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Measurement of Radon Concentration in Selected Houses in Ibadan, Nigeria

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Abstract. Radon is a natural radioactive gas without colour or odour and tasteless. The World Health Organization (WHO) grouped radon as a human lung carcinogen. For this reason, there has been a lot of interest on the effects of radon exposure to people all over the world and Nigeria is no exception. The aim of this study is to investigate the radon concentration in selected houses in three local government areas of Ibadan. The indoor radon was measured in both mud and brick houses. Fifty houses were considered from the three Local government areas. A calibrated portable continuous radon monitor type (RAD7) manufactured by Durridge company was used for the measurement. A distance of 100 to 200 m was maintained between houses in all the locations. The living room was kept closed during the measurements. The mean radon concentration measured in Egbeda is 10.54 ±1.30 Bqm^{-3}; Lagelu is 16.90 ± 6.31 Bqm^{-3} and Ona-Ara is 17.95 ± 1.72 Bqm^{-3}. The mean value of the annual absorbed dose and annual effective dose for the locations in the three local government areas was 0.19 $mSvy^{-1}$and 0.48 $mSvy^{-1}$respectively. The radon concentration for location 10 in Ono-Ara local government exceeded the recommended limit. However, the overall average indoor radon concentration of the three local governments was found to be lower than the world average value of 40 Bqm^{-3}. Hence, there is need for proper awareness about the danger of radon accumulation in dwelling places.

1. Introduction

Radon is a natural radioactive gas that is derived from the decay of ^{238}U. It exists ubiquitously, small in degree to be noticed but can only be measured using a detector.^{238}Uranium is available in soil and rocks in limited quantity. It slowly disintegrates to other compounds like radium, which later turns to radon. Part of the radium migrates to the soil surface and finds their ways to the air, while other part remains at the sub-surface and penetrates the ground water [1, 2]. Admit the radioisotopes that add to general background radiation, radon posed major risk to human health. About 55% of the yearly radiation dose incurred by the general public can be traced to it [3]. Alpha particles are heavy particles and can only move a short distance. It cannot permeate through our skin but it can be inhaled and settled in the lung tissue. The energy deposition in lungs is highly localized and this will likely elevate the risk of lung cancer [4]. The International Agency for Research on Cancer (IARC) and the World Health Organization (WHO) categorized it as a human lung carcinogen [5, 6]. The ICRP suggests that all the countries of the world should carry out radon survey to find radon prone areas [7]. Due to dearth of information about the concentration and harmful effects [8, 9] of radon in Nigeria, lot of people are working and living in places unaware of the dangers posed to their lives. Concentration of radon gas in dwellings has been found to depend on geological condition, meteorological condition, construction materials and ventilation [10]. The buildings in the study areas were built from cement, concrete, mud, brick, granite etc, thus it is nearly impossible not to detect activity of radon in the areas. Also, there is a large variability in indoor concentration levels between different countries, even between areas in the same country, due to variations in the climatic parameters, geology of the subsoil, and building characteristics [11]. ^{222}Rn exposure levels in large buildings such as commercial buildings, schools and multiunit residential structures may be different from exposure patterns in

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detached houses due to difference in operation going on in the building [3]. There is no specific regulation or safe limit value in Nigeria concerning indoor radon levels in either homes or workplaces. Therefore, it is necessary to take measurement with the RAD 7 radon detector and other passive detector [12] to measure radon levels inside homes. Hence, the aim of this study is to investigate the concentration of radon in homes (both mud and brick houses) in Egbeda, Lagelu and Ona-Ara local government areas of Ibadan, Oyo State, Nigeria and the results will be used to estimate the annual effective dose for the homes dwellers.

2. Materials and Method

Ibadan is located on latitude 7.39° N and longitude 3.9° E, southwestern Nigeria. It has mud houses in rural areas and brick houses in both rural and urban area. The elevation of the town ranges from 150 m in the valley to 275 m above sea level. It has eleven local governments out of which three were selected for this study. They are: Egbeda, Lagelu and Ona-ara local Government Area. Egbeda headquarter has an area of 191 km^2 and a population of 281,573 according to the 2006 census. Iyana Offa is the headquarter town of Lagelu. It has an area of 338 km^2 with an estimated population of 147,957. Akanran is the headquarter town of Ona-Ara local government. It has an area of 290 km^2 and population of 265,059. The choice of selecting the three local governments is because of mud houses and brick houses situated at the locations. There are more mud houses in Egbeda and Ona-Ara local Government than Lagelu local Government. In this study, indoor radon was measured in both mud and brick houses. A calibrated portable continuous radon monitor type RAD7 manufactured by Durridge company was used. The gas to be measured enters in diffusion mode through a large surface of glass filter into an ionization chamber. The radon progeny products were prevented while only the gaseous ^{222}Rn can enter the ionization chamber. A personal computer (PC) Software (CAPTURE) allows a graphic presentation and calculation of the average concentration in the measured period. The measurements were carried out in fifty houses from the three locations: twenty were taken from Lagelu local Government (all brick houses), twenty five were taken from Ona- Ara local Government (fifteen mud houses and ten brick houses) and five mud houses were taken from Egbeda local Government. 100 to 200 m was maintained from one house to the other in all the locations. For all runs, the RAD7 was positioned on the table and on the floor in the center of the living room (Figure 1). The living room was kept closed during the measurements. The average radon concentration was calculated by the system in RAD7 for every cycle (20 min), displayed on LCD and a printer printed out the reading.

2.1 Dose Estimation

The indoor radon concentrations measured in each location of the study were used to estimate the annual effective doses and annual absorbed dose. The annual absorbed dose was calculated using equation 1.

$$D\ (mSvy^{-1}) = C_{Rn}\, D_c\, F\, H\, T \tag{1}$$

where D is the annual absorbed dose ($mSvy^{-1}$); C_{Rn} is the radon concentration (Bqm^{-3}); D_c is the dose conversion factor ($9.0 \times 10^{-6} mSvh^{-1}$ per Bqm^{-3}); F is the equilibrium factor (0.4); T is hours in a year (8760); H is the occupancy factor (0.4). The annual effective dose was calculated by using equation 2.

$$E\ (mSvy^{-1}) = DW_R\, W_T \tag{2}$$

where E is the annual effective dose; D is the annual absorbed dose ($mSvy^{-1}$); W_R is the radiation weighting factor for alpha particles (20) according to [1]; W_T is the tissue weighting factor for the lung (0.12) according to [1].

3. Results and Discussion

The radon concentration measured, estimated annual effective dose and annual absorbed in the study areas are presented in Table 1-3. The concentration of radon was found to vary from one location to the other. Figure 1 is the pictorial presentation of the radon concentration in the three local government areas. Table 1 showed the measured concentrations in Ona-Ara local government, the

concentration of the radon was found to have the highest value in location 10 (which is mud house) with the mean radon concentration of 42.54 ± 1.32 this was found to exceed the recommended limit of 40 Bqm^{-3}. This may be because the measurement was done in the night when all the windows were closed and this increased the radon concentration level as they were trapped due to decrease in the cross ventilation.

Table 1. Indoor Radon Concentration, annual absorbed dose and annual effective dose of Ona-Ara Local Government mud and brick houses

Location	Age of the building (yr)	Mean radon concentration (Bqm^{-3})	Annual absorbed dose ($mSvy^{-1}$)	Annual effective dose ($mSvy^{-1}$)
1	30+	38.09 ± 20.43	0.48	1.15
2	30+	8.76 ± 0.01	0.11	0.26
3	30+	8.74 ± 0.02	0.11	0.26
4	30+	11.03 ± 0.29	0.14	0.34
5	30+	18.28 ± 1.18	0.23	0.55
6	20+	14.58 ± 0.94	0.18	0.43
7	25+	17.00 ± 0.48	0.21	0.50
8	30+	8.76 ± 0.10	0.11	0.26
9	30+	37.79 ± 7.04	0.48	1.15
10	30+	42.54 ± 1.32	0.54	1.30
11	30+	33.62 ± 0.90	0.42	1.01
12	30+	8.67 ± 0.07	0.11	0.26
13	30+	10.77 ± 0.12	0.14	0.34
14	30+	9.81 ± 0.04	0.12	0.29
15	25+	8.78 ± 0.01	0.11	0.26
Mean (Mud)		**18.48 ± 0.58**	**0.23**	**0.56**
16	10+	18.23 ± 5.10	0.23	0.55
17	20+	8.78 ± 0.00	0.11	0.26
18	15+	15.71 ± 0.01	0.20	0.48
19	10+	16.81 ± 1.72	0.21	0.50
20	10+	20.66 ± 0.16	0.26	0.62
21	10+	17.64 ± 0.14	0.22	0.53
22	8+	13.27 ± 0.66	0.17	0.41
23	10+	17.12 ± 1.39	0.22	0.53
16	10+	18.23 ± 5.10	0.23	0.55
17	20+	8.78 ± 0.00	0.11	0.26
18	15+	15.71 ± 0.01	0.20	0.48
19	10+	16.81 ± 1.72	0.21	0.50
20	10+	20.66 ± 0.16	0.26	0.62
21	10+	17.64 ± 0.14	0.22	0.53
20	10+	20.66 ± 0.16	0.26	0.62
21	10+	17.64 ± 0.14	0.22	0.53
22	8+	13.27 ± 0.66	0.17	0.41
23	10+	17.12 ± 1.39	0.22	0.53
24	15+	19.78 ± 0.67	0.25	0.6
25	15+	23.66 ± 0.11	0.3	0.72
Mean (Brick)		**17.17± 1.72**	**0.22**	**0.52**

Note: Locations 1 - 15 are mud houses while 16 to 25 are brick houses.

Table 2. Indoor Radon Concentration, annual absorbed dose and annual effective dose of Egbeda Local Government Area mud houses

Location	Age of the building (yr)	Mean radon concentration (Bqm^{-3})	Annual absorbed dose ($mSvy^{-1}$)	Annual effective dose ($mSvy^{-1}$)
1	30+	13.46 ± 4.43	0.17	0.71
2	30+	9.27 ± 0.50	0.12	0.29
3	30+	8.76 ± 0.01	0.11	0.26
4	30+	11.39 ± 1.56	0.14	0.34
5	30+	9.80 ± 0.01	0.12	0.29
Average		**10.45** ± **1.30**	**0.13**	**0.38**

Table 3. Indoor Radon Concentration, annual absorbed dose and annual effective dose of Lagelu Local Government brick houses

Location	Mean radon concentration (Bqm^{-3})	Annual absorbed dose ($mSvy^{-1}$)	Annual effective dose ($mSvy^{-1}$)
1	24.73 ± 7.80	0.31	0.74
2	18.54 ± 9.30	0.23	0.55
3	3.67 ± 4.45	0.05	0.12
4	19.99 ± 8.96	0.25	0.60
5	17.35 ± 4.81	0.22	0.53
6	18.50 ± 8.86	0.23	0.55
7	12.42 ± 5.70	0.17	0.41
8	28.76 ± 1.44	0.36	0.86
9	4.79 ± 4.41	0.06	0.14
10	14.28 ±12.88	0.18	0.43
11	15.64 ± 7.98	0.20	0.48
12	19.29 ± 1.29	0.24	0.58
13	15.72 ± 0.01	0.20	0.48
14	13.27 ± 0.56	0.17	0.41
15	18.83 ± 9.02	0.24	0.58
16	18.87 ± 9.02	0.24	0.58
17	14.30 ±12.85	0.18	0.43
18	14.26 ± 5.95	0.18	0.43
19	17.95 ± 4.07	0.23	0.55
20	26.81 ± 6.92	0.34	0.82
Average	**16.90** ± **6.31**	**0.21**	**0.51**

The overall mean value of the indoor radon concentration in Ona-Ara was 17.95 Bqm^{-3}. In Ona-Ara it was found that radon concentration measured in some mud houses and the mean was higher when compared to those obtained in brick houses. Table 2 displayed measured concentration in Egbeda local Government. The highest radon concentration in Egbeda was obtained in location 1 with a mean value of 13.46 ± 4.43 Bqm^{-3} while the lowest value was obtained in location 3 with the average value of 8.76 ± 0.01 Bqm^{-3}. The highest value may be attributed to type of ventilation in location 1 the window is small and there is very low ventilation as a result of this, the radon concentration levels accumulate, while in location 3 there is a good ventilation in which the radon concentration mixed with the air to reduce the radon concentration level. The overall mean value of the indoor radon concentration in Egbeda was 10.45 Bqm^{-3}.

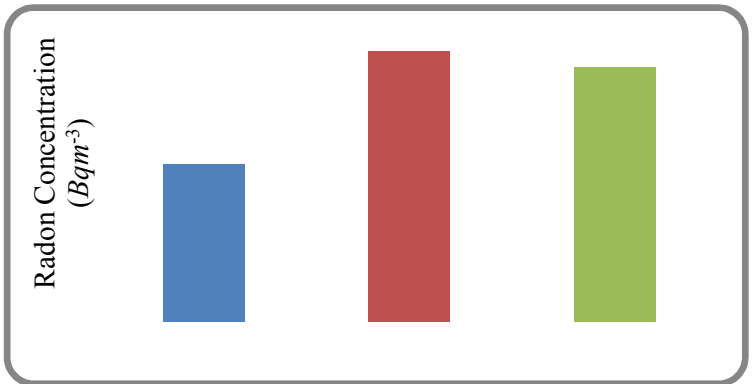

Figure 1. Variation of Radon Concentration in the Locations

Table 3 displayed the measured concentration in Lagelu local Government, the highest radon concentration was found in location 8 with the mean concentration of 28.76 ± 1.44 Bqm^{-3} while the lowest value was in location 3 with the average value of 3.67 ± 4.45 Bqm^{-3}. The high value of radon concentration in location 8 may be due to the age of the building, due to crack on the ground which is likely to be one of the causes of increase in the concentration. Also in location 3, the reading were taken at the first floor of the building, the elevation of the building can also contribute to the decrease in radon concentration level. The overall mean value of indoor radon concentration in Lagelu was 16.90 Bqm^{-3}.

The radon concentration obtained in Ono-Ara local government was quite high when compared to the other two local governments which may be as result of the materials used in the construction of the houses and the mode of the construction of the building as the sizes of the window in this location was small compared to other locations. Meanwhile, the overall average radon concentration from the three (3) local Government Areas in Ibadan is 15.10 ± 3.11 Bqm^{-3}, which is lower than the world average value of 40 Bqm^{-3} [4, 13]. The radon concentration obtained in these locations compared well with studies conducted by [14] where the concentration measured was 52 Bqm^{-3}, 28 Bqm^{-3} and 17Bqm^{-3} for Japan, Pakistan and Kuwait respectively. The correlation coefficient of Lagelu brick and Egbeda mud houses; Egbeda mud and Ona-Ara brick houses; Lagelu brick and Ona-Ara mud houses and Lagelu brick and Ona-Ara brick houses values are 0.45, 0.09, -2.26 and -0.28 respectively. The negative means the correlation coefficient between them are extremely low. The correlation coefficient value between the three locations is -5.53 and this means there is no correlation between them. The mean annual absorbed dose calculated was 0.13 $mSvy^{-1}$, 0.23 $mSvy^{-1}$ and 0.21 $mSvy^{-1}$for Egbeda, Ona-Ara and Lagelu respectively. Since the annual effective dose depends on mean indoor radon concentrations, the location with highest mean indoor radon concentration also has the highest value of the effective dose. The estimated mean annual effective was of 0.38 $mSvy^{-1}$, 0.54 $mSvy^{-1}$ and 0.51 $mSvy^{-1}$for Egbeda, Ona-Ara and Lagelu respectively. Locations 1, 9, 10 and 11 exceeded the recommended limit of 1 $mSvy^{-1}$. However, the average annual effective dose obtained for the three study areas is below 1 $mSvy^{-1}$ the world average value for normal background radiation.

The results obtained from RAD7detector showed that, the average radon concentration for the 3 local government areas surveyed in Ibadan was 15.10 ± 3.11 Bqm^{-3} which is lower when compared to the measurement reported by [9] conducted in some Secondary Schools in Oke-Ogun area of Oyo State with average radon concentration of 45 ± 27 Bqm^{-3}. This study revealed that proper ventilation in a building reduces the level of radon that will be recorded in a particular building, the more the ventilation the more the air enters into the room, the lower the radon level. The lifestyle of the individual living in this building is also important in some of these places people smoked cigarratte which increased the radon level. The floor of the room equally plays some role as observed here. The rooms in ground floor have higher value than those in first floor. The age of a building is equally important in the concentration obtained.

4. Conclusion

The first radon measurement in Lagelu, Egbeda and Ona-Ara Local Government Areas, Ibadan Southwestern Nigeria was conducted using RAD7. The mean value of indoor radon concentration of the three local governments was found to be 15.10 ± 3.1 Bqm^{-3} which is lower than the recommended limit of 40 Bqm^{-3}. The average annual effective dose estimated for this study was found to be 0.48 $mSvy^{-1}$which is lower than the recommended limit of 1 $mSvy^{-1}$. Therefore, the study provides preliminary data about indoor radon levels in the three local governments in Ibadan as a baseline study for a wider future national survey in the whole Ibadan city.

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References

[1] Bodansky D., Maurice A., Robkin and David R. S. 1989 Indoor Radon and its Hazards. *Univ. of Washington Press Seattle and London, second edition*

[2] Patrick RichonYann Klinger, Paul Tapponnier, Chen-Xia Li, Jerome Van Der Woerd, Fre´de´ric Perrier 2010 Measuring radon flux across active faults: Relevance of excavating and possibility of satellite discharges. **45** 211–218.

[3] George, A.C 2009 World history of radon research and measurement from the early 1900's to today *26th Avenue Bayside NY 11360 US*, pp.201-207.

[4] UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) 2000 Sources and Effects of Ionizing Radiation.*Scientific Annexes*

[5] Darby, S., Hill, D., Auvinen, A., Barros-Dios, J.M., Baysson, H., Bochicchio, F. 2005 A radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. *British MedicalJournal*, **330**: 223-227.

[6] International Commission on Radiological Protection (ICRP) 2010. Lung Cancer Risk from Radon and Progeny and Statement on Radon. *Ann*. **40**(1).

[7] Ji Young Yoon, Jung-Dong Lee, So Won Joo and DaeRyong Kang 2016 Indoor radon exposure and lung cancer: a review of ecological studies. Annals of Occupational and Environmental Medicine **28**:15 DOI 10.1186/s40557-016-0098-z.

[8] Nasir T. and Shah M., 2012 Measurement of Annual Effective Doses of Radon from Drinking Water and Dwellings by CR-39 Track Detectors in Kulachi City of Pakistan. *Journal of Basic & AppliedSciences*.**8**: 528-536.

[9] Obed R.I., Ademola A.K., Vascotto M., Giannini G., 2011 Radon measurements by nuclear track detectors in secondary schools in Oke-Ogun region, Nigeria. *Journal of Environmental Radioactivity*, **102**: 1012-1017.

[10] Jung K.W, Won Y.J, Kong H.J, Oh C.M, Cho H, Lee D.H. 2015 Cancer statistics in Korea: incidence, mortality, survival and prevalence in 2012. Cancer Res Treat, **47**(2):127–41.

[11] Yu K.N., Young, E.C.M., Stokes, M.J. and Tang K.K. 1998 Radon properties in offices. *Health Phys*, ***75***: 159-164.

[12] Papastefanou C., 2008 Radioactive Aerosols. Aristotle University of Thessaloniki.Atomic & Nuclear Physics Laboratory. Greece.

[13] Ali K. Alsaedi, B.A. Almayahi, A.H. Alasadi 2013 Cement ^{222}Rn and ^{226}Ra concentration measurements in selected samples from different companies. Asian journal of natural & applied sciences, **2**: 2186 –8468.

[14] Shafik S. Shafik, Aamir A. Mohammed. 2013 Measurement of Radon and Uranium Concentrations and Background Gamma Rays at the University of Baghdad -Jadiriyah Site. International Journal of Application or Innovation in Engineering & Management **5**: 2319 – 4847.