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Research Article

Indoor Radon Survey in Some Buildings of Mkwawa University College of Education

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Abstract

Background: Radon is a radioactive gas that is found all over the world and is well-known for its capacity to induce lung cancer. Purpose: This study aimed at the determination of indoor radon and its association with the excess lifetime cancer risk (ELCR) and annual effective dose in Mkwawa University College of Education (MUCE). Methods: The measurements of indoor radon concentrations were carried out using radon eye. Results: It was found that the indoor radon concentrations ranged from 0-55.7±4.0 Bq/m^3 with an arithmetic mean of 12.2±3.5 Bq/m^3 which are all below the limit of 100 Bq/m^3 set by WHO. The annual effective dose was estimated in the range of 0.01-0.69 mSv/y with an average of 0.165±0.075 mSv/y which are below the limit of 1 mSv set by ICRP. The ELCR was estimated to be in the range of 0.035-2.415×10^{-3} with the mean value of 0.588±0.262×10^{-3} which are below 1.45×10^{-3} the value of world average. The lung cancer cases per million people per year (LCC) was estimated in the range values of 0.18-12.42 per million persons with mean value of 3.015±1.355 per million persons. The LCC obtained in this study is below the ICRP recommended limit of 170-230 per million persons. Conclusion: The results of indoor radon concentration obtained in this study are well below the limits set by WHO, EPA and ICRP. Hence, the students and staff at MUCE are all safe as the annual effective dose, ELCR, LCC due to radon exposure are within the allowable limits.

Keywords

Indoor Radon, Lung Cancer, Annual Effective Dose, Radon Eye Detector, Mkwawa University

1. Introduction

One of the main pollutants of indoor air is radon. Radon is an odorless, invisible, colorless and radioactive gas which is found in our natural environment. Radon occurs mainly in three isotopes ^{219}Rn, ^{220}Rn and ^{222}Rn. ^{219}Rn is formed from Actinium (^{235}U) and its half-life is 3.96 seconds. ^{220}Rn is formed from thorium (^{232}Th) and its half-life is 55.6 seconds, ^{222}Rn is formed from uranium (^{238}U) and its half-life is 3.82 days. ^{219}Rn is also known as actinon, ^{220}Rn is called thoron and ^{222}Rn is called radon [1, 2]. Due to the short half-lives of ^{219}Rn and ^{220}Rn they are ignored in this study. Radon comes from the decay of uranium-238, which originates from soil, water, building materials such as sand, rocks and cement, outside air and natural energy used for cooking such as gas and coal. Radon gas can enter buildings through faults and

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cracks in foundations, walls, hollow concrete blocks, pipes, sumps, drains and other openings [3-5]. Inside–buildings, radon gas decays to its short-lived daughters such as Pollium-218, Lead-214, Bismuth-214 and Pollium-214, which are alpha and beta emitters, by attaching to tiny dust particles in the indoor air. There is a chance that lung cancer will develop more frequently when these particles are breathed since portion of them get lodged in the lungs. The risk of lung cancer is attributable to the lung dosage caused by inhaling airborne radon progeny and alpha radiation [6-8]. The concentration level of radon gas can be minimized by highly ventilating the building by means such as opening of windows and using fans. The indoor radon concentration is normally higher at night than during the day. This can be attributed to various factors, including the sealing and poor ventilation of structures, which decreases the amount of outside air entering the house and allow radon to accumulate inside the structure [9-11].

Indoor radon measurements are important because humans spend more time indoors [3-6]. In fact, any radon level may result into effects depending on the time and amount of radon exposure. Previous research suggests that prolonged exposure to radon may increase the likelihood of lung cancer development [7, 8]. Radon is known to be responsible for more than 50% of the effective radiation dosage from natural sources worldwide[9] and is the second most common cause of lung cancer globally, following tobacco cigarette smoking [4, 6, 10-15]. Indoor radon concentrations can be detected as lower as or higher than the permissible limit set by different global organizations such, World Health Organization (WHO), Environmental Protection Agency (EPA) and the International Commission on Radiological Protection (ICRP). These organizations have different recommended radon limits with respect to health implications. WHO suggests that once the level of radon exceeds 100 Bq/m^3 the homeowners should take an action whereas EPA and ICRP suggest 148 Bq/m^3 and 300 Bq/m^3 respectively [12, 16]. The maximum annual radiation dose permitted for the general public is 1 mSv/y [12]. The average value for excess lifetime cancer risk (ELCR) in the world is 1.45×10^{-3} [17-19]. The ICRP recommends a lung cancer case (LCC) limit of 170 to 230 per million people per year [20-23].

In Tanzania, only a limited number of studies have been carried out on indoor radon measurements [16, 24-26]. No study found in literature review was conducted at a university campus in Tanzania. In Iringa, no radon measurements have ever been taken. Information and data on the status of indoor radon concentrations are inadequate in several parts of the world including Mkwawa University College of Education (MUCE). This inadequacy makes it difficult to arrive at global average values of action levels of indoor radon concentration. The purpose of the study was to check whether the students, staff and other workers in the college are exposed to high-radon concentration during their activities in the college. Therefore, the study is needed to obtain indoor radon concentration at MUCE. This study presents a survey on indoor radon measurements and examines their correlation with the annual effective radiation dose, the excess lifetime cancer risk (ELCR) and LCC at Mkwawa University College of Education (MUCE) in Iringa, Tanzania. The indoor radon measurements were carried out using radon eye detector (RD 200). We carried out measurements in student hostels, lecture rooms, staff offices and the college library. The results obtained under this study will help local, national, and international regulatory agencies as well as organizations dedicated to public health make improved decisions in the health sector.

2. Materials and Methods

2.1. Study Area

MUCE is located about 3 km from Iringa municipal centre. Iringa municipal is located at the Southern Highlands of Tanzania in Iringa region about 260 and 500 kilometres from Dodoma and Dar es Salaam, respectively. The college has 6300 students taking different undergraduate and graduate courses.

2.2. Indoor Radon Measurements

A South Korean business called RadonFTLab manufactures the intelligent radon detector known as the Radon Eye Detector (RD200). The business is primarily involved in the creation and marketing of precision equipment, particularly radon sensors and detectors. The RD200 is Twenty times as sensitive as many other radon detectors [27]. The RD200 boasts a highly precise detecting circuit and a dual structured pulsed-ionization chamber design. If you're curious about the variations in radon levels in homes or workplaces, the RD200 is a quicker instrument to use. Both the display and the mobile phone that is linked via Bluetooth may read the radon level. The device records and saves values or information every hour. The user can see how the value has varied during the measurement periods. It displays the data value in either Bq/m^3 or $\rho Ci/l$ for every 10 minutes for at least one hour for reliable data [27]. In this study, an average of one hour was taken as mean in a specific location. Measuring procedures and its connections can be done by placing the Radon eye detector on the table or desk and connecting it to the 12 V adapter of the Radon eye detector and it starts automatically. The measured radon data is displayed on the screen. Indoor radon concentrations in the offices were measured during the daytime only while in the library, computer laboratories, hostels, and learning venues measurements were measured during day and night hours. The Main building materials used in all the hostels and many of the offices and learning venues are burnt clay bricks, cement and wood. Few offices and learning venues were made with block bricks, cement and woods. In the offices and hostels the window were closed as much as possible while in the study rooms the window were not closed due to different factor such as the buildings were being used for lecturing and private studies. The students hostel rooms, learning venues and staff offices were abbreviated as HR, LV and SO, respectively. HR, Hostel Room (study conducted in 40 Hostel Room, HR1-HR40). LV, Leaning Venue (study conducted in 11 Learning Venues, LV1-LV11). SO, Staff Office (study conducted in 16 Staff offices, SO1-SO16). The total measurements sites were 67. The measurements obtained from hostels are all ground floors while in offices and learning venues were mostly from the ground floors with few measurements sites on the second and third floors. No measurements were obtained underground rooms. The measurements obtained from the second and third floors are given with -SF and -TF, respectively. If none of these symbols were used it means the measurement was obtained from the ground floors.

2.3. Determination of the Annual Effective Dose

The annual effective dose (E) in mSv/y was calculated using equation (1) [28, 29].

$$E(mSv/y) = CFTHD \tag{1}$$

Where; C represents the measured concentration of ^{222}Rn (in Bq/m^3), F denotes the equilibrium factor for ^{222}Rn and its decay products (0.4), and T refers to the duration of time spent indoors which is 24 h ×240 = 5760 h/y. Here we assume two semesters per year and during each semester students spent 120 days totaling 240 days and for staff is 5 days per week times 48 weeks which is equivalent to 240 days, we assume 4 weeks for holiday vacation for staff. H is the indoor occupancy factor; we assume that students spend 18 hours in hostel per day which is equivalent to 0.8 and for staff we assume that staff spend 8 hours per day in the office (8 am-4 pm) which is equivalent to 0.3. D represents the dose conversion factor, which is (9.0 x 10^{-6} mSv/h per Bq/m^3).

2.4. Determination of the Excess Lifetime Cancer Risk

The Excess Lifetime Cancer Risk (ELCR) was determined using equation 2 [30, 31].

$$ELCR = E \times DL \times RF \tag{2}$$

Where, DL is the average duration of life expectancy which is estimated to be 70 years, E is annual effective dose, and RF is the fatal cancer risk per Sievert which is 0.05 Sv^{-1} recommended by ICRP.

2.5. Determination of Lung Cancer Cases per Million People per Year

Lung cancer cases per million people per year (LCC) were calculated using equation 3 [8]

$$LCC = E \times 18 \times 10^{-6} \tag{3}$$

Where, E represents the annual effective dose, and the risk factor for inducing lung cancer which is 18×10^{-6}.

2.6. Statistical Analysis

The data were analysed using Origin 2018 and IBM SPSS Statistics 26, which are statistical software programs for the social sciences.

3. Results

This section includes indoor radon measurements, estimates of the annual effective dose, excess lifetime cancer risk (ELCR) and lung cancer cases per million people annually (LCC), Tables 1, 2 and 3 shows the average radon concentration recorded using RD200 for one hour in the students hostel Rooms (HR), Learning Venues (LV) and Staff offices (SO). Tables 1 and 2 show both day and night measurements while Table 3 shows only day measurements. The overall indoor radon concentration for 67 sites ranged from 0-55.7±4.0 Bq/m^3 with an arithmetic mean of 12.2±3.5 Bq/m^3. The average of indoor radon concentrations in student's rooms, learning venues and staff offices are 14.5 ±4.2, 7.2±1.1 and 14.8±12.1 Bq/m^3, respectively. Figure 1 shows the variation of indoor radon concentrations recorded at HR1. From Figure 1, it is clearly seen that radon concentration varies every10 minutes, however the variation is not significant. Figure 2 shows indoor radon concentration for downstairs and upstairs recorded at learning venues and offices. The results shows that the radon concentrations upstairs are higher than downstairs. The means of the various floor types did not differ significantly from one another. Table 4 shows the comparison of the results of indoor radon concentrations at universities and colleges conducted in different countries.

Tables 5 and 6 show the estimation of annual effective dose, ELCR and LCC from the student's hostel rooms and staff offices. The annual effective dose, ELCR and LCC were estimated using equation 1, 2 and 3, respectively. The annual effective was estimated in the range of 0.04-0.69 mSv/y with an average of 0.24±0.14 mSv/y for students. The estimated annual dose received by staff is in the range of 0.01-0.28 with mean of 0.09±0.08 mSv/y. The ELCR for students and staff are 0.14-2.45$\times 10^{-3}$ and 0.035-0.98$\times 10^{-3}$, respectively. The average value of ELCR is 0.85 ±0.491 $\times 10^{-3}$ and 0.326 ±0.266 $\times 10^{-3}$ for students and staff, respectively. The LCC values obtained in this study are in the range of 0.72-12.42$\times 10^{-6}$ and 0.18-5.04$\times 10^{-6}$ for students and staff, respectively. The mean value of LCC is $4.35\pm2.52\times10^{-6}$ and $1.68\pm1.35\times10^{-6}$ for student and staff, respectively.

Table 1. Indoor radon concentration from student's hostel rooms during day and night.

Students hostel rooms (HR)	Indoor radon concentration (Bq/m^3)		Students hostel rooms (HR)	Indoor radon concentration (Bq/m^3)	
	Day	Night		Day	Night
HR1	14.5±3.2	18.0±2.8	HR21	1.6±1.3	5.2±4.5
HR2	13.0±0.0	13.8±1.9	HR22	6.0 ± 0	20.3±2.9
HR3	9.7±5.1	23.5±4.8	HR23	17.8±3.3	30.0±3.2
HR4	6.0±0.0	16.2±2.3	HR24	12.7±7.6	19.3±3.0
HR5	13.5±4.2	14.7±7.2	HR25	15.7±3.5	16.7±7.2
HR6	12.3±4.9	13.2±0.4	HR26	6.0±0	15.0±2.2
HR7	27.8±8.9	55.7±4.0	HR27	2.7±3.5	8.2±2.4
HR8	4.7±5.6	12.3 ±4.3	HR28	9.8±2.3	11.8±3.3
HR9	9.0±2.5	33.7±12.4	HR29	10.0±2.5	17.2±9.5
HR10	13.0±3.7	19.8±3.9	HR30	8.0±2.9	10.8±2.6
HR11	11.2±4.7	12.0±4.3	HR31	2.7±1.8	23.3±4.0
HR12	3.8±2.3	13.5±1.1	HR32	14.5±1.1	22.3±2.1
HR13	6.1±2.0	21.7±9.1	HR33	6.7±1.5	10.0±6.1
HR14	10.7±2.6	35.2±14.6	HR34	1.2±1.9	4.0±1.5
HR15	18.5±5.2	22.6±2.8	HR35	8.7±2.2	12.3±3.7
HR16	0.5±0.8	13.0±1.5	HR36	7.7±2.6	12.0±3.6
HR17	15.2±1.7	23.5±8.7	HR37	7.2±1.1	9.2±2.6
HR18	10.2±4.1	34.3±11.1	HR38	6.2±3.1	8.8±3.1
HR19	26.7±6.6	39.7±15.3	HR39	3.3±1.5	7.3±1.6
HR20	34.0±6.8	41.7±6.9	HR40	4.0±0	6.8±3.4
Average				10.3±7.2	18.7±11.0

HR, Hostel Room (study conducted in 40 rooms, HR1-HR40)

Table 2. Indoor radon concentration from learning venues during day and night.

Learning Venues (LV)	Indoor radon concentration (Bq/m^3)	
	Day	Night
LV1	6.5±5.1	6.7±5.1
LV2-SF	2.0±0	3.7±2.0
LV3	14.2±2.5	15.8±4.2
LV4-SF	10.2±1.2	14.2±2.6

Learning Venues (LV)	Indoor radon concentration (Bq/m^3)	
	Day	Night
LV5	9.0±2.9	10.2±7.2
LV6-SF	3.5±3.8	3.7±4.6
LV7-TF	4.5±2.8	8.5±3.6
LV8	10.2±4.7	13.7±3.9
LV9	5.5±1.1	7.8±1.5
LV10-SF	1.8±2.0	5.5±2.4
LV11	0±0	1.7±0.5
Average	6.1±4.2	8.3±4.5

Study conducted in 11 Learning Venues, LV1-LV11

Table 3. Indoor radon concentration from staff offices during day time.

Staff offices (SO)	Indoor radon concentration (Bq/m^3)
SO1	18.7±1.4
SO2-SF	2.3±2.4
SO3	10.7±5.7
SO4-SF	4.2±4.4
SO5	44.7±12.0
SO6	28.3±4.0
SO7	12.5±3.5
SO8	18.3±4.7
SO9	32.3±15.3
SO10	6.3±2.4
SO11	28.5±12.9
SO12	6.3±2.4
SO13	4.3±2.4
SO14-SF	6.5±1.1
SO15-SF	5.0±2.2
SO16-SF	7.8±3.0
Average	14.8±12.1

Study conducted in 16 Staff offices, SO1-SO16

Table 4. Comparison of the indoor radon concentrations at universities and colleges conducted in different countries.

Country	Range Mean Indoor Radon concentrations (Bq/m^3)	Mean Indoor Radon concentrations (Bq/m^3)	Reference

Country	Range Mean Indoor Radon concentrations (Bq/m^3)	Mean Indoor Radon concentrations (Bq/m^3)	Reference
Iran	BDL-322	35.66	[32]
Nigeria	157-495	293.3	[33]
Turkey	5.2-32.5	12.95	[34]
China	1.3-65	14.68	[35]
Kenya	30-315	188	[36]
Saudi Arabia	4-32	15	[37]
Turkey	6-60	21.96	[38]
Ethiopia	171.31-394.05	273.79	[39]
Tanzania	0-55.7	12.2	Present Study

BDL, Below detection limit

Table 5. *Average indoor radon concentrations, annual effective dose, excess lifetime cancer risk and lung cancer cases per million people per year from students hostel rooms.*

Hostel Rooms (HR)	Average Indoor radon concentration ± SD (Bq/m^3)	Annual Effective Dose (mSv/y)	Excess Lifetime Cancer Risk ($\times 10^{-3}$)	Lung Cancer Cases per Million People per Year $\times 10^{-6}$
HR1	16.3±1.8	0.27	0.945	4.50
HR2	13.4±0.4	0.22	0.770	3.96
HR3	16.6±6.9	0.28	0.980	5.04
HR4	11.1±5.1	0.18	0.630	3.24
HR5	14.1±0.6	0.23	0.805	4.14
HR6	12.8±0.5	0.21	0.735	3.78
HR7	41.8±14.0	0.69	2.415	12.42
HR8	8.5±3.8	0.14	0.490	2.52
HR9	21.4±12.4	0.36	1.260	6.48
HR10	16.4±3.4	0.27	0.945	4.86
HR11	11.6±0.4	0.19	0.665	3.42
HR12	8.7±4.9	0.14	0.490	2.52
HR13	13.9±7.8	0.23	0.805	4.14
HR14	23.0±12.3	0.38	1.380	6.84
HR15	20.6±2.1	0.34	1.190	6.12
HR16	6.8±6.3	0.11	0.385	1.98
HR17	19.4±4.2	0.32	1.120	5.76
HR18	22.3±12.1	0.37	1.295	6.66
HR19	33.2±6.5	0.55	1.925	9.90
HR20	37.8±3.9	0.63	2.205	11.34
HR21	3.4±1.8	0.06	0.210	1.08

Hostel Rooms (HR)	Average Indoor radon concentration ± SD (Bq/m^3)	Annual Effective Dose (mSv/y)	Excess Lifetime Cancer Risk (× 10^{-3})	Lung Cancer Cases per Million People per Year × 10^{-6}
HR22	13.2±7.2	0.22	0.770	3.96
HR23	23.9±6.1	0.40	1.400	7.2
HR24	16.0±3.3	0.27	0.945	4.86
HR25	16.2±0.5	0.27	0.945	4.86
HR26	10.5±4.5	0.17	0.595	3.06
HR27	10.9±2.8	0.18	0.63	3.24
HR28	10.8±1.0	0.18	0.63	3.24
HR29	13.8±3.8	0.23	0.805	4.14
HR30	9.4±1.4	0.16	0.560	2.88
HR31	13.0±10.3	0.22	0.770	3.96
HR32	18.4±3.9	0.31	1.085	5.58
HR33	8.4±1.7	0.14	0.490	2.52
HR34	2.6±1.4	0.04	0.140	0.72
HR35	10.5±1.8	0.17	0.595	3.06
HR36	9.9±2.2	0.16	0.560	2.88
HR37	8.2 ±1.0	0.14	0.490	2.52
HR38	7.5±1.3	0.12	0.420	2.16
HR39	5.1±1.8	0.08	0.280	1.44
HR40	5.4±1.4	0.09	0.315	1.62
Mean ±SD	14.5±4.2	0.24 ± 0.14	0.850 ± 0.491	4.37 ± 2.52

HR, Hostel Room (study conducted in 40 rooms, HR1-HR40), SD, Standard Deviation

Table 6. *Average indoor radon concentrations, annual effective dose, excess lifetime cancer risk and lung cancer cases per million people per year from Staff offices.*

Staff offices (SO)	Average Indoor radon concentration ± SD (Bq/m^3)	Annual Effective Dose (mSv/y)	Excess Lifetime Cancer Risk (× 10^{-3})	Lung Cancer Cases per Million People per Year × 10^{-6}
S01	18.7±1.4	0.12	0.42	2.16
SO2	2.3±2.4	0.01	0.035	0.18
SO3	10.7±5.7	0.07	0.245	1.26
SO4	4.2±4.4	0.03	0.105	0.54
SO5	44.7±12.0	0.28	0.980	5.04
SO6	28.3±4.0	0.18	0.630	3.24
SO7	12.5±3.5	0.08	0.280	1.44
SO8	18.3±4.7	0.11	0.385	1.98
SO9	32.3±15.3	0.20	0.700	3.60
SO10	6.3±2.4	0.04	0.140	0.72

Staff offices (SO)	Average Indoor radon concentration ± SD (Bq/m^3)	Annual Effective Dose (mSv/y)	Excess Lifetime Cancer Risk (× 10^{-3})	Lung Cancer Cases per Million People per Year × 10^{-6}
SO11	28.5±12.9	0.18	0.630	3.24
SO12	6.3±2.4	0.04	0.140	0.72
SO13	4.3±2.4	0.03	0.105	0.54
SO14	6.5±1.1	0.04	0.140	0.72
SO15	5.0±2.2	0.03	0.105	0.54
SO16	7.8±3.0	0.05	0.175	0.90
Mean±SD	14.8±12.1	0.09±0.08	0.326±0.266	1.68±1.37
Average	10.3±7.2		18.7±11.0	

HR, Hostel Room (study conducted in 40 rooms, HR1-HR40), SD, Standard Deviation

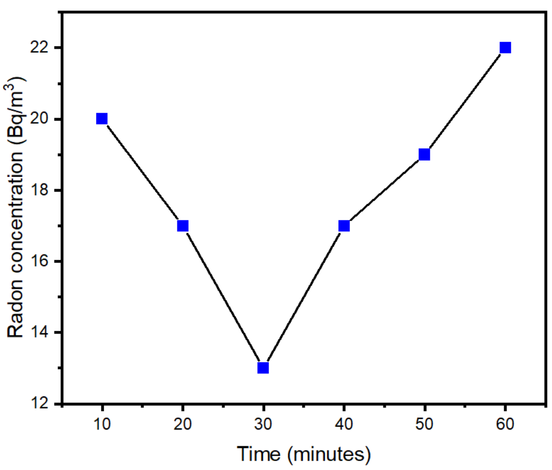

Figure 1. *Variation of indoor radon concentrations recorded at HR1.*

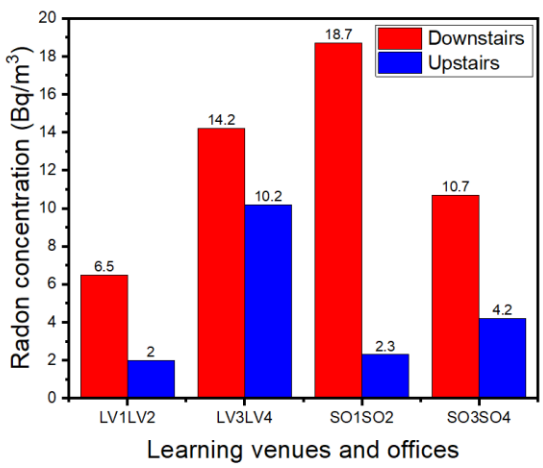

Figure 2. *The indoor radon concentration for downstairs and upstairs recorded at learning venues and offices.*

4. Discussion

The mean indoor radon concentrations during day and night are 10.4±3.6 and 13.5±5.2 Bq/m^3, respectively. These values are well below the limit of 100 Bq/m^3set by WHO. The results of radon concentrations for variation of time, upstairs versus downstairs and day versus night are all consistent with literature. From the radon results obtained, students and staff at MUCE are safe from radon exposure. The mean indoor radon obtained in this study is lower in comparison with other similar studies reported in the literature [32-39]. However, the mean indoor radon level of this study is not difference significant compared to that obtained from Turkey, China and Saudi Arabia (Table 4). Table 4 shows that three studies conducted from Nigeria, Kenya and Ethiopia exceed the limit of 100 and 148 set by WHO and EPA, respectively. The annual dose received by staff is lower than that of students because is assumed staff to spend only 8 hours on working days while students are assumed to spend 18 hours in hostel. The value of annual effective dose received by both staff and students are all below the limit of 1 mSv. The mean ELCR in this study is below 1.45× 10^{-3} which is the world average value. All the LCC values found in this investigation fall below the specified limit range of 170 to 230 per million individuals. Hence, the students and staff at MUCE are all safe as the annual effective dose, ELCR, LCC due to radon exposure are within the allowable limits.

5. Conclusion

The results shows that the indoor radon concentration is ranged from 0-55.7±4.0 Bq/m^3 with arithmetic mean of 12.2±3.5 Bq/m^3. The average of indoor radon concentrations in student's rooms, learning venues and staff offices are 14.5 ±4.2, 7.2±1.1 and 14.8±12.1 Bq/m^3, respectively. The mean indoor radon concentrations during day and night are 10.4±3.6 and 13.5±5.2 Bq/m^3, respectively. The value of annual effective dose received by both staff and students are all below the limit of 1 mSv. The ELCR and LCC values from this study are within the acceptable range. Hence, the students and staff at MUCE are all safe as the annual effective dose, ELCR, LCC due to radon exposure are within the allowable limits. Future research could focus on investigating radon concentration levels across different seasons to assess any significant fluctuations caused by variations in temperature, ventilation habits, or rainfall, as well as implementing long-term monitoring in the same rooms to evaluate temporal trends and ensure the consistency of safety levels over time.

Abbreviations

ELCR	Excess Lifetime Cancer risk
EPA	US Environmental Protection Agency
ICRP	International Commission on Radiological Protection
LCC	Lung Cancer Cases per Million People per Year
MUCE	Mkwawa University College of Education
WHO	World Health Organization

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Author Contributions

All authors were involved in all parts of research and preparation of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest.

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