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Evaluation of Radon Concentration and the Health Risk in the Offices of the Institute of Science and Technology of the “École Normale Supérieure”, Burkina Faso

Rouamba M. M. Jonathan[1], Bambara Telado Luc[1,2*], Doumounia Ali[1,2], Kohio Nièssan[1,2], Ouédraogo Soumaila[1,2], François Zougmore[1]

[1]Laboratory of Materials and Environment, Physics Department, University Joseph Ki-Zerbo, Ouagadougou, Burkina Faso
[2]Institute of Science and Technology, Ecole Normale Supérieure, Koudougou, Burkina Faso
Email: *telado.luc.bambara@gmail.com

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Abstract

The second most important cause of lung cancer after smoking is radon gas. Thus, the determination of indoor radon concentrations in residential buildings and workplaces is an important public health concern. The purpose of this research was to measure the concentration of radon gas in the offices of the Institute of Science and Technology and to evaluate the effective dose in the lungs and the risk of cancer. This study used Corentium’s AIR THINGS digital radon detector to determine the radon concentration in sixteen (16) offices. The digital radon detector air Things of Corentium was placed in each office for a minimum period of one week and the concentration values were recorded every 24 hours. The values recorded in each office were the short-term average and the long-term average during seven days of measurement. The short-term radon concentrations vary between 5.286 Bq/m^3 and 192.714 Bq/m^3 with an average of 48.01 Bq/m^3 and those in the long-term were between 6.143 Bq/m^3 and 172.571 Bq/m^3 with an average of 52.46 Bq/m^3. The measurements in office N˚6 and 13 were above the lower limit of 100 Bq/m^3 proposed by the WHO. The short-term and long-term effective doses in the lungs for offices N˚6 and 13 were above the “normal” background level of 1.1 mSv/year proposed by UNSCEAR-2000. The short-term effective dose in the lungs for office N˚6 was above the lower limit of 3 mSv per the ICRP-23 recommendation. The average number of lung cancer cases per year per million people was 15.

Keywords

Radon, Concentration, Absorbed Dose, Effective Dose

1. Introduction

Radon is a colourless, odourless and incessant radioactive gas resulting from the decay of radium 226Ra itself from the decay chain of uranium 238U. In buildings, radon is considered the most important indoor air pollutant with harmful effects on the health of occupants. The main sources of radon inside homes are soil, building materials (sand, rocks, cement and bricks), water sources and natural energy sources (gas and coal) which may contain traces of uranium 238U [1]. Being radioactive gas, radon is considered by health authorities to be a lung carcinogen and the primary factor of exposure to radioactivity in humans [2]. The radon concentration in outdoor air is generally very low. Unlike inside houses, radon can accumulate by confinement effect, often reaching very high concentrations, which represents a health risk [3].

When radon gas is inhaled, it can interact with biological tissue in the lungs leading to DNA damage which is considered an important step in the carcinogenic process [4].

In the USA, studies have shown that radon in homes has caused 21,100 lung cancer deaths per year, making it the second leading cause of lung cancer deaths [4]. The average radon concentration in homes in the UK is 21 becquerels per cubic meter (Bq/m^3). Each year around 1100 lung cancer deaths are related to radon in the home [5]. Radon offspring concentrations in Canadian homes are approximately three times higher than in school buildings, 4.7 times higher than in public buildings and indoor workplaces, and 12 times higher than in the outdoors. Exposure at home contributes to 90% of the risk of radon-induced lung cancer [6]. In Palestine, the mean (range) radon concentration in major water sources was 6.9 (1.5 - 23.4) Becquerel/liter (Bq/L). Mean concentrations in springs and sinks were 4.6 Bq/L and 9.5 Bq/L, respectively [4]. In the newly built community in Chengdu China, the average indoor air radon concentration was about (249 ± 72) Bq·m^{-3}, and the annual effective dose received by residents was about 8 mSv [7].

In Burkina Faso, cancer is one of the main causes of death after infectious diseases and cardiovascular diseases. In 2018, 11643 new cases of cancer were recorded in health facilities with 9221 cancer-related deaths [8]. Colon, stomach, liver, lung, bladder and kidney cancers are the most common cancers according to existing data from the Yalgado Ouédraogo University Hospital [8]. Preliminary studies on the concentration in places of residence in a few districts of Ouagadougou city and in university residences have revealed very varied and high concentrations by location [9] [10].

This article aims to contribute to the evaluation of the radon concentration in the offices of the Institute of Science and Technology of "the Ecole Normale Supérieure", and their impacts on the health of workers.

2. Material and Methods

2.1. Presentation of the Study Area

The study was conducted in the city of Ouagadougou, precisely on the site of the

Institute of Science and Technology of "the Ecole Normale Supérieure". The Institute of Science and Technology, located in sector 46 of the arrondissement 11 Rue 29 - 119 of the city of Ouagadougou is a training institute for teachers of high schools and colleges in scientific disciplines.

The geographical data of the Institute of Sciences are as following:

- Latitude: 12˚21'26.47" North
- Longitude: 1˚28'49.93" West

This study therefore focuses on a total of sixteen (16) offices in seven (7) buildings (**Figure 1**) of the Institute of Science and Technology.

Table 1 shows the location of each office in the different buildings of the Institute of Science and Technology.

2.2. Materials Used

The CORENTIUM AIR THINGS Digital Radon Detector (**Figure 2**) is our choice for radon concentration measurement in offices at the Institute of Science and Technology. It is one of the three (3) best detectors by its very high precision

Figure 1. Study area.

Table 1. Distribution of offices in the different buildings.

Building	Offices
Administrative Building	Office 5, office 7 and office 8
DAF Building	Office 1 and office 2
Pedagogical Building	Office 3
Block Amphi 700	Office 4, office 6 and office 11
Block of "Villas"	Office 9, office 12, office 13, office 15 and office 16
Laboratories Block	Office 14
Schooling Block	Office 10

Figure 2. Two faces of the AIR THINGS CORENTIUM detector.

and also in relation to its price. It is a very interesting device to know the state of indoor radon concentration. CORENTIUM AIR THINGS radon sensors are designed for indoor use only. The CORENTIUM AIR THINGS detector is easy to handle and pass. The CORENTIUM AIR THINGS detector has an accuracy of 10% after seven (7) days and an accuracy of 5% after two (2) months.

The detectors were installed in sixteen (16) offices of the Institute of Sciences and Technology. For concentration measurements, CORENTIUM's AIR THINGS digital radon detector was placed inside each office a minimum period of one week. To start the measurements, the device is reset by using the RESET function located on the back of the detector to erase the data from the device once inside the chosen house before starting a new measurement.

All results are given in a specific numerical value of Becquerels per cubic meter (Bq/m^3). Concentration values were recorded onto a radon concentration data collection sheet every 24 hours for a week. The CORENTIUM AIR THINGS Digital Radon Detector gives two values on each reading. These values are also the "SHORT TERM AVERAGE" and the "LONG TREM AVERAGE" (**Figure 2**).

The "long-term average" value displayed by AIR THINGS by CORENTIUM designates the average radon concentration for a continuous measurement, a maximum (recalculated once a day). The "short-term average" value represents the average of the radon concentration of the last 24 hours ("1 day", recalculated every hour) and the average concentration of the last day of the week ("day 7", recalculated once per hour).

2.3. Dose Estimate

For a representative estimate of radon levels in residential areas, measurements were taken in occupied rooms in buildings. The absorbed dose quantifies this energy per unit mass of the organs and tissues affected. The absorbed dose in gray (Gy) is the energy in joule (J) compared to the mass in kilogram (kg) therefore (J/kg) with 1 gray (Gy) = 1 joule (J) per kilogram (kg). The regulations quantify exposure to ionizing radiation by an average dose over the whole body: the effective dose, expressed in sieverts (Sv). The effective dose balances the absorbed dose according to the radiotoxicity of the different types of radiation and the radiosensitivity of the organs and tissues. The lung is one of the most radiosensitive organs in the human body. The effective dose is an indicator of overall health detriment. The concentration of potential alpha energy of a mixture of progeny in the air is expressed in J/m^3. From the relationship between the concentration of radon and that of potential alpha energy, 1 Bq/m^3 = 5.56×10^{-6} mJ/m^3. The Balance factor F depends on the level of ventilation: $F = 0.4$ in natural ventilation and $F = 0.2$ in forced ventilation.

The annual absorbed dose (mSv) due to indoor exposure to radon was estimated using the radon concentration (C_{Rn}), the equilibrium factor (F), the occupancy factor (O), the number of hours per year (T) and the dose conversion factor (D) [9] [11] [12].

The formula used to calculate the annual absorbed dose is given as following:

$$D_T\left(\text{mSv}\right) = C_{Rn} \cdot F \cdot O \cdot T \cdot D$$

where: C_{Rn} is the concentration in Bq/m^3; F is taken as 0.4; O is estimated that people spend 13% of their time in the office; T = 24 hours × 365 days = 8760 hours, and D converts the radon concentration to an effective dose [1] [13] [14] [15] [16] [17].

2.4. Effective Dose to the Lung (mSv)

The annual effective dose to the lung (E_T) is determined from the annual absorbed dose (D_T), the radiation weighting factor (W_R) which has a value of 20 for alpha particles and the tissue weighting factor (W_T) which is 0.12 for the lung (ICRP, 1991) [18].

The formula used to calculate the effective dose to the lung is given as following [1] [9] [13] [14] [19]:

$$E_T\left(\text{mSv}\right) = D_T \cdot W_R \cdot W_T$$

2.5. Radon Exposure

The formula used to calculate the radon exposure (RE) is given as following:

$$RE\left(\text{WLM per year}\right) = C_{Rn} \cdot O \cdot F \cdot C_{WL} \cdot T/T_W$$

C_{WL} is Conversion of radon concentration to working level, which has a value of 2.7×10^{-4}.

T is the number of hours in a year.

T_w is the number of working hours in a month.

The working level is equivalent to a radon activity concentration of 12,000 Bq/m^3 and 1 WLM roughly corresponds to exposure for one year to an atmosphere where the radon activity would be 230 Bq/m³.

2.6. Lifetime Cancer Risk

The formula used to calculate lifetime cancer risk (*CR*) is given as following [20]:

$$RC = RE \cdot T \cdot F_R$$

T is the average life expectancy which is 61.9 in Burkina in 2019.

F_R is the risk coefficient of exposure to 222Rn gas in equilibrium with its progeny (5×10^{-4} by WLM).

2.7. Number of Lung Cancer Cases per Year and per Million People

The formula used to calculate the number of lung cancer cases per year per million people (*NLCC*) is given as following [14]:

$$NLCC = E_T \times \left(18 \times 10^{-6}\ \text{mSv}^{-1} \cdot \text{year}\right)$$

3. Results and Discussions

3.1. Radon Concentration in Some Offices of the Institute of Science and Technology

Figure 3 presents the average radon gas concentrations in the sixteen (16) offices of Institute of Science and Technology.

The average short-term radon concentrations in the sixteen (16) offices varied between 5.286 Bq/m³ and 192.714 Bq/m³. Considering the public health implications of radon exposure, the WHO published a radon initiative recommending a reference level of 100 Bq/m³ and not exceeding 300 Bq/m³. Offices 6 and 13 have short-term concentrations that exceed the lower limit of 100 Bq/m³ but below the upper limit of 300 Bq/m³. The short-term concentrations of radon gas in the two offices can have health effects on the occupants.

The average long-term radon concentrations in the sixteen (16) IST/ENS

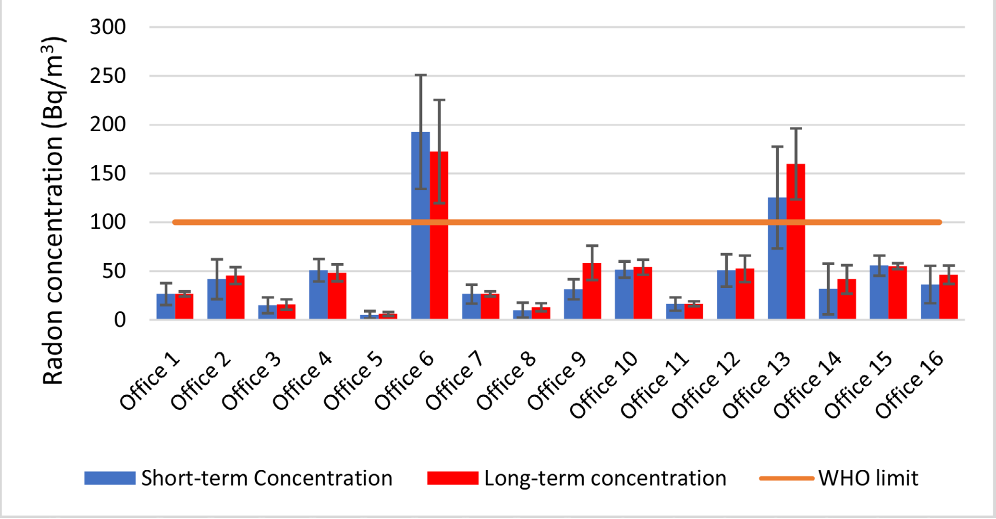

Figure 3. Radon concentration in institute of science and technology offices.

offices were between 6.143 Bq/m^3 and 172.571 Bq/m^3. Offices 6 and 13 have long-term concentrations that exceed the lower limit of 100 Bq/m^3 but below the upper limit of 300 Bq/m^3. The long-term concentrations of radon gas in the two offices can have health effects on the occupants of these offices.

The average short-term and long-term radon gas concentrations in offices 6 and 13 in the IST/ENS were above the limit of 100 Bq/m^3. In offices 2, 8, 9, 10, 11, 12, 13, 14, and 16, the average long-term radon concentration values are higher than the short-term ones.

3.2. Absorbed Dose and Effective Dose in IST/ENS Offices

Table 2 shows the short-term and long-term absorbed dose and the short-term and long-term effective lung dose for the different offices that were the subject of this study.

The short-term radon absorbed dose calculated from the measured radon concentrations varies between 0.035 mSv and 1.276 mSv with an average of 0.318 mSv. The long-term absorbed dose of radon was between 0.041 mSv and

Table 2. Absorbed dose and effective dose in the short- and long-terms.

	Short-term absorbed dose of radon (mSv)	Long-term absorbed dose of radon (mSv)	Short-term effective dose in the lungs (mSv)	Long-term effective dose in the lungs (mSv)
Office 1	0.176	0.176	0.422	0.422
Office 2	0.276	0.301	0.663	0.722
Office 3	0.099	0.105	0.238	0.252
Office 4	0.338	0.320	0.811	0.767
Office 5	0.035	0.041	0.084	0.098
Office 6	1.276	1.143	3.063	2.743
Office 7	0.176	0.177	0.422	0.425
Office 8	0.066	0.087	0.159	0.209
Office 9	0.208	0.388	0.500	0.931
Office 10	0.342	0.359	0.820	0.861
Office 11	0.108	0.110	0.259	0.263
Office 12	0.337	0.347	0.808	0.833
Office 13	0.831	1.059	1.994	2.541
Office 14	0.210	0.275	0.504	0.661
Office 15	0.369	0.365	0.886	0.876
Office 16	0.240	0.307	0.577	0.738
Average	**0.318**	**0.347**	**0.763**	**0.834**
Minimum	**0.035**	**0.041**	**0.084**	**0.098**
Maximum	**1.276**	**1.143**	**3.063**	**2.743**

1.143 mSv with an average of 0.347 mSv.

The short-term effective dose in the lungs calculated from the short-term absorbed dose of radon varies between 0.084 mSv and 3.063 mSv with an average of 0.763 mSv. The long-term effective dose in the lungs was between 0.098 mSv and 2.743 mSv with an average of 0.834 mSv. The short-term and long-term effective lung dose in office 6 and office 13 were above the "normal" background level of 1.1 mSv per year proposed by UNSCEAR-2000 [21]. The short-term effective lung dose in the lungs in office 6 is above the lower limit of 3 mSv per year recommended by ICRP-23 [22]. Since the short-term effective lung dose in office 6 is greater than 3 mSv, the occupants of this office may be exposed to the health effects of radon gas.

3.3. Risk of Lung Cancer

Table 3 shows the radon exposure, cancer risk, and number of lung cancer cases (NLCC) per year per million people in the offices surveyed.

In the studied offices, exposure to radon varies between 7.40 * 10^{-03} WLM per year and 2.15 * 10^{-1} WLM per year with an average of 5.39 * 10^{-2} WLM per year. The risk of lung cancer is between 2.29 * 10^{-4} and 6.66 * 10^{-3} with an average risk of 1.67 * 10^{-3}. In office 6, the number of lung cancer cases per year per million people is 49. The average number of lung cancer cases per year per million people

Table 3. Relative risk of lung cancer in institute of science and technology offices.

	Radon Exposure (WLM par an)	Cancer Risk	NLCC
Office 1	$3 \times 11 \times 10^{-2}$	$9 \times 61 \times 10^{-4}$	$7 \times 60 \times 10^{-6}$
Office 2	$5 \times 53 \times 10^{-2}$	$1 \times 71 \times 10^{-3}$	$1 \times 30 \times 10^{-5}$
Office 3	$1 \times 91 \times 10^{-2}$	$5 \times 91 \times 10^{-4}$	$4 \times 54 \times 10^{-6}$
Office 4	$5 \times 86 \times 10^{-2}$	$1 \times 81 \times 10^{-3}$	$1 \times 38 \times 10^{-5}$
Office 5	$7 \times 40 \times 10^{-3}$	$2 \times 29 \times 10^{-4}$	$1 \times 76 \times 10^{-6}$
Office 6	$2 \times 15 \times 10^{-1}$	$6 \times 66 \times 10^{-3}$	$4 \times 94 \times 10^{-5}$
Office 7	$2 \times 92 \times 10^{-2}$	$9 \times 04 \times 10^{-4}$	$7 \times 64 \times 10^{-6}$
Office 8	$1 \times 48 \times 10^{-2}$	$4 \times 58 \times 10^{-4}$	$3 \times 76 \times 10^{-6}$
Office 9	$6 \times 70 \times 10^{-2}$	$2 \times 07 \times 10^{-3}$	$1 \times 68 \times 10^{-5}$
Office 10	$6 \times 92 \times 10^{-2}$	$2 \times 14 \times 10^{-3}$	$1 \times 55 \times 10^{-5}$
Office 11	$1 \times 90 \times 10^{-2}$	$5 \times 87 \times 10^{-4}$	$4 \times 74 \times 10^{-6}$
Office 12	$6 \times 35 \times 10^{-2}$	$1 \times 97 \times 10^{-3}$	$1 \times 50 \times 10^{-5}$
Office 13	$1 \times 50 \times 10^{-2}$	$4 \times 65 \times 10^{-4}$	$4 \times 57 \times 10^{-5}$
Office 14	$3 \times 41 \times 10^{-2}$	$1 \times 05 \times 10^{-3}$	$1 \times 19 \times 10^{-5}$
Office 15	$1 \times 24 \times 10^{-1}$	$3 \times 83 \times 10^{-3}$	$1 \times 58 \times 10^{-5}$
Office 16	$4 \times 10 \times 10^{-2}$	$1 \times 27 \times 10^{-3}$	$1 \times 33 \times 10^{-5}$
Average	$\mathbf{5 \times 39 \times 10^{-2}}$	$\mathbf{1 \times 67 \times 10^{-3}}$	$\mathbf{1 \times 50 \times 10^{-5}}$

is 15. The occupants of office 6 are those most exposed to radon gas at the IST/ENS, hence the need to provide permanent ventilation of the office to lower the concentration of the gas.

3.4. Daily Concentration of Radon Gas in the Office 6

The results of the radon gas concentrations in the IST/ENS offices showed that the radon gas concentrations in office 6 were above the lower limit proposed by the WHO (100 Bq/m^3). In view of these results, a campaign to measure the concentration of radon gas in office 6 over a period of three months (90 days) was carried out to assess the variation in concentration and effective dose in the lungs.

Table 4 gives the average, maximum, minimum concentrations and the standard deviations of the long-term and short-term radon concentrations in office number 6 of the Institute of Science and Technology for a period of three months (90 days).

The long-term concentration of radon gas in office 6 during the three months of measurement varies between 149.00 Bq/m^3 and 299.00 Bq/m^3 with an average of 265.26 Bq/m^3. The long-term average concentration of radon gas in office 6 is above the WHO lower limit of 100 Bq/m^3. The short-term concentration of radon gas in office 6 during the three months of measurement varies between 119.00 Bq/m^3 and 621.00 Bq/m^3 with an average of 287.04 Bq/m^3. The short-term average concentration of radon gas in office 6 was above the WHO lower limit of 100 Bq/m^3. After three months of measurement, the concentration of radon gas in office 6 was greater than 100 Bq/m^3, hence the need for ventilation of office 6 of the Institute of Science and Technology to lower the concentration in this desk.

3.5. Variation of the Daily Radon Concentration in the Office 6

Figure 4 shows the variations in long-term and short-term daily concentrations of radon gas in office 6 of the Institute of Science and Technology during the three months of measurement.

The long-term daily concentration of radon gas varies slightly, while the short-term daily concentration varies considerably from day to day. The short-term daily concentration on some days is above the WHO upper limit (300 Bq/m^3).

Table 4. Average radon concentration in office 6 of the institute of science and technology.

	Long-term Concentration (Bq/m^3)	Short-term Concentration (Bq/m^3)
Average	265.26	287.04
Minimum	149.00	119.00
Maximum	299.00	621.00
Standard Deviation	35.09	105.18

The measurements showed that the thirty-five-day short-term concentrations were greater than 300 Bq/m^3 and the maximum concentration was 621 Bq/m^3. This could lead to significant exposure of the occupants to radon.

3.6. Variation of the Effective Dose of Radon in the Lungs in the Office 6

Figure 5 presents the variations of the long-term and short-term effective dose in the lungs of radon gas in office 6 of the Institute of Science and Technology during the three months of measurements.

The long-term effective daily dose of radon gas varies slightly, while the

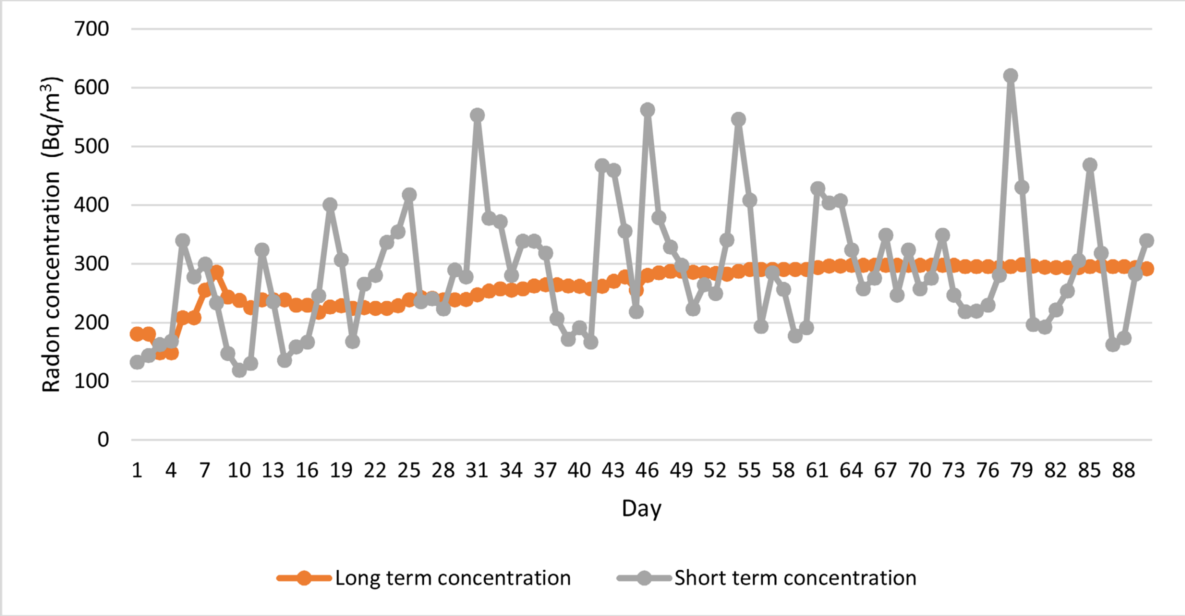

Figure 4. Variation of the daily radon concentration in office 6 during three months of measurement.

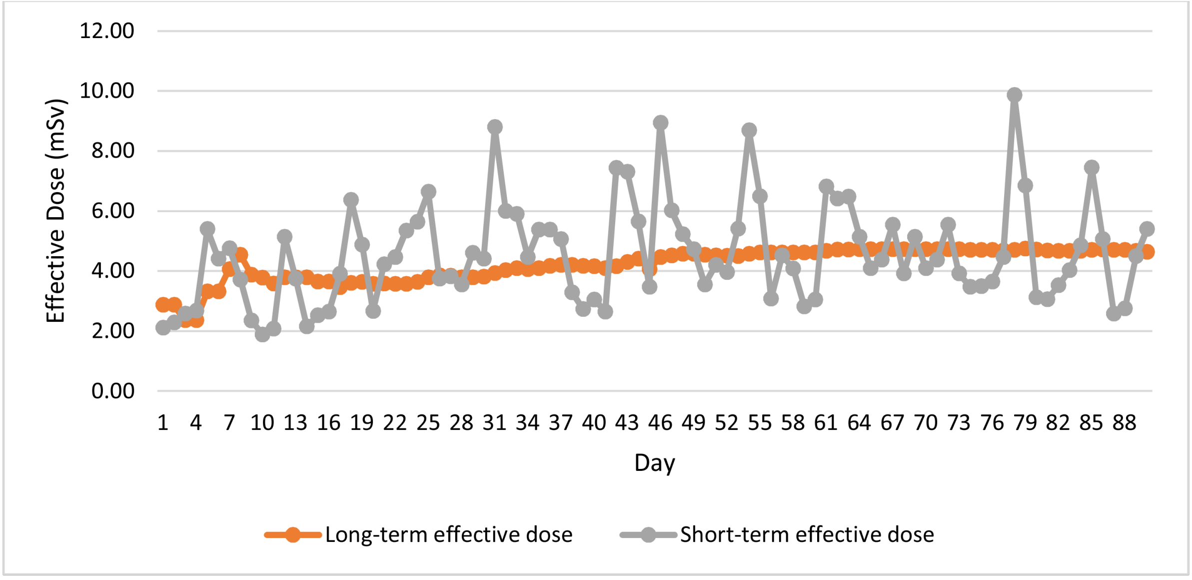

Figure 5. Variation of the daily effective dose of radon in office 6 during three months of measurements.

Table 5. Comparison of concentrations with other studies.

Country	Study Site	Concentration Range	Average Concentration (Bq/m^3)	Source
Burkina Faso	Institute of Science and Technology	6.143 Bq/m^3 to 172.571 Bq/m^3	52.46	This Study
Nigeria	Campus de Enugu, University of Nigeria	2.5 Bq/m^3 to 21.3 Bq/m^3	11.8	Okeji *et al.*, 2013 [23]
Nigeria	Université de Ibadan	157 Bq/m^3 to 495 Bq/m^3	293.3	Obed *et al.*, 2010 [24]
Nigeria	Université de Obafemi Awolowo	0 Bq/m^3 to 196 Bq/m^3	37	Afolabi *et al.*, 2015 [25]
Türkiye	Adapazarı	45 Bq/m^3 to 173 Bq/m^3	76	Enis Kapdan and Nesrin Altınsoy, 2014 [26]

short-term daily dose varies considerably from day to day. The long-term daily effective dose during the ninety (90) days of measurement in office 6 was between 2.37 mSv and 4.75 mSv with an average of 4.22 mSv. The short-term daily effective dose during the ninety (90) days of measurement in office 6 was between 1.89 mSv and 9.87 mSv with an average of 4.56 mSv. The short-term and long-term average values are above the lower limit of 3 mSv, which shows that the level of radon gas in office 6 may be the cause of the health effects on the occupants. It is necessary to lower the concentration of radon by creating permanent ventilation in the office 6.

3.7. Comparisons of Concentrations with Other Studies Carried out

Table 5 presents the concentration range and the average concentration of this study and those of other similar studies carried out in Nigeria and Türkiye.

The average concentration obtained in this study was 52.46 Bq/m^3. This average value was higher than that obtained in the Enugu campus and at the University of Obafemi Awolowo in Nigeria. But the average of this study was lower than that obtained in the University of Ibadan and that obtained in the city Adapazarı in Türkiye.

4. Conclusion

Radon concentrations were measured in sixteen offices at the Institute of Science and Technology. The results obtained for radon concentrations differed from one office to another. However, the concentrations were above the limit imposed by the WHO in two offices. The short-term and long-term effective lung doses in office 6, and office 13 were above the “normal” background level of 1.1 mSv per year proposed by UNSCEAR-2000. The short-term effective lung dose in office 6 is above the lower limit of 3 mSv per year recommended by ICRP-23. The average number of lung cancer cases per year per million people is 15.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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