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Evaluation of Radon Gas Concentrations in some Selected Basement Buildings in Port Harcourt, Rivers State

[*1]Gregory O. Avwiri, [2]Emmanuel Esi & [3]Israel Idoko

[1]Department of Physics,
University of Port Harcourt, Choba, Rivers State, Nigeria

[2,3]Department of Science laboratory Technology,
School of Marine Technology, Burutu, Delta State, Nigeria
E-mail: [1]gregory.avwiri@uniport.edu.ng; [2]esiemmanuel@yahoo.com ; [3] idokoisrael@gmail.com

ABSTRACT
This study evaluates indoor and outdoor radon activity concentrations and its radiological health hazard in basement of five selected buildings in Port Harcourt Metropolis, Rivers State, Nigeria. These measurements were carried out using Corentium digital radon detector and geographical positioning system (GPS-Garmin GPS Map 76S). The mean indoor and outdoor radon activity concentrations obtained results in all the locations ranged from 8.36 Bq/m^3 to 61.35 Bq/m^3 with an average of 35.71 Bq/m^3 and 1.89 Bq/m^3 to 6.36 Bq/m^3 with an average of 3.23 Bq/m^3 respectively. These values are lower than the action level of 100Bq.m^{-3} and 15Bq.m^{-3} stipulated by World Health Organization (WHO). Also, the mean indoor and outdoor calculated equilibrium equivalent concentrations of radon (C_{EEC}), potential alpha energy (PAE), annual human exposure rate or working level month (WLM), annual effective dose (AED) and annual risk of lung cancer (ARLC) were found to be 16.070 Bq/m^3, 4.3434 mWL, 0.13928 WLM/y, 1.2535 mSv/y, 0.6101 and 1.455 Bq/m^3, 0.3934 mWL, 0.0188 WLM/y, 0.1690 mSv/y, 0.0823 respectively. These obtained results shown that the buildings are within safe limits radiologically and there is no danger of radon exposure in the respective basements.
Keywords: Dose, Inhalation, Cancer, Building, Radon, Concentrations, Detector.

1.0 INTRODUCTION

Radon (^{222}Rn) is a naturally occurring radioactive gas. It is a chemically inert, odourless and colourless gas that is produced during the natural decay series chains of radioactive elements such as uranium, thorium and radium (Amin et al., (2015); El-Gamal and Hosny (2008); Fovt et al., (1999)). Radon gas is common in many soils and rocks, though its concentration can vary widely due its geological locations. Because radon is a gas, it can leave the soil or rock where it formed and enter the surrounding air. It is a major indoor and outdoor contribution of ionizing radiation exposure in buildings. This gas contaminates indoor and outdoor air which is emitted from soil and rocks by molecular or gaseous diffusion methods and thereby infiltrates building foundations (Afolabi et al., (2015); Etiope and Martinelli (2002). However, radon penetrates inside buildings through the openings in the concrete basement structure; the concentration of radon gas can reach high levels if the ventilation rates of the buildings are low. High concentrations of radon gas in building can cause health hazard to dwellers.

Radon as a noble gas is rapidly exhaled after being breathed in; however, radon progeny, combine with other molecules in the air and with particles of dust, aerosols or smoke, and readily deposit in the airways of the lung. While lodged there, the progeny emits ionizing radiation in the form of alpha particles, which can damage the cells lining the airways (Ingrid and Jiri (2017). The possible health effects of exposure to radon can primarily cause damage due to inhalation of alpha particles. These health effects will depend on the concentration of radon exposure level. The radon (^{222}Rn) is a potential health hazard gas that is responsible for thousand lung cancer deaths yearly and other radiological health problems such as leukemia, genetic and human fertility damage (Mamta et al., 2012).

There has been extensive research regarding radon in residences and schools in recent years but, there is still relatively little information regarding radon in buildings in the Niger Delta, Nigeria. Hence the study of radon in some selected buildings in Port-Harcourt city that are always populated due to the routine activities going on daily in these selected buildings.

2.0 Study Area

This study was carried out in basements of selected buildings in Port Harcourt City, Rivers State, Nigeria. Port Harcourt is the capital of Rivers State with its geographical coordinates at $4^0 47^{'} 2^{''}$ North, $6^0 59^{'} 55^{''}$ East. It lies along the Bonny River and is located in the Niger Delta with estimated population of 1,865,000 inhabitants NPC, (2006). The selected buildings whose basements was study are: Atrium Event Center (ATRIUM) with about four multipurpose halls ranging from 1000 to 250 seating capacity, Rivers State Government State Secretariat (PBSS) one of the tallest and biggest in the southern part of Nigeria, Corpus Christi Cathedral (COCC) is a Roman Catholic cathedral worship center and worshipers in their population goes in daily for worship, University of Port Harcourt Teaching Hospital (UPTH) accommodate nearly 200,000 outpatients and inpatients annually, as well as over 3000 surgical operations a year. The hospital tends to provide clinical education and training to students and other healthcare professionals. Others are Anatomy Laboratory in the Faculty of Science complex, University of Port Harcourt (MM-AL) that accommodates several thousands of both staff and students on a daily basis.

3.0 MATERIALS AND METHODS

The radon concentration measurements were carried out within five days each in five different buildings (Basements) in Port Harcourt city in Nigeria. The research work was done within six months (October 2019 to March 2020) in order to show precise results of indoor and outdoor radon concentrations in dry (warm) seasons.

The work was performed with a well calibrated Corentium Digital Radon Detector (BQM model) and the Global Positioning System device. The Corentium Digital Radon Detector set was installed at least 1.5 m above the floor of each of the selected building basements in the typical breathing zone. However, the Corentium Digital Radon Detector set was placed at least 50cm from the ceiling and 2cm from other objects to enable inflow of air around the device (Environmental Protection Agency, 2009). Readings for the long term and short term average of radon concentration were taken in (Bq/m3) after 48 hours for each basement. The Global Positioning System Device (GPS) was used to identify the coordinate of the various locations where radon measurements were taken.

3.1 Estimate of the Natural Radiation Exposure

The radiological risk parameters such as equilibrium equivalent concentration (EECs), equivalent dose, annual effective dose, effective-equivalent dose, potential alpha energy, lifetime fatality risks and effective dose were computed from the radon concentration count rate measurements from the surveyed areas.

3.2 Equilibrium Equivalent Radon Concentration (EEC_{Rn})

The radon concentration decay products or their equivalent equilibrium concentrations (EEC_{Rn}) were obtained using the following relation:

$$EEC_{Rn} \left(\frac{Bq}{m^3}\right) = C_{Rn} \times F \qquad (1)$$

Where C_{Rn} is the measured activity concentration of radon and F is the equilibrium factor (F = 0.45) (Kranrod et al., 2009).

3.3 Potential Alpha Energy (PAE)

The Annual exposure to potential alpha energy (PAE) concentration is calculated in mWL using the equation below according to Abojassim and Husain (2015):

$$PAE\,(mWL) = \frac{EEC_{Rn}}{3700} \quad (2)$$

3.4 Annual Human Exposure Rate or Working Level Month (WLM)

The Annual human exposure due to radon progeny is calculated using the equation below. In this work, the EPA recommended value was used to estimate working level month as to the annual human exposure rate (Abojassim and Husain, 2015):

$$WLM_{(Y)} = C_{Rn} \times F \times 2.7 \times 10^{-4} \times S \times \frac{8760}{170} \quad (3)$$

Where $WLM_{(Y)}$ is the annual human exposure rate, C_{Rn} is the radon concentration value (Bq/m^{-3}), F is the equilibrium factor F = 0.4 for indoor and 0.6 for outdoor, 2.7×10^{-4} is the radon progeny concentration in equilibrium ($WL/Bq/m^{-3}$), S = 0.7 is the fraction of spending time indoors (USEPA, 1993).

3.5 Annual Effective Dose (AED)

The annual effective dose from inhaled radon is calculated using the equation below:

$$AED = WLM_{(Y)}\, I \quad (4)$$

Where AED is the annual effective dose ($mSvy^{-1}$) and I is the conversion factor with value of 9 (mSv per WLM)(USEPA ,1993).

3.6 Annual Risk of Lung Cancer (ARLC)

The annual risk of lung cancer from inhaled radon and its progeny is calculated using the equation (Amin et al., 2015):

$$ARLC = WLM_{(Y)}\, DK \quad (5)$$

Where ARLC is the annual risk of lung cancer, $WLM_{(Y)}$ is the annual human exposure rate of radon, D is the exposure time (Year) and K is the risk factor. The risk factor used to estimate the risk of lung cancer from radon inhalation for dwellers is 5×10^{-4} (ICRP, 2014).

4.0 RESULTS

The obtained indoor and outdoor radon activity concentration results are presented in Table 1. The comparisons of indoor and outdoor radon activity concentrations and with standard and the contour relationship are shown in Figures 1 - 4.

Table 1: ^{222}Rn concentration (C_{Rn}) in indoor and outdoor air in some selected Locations in Rivers State

DAYS	ATRIUM C_{Rn} (Bq/m^3)		PBSS C_{Rn} (Bq/m^3)		COCC C_{Rn} (Bq/m^3)		UPTH C_{Rn} (Bq/m^3)		MM-AL C_{Rn} (Bq/m^3)	
	Indoor	**Outdoor**	**Indoor**	**Outdoor**	**Indoor**	**Outdoor**	**Indoor**	**Outdoor**	**Indoor**	**Outdoor**
1	2.78	0.74	48.66	3.89	41.81	3.33	92.69	1.30	2.96	3.52
2	11.84	2.78	38.85	0.00	52.73	4.81	23.68	5.37	14.06	9.99
3	15.36	2.78	94.17	2.22	28.31	1.30	16.47	2.78	6.85	4.44
4	5.37	1.30	73.82	1.30	38.85	0.37	54.76	2.59	14.43	12.03
5	7.77	1.85	51.25	3.70	53.28	1.85	98.61	4.81	3.52	1.85
Mean	**8.62**	**1.89**	**61.35**	**2.22**	**42.99**	**2.33**	**57.24**	**3.37**	**8.36**	**6.36**
WHO 2009	**100**	**15**	**100**	**15**	**100**	**15**	**100**	**15**	**100**	**15**

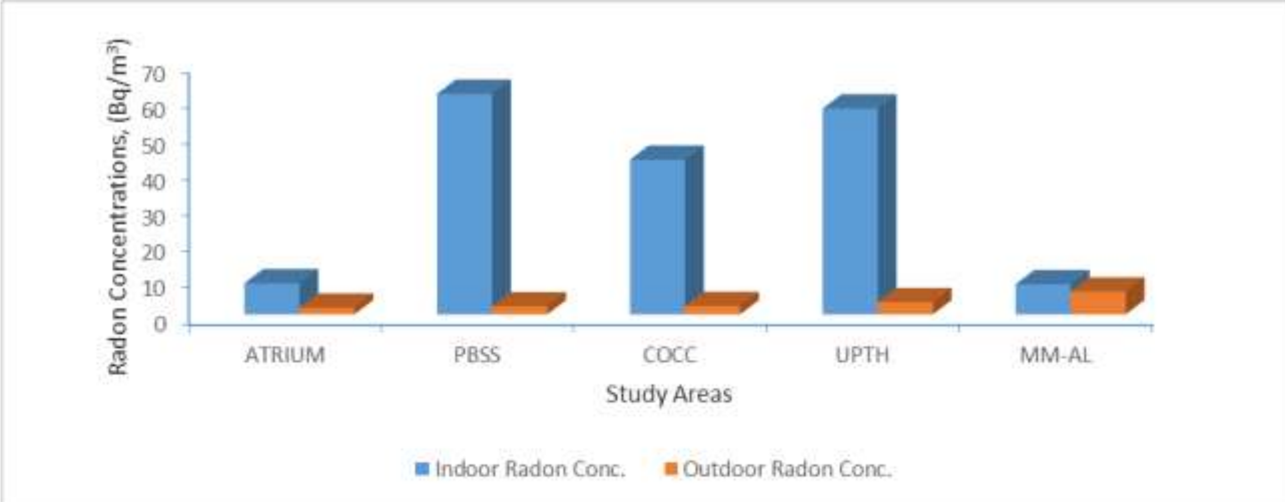

Figure 1: Comparison of mean indoor and outdoor radon concentration in different locations

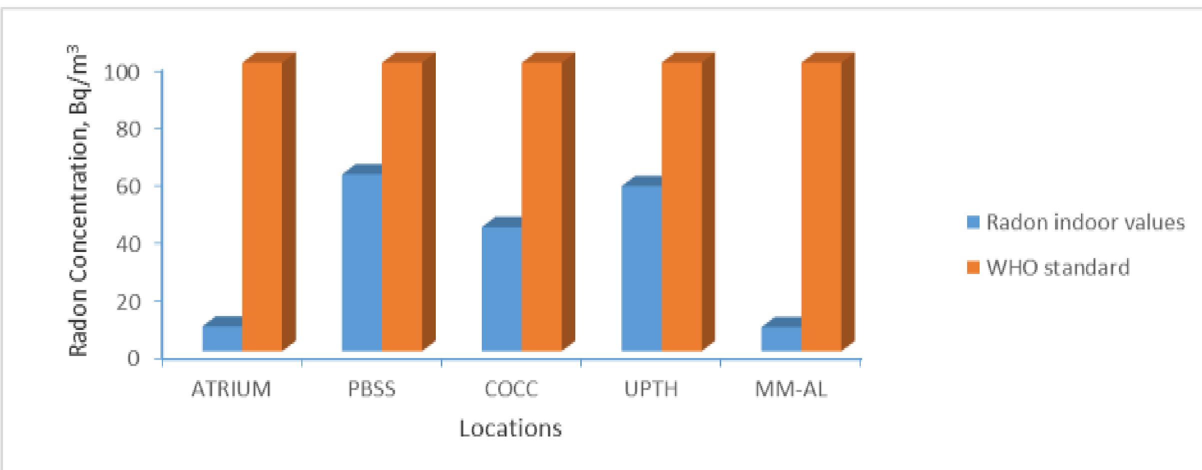

Figure 2: Comparison of indoor radon concentration and WHO standard

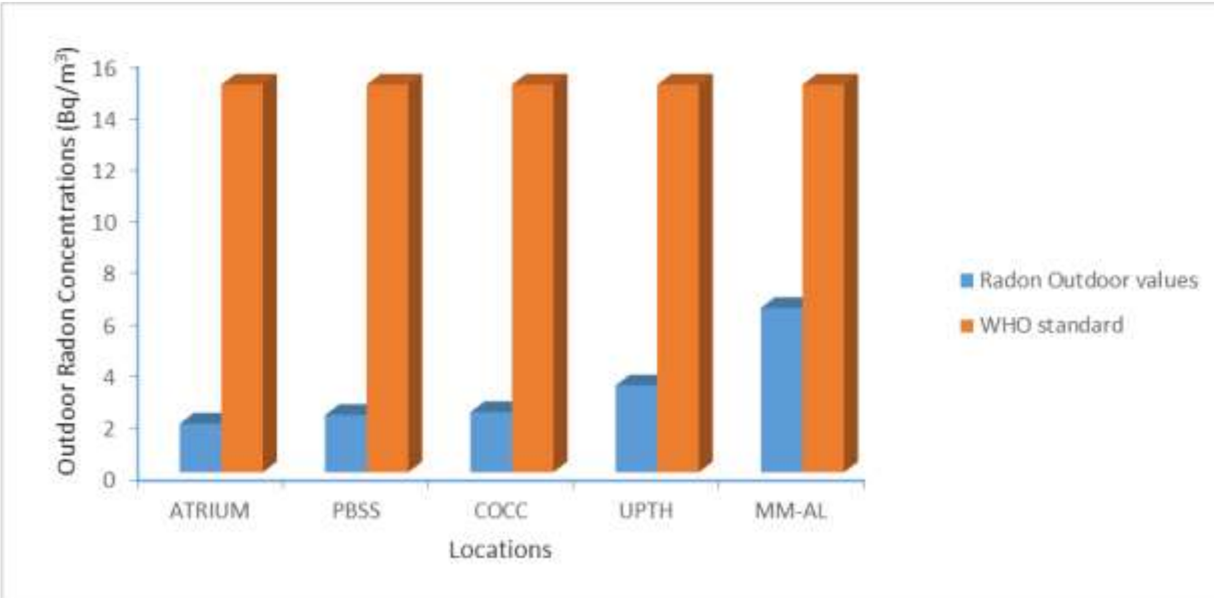

Figure 3: Comparison of outdoor radon concentration and WHO standard

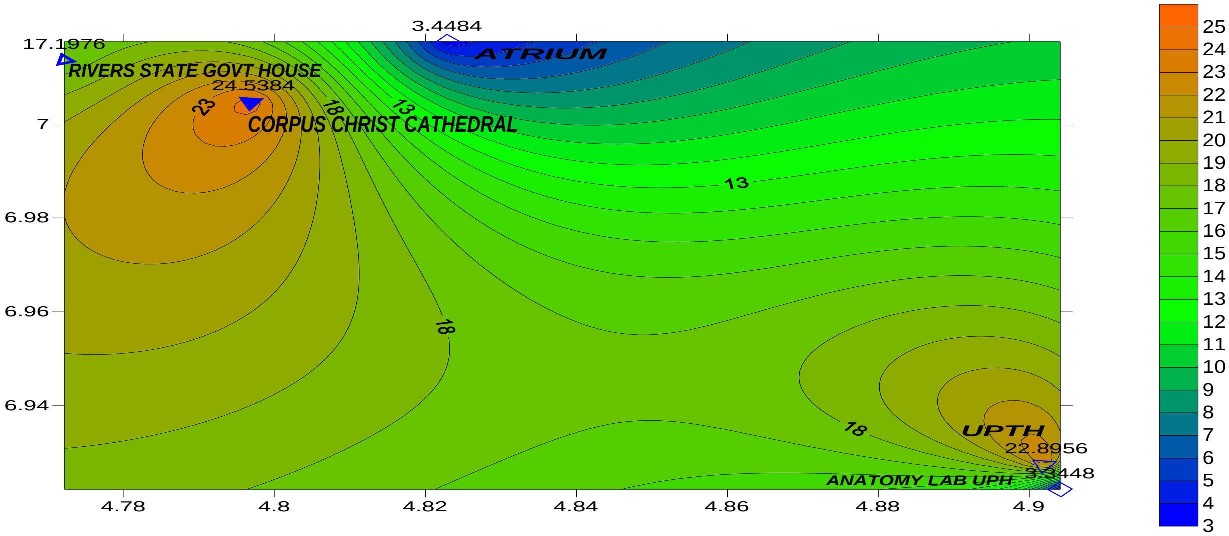

Figure 4: Contour map of radon concentration levels in study locations

Table 2: Calculated values of Equilibrium Equivalent Concentrations of radon (C_{EEC}), Potential Alpha Energy (PAE), Annual Human Exposure Rate or Working Level Month (WLM), Annual Effective Dose (AED) and Annual Risk of Lung Cancer (ARLC) in indoor air in Rivers State

Locations	C_{EEC} Bq/m^3	PAE (mWL)	WLM	AED (mSvy^{-1})	ARLC
ATRIUM	3.879	1.0484	0.0336	0.3024	0.1472
PSBB	27.608	7.4616	0.2393	2.1537	1.0481
COCC	19.346	5.2287	0.1677	1.5093	0.7345
UPTH	25.758	6.9616	0.2232	2.0088	0.9776
MM-AL	3.762	1.0168	0.0326	0.2934	0.1428
MEAN	16.070	4.3434	0.13928	1.2535	0.6101

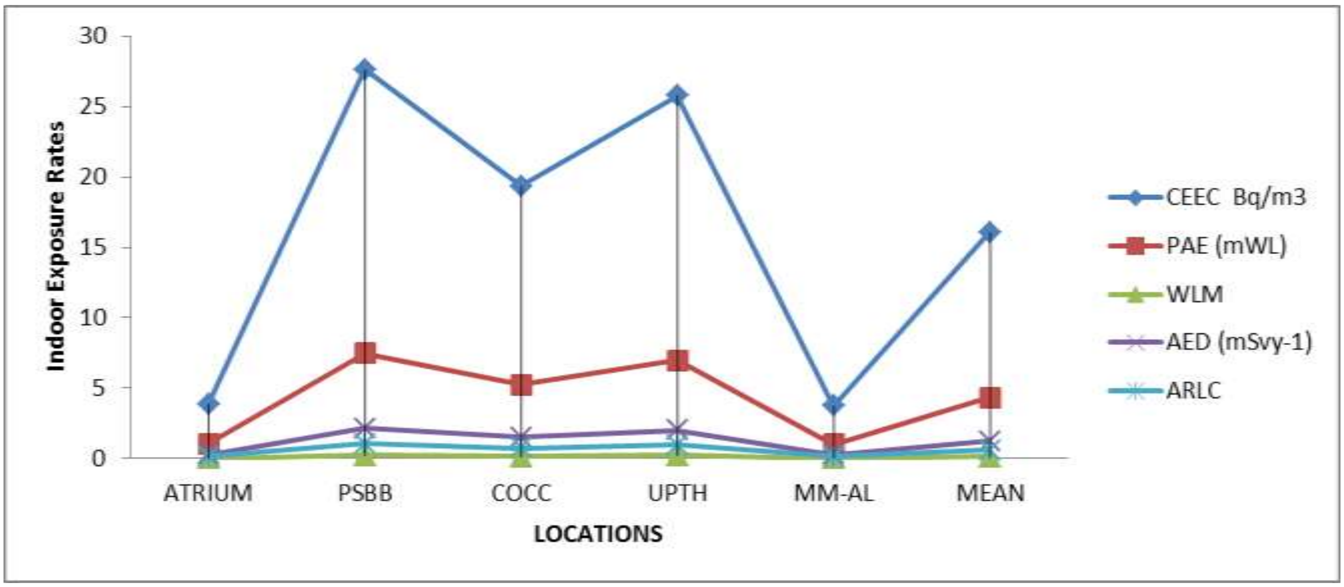

Figure 5: Comparison of indoor Exposure Risk Rates with Location

Table 3: Calculated values of Equilibrium Equivalent Concentrations of radon (C_{EEC}), Potential Alpha Energy (PAE), Annual Human Exposure Rate or Working Level Month (WLM), Annual Effective Dose (AED) and Annual Risk of Lung Cancer (ARLC) in outdoor air in Rivers State

Locations	C_{EEC} Bq/m^3	PAE (mWL)	WLM	AED (mSvy^{-1})	ARLC
ATRIUM	0.851	0.2300	0.0110	0.0990	0.0482
PSBB	0.999	0.2700	0.0129	0.1161	0.0565
COCC	1.049	0.2835	0.0135	0.1215	0.0591
UPTH	1.517	0.4100	0.0196	0.1764	0.0859
MM-AL	2.862	0.7735	0.0369	0.3321	0.1616
MEAN	1.455	0.3934	0.0188	0.1690	0.0823

5.0. DISCUSSION

5.1: ^{222}Rn concentration (C_{Rn}) in indoor and outdoor

The mean indoor radon activity concentrations obtained in all the locations ranged from 8.36 Bq/m^3 (MM-AL) to 61.35 Bq/m^3 (PBSS) with an average of 35.71 Bq/m^3, while the mean outdoor radon activity concentrations obtained ranged from 1.89 Bq/m^3 (MM-AL) to 6.36 Bq/m^3 (ATRIUM) with an average of 3.23 Bq/m^3. The difference between the indoor radon concentration levels and that of the outdoor radon concentration levels may be attributed to the ventilation system of the building, the type of construction materials used, the age of the building and dust accumulation in the room. The mean radon activity concentrations obtained were found to be higher than those reported Amin et al., (2015); Abojassim and Husain (2015); Mamta et al., (2012). The mean indoor and outdoor concentrations of radon obtained were found to be lower than the radon average level of 100Bq/m^3 and 15Bq/m^3 respectively WHO (2009) except in PBSS which is higher than the radon average level. The mean indoor radon concentrations in the present study indicate that most of the study areas investigated had values which are significantly low. These buildings are built mainly from the same skeletal building materials (mud, sand, blocks, stones and cement) and the finishing materials used are basically the same in all the building. However, the outdoor low values indicate the fact that the areas are highly ventilated and thus the radon gas emitted is diluted and only small amount of radon gas may have entered the apartments.

5.2: Indoor and Outdoor Health Hazard Calculations

Tables 2 and 3 showed the calculated values of equilibrium equivalent concentrations of radon (C_{EEC}), potential alpha energy (PAE), annual human exposure rate or working level month (WLM), annual effective dose (AED) and annual risk of lung cancer (ARLC) in indoor and outdoor air in Rivers State. Figure 5 showed the relation between the indoor radon concentration exposure rates in the various locations.

The indoor equilibrium equivalent radon concentration (C_{EEC}) varied from 3.762 Bq/m^3 (MM-AL) to 27.608 Bq/m^3 (PBSS) with an average of 16.070 Bq/m^3 and that of the outdoor varied from 0.851 Bq/m^3 (Atrium) to 2.862 Bq/m^3 (MM-AL) with an average of 1.455 Bq/m^3. The mean indoor and outdoor concentrations of potential alpha energy (PAE) ranged from 1.0168 mWL (MM-AL) to 7.4616 mWL (PSBB) with an average of 4.3434 mWL and 0.2300 mWL (Atrium) to 0.7735 mWL (MM-AL) with an average of 0.3934 mWL respectively. The indoor and outdoor annual human exposure rate or working level month (WLM) varies from 0.0326 WLM/y (MM-AL) to 0.2393 WLM/y (PBSS) with an average of 0.13928 WLM/y and 0.0110 WLM/y (Atrium) to 0.0369 WLM/y (MM-AL) with an average of 0.0188 WLM/y respectively. The indoor and outdoor annual effective dose (AED) varied from 0.2934 mSv/y (MM-AL) to 2.1537 mSv/y (PBSS) with an average of 1.2535 mSv/y and 0.0990 mSv/y (Atrium) to 0.3321 mSv/y (MM-AL) with an average of 0.1690 mSv/y respectively. It is evident that the obtained annual effective dose rates were within the permissible limits range of 3 to 10 mSv/y ICRP (1993). The results are lower than those recorded by Oni et al., (2012); Abd-Elzaher (2012); Shashikumar et al., (2009). The indoor and outdoor annual risk of lung cancer (ARLC) varied from 0.1472 (Atrium) to 1.0481 (PBSS) with an average of 0.6101 and 0.0482 (Atrium) to 0.1616 (MM-AL) with an average of 0.0823 respectively. In general, these low results obtained may be attributed to ventilation condition of the building, the type of construction materials used, the age of the building, Therefore, less potential health hazard problem would be cause due to its inhalation and exposure.

6.0 CONCLUSION

The evaluation of the concentration of the radon gas and the radiological health risk in basement of selected buildings in Port Harcourt Metropolis, Rivers State has been carried out. The indoor and outdoor concentrations of radon vary significantly from one building to the other within the study areas. The indoor and outdoor concentration of radon has average mean values of 35.71 Bq/m^3 and 3.23 Bq/m^3 respectively. The radiological health risks are below the WHO and ICRP permissible limit. The work has shown that the studied buildings are likely to be radiologically free since radon concentrations were below world allowable average dose limits.

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