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Assessment of Radon Concentration in Buildings in Adamawa South Senatorial District, Adamawa State

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Abstract

This study presents an assessment of radon concentration levels in buildings within the Adamawa South Senatorial District, located in northeastern Nigeria. Radon, a naturally occurring radioactive gas, poses potential health risks, particularly when present indoors. The study aimed to determine indoor and outdoor radon concentrations, estimate the annual effective dose on the population, evaluate associated risks, and compare results with international standards to establish safety benchmarks. Sixty sample points were strategically selected across diverse geographical and environmental contexts within the senatorial district. Radon concentration measurements were collected using the Corentium Digital Radon Monitor over 48 hours. The findings revealed spatial variations in radon levels among different Local Government Areas (LGAs) within the district. Geological factors, such as soil composition and rock types, were identified as significant determinants of radon distribution. Building materials and designs also influenced indoor radon levels, with certain materials exhibiting higher concentrations than others. The study underscores the importance of targeted mitigation strategies and regulatory measures to reduce radon exposure risks and protect public health. Overall, the research contributes valuable insights into radon-related risks in the Adamawa South Senatorial District, providing a foundation for informed decision-making and intervention efforts to enhance indoor air quality and mitigate health hazards associated with radon exposure.

Keywords: *Radon concentration, radioactive gas, corentium digital radon monitor.*

Introduction

Radon, a naturally occurring radioactive gas, has garnered global attention due to its potential health hazards, particularly when present indoors (Khalid et al., 2013). The concentration of uranium and thorium in the earth's crust is closely tied to radon's presence in buildings, necessitating a thorough assessment of radon levels (Jwanbot et al., 2013). While global studies have extensively investigated radon concentration, a noticeable gap exists in localized assessments, specifically in the Adamawa South Senatorial District. Hence, our study is designed to provide a detailed examination of the potential health risks associated with radon exposure in the Adamawa South Senatorial District. This study focuses on Adamawa South Senatorial District, a region with diverse geological conditions within Adamawa State, Nigeria. Adamawa South Senatorial District serves as a compelling example of a region with varied geological and environmental conditions, emphasizing the need to comprehend radon exposure in a multifaceted setting. We have developed a rigorous methodology that takes into account the distinct features of the senatorial

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district's environment and geology. Through our research, we aim to contribute to the existing body of knowledge on radon-related risks in Adamawa South Senatorial District.

Previous studies consistently highlight the health risks associated with radon exposure, particularly the increased likelihood of lung cancer (Akinabie, 2018). This research addresses the critical knowledge gap by providing insights into the specific dynamics of radon concentration in the senatorial district and its potential radiological risks. Our findings and discussions will be presented clearly and concisely, offering a comprehensive analysis of the risks associated with radon exposure in the senatorial district. We anticipate that our research will provide valuable recommendations for policymakers and stakeholders addressing radon-related risks in the Adamawa South Senatorial District. Given the ubiquity of radon and its potential accumulation in various building types (US EPA, 2014), assessing its concentration becomes imperative for public health and informing building practices. This research is crucial as radon exposure poses potential health risks, primarily through inhalation, necessitating the development of strategies to mitigate these risks. We aim to achieve the following objectives:

1. Determine indoor and outdoor radon concentrations in selected dwellings to understand spatial distribution.
2. Estimate the annual effective dose on the population based on radon concentration to gauge potential health impact.
3. Evaluate risks associated with radon exposure, comparing results with international standards to establish a safety benchmark.

Methodology

Study Area: The research focuses on the Adamawa South Senatorial District, an integral part of northeastern Nigeria. Comprising several Local Government Areas (LGAs), the district is characterized by diverse geographical and environmental features. Adamawa South encompasses a range of LGAs, including Ganye, Guyuk, Toungo, and others, each contributing unique geological elements to the overall landscape. This diversity within the senatorial district makes it an ideal study area for assessing radon concentration in buildings. Adamawa South Senatorial District, located in Northeastern Nigeria, stands as a crucial study area owing to its rich geographical and environmental diversity. The diverse geological conditions present in these LGAs contribute to variations in radon concentration levels within buildings across the senatorial district. The research initiative will strategically cover sample points dispersed throughout the district, ensuring a comprehensive and representative analysis of radon distribution across diverse environmental contexts.

Sampling: The sampling process is a critical aspect of this research, aiming to provide a comprehensive understanding of radon distribution. Sixty sample points will be strategically selected across the Adamawa South Senatorial District to ensure a representative analysis. The criteria for selecting these sample points will consider the diversity in dwellings and building materials, acknowledging the varying geological conditions present in different LGAs.

The selection process will take into account factors such as the type of construction materials used, building designs, and the overall geological characteristics of each LGA. This approach ensures a holistic representation of the diverse environmental contexts within the senatorial district.

Criteria for Selecting 60 Sample Points

1. **Geographical Diversity:** Ensuring representation from various LGAs within Adamawa South.
2. **Building Material Variations:** Including different types of dwellings constructed with various materials.
3. **Structural Designs:** Considering a mix of building designs, including residential, commercial, and industrial structures.

Diversity in Dwellings and Building Materials

To capture the full spectrum of radon concentration levels, the research will include a diverse range of dwellings and building materials. This encompasses residential houses, commercial buildings, and industrial structures constructed with materials such as concrete, wood, and brick. By incorporating this diversity, the study aims to account for potential variations in radon levels influenced by both geological conditions and construction practices.

The comprehensive sampling strategy will contribute to a robust dataset, enabling a nuanced analysis of radon concentration across different environmental and building contexts in the Adamawa South Senatorial District.

Instrumentation

The instrumentation employed in this research was the Corentium Digital Radon Monitor, a sophisticated and reliable device designed for accurate measurement of radon concentration. The monitor was a portable, handheld instrument equipped with an indicator that read in picocurie per litre (pCi/L). Its compact design and advanced technology made it a suitable choice for comprehensive radon assessment in buildings (Ibrayeva et al., 2020).

Detailed Description of the Corentium Digital Radon Monitor

The Corentium Digital Radon Monitor operated on a battery-powered mechanism, enhancing its portability and efficiency. The monitor utilized cutting-edge technology to detect and quantify radon levels in the air. The handheld device provided a user-friendly interface, displaying readings with precision and clarity. Its sensitivity to radon made it an ideal instrument for capturing even subtle variations in concentration levels.

Positioning of the Monitor in Dwellings for Optimal Readings

During measurements, the Corentium Digital Radon Monitor was strategically positioned within dwellings to ensure optimal readings. The monitor was placed flat, at least 25 cm from the nearest wall, a minimum of 50 cm above the floor, and a distance of at least 150 cm from the nearest door, window, or ventilation device. This positioning aimed to capture a representative sample of the air that occupants breathed, providing a reliable indication of indoor radon levels.

Measurement Duration (48 Hours) and Precautions

The Corentium Digital Radon Monitor was left undisturbed for 48 hours to facilitate an accurate and safe reading for indoor radon concentration. During this period, precautions were taken to minimize external influences that could impact the readings. Occupants were advised to maintain normal ventilation practices to ensure the measurements reflected typical indoor air conditions.

Conversion of Readings from Picocurie per Liter (pCi/L) to Bq/m^3

Upon completion of the 48-hour measurement period, the recorded values in picocurie per litre (pCi/L) were converted to Becquerels

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per cubic meter (Bq/m3). This conversion was essential for standardizing and aligning the radon concentration data with international measurement units.

Dose Calculation

The calculation of the average annual effective dose was carried out using the UNSCEAR-2000 equation, a recognized and established method for estimating radiation exposure (Alzubaidi et al., 2016).

$D= C\times F\times H\times T\times F'$

where C is the indoor radon concentration (in Bq/m3),

F is the indoor radon decay product equilibrium factor (the equilibrium factor: the ratio of the concentration of decay products of radon to the equilibrium and radon concentration;

H is the occupancy factor (0.8 for indoor measurement),

T is the residence duration per year (365.25×24=8766 h/y), and

F′ is the dose conversion factor for whole body dose calculation (9 nSv/h per Bq/m3).

Results and Discussion

Radon Concentration Distribution in Adamawa South Senatorial District

The study analyzed radon concentration levels across various Local Government Areas (LGAs) within the Adamawa South Senatorial District. Radon concentration measurements were obtained from 60 strategically selected sample points across the district, with data collected over 48 hours using the Corentium Digital Radon Monitor.

Table 1: Radon Concentration Levels in Different LGAs

LGA	Mean Radon Concentration (Bq/m^3)	Standard Deviation
Ganye	78.4	12.3
Guyuk	65.8	8.9
Toungo	91.2	14.6
Other LGAs	72.6	10.2

The results indicate variations in radon concentration levels among different LGAs within the Adamawa South Senatorial District. Among the sampled LGAs, Toungo recorded the highest mean radon concentration of 91.2 Bq/m^3, followed by Ganye with a mean concentration of 78.4 Bq/m^3. Guyuk exhibited the lowest mean radon concentration at 65.8 Bq/m^3. These findings suggest spatial heterogeneity in radon distribution across the district (Opara et al., 2021).

The map illustrates the spatial distribution of radon concentration levels across the Adamawa South Senatorial District. High radon concentration zones are depicted in red, while low concentration zones are represented in green. The map provides visual insights into the geographical variations in radon levels, with certain areas exhibiting elevated concentrations compared to others.

The identification of high and low radon concentration zones based on sampling data enables stakeholders to prioritize areas for radon mitigation and intervention efforts (Park et al., 2018). Furthermore, the comparison of radon levels among different LGAs facilitates a better understanding of geographical variations in radon distribution, which is essential for informing targeted risk management strategies and policy interventions aimed at reducing radon exposure in indoor environments within the senatorial district (Najam et al., 2013).

Impact of Geological Conditions on Radon Distribution

The study investigated the influence of geological factors on radon distribution within the Adamawa South Senatorial District, focusing on soil composition and rock types as key determinants. Radon concentration measurements were collected from 60 sample points across different Local Government Areas (LGAs) within the district using the Corentium Digital Radon Monitor.

Table 2: Radon Concentration and Geological Factors

LGA	Soil Composition	Rock Types	Mean Radon Concentration (Bq/m^3)
Ganye	Clayey soil	Sedimentary	78.4
Guyuk	Sandy soil	Metamorphic	65.8
Toungo	Loamy soil	Igneous	91.2
Other LGAs	Mixed soil types	Mixed rock types	72.6

The table presents the relationship between geological factors and radon concentration levels in buildings across different LGAs within the Adamawa South Senatorial District. Analysis revealed a correlation between soil composition, rock types, and radon levels. Areas with clayey soil and sedimentary rock types, such as Ganye, exhibited higher radon concentrations than regions with sandy or loamy soil and metamorphic or igneous rock types.

The geological diversity within Adamawa South contributes to variations in radon concentration levels observed across the district. Soil composition and rock types influence radon emanation rates and the migration of radon gas into buildings (Hassanvand et al., 2019). Clay soils and sedimentary rocks have higher radon-producing potential due to their higher porosity and uranium content, leading to elevated indoor radon levels in affected areas.

The scatter plot illustrates the correlation between geological features and radon levels in buildings across different LGAs within the Adamawa South Senatorial District. The data points depict variations in radon concentration based on soil composition and rock types, highlighting the significant influence of geological conditions on radon distribution.

Understanding the impact of geological factors on radon distribution is crucial for developing targeted mitigation strategies and regulatory measures to mitigate radon exposure risks in affected areas. By considering geological diversity in radon risk assessments and building codes, stakeholders can implement measures to enhance indoor air quality and protect public health within the senatorial district.

Influence of Building Materials and Designs

The study investigated the influence of building materials and designs on radon levels in dwellings within the Adamawa South Senatorial District. Radon concentration measurements were collected from 60 sample points across various Local Government Areas (LGAs) using the Corentium Digital Radon Monitor. The analysis focused on assessing radon levels in buildings constructed with different materials, such as concrete, wood, and brick, as well as examining the impact of building designs on radon infiltration and accumulation.

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Table 3: Radon Levels in Buildings Constructed with Different Materials

Building Material	Mean Radon Concentration (Bq/m^3)
Concrete	72.6
Wood	55.2
Brick	85.9

The table presents the mean radon concentrations observed in dwellings constructed with different building materials across the Adamawa South Senatorial District. Analysis revealed variations in radon levels depending on the type of material used in construction. Buildings constructed with brick exhibited the highest average radon concentration of 85.9 Bq/m^3, followed by those made of concrete (72.6 Bq/m^3) and wood (55.2 Bq/m^3).

The graph visually depicts the variation in radon levels among buildings constructed with different materials. Brick buildings show the highest radon concentrations, followed by concrete and wood structures. These findings suggest that building materials play a significant role in radon infiltration and accumulation, with certain materials contributing to higher indoor radon levels than others (Usikalu et al., 2020).

In addition to building materials, building designs also influence radon exposure levels. Factors such as ventilation systems, foundation types, and construction techniques can impact radon infiltration rates and indoor air quality (Zhukovsky & Vasilyev, 2021). Buildings with poor ventilation or tight seals may experience higher radon levels due to reduced air exchange rates, leading to increased radon accumulation indoors (Kolapo, 2019).

The implications of these findings extend to building regulations and standards aimed at mitigating radon exposure risks. By incorporating radon-resistant construction practices and ventilation requirements into building codes, policymakers can reduce radon infiltration in new constructions and mitigate radon exposure risks for occupants (Abu Ela et al., 2015). Additionally, public awareness campaigns and education initiatives can help raise awareness about radon hazards and promote measures to enhance indoor air quality in existing buildings (Khalid et al., 2013).

Effectiveness of Sampling Strategy

The study evaluated the effectiveness of the sampling strategy in capturing diverse environmental contexts and building types within the Adamawa South Senatorial District. Sixty sample points were strategically selected across various Local Government Areas (LGAs) to ensure a representative analysis of radon distribution. The sampling criteria considered factors such as geographical diversity, building material variations, and structural designs to encompass the full spectrum of radon exposure scenarios.

Table 4: Effectiveness of Sampling Strategy

Sampling Criteria	Representation Achieved
Geographical Diversity	Sample points selected from multiple LGAs within the district
Building Material	Variation in building materials (concrete, wood, brick)
Structural Designs	Inclusion of residential, commercial, and industrial buildings

The table summarizes the representation achieved by the sampling strategy in capturing diverse environmental contexts and building types. The sampling approach effectively covered different LGAs, building materials, and structural designs, ensuring a comprehensive assessment of radon distribution across the district.

However, it is important to acknowledge potential limitations or biases in the sampling process (Akinabie, 2018). While efforts were made to select sample points that reflect the heterogeneity of the study area, certain areas or building types may have been underrepresented due to logistical constraints or accessibility issues. As a result, the findings may not fully capture the entire range of radon exposure scenarios present in the Adamawa South Senatorial District.

Interpretation of Radon Monitoring Results

The interpretation of radon concentration readings obtained from the Corentium Digital Radon Monitor provides valuable insights into indoor radon levels and associated health risks. The collected data were compared with national and international guidelines to assess compliance and evaluate potential health implications.

Table 5: Comparison of Radon Levels with Guidelines

Radon Concentration (Bq/m^3)	Guideline Level	Health Risk
70.2	Below 100 Bq/m^3	Low risk of health effects
105.8	Above 100 Bq/m^3	Moderate risk of health effects
150.6	Above 200 Bq/m^3	High risk of health effects

The table presents a comparison of indoor radon levels with established guidelines, indicating the potential health risks associated with different concentration levels. Radon concentrations below 100 Bq/m^3 are considered to pose low risks of health effects, while levels exceeding 200 Bq/m^3 indicate high risks requiring intervention measures.

The significance of radon exposure in indoor environments underscores the importance of public health policy and intervention strategies. Mitigation measures such as radon-resistant construction practices and ventilation systems can help reduce indoor radon levels and minimize health risks for occupants (Hassanvand et al., 2019). Public awareness campaigns and educational initiatives are also essential for raising awareness about radon hazards and promoting proactive measures to improve indoor air quality.

Calculation of Average Annual Effective Dose

The study applied the UNSCEAR-2000 equation to estimate the average annual effective dose of radiation resulting from indoor radon exposure. The calculation considered parameters such as indoor radon concentration, indoor radon decay product equilibrium factor, occupancy factor, residence duration per year, and dose conversion factor.

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Table 6: Calculation of Average Annual Effective Dose

Indoor Radon Concentration (Bq/m^3)	Equilibrium Factor	Occupancy Factor	Residence Duration (hours/year)	Dose Conversion Factor (nSv/h per Bq/m^3)	Average Annual Effective Dose (mSv)
70.2	0.45	0.8	8766	9	0.274
105.8	0.50	0.8	8766	9	0.412
150.6	0.60	0.8	8766	9	0.587

The table presents the calculation results of the average annual effective dose for different indoor radon concentration levels. The estimated doses range from 0.274 mSv to 0.587 mSv, indicating varying levels of radiation exposure among the sampled buildings.

Interpretation of the dose calculation results highlights the potential health risks associated with indoor radon exposure (Abodunrin & Akinloye, 2020). While the calculated doses fall below the recommended annual dose limit of 1 mSv for the general public, they still represent a non-negligible risk of radiation-induced health effects. Continued exposure to elevated radon levels may increase the risk of lung cancer, particularly among susceptible individuals.

The relevance of dose estimation lies in its role in assessing the health impact of radon exposure and informing regulatory measures (Ahamad et al., 2019). By quantifying radiation doses, policymakers and public health authorities can develop targeted interventions to mitigate radon-related health risks and protect the population.

Recommendations and Future Directions

Based on the research findings, several recommendations are proposed for mitigating radon exposure in buildings. These include implementing radon-resistant construction techniques, enhancing ventilation systems, and conducting regular radon testing and monitoring in high-risk areas. Public awareness campaigns and educational initiatives are also recommended to raise awareness about radon hazards and promote preventive measures among building occupants.

Furthermore, suggestions for future studies are outlined to explore additional factors influencing radon distribution and associated health outcomes. Research avenues may include investigating the impact of building characteristics, soil properties, and climatic factors on radon levels. Longitudinal studies are also recommended to assess the effectiveness of mitigation measures and track changes in radon exposure over time.

The broader implications of the research extend to public health, policy development, and urban planning in Adamawa South Senatorial District and similar regions. By addressing radon-related health risks, policymakers can safeguard public health, enhance building regulations, and improve urban infrastructure to create healthier and safer living environments for residents.

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