Improvement on indoor radon accumulation rate in CST Laboratories at Covenant University, Ota, Nigeria

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IMPROVEMENT ON INDOOR RADON ACCUMULATION RATE IN CST LABORATORIES AT COVENANT UNIVERSITY, OTA, NIGERIA

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ABSTRACT

Radon is becoming one of the most extensively investigated human carcinogens. Radon and its progeny in the air contribute to human exposure from natural radiation sources. The present study analyzed the indoor radon concentration in air at several laboratory spaces of CST building using RAD7 electronic radon detector. The measured radon concentration ranged from 0 to 57.3 Bqm^{-3} for all study locations. The obtained radon concentration results is well below the world set limit of 40 Bqm^{-3} as recommended by International Commission on Radiological Protection. The annual effective dose and annual effective dose expressed in terms of work level month (WLM) ranged from 0.079 - 0.655 mSvy^{-1} and 0.0139 to 0.116 mSvy^{-1} respectively, which are below the world limit of 1.15 mSvy^{-1} as recommended by United Nations Scientific Committee on the Effects of Atomic Radiation. The correlation was obtained for the mean indoor radon concentrations and mean indoor air relative humidity for each study location with value range from 0.014 to 0.838. This reveals that there is a relevant correlation and indoor relative humidity has high influence on indoor radon concentration in most of the locations.

Keywords: Radiation, radon concentration, carcinogens, annual effective dose
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1. INTRODUCTION

Radon is the last on the list of inert gas family. It is soluble and gotten from the decay series of Ra-226. Radium 226 is one of the decay products of uranium - 238 decay series [1- 3]. Radon further decays to Po-218 (Polonium) with the emission of alpha particle radiation of energy 5.5 MeV and has half life of 3.8 days. This inert gas is present everywhere; in air, on material surfaces, in water and in soil. Radon accumulates more in closed spaces than in open air. According to [4], radon gas makes up about 55% of human total internal radiation exposure especially from indoor confinements. Outdoor radon dilutes quickly into the air but accumulates when indoors in, confined spaces like our houses, at work places, in the school laboratories and store houses. Inhalation of accumulated radon gas in confined spaces can result in adverse health effect on exposed persons [5]. Radon is believed to be the second largest cause of lung cancer, after smoking, according to [6].

The major source of radon accumulation in the indoor air is from the uranium that is present in the soil, concretes and rocks beneath the house as well as the building material, drinking water, and the cooking gas of common use [7]. This is why radon is now one of the most extensively investigated human carcinogens. Since radon and its progeny in the air contribute to human exposure from natural radiation sources [8] and people tend to spend so much of time indoors, than outdoors, which make them to be more exposed to indoor accumulated radon. Long-term exposure to elevated indoor radon concentrations has been linked to increased lung cancer risk [9].

[10] reported the adverse health implications of radon gas in his study and recorded mean concentration of 410.00 Bqm^{-3} in the indoor air of many residential houses. Furthermore, it was reported that radon causes over 21,800 lung cancer deaths in addition to the total death count in the United States of America [11]. Many scientists have studies the impacts of important factors that could influence the accumulation of radon gas indoor and possible hazards that elevated radon concentration can pose. [12] revealed in-depth the relationship between indoor radon accumulation level and environmental parameters. The studies conducted by [13, 14, 15] clearly showed how indoor and outdoor temperature difference can influence indoor radon accumulation levels. [14] added that, temperature variation has little correlation with wind speed and barometric pressure. [16 – 24] all show that building materials, metrological parameters, geology, the degree of confined space ventilation and building construction types are all included in the list of factors influencing radon accumulation level in closed environment (indoors). Since there are various types of building, construction styles and varying ventilation openings, diverse weather conditions at different locations and regions, so also will indoor radon accumulation differ. Therefore, indoor radon level tends to show seasonal, monthly and daily variations in line with the conditions of the influencing factors. [9] reported that building characteristics has less influence on indoor radon accumulation than meteorological parameters. The study of [25] revealed that indoor radon accumulation depends primarily on three atmospheric parameters; such as: vapor pressure, barometric pressure and wind variation. [26] followed a new trend of discovery; the study reported that increased ventilation led to reduction of indoor radon accumulation despite the increase in outdoor and indoor temperature difference. As a result of that, low indoor radon concentration was recorded at high outdoor temperature. [27] research results showed that over-pressure generated from wind speed can have positive effect on how radon enters confined spaces from the soil. [28] had contrasting thought in their study they reported that barometric pressure and rainfall had little influence on radon concentration. It reported by [29] that increased snowfall and seasonal rainfall could cause high unexpected indoor radon accumulations. From the reviews of all the above studies, it can be said that indoor radon accumulation pattern and influencing factors are complex and numerous, but above all, knowing the concentration level in any confined space will be of human health benefit. Since some influencing parameters has cross correlations with one another; such as building ventilation, weather parameters, geographical region and different building and structure types, there can be millions of angle to harness indoor radon study from, to better the safety of human in the environment. In Nigeria, only a few studies have been done on radon measurement and accumulation evaluation. Few of such studies are the work of [30, 24]. The

studies reported radon measurements by nuclear track detectors in secondary schools in Oke-Ogun and the later used RAD7 to assess radon concentration in selected locations in Ibadan. In the current study, an estimation of indoor radon concentration level is investigated, in order to know and analyze the health implication of radon accumulation in the study areas and also to assess the safety of staff that spend about 9 working hours or more in the laboratories. The major goal of this present paper is to analyze indoor radon variations and to find the possible relationships between the indoor radon concentrations and main environmental variables, such as temperature and relative humidity. In the end, the result of this present study would provide useful information on the variation pattern of indoor radon accumulation in study areas, as well as providing the relationship between radon accumulation and the selected metrological parameters.

2. DESCRIPTION OF STUDY LOCATION AND BUILDING

The study areas are located at the College of Science and Technology (CST) building, Covenant University campus, at varying heights from the ground floor upward to the 3rd floor, in Ota town, Ogun State, Nigeria [31]. Ota town is located at north latitude 6.6734061 and east longitude 3.159195. Its climate is sunny in March- April and this is typical of tropical climate geographical regions. In Nigeria generally, the rainy season in the northern part of Nigeria last for only three to four months (June–September). The rest of the year is hot and dry with temperatures climbing as high as 40°C (104.0 °F) (typically sunny). Alpine climate or highland climate or mountain climate are found on highlands regions in Nigeria. Figure 1a shows the typical image of the study site.

Figure 1 a Satellite image of CST

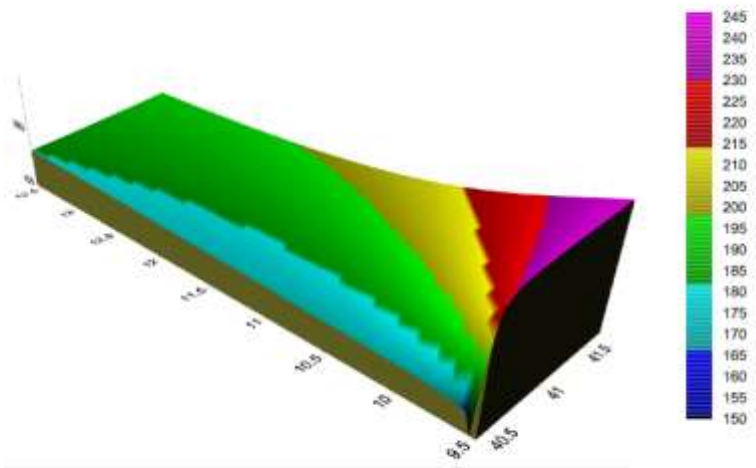


Figure 1 b 3D surface map of coordinates in CST

Figure 1b shows the spatial maps of the coordinates where the measurements were taken in CST using Surfer 13 software. The purple colour is the topmost floor where STF37 is located while the blue region is the ground floor where PhyGF1 and MBF12 are located. This particular CST building where the study site is situated which has three stories, and it is constructed from sand/cement blocks, concrete pillars and decking with aluminum roofing and block interior walls. Sandy soil and tarred car parks surrounds the ground structures. Parts of the building's occupied portions are served with several laboratories and offices, each furnished with A/C systems to regulate the air by its cooling effect. The primary spaces studied in the CST building are the laboratories. The lab spaces have designated areas for staff, to serve as office space. The RAD7 radon detector machine was placed in the room, situated directly on top of the office table at a designed corner for staff in the laboratory. The instrument for radon accumulation level detector was set to read for few days. There are some laboratories with closed windows that are not usually opened, thus, the lab space is always confined with no ventilation but with operational A/C system.

3. METHODS AND MATERIALS

3.1. Experimental Details

Indoor radon accumulation levels were measured continuously on hourly basis at the different sampling locations (laboratories) in the College of Science and Technology (CST) building at Covenant University Ota, Ogun State Nigeria between March and April 2018 through to May and June 2018, second quarter of the year and early wet season-rainy season, using RAD7 electronic radon detector. Each sampling laboratory was situated at different heights, starting from ground to third floor at height 0.50 to 10.6 meters. The DURRIDGE RAD7 device is designed for alpha particle detection only, thus its focus is on alpha radiation in the environment. The detection system is of solid state detector design with silicon as the semiconductor material due to its rugged nature. Alpha radiation is usually converted directly into electrical signal for easy readout. RAD7 device electronically determines characteristics energy of the incoming alpha radiation by alpha spectrometry techniques during sniffing (sampling or grabbing of radon concentration in the air). All sampling procedures were done by setting RAD7 radon detector on sniff mode to allow for primary focus on only polonium-218 decays, ignoring polonium-214 decays the residue of previous sniffs. Figure 2 shows a schematics diagram of the sniffing procedures. During RAD7 sniffing process, it takes 45 seconds for air sample to pass through the small drying tube and flow into the measurement chamber for radon concentration readout. Air flows into the measurement chamber through an inlet opening with fine filter system that helps to exclude the progeny and allows free inflow of the needed sample (especially polonium isotopes). In the measurement chamber, only radon gas is measured and recorded, while alpha emitting progeny of polonium isotopes are internally detected and ignored in the radon concentration report of sniffing rounds. RAD7 detector response span goes from virtually instantaneous to 15 minutes to account for possible increase and decrease radon concentration in a place over a short time. Polonium-216 has half life of 150 milliseconds; this is within the instantaneous response capability of RAD7 detector also. Radon daughter influence and fluctuation in background environmental factors are filtered away in the RAD7 operation module to avoid unwanted interference.

3.2. Dose Estimation

The annual effective dose (H) to staff and students using these laboratories was calculated using equation 1.

$$H(mSvy^{-1}) = CR_n \times F \times T \times DCF \tag{1}$$

H is the annual effective dose, CR_n is the measured mean radon concentration, F is the equilibrium factor for radon and its progeny, T is the indoor occupancy factor and DCF is dose concentration factor for radon and its progeny [32]. The recommended worldwide average for annual effective dose is 1.15 $mSvy^{-1}$ [32].

The potential alpha-energy exposure reaching us from radioactive decay chain of radon-progeny is often expressed in working level months (WLM). The effective dose calculation in terms of working level month (E_{WLM}) was obtained using equation 2.

$$E_{WLM} = \sum \frac{(CR_n \times F \times T)_m}{629000} \tag{2}$$

E_{WLM} is the effective dose in terms of annual WLM, $(CR_n \text{ x } F \text{ x } T)_m$ is the proportional WLM per month (m ranges from 1…..12 months). One WL is defined as a concentration of the potential alpha-energy of 1.3 x 10^5 MeV m^{-3}, this corresponds to a potential concentration of the radon progeny in equilibrium (F = 1) with 3700 Bqm^{-3} and considering an occupational exposure of 170 h per month [4]. ICRP-65 report recommended the use of an epidemiological estimation for dose conversion factor (DCF) to be equal to 5.06 mSv per WLM for workers and 3.88 mSv per WLM for the public [33].

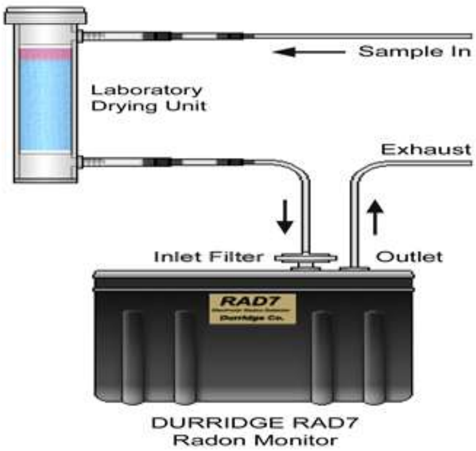


Figure 2 Schematic diagram of RAD7 sniffing configuration for radon concentration measurement

4. RESULT AND DISCUSSION

The data acquired and reported variables of interest are the indoor temperature, Relative humidity RH, radon concentration, and measurement time. Three commercially available softwares are used for this study. Surfer 13, which was use to get the 3D surface map of the location, SPSS was used for statistical analysis and RAD7 Capture tool was employed too for data analysis. Figures 3a-3g show the laboratories radon concentration result in (Bqm^{-3}) with their respective time. A comparison of the average radon concentration of the present study with studies in schools at different countries was done and presented in Table 1. Figures 3a to 3c, shows the obtained data for mean radon concentration, annual effective dose (H) and annual effective dose expressed in terms of work level month (WLM)

The variation in the compared results shown in Table 1 could be due to different factors determinants of indoor radon concentrations and one important factor is the geology of a place. In the present study, evaluation of the risk related to radon concentration in laboratories located at the College of Science and Technology building of Covenant University, Ota Nigeria was reported. The mean radon concentration ranged from 3.14 Bqm^{-3} to 26 Bqm^{-3}, the maximum mean value was recorded at sample location PhyGF1 which was found to be 26.00 Bqm^{-3}, while the minimum recorded radon concentration mean value was recorded at STF37 (3.14 Bqm^{-3}). The obtained result compared well with existing data of radon in schools and also well below the world recommended limit of 40 Bqm^{-3} [32].

The eight sampling locations are all in the 3 story building, of the College of Science and Technology. Two laboratories were selected on each floor. The floor codes started from 1 to 4, beginning from the Ground floor with code 1. The sampling locations PhyGF1 and MLGF2 are on floor 1, PhyF13 and MBF14 are on floor 2, DRF25 and BCHF26 are on floor 3, while STF37 and MOF38 are on the 4th and last floor. It is a known fact that the ground floor due to crack and radon emanating from the ground the radon level is usually high also the ground floor of story building is not as aerated as the top floors, thus the higher you go from the ground floor upward, the more ventilated the comparable designated spaces becomes [30, 24]. PhyGF1, MLGF2, PhyF13, MBF14, BCHF26, and STF37 are comparable laboratory spaces, while DRF25 and MOF38 are comparable designated laboratory confines for unique research. For the first set of comparable laboratory group, the observed radon concentration trend goes from highest value at the floor 1 (ground floor), then decreases upwards, the 4th which is the last floor recorded the least radon concentration value. PhyGF1 has the highest percentage contribution of 28% to radon concentration at floor 1 to the total distribution chart as shown in Figure 4b. MLGF2 contributed 17%, both PhyGF1 and MLGF2 combined to give the total of 44% distribution for floor 1, as shown in Figure 4a. PhyF13, MBF14, BCHF26, and STF37, recorded, 9%, 6%, 8% and 3% concentration respectively. Figure 5 shows the second group of comparable designated space, DRF25 on floor 2 recorded 17%, while MOF38 on floor 3 recorded 11%. PhyF13 and MBF14 add up to give the 16% radon distribution for floor 2. DRF25 and BCHF26 add up to give 26% for floor 3, with high percentage coming from DRF25 this may be due to its designated confined nature. DRF25 is the Physics Department DARK experimental laboratory room, with the door and windows always shut, no AC and there are black curtains blinds on the windows for experimental reasons, hence there is little ventilation in DRF25 study location and this influenced the radon accumulation level. STF37 and MOF38 add up to give 14% of total radon distribution by floor levels.

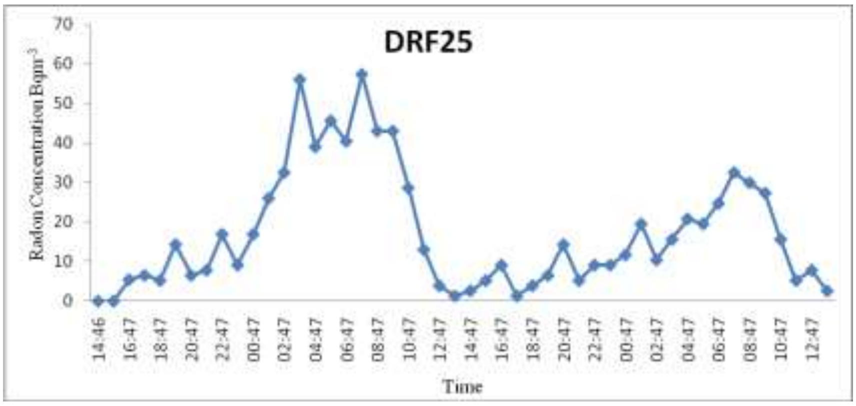


Figure 3 a

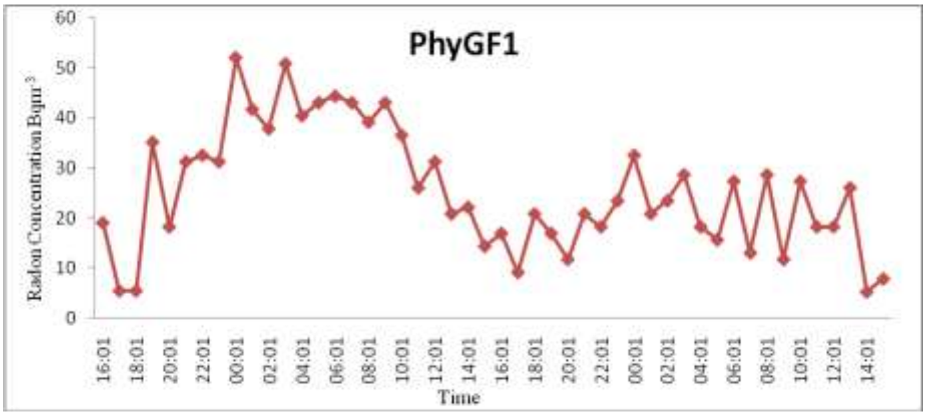


Figure 3 b

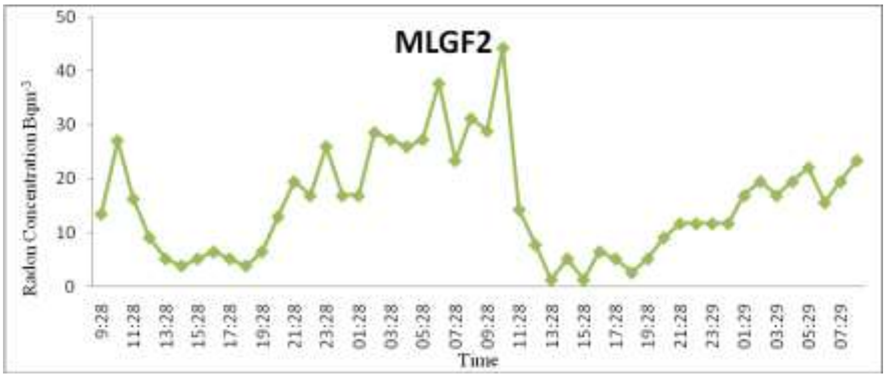
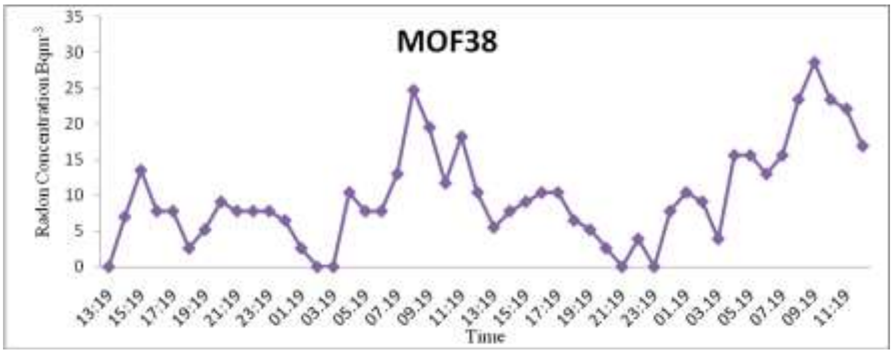


Figure 3 c



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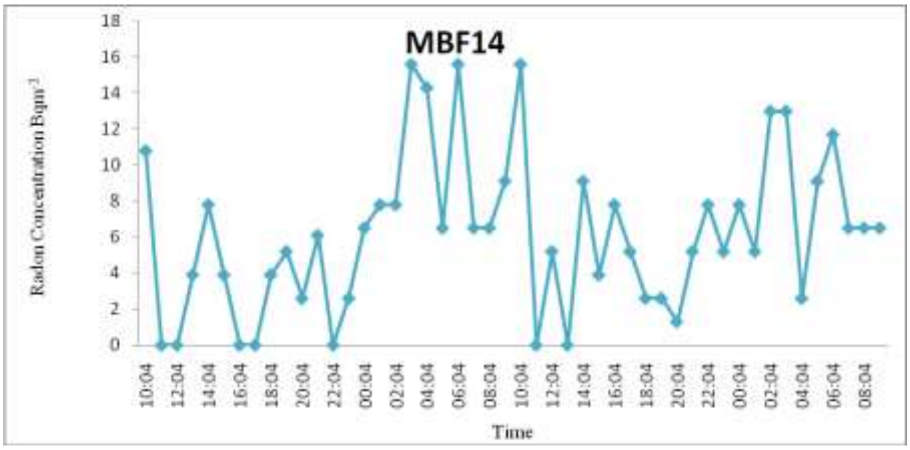

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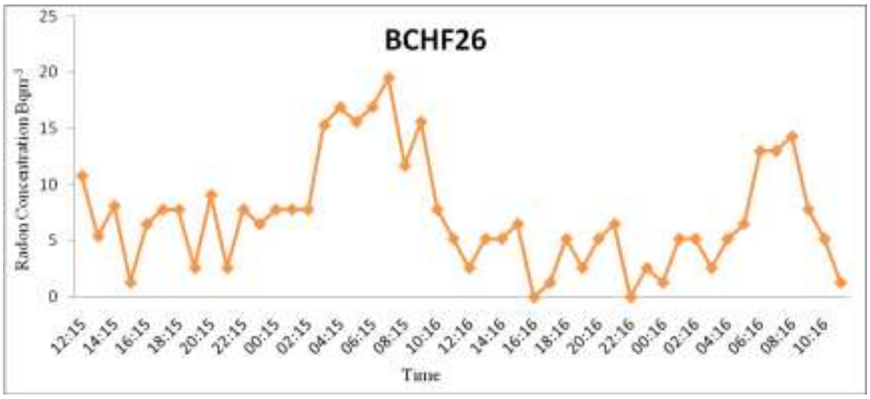

Figure 3 f

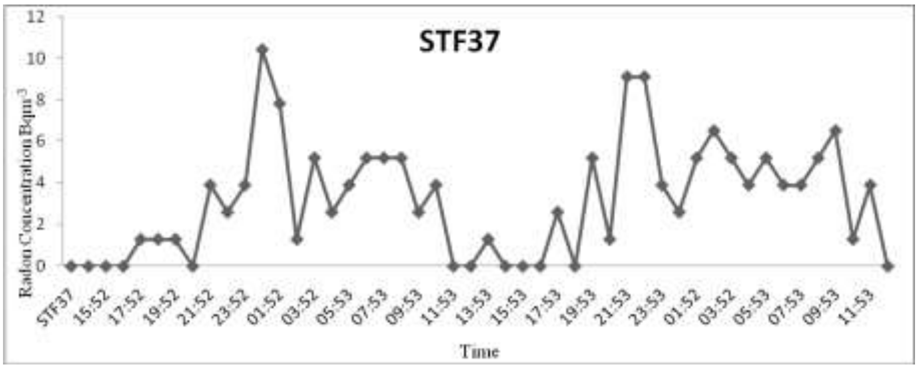

Figure 3 g

Figure 3 a- g spectrum of radon concentration in all the locations

Table 1 Comparison of the average radon concentration of the present study with studies in schools

Country (region)	Reference	Radon Concentration (Bqm-3)
Croatia (Osijek)	[34]	93
Jordan (Amman)	[35]	76.8
Serbia	[36]	28.8±4.3
Japan	[37]	28±25
Kuwait (Kuwait city)	[38]	17
Spain (Tenerife Island)	[39]	130±100
Pakistan (Punjab)	[19]	52 ± 9

Nigeria (Ibadan)	[24]	15.10 ± 3.1
Nigeria (CU-Ota)	Present Study	12.114
UNSCEAR, 2000	[32]	40

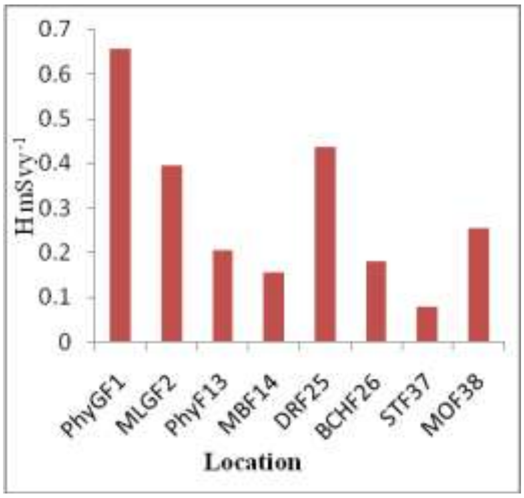

Figure 4 a

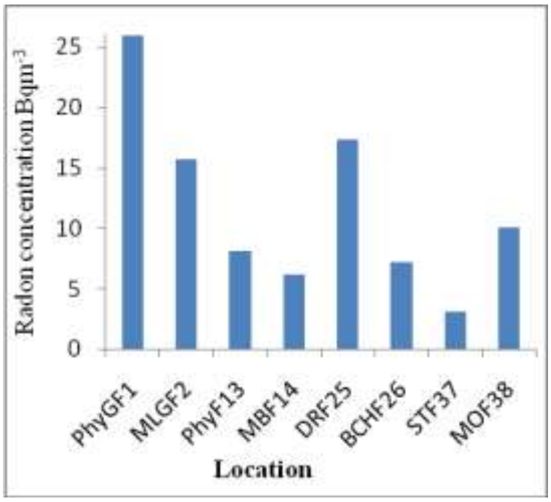

Figure 4 b

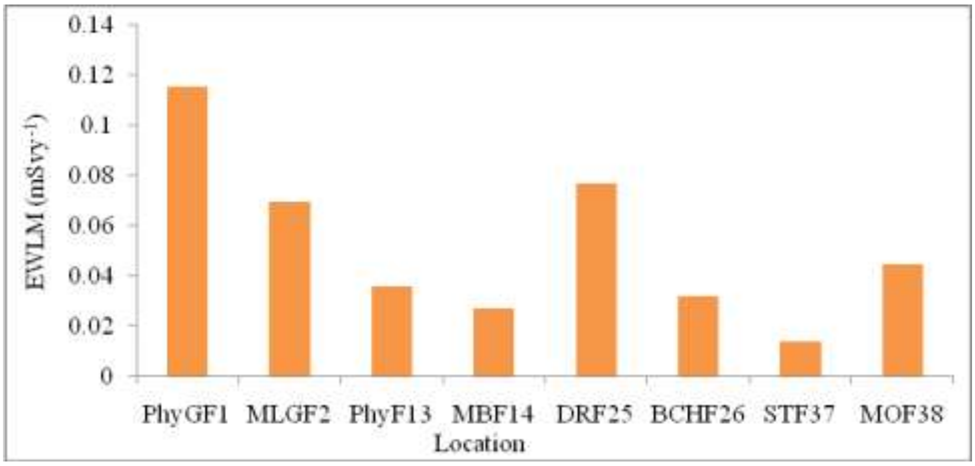

Figure 4 c

Figure 4 Mean radon concentration, annual effective dose (H) and annual effective dose expressed in terms of work level month.

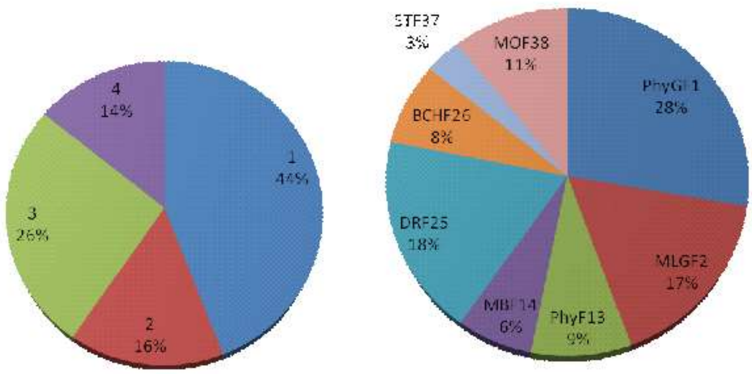

Figure 5 Distribution chart evaluation of radon concentration (a) by building floor (b) by comparable labs

4.1. Meteorological Influence on Indoor Radon Accumulation

The present study considered air temperature and relative humidity (RH) as the meteorological parameter that can influence the rate of indoor radon accumulation. Mean meteorological parameters and radon concentration presented as a function of data reading time is shown in Figures 6 to 8**.** Radon concentration is seen to have conventional relationship pattern with meteorological parameters as a function of time. These were done with the aid of data analysis embedded in RAD7.The correlation between the meteorological parameters and indoor radon accumulation levels was done using SPSS and was found to be in consonance with results gotten from data analysis of RAD7. This demonstrates that relative humidity has strong influence on indoor radon accumulation levels. The SPSS correlation value ranged from 0.014 to 0.838 as seen in Table 2. The correlations of mean relative humidity were done in relation to the mean indoor radon concentrations. The correlation results show that increase in indoor relative humidity resulted in decrease of indoor radon concentration in most of the study locations while steady indoor relative humidity level had no effect on the indoor radon concentration values. According to the study of Müllerova and Holý (2010) the outdoor and indoor air temperature difference affects the pressure difference of the building walls and this influences rate of radon accumulation. Figures 6-8 show the graphical representation of the influence of indoor relative humidity and air temperature on radon concentration level of the current study in labs. It was observed that at mean temperature of 32 ^{o}C and relative humidity (RH) below 10%, high radon concentration was recorded. When air temperature reduced to 30^{o}C, at the same RH percentage, indoor radon concentration went even higher, while drops in radon concentration level were observed at increased indoor relative humidity. This reveals that indoor relative humidity has higher influence on indoor radon concentration than air temperature difference, because radon is soluble at higher rate in humid air. Figure 6a and 6b clearly shows the expanded increase in relative humidity trend and its reduction influence on indoor radon levels

Table 2 Correlation between Radon Values in PhyGF1 and its Humidity

		PhyGF1	**PhyGF1 Humidity**
PhyGF1	Pearson Correlation	1	-0.352*
	Sig. (2-tailed)		0.014
	N	48	48
PhyGF1 Humidity	Pearson Correlation	-0.352*	1
	Sig. (2-tailed)	0.014	
	N	48	48
Correlation is significant at the 0.05 level (2-tailed).			

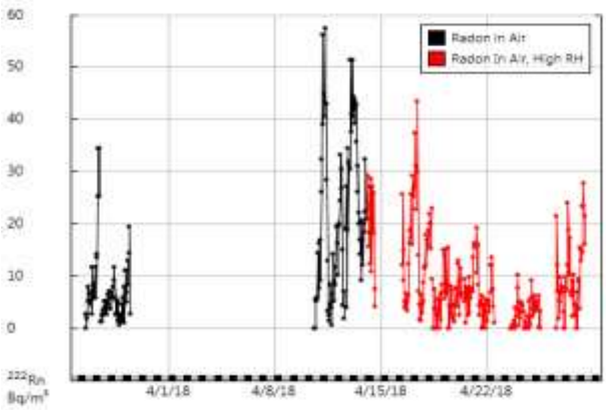

Figure 6 Indoor radon concentration in air

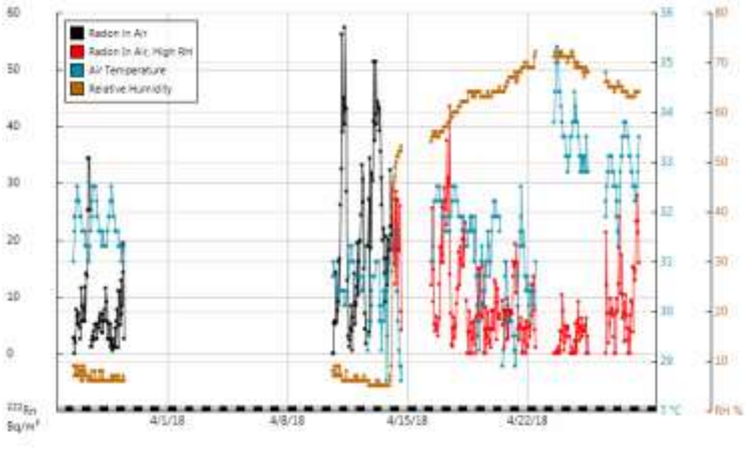

Figure 7 Representation of relative humidity (RH) and air temperature (T) as meteorological influence on indoor radon levels

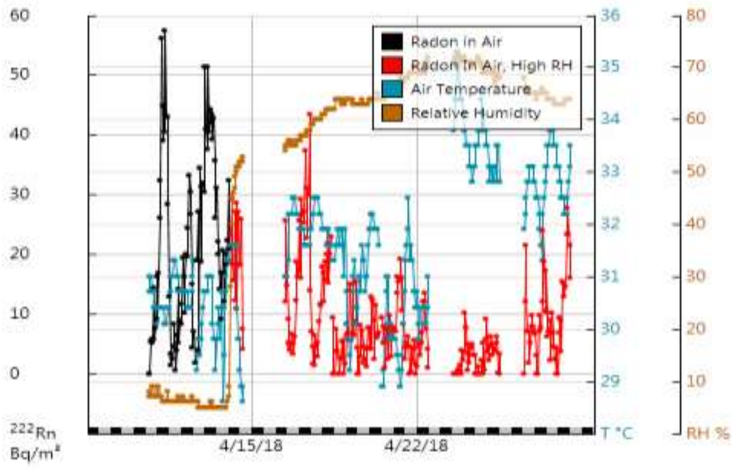

Figure 8 a Expanded graphical trend of RH and T influence on indoor radon level

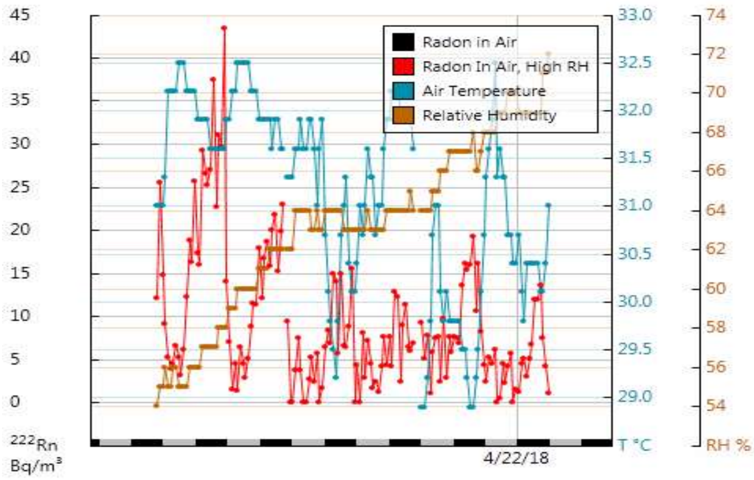

Figure 8 b Expanded graphical trend of RH and T influence on indoor radon level

5. CONCLUSION

The current study reports the indoor radon concentration level and accumulation rate in CST laboratories at Covenant University, Ota, Nigeria. Radon concentration was measured on hourly basis and was assessed based on two selected meteorological parameters, following to the RAD7 measurement protocols. Measurement was done all through the 2nd quarter, marking early rainy season of the year 2018. The indoor radon level obtained varied from 0 to 57.3 Bqm^{-3} in all the study locations. From the results obtained Lab PhyGF1 at the ground floor recorded the highest radon concentration. The variation in indoor radon concentration levels reflects the impact of ventilation in each laboratory. The indoor radon level has negative correlation with the selected influencing meteorological parameters. The annual effective dose (H) and annual effective dose expressed in terms of work level month (WLM) ranged from 0.079 - 0.655 mSvy^{-1} and 0.0139 to 0.116 mSvy^{-1}in terms of WLM respectively, which are below the world limit of 1.15 mSvy^{-1} . The obtained indoor radon level is below the recommended limit of 40 Bqm^{-3}. Short term indoor radon accumulation measurement and its correlation to meteorological parameters can be extrapolated to long term accumulation trend in diverse seasons of the year, but certainty is also required. Hence, future research on long time study of indoor radon and meteorological parameter impact in extended locations is recommended.

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