposure rate in $mR.h^{-1}$.

2.4.2. Annual Effective Dose Equivalent ($AEDE$)

According to Ugbede and Benson [21] the annual effective dose equivalent (AEDE) was calculated using Equation 2:

$$AEDE\ (mSv.y^{-1}) = D\ (nGy.h^{-1}) \times 8760(h.y^{-1}) \times 0.2 \times 0.7\ (Sv.Gy^{-1}) \times 10^{-6} \quad (2)$$

Where $0.7\ (Sv.Gy^{-1})$ is the dose conversion factor, 0.2 (5/24) is the occupancy factor, and 8760 is the total number of hours in a year. With regards to this study, only the outdoor $AEDE$ was considered.

2.4.3. Excess Lifetime Cancer Risk ($ELCR$)

The $ELCR$ involves the risk of cancer development throughout a lifetime due to a specific level of irradiation. It represents the number of cancers estimated in a specified number of persons after radiation irradiation at a particular dosage. It's worth noting that an increment in $ELCR$ corresponds to increased chances of cancer development. Equation 3 calculates the $ELCR$ [22].

$$ELCR = AEDE \times DL \times RF \times 10^{-3} \quad (3)$$

Where $AEDE$ is the annual effective dose equivalent, Duration of Life (DL) is the expectancy factor (70 years), and RF is the risk factor (Sv^{-1}), i.e., fatal cancer risk per Sievert. For deterministic effects, ICRP recommends Risk Factor (RF) as 0.05 for the public.

2.4.4. Organs Effective Dose (D_{organ})

The organs' effective dose is a measurement of the amount of radiation dose that is absorbed by specific human organs and tissues. Equation 4 was used to calculate the D_{organ} due to different pathways (ingestion, breathing, and direct contact) [23].

$$D_{organ}\ (mSv.y^{-1}) = AEDE \times F \quad (4)$$

Where $AEDE$ is the mean annual effective dose equivalent for outdoor and F is the air to organ dose conversion factor. The values of the organs dose for the lungs, ovaries, bone marrow, testes, kidney, liver, and overall body are 0.64, 0.58, 0.69, 0.82, 0.62, 0.46, and 0.68, respectively [24].

3. RESULTS

The recorded radiation exposure rate and the associated radiation hazards indices in the selected palm oil mills during working and non-working hours are presented in Tables 1 to 10. In contrast, Table 11 and 12 show the results of the $AEDE$ and D_{organ} of the study area.

Table 1. Radiation exposure rate and the associated radiation hazard indices in the palm oil processing mills of Ode Aye (Working hours).

Sampling codes	Location	R_{ER} ($mR.h^{-1}$)	$D(nGy.h^{-1})$	$AEDE\ (mSv.y^{-1})$	Excess lifetime cancer risk ($ELCR$)
OA 1	6°35'44"N, 4°44'30"E	0.014	121.80	0.149	0.523
OA 2	6°36'41"N, 4°45'1"E	0.014	121.80	0.149	0.523
OA 3	6°35'29"N, 4°28'27"E	0.013	113.10	0.139	0.485
OA 4	6°35'43"N, 4°44'28"E	0.016	139.20	0.171	0.598
OA 5	6°36'45"N, 4°44'21"E	0.015	130.50	0.160	0.560
OA 6	6°36'42"N, 4°45'41"E	0.014	121.80	0.149	0.523
OA 7	6°35'39"N, 4°28'32"E	0.014	121.80	0.149	0.523
OA 8	6°36'29"N, 4°48'37"E	0.013	113.10	0.139	0.485
OA 9	6°35'43"N, 4°44'37"E	0.015	130.50	0.160	0.560
OA 10	6°36'41"N, 4°45'29"E	0.016	139.20	0.171	0.598
Mean	-	0.014	125.28	0.154	0.538

Table 2. Radiation exposure rate and the associated radiation hazard indices in the palm oil processing mills of Ode Aye (Non-working hours).

Sampling codes	Location	R_{ER} ($mR.h^{-1}$)	$D(nGy.h^{-1})$	$AEDE\ (mSv.y^{-1})$	$ELCR$
OA 1	6°35'44"N, 4°44'30"E	0.007	60.90	0.075	0.261
OA 2	6°36'41"N, 4°45'1"E	0.005	43.50	0.053	0.187
OA 3	6°35'29"N, 4°28'27"E	0.006	52.20	0.064	0.224
OA 4	6°35'43"N, 4°44'28"E	0.006	52.20	0.064	0.224
OA 5	6°36'45"N, 4°44'21"E	0.006	52.20	0.064	0.224
OA 6	6°36'42"N, 4°45'41"E	0.005	43.50	0.053	0.187
OA 7	6°35'39"N, 4°28'32"E	0.006	52.20	0.064	0.224
OA 8	6°36'29"N, 4°48'37"E	0.007	60.90	0.075	0.261
OA 9	6°35'43"N, 4°44'37"E	0.006	52.20	0.064	0.224
OA 10	6°36'41"N, 4°45'29"E	0.009	78.30	0.096	0.336
Mean	-	0.006	54.81	0.067	0.235

Table 3. Radiation exposure rate and the associated radiation hazard indices in the palm oil processing mills of Igbotako (Working hours).

Sampling codes	Location	R_{ER} ($mR.h^{-1}$)	$D(nGy.h^{-1})$	$AEDE\ (mSv.y^{-1})$	$ELCR$
ITK 1	6°34'31"N, 4°38'49"E	0.014	121.80	0.149	0.523
ITK 2	6°34'30"N, 4°38'38"E	0.013	113.10	0.139	0.485
ITK 3	6°34'41"N, 4°38'39"E	0.018	156.60	0.192	0.672
ITK 4	6°34'41"N, 4°38'49"E	0.016	139.20	0.171	0.598
ITK 5	6°34'29"N, 4°38'36"E	0.015	130.50	0.160	0.560
ITK 6	6°34'41"N, 4°38'35"E	0.012	104.40	0.128	0.448
ITK 7	6°34'40"N, 4°38'37"E	0.016	139.20	0.171	0.598
ITK 8	6°34'34"N, 4°39'40"E	0.015	130.50	0.160	0.560
ITK 9	6°34'24"N, 4°37'41"E	0.022	191.40	0.235	0.822
Mean	-	0.016	136.30	0.167	0.585

Table 4. Radiation exposure rate and the associated radiation hazard indices in the palm oil processing mills of Igbotako (Non-working hours).

Sampling codes	Location	R_{ER} ($mR.h^{-1}$)	$D(nGy.h^{-1})$	$AEDE$ $(mSv.y^{-1})$	$ELCR$
ITK 1	6°34'31"N, 4°38'49"E	0.008	69.60	0.085	0.299
ITK 2	6°34'30"N, 4°38'38"E	0.006	52.20	0.064	0.224
ITK 3	6°34'41"N, 4°38'39"E	0.007	60.90	0.075	0.261
ITK 4	6°34'41"N, 4°38'49"E	0.009	78.30	0.096	0.336
ITK 5	6°34'29"N, 4°38'36"E	0.006	52.20	0.064	0.224
ITK 6	6°34'41"N, 4°38'35"E	0.005	43.50	0.053	0.187
ITK 7	6°34'40"N, 4°38'37"E	0.007	60.90	0.075	0.261
ITK 8	6°34'34"N, 4°39'40"E	0.008	69.60	0.085	0.299
ITK 9	6°34'24"N, 4°37'41"E	0.006	52.20	0.064	0.224
Mean	-	0.007	59.93	0.074	0.257

Table 5. Radiation exposure rate and the associated radiation hazard indices in the palm oil processing mills of Iju Odo (Working hours).

Sampling codes	Location	R_{ER} ($mR.h^{-1}$)	$D(nGy.h^{-1})$	$AEDE$ $(mSv.y^{-1})$	$ELCR$
IO 1	6°38'24"N, 4°38'27"E	0.013	113.10	0.139	0.485
IO 2	6°35'23"N, 4°40'29"E	0.014	121.80	0.149	0.523
IO 3	6°37'59"N, 4°38'40"E	0.019	165.30	0.203	0.710
IO 4	6°36'43"N, 4°39'32"E	0.021	182.70	0.224	0.784
IO 5	6°37'59"N, 4°38'42"E	0.013	113.10	0.139	0.485
IO 6	6°38'24"N, 4°38'27"E	0.019	165.30	0.203	0.710
IO 7	6°36'40"N, 4°39'32"E	0.015	130.50	0.160	0.560
Mean	-	0.016	141.69	0.174	0.608

Table 6. Radiation exposure rate and the associated radiation hazard indices in the palm oil processing mills of Iju Odo (Non-working hours).

Sampling codes	Location	R_{ER} ($mR.h^{-1}$)	$D(nGy.h^{-1})$	$AEDE$ $(mSv.y^{-1})$	$ELCR$
IO 1	6°38'24"N, 4°38'27"E	0.006	52.20	0.064	0.224
IO 2	6°35'23"N, 4°40'29"E	0.007	60.90	0.075	0.261
IO 3	6°37'59"N, 4°38'40"E	0.006	52.20	0.064	0.224
IO 4	6°36'43"N, 4°39'32"E	0.008	69.60	0.085	0.299
IO 5	6°37'59"N, 4°38'42"E	0.006	52.20	0.064	0.224
IO 6	6°38'24"N, 4°38'27"E	0.008	69.60	0.085	0.299
IO 7	6°36'40"N, 4°39'32"E	0.008	69.60	0.085	0.299
Mean	-	0.007	60.90	0.075	0.261

Table 7. Radiation exposure rate and the associated radiation hazard indices in the palm oil processing mills of Erinje (Working hours).

Sampling codes	Location	R_{ER} ($mR.h^{-1}$)	$D(nGy.h^{-1})$	$AEDE$ $(mSv.y^{-1})$	$ELCR$
ERN 1	6°26'22"N, 4°43'53"E	0.016	139.20	0.171	0.598
ERN 2	6°28'24"N, 4°41'49"E	0.015	130.50	0.160	0.560
ERN 3	6°29'30"N, 4°42'29"E	0.014	121.80	0.149	0.523
ERN 4	6°27'26"N, 4°43'42"E	0.015	130.50	0.160	0.560
ERN 5	6°28'34"N, 4°41'49"E	0.013	113.10	0.139	0.485
ERN 6	6°29'31"N, 4°42'39"E	0.013	113.10	0.139	0.485
ERN 7	6°28'26"N, 4°43'44"E	0.015	130.50	0.160	0.560
ERN 8	6°27'23"N, 4°43'43"E	0.014	121.80	0.149	0.523
ERN 9	6°28'52"N, 4°45'35"E	0.016	139.20	0.171	0.598
ERN 10	6°28'50"N, 4°45'36"E	0.015	130.50	0.160	0.560
Mean	-	0.015	127.02	0.156	0.545

Table 8. Radiation exposure rate and the associated radiation hazard indices in the palm oil processing mills of Erinje (Non-working hours).

Sampling codes	Location	R_{ER} ($mR.h^{-1}$)	$D(nGy.h^{-1})$	$AEDE$ $(mSv.y^{-1})$	$ELCR$
ERN 1	6°26'22"N 4°43'53"E	0.009	78.30	0.096	0.336
ERN 2	6°28'24"N 4°41'49"E	0.007	60.90	0.075	0.261
ERN 3	6°29'30"N 4°42'29"E	0.009	78.30	0.096	0.336
ERN 4	6°27'26"N 4°43'42"E	0.007	60.90	0.075	0.261
ERN 5	6°28'34"N 4°41'49"E	0.006	52.20	0.064	0.224
ERN 6	6°29'31"N 4°42'39"E	0.006	52.20	0.064	0.224
ERN 7	6°28'26"N 4°43'44"E	0.007	60.90	0.075	0.261
ERN 8	6°27'23"N 4°43'43"E	0.008	69.60	0.085	0.299
ERN 9	6°28'52"N 4°45'35"E	0.006	52.20	0.064	0.224
ERN 10	6°28'50"N 4°45'36"E	0.008	69.60	0.085	0.299
Mean	-	0.007	63.51	0.078	0.273

Table 9. Radiation exposure rate and the associated radiation hazard indices in the palm oil processing mills of Ere-Ekiti (Working hours).

Sampling codes	Location	R_{ER} ($mR.h^{-1}$)	$D(nGy.h^{-1})$	$AEDE$ $(mSv.y^{-1})$	$ELCR$
EE 1	6°36'32"N 4°39'39"E	0.011	95.70	0.117	0.411
EE 2	6°35'31"N 4°40'60"E	0.012	104.40	0.128	0.448
EE 3	6°37'26"N 4°38'42"E	0.011	95.70	0.117	0.411
EE 4	6°36'34"N 4°39'37"E	0.013	113.10	0.139	0.485
EE 5	6°36'38"N 4°40'62"E	0.013	113.10	0.139	0.485
EE 6	6°37'28"N 4°38'49"E	0.012	104.40	0.128	0.448
EE 7	6°36'12"N 4°56'22"E	0.015	130.50	0.160	0.560
Mean	-	0.012	108.13	0.133	0.464

Table 10. Radiation exposure rate and the associated radiation hazard indices in the palm oil processing mills of Ere-Ekiti (Non-working hours).

Sampling codes	Location	R_{ER} ($mR.h^{-1}$)	$D(nGy.h^{-1})$	$AEDE$ $(mSv.y^{-1})$	$ELCR$
EE 1	6°36'32"N 4°39'39"E	0.006	52.20	0.064	0.224
EE 2	6°35'31"N 4°40'60"E	0.006	52.20	0.064	0.224
EE 3	6°37'26"N 4°38'42"E	0.005	43.50	0.053	0.187
EE 4	6°36'34"N 4°39'37"E	0.006	52.20	0.064	0.224
EE 5	6°36'38"N 4°40'62"E	0.006	52.20	0.064	0.224
EE 6	6°37'28"N 4°38'49"E	0.006	52.20	0.064	0.224
EE 7	6°36'12"N 4°56'22"E	0.009	78.30	0.096	0.336
Mean	-	0.006	54.69	0.067	0.235

Table 11. $AEDE$ and D_{organ} (Working hours).

Sampling locations	$AEDE$ $(mSv.y^{-1})$	D_{organ} $(mSv.y^{-1})$						
		Lungs	Ovaries	Bone marrow	Testes	Kidney	Liver	Whole body
Ode-Aye	0.015	0.010	0.009	0.010	0.012	0.009	0.007	0.010
Igbotako	0.167	0.107	0.097	0.115	0.137	0.104	0.077	0.114
Iju-Odo	0.174	0.111	0.101	0.120	0.143	0.108	0.080	0.118
Erinje	0.156	0.100	0.090	0.108	0.128	0.097	0.072	0.106
Ere Ekiti	0.133	0.085	0.077	0.092	0.109	0.082	0.061	0.090

Table 12. $AEDE$ and D_{organ} (Non-working hours).

Sampling locations	$AEDE$ $(mSv.y^{-1})$	D_{organ} $(mSv.y^{-1})$						
		Lungs	Ovaries	Bone marrow	Testes	Kidney	Liver	Whole body
Ode-Aye	0.067	0.043	0.039	0.046	0.055	0.042	0.031	0.046
Igbotako	0.074	0.047	0.043	0.051	0.061	0.046	0.034	0.050
Iju-Odo	0.075	0.048	0.044	0.052	0.062	0.047	0.035	0.051
Erinje	0.078	0.050	0.045	0.054	0.064	0.048	0.036	0.053
Ere Ekiti	0.067	0.043	0.039	0.046	0.055	0.042	0.031	0.046

4. DISCUSSIONS

From the results, the recorded radiation exposure rate (R_{ER}) in all the selected palm oil processing mills in the study area was below the ICRP acceptable limit of 0.013 $mR.h^{-1}$ for the public during non-working hours, indicating that the study area is naturally radiologically safe.

During the working hours, the recorded radiation exposure rate of the selected palm oil processing mills in Ode Aye (OA) varied from 0.013 to 0.016 $mR.h^{-1}$ with an average value of 0.014 $mR.h^{-1}$, the calculated absorbed dose rate, annual effective dose equivalent ($AEDE$) and excess lifetime cancer risk varied from 113.10 to 139.20 $nGy.h^{-1}$ with an average value of 125.28 $nGy.h^{-1}$, 0.139 to 0.171 $mSv.y^{-1}$ with an average value of 0.154 $mSv.y^{-1}$ and 0.485 x 10^{-3} to 0.598 x 10^{-3} with an average value of 0.538 x 10^{-3}, respectively.

During the working hours of the selected palm oil processing mills in Igbotako (ITK), the recorded radiation exposure rate varied from 0.012 to 0.022 $mR.h^{-1}$ with an average value of 0.016 $mR.h^{-1}$. The calculated absorbed dose, annual effective dose equivalent, and excess lifetime cancer risk varied from 104.40 to 191.40 $nGy.h^{-1}$ with an average value of 136.30 $nGy.h^{-1}$; 0.128 to 0.235 $mSv.y^{-1}$ with an average value of 0.167 $mSv.y^{-1}$; and 0.448 x 10^{-3} to 0.822 x 10^{-3} with an average value of 0.585 x 10^{-3}, respectively.

For the working hours of the selected palm oil processing mills in Iju Odo (IO), the recorded radiation exposure rate varied from 0.013 to 0.021 $mR.h^{-1}$ with an average value of 0.016 $mR.h^{-1}$. The calculated absorbed dose, annual effective dose equivalent, and excess lifetime cancer risk varied from 113.10 to 182.70 $nGy.h^{-1}$ with an average value of 141.69 $nGy.h^{-1}$; 0.139 to 0.224 $mSv.y^{-1}$ with an average value of 0.174 $mSv.y^{-1}$; and 0.485 x 10^{-3} to 0.784 x 10^{-3} with an average of 0.608 x 10^{-3}, respectively.

The recorded radiation exposure rate during the working hours of the selected palm oil processing mills in Erinje (ERN) varied from 0.013 to 0.016 $mR.h^{-1}$ with an average of 0.015 $mR.h^{-1}$. The calculated absorbed dose, annual effective dose equivalent, and excess lifetime cancer risk varied from 113.10 to 139.20 $nGy.h^{-1}$ with an average of 127.02 $nGy.h^{-1}$; 0.139 to 0.171 $mSv.y^{-1}$ with an average of 0.156 $mSv.y^{-1}$; and 0.485 x 10^{-3} to 0.598 x 10^{-3} with an average of 0.545 x 10^{-3}, respectively.

In the working hours of the selected palm oil processing mills in Ere-Ekiti (EE), the recorded radiation exposure rate varied from 0.011 to 0.015 $mR.h^{-1}$ with an average of 0.012 $mR.h^{-1}$. The calculated absorbed dose, annual effective dose equivalent, and excess lifetime cancer risk ranged from 95.70 to 130.50 $nGy.h^{-1}$ with an average of 108.13 $nGy.h^{-1}$; 0.117 to 0.160 $mSv.y^{-1}$ with an average 0.133 $mSv.y^{-10}$; and 0.411 x 10^{-3} to 0.560 x 10^{-3} with an average of 0.464 x 10^{-3}, respectively.

As it can be seen from the results, virtually all of the selected Palm Oil Processing Mills had radiation exposure rates that exceeded the recommended acceptable limit of 0.013 $mR.h^{-1}$ during working hours. The absorbed dose rates were much greater than the world weighted mean value of 59.00 $nGy.h^{-1}$ and the suggested safe limit of 84.0 $nGy.h^{-1}$. The excess lifetime cancer risks exceeded the UNSCEAR and ICRP's recommended safe limits of 0.29 x 10^{-3} [24, 25]. All of the obtained annual effective dose equivalent values calculated were higher than the world mean value of 0.07 $mSv.y^{-1}$. However, they are still within the ICRP's and UNSCEAR's suggested tolerable limits of 1.00 $mSv.y^{-1}$ for the general public [24, 25].

Due to palm oil processing activities, the study area is radiologically enhanced; however, these enhancements do not constitute any instant radiological health hazards to humans. Still, due to accumulated doses, there is the possibility of cancer development in the future.

The obtained values of the effective dose to different body organs (D_{organ}) due to irradiation in the selected oil processing mills during working and non-working hours are shown in Tables 11 and 12. These D_{organ} values were lower than the acceptable international limit of 1.0 $mSv.y^{-1}$, indicating that the irradiation levels in the examined area do have any immediate radiation health impact on the residents. The results also show that the testes are more radio-sensitive while the livers are radio-recessive.

5. CONCLUSION

This study examined the radiological impact of the study area by assessing the radiation exposure rate around palm oil processing mills during working and non-working hours. The background ionizing radiation exposure levels measured during non-working hours in all the palm oil processing mills were below the recommended acceptable limit of 0.013 $mR.h^{-1}$. The recorded background ionizing radiation exposure rates indicate high radiation levels when palm oil processing activities are ongoing. This shows that background radiation exposure rates are enhanced due to the various palm oil processing activities during the working hours of the selected mills.

The absorbed dose rates from the radiation exposure during the working (operational) hours of the selected mills were much higher than the world mean value, indicating a radiation-contaminated environment. The obtained values of the excess lifetime cancer risk of the mill's working hours were higher than the UNSCEAR and ICRP's recommended acceptable limit, indicating the probability of cancer development in dwellers who desire to live their life in the studied environment. In conclusion, the study shows the various towns and communities in the Okitipupa

Local Government Area in Ondo State, Nigeria, have a higher degree of background ionizing radiation than the recommended limits due to ongoing palm oil processing activities.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study.

REFERENCES

[1] H. Inegbedion, E. Obadiaru, B. Obasaju, A. Asaleye, and A. Lawal, "Financing agriculture in Nigeria through agricultural extension services of agricultural development programmes," *F1000research*, vol. 7, pp. 1833-1833, 2018.

[2] T. Igbeasere, "The effect of oil dependency on Nigeria's economic growth," *Journal of International Institute of Social Sciences*, vol. 3, no. 1, pp. 24–28, 2013.

[3] F. O. Ilori and A. O. Efuntade, "Comprehensive analysis of the effect of oil and non-oil revenues on economic growth in Nigeria," *KIU Interdisciplinary Journal of Humanities and Social Sciences*, vol. 1, no. 3, pp. 161–186, 2020.

[4] S. U. Okoro, U. Schickhoff, J. Boehner, U. A. Schneider, and N. I. Huth, "Climate impacts on palm oil yields in the Nigerian Niger Delta," *European Journal of Agronomy*, vol. 85, pp. 38-50, 2017. https://doi.org/10.1016/j.eja.2017.02.002

[5] D. J. Murphy, K. Goggin, and R. R. M. Paterson, "Oil palm in the 2020s and beyond: Challenges and solutions," *CABI Agriculture and Bioscience*, vol. 2, no. 1, pp. 1-22, 2021. https://doi.org/10.1186/s43170-021-00058-3

[6] J. Abrams, E. C. Pischke, M. A. Mesa-Jurado, A. Eastmond, C. A. Silva, and C. Moseley, "Between environmental change and neoliberalism: The effects of oil palm production on livelihood resilience," *Society & Natural Resources*, vol. 32, no. 5, pp. 548-565, 2019. https://doi.org/10.1080/08941920.2018.1544678

[7] M. Qaim, K. T. Sibhatu, H. Siregar, and I. Grass, "Environmental, economic, and social consequences of the oil palm boom," *Annual Review of Resource Economics*, vol. 12, no. 1, pp. 321-344, 2020. https://doi.org/10.1146/annurev-resource-110119-024922

[8] K. Obidzinski, R. Andriani, H. Komarudin, and A. Andrianto, "Environmental and social impacts of oil palm plantations and their implications for biofuel production in Indonesia," *Ecology and Society*, vol. 17, no. 1, pp. 25–27, 2012. https://doi.org/10.5751/es-04775-170125

[9] O. E. Agbalagba, G. O. Avwiri, and C. P. Ononugbo, "GIS mapping of impact of industrial activities on the terrestrial background ionizing radiation levels of Ughelli metropolis and its environs, Nigeria," *Environmental Earth Sciences*, vol. 75, no. 21, p. 1425, 2016. https://doi.org/10.1007/s12665-016-6216-y

[10] I. A. Olawale, O. P. Adefisoye, and B. S. Catherine, "Estimation of natural radionuclide concentrations and heavy metal contents due to bitumen exploitation at Gbeledu-Loda, Ode-Irele, Ondo State, Southwestern Nigeria," *Asian Journal of Physical and Chemical Sciences*, vol. 6, no. 4, pp. 1-10, 2018. https://doi.org/10.9734/ajopacs/2018/46230

[11] P. O. Ukaogo, U. Ewuzie, and C. V. Onwuka, "21 -environmental pollution: Causes, effects, and the remedies," Elsevier, 2020, pp. 419-429.

[12] O. Omogunloye, A. Adepoju, and P. Kururimam, "Assessment of radiation risk from background radiation exposures in selected hospitals within Makurdi Metropolis, North-Central, Nigeria," *European Journal of Applied Physics*, vol. 3, no. 4, pp. 43-47, 2021. https://doi.org/10.24018/ejphysics.2021.3.4.91

[13] A. Rahman, R. Abdullah, F. M. Shariff, and M. A. Simeh, "The Malaysian palm oil supply chain: The role of the independent smallholder," *Oil Palm Industry Economic Journal*, vol. 8, no. 2, pp. 17-27, 2008.

[14] F. Rosillo-Calle, L. Pelkmans, and A. Walter, "A global overview of vegetable oils with reference to biodiesel, a Report for the IEA bioenergy task 40," Retrieved: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.508.5759&rep=rep1&type=pdf [Accessed 2009.

[15] M. B. Wahid, S. N. A. Abdullah, and H. IE, "Oil Palm—achievements and potential—," *Plant Production Science*, vol. 8, no. 3, pp. 288-297, 2005.

[16] S. Alusa, K. Odunaike, and I. Adeniji, "Transfer factor of radionuclides from soil-to-palm oil produced from elere palm tree plantation near Ibadan Oyo state, Nigeria," *Nigeria Journal of Pure and Applied Physics*, vol. 7, no. 1, pp. 7-12, 2017.

[17] C. C. Mbonu and U. C. Ben, "Assessment of radiation hazard indices due to natural radioactivity in soil samples from Orlu, Imo State, Nigeria," *Heliyon*, vol. 7, no. 8, pp. 1-9, 2021. https://doi.org/10.1016/j.heliyon.2021.e07812

[18] M. P. Iloeje, "A new geography of Nigeria." Nigeria: Longman, 1981, pp. 26–28.

[19] O. Ajanaku, A. Ilori, G. Ibitola, and O. Faturoti, "Assessment of natural radioactivity and associated dose rates in surface soils around oluwa glass Industry environments, Igbokoda, Ondo State, Southwestern Nigeria," *Physical Science International Journal*, vol. 20, no. 3, pp. 1-13, 2018. https://doi.org/10.9734/psij/2018/42372

[20] L. L. C. GQ Electronics, "GQ GMC-500/GMC-500+ geiger counter user guide," vol. 1, Retrieved: http://www.gqelectronicsllc.com/GMC-500UserGuide.pdf. 2018.

[21] F. Ugbede and I. Benson, "Assessment of outdoor radiation levels and radiological health hazards in emene industrial layout of Enugu State, Nigeria," *International Journal of Physical Sciences*, vol. 13, no. 20, pp. 265-272, 2018. https://doi.org/10.5897/ijps2018.4763

[22] H. Taskin, M. Karavus, P. Ay, A. Topuzoglu, S. Hidiroglu, and G. Karahan, "Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey," *Journal of Environmental Radioactivity*, vol. 100, no. 1, pp. 49-53, 2009. https://doi.org/10.1016/j.jenvrad.2008.10.012

[23] International Commission on Radiological Protection, "The 1990 recommendations of the international commission on radiological protection," *Ann ICRP*, vol. 21, no. 1-3, pp. 1-201, 1991.

[24] International Commission on Radiological Protection, *Age-dependent doses to members of the public from intake of radionuclides, part 5 compilation of ingestion and inhalation coefficients. ICRP publication 72*. Oxford: Pergamon Press, 1996.

[25] UNSCEAR, "Sources and effects of ionizing radiation, UNSCEAR 2006 report to the general assembly with scientific annexes," vol. 1. New York: United Nations Sales Publication United Nations, 2008.