Nigerian Journal of Applied Physics (NJAP)
ISSN Print: 3115-5871
ISSN Online: 3115-588X
DOI: https://doi.org/10.62292/njap-v2i2-2026-44
Volume 2(2), June 2026

Radiological Risk Assessment of Roasted Food Processing Activities and Implications for Sustainable Public Health in Ondo State, Nigeria

***[1]Olusegun Yemi Omogunloye, [2]Abiola Olawale Ilori, and [1]Temitope Isaiah Ojo, [3]Iwamisan Mark Adewumi**

[1]Department of Physical Sciences, Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria.
[2]Department of Physics, University of Ibadan, Ibadan, Oyo State, Nigeria.
[3]Bioresources Development Centre, National Biotechnology Development Agency (Federal Ministry of Innovation, Science and Technology), Akure, Ondo State, Nigeria.

[*]Corresponding author's email: oy.omogunloye@oaustech.edu.ng

ABSTRACT
Roasted food vending is a widespread informal economic activity in Southwestern Nigeria, where biomass fuels such as charcoal and firewood are commonly used for food preparation. This study assessed the radiological hazards associated with ionizing radiation exposure around selected roasted food vending sites in Ondo State, Southwestern Nigeria, with emphasis on environmental sustainability and public health implications. Background ionizing radiation measurements were conducted around twenty-one (21) randomly selected roasted food vendors located in Okitipupa (OK), Ode-Irele (IR), and Ore (OR) during roasting and non-roasting periods using a digital GQ-500 Geiger–Müller counter positioned at 1 m above ground level. Absorbed dose rate (Ḋ), annual effective dose (Ė), and excess lifetime cancer risk (ELCR) were evaluated from the measured exposure rates, while descriptive and inferential statistical analyses were employed. Mean exposure rates during non-roasting periods ranged from 0.006 to 0.007 mRh^{-1}, whereas significantly higher values of 0.017 to 0.020 mRh^{-1} were recorded during roasting periods. The maximum absorbed dose rate during roasting was 234.9 nGy h^{-1}, exceeding the global average background value of 59 nGy h^{-1} and the recommended public limit of 84 nGy h^{-1}. Statistical analysis revealed a significant increase in radiation exposure during roasting activities ($p < 0.05$), with approximately 186% higher levels than during non-roasting periods. Although annual effective dose and ELCR values remained below internationally recommended limits, the findings indicate that combustion-related roasting activities contribute to localized increases in environmental radiation levels. The study highlights the need for environmental radiation monitoring, cleaner fuel adoption, improved ventilation, and occupational safety practices to promote sustainable public health and environmental protection.

Keywords:
Background ionizing radiation,
Roasted food vendors,
Radiological risk assessment,
Annual effective dose,
Excess lifetime cancer risk.

INTRODUCTION

Human exposure to ionizing radiation from both natural and artificial sources is unavoidable, as radiation has been inherently present on the Earth since its formation. Extensive scientific evidence demonstrates that uncontrolled exposure to ionizing radiation poses significant health risks by damaging biological tissues. At high exposure levels, ionizing radiation may result in deterministic effects such as skin burns and acute radiation sickness (Sidi *et al.*, 2022; Mettler, 2012; Talapko et al., 2024). Conversely, at lower exposure levels, stochastic effects, including increased risks of cancer, genetic mutations, and tumor development, become the primary concern (Sidi *et al.*, 2022). These established health risks necessitate continuous environmental radiation monitoring and the implementation of effective radiation protection practices.

Radiation protection encompasses all measures aimed at safeguarding humans and the environment from the harmful effects of ionizing radiation. It is both a scientific discipline and a practical framework designed to minimize radiation exposure in accordance with established safety principles (Eze *et al*., 2013; Frane and Bitterman, 2023). These protective measures apply to both occupationally exposed individuals and members of the public.

In developing economies such as Nigeria, socio-economic factors have contributed to the widespread proliferation of street food vending, particularly roasted food enterprises involving plantain, yam, and maize. The relatively low capital requirement and increasing urban demand have led to a steady rise in the number of vendors engaged in this informal economic activity (Alimi *et al*., 2014; Salamandane *et al*., 2023). Street food vending is particularly prevalent in urban and semi-urban areas of developing countries, where regulatory oversight is often limited (Ekanem, 1998). Despite its informal nature and limited regulatory recognition, the sector plays a significant socio-economic role by providing affordable and readily available food options to a large proportion of the population (Choudhury, 2011; Alimi and Workneh, 2015; Alimi *et al*., 2016).

The preparation of roasted foods is typically carried out using locally fabricated heating systems, predominantly charcoal combustion. This process generates heat energy and may contribute to the release of combustion-related emissions into the surrounding environment. Although not traditionally classified as a radiation source, continuous exposure to combustion products and enhanced environmental radiation levels in such settings may contribute to elevated background ionizing radiation in the immediate vicinity (Jha *et al*., 2024). Consequently, individuals operating in these environments may experience prolonged exposure conditions that resemble those associated with occupational settings, thereby necessitating radiological evaluation.

The increasing prevalence of roasted food vending activities in Southwestern Nigeria, combined with inadequate environmental monitoring and regulatory enforcement, raises concerns about potential enhancement of environmental radiation in these microenvironments. Environmental degradation and contamination have become global concerns due to their associated public health implications (UNSCEAR, 2000; Agbalagba *et al*., 2016; Ilori *et al*., 2019). Radiological contamination is typically inferred when measured radiation levels exceed recommended permissible limits for occupational and public exposure (Omogunloye *et al.*, 2021).

Background ionizing radiation in the environment arises primarily from natural terrestrial radionuclides and cosmic radiation; however, anthropogenic activities can further modify and enhance these levels (Shahbazi-Gahrouei *et al*., 2013). Over time, localized human activities may contribute to measurable increases in environmental radiation fields, thereby altering baseline exposure conditions. In this context, roasted food vending environments may represent micro-settings where radiation exposure levels warrant systematic evaluation.

Therefore, this study aims to assess the radiological risks associated with enhanced background ionizing radiation around selected roasted food vending sites in Southwestern Nigeria and to evaluate the radiation safety status of these environments. The findings are expected to provide baseline radiological data necessary for future monitoring, regulatory assessment, and environmental health surveillance in the study area.

MATERIALS AND METHODS

The Study Area

The selected areas for this study are Ode-Irele (IR), Okitipupa (OK), and Ore (OR) in the Southern Senatorial District of Ondo State, Southwestern Nigeria. These selected areas are the three most significant and densely populated towns within the bitumen belt zone of Ondo State, the southwest geopolitical zone of Nigeria. Ode Irele and Okitipupa are the administrative headquarters of Irele and Okitipupa local government areas of Ondo State, with their dwellers predominantly the Ikales of the country's Yoruba extraction. In contrast, Ore, not the administrative headquarters of its local government area, is the most civilized, densely populated, and commercialized town within the Odigbo local government area of Ondo State. The dwellers of Ore comprise people from virtually all the ethnic groups of Nigeria, as it is one of the major commercial towns in the Southwest geopolitical zone. Figure 1 depicts the map of Ondo State showing the study locations.

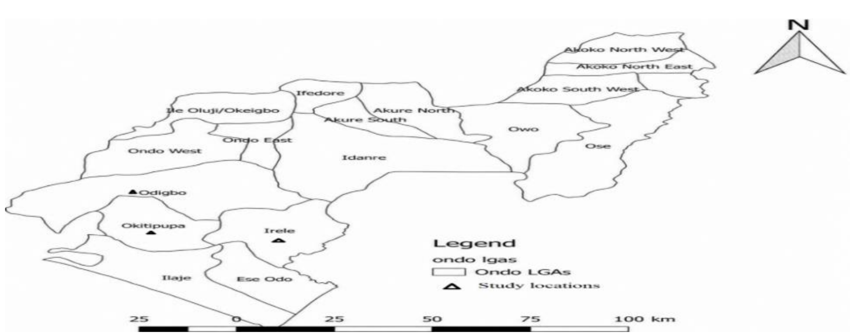

Figure 1: Map of the LGAs in Ondo State, Nigeria, Showing the Study Locations

The main factor responsible for Ore town's commercial status is its geographical location, as it's the main town connecting not only the Southern senatorial district of the State to other parts of the State, but also the Western part of the country to the entire Southern part of the country. The topographic altitudes of these areas vary from about 84 m above sea level in the Northern part, with a gradual slope, to a relatively sea-level swamp flat in the coastal area to the South, with the landscape gradually undulating southward. The average yearly rainfall is over 2500 mm, and the mean annual temperature is between 24 and 27 ℃ (Iloeje, 1981). The residents of these areas are predominantly farmers, with staple foods including yams, plantains, maize, yam flour, vegetables, cassava flakes (garri), and baked cassava (popularly known as pupuru) (Omogunloye *et al*., 2023). The study area is significant from environmental and economic perspectives because the weather and climatic conditions favor the cultivation and growth of the various foods roasted by street food vendors.

However, these study areas were selected because they are the major commercial centers in their respective local government areas within the State, where many people (especially women) engage in food roasting to earn a living, and a reasonable number of people patronize them daily.

Instrumentation

This survey was carried out using a measuring tape, a Garmin eTrex 10 Geographical Positioning System (GPS) device, and a digital GQ-500 Geiger-Müller Counter (GMC). Audible and visual cues built into the digital GQ-500 GMC indicate the measured radiation level. Geiger tubes are installed in the digital GMC to detect environmental radiation levels. The intensity of the radiation field is measured in terms of the number of pulses per second. The central processing unit (CPU) interprets the electrical pulses generated as counts whenever radiation passes through the Geiger tube of the GQ-500 GMC. The basic count rate unit is the Count per minute (CPM), representing the quantity of radiation present. This typical radiation measurement unit (CPM) can be converted to other radioactivity units, such as μSvh^{-1} or mRh^{-1} (GQ L.L.C. Electronics, 2018).

Radiation Exposure Rate (X) Measurement

The background radiation exposure rates "X (mRh^{-1})" around twenty-one (21) randomly selected roasted food vendors in the study area were measured. Seven (7) roasted food vendors per City. These measurements were carried out during the roasted food vendors' roasting and non-roasting hours. The roasting hours span from around 8.00 a.m. to 6.00 p.m., while the non-roasting hours span from 6.00 p.m. to 8.00 a.m. daily. The background ionizing radiation exposure levels around roasted food vendors in the study areas were measured by placing the Geiger-Müller counter 1.0 m above ground level, turning it on, and recording the levels directly on its screen in μSvh^{-1}. Three different readings were taken for each measurement point, and the mean value was determined and recorded. The device is placed 1m above ground level using a meter rule. The coordinates (locations) of the measurement points were also recorded using the GPS device.

Radiological Risk Parameters Assessment

To determine the radiological risk associated with the enhanced ionizing radiation generated and to which the roasted food vendors are exposed in the study area, the absorbed dose rate ($\dot{D}$), Annual effective dose ($\dot{E}$), and Excess lifetime cancer risk (*ELCR*) are employed as radiological risk parameters.

Absorbed Dose Rate ($\dot{D}$)

This is an essential radiological risk assessment parameter because it evaluates the amount of absorbed radiation doses per unit time in matter. To ensure a radiologically safe environment, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has established a maximum acceptable limit of 84 nGyh-1 for the public (UNSCEAR, 2000). The absorbed dose rates were determined by converting the measured radiation exposure rate (X) in μSvh^{-1} to mRh^{-1} using equations 1, 2, and 3, respectively (Ugbede and Benson, 2018).

$$1\mu Svh^{-1} = 0.1 mRh^{-1} \quad (1)$$

$$1 mRh^{-1} = 8.7 nGyh^{-1} = 8700 nGyh^{-1} \quad (2)$$

$$\dot{D}\left(nGyh^{-1}\right) = 8700 \times X\left(mRh^{-1}\right) \quad (3)$$

Where X is the measured radiation exposure rate.

Annual Effective Dose ($\dot{E}$)

The Annual Effective Dose ($\dot{E}$) is a radiological parameter used to assess the likelihood of future consequences of long-term radiation exposure, as it determines the overall absorbed dose per year (Darwish *et al*., 2015). The annual effective dose ($\dot{E}$) received by a person is determined using the absorbed dose rate, a dose conversion factor of 0.7 $SvGy^{-1}$, and a corresponding occupancy factor of 0.42 (10/24) and 14/24 (0.58) for roasting and non-roasting hours, respectively. Equations 4 and 5 calculate the annual effective dose for roasted food vendors during roasting and non-roasting hours, respectively (Omogunloye *et al*., 2023).

$$\dot{E}(mSvy^{-1}) = \dot{D}\left(nGyh^{-1}\right) \times 8760h \times 0.42 \times 0.7 SvGy^{-1} \times 10^{-6} \quad (4)$$

$$\dot{E}(mSvy^{-1}) = \dot{D}\left(nGyh^{-1}\right) \times 8760h \times 0.58 \times 0.7 SvGy^{-1} \times 10^{-6} \quad (5)$$

8760 is the number of hours a year, and $\dot{D}$ is the absorbed dose rate in $nGyh^{-1}$, respectively.

Excess Lifetime Cancer Risk (ELCR)

The possibility of cancer inducement throughout a lifetime for a given radiation exposure level is determined using the excess lifetime cancer risk (Ajanaku *et al.*, 2018). After exposure of a given number of persons to ionizing radiation at a specific dose, the expected number of cancers among those persons is represented by this number. It is of great importance to know that an increase in the excess lifetime cancer risk led to an increased possibility of breast, prostate, blood, and other forms of cancer development. The excess lifetime cancer risk was calculated using equation 6 (Taskin *et al.*, 2009).

$$ELCR = \dot{E} \times DL \times RF \times 10^{-3} \quad (6)$$

where $\dot{E}$ is the annual effective dose, DL is the duration of life (70 years), and RF is the fatal cancer risk per Sievert, the risk factor ICRP uses of 0.05 for the public (ICRP, 1995).

RESULTS AND DISCUSSION

The radiological parameters measured around the roasted food vending areas during non-roasting and roasting periods are presented in Tables 1 and 2, respectively. The datasets reveal a distinct contrast between baseline environmental radiation levels and those recorded during active roasting operations, indicating the influence of localized anthropogenic activities on the ambient radiation field.

Table 1: The Measured Radiation Exposure Rate and the Evaluated Radiation Risk Parameters around the Roasted Food Vendors (Non-Roasting Hours)

Sampling Codes	Sampling Location	X (mRh^{-1})	$\dot{D}$ ($nGyh^{-1}$)	$\dot{E}$ ($mSvy^{-1}$)	ELCR x 10^{-3}
OK 1	6°30'19"N4°47'13"E	0.009	78.3	0.278	0.0010
OK 2	6°30'22"N4°47'12"E	0.005	43.5	0.155	0.0005
OK 3	6°30'25"N4°47'11"E	0.005	43.5	0.155	0.0005
OK 4	6°30'25"N4°47'9"E	0.007	60.9	0.217	0.0008
OK 5	6°30'22"N4°46'55"E	0.006	52.2	0.186	0.0007
OK 6	6°30'27"N4°46'57"E	0.008	69.6	0.248	0.0009
OK 7	6°30'26"N4°46'51"E	0.004	34.8	0.124	0.0004
MEAN		0.006	54.7	0.194	0.0007
IR 1	6°29'23"N4°46'55"E	0.007	60.9	0.217	0.0008
IR 2	6°29'23"N4°51'60"E	0.008	69.6	0.248	0.0009
IR 3	6°29'19"N4°52'3"E	0.006	52.2	0.186	0.0007
IR 4	6°30'26"N4°52'0"E	0.007	60.9	0.217	0.0008
IR 5	6°29'28"N4°52'4"E	0.004	34.8	0.124	0.0004
IR 6	6°29'25"N4°52'7"E	0.004	34.8	0.124	0.0004
IR 7	6°29'29"N4°52'12"E	0.005	43.5	0.155	0.0005
MEAN		0.006	51.0	0.181	0.0006
OR 1	6°54'3"N4°52'23"E	0.008	69.6	0.248	0.0009
OR 2	6°54'10"N4°52'25"E	0.007	60.9	0.217	0.0008
OR 3	6°54'8"N4°52'20"E	0.007	60.9	0.217	0.0008
OR 4	6°54'25"N4°51'19"E	0.009	78.3	0.278	0.0010
OR 5	6°54'30"N4°51'15"E	0.009	78.3	0.278	0.0010
OR 6	6°54'29"N4°51'17"E	0.005	43.5	0.155	0.0005
OR 7	6°54'22"N4°50'14"E	0.007	60.9	0.217	0.0008
MEAN		0.007	64.6	0.230	0.0008

Table 2: The Measured Radiation Exposure Rate and the Evaluated Radiation Risk Parameters around the Roasted Food Vendors (Roasting Hours)

Sampling Codes	Sampling Location	X(mRh^{-1})	$\dot{D}$ ($nGyh^{-1}$)	$\dot{E}$($mSvy^{-1}$)	ELCR x 10^{-3}
OK 1	6°30'19"N4°47'13"E	0.018	156.6	0.403	0.0014
OK 2	6°30'22"N4°47'12"E	0.021	182.7	0.471	0.0016
OK 3	6°30'25"N4°47'11"E	0.015	130.5	0.336	0.0012
OK 4	6°30'25"N4°47'9"E	0.022	191.4	0.493	0.0017
OK 5	6°30'22"N4°46'55"E	0.016	139.2	0.359	0.0013
OK 6	6°30'27"N4°46'57"E	0.023	200.1	0.515	0.0018
OK 7	6°30'26"N4°46'51"E	0.019	165.3	0.426	0.0015
MEAN		0.019	166.5	0.429	0.0015

Sampling Codes	Sampling Location	X(mRh^{-1})	Ḋ (nGyh^{-1})	Ė($mSvy^{-1}$)	ELCR x 10^{-3}
IR 1	6°29'23"N4°46'55"E	0.014	121.8	0.314	0.0011
IR 2	6°29'23"N4°51'60"E	0.016	139.2	0.359	0.0013
IR 3	6°29'19"N4°52'3"E	0.015	130.5	0.336	0.0012
IR 4	6°30'26"N4°52'0"E	0.018	156.6	0.403	0.0014
IR 5	6°29'28"N4°52'4"E	0.021	182.7	0.471	0.0016
IR 6	6°29'25"N4°52'7"E	0.017	147.9	0.381	0.0013
IR 7	6°29'29"N4°52'12"E	0.019	165.3	0.426	0.0015
MEAN		0.017	149.1	0.384	0.0013
OR 1	6°54'3"N4°52'23"E	0.022	191.4	0.493	0.0017
OR 2	6°54'10"N4°52'25"E	0.022	191.4	0.493	0.0017
OR 3	6°54'8"N4°52'20"E	0.012	104.4	0.269	0.0009
OR 4	6°54'25"N4°51'19"E	0.019	165.3	0.426	0.0015
OR 5	6°54'30"N4°51'15"E	0.027	234.9	0.605	0.0021
OR 6	6°54'29"N4°51'17"E	0.015	130.5	0.336	0.0012
OR 7	6°54'22"N4°50'14"E	0.021	182.7	0.471	0.0016
MEAN		0.020	171.5	0.442	0.0015

Under non-roasting conditions, the measured exposure rates and associated radiological risk parameters reflect typical terrestrial background radiation levels largely controlled by soil composition and naturally occurring radionuclides. The relatively narrow variation observed across the sampling locations suggests a fairly homogeneous distribution of these primordial radionuclides within the study areas. Mean absorbed dose rates ranged from 51.0 to 64.6 nGy h^{-1}, values comparable to global background radiation levels reported by UNSCEAR, indicating that external gamma exposure during non-roasting periods was primarily due to natural environmental sources.

During roasting hours, however, a marked increase in radiation exposure and associated dose parameters was observed across all locations. This increase suggests that roasting activities contributed significantly to increased local radiation levels. Biomass fuels such as charcoal and firewood are known to accumulate radionuclides through root uptake from contaminated soils (ICRP, 1995; UNSCEAR, 2008). During combustion, these radionuclides may become concentrated in ash residues or released into the atmosphere as particulate matter, thereby elevating the surrounding gamma radiation field.

To further evaluate variation in radiation exposure, descriptive statistics of exposure rates were performed, and the results are presented in Table 3.

Table 3: Descriptive Statistics of Radiation Exposure Rate (X)

Condition	Location	Mean (mRh^{-1})	SD	Minimum	Maximum	CV (%)
Non-roasting	OK	0.0063	0.0018	0.004	0.009	28.63
Non-roasting	IR	0.0059	0.0016	0.004	0.008	26.87
Non-roasting	OR	0.0074	0.0014	0.005	0.009	18.81
Roasting	OK	0.0191	0.0030	0.015	0.023	15.80
Roasting	IR	0.0171	0.0024	0.014	0.021	14.06
Roasting	OR	0.0197	0.0050	0.012	0.027	25.14

The descriptive statistics show that mean exposure rates during roasting periods were substantially higher than those measured during non-roasting periods across all sampling locations. During non-roasting hours, OR recorded the highest mean exposure rate (0.0074 mRh^{-1}), while IR recorded the lowest (0.0059 mRh^{-1}). Similarly, during roasting periods, OR maintained the highest mean value (0.0197 mRh^{-1}), whereas IR remained the lowest (0.0171 mRh^{-1}). The coefficients of variation ranged from 18.81% to 28.63% during non-roasting periods and from 14.06% to 25.14% during roasting periods, indicating moderate variability and relative consistency in the measured radiation levels.

Figure 2 further illustrates the increase in radiation exposure rates during roasting compared with non-roasting conditions. Across all sampling locations, the mean exposure rate increased from approximately 0.006–0.007 mR h^{-1} during non-roasting periods to about 0.017–0.020 mR h^{-1} during roasting activities. The larger error bars observed during roasting periods indicate greater variability in radiation levels, likely associated with combustion dynamics, fuel composition, and particulate dispersion patterns.

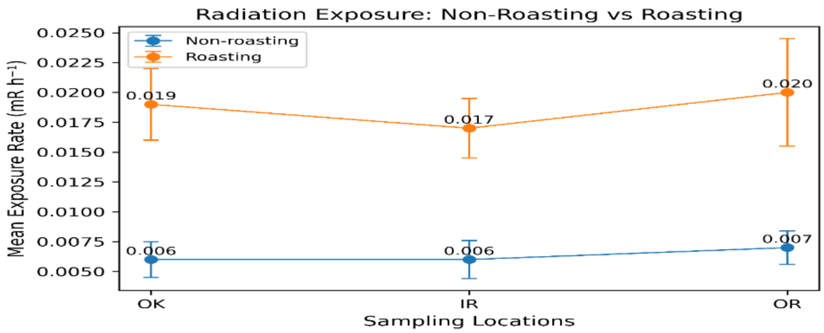

Figure 2: Radiation Exposure – Non-Roasting vs. Roasting (with SD)

To determine whether the observed increase in exposure rates was statistically significant, an independent sample t-test was conducted. The results are presented in Table 4.

Table 4: Independent Sample T-Test Comparing Exposure Rates during Roasting and Non-Roasting Hours

Parameter	Value
Mean Exposure Rate (Non-roasting)	0.00652 mRh^{-1}
Mean Exposure Rate (Roasting)	0.01867 mRh^{-1}
t-value	-13.96
p-value	3.77×10^{-14}
Level of significance	0.05

The t-test results showed a statistically significant difference between roasting and non-roasting exposure rates ($p < 0.05$), confirming that roasting activities significantly increased environmental radiation levels around the vendors. The percentage increase in radiation exposure during roasting activities was estimated at approximately 186.35%, indicating a substantial enhancement of the ambient radiation field due to combustion-related processes.

A likely mechanism responsible for this increase is the redistribution of radionuclides into airborne particulate fractions during combustion. Elevated temperatures may facilitate volatilization of radionuclide progeny, which subsequently condense onto aerosols and fine particles. These particles can remain suspended within the microenvironment, increasing the probability of radiative interaction and localized dose enhancement. In addition, the resuspension of contaminated ash through human activity and convective air movement may further contribute to elevated dose rates.

The maximum absorbed dose rate recorded during roasting periods reached 234.9 nGy h^{-1} at the OR location, suggesting that active roasting environments may temporarily function as localized radiological hotspots. Such elevated values are comparable to those reported in studies of technologically enhanced naturally occurring radioactive materials (TENORM), in which industrial or thermal processes increase the concentration and redistribution of naturally occurring radionuclides. The relatively higher values observed at OR may be associated with differences in fuel type, combustion efficiency, oxygen availability, or fuel sourcing practices.

To assess possible spatial differences among the study locations, a one-way analysis of variance (ANOVA) was performed. The results are shown in Table 5.

Table 5: One-Way ANOVA for Exposure Rates across Sampling Locations

Condition	F-value	p-value	Remark
Non-roasting hours	1.81	0.193	Not significant
Roasting hours	0.97	0.399	Not significant

The ANOVA results indicated no statistically significant differences in exposure rates among the three sampling locations during both roasting and non-roasting periods ($p > 0.05$). This suggests that the observed radiological enhancement was relatively uniform across the study areas and may reflect similarities in roasting practices, fuel usage, and environmental conditions.

Figure 3 presents the relationship between the mean exposure rates and the corresponding annual effective dose values across all sampling locations during roasting and non-roasting periods.

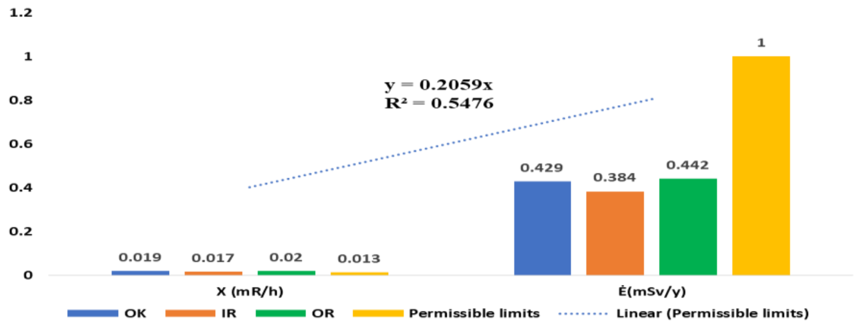

Figure 3: Mean Radiation Exposure Rate (Roasting and Non-roasting Periods) and Corresponding Annual Effective Dose across Sampling Locations

Although the estimated annual effective dose (AED) values remained within internationally recommended public exposure limits, prolonged occupational exposure among vendors may result in cumulative doses higher than predicted under standard occupancy assumptions. Furthermore, the conversion of absorbed dose in air to effective dose assumes uniform irradiation geometry. In contrast, roasting environments may involve anisotropic exposure conditions due to proximity to combustion sources and uneven radionuclide distribution.

Pearson correlation analysis was also conducted to evaluate the relationship between exposure rate and the derived radiological risk parameters. The results are presented in Table 6.

Table 6: Correlation between Exposure Rate and Radiological Risk Parameters

Parameters Compared	Correlation Coefficient (r)	Relationship
X and Ḋ	+1.000	Perfect positive correlation
X and Ė	+1.000	Perfect positive correlation
X and ELCR	+1.000	Perfect positive correlation

The strong positive correlations indicate that increases in exposure rate directly resulted in corresponding increases in absorbed dose rate, annual effective dose, and excess lifetime cancer risk. This relationship is expected, as the radiological risk parameters were derived mathematically from the measured exposure rates.

Although the Excess Lifetime Cancer Risk (ELCR) values obtained during roasting periods remained below internationally accepted threshold limits, the consistent increase observed relative to non-roasting conditions is noteworthy. Under the linear no-threshold (LNT) model, repeated low-dose exposure over extended periods may cumulatively contribute to stochastic health effects, particularly among occupationally exposed individuals, such as food vendors.

In addition to external exposure pathways, internal exposure through inhalation of radionuclide-bearing particulates may also contribute to the total radiological burden. Combustion-derived aerosols may contain radionuclides such as ^{210}Pb and ^{210}Po, both of which are radiotoxic alpha emitters capable of delivering localized doses to pulmonary tissues following inhalation. Consequently, the AED values reported in this study may represent only a partial estimate of total occupational exposure.

Environmental and microclimatic factors may also influence the observed radiation patterns. Atmospheric stability, wind speed, particulate dispersion, soil characteristics, and moisture content can affect radionuclide transport, deposition, and resuspension processes, thereby modulating localized exposure levels. Differences in vendor density, fuel storage methods, and proximity to other anthropogenic activities may further contribute to site-specific variations.

The findings demonstrate that roasted food vending environments constitute dynamic radiological microenvironments in which combustion and particulate processes significantly modify natural background radiation levels. However, the broader *implications for sustainable public health were not directly assessed or discussed in this study*, and therefore any interpretation regarding long-term population health outcomes or sustainability impacts should be made with caution. Although the measured radiological parameters remained within permissible exposure limits, the significant increase observed during roasting periods underscores the need for continued environmental monitoring and the implementation of practical exposure-reduction measures, such as improved ventilation, cleaner fuel selection, and enhanced occupational safety practices.

CONCLUSION

This study assessed the levels of background ionizing radiation and the associated radiological risk parameters around selected roasted food vending sites in Okitipupa, Ode-Irele, and Ore, Southwestern Nigeria. The measured radiation exposure rates during non-roasting periods were generally within typical natural background levels, indicating that the baseline radiological conditions of the study areas are primarily controlled by naturally occurring terrestrial radionuclides. However, a substantial increase in radiation exposure was observed during roasting activities across all sampling locations.

The absorbed dose rates recorded during roasting periods exceeded the global average background value of 59 nGy h^{-1} and, in some cases, surpassed the recommended public limit of 84 nGy h^{-1}. Statistical analysis further confirmed a significant difference between roasting and non-roasting exposure conditions ($p < 0.05$), with radiation levels increasing by approximately 186% during active roasting operations. Despite this increase, the evaluated annual effective dose and excess lifetime cancer risk values remained below the internationally recommended limits for public exposure established by UNSCEAR and ICRP. The findings indicate that combustion processes associated with roasted food vending contribute measurably to localized increases in environmental radiation levels through the release and redistribution of radionuclide-bearing particulates. Although the present radiological risk may not constitute an immediate public health concern, repeated occupational exposure among vendors and frequent exposure among nearby residents could contribute to cumulative exposure over time.

Overall, the study highlights the radiological influence of roasting activities within informal food vending environments and underscores the importance of continued environmental monitoring and the adoption of practical exposure reduction measures, including improved ventilation, careful fuel selection, and general occupational safety practices.

REFERENCES

Agbalagba O, Avwiri G, Ononugbo C. GIS mapping of impact of industrial activities on the terrestrial background ionizing radiation levels of Ughelli metropolis and its environs, Nigeria. *Environ Earth Sci*. 2016; 75:1–10. https://doi.org/10.1007/s12665-016-6216-y

Ajanaku O, Ilori AO, Ibitola GA, Faturoti OB. Assessment of natural radioactivity and associated dose rates in surface soils around Oluwa Glass Industry environments, Igbokoda, Ondo State, Southwestern Nigeria. *Phys Sci Int J*. 2018; 20(3):1–13. https://doi.org/10.9734/PSIJ/2018/42372

Alimi BA, Oyeyinka A, Olohungbebe L. Socio-economic characteristics and willingness of consumers to pay for the safety of fura de nunu in Ilorin, Nigeria. *Qual Assur Saf Crops Foods*. 2016; 8:81–86. https://doi.org/10.3920/QAS2014.0494

Alimi BA, Shittu TA, Sanni LO. Effect of hydrocolloids and egg content on sensory quality of coated fried yam chips. *J Culin Sci Technol*. 2014; 12:168–180. https://doi.org/10.1080/15428052.2014.880097

Alimi BA, Workneh TS. Consumer awareness and willingness to pay for safety of street foods in developing countries: a review. *Int J Consum Stud*. 2015; 40:242–248. https://doi.org/10.1111/ijcs.12248

Choudhury M, Mahanta L, Goswami J, Mazumder M, Pegoo B. Socio-economic profile and food safety knowledge and practice of street food vendors in the City of Guwahati, Assam, India. *Food Control*. 2011; 22:196–203. https://doi.org/10.1016/j.foodcont.2010.06.020

Darwish DAE, Abdul-Nasr KTM, El-Khayatt AM. The assessment of natural radioactivity and its associated radiological hazards and dose parameters in granite samples from South Sinai, Egypt. *J Radiat Res Appl Sci*. 2015;8(1):17–25. https://doi.org/10.1016/j.jrras.2014.10.003

Ekanem EO. The street food trade in Africa: safety and socio-environmental issues. *Food Control*. 1998; 9:211–215. https://doi.org/10.1016/S0956-7135(97)00085-6

Eze CU, Abonyi LC, Njoku J, Irurhe NK, Olowu O. Assessment of radiation protection practices among radiographers in Lagos, Nigeria. *Niger Med J*. 2013; 54:386–391. https://doi.org/10.4103/0300-1652.126290

Frane N, Bitterman A. Radiation safety and protection. *StatPearls [Internet]*. Treasure Island (FL): StatPearls Publishing; 2023. https://www.ncbi.nlm.nih.gov/books/NBK557499/

GQ Electronics LLC. GQ GMC-500/GMC-500+ Geiger counter user guide. 2018. Available from: http://www.gqelectronicsllc.com/GMC-500UserGuide.pdf

Iloeje NP. *A new geography of Nigeria*. London: Longman; 1981, 26–28.

Ilori AO, Adefisoye OP, Catherine BS. Estimation of natural radionuclide concentrations and heavy metal contents due to bitumen exploitation at Gbeleju-Loda, Ode-Irele, Ondo State, Southwestern Nigeria. *Asian J Phys Chem Sci*. 2019; 6:1–10. https://doi.org/10.9734/AJOPACS/2018/46230

International Commission on Radiological Protection (ICRP). 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; 1995. https://www.icrp.org/publication.asp?id=icrp%20publication%2072

Jha SK, Patra AC, Verma GP, Iyer IS, Aswal DK. Natural radiation and environment. In: *Natural Radiation and Environment*. Springer; 2024. p. 27–72. https://doi.org/10.1007/978-981-97-2795-7_2

Mettler FA. Medical effects and risks of exposure to ionising radiation. *J Radiol Prot*. 2012; 32(1):N9–N13. https://doi.org/10.1088/0952-4746/32/1/n9

Omogunloye OY, Adepoju AT, Kururimam P. Assessment of radiation risk from background radiation exposures in selected hospitals within Makurdi Metropolis, North-Central, Nigeria. *Eur J Appl Phys*. 2021; 3:43–47. https://doi.org/10.24018/ejphysics.2021.3.4.91

Omogunloye OY, Ilori AO, Abolade OI. Radiological impact assessment due to background ionizing radiation around palm oil processing mills in Southwestern Nigeria. *J Asian Sci Res*. 2023; 13:45–53. https://doi.org/10.55493/5003.v13i1.4728

Salamandane A, Malfeito-Ferreira M, Brito L. The socioeconomic factors of street food vending in developing countries and its implications for public health: a systematic review. *Foods*. 2023;12(20):3774. https://doi.org/10.3390/foods12203774

Shahbazi-Gahrouei D, Setayandeh S, Gholami M. A review on natural background radiation. *Adv Biomed Res*. 2013; 2:65. https://doi.org/10.4103/2277-9175.115821

Sidi, M., England, A., Mansur, U., Muhammad, Z., Garba, I., DJ Zira, Abubakar, U., Abubakar, A. A., A. Ya'u, & G. Luntsi. (2022). Radiation protection measures of the radiological facilities in Kano metropolis, Nigeria. *West African Journal of Radiology*, *29*(2), 118–124. https://www.wajr.org/index.php/home/article/view/49

Talapko J, Talapko D, Katalinić D, et al. Health effects of ionizing radiation on the human body. *Medicina (Kaunas)*. 2024;60(4):653. https://doi.org/10.3390/medicina60040653

Taskin H, Karavus M, Ay P, et al. Radionuclide concentrations in soil and lifetime cancer risk due to the gamma radioactivity in Kirklareli, Turkey. *J Environ Radioact*. 2009; 100:49–53. https://doi.org/10.1016/j.jenvrad.2008.10.012

Ugbede FO, Benson ID. Assessment of outdoor radiation levels and radiological health hazards in Emene industrial layout of Enugu State, Nigeria. *Int J Phys Sci*. 2018; 13(20):265–272. https://doi.org/10.5897/IJPS2018.4763

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Sources and effects of ionizing radiation: UNSCEAR 2000 report to the General Assembly. Vol I. New York: United Nations; 2000.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Sources and effects of ionizing radiation: UNSCEAR 2006 report to the General Assembly. Vol I. New York: United Nations; 2008.