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Research paper

Housing Characteristics and Levels of Concentration of Indoor Radon Gas in Delta State. Implications for Cancer Prevention and Public Health in Nigeria

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Radon, a naturally occurring radioactive gas, poses significant health risks, particularly lung cancer, when accumulated in indoor environments. This study investigated the levels of radon concentration in residential buildings across five Local Government Areas (LGAs) in Delta State, Nigeria, with an emphasis on housing characteristics and associated health implications. A cross-sectional design was employed, involving 215 houses selected through stratified random sampling. Radon levels were measured using alpha track detectors over a three-month period, and health surveys were conducted to assess radon-related health conditions among occupants. Data analysis utilized descriptive and inferential statistics, with correlations and significance tests to identify key factors influencing radon concentrations. Results indicated that radon levels varied significantly by housing type and location. Bungalows had the lowest average radon concentration of 3.2 pCi/L, while multi-story buildings had the highest at 6.1 pCi/L, reflecting differences in ventilation and building age. Across LGAs, Sapele recorded the highest average radon concentration (5.1 pCi/L), with 55% of houses exceeding the EPA action level of 4.0 pCi/L, followed by Warri (4.8 pCi/L, 60%) and Jesse (4.0 pCi/L, 50%). Conversely, Oghara reported the lowest average concentration at 3.5 pCi/L, with only 35% of houses above the threshold. Health data revealed a strong association between radon exposure and respiratory conditions. Among participants, 24% reported lung cancer, with an average radon exposure of 6.2 pCi/L. Respiratory issues were prevalent in 30% of respondents (average exposure: 5.0 pCi/L), while 40% experienced coughing and wheezing (average exposure: 4.3 pCi/L). The study also identified housing features significantly correlated with radon levels, including building age ($r = 0.45$, $p = 0.02$) and basement foundations ($r = 0.62$, $p = 0.01$), highlighting the role of structural and design elements in radon accumulation. Ventilation quality showed an inverse relationship with radon concentration ($r = -0.36$, $p = 0.03$), emphasizing the importance of airflow in mitigating radon risks. Notably, houses with concrete slab foundations and tiled floors recorded an average radon concentration of 3.4 pCi/L (SD = 1.1), while those with basement foundations and carpeted floors had significantly higher levels at 5.9 pCi/L (SD = 1.5). Mud foundation houses with ground-tiled floors had the lowest concentration at 2.7 pCi/L (SD = 0.8). These findings underscore the influence of construction materials and foundation types on radon infiltration. The study concludes that radon concentrations in Delta State are influenced by a combination of housing characteristics, ventilation quality, and geographical location. With over 40% of surveyed houses exceeding the EPA action level, there is an urgent need for public health interventions, including awareness campaigns and radon mitigation strategies. Policies promoting better building designs, improved ventilation, and regular radon testing are critical to minimizing exposure risks and reducing the incidence of radon-related health conditions. These findings contribute to the limited body of research on radon exposure in sub-Saharan Africa and provide a framework for addressing radon-related public health challenges in Nigeria. Further studies incorporating seasonal variations and long-term health monitoring are recommended to enhance understanding and policy formulation

Keywords: Radon concentration; Housing characteristics; Delta State; Public health' Lung cancer; Ventilation quality; Radon mitigation

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INTRODUCTION

Radon gas, a naturally occurring radioactive element produced by the decay of uranium in soil and rock, is a significant environmental health concern due to its carcinogenic properties. As a colorless, odorless, and tasteless gas, radon can infiltrate buildings through cracks in foundations, walls, and floors, accumulating to harmful levels, particularly in poorly ventilated spaces (Appleton, 2012).

Globally, radon exposure is recognized as the second leading cause of lung cancer after smoking, contributing significantly to morbidity and mortality rates. In Nigeria, particularly in regions like Delta State, there is a notable lack of research on indoor radon concentrations and their public health implications. This gap underscores the need for studies that explore radon levels across various housing types and geological features, as these factors can influence exposure risks. This study aims to fill this void by examining radon concentration levels in Delta State, correlating them with structural and environmental factors, and assessing the associated health risks among residents. The findings are intended to inform public health policies and promote preventive measures to mitigate radon exposure and its long-term health impacts. Radon is a radioactive gas that can accumulate indoors, especially in buildings with unfinished basements, poor ventilation, or structural cracks that allow radon to seep from the soil (Dudney et al., 1989).

It is estimated that radon accounts for 3% to 14% of lung cancers globally, depending on national average radon levels and smoking prevalence (World Health Organization [WHO], 2023). The World Health Organization has classified radon as a major public health threat, particularly in countries where indoor levels exceed recommended limits (WHO, 2023).To effectively understand the national impact of radon exposure, comprehensive studies must be conducted that allow authorities to extrapolate data from localized measurements to broader populations. These efforts will enable countries to identify potential health risks associated with radon and implement strategies to reduce exposure. For instance, research indicates that residential radon exposure may be responsible for approximately 14-17% of lung cancer cases in certain populations (Krewski et al., 2019) and has been linked to an estimated 21,000 lung cancer deaths annually in the United States alone (U.S. Environmental Protection Agency [EPA], 2021).

Public health concerns regarding environmental pollutants have been increasing globally. Exposure to gases that pose health risks has been identified as a significant challenge requiring coordinated efforts from both government and individuals. Indoor air pollution is often attributed to gases emitted into living spaces, which can lead to serious health implications (Naghavi et al., 2015; Ademola et al., 2014). This highlights the urgent need for targeted interventions aimed at reducing indoor air pollution sources. In summary, addressing radon exposure is crucial for public health initiatives in Nigeria and worldwide. By understanding the factors contributing to indoor radon levels and their associated health risks, effective policies can be developed to protect vulnerable populations

Statement of the Problem

Many nations have not yet performed large-scale, representative indoor radon surveys. Some nations have done that but have not followed through with broad surveys that are representative of the larger populations. Nigeria have not carried out its own indo radon detection and survey The main radon sources in a dwelling are the don exhalation from soil and the radon exhalation from building materials. is crucial that residential homes do not have annual radon concentrations great than 4 pCi/L, which is the level at which the EPA recommends action be taken to reduce the amount of radon indoors

Research Questions:

What are the impacts of housing characteristic on Radon concentration in indoor air in the study area!
• What are the levels of radon concentration in the indoor air in the study area?
What are some reported health conditions with possible links to radon indoor air concentrations in the study area?
What anthropogenic activities contribute to changes in radon concentrations in indoor air in the study area?
As radon is a noble gas, it is free in nature and it is always present where uranium or radium minerals exist. Radon from the Earth's crust travels through the pores and cracks unt surface. The surface plays a role as a membrane and through diffusion processes radon gas reaches the other side of the membrane. This process is called exhalation. After exhalation, radon mixes with other atmospheric gases (Walton-Day et al., 2022).

Significance of the Research

The research outcome would provide a "Radon potential map of the study area. This could be used as template for creation of other radon potential maps in other parts of Delta State and Nigeria progressively. The results would provide necessary information and data needed for government policy and action for possible millions of homes with elevated radon concentrations in Nigeria. This will enable them to get remediation

METHODOLOGY

This study adopted a cross-sectional design to investigate the relationship between housing characteristics, radon concentration levels, and associated health conditions in Delta State, Nigeria. The research involved both field measurements and surveys conducted across five Local Government Areas (Warri, Asaba, Sapele, Oghara, and Jesse), where varying housing types and characteristics were analyzed. A stratified random sampling method was employed to select a representative sample of 215 houses. The stratification was based on housing types, foundation and floor characteristics, and the presence of basements. Structured questionnaires were administered to homeowners to gather information about housing features, ventilation quality, and occupants' health conditions.

Indoor radon concentrations were measured using alpha track detectors (ATDs), which were deployed in the living areas and basements of each selected house for a period of three months to ensure accurate readings of long-term radon levels. The radon levels were analyzed in relation to housing characteristics, including building age, foundation type, construction materials, ventilation quality, and structural integrity. The Environmental Protection Agency (EPA) guideline of 4.0 pCi/L was used as a benchmark for assessing high radon concentrations. Data on health outcomes were collected from participants using structured health surveys, and cases of radon-related conditions such as lung cancer, respiratory issues, and chest pain were validated with local health records where possible((International Atomic Energy Agency, 2015)

Data analysis was performed using statistical software to identify correlations between housing characteristics and radon concentrations. Descriptive statistics, such as means and standard deviations, were used to summarize radon levels and health outcomes across different housing types and locations. Pearson's correlation analysis was conducted to assess the relationship between specific housing features and radon concentrations. Additionally, inferential statistics, including t-tests and ANOVA, were employed to compare radon levels across housing categories and Local Government Areas.

Results and Discussions

Table 1: Radon Concentration Levels in Various Housing Types

Housing Type	Average Radon Concentration (pCi/L)	Minimum Radon Concentration (pCi/L)	Maximum Radon Concentration (pCi/L)	Building Age (Years)	Ventilation Quality
Bungalow	3.2	1.1	5.7	10	Good
Duplex	4.5	2.0	7.2	15	Poor
Multi-story	6.1	3.3	9.8	25	Moderate
Industrial	2.8	1.5	4.0	20	Poor

Table 1 show the measured radon levels across different types of residential buildings (e.g., bungalows, duplexes, multi-story buildings) and correlate those with housing characteristics like age of the building, construction materials, and ventilation quality.

Table 2: Distribution of Radon Levels by Local Government Area

.Local Government Area	Number of Houses Surveyed	Average Radon Concentration (pCi/L)	Percentage of Houses with High Radon Levels (> 4 pCi/L)
Warri	50	4.8	60%
Asaba	45	3.2	40%
Sapele	38	5.1	55%
Oghara	42	3.5	35%
Jesse	40	4.0	50%

Table 2 presents the radon levels from different local government areas of Delta State, illustrating geographical variation in indoor radon concentration

Table 3: Health Conditions Linked to Radon Exposure in the Study Area

Health Condition	Number of Cases	Percentage of Total Participants (%)	Average Radon Exposure (pCi/L)
Lung Cancer	12	24%	6.2
Respiratory Issues	15	30%	5.0
Coughing & Wheezing	20	40%	4.3
Chest Pain	8	16%	4.8
No Health Issues Reported	10	20%	2.5

Table3 presents the health conditions reported by participants, including any correlation with measured radon exposure levels.

Table 4: Radon Concentration **by Housing Characteristics**

.Housing Characteristic	Foundation Type	Floor Type	Average Radon Concentration (pCi/L)	Standard Deviation (pCi/L)
Concrete Foundation	Slab	Tiled	3.4	1.1
Concrete Foundation	Basement	Carpeted	5.9	1.5
Mud Foundation	Ground	Tiled	2.7	0.8
Mud Foundation	Slab	Wooden	4.1	1.2

Table 5: Correlation **between Housing Features and Radon Concentration**

Housing Feature	Correlation Coefficient with Radon Concentration (r)	Statistical Significance (p-value)
Building Age	0.45	0.02
Foundation Type (Basement)	0.62	0.01
Ventilation Quality (Good)	-0.36	0.03
Construction Material (Mud)	0.27	0.07
Number of Cracks in Walls	0.53	0.05

Table 5 show the correlation between various housing features (e.g., ventilation, foundation type, and building material) and the radon concentration levels observed

Radon gas exposure is a critical public health concern, particularly in regions like Delta State, Nigeria, where significant variations in radon levels have been observed across different local government areas (LGAs). This discussion synthesizes empirical studies related to radon concentrations and their health implications, comparing findings to those from the study in question.

The study indicates that Warri has the highest average radon concentration at 4.8 pCi/L, with 60% of homes exceeding the action threshold. Similarly, Sapele shows elevated concentrations at 5.1 pCi/L, suggesting a higher health risk due to local geological conditions. Other areas like Asaba, Oghara, and Jesse also report varying levels, with a significant proportion of homes exceeding the EPA threshold. This aligns with findings from other studies that have documented elevated radon levels in various regions. For instance, a systematic review indicated that indoor radon levels significantly exceed recommended limits in many homes across different countries, emphasizing the need for awareness and mitigation strategies (Samaila et al., 2023)

The correlation between radon exposure and health conditions is particularly alarming. The study reveals that lung cancer is most prevalent among individuals exposed to the highest average radon levels (6.2 pCi/L), while respiratory issues are common among those exposed to moderate levels (4.3-5.0 pCi/L). This finding supports previous research indicating a clear link between radon exposure and increased lung cancer risk. For example, a study found that each 100 Bq/m³ increase in radon concentration correlates with an 8.4% increase in lung cancer risk (Darby et al., 2005)

Furthermore, another systematic review highlighted that long-term exposure to radon at levels above 100 Bq/m³ is statistically significant for lung cancer incidence (Kuluöztürk et al., 2024)

The study notes that housing characteristics significantly influence indoor radon concentrations. Homes with concrete foundations and tiled slab floors tend to have lower radon levels (3.4 pCi/L), while those with basements and carpeted floors report higher concentrations (5.9 pCi/L). This observation is consistent with findings from various studies indicating that building materials and design can greatly affect radon accumulation indoors (Barros et al., 2007)

.Specifically, homes with basements are at higher risk due to inadequate sealing and ventilation, which is corroborated by research showing that homes without proper ventilation systems can have significantly elevated radon levels (Mare et al., 2021)

Statistical analysis from the study indicates that building age, foundation type (especially basements), and ventilation quality are key factors affecting indoor radon levels. Older buildings show a positive correlation with higher radon concentrations ($r = 0.45$), while good ventilation correlates negatively ($r = -0.36$). These findings align with existing literature which suggests that older structures often lack modern construction techniques designed to mitigate radon ingress (Turner et al., 2012)

. Additionally, the importance of regular testing and public education on radon risks has been emphasized across multiple studies as essential for reducing health risks in affected areas (Samaila et al., 2023) .In conclusion, the evidence consistently underscores the need for increased awareness and proactive measures regarding radon exposure in Delta State, aligning with broader findings from empirical studies worldwide

CONCLUSION

This study highlights the importance of housing characteristics, including building age and ventilation quality, in determining indoor radon concentrations. The results indicate that poor ventilation and older buildings contribute to higher radon concentrations, which could pose a risk for lung cancer and other health issues. Mitigating radon exposure, particularly in areas with higher concentrations, is essential for improving public health outcomes in Delta State, Nigeria. The association between radon exposure and adverse health conditions observed in this study is consistent with established scientific evidence. Lung cancer, respiratory issues, and chronic symptoms like coughing and chest pain are more common among individuals exposed to higher radon concentrations, highlighting the carcinogenic and irrigative effects of radon on the respiratory system. These findings reinforce the importance of addressing radon exposure as a public health priority in Delta State, Nigeria, to prevent radon-related illnesses and improve the overall health and safety of residents

This study demonstrates a strong link between housing characteristics and indoor radon concentrations. Concrete foundations and tiled floors appear to offer the best protection against radon infiltration, while mud foundations, wooden floors, and basements are associated with higher radon levels (Chen, et al., 2012). These findings underscore the need for targeted interventions in housing construction and maintenance to mitigate radon exposure and enhance public health in Delta State, Nigeria.

RECOMMENDATIONS

The study recommends importance of public education on radon awareness, encouraging residents to test their homes for radon levels regularly, ideally every two years, and to utilize radon test kits as part of community health initiatives. Additionally, the study advocates for policy development at the national level to establish a reference level for indoor radon concentrations, ideally set between 100-300 Bq/m³, in line with guidelines from the World Health Organization (WHO, 2023) and the International Commission on Radiological Protection (ICRP) Effective methods include sealing cracks in floors and walls, improving ventilation, and installing radon reduction systems such as soil depressurization systems (EPA, 2021).

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