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# Soil-gas and Indoor Radon Measurement for Cancer Mitigation in Nigeria Tertiary Institutions Using Higher Institutions in Ibadan as a Case Study

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## Abstract

Radon – a Radiologically Hazardous Gas Generated Within Bedrocks, Capable of Building Up in Confined Spaces, Has Been Identified as a Major Cause of Lung Cancer After Smoking. Lack of Information, Awareness and Data on Spatial Radon Variability in Africa and Most Especially in Nigeria Has Hindered Effective Mitigation Measures. Staff and Students of Tertiary Institutions Are Exposed to Radon Gas Emanating from the Bedrocks on Which the Institutions Are Sited. This Study Was Designed to Measure Soil-gas and Indoor Radon in Six Tertiary Institutions in Ibadan Towards Effective Radon Mitigation. Indoor Radon Concentration Was Measured in a Total of 42 Selected Ground Level Offices and 60 Classrooms While 220 Soil-gas Radon Concentration Measurements Were Carried Out Using Rad7. Indoor Radon Concentrations for the 60 Classrooms Had a Range of 29.41 – 156.73 Bqm-3 With an Average Value of 69.58 ± 23.67 Bqm-3 While That for Offices Had a Range of 37.82 Bqm-3 to 234.52 Bqm-3 With a Mean Value of 95.42 ± 36.82bqm-3. 21.72% of Sampled Offices Had Radon Concentration Values Above the 100 Bqm-3 Limit Set by World Health Organization for Indoor Radon. Soil Gas Radon Concentration Had a Range of 0.46 - 43.249 Kbqm-3 and Mean Value of 9.69 ± 3.72 Kbqm-3. With 21.36% of Sites Above 10 Kbqm-3, Tertiary Institutions in Ibadan, Based on Akerblom Classification Are Mainly Under Low Level of Soil-gas Radon Infiltration. A Positive Correlation (R2 = 0.67) Was Observed Between the Indoor Radon and Soil-gas Radon. Sites on Granitic Lithology Presented the Highest Mean Soil-gas Radon Concentration.

**Keywords:** Indoor Radon; Soil-gas Radon; Higher Institutions; E-perm; Rad 7

## Introduction

Radon Has Been Identified as a Major Cause of Lung Cancer After Smoking Resulting in 14% Deaths Yearly on a Global Scale (1). Radon Being a Tasteless, Odorless and Non-reactive Gas is Not Easily Perceived or Measured Despite Being Very Dangerous. It Constitutes Over 50% of the Radiation Exposure to Human Population When Compared to Other Primordial Radionuclides (2).

The World Health Organization (Who) and Related Scientific Studies Had Reported That There is No Safe Level of Radon Exposure in the Environment (3). Radon is a Decay Product from Uranium-238 and Uranium-235 Decay Which Either Stays in the Bedrock Where It Was Produced or Migrates into the Pore Space Within Bedrock Particles. Radon Gas Can Be Transported by Diffusion, Advection or by Pressure-driven Flow (4). The Most Abundant and Longest-lived Radon Isotope is Radon-222 (T1/2 = 3.82 Days), the Immediate Daughter of Radium-226 in the Uranium-238 Decay Series. When Radon Gas (or Its Decay Products) Escape from the Bedrock or Soil, It Enters the Atmosphere or Infiltrates into Buildings and Build Up. Radon Build Up and Its Subsequent Inhalation Becomes Hazardous Thus Becoming a Threat to Human Health. Radon Decays into Its Progeny on Entering the Lungs, Emitting Alpha Particles Which Irradiate Lung Tissues and Other Organs, Potentially Causing Mutation That Can Lead to Lung Cancer. Although There Are Other Sources of Indoor Radon Such as Cracks in Building Walls, Water Supply and Building Materials, the Most Important Factor Contributing to High Indoor Radon is the Geogenic Radon Which is the Radon Emanating from the Soil and Bedrock (5).

Positive Correlation Has Been Established Between Indoor Radon Concentration and Soil Gas Radon Concentration (6), (7). Soil-gas Radon Exceeding 2000 Bqm-3 Has the Potential to Increase the Indoor Radon Concentration Beyond 400 Bqm-3 if Sufficient Quantities of Soil Gas Leak into the Building (8). A Positive Correlation Between Indoor and Soil-gas Radon Concentrations Was Reported in a Survey Conducted in Tehri Garhwal, India, With Seasonal Effects on Indoor Concentrations (9). In Afyonkarahisar Province, Turkey, an Effective Correlation Coefficient of 0.97 Between Indoor and Soil-gas Radon Concentrations Was Recorded with Particular Observance of the Contribution of Lithology to Indoor Radon Concentration (10). A Moderate Linear Correlation Was Also Observed in a Desert Climate in Jordan, Indicating That Soil-gas Radon May Be a Suitable Predictor of Indoor Radon Potential (11). There Was a Fair Positive Relationship Between Indoor Radon Potential and Soil Radon Potential in Some Canadian Cities, While Soil Permeability Also Played a Significant Role. This Suggests That Soil-gas Radon Measurements Can Be Applied to Predict Indoor Radon Potential Towards Land-use Planning (12).

When Indoor Radon Builds Up, there is a Finite Possibility That Individuals Would Be Exposed to High Level of Radon Leading to Possible Significant Health Hazard (13). It Therefore Becomes Imperative to Assess the Level and Danger Posed by Radon to Any Human Population. Measured Data of Indoor Radon Concentration and Soil-gas Radon is Essential Towards Limiting the Associated Health Risk Due to Radon Exposure.

Among the Assets of Any Country is the Young Budding Population, Especially Tertiary Institution Students Who Spend Appreciable Long Hours in Lecture Rooms, Laboratories, Workshops, Studios and Hostels. Radon Measurement and Monitoring in Higher Institutions is Important Towards Safeguarding Public Health. Several Regulatory Bodies Such as Who, Us Epa E.t.c, Mandate Tertiary Institutions Administrators to Incorporate Radon Testing and Mitigation Plans into Campus Health and Safety Manuals, Provide Training for Facilities Staff, and Awareness Campaigns for Students and Staff. They Are Also to Ensure Compliance with Occupational Radon Exposure Limits in Research Labs and Areas Where Students and Staff Spend Extended Hours, (E.g., Osha's 100 Pci/l Averaged Over a Workweek) and Periodic Monitoring. Moreover, Tertiary Institution Administrators Are Expected to Comply with National Action Plans and Ensure That University Building Permits Include Radon Assessment Requirements.

Institutions of Higher Learning in Nigeria Are Often Overpopulated and Students Are Usually Densely Packed in Poorly Ventilated Lecture Rooms, Laboratories and Workshops. Unfortunately, Many Students and School Administrators Are Unaware of the Danger Posed by Inhalation of Radon Gas. in a Greater Number of Higher Institutions in Nigeria, the Radon Levels and Consequent Hazard Has Not Been Determined Despite the Danger Posed by Radon Exposure. It is Pertinent to Note That These Institutions of Higher Learning Are Sitting on Vast Hectares of Land Overlying Different Bedrocks from Which Radon Gas Emanate. Measurement of Soil-gas Radon Concentration Over the Different Lithologies in Any Higher Institution Serves to Determine the Radon Infiltration Capacity into the Buildings Used by Staff and Students for Both Academic and Leisure Activities. Radon Data as Obtained in This Study Area, is Useful for Immediate Assessment of the Level of Risk Associated with Radon Gas That Staff and Students in Tertiary Institutions Are Exposed to. Where Data Reveals Above Reference Values, Mitigation Measures Can Be Suggested for Existing Buildings in These Institutions While Regulatory Measures Can Be Recommended for Newly Approved Sites. This Study Was Designed to Investigate the Radon Levels Towards Mitigating the Hazard Posed by Radon Gas to Staff and Students of Tertiary Institutions in Nigeria Using Selected Institutions in Ibadan as a Case Study.

**Study Area**

Ibadan is the Capital City of Oyo State Situated in the Southwest Region of the Six Geopolitical Regions in Nigeria. It Has a Land Mass of 3,080 M2 Into Which Thirty-three Local Governments Co-exist. Ibadan is Largely Made Up of Yoruba Speaking People and is Reputed to Be the Third Largest City in Nigeria After Lagos and Kano with a Total Population of Over Three Million People. Ibadan is Within the Equatorial Rain Forest Region of Nigeria with Coordinates of Longitude 30 54′ East of the Greenwish Meridian and 70 32′ North of the Equator. The Geology of Ibadan is Mainly Basement Complex Formation Consisting Mainly of Metamorphic Rocks of Precambrian Age with Few Intrusions of Granite and Porphyries (14). These Rocks Can Be Classified into Major and Minor Types. The Major Rocks Consist of Quartzite and Quartz Schists, Migmatite and Banded Gneiss, Undifferentiated Gneiss Complex and Granite Gneiss Which Consist of Biotite Granite Gneiss, Muscovite Tourmaline Granite Gneiss, Hornblende Biotite Granite Gneiss and Biotite Granite Schist and Gneiss While the Minor Rock Types Consist of Pegmatite and Amphibolite (Figure 1). The City Has a Range of Elevation of 150 M at the Lowest Valley and 275 M Above Sea Level.

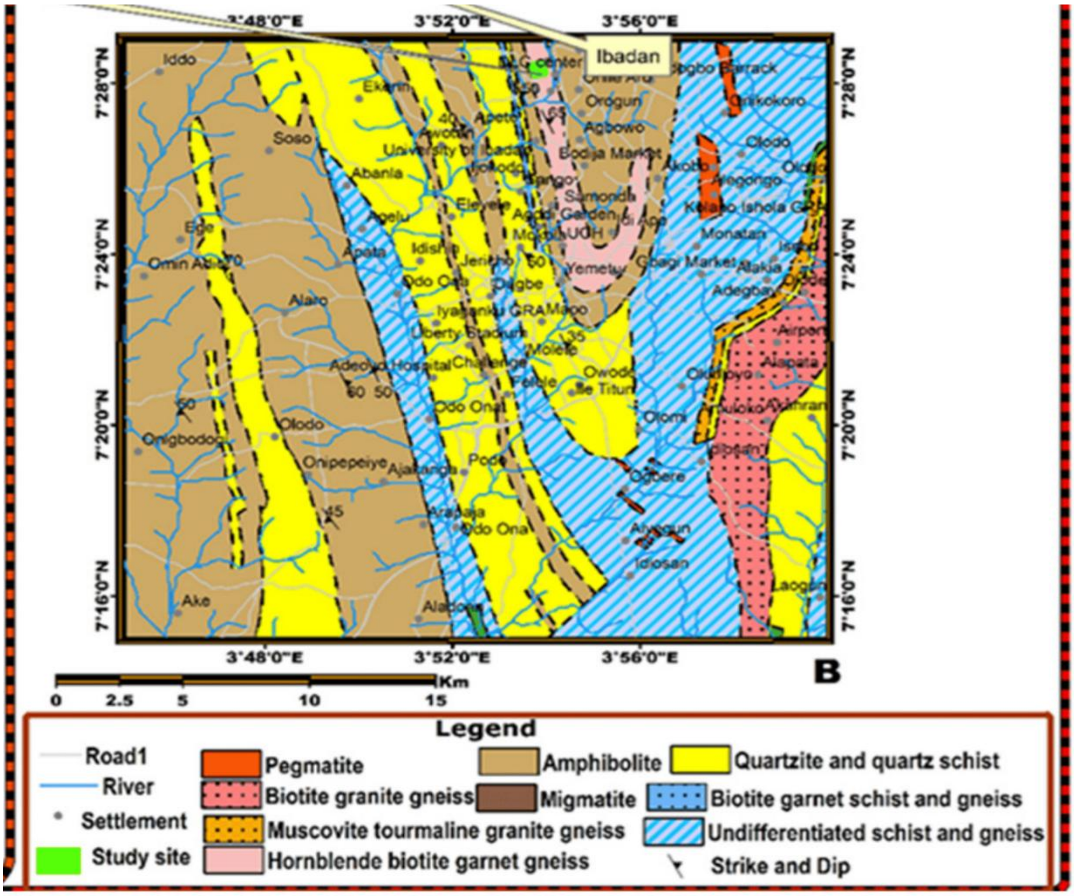


**Figure 1: Geology of Ibadan (15)**

**Materials and Methods**

The Study Was Designed to Measure the Soil-gas Radon Concentration in a Total of Two Hundred and Twenty (220) Selected Locations in Six Tertiary Institutions Within Ibadan, Nigeria with Mean Value of Two Hundred and Twenty (220) Representing the Mean of Three Measurements of Six Hundred and Sixty (660) Values. Measurements Were Taken at Close Proximity to Lecture Halls, Offices, Hostels, Laboratories and Workshops Where Students and Staff Spend at Least Five to Eight Hours Per Day. Measures Were Taken to Ensure That the Points for Soil Gas Measurement Were Such That Would Give Unobstructed Measurement. Such Measures Include Avoiding Low-lying Areas Such as Valleys as Such Areas Tend to Accommodate More Soil Moisture Which Can Reduce the Efficiency of the Measurement. Points of Measurement Were Chosen Such That They Were Not Too Close or Too Far Away from Buildings Because During Construction of the Buildings Soil Must Have Been Excavated Thereby Rendering the Soil Beside Them in a Disturbed State That Would Not Represent the True Nature of the Soil Before Excavation. Likewise, Points Were Chosen Away From Trees as Root Fissures Create a Preferential Pathway for Radon Migration Out of the Soil.

A Garmin 76 Gps Instrument Was Used to Obtain the Coordinates of Each Measurement Location in Conjunction with the Geological Map of Ibadan Which Allowed the Identification of the Underlying Bedrock Type.

**Soil-gas Radon Measurement**

The Soil Gas Radon Concentration Was Measured Using a Rad7 Radon Equipment Produced by Durridge Company Incorporation in Usa (Figure 2). The Principal Components of the Rad7 Equipment Include the Cylindrical Hollow Soil Probe, a Desiccant, Air Pump, a Silicone Radon Detector and a Battery Pack. The Soil Probe is a Steel Pipe Having 8 Mm Inner Diameter, 15mm Outer Diameter and 110 Cm Length. The Soil Probe Was Connected to the Radon Detector via a Vacuum Gauge and Hose Connector (Figure 3). The Desiccant (Which Contains Cobalt Chloride) Interfaces Between the Soil Probe and the Detector as It Serves to Remove Air Moisture from the Pumped Soil Gas and Ensures That the Equipment Operates at Humidity of Less Than 10 %.

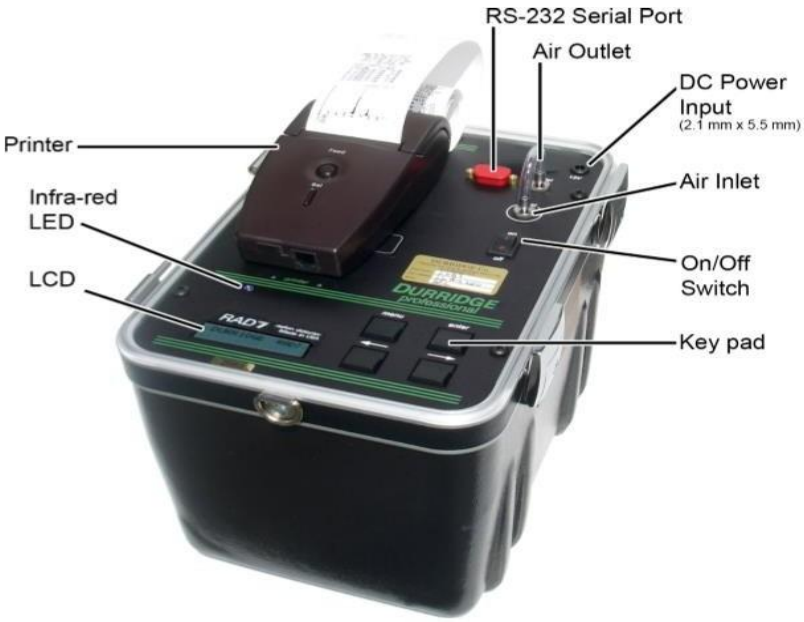


**Figure 2: Rad7 Radon Detector (16)**

Rad7 Measures the Energy of the Alpha Particles Emitted by Polonium (218po) in Secular Equilibrium with Radon-222 Gas (222rn). The Soil Probe of the Rad7 is Used to Draw Soil Gas at 80 – 100 Cm Depth into the Measurement Chamber of the Rad7 Where a Silicon Semiconductor Measures the Alpha Particles Emitted by the Polonium Atoms. Several Modes Are Available for the Rad7 in Measuring the Soil Gas Radon Concentration. A Regular Protocol is the “grab” Sampling Protocol With the “sniff” Mode Which Was Adopted for This Work. Table 1.0 Summarizes the “grab” Protocol.

**Table 1.0: Rad7 Protocol Used in Measurement of Radon Concentration**

| Protocol | Cycle | Recycle | Mode | Thoron | Pump |
|---|---|---|---|---|---|
| Grab | 0.05 | 04 | Sniff | Off | Auto |

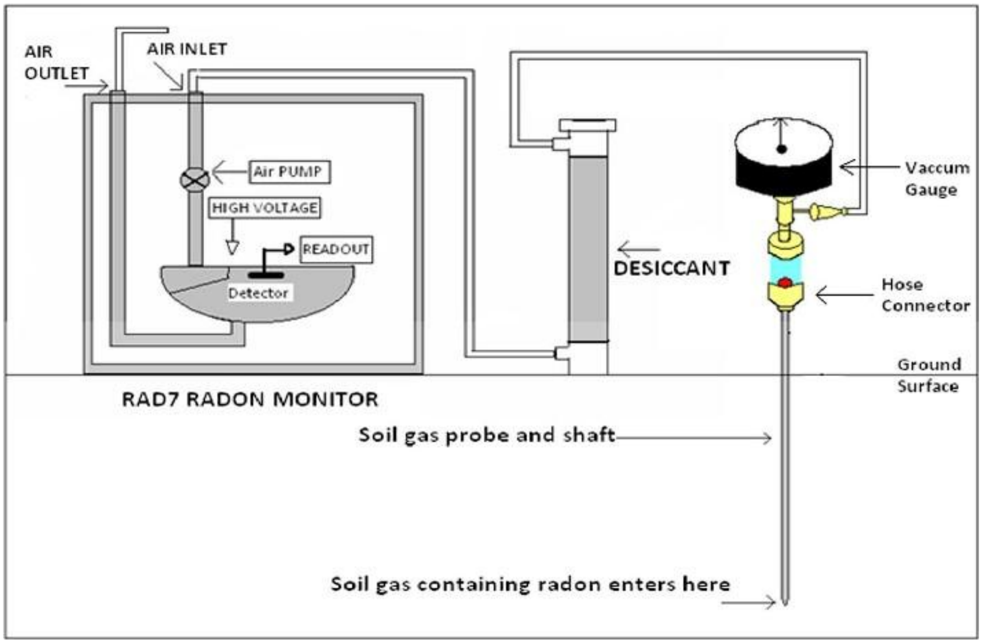


**Figure 3: Rad7 Schematic Diagram (17)**

**Indoor Radon Measurement**

Indoor Radon Measurement is Carried Out Using Passive Detectors or Monitors to More Advanced Electronic Instruments. Example of Passive Radon Monitors Are Alpha Track Detectors, Electret Ion Chamber (Eic) Detectors While an Example of Electronic Detectors is Continuous Radon Monitors Which Provide Real Time Measurement on Real Time Basis.

One of the Most Proficient Electronic Continuous Indoor Radon Detector and Monitor Presently in the Market is the Rad7 Radon Monitor Which Can Be Adapted for Both Rapid and Long-Term Measurement Which Can Be Averaged Over Longer Period. For Rapid Measurement of Indoor Radon, the Rad7 is Set in Auto Mode Using the "sniff" Mode Under the "grab" Protocol.

The Indoor Radon Concentration Measurement Was Done Using Rad7 Radon Monitor (Figure 2). The Rad7 Measures Indoor Radon by Drawing in Indoor Air Through a Filter and Dessicant That Disallows Air Particles and Suspended Water Droplets from Entering the Detector Chamber. The Detector Chamber is Made of a Silicon-based Hemispherical, Ion-implanted, 0.7 Litres Core. A High-voltage Circuit Induces an Electric Field of Between 2000 – 2500 V Within the Chamber. As Air Enters the Chamber by Means of the in-built Air Pump, Radon Gas Decay to Polonium (218po) Which Also Decays, Emitting Alpha Particles in the Process. The Positively Charged Polonium (218po) is Drawn to the Silicon Detector Surface in the Chamber by the Electric Field Operating Within the Chamber. The Alpha Particles, released as the Polonium (218po) Decays, Having Characteristic Energy Values Are Registered by the Silicon Detector Sensor. The Rad7 Microprocessor Picks Up These Energy Values, Converting Them to Electronic Signals Which Are Then Used to Generate an Alpha Spectrum. The Alpha Spectrum is Stored in Different Windows Indicating the Energy Deposited by the Alpha Particle. This Enables the Rad7 Microprocessor to Differentiate the Different Daughters of Radon (222rn) Such as 218po and 214po. Under the "sniff" Mode of Operation of the Rad7, All the Measurement Procedure Takes 15 Minutes Which Ensures Rapid Multiple

Measurements. These Measurements or Data Are Stored and Retrieved Through Durridge's Capture Software or Printed Using the Attached Wireless Printer.

The Flexibility, Quick Response Time and Ability to Discriminate Between Radon and Thoron, of the Rad7, Makes It a Reliable Instrument Both for Routine Monitoring and for Specialized Research Purposes.

Indoor Radon Concentration Was Carried Out in a Total of Forty-two (42) Selected Offices and Sixty (60) Classrooms in Six Tertiary Institutions Within Ibadan in Oyo State. The Average Dimension of the Offices Was 3.8 M X 3.6 M, With an Average Height of 2.65 M. The Classrooms Were Classified as Low Capacity (Lc – for Less Than 50 Students), Medium Capacity (Mc – for Between 50 – 100 Students) and High Capacity (Hc – for More Than 100 Students). Measurements Were Carried Out in 15 Lc Classrooms, 32 Mc Classrooms and 13 Hc Classrooms. the Offices and Classrooms Were Roughly Having the Same Type of Building Materials (E.g Concrete, Wood, Iron, Painting E.t.c) Thus Limiting the Factors of Variation to Lithology, Soil and Indoor Radon Measurement. Before Commencement of Indoor Radon Measurement, the Offices and Classrooms Were Locked Up for Between 18 - 24 Hours (Depending on the Usage) in Order to Allow Indoor Radon, Build Up. Access to the Classrooms Were Curtailed with Door Labels Indicating Restriction While the Rad7 Was Mounted in the Classrooms.

The Measurement of Soil Gas Radon Concentration and Indoor Radon Concentration Using Rad7 Was Conducted Between May to November, 2024 and It is Intended to Continue Adding to the Measurement as Resources Become Available for a More Comprehensive Measurement Campaign. Three Measurements of the Soil Gas Radon Concentration Were Made at Each Location and the Mean Value Represents the Soil Gas Radon Concentration at That Location. In Essence About Six Hundred (600) Measurements Were Made but Mean Values of Two Hundred Were Recorded for Further Analysis. Another Set of Twenty (20) Measurements Were Made Further Away from the Buildings to Serve as Control.

**Results and Discussion**

Soil-gas Radon Concentration (Crn) Across the 200 Sampled Points Had a Minimum Value of 0.46 Kbqm-3, a Maximum Value of 43.249 Kbqm-3 and Mean Value of 9.69 ± 3.72 Kbqm-3. Similar Studies in Different Part of the World as Well as in Nigeria as Presented in Table (2) Shows That the Mean Soil-gas Radon Concentration Obtained in This Study Follows the Same Trend. The Underlying Bedrocks in Ibadan Can Be Categorized into Two Major Bedrocks Which Are Igneous and Metamorphic Bedrocks with Metamorphic Rocks Being Predominant. Igneous (Granitic) Rocks Had the Highest Mean Value of Soil-gas Radon Concentration of 11.41 ± 7.22 Kbqm-3 Which is Consistent with Similar Studies (18,19) While the Metamorphic Bedrocks Had a Mean Value of 8.43 ± 5.34 Kbqm-3. For the 20 Control Points Measured Away from Any Infrastructure Within the Institutions, the Minimum Value of the Soil-gas Radon Concentration Obtained Was 0.26 Kbqm-3 While the Highest Value Was 32.39 Kbqm-3 With a Mean Value of 10.88 ± 6.45 Kbqm-3. The Variability in the Control is in the Same Range as the Variability in the Experimental Values. This Shows That the Soil-gas Radon Concentration is More of a Function of the Bedrock Rather Than the Building(S) on the Bedrock.

For the Indoor Radon Concentrations, the Measurement for Classrooms Had a Range of 29.41 – 156.73 Bqm-3 With an Average Value of 69.58 ± 23.67 Bqm-3 (Table 3.0) Which is Lower

Compared to That of Offices Which Had a Range of 37.82 Bqm-3 to 234.52 Bqm-3 With a Mean Value of 95.42 ± 36.82bqm-3 (Table 4.0). None of the Values Obtained Were Above the Upper Limit of 1500 Bqm-3 (20) for Indoor Radon Set by International Committee on Radiation Protection (Icrp). However, Some Offices Making Up 21.72% of the Sampled Offices Had Radon Concentration Values Above the 100 Bqm-3 Limit Stated by World Health Organization (3).

**Table 2.0: Mean Soil-gas Radon Concentration in Other Studies Compared to This Study**

| Country/Region | Mean Soil-gas Radon ($kBqm^{-3}$) | Reference |
|---|---|---|
| Sudan | 8.20 | Elzain (2015) |
| Jeddah, Saudi Arabia | 6.71 | Farid (2016) |
| Perak State, Malaysia | 18.96 | Nuhu et. al. (2021) |
| Southwest Nigeria | 10.39 | Farai et al. (2022) |
| Present study | 9.69 | ----- |

**Table 3.0: Indoor Radon Range and Mean Values for Offices in the Six Institutions**

| | **TPI** | **UI** | **SCON** | **IAR&T** | **FCAHPT** | **FCAM** |
|---|---|---|---|---|---|---|
| No. of Offices | 10 | 4 | 5 | 8 | 7 | 8 |
| Max. Indoor Radon ($Bqm^{-3}$) | 228.11 | 189.63 | 193.72 | 234.52 | 230.61 | 232.46 |
| Min. Indoor Radon ($Bqm^{-3}$) | 42.16 | 37.82 | 39.48 | 49.72 | 38.14 | 39.25 |
| Mean Value | 114.56 | 96.40 | 86.11 | 118.46 | 109.76 | 121.82 |

Tpi: The Polytechnic, Ibadan; Ui: University of Ibadan; Scon: School of Nursing Eleyeile;

Iar&t: Institute of Agricultural Research and Training; Fcahpt: Federal College of Animal Husbandry and Production Training; Fcam: Federal College of Agriculture, Moore Plantation

**Table 4.0: Indoor Radon Range and Mean Values for Classrooms in the Six Institutions**

| | **TPI** | **UI** | **SCON** | **IAR&T** | **FCAHPT** | **FCAM** |
|---|---|---|---|---|---|---|
| No. of Classrooms | 15 | 5 | 7 | 12 | 14 | 7 |
| Max. Indoor Radon ($Bqm^{-3}$) | 156.73 | 123.46 | 128.78 | 149.11 | 151.62 | 138.02 |
| Min. Indoor Radon ($Bqm^{-3}$) | 42.15 | 37.83 | 41.53 | 54.16 | 49.19 | 29.41 |
| Mean Value | 53.23 | 49.25 | 58.17 | 62.31 | 64.57 | 61.73 |

Tpi: The Polytechnic, Ibadan; Ui: University of Ibadan; Scon: School of Nursing Eleyeile;

Iar&t: Institute of Agricultural Research and Training; Fcahpt: Federal College of Animal Husbandry and Production Training; Fcam: Federal College of Agriculture, Moore Plantation

The Lower Range and Mean Value of the Classrooms Compared to That of Offices Could Be Attributable to the Fact That Classrooms Are Left Open More Than Offices Especially During Working Hours and Also to the Wider Ventilation of Classrooms. A Similar Study for 24 Offices in University of Ibadan (25) Found the Range to Be 157 – 495 Bqm-3 With Mean and Standard Deviation Value of 293.3 ± 79.6 Bqm-3. Also, a Study Conducted in 11 Buildings in Nnamdi Azikiwe University, Awka, Nigeria Found the Mean Value of Indoor Radon to Be 55.03 ± 9.51 Bqm-3 for the Ground Floors and 13.90 ± 3.83 Bqm-3 at the Upper Floors (26). In a Similar Study at the Obafemi Awolowo University, Ife for 62 Offices, Indoor Radon Concentration Had a Range of 0.0 – 5.5 Pci/l (or 0.0 – 196.1 Bqm-3) With a Mean Value of 1.0 Pci/l (37 Bqm-3) (27). These Studies Alongside This Present Study Shows the Variability Pattern of Indoor Radon Concentration Which Can Be Attributable Mostly to the Dominating Influence of the Underlying Lithology.

From Figure 4, It Was Observed That Granitic Lithology (Fine Grained Biotite Granite) Contributed the Highest Amount to the Mean Soil-gas Radon Concentration with a Mean Value of 11.41 Kbqm-3 While Metamorphic Lithology (Undifferentiated Schist and Gneiss) Had the Lowest Mean Soil-gas Radon Concentration of 3.83 Kbqm-3 for the 220 Sampled Sites. The Bedrocks with Mean Soil-gas Radon Concentration Above 10 Kbqm-3 Are Migmatite, Amphibolite and Fine-grained Biotite Granite.

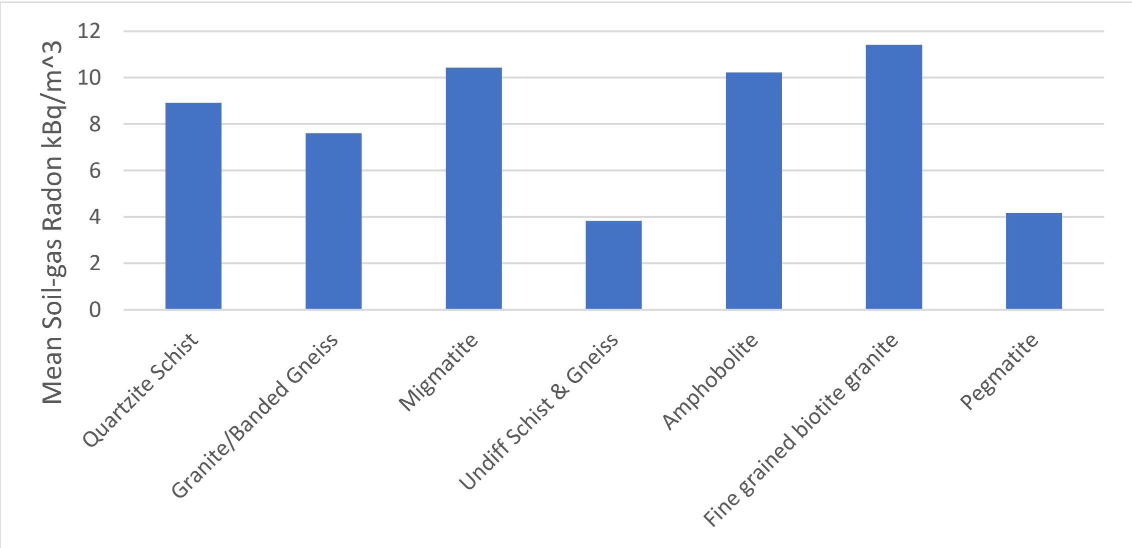


**Figure 4: Mean Soil-gas Radon Concentration of the Bedrocks**

Using the Widely Adopted Swedish or Akerblom Soil-gas Classification Criteria (8), 47 Sites Underlain by Different Types of Bedrocks (Representing 21.36% of the Total Number of 220 Sites) Were Found to Be Above 10 Kbqm-3. It the Implies That Tertiary Institutions in Ibadan, based on the Number of Institutions Accessed, Are Mainly Under Low Level of Soil-gas Radon Infiltration Risk. The Sites Above 10 Kbqm-3 (Classified as Normal Risk) Would Require Some Mitigation Measures Such as Sealing Up All Cracks in the Walls of the Offices and Classrooms, Designing Better Natural and Extra Ventilation Channels in the Existing Buildings as Well as Use of Low Radon Content Materials for New Construction. None of the Sites Had

Soil-gas Radon Concentration Value Above 50 Kbqm-3 Which Can Be Classified as 'high' Level of Infiltration Risk (Table 5.0).

**Table 5.0: Soil Gas Radon Risk Classification Based on Swedish/akerblom Criteria**

| Radon Conc. Range ($kBqm^{-3}$) | Frequency | Percentage | Category |
|---|---|---|---|
| < 10 | 173 | 78.64 | Low risk |
| 10 – 50 | 47 | 21.36 | Normal risk |
| > 50 | 0 | ----- | High risk |

A Strong Positive Correlation (R2 = 0.67) Was Observed Between the Indoor Radon Measurement and Soil-gas Radon Measurement for One of the Institutions, Showing the Dependence of the Indoor Radon Concentration on the Soil-gas Radon Concentration (Figure 5). However Other Factors Such as Meteorological Condition, Soil Porosity and Permeability, Soil Moisture, Ventilation, Building Materials Also Contribute to the Variation in Indoor Radon Concentration.

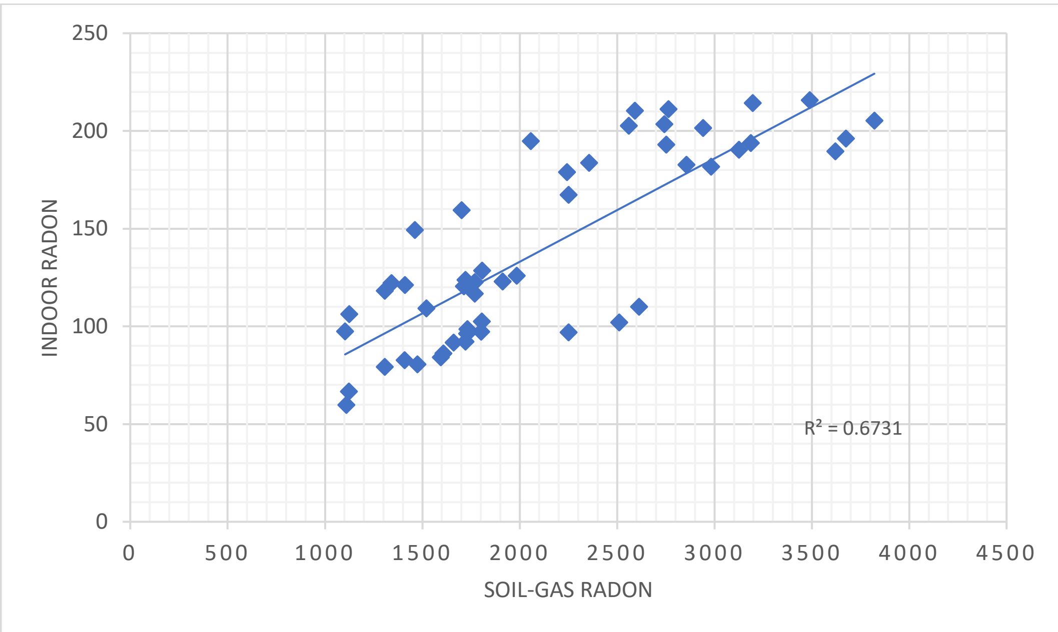


**Figure 5: Plot of Indoor Radon (Bqm-3) Against Soil-gas Radon (Bqm-3)**

More Institutions Could Have Been Covered in the Study but for the Lack of Awareness About Radon and Its Hazardous Nature by Some of the Other Institutions Visited. Moreover, there is a Lack of Government Legislation and Regulation on Radon Risk Criteria for Nigeria, Thus Making Public and Private Tertiary Institutions Not to Bother About Meeting Any Regulation with Regards to Radon Risk and Mitigation. It is Obvious That Nigeria Stands in Dire Need of Baseline Radon Data and Sustained Vigorous Awareness Campaign for Radon Risks in Order to Raise the Bar of Public Knowledge About Radon.

Although None of the Measurements Presented a High Level of Soil-gas Radon, it is Highly Recommended That Continuous Monitoring of the Soil-gas Radon and Indoor Radon Levels Be Done to Ensure That No Abrupt Changes Are Observed. From the Obvious Lack of Awareness of the Danger of Radon Exposure, Nigeria and Most Especially Institutional Administrators Need More Enlightenment on Radon Risk and Mitigation Measures. It is Highly Recommended That Soil-gas Radon Measurement Be Part of the Environmental Impact Assessment Report Presented for the Approval of New Tertiary Institutions in Nigeria. This Would Ensure That Radon Protective Measures Are Engaged Right from the Planning Stages for Establishment and Siting of New Tertiary Institutions.

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**Declaration of Competing Interest**

The Authors Declare That They Have No Known Competing Financial Interests or Personal Relationships That Could Have Appeared to Influence the Work Reported in This Publication.

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