Nigerian Journal of Theoretical and Environmental Physics (NJTEP)
ISSN Print: 3026-9601
DOI: https://doi.org/10.62292/njtep.v3i1.2025.66
Volume 3(1), January 2025

An Evaluation of Excess Lifetime Cancer Risk from Indoor and Outdoor Radiation Exposure in Okutukutu Computer Village, Yenagoa, Bayelsa State, Nigeria: A Monte Carlo Simulation Approach

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ABSTRACT

Some of the components of smart phones and computers, like ceramic capacitors may contain small amounts of radioisotopes. In this work, indoor and outdoor radiation exposure rates in Okutukutu "computer village" have been measured using the in-situ method. Ten indoor and ten outdoor readings were taken during working hours using a digital radiation meter. Standard equations and the Monte Carlo approach were used to analyze the data. The results show that mean exposure rates of 0.019 mRh^{-1} and 0.016 mRh^{-1} for indoor and outdoor respectively are not significantly high above the 0.013 mRh^{-1} world average. Approximately 700 and 90 people out of a population of one million (106) are expected to develop cancer as a result of indoor and outdoor exposure, respectively, according to the Monte Carlo simulation's assessment of minimum probable risk (P 5% = best case scenario). However, according to the maximum likely risk assessment results (P 95% = worst-case scenario), the estimated rates of cancer development from indoor and outdoor exposures are 480 and 2090, respectively, in a population of one million (10^6). Similar to this, the most likely risk calculation (50%) indicates that, out of a population of one million, 1320 and 270 people, respectively, are likely to acquire cancer as a result of indoor and outdoor exposure rates. Therefore, strict and efficient procedures must be implemented to protect both traders and buyers in the environments.

Keywords:
Radioisotopes,
Exposure rates,
Indoor,
Outdoor,
Cancer risk.

INTRODUCTION

The rapid evolution of technology all over the globe has led to an unprecedented proliferation of electronic devices (Cusick, 2007), including smartphones and computers (Leahy, 2012). While these devices have revolutionized communication and information exchange, concerns about potential radiation exposure have grown. The source of radiation in an environment could be natural or manmade (Tavernier, 2009; Mitrovic et al., 2020). Natural sources are the primordial radionuclides that exist inherently in different extents throughout earth's crust as well as the atmosphere and in all media in the environment or cosmogenic radionuclides such as ^{7}Be, ^{3}H, ^{14}C and ^{22}Na produced as when cosmic ray collide with atmospheric matter (Anjos et al., 2008; Gawad et at., 2023; Sanjay et al., 2024). Human activities have led to the introduction of radionuclides into the environment, contributing to humanmade sources of radiation. These activities include nuclear testing, routine release of from nuclear reactors, accidental discharges, and the use of radiation in medicine, agriculture and industry. Examples of radionuclides released through these activities include ^{95}Zr, ^{131}I and ^{137}Cs (Abu-Jarad, 2008). Additionally, other artificial sources of exist, such as emissions from x-ray machines and certain types of lanterns. Although, phones and computers sales and repair environment may not likely pose much danger in terms of ionizing radiation however, some of the components like ceramic capacitors may contain small amounts of radioisotopes. While the likelihood of significant radiation exposure is low, measuring background ionizing levels ensures a safe environment for employees and customers. In this work, the indoor as well as outdoor exposure rates of radiation in Okutukutu "computer village" will be measured to estimate associated radiological parameters. The monte Carlo simulation approach would be used to provide valuable insight into the radiation exposure risk associated with this environment. The Monte Carlo simulation approach allows for the quantification of uncertainty arising from measurements errors, model assumptions as well as parameter uncertainties and the performance of sensitivity in analysis (ICRP, 2010).

Study area

Okutukutu computer village is located in Yenagoa Bayelsa state Nigeria.it is situated in the heart of Yenagoa the capital city of Bayelsa state along Melford Okilo Road. Yenagoa city is situated within latitude $4^0$55'N and $5^0$05'N and longitude $6^0$15'E and $6^0$20'E ((Nwankwoala and Oborie 2014) The village which is an adaptation of traditional marketing strategies to modern technology, is a sprawling complex of make shift stalls, shops, and warehouses occupying a few plots of land. Activities carried out in the village include computer and electronics sales, repair and maintenance services, software development and installation, phone and gadgets accessories sales and repair, internet and networking services etc. the atmosphere is always vibrant with hundreds of vendors and customers along its narrow alleys and passageways between stalls.

MATERIALS AND METHODS

In-situ method which is a standard practice in measurement was adopted in this research. The method ensures the preservation of samples inherent environmental characteristics throughout the measurement process (Yusuf *et al.*, 2022). This study utilized a digital radiation meter, specifically the Radalert-100X model, which is configured to survey radiation exposure in mR/h with a ± 15 % error margin. It also contains a Geiger-Muller tube which creates pulse current any time radiation goes into it, resulting in ionization (Ovuomarie-Kelvin e*t al.,* 2018). Signals outputs are quantified and logged as count rates (Biere *et al.*, 2023). Measurement was carried out in mRh^{-1}, in twenty randomly selected points. Ten indoor readings and ten outdoor readings during working hours. At each point, measurements were taken with the radiation survey meter kept at a usual elevation of 1.0 m from ground surface, having the window facing supposed source for about 120 s.

The exposure rate in $mRhr^{-1}$ in all points were changed to absorbed dose in air, annual effective dose equivalent (AEDE) and Excess lifetime cancer risk (ELCR) using equations (1), (2) and (3) (Ezekiel, 2017; Biere et al., 2022; Rafique et al., 2014) respectively.

$$1\ mRh^{-1} = 8.7\ nGyh^{-1} \times 10^3 = 8700\ nGyh^{-1} \qquad (1)$$

$$AEDE\ (mSvy^{-1}) = D(nGyh^{-1}) \times 8760\ h \times CF \times OF \times 10^{-3} \qquad (2)$$

$$ECLR = AEDE\ (mSvy^{-1}) \times DL \times RF \qquad (3)$$

where CF is dosage conversion factor from the absorbed dose in air to effective dose in Sv/Gy, and D is absorbed dose rate in $nGyh^{-1}$, with 8760 hours a year. CF is equal to 0.7 Sv/Gy. DL = 70 years (average life duration), RF is fatal cancer risk factor stated in (Sv^{-1}), and OF is occupancy factor; according to UNSCEAR (2008), OF = 0.2 for outdoor and 0.75 for indoor. ICRP 103 suggests threshold of 0.05 Sv^{-1} for general population in situation of low background radiation, expected to result in stochastic effects (ICRP, 2007).

RESULTS AND DISCUSSION

Result

Detected background ionizing radiation readings, indoor and outdoor, have been used to plot against the World average value and are presented in figures 1 and 2. Table 1 shows the statistics of calculated parameters and world average values.

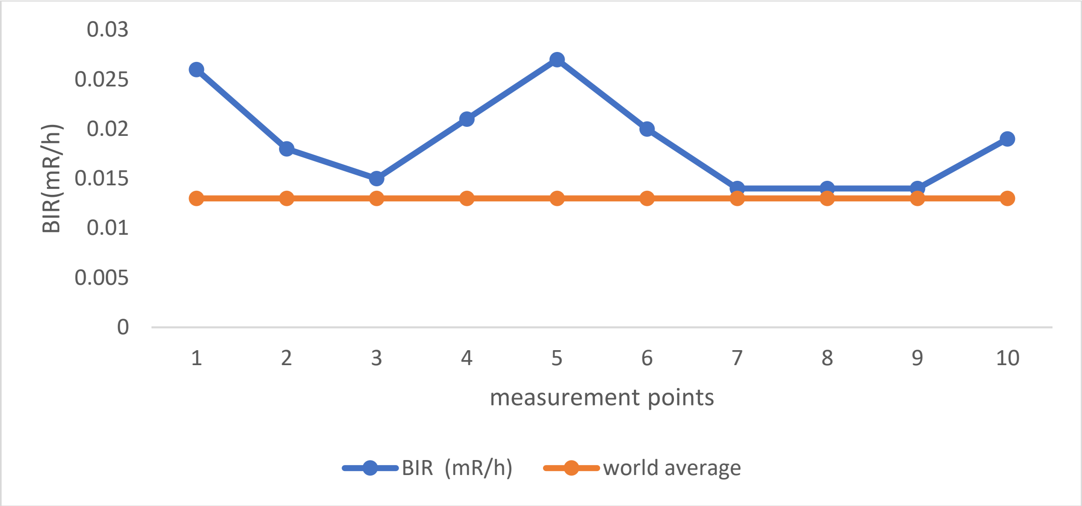

Figure 1: Measured indoor exposure rate against World average

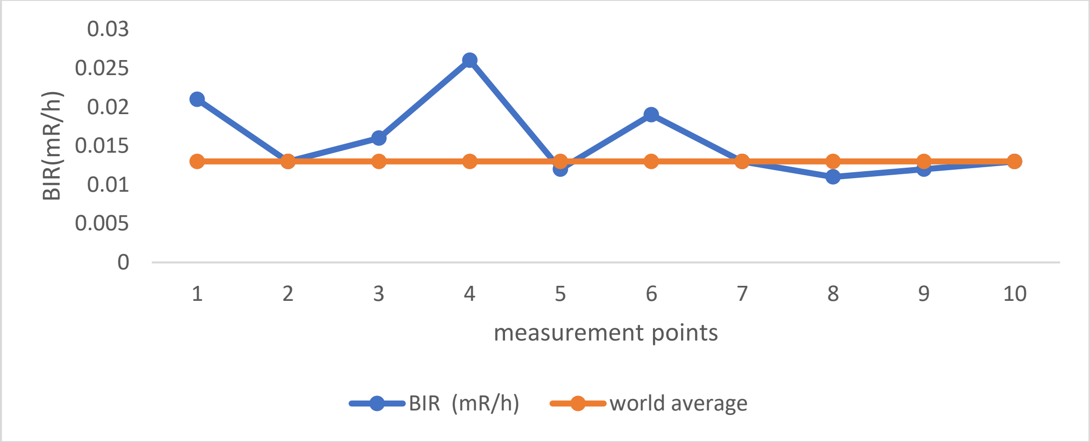

Figure 2: Measured outdoor exposure rate against World average

Table 1: Statistics on radiation indices for indoor and outdoor exposure in the study area compared with world average

Radiation Indices	Minimum	Maximum	This work average	World average*
Din ($nGyh^{-1}$)	122.1	235.2	164.1	84.0
Dout ($nGyh^{-1}$)	96.2	226.2	139.1	59.0
AEDEin ($mSvy^{-1}$)	0.187	0.360	0.251	0.41
AEDEout ($mSvy^{-1}$)	0.147	0.347	0.208	0.07
ELCRin x 10^{-3}	0.52	0.99	0.69	1.16
ELCRout x 10^{-3}	0.41	0.96	0.59	0.29

*Qureishi et al., (2014)

Discussion

The measured Background Ionizing Radiation (BIR) levels revealed that indoor values varied between 0.011 mRh^{-1} and 0.027 mRh^{-1}, averaging 0.019 mRh^{-1}. Outdoor values ranged from 0.011 mRh^{-1} to 0.026 mRh^{-1}, averaging 0.016 mRh^{-1}. Notably, both indoor and outdoor averages exceed the global average of 0.013 mRh^{-1}, as reported by UNSCEAR (2000). Absorbed dose rates (D) in air determined using equation 1 above which yielded minimum: 122.1 $nGyh^{-1}$, maximum: 235.2 $nGyh^{-1}$ and mean: 164.1 $nGyh^{-1}$for indoor then minimum: 96.2 $nGyh^{-1}$, maximum: 226.2 $nGyh^{-1}$ and mean: 139.1 $nGyh^{-1}$for outdoor. Notably, both indoor and outdoor mean absorbed dose rates exceed the global average, as stated by Qureishi et al. (2014). Annual Effective Dose Equivalent (AEDE) was computed using equation 2, yielding indoor minimum: 0.187 mSv/y, maximum: 0.360 mSv/y and average: 0.251 mSv/y for indoor as well as minimum: 0.147 mSv/y, maximum: 0.347 mSv/y and average: 0.208 mSv/y for outdoor.

Notably, both indoor and outdoor average AEDE values fall below the global average of 1.0 mSv/y, as reported by Qureishi et al. (2014). Excess Lifetime Cancer Risk (ELCR) Assessment using lifetime fatality probability coefficient (5×10^{-2}) recommended by UNSCEAR for a general population was estimated. This coefficient quantifies risk of having cancer because of radiation exposure over a lifetime. ELCR calculations, based on Annual Effective Dose Equivalent (AEDE) values using equation 3, yielded indoor ELCR minimum: 0.52×10^{-3}, maximum: 0.99×10^{-3} and average: 0.69×10^{-3}. Outdoor ELCR minimum: 0.41×10^{-3}, maximum: 0.96×10^{-3} and average: 0.59×10^{-3}. Notably, all recorded averages exceed the global average ELCR value of 0.29×10^{-3} (UNSCEAR, 2000).

In this study, the Monte Carlo simulation (MCS) and probabilistic technique have been suitably adopted to take advantage of the more realistic cancer risks linked to background ionizing radiation in a computer trading area. Version 11.1.2.4.850 of Oracle Crystal Ball software was utilized to conduct the simulations (Omeje et al. 2021; Orosun 2021). One benefit of using Oracle Crystal Ball software version 11.1.2.4.850 is; it automatically selects distribution which best matches the data, as determined by the goodness of fit statistic. Another benefit is that it can project all potential results as well as evaluate most possible health hazard, allowing better decision-making in the face of uncertainty that may emerge from varying exposure periods, rates of ingestion, or inhaling. It calculates the findings severally. 10,000 trials were employed in this work, each time, a new set of random values in the probability functions were used.

The distribution of Excess Lifetime Cancer Risk (ELCR) was analyzed, yielding key statistics. Monte Carlo simulation results are listed in Table 2 and shown in Figures 3 and 4. Notably, the computed ELCR values ($\times 10^{-3}$) for indoor Background Ionizing Radiation (BIR) exposure showed mean: 1,320, lower bound (5th percentile): 700, upper bound (95th percentile): 2,090. Similarly, outdoor BIR exposure yielded mean: 270, lower bound (5th percentile): 90, upper bound (95th percentile): 480. Comparing these estimates to international guidelines, both indoor and outdoor cancer risk values exceed the suggested threshold of 0.2 ($\times 10^{-3}$) set by ICRP and UNSCEAR. Notably, indoor Background Ionizing Radiation (BIR) sources pose a significantly higher cancer risk compared to outdoor BIR. When assessing the most optimistic scenario (5th percentile), our findings suggest that approximately 700 individuals (indoor BIR), 90 individuals (outdoor BIR), out of 1 million people may develop cancer. Our risk assessment findings indicate that in a worst-case scenario (95th percentile), approximately 2,090 and 480 people per million may develop cancer due to indoor and outdoor Background Ionizing Radiation (BIR) exposure, respectively. Under a median risk scenario (50th percentile), the likely cancer incidence is around 1,320 and 270 cases per million for indoor and outdoor BIR exposure.

The calculated mean, 5th percentile, and 95th percentile cancer risk probabilities for both indoor and outdoor environments exceed the recommended limits set by UNSCEAR 2000 (Orosun et al., 2021). However, the overall findings suggest that the study areas do not pose significant environmental or radiological health risks. Notably, residents and workers in the computer village, Okutukutu, Yenagoa, Bayelsa State, Nigeria, who spend extended periods indoors, are identified as the most susceptible population. This research has significant implications, as its outcomes can inform the development of radiation risk assessment models. These models can guide stakeholders and decision-makers in conducting further environmental studies and making informed decisions.

Table 2: Results of the Monte Carlo simulation

	Excess lifetime cancer risk (ELCR x 10^{-3})		
	5%	**Mean**	**95%**
Indoor	0.07	1.32	2.09
Outdoor	0.09	0.27	0.48

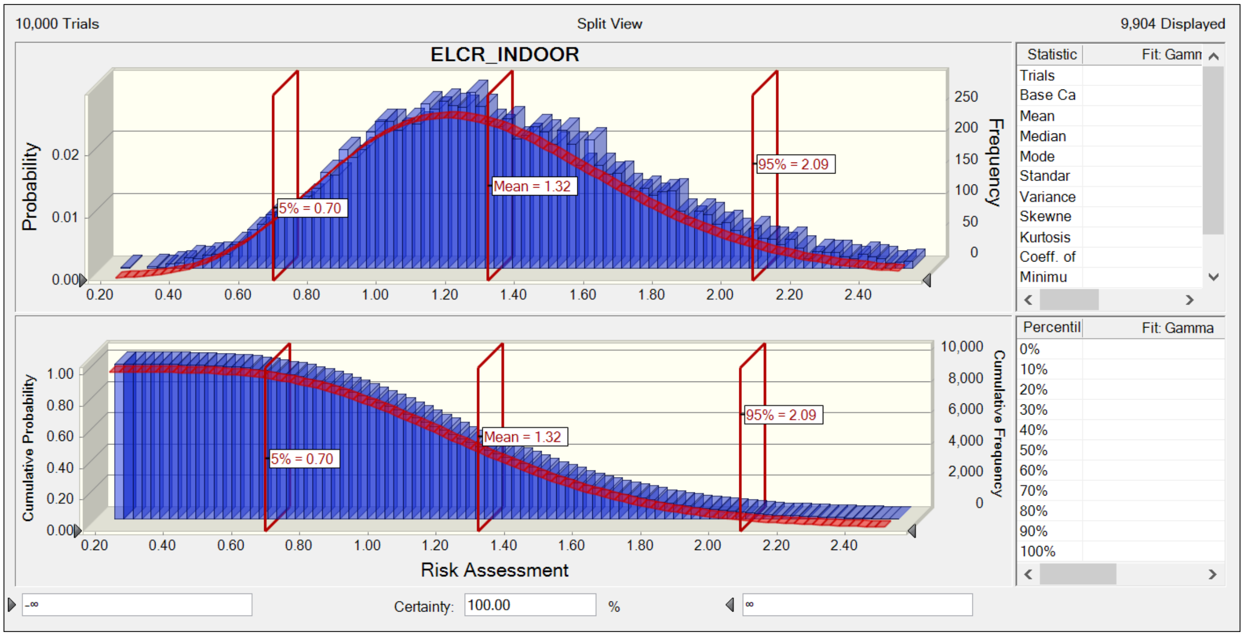

Figure 3: ELCR for indoor BIR

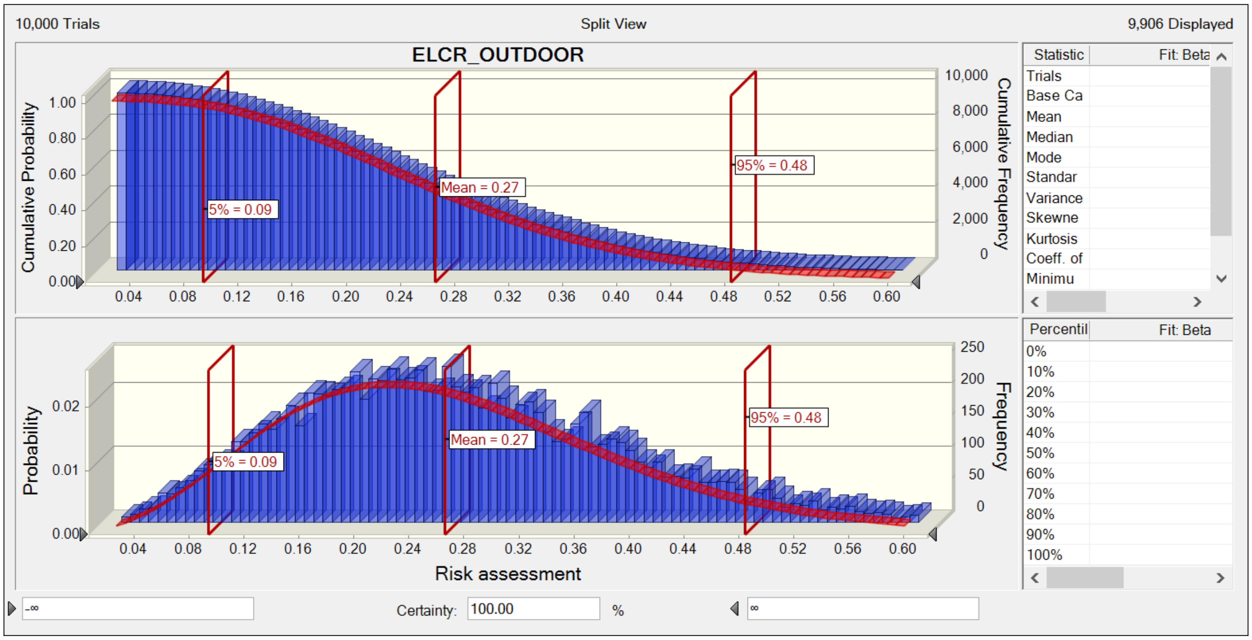

Figure 4: ELCR for outdoor BIR

CONCLUSION

Ambient exposure rates (indoor and outdoor) in Okutukutu computer village, Yenagoa, has been measured. Radiological indices have also been calculated using risk calculation models as well as the probabilistic approach using Monte Carlo simulation to further evaluate excess lifetime cancer risk. The mean exposure rates of 0.019 mRh^{-1} and 0.016 mRh^{-1} for indoor and outdoor respectively are not significantly high above the 0.013 mRh^{-1} world average. Estimated values of cancer risk for indoor and outdoor in the study area applying Monte Carlo simulation shows that greater number of individuals are likely to develop cancer due to indoor exposure rate compared to outdoor exposure rate. This research has shown that electronic devices, including smartphones and computers, have the possibility of escalating ambient exposure rate. Firm and enforceable policies are therefore needed to mitigate risk to both traders and buyers in such environments.

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