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DETERMINATION OF RADON EXHALATION RATE FROM SOME SELECTED BUILDING MATERIALS IN SAMARU, ZARIA-NIGERIA

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ABSTRACT

In this study, Radon exhalation rate of some selected building materials in Zaria was measured and analyzed using a closed chamber method and an electronic radon detector. Each sample was placed in a container of 0.075 m^3 volume for 48 hours. The results obtained from the selected building materials indicated that wood has the highest exhalation rate of 0.79 Bq/kgh while gravel has the least with an exhalation rate of 0.44 Bq/kgh. Of all the selected building materials measured, the radium content is below that of the recommended limit according to OECD which implies they pose no indoor radiation risk.

Keywords: Radon concentration, Electronic radon detector, Wood, Gravel, OECD

INTRODUCTION

Radon-222 is a naturally occurring radioactive gas which is generated from the spontaneous decay of naturally existing Radium (a decay product of Uranium) in soil, rock, water and building materials all over the earth. It is a tasteless, odourless and colourless radioactive gas that can be inhaled by humans (Nisha et al, 2016). It is the most hazardous radionuclides among all the Radon isotopes (Harb, 2016). It is also the second leading gas that causes lung cancer when inhaled by human beings for a period of time (Pankaj et al., 2017). Aside from being capable of breaking into four relatively short-lived progenies, which are; Po-218, Pd-214, Bi-214 and Po-214, its four decay product easily mix with the surrounding air which implies that the ambient air contains both radon and it's progenies.

Radon emanates and is exhaled from building materials but the exhalation rate depends on the type of building material. Since Radon and its progenies are mixed with the atmospheric air, it can be inhaled by humans and may constitute radiation risk depending on the exposure especially for poorly ventilated homes.

Common building materials in Samaru-Zaria include sand, cement, gravel, wood, granite, and water. These materials have different geological structure and geophysical compositions that permit exhalation of radon 222 (Harb et al, 2016). Sadly, very little consideration, if any, by builders or house owners are made in terms of radon 222 exhalations or exposure that may arise from certain combination or compositions of building materials as builders may cut corners either to hasten building constructions or reduce cost. It is also important to note that most people spend more time indoors than outdoor which may also account for prolonged exposure conditions to radon that may constitute serious radiation risk. Therefore there is a need for relevant government agencies to be saddled with the responsibility of setting a domestic radon exposure limit to compliment that of the international limit set by the Organization for Economic Cooperation and Development (OECD, 2009). This is why data from researches that will provide information on radon exhalation rate from building materials are quite important and should be encouraged.

Stoulos et al (2003) carried out a research in Greece on some selected building materials and showed that granite and phosphogypsum with quite high radon concentration and exhalation rate of approximately five times higher than international limit. Also, Lu et al (2013) carried out a similar study on selected building materials from Yan'an, China and showed that the building materials had radon concentration and radon exhalation rate below OECD set limit. These researches among several others have shown that both radon concentration and radon exhalation rate depends majorly on the amount of radioactivity (radium content) in the soil and rocks from where these building materials are obtained because radium is the major source of radon (Dugal et al, 2015; Pankaj et al, 2017; Nisha et al, 2016).

Fasae (2013) measured radium concentrations in brick blocks and concrete blocks produced in Ekiti, Southwestern Nigeria. Radon concentration was not measured in the study. Another previous work determined radon exhalation and emanation rate of some building materials in Zaria (Arabi, 2015), but radium content, radon concentration and exhalation rate reports for clay, granite, and wood was not available. Also we couldn't find attempts to examine the correlation between radium content and radon concentration of the selected building materials in the study area. The present work therefore determines the radon exhalation rate from some selected building materials including sand, cement, granite, gravel, wood, and clay by measuring and correlating their radon concentration and radium content using an electronic radon detector (RAD7).

This is extremely important from a radiation protection point of view because the data from this work would contribute to other available data on naturally occurring radioactive materials (NORMS) for environmental radiation monitoring which should help keep radiation risks of Zaria residents in check.

THEORETICAL CONSIDERATIONS

Radon activity concentration

The equation used for the measurement of the Radon activity concentration from each of the selected building materials is given by equation (1) (Rafat, 2015):

$$C_{Rn}(t) = C_{eq}\left(1 - e^{-\lambda t}\right) \quad (1)$$

where C_{Rn} is the radon activity concentration at a time t. The system international (S.I) unit of C_{Rn} is Becquerel per meter cube (Bq/m^3). C_{eq} is the equivalent Radon (Rn-222) activity concentration which takes secular equilibrium into account for a given time t. It has the same unit as C_{Rn} and λ is decay constant of Radon and t is the time taken to build Radon activity inside tight exhalation container.

Radon exhalation rate

The surface area and mass of selected building material helps in the determination of the exhalation rate in building materials. The radon exhalation rate is a constant while the radon concentration discussed previously vary and can reach a maximum depending on the exhalation rate (Rafat, 2015). This exhalation rate expressed in terms of mass (E_m) can be calculated by equation (2); (EC, 1999, Rafique, 2015, Dugal et. al, 2015):

$$E_m = \frac{C_{eq}\lambda_{Rn}V_{eff}}{M} \quad (2)$$

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where M is the mass (kg) of the selected building materials, V_{eff} (m^3) is the effective volume of the chamber.

Radium content

Due to the phenomenon of secular equilibrium, it is possible to determine the radium contents in from short-lived radon. Using the equation (3) one can calculate the radium content from known radon concentration (Rafat, 2015).

$$C_{Ra} = \frac{E_m}{\lambda} \quad (3)$$

where C_{Ra} is the effective Radium content of the selected building material per unit mass of the building material. And it has an S.I unit of Becquerel per kilogram.

MATERIALS AND METHODS

The selected building materials commonly found in Samaru district, Zaria Nigeria were purchased from random suppliers which included sand, cement, granite, clay, gravel, and wood. The samples were collected in clean, dry polyethylene bags and crushed into powder. In order to ensure a fine quality of the sample, a sieve with a 150-micron mesh size was used. The samples were crushed to allow for maximum exhalation. Before measurement, samples are dried in an oven at about 80^{o}C for 24 hrs. Each sample was packed, sealed and kept for about four-week duration in an airtight PVC container. This was done to allow radioactive equilibrium between radon (^{222}Rn), thoron (^{220}Rn), and their short-lived progenies. The mass of each sample was 0.60 kg. All samples were labeled for easy identification during measurement in other to avoid interchanging values measured by the electronic radon detector. The method used in carrying measurements was the short term or accumulator chamber method where each of selected samples is placed one after the other inside a container called "accumulator chamber" in other to allow radon concentration to build up inside the chamber. This was done for 48 hours (two days). The accumulator chamber was attached to the electronic radon detector by two pipes, one to the inlet on the detector through a desiccant, which was also necessary during measurement in order to absorb all the moisture present so that concentrations would not be affected, and the other to the output which measures the radioactivity from each of the selected sample through the decay of the accumulated radon gas which emits alpha-particles.. The detector achieves this by detecting alpha particles emitted by the Radon and its progenies. The accumulator chamber was purged before and after every measurement in order to avoid contamination. Each test measurement was automatically assigned a test number by the detector and all results were automatically saved.

RESULTS AND DISCUSSION

Radon concentration, exhalation rate and radium content of the selected building materials

The results of the experiment in this work can be seen in table 1 and 2. The building materials measured herein are commonly used Samaru, Zaria-Nigeria. The equivalent radon concentration of the building materials is found to vary within the range of 142 Bq/m^3 - 253 Bq/m^3 with the highest and lowest corresponding to wood and gravel respectively as shown in fig.1. The mean value of radon concentration for all selected samples of building materials is 204.16 ± 48.73 Bq/m^3 which is higher than the 96.00 ± 70.00 Bq/m^3 obtained by Arabi et al (2015). The mean radium content for building materials in the present study is 83.71 ±8.24 Bq/kg whereas Arabi (2015) reported 32 ± 19 Bq/kg for different building materials in the same study area while Fasae (2013) reported 47.9 ± 9.8 Bq/kg for concrete blocks in Ekiti State, Southwest –Nigeria. The differences in the results may be as a result of the difference in the building materials studied. It can be seen from table 1 that a combination of sand, cement, and granite used for block construction would give the highest indoor radon concentration. One can also see from table 1 that the radon exhalation rate in terms of mass varies from 0.44 Bq/kg.h – 0.79 Bq/kg.h. Notice that wood has the highest exhalation rate (0.79 Bq/kg.h) due to its high level of radium content (104.40 Bq/kg). On the other hand, gravel has the least exhalation rate and radium content. The mean value of radium exhalation rate is found to be 0.63 ±0.06 Bq/kg.h. Our results show that the values of radium content for all the selected building materials are far below the permissible safe limit (OECD, 2009) and therefore suggest that they pose no radiation hazard.

Since radium is the parent nuclide of radon, it becomes necessary to plot a graph of radium content against radon concentration of the selected building materials as seen in fig.2. This figure helps us to examine the correlation coefficient or quality factor (R^2) between the two physical parameters. The R^2 value obtained is 0.9997. Our R^2 value is exactly the same as that obtained from similar research in Egypt (Rafat, 2015). This shows a very strong correlation between radium content against radon concentration. Statistical errors may have accounted for why the R^2 value is not equal to unity. It may also be an indication of negligible radon back absorption that may have occurred in the sample matrix.

Table 1: Radon concentration (C_{Rn}), exhalation rates (E_m), radium content (C_{Ra}), equilibrium radon concentration in building materials

SAMPLE	Mass(Kg)	C_{Rn}(Bq/m³)	E_m(Bq/kg.h)	C_{Ra}(Bq/kg)	C_{eq}(Bq/m³)
Wood	0.6	253	0.79	104.4	830.7
Sand	0.6	249	0.77	101.75	817.56
Cement	0.6	228	0.71	93.83	748.61
Granite	0.6	204	0.63	83.36	669.81
Clay	0.6	149	0.46	60.79	489.22
Gravel	0.6	142	0.44	58.15	466.24
	MEAN	204.16 ±48.73	0.63 ±0.06	83.71 ±8.24	670.36 ±65.31

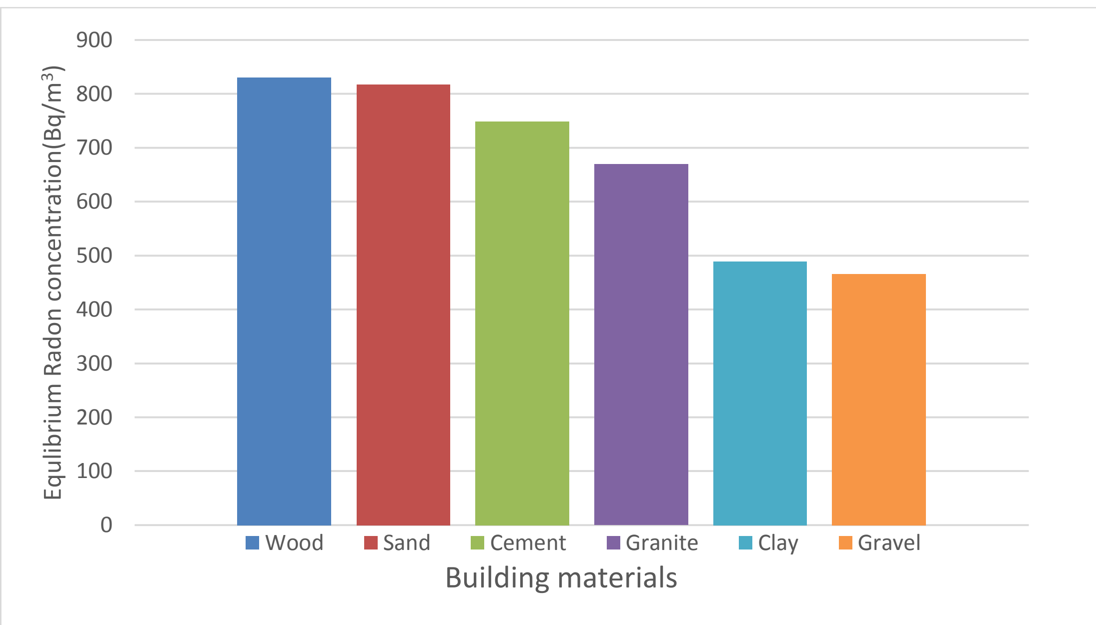

Fig. 1: Variation of radon exhalation rate for selected building materials

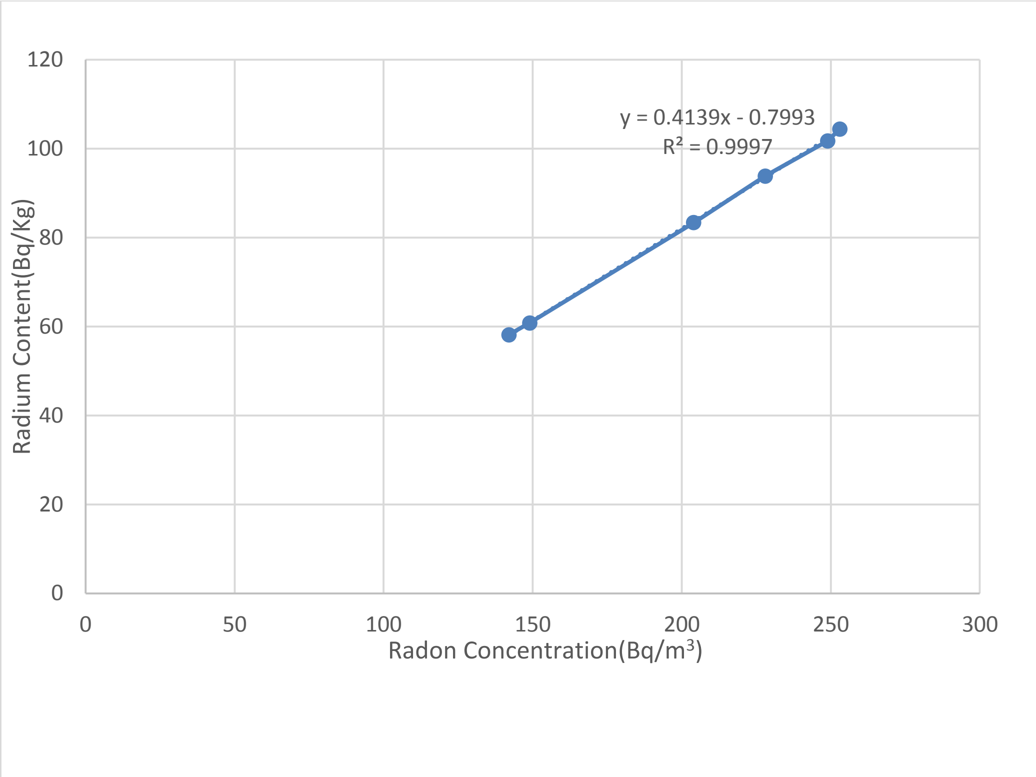

Fig. 2: Variation of radon exhalation rate with radon concentration

Table 2 shows a comparison between our results for radon exhalation rate and that obtained in other parts of the world. It is obvious that radon exhalation rate in terms of mass is higher than that obtained from the selected references. Our results compare well with most of the countries and fall within international limits.

Table 2: Comparison of Radon exhalation tare of building materials in different countries

SAMPLE	Country	E_m(Bq/kg.h)	References
Wood	Nigeria	0.79	present work
Sand	Nigeria	0.77	Present work
	India	0.05	Pankaj et al, (2017)
	Saudi Arabia	0.59	Abo-Elmagd et al. (2018)
	Iraq	0.022	Zakariya et. al (2013)
Cement	Nigeria	0.71	Present work
	Saudi Arabia	0.26	Abo-Elmagd et al. (2018)
	Egypt	0.019	Shoeib and Thabayneh (2014)
	Sudan	0.0045	Elzain (2014)
Granite	Nigeria	0.63	present work
	India	0.81	Pankaj et al, (2017)
Clay	Nigeria	0.46	present work
Gravel	Nigeria	0.44	Present work
	Saudi Arabia	0.14	Abo-Elmagd et al. (2018)
	Lebanon	0.037	Kobeissi et al. (2008)

CONCLUSION

The closed chamber or accumulator method has been used to determine radon exhalation, radium content and radon concentration of some common building materials in samara Zaria Nigeria. Wood has the highest exhalation rate (0.79 Bq/kg.h) which is due to its high level of radium content (104.40 Bq/kg) while gravel has the least exhalation rate (0.44 Bq/kg.h) and radium content. All measured parameters for all the selected building materials is below the permissible safe limit (OECD, 2009) and therefore suggests that they pose no radiation risk.

REFERENCES

Pankaj Bala1, Vinod Kumar1 and Rohit Mehra (2017) Measurement of radon exhalation rate in various building materials and soil samples, *Journal of earth system science* 126:31 DOI 10.1007/s12040-017-0797-z

Organization for Economic Cooperation and Development, OECD. (2009). Exposure to radiation from natural radioactivity in building materials. Report by a group of experts of the OECD. Nuclear Energy Agency.

Nisha Sharma, Jaspal Singh, S. Chinna Esakk R.M. Tripathi (2016) A study of the natural radioactivity and radon exhalation rate in some cements used in India and its radiological significance *Journal of Radiation Research and Applied Sciences 9 (2016) 47-56.*

Stoulos, S., Manolopoulou, M., & Papastefanou, C. (2003).Assessment of natural radiation exposure and radon exhalation from building materials in Greece. Journal of Environmental Radioactivity, 69, 225e240**.**

Lu, X., Li, N., Yang, G., & Zhao, C. (2013). Assessment of natural radioactivity and radiological hazards in building materials used in Yan'an, China. Health Physics, 104(3), 325e331.

Duggal, V., Mehra, R.A. J Geol Soc India (2015) 86:331https://doi.org/ 10.1007/s12594-015-0319-z

Rafat M. Amin (2015) A study of radon emitted from building materials using solid state nuclear track detectors *Journal of Radiation Research and Applied Sciences 9 (20 15) 516-522.*

European Commission (EC), Radiation Protection Unit. (1999). Radiological protec- tion principles concerning the natural radioactivity of building materials. Radiation Protection, 112.

Rafique, M., Rehman, H., Matiullah, Malik, F., Rajput, M., Rahman, S., et al. (2011). Assessment of radiological hazards due to soil and building materials used Mirpur Azad Kashmir, Pakistan. Iranian Journal of Radiation Research, 9(2), 77.

Abo-Elmagd M, Ahmed Saleh , G. Afifi Evaluation of radon related parameters in environmental samples from Jazan city, Saudi Arabia *Journal of Radiation Research and Applied Sciences 9 (2018) 104-110.*

Elzain, A. (5 June 2014). Radon exhalation rates from some building materials used in Sudan. published online Indoor and Built Environment, 1-9

Harb .S, N. K. Ahmed, Sahar Elnobi (2016), Effect of Grain Size on the Radon Exhalation Rate and Emanation Coefficient of Soil, Phosphate and Building Material Samples *Journal of Nuclear and Particle Physics 2016, 6(4): 80-87* DOI: 10.5923/j.jnpp.20160604.02

Shoeib, M. Y., & Thabayneh, K. M. (2014). Assessment of natural radiation exposure and radon exhalation rate in various samples of Egyptian building materials. Journal of Radiation Research and Applied Sciences, 7, 174-181

Natural radioactivity measurements in building materials in Southern Lebanon (2008)..Kobeissi, M. A., El Samad, O., Zahraman, K., Milky, S., Bahsoun, F., & Abumurad, K. M. *Journal of Environmental Radioactivity,* 99, 1279e1288.

Background Radiation and Radiological Hazard Associated with Local Building Materials around Zaria, Nigeria (2015) Arabi .A.S, Funtua I.I, B. B. M. Dewu, and A. M. Muhamma *Radiochemistry,* 2015, Vol. 57, No. 2, pp. 207–212.

Natural Radioactivity in Locally Produced Building Materials in Ekiti State, Southwestern Nigeria (2013) Fasae K.P *Civil and Environmental Research* Vol.3, No.11,