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# ASSESSMENT OF INDOOR RADON GAS CONCENTRATION IN NATIONAL OPEN UNIVERSITY OF NIGERIA: A CASE STUDY OF CALABAR STUDY CENTRE

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The current work deals with indoor radon ($^{222}$Rn) concentrations measurements in the Calabar Study Centre of the National Open University of Nigeria using a Corentium Arthings digital radon detector meter for seven days representing a short–term average measurement of indoor radon gas concentration level. The geographical coordinates were recorded using a hand-held geographical positioning system for the sample point. Measurement was taken for seven days and the following data where obtained 83±2.19 Bq/m$^3$, 80±3.69 Bq/m$^3$, 86±5.57 Bq/m$^3$,84±1.59 Bq/m$^3$, 82±3.59 Bq/m$^3$, 81±4.89 Bq/m$^3$ and 85±5.59 Bq/m$^3$. The average radon ($^{222}$Rn) concentration level was found to be 83 ± 3.87 Bq/m$^3$ with a geometric mean of 82 ± 3.54 Bq/m$^3$. It was observed that the radon concentration was below the reference level of 100 Bq/m$^3$ recommended by the World Health Organization (WHO). Although the current exposure of members of the public to natural radiation is not critical, the situation could change abruptly when other activities commenced. The excess life time cancer risk calculated for 70 years, 60 years, 50 years, 40 years and 30 years were $1.72\times10^{-3}$, $1.65\times10^{-3}$, $1.44\times10^{-3}$, $1.39\times10^{-3}$and $0.69\times10^{-3}$ respectively. The calculated values of the excess life time cancer risk are all higher than the set limit of $0.029 \times 10^{-3}$ by International Commission on Radiological Protection. However, there are no observed cases of lung cancer epidemic in this Centre. Therefore, it is advised to use fans and effective ventilation techniques to reduce radon levels. Identifying the regions of the country where people are most at risk from radon exposure should be the main goal of any national radon policy.
**Keywords:** *Indoor radon; Radon concentration; Digital Radon Gas detector; Calabar Study Centre*
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## 1. INTRODUCTION

The human environment is continually exposed to ionizing radiation such as radon resulting from natural radionuclides found within the earth's crust and cosmic rays originating from outside the earth's atmosphere [1]. Starting with uranium or thorium, radon is found in decay chains and its daughter are present everywhere [2]. When compared to other naturally occurring radiation sources, it exposes people to the most radiation. This is the rationale behind the numerous radon studies conducted by academic institutions [3]. The radon in groundwater, the atmosphere, and buildings are only a few examples of the broad areas they research [4]. The radon atoms that were stopped in water or air spread through the substance's pore space, eventually becoming the cause of radiation exposure. The main natural source of ionizing radiation and the main factor in the amount of ionizing radiation that the global population is exposed to is radon gas. Numerous in-depth scientific studies on the health impacts of radon, identified radon and the decay products it produces as the second risk factor for the development of lung cancer, right behind smoking [5, 6]. Even in the case of typical residential concentrations, recent studies have shown evidence of a link between lung cancer and radon levels inside buildings [7]. Several authorities [6, 8] have established suitable action thresholds to reduce radon exposure, over which households that exceeded such limits would need to take radon mitigation measures. The World Health Organization (WHO) advised against radon levels in indoor air above 100 Bq·m$^{-3}$ or 300 Bq·m$^{-3}$ in special circumstances [9]. The concentration of radon in indoor air has been measured in many countries and in a large number of buildings as a consequence of the implementation of radon policies and regulation requirements. This has been done in order to identify all radon-prone regions and to apply the proper corrective measures. Alpha track detectors exposed for at least three months within buildings have been used in the majority of national measurement campaigns [10, 11]. The indoor radon concentration in the Cholula along the Pyramid tunnels was described by Lima Flores et al., [12]. It contributes to the understanding of the radon dynamic inside of the Pyramid tunnels and to evaluate the radiological health risk to visitors, archaeologists, anthropologists and persons who spend extended periods inside the Pyramid. Additionally, Nikolopoulosa and Louizi [13] provide estimates of exposure doses as well as passive and active radon concentrations in drinking water and indoor air in Cyprus and Greece. The levels of passive indoor radon in Cyprus ranged from (14 ± 3) and (74 ± 6) Bq·m$^{-3}$. Attica's active indoor radon concentrations varied from (5.6 ± 1.8) and (161 ± 12) Bq·m$^{-3}$, while those in Crete ranged from (1.7 ± 0.4) and (141 ± 12) Bq·m$^{-3}$. In Greece, radon levels in drinking water ranged from (0.8 ± 0.2) and (24 ± 6) Bq·m$^{-3}$, while those in Cyprus ranged from (0.3 ± 0.3) and (20 ± 2) Bq·m$^{-3}$. They came to the conclusion that radon is the primary source of exposure and dose in the populations of both Greece and Cyprus. Furthermore, indoor radon was investigated by Janik et al. [14] to be a serious threat to people's health and one of the main factors in lung cancer. They gave a summary of radon-related surveying and research projects carried out in recent years in western, southern, and eastern Asia. They discovered that as the human

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development index (HDI) rises, there are more indoor radon measurements per million people. Prior to the start of mining in the Adamawa region of Cameroon in 2022, Sadou et al. [15] investigated indoor radon ($^{222}Rn$) concentrations and ambient dose-equivalent rate measurements. The $^{222}Rn$ concentrations ranged between 175 ± 16 $Bq \cdot m^{-3}$ and 43 ± 12–270 ± 40 $Bq \cdot m^{-3}$, with a geometric mean of 101 ± 21 $Bq \cdot m^{-3}$. Most of the average values in terms of concentration and radiation dose were found to be above the corresponding world averages given by the United Nations Scientific Commission on the Effects of Atomic Radiation (UNSCEAR). Furthermore, using RADUET detectors and TnP monitors, Nkoulou et al. [16] measured indoor radon (Rn), thoron (Tn), and thoron progeny (TnP) simultaneously in the gold mining areas of Betare Oya. The WHO reference level of 100 $Bq \cdot m^{-3}$ is exceeded in 76% of Rn and Tn homes, while only 3% of homes exceed the 300 Bq $m^{-3}$ threshold set by the International Commission on Radiological Protection (ICRP). Radon has been acknowledged as a significant contributor to lung cancer and has been classified as a human lung carcinogen. According to surveys, radon is the main source of radiation for the general population. The biological effects of radon and its offspring's alpha emissions are greater than those of beta and gamma radiation. Experiments on rodents exposed to radon results in similar risk, and confirm a linear relationship between risk and dose [17]. This research therefore seeks to investigate whether or not the accumulation of radon gas within the Calabar Study Centre of the National Open University of Nigeria (NOUN) are within WHO acceptable limits. Hence, this study will be a guide to checkmate the challenges that may occur in the future due to the overexposure of this gas and to advise the Government and the NOUN management on the implications of overexposure to the radon gas.

## 2. MATERIALS AND METHOD

The Airthings Corentium Digital Radon Detector, created in Oslo, Norway, is the radon detector utilized in this project. The unit of measurement for radon-222 is picocuries per liter, or pCi/L. For daily, weekly, monthly, and annual monitoring of radon concentration levels, the Airthings Corentium digital detector can be used for a minimum of 24 hours. The radon meter operates under the premise that radon diffuses into a chamber for detection. The atoms release energetic alpha particles as they decompose. A silicon photodiode detects the energetic alpha particles. When the alpha particle strikes the photodiode, it produces a small signal current. The signal current is changed into a large voltage signal by using a low power amplifier stage. An analogue to digital converter measures and samples the voltage signal's maximum amplitude. The energy of the alpha particle that struck the photodiode determines the signal's amplitude. A micro-controller serves as the monitor's central processing unit and logs the time and energy of each particle it detects.

The mean radon concentration for daily, weekly, monthly, and yearly time periods is determined using this data. The Arthings digital radon detector was used to measure the indoor radon concentration in-situ at the Calabar Study Center in Cross River State, Nigeria. The GPS was used to determine the geographic coordinates of the sample point. Calabar study Centre is one of the many Study Centres run by the National Open University of Nigeria. The Arthings Corentium digital radon detector was installed in the room at a distance of 0.25 m from the walls, 1.5 m from the window, and 0.5 m from the door [18]. These positions were fixed throughout the work and were maintained since radon levels depend remarkable on the sampling position. The detector was kept for a period of 24 hours before reading was taken and this was repeated for seven days. The windows and doors were kept closed throughout the period of the measurement to ensure that the indoor air is not distorted to achieve accuracy within the period of 24 hours.

### 2.1. EXCESS LIFE TIME CANCER RISK FROM RADON CONCENTRATION

The possible carcinogenic effects, as determined by a calculation based on the probability of cancer-induced incidence in a population known as the excess lifetime cancer risks (ELCR). The sample location ELCR is the World Standard probability of developing cancer over a given lifetime due to radiation or toxic chemical exposure.
According to Ref. [2] the ELCR is given as

$$ECLR = A_E \times D_L \times R_F \quad (1)$$

where $A_E$ = Annul effective dose rate, $D_L$ = Average duration of life (70 years), $R_F$ = Risk Factor (0.05). By using a tissue and radiation weighting factor, the Annual Effective Dose Rate (AEDR) from Radon Concentration was computed [8, 10]. The inhalation dose equation takes the form:

$$AEDR(mS\ v/y) = D_{Rn} \times W_R \times W_T \quad (2)$$

where $D_{Rn}$ = indoor radon concentration, $W_R$ = radiation weighting factor for alpha particles, and $W_T$ = tissue weighting factor for the lung [18].

### 2.2 STUDY AREA

The study area is located in Calabar, the capital of Cross River state, Nigeria. Administratively the city is divided into Calabar `municipal and Calabar South Local Government Areas. It has an area of 406 $km^2$ and had a population of 371,022 at the 2006 census. The city is adjacent to the great Kwa Rivers and creeks of the Cross River (from inland delta) [19]. The study area is located between longitude N4°50' to N5°00' and latitude E8°15' to E8°30' as indicated in Figure 1 [20]. The location is Calabar study Centre, it was chosen for the study being a less populated Study Centre in NOUN.

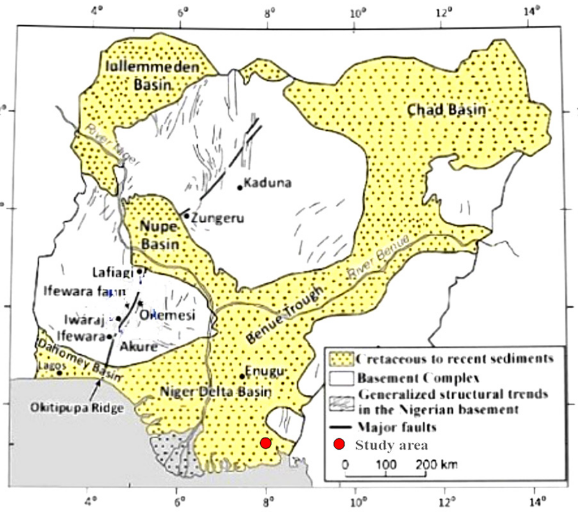


**Figure 1.** Geological map of Nigeria showing the study area (after NGSA, 2004)

## 3. RESULTS AND DISCUSSION

The readings were obtained from NOUN Calabar study Centre in Cross River State, Nigeria. The geology of Cross River State lies partly in the Oban Massif and the Calabar flank geological formations. These geological formations are characterized by unique structural imprints. Geological map of Cross River State shows two types of rock formation, the sedimentary and base complex rock. The Obudu Plateau flank and the Oban Massif in Akamkpa shows the basement complex rocks, while the central and the southern parts of the state shows the sedimentary rocks [21]. Before the detector is set for measurement counts or monitoring, on pressing the reset button, it calibrates itself to ensure that the results so obtained would be same ease where under the same physical, environment, geological and meteorological conditions. The reading was for seven days which accounted for short-term average measurement. Figure 2 shows a chart distribution of indoor radon concentration level for seven days.

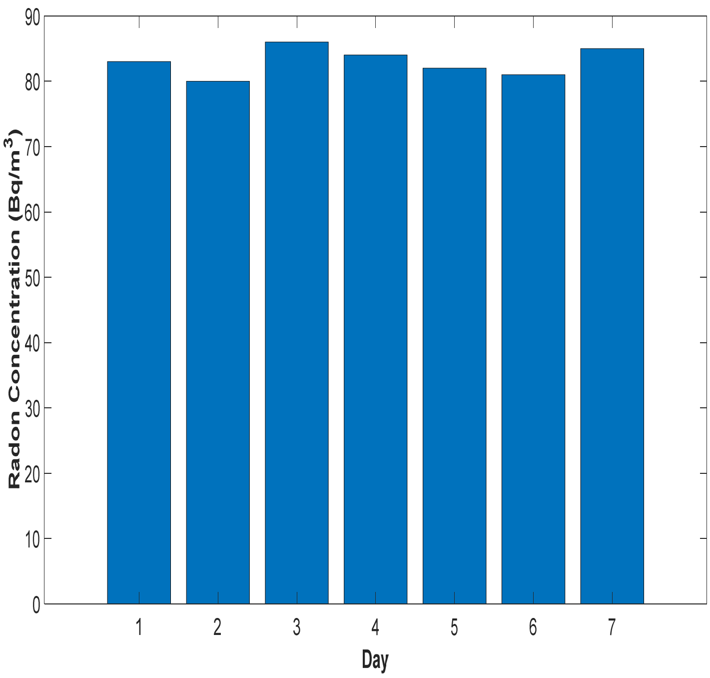


**Figure 2.** A chart showing Radon distribution in Bq/m$^3$ for 7 days

The average indoor radon concentration level was found to be 83 ± 3.87 Bq/m$^3$ with a geometric mean of 82 ± 3.54 Bq/m$^3$. This shows that the rate of diffusion or exhalation of radon is higher in the study area because of probably humidity, high temperature and exhalation and it was also found that radon concentrations was not above the reference level of 100 Bq/m$^3$ recommended by the WHO. The distribution of radium in soil grains are described as the key factor that affects radon emanation. Original models of radon emanation assumed that radium distribution was homogenous throughout the grain and that these grains were also spherical. The excess lifetime cancer risk calculated for 70 years, 60 years, 50 years, 40 years, and 30 years are shown in Table 1. The calculated values of the excess life time cancer risk calculated are all higher than the set limit of $0.029\times10^{-3}$ by International Commission on Radiological Protection (ICRP). However, there are no observed cases of lung cancer epidemic in this Centre.

**Table 1.** Computed values of excess lifetime cancer risk for ages of 70. 60, 50, 40 and 30 years of NOUN Calabar Study Centre

| S/N | ELCR$\times10^{-3}$ 70 years | ELCR$\times10^{-3}$ 60 years | ELCR$\times10^{-3}$ 50 years | ELCR$\times10^{-3}$ 40 years | ELCR $\times10^{-3}$ 30 years |
|---|---|---|---|---|---|
| 1 | 1.72 | 1.65 | 1.44 | 1.39 | 0.69 |

## 4. CONCLUSION

In this work, $^{222}$Rn was measured in the Calabar study Centre of the NOUN using Airthings Corentium Digital Radon Detector. The average radon $^{222}$Rn concentration was found to be 83 ± 3.87 Bq/m$^3$ with a geometric mean of 82 ± 3.54 Bq/m$^3$. It is abundantly clear that the exposure level is not dangerous. The situation could change in the near future. However, the excess life time cancer risk for the study Centre was higher than the world average. The current findings will also help with the ongoing project in Nigeria to establish national reference levels for indoor radon. Therefore, it is advised to use fans and effective ventilation techniques to reduce radon levels. Identifying the regions of the country where people are most at risk from radon exposure should be the main goal of any national radon policy.

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**Competing interests.**

The authors affirm that they do not have any competing interests.

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## ОЦІНКА КОНЦЕНТРАЦІЇ РАДОНУ В ПРИМІЩЕННЯХ НАЦІОНАЛЬНОМУ ВІДКРИТОГО УНІВЕРСИТЕТУ НІГЕРІЇ: ПРИКЛАД ДОСЛІДНИЦБКОГО ЦЕНТРУ КАЛАБАРА

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Поточна робота стосується вимірювань концентрації радону ($^{222}$Rn) у приміщеннях у Калабарського дослідницькому центру Національного відкритого університету Нігерії за допомогою цифрового радонометра Corentium Arthings протягом семи днів, що представляє короткочасне середнє вимірювання рівня концентрації газу радону в приміщенні. Географічні координати були записані за допомогою портативної системи географічного позиціонування точки вибірки. Вимірювання проводилися протягом семи днів і були отримані наступні дані: 83±2,19 Бк/м$^3$, 80±3,69 Бк/м$^3$, 86±5,57 Бк/м$^3$, 84±1,59 Бк/м$^3$, 82±3,59 Бк/м$^3$, 81±4,89 Бк/м$^3$ та 85 ± 5,59 Бк/м3. Середній рівень концентрації радону ($^{222}$Rn) склав 83 ± 3,87 Бк/м$^3$ із середнім геометричним значенням 82 ± 3,54 Бк/м3. Було виявлено, що концентрація радону була нижчою за контрольний рівень 100 Бк/м$^3$, рекомендований Всесвітньою організацією охорони здоров'я (ВООЗ). Хоча нинішнє опромінення населення природним випромінюванням не є критичним, ситуація може різко змінитися, коли розпочнуться інші види діяльності. Надлишковий ризик розвитку раку протягом життя, розрахований для 70 років, 60 років, 50 років, 40 років і 30 років, становив $1,72\times10^{-3}$, $1,65\times10^{-3}$, $1,44\times10^{-3}$, $1,39\times10^{-3}$ та $0,69\times10^{-3}$ відповідно. Усі розрахункові значення ризику розвитку раку протягом тривалого життя перевищують межу $0,029\times10^{-3}$, встановлену Міжнародною комісією з радіологічного захисту. Однак випадків епідемії раку легень у Центрі не спостерігається. Тому для зниження рівня радону рекомендується використовувати вентилятори та ефективні методи вентиляції. Головною метою будь-якої національної радонової політики має бути визначення регіонів країни, де люди найбільше піддаються ризику впливу радону.

**Ключові слова:** *радон у приміщеннях; концентрація радону; цифровий детектор газу радону; центр досліджень Калабара*