Journal of the Nigerian Association of Mathematical Physics
***Volume 60* (April – June *2021 Issue*), pp157 –166**
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RADON EXHALATION RATES AND EFFECTIVE DOSES IN GRANITES AND GRAVELS USED FOR RESIDENTIAL BUILDINGS IN SOUTH-WESTERN NIGERIA

Aladeniyi K.

Department of Physics, Federal University of Technology, Akure, Ondo State, Nigeria

Abstract

Granites and gravels are popularly used for building constructions in the SW Nigeria and the materials are known to contain radium in varying quantities and the materials may therefore be potential sources of indoor radon when use for residential buildings. To assess the potential health hazard due to the applications of the materials as building materials, samples of the materials were randomly collected across the study area, processed and analyzed for radon exhalation rates, efficient radium contents and annual effective dose using a closed can technique. The results show that radon concentrations, mass exhalation rates, surfaces exhalation and the effective radium contents varied appreciably among the samples The computed annual effective doses ranged from 0.06 to 0.26 mSvy^{-1} with a mean value of 0.15 mSvy^{-1} for the granites and 0.01 to 0.15 mSvy^{-1} with a mean value of 0.08 mSvy^{-1} for the gravels. The effective doses of all the investigated materials fall below the lower limit of the range of recommended action level (3-10 mSvy^{-1}) of the International Commission on Radiation Protection (ICRP). Therefore, the materials are considered safe for building constructions and hence no health hazard can be posed to the residents of the study area. The data of this study would form part of data bank on radon assessment in building materials and formulation of guide for technical and economic use of the investigated materials.

***Keywords*:** Radon, Exhalation rates, CR-39, Building materials, Granites and Gravels.

1 Introduction

Radon (^{222}Rn) with its progeny is a noble and radioactive gas, recognized as a class A carcinogen and by ranking, it assumes second position among lung cancer-causing agents after smoking [1]. It is naturally produced from ^{226}Ra in the decay series of ^{238}U. Radium, ^{226}Ra (^{238}U) is naturally present in varying quantity in almost all components (Rocks, Soils, water, building materials etc.) of the Earth Crust. Being an inert gas with relatively long half-life (3.82 days), ^{222}Rn has a great potential to migrate from its point of generation through rocks and soils underlying dwelling places and gets released into enclosed indoor environments (rooms) where it may be trapped without interacting with the surrounding elements. In any room with inadequate ventilations, the trapped gas may rise significantly to elevated levels and becomes hazardous to human health upon continuous inhalation [2–4]. As a radioisotope, ^{222}Rn may decay either prior to its inhalation or decay directly in the lung chamber after inhalation to release its short-lived radioactive daughters (^{214}Po and ^{218}Po) and alpha particles which in turn bombard the cells of the lining of the lung, leading to development of lung cancer. Apart from soils and rocks underneath residential buildings that generates radon gas which migrates into rooms, building materials such as granite and gravels sourced from the Earth Crust and used for building construction sometimes become sources of indoor radon with elevated level if not checked. Granites and gravels are natural resources, mined from various locations in Nigeria for residential buildings and other industrial applications. The materials are recognized to contain Naturally Occurring Radioactive Materials (NORMs) in varying amount depending on the geology of the sourcing locations. Granites

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Corresponding Author**:** Aladeniyi K., Email: kaladeniyi@futa.edu.ng, Tel: +2348038031783

and gravels are aggregates that form the major components (60-80%) of concretes used for flooring, ceiling, wall blocks and pillars in residential houses. Granites are igneous rocks composed mainly of not only Quartz and Alkalie but also contain Feldspar all of which are rich in NORMS, that is, ^{40}K is found in white or pink feldspars, ^{40}K, ^{238}U (the ultimate precursor of ^{226}Ra) and ^{232}Th in hornblendes and black biotites, ^{238}U and ^{232}Th in apatite, zircon and sphene minerals [1,5]. As one of the major building materials that contains ^{238}U (^{226}Ra), it has the potentials of becoming major source of indoor radon. In the same vain, gravel is a loosely packaged of small and variously sized particles of rocks, formed naturally by weathering and erosion of rocks. It may also be manufactured artificially in gravel pits (quarries) where rocks like basalt, limestone and sandstone are broken down into range of sizes (from 2mm to over 60 mm), characterized by textures, colours and stone types. Although the use of granite for residential buildings in SW-Nigeria is gradually gaining popularity, gravel-built houses are common especially among rural areas or among the low income earners. This is not unconnected with the fact that the cost of producing granites during blasting and crushing of solid rocks and the cost of transportation of the products to the point of use are on the high side [6], whereas gravels are abundant, cheap and easily accessible as compared with granites. Even though buildings are indispensable property of human life, since most individuals spend more than 80% of their time indoors to derive comforts, sometimes buildings can subject the dwellers to life-threatening conditions if certain building materials such gravel and granites are not checked for radon-emitting properties prior to use. The rocks and soils underneath residential buildings constitute the major sources of indoor radon while significant contributions of indoor radon concentration may come from the building materials used for flooring, walls, roofing, plastering etc. To assess the contributions of the building materials to the total indoor radon levels, a parameter referred to as radon exhalation rates is determined. To accurately assess the level of indoor radon exposure to human population, the knowledge of radon exhalation rates in building materials such as granites and gravels is very important and this will enhance evaluation of potential radiological hazards that may be associated with the gas level at home [7–11]. Like in the soils, when ^{226}Ra undergoes alpha disintegration within the building materials, ^{222}Rn is emitted and migrated through the pore space of the materials in the process referred to as emanation which is governed mainly by recoil process and less by diffusion because of the state of the matter. The ratio of the amount of radon getting into the pore space to the amount of the generated radon is called emanation coefficient of the gas. By diffusion and advection, the radon atoms in the pore spaces of the materials travel and get decayed or released into the atmosphere in the process known as radon exhalation [12,13]. The amount of activity of releasing radon per unit surface area or per unit mass per time is referred to a radon exhalation rates. Radon exhalation does not only depend on emanation coefficients but also depends on a chain of factors such as concentration of ^{226}Ra in the materials, geology of the location, atmospheric pressure, surface wind etc. Realizing the possible health hazards via exposure to indoor radon and knowing fully well that building materials sourced from the Earth crust have potentials to sometimes contribute significantly to the effective radiation dose from indoor radon, several studies on radon exhalation rates of soil and building materials have been globally reported in the past four decades and more studies are under ways [14–18]. Although huge amount of studies on specific activity concentrations with association risks have been carried out and reported in Nigeria, to the best of our knowledge there is little or no work carried out on radon exhalation rates on soil and building materials in Nigeria.

In this study, radon concentrations and radon exhalation rates in two major building materials, that is, granites and gravels selected from SW-Nigeria were measured using closed can technique with solid state nuclear track Detector (SSNTD) that is, CR-39 type. Effective radium contents, the contributions of the materials to the total indoor radon concentration, Potential alpha energy and annual effective dose due to radon concentration in the materials were evaluated. The research presents good data that form part of data bank for technical and economic use of the investigated materials.

2 Materials and Methods

2.1 Study Area

The study area, SW-Nigeria, can be found between longitudes 2^0 30’ E and 7^0 00’E and between latitude 4^0 00’N and 7^0 00’N, comprising six states namely; Lagos, Ogun, Osun, Oyo, Ondo and Ekiti, states. The SW-Nigeria falls within the equatorial rain forest region in Africa. Geologically, the area is underlain by basement complex rock with a thick bed of sedimentary rock occupying the southern part of the area. Common Precambrian basement rock units dominating the area are pegmatites, granites, migmatites, and host of others like gneisses, quartzite and schist/metasediments. Granites and gravels are mined from different locations across the area for residential and industrial building constructions. The bed rocks in this study area weathered to form various soils characterized by heterogeneous properties [19]. The use of gravels for building constructions is more popular in the rural areas than the use of granite while granite usage takes prominence over gravel in urban areas, this may be due to the cost of production and transportation difference.

2.2 Sample Collections and Sample Preparation

A total of 14 samples of granites and 17 samples of gravels (approximately 600-800g each) were randomly collected from different deposits and quarries across the SW-Nigeria. The samples were separately packaged into polythene bag at the point of collection and transported to the laboratory in the Department of physics, Federal University of Technology, Akure for pre-treatment prior to final radon-analytical process. At the laboratory, all the samples were sundried, ground, sieved through 2mm mesh and thereafter oven dried at 110 ^{0}C for hours until each sample attained a constant weight. 200g of each sample was poured into in a prepared cylindrical plastic can of volume 500 cm^3. In each of the sample-filled plastic containers, a CR-39 radon detector (batched calibrated and supplied by Radosy Limited in Portugal) was installed on the inner surface of the container lid such that the sensitive surface of the detector faced the sample. The sensitive surface of the exposed detectors record the tracks placed on it by emitted alpha particles upon the decay of ^{222}Rn as it released from ^{226}Ra and exhaled from the sample surfaces. Each of the sample-filled plastic can, together with the detector inside it was hermetically sealed and kept for three months prior to laboratory analysis as shown in the Fig. 1. The exposed detectors were retrieved from the containers and packaged into an airtight container for easy transfer to the Laboratory of Natural Radioactivity at the University of Coimbra, Portugal where analysis took place. Background exposures due to transit and storage were considered using separate detectors (10), carried along with the exposed ones. In the laboratory, each of the exposed radon detectors was chemically etched in a 30 % solution of NaOH, at a constant temperature of 90 ^oC for 4 hrs. The numbers of tracks produced by alpha particles on the detector were automatically counted using digital image-processing techniques (Radosys system). Tracks per unit area [track densities, T_D (Track per cm^2)] on the detectors were computed and converted into radon activity concentration $C_{Rn,}$ (Bq.m^{-3}) as shown in equation (1). The measured activity concentrations of the ^{222}Rn were used to evaluate surface E_X (Bq.m^{-2}h^{-1}) and mass E_M (Bq.kg^{-1}h^{-1}) exhalations rates with the application of the predetermined calibration constant, K_{Rn} (Track cm^{-2}.h^{-1}/ Bq.m^{-3}) with equations (2) and (3) [13,15,18,20–23];

$$C_{Rn} = \frac{T_D}{K_{Rn}T} \qquad (1)$$

$$E_X = \frac{\lambda V T C_{Rn}}{A[T + \lambda^{-1}\{exp(-\lambda T) - 1\}]} \qquad (2)$$

$$E_M = \frac{\lambda V T C_{Rn}}{M[T + \lambda^{-1}\{exp(-\lambda T) - 1\}]} \qquad (3)$$

where T is the exposure time (hours), V is the hollow holder volume (m^3), λ is the radon decay constant (h^{-1}), A is the surface area (m^2) from which radon is exhaled and M is the mass of the sample (kg). To avoid underestimation of parameters due to possible leakages from the sample-filled plastic containers and back diffusion, the line of contact between the lids and containers were doubled sealed with impermeable cellotape for radon leakages and the back diffusion was accounted for by replacing the radon constant (λ) with effective decay constant (λ_e) using equation (4) [24];

$$\lambda_e = \lambda + \lambda_b \qquad (4)$$

Where λ_b is referred to as back diffusion. The back diffusion effects set in when the radon (concentration) emitted by the materials in the sealed containers grows and diffuses back to the materials for its porosity. The effects reduce the equilibrium radon concentration in the containers and hence, the needs to account for the effects using λ_b as shown in equation (4). The back diffusion λ_b is defined according to equation (5) [24];

$$\lambda_b = \frac{\alpha S}{V_a} = \frac{\lambda V_s}{V_a} \qquad (5)$$

Where α, S, V_s and V_a are the correction term for the effects of back diffusion, sample surface area(m^2), sample volume(m^3) and the air space volume (m^3) of the sealed container respectively.

2.3 Other Radiological Indices

The effective radium contents (ERC) of the samples were calculated using equation (6) [23]:

$$ERC = \frac{T_D h A}{K_{Rn} T_e M} \qquad (6)$$

where T_D is the track density in Track per cm^2, M is the mass of the sample, A, the area of cross-section of the cylinder in

m^2, h the distance between the detector and the top of solid samples in m, K_{Rn} is the calibration constant in (Track $cm^{-2}.h^{-1}$/ $Bq.m^{-3}$) and T_e is the effective exposure time in hour. The effective exposure time is calculated using equation (7)

$$T_e = T - \frac{1}{\lambda}\left(1 - e^{-\lambda T}\right) \qquad (7)$$

Or

$$T_e = T + \frac{1}{\lambda}\left(e^{-\lambda T} - 1\right) \qquad (8)$$

where T is the exposure time (hours) and λ is the radon decay constant (h^{-1}). It is well known that all building materials that contain ^{226}Ra or ^{238}U will emits ^{222}Rn as the parents' radionuclide disintegrates. In a typical room, ^{222}Rn is being generated through the disintegration of ^{226}Ra from both the soil and the walls and at the same time ^{222}Rn is being lost through α-alpha decay of itself and through ventilation and therefore the contribution (C_{RnC}) of the building materials to the indoor radon concentration is the excess indoor radon generated by the building materials (granite and gravels) which is may be calculated using (9):

$$C_{RnC} = \frac{E_X \times S_R}{V_R \times A_R} \qquad (9)$$

where E_X is the surface exhalation rates, S_R represents the surface area of the room, V_R the volume of the room and $A_R = 0.5$ h^{-1} is the air exchange rate. In this study the maximum indoor radon concentration from the building materials are obtained with the assumption that the room is a cavity with the ratio (S_R/ V_R) = 2.0 m^{-1} [10]

The risk from radon inhalation is closely related to the energy imparted by the short-lived daughters of radon in the radiosensitive cells of the respiratory system [25].By convention, the concentration of radon daughters is measured in working levels (WL) and the accumulation of exposures over a month (170 h per month) are measured in working level months (WLM).The annual exposure potential alpha energy E_{AP} (WLM y^{-1}) was related to the average radon concentration contributed by the materials based on equation (10) [26]:

$$E_{AP} = \frac{8760 \times n \times F \times C_{RnC}}{170 \times 3700} \qquad (10)$$

where, C_{RnC} is in Bq m^{-3}; n is the fraction of time spent indoor (0.8); 8760 is the number of hours per year; 170, the number of hours per working month and F, the equilibrium factor for radon which is assumed as 0.4 as suggested by [27] . Applying a conversion factor of 6.3 mSv $(WLM)^{-1}$ according to [28] the effective dose (EFD) in mSv were estimated as follows:

$$EFD = 6.3 \times E_{AP} \qquad (11)$$

3 Results and Discussion

Table 1 and Table 2 show the results of the measured radon concentrations, exhalation rates, effective radium contents, and radon contributions to indoor radon concentration for investigated granites and gravels respectively. Shapiro-Wilk test of normality ($P<0.05$) indicated that the measured radon concentrations from both granites and graves were not from normally distributed population. However, a Mann-Whitney U test revealed that measured radon concentrations in granites (Md = 1478.84, n = 17) were significantly higher than the concentrations in the gravels (Md = 555.0, n = 14), U = 46.0, Z = -2.898, P = 0.003, with an effect size of 0.52. This indicates that more exposure to indoor radon is possible in homes built with granites than those built with gravels. Excessive use of granites in building foundations and room flooring should be minimized to avoid undue exposures to indoor radon. Although the use of granite for concretes and other building constructions is preferred to the use of gravel, previous studies have shown that granites may not be suitable as a building materials because of the higher radionuclide content in granites than in other building materials [1,29,30]. The mass and the surface exhalations rates varied from 9.74 mBq kg^{-1} h^{-1} (GN17) to 44.97 mBq kg^{-1} h^{-1} (GN9) with an arithmetic mean (AM) of 25.90 mBq kg^{-1} h^{-1} and geometric mean (GM) of 22.41 mBq kg^{-1} h^{-1}, from 505.87 mBq m^{-2} h^{-1} (GN17) to 2336.29 mBq m^{-2} h^{-1} (GN9) with an arithmetic mean (AM) of 1345.56 mBq m^{-2} h^{-1} and geometric mean (GM) of 1164.14 mBq m^{-2} h^{-1} respectively for granites. Whereas, the mass and the surface exhalation rates varied from 1.74 mBq kg^{-1} h^{-1} (GV14) to 25.76 mBq kg^{-1} h^{-1} (GV1) with an arithmetic mean (AM) of 13.14 mBq kg^{-1} h^{-1} and geometric mean (GM) of 8.70 mBq kg^{-1} h^{-1}, from 90.54 mBq m^{-2} h^{-1} (GV14) to 1338.13 mBq m^{-2} h^{-1} (GV1) with an arithmetic mean (AM) of 682.67 mBq m^{-2} h^{-1} and geometric mean (GM) of 452.20 mBq m^{-2} h^{-1} respectively for gravels. The obtained average of mass exhalation rate, 25.90 mBq kg^{-1} h^{-1} in this study is less than the reported value 270 mBq kg^{-1} h^{-1} by Aykamiş *et al* [31] from Turkey, 74.36 mBq kg^{-1} h^{-1} by Bala *et al*., [32] from India and 15.5 mBq kg^{-1} h^{-1} by Shoeib & Thabyneh [33] from Egypt for granites. The obtained average value of surface exhalation rate 1346 mBq m^{-2} h^{-1} is higher than 88, 159, 204 and 240 mBq m^{-2} h^{-1} reported from Egypt, Turkey, Pakistan, and Iran respectively except 10600 mBq m^{-2} h^{-1} reported from Turkey for granites [12,15,31,33,34]. Both the average values of mass exhalation rate, 13 mBq kg^{-1} h^{-1} , and the surface exhalation rate 683 mBq m^{-2} h^{-1} obtained for gravels are higher than the corresponding average values 3.7 mBq kg^{-1} h^{-1} and 409 mBq m^{-2} h^{-1} presented by Kobeissi *et al*. from Lebanon [35], 1.7 mBq kg^{-1} h^{-1} and 75 mBq m^{-2} h^{-1} presented by Amin from southern Saudi Arabia [10]. The mean surface exhalation rates for granite and the gravels are far less than the world average values 57,600 mBq m^{-2} h^{-1} [1,12,13]. The relatively low of the radon exhalations rates may be attributed to radium contents of the materials. The radium content has direct link with geology of the area of interest. Other factors that determine the level of radon exhalation rates in building materials are porosity, permeability, density and grain size of the materials[24]. Table 3 shows the comparisons between the obtained radon exhalations rates (for granites and gravels) with for exhalations rates (for some building materials) of similar studies.

Effective radium content is a measure of actual release rate of radon from the materials. The effective radium contents of the investigated granites as shown in the Table 1, it ranged from 0.47 to 2.19 Bq kg^{-1} with a mean value of 1.26 Bq kg^{-1} while the effective radium contents for the gravels as presented in the Table 2 ranged from 0.08 to 1.21 Bq kg^{-1} with a mean value of 0.57 Bq kg^{-1}. All the calculated effective radium content in all the surveyed samples are far less than the permissible value of 370 Bq kg^{-1} as recommended by Organization for Economic Co-operation and Development (OECD) [36], indicating that the use of the surveyed granites and gravels for building purposes in the study area is safe as regards to the risks of exposure to indoor radon gas through radium decay. In other words, the study reveals that the suitability of the materials for building constructions is guaranteed as far as radiological hazard effect is concerned. The contribution of radon from the studied materials to indoor radon levels were computed using the surface exhalation rates with estimated mean values 5.38 ± 2.7 Bq m^{-3} 2.73 ± 2.00 Bq m^{-3} obtained for granites and gravels respectively. Granites and gravels are among the major building materials used for foundation, flooring, decking and decorations in the study area. Although granites and gravels are not the only building materials contributing to the levels of indoor radon at homes, results of this study reveal that radon contribution to indoor radon from the investigated materials may be considered insignificant when compared with the recommended action levels (100 Bq m^{-3}) of World Health Organization (WHO) [37], 148 Bq m^{-3} recommended by Environmental Protection Agency (EPA) [38] and 200 Bq m^{-3} by European Commission (EC) [39]. The computed radon contributions and the potential alpha energy according to equation (9) & (10) were used to calculate the annual effective dose with the results presented in the Fig. 2. The results ranged from 0.06 mSvy^{-1} (GN16) to 0.26 mSvy^{-1} (GN9) with a mean value of 0.15 mSvy^{-1} for the granites and 0.01 mSvy^{-1} (GV17) to 0.15 mSvy^{-1} (GV1) with a mean value of 0.08 mSvy^{-1} for the gravels. The effective doses of all the investigated building materials fall below the lower limit of the range of recommended action level (3-10 mSvy^{-1}) as given by the International Commission on Radiation Protection (ICRP) [40]. Therefore, the materials are considered safe for building constructions and hence no health hazard can be posed to the residents of the study area.

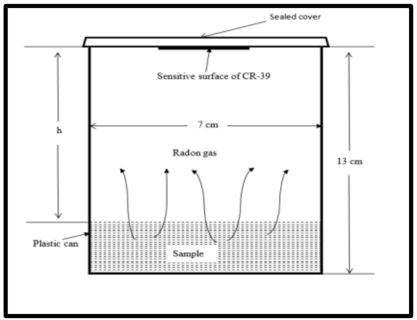

Figure 1 Experimental Set-up for Radon Concentration Measurement

Table 1 Radon Concentration, Exhalation Rates, Radium Contents and Radon Contribution from Granites

Samples	Radon Concentration (Bqm^{-3})	Mass Exhalation Rates (mBq kg^{-1} h^{-1})	Surface Exhalation Rates (mBq m^{-2} h^{-1})	Effective Radium Contents (Bq kg^{-1})	Radon Contributions (Bqm^{-3})
GN1	597.78	11.82	613.79	0.58	2.46
GN2	660.27	13.05	677.95	0.64	2.71
GN3	610.66	12.07	627.01	0.59	2.51
GN4	657.91	13.00	675.53	0.63	2.70
GN5	1559.27	30.82	1601.02	1.50	6.40
GN6	1457.20	28.8	1496.22	1.40	5.98
GN7	1588.12	31.39	1630.65	1.53	6.52
GN8	1478.84	29.23	1518.44	1.42	6.07
GN9	2275.36	44.97	2336.29	2.19	9.35
GN10	1819.63	35.97	1868.36	1.75	7.47
GN11	2102.98	41.57	2159.29	2.02	8.64
GN12	1901.34	37.58	1952.25	1.83	7.81
GN13	2073.32	40.98	2128.84	2.00	8.52
GN14	1877.14	37.1	1927.4	1.81	7.71
GN15	607.49	12.01	623.75	0.58	2.50
GN16	492.68	9.74	505.87	0.47	2.02
GN17	517.96	10.24	531.83	0.50	2.13
GM	**1133.78**	**22.41**	**1164.14**	**1.09**	**4.66**
GSD	**1.79**	**1.79**	**1.79**	**1.79**	**1.79**
Mean	**1310.47**	**25.90**	**1345.56**	**1.26**	**5.38**
SD	**656.54**	**12.98**	**674.12**	**0.63**	**2.70**

Table 2 Radon Concentration, Exhalation Rates, Radium Contents and Radon Contribution from Gravels

amples	Radon Concentration (Bqm^{-3})	Mass Exhalation Rates (mBq kg^{-1} h^{-1})	Surface Exhalation Rates (mBq m^{-2} h^{-1})	Effective Radium Contents (Bq kg^{-1})	Radon Contribution (Bqm^{-3})
GV1	1304.44	25.76	1338.13	1.21	5.35
GV2	1213.02	23.95	1244.36	1.12	4.98
GV3	1152.55	22.76	1182.32	1.07	4.73
GV4	1079.80	21.21	1101.62	0.75	4.41
GV5	1213.96	23.84	1238.49	0.84	4.95
GV6	1123.69	22.07	1146.4	0.78	4.59
GV7	393.58	7.78	404.11	0.38	1.62
GV8	526.59	10.41	540.69	0.51	2.16
GV9	344.23	6.8	353.44	0.33	1.41
GV10	583.42	11.53	599.04	0.56	2.40
GV11	91.21	1.8	93.66	0.09	0.37
GV12	124.45	2.46	127.78	0.12	0.51
GV13	94.32	1.86	96.84	0.09	0.39
GV14	88.18	1.74	90.54	0.08	0.36
GM	**441.10**	**8.70**	**452.20**	**0.39**	**1.81**
GSD	**2.73**	**2.73**	**2.72**	**2.56**	**2.72**
Mean	**711.17**	**14.02**	**728.22**	**0.60**	**2.91**
SD	**489.34**	**9.64**	**500.47**	**0.40**	**2.00**

Table 3 Comparison of exhalation rates of the study with the results of exhalation rates for some building materials in the world..

Building Materials	Countries	Mass Exhalation Rate E_m(mBq kg^{-1} h^{-1})	Surface Exhalation Rate E_A(mBq m^{-2} h^{-1})	References
Granites	**Nigeria**	**25.90 ± 12.98**	**1345.56 ± 674.12**	**Present work**
Gravels	Nigeria	**13.14 ± 9.64**	**682.67 ± 500.47**	**Present work**
Mud bricks	Sudan (Kasala)	9.65 ± 1.74	814 ± 69	[18]
	Saudi Arabia	3.93	196.58	[41]
Clay Bricks	Iberian Peninsula	4.3 ± 1.3		[42]
	Saudi Arabia	3.7	184.77	[41]
	Greece	0.011 ± 0.009	0.21 ± 0.18	[10]
Concrete Blocks	Sudan	4.34 ± 121	369 ± 48	[18]
	Iran	0.31 ± 0.03		[34]
Cement	Egypt	3.4	161.3	[32]
	Sudan	4.5	379	[18]
	Lebanon	1.3 ± 0.13	99 ± 11	[35]
	Egypt	19.5	93.26	[33]

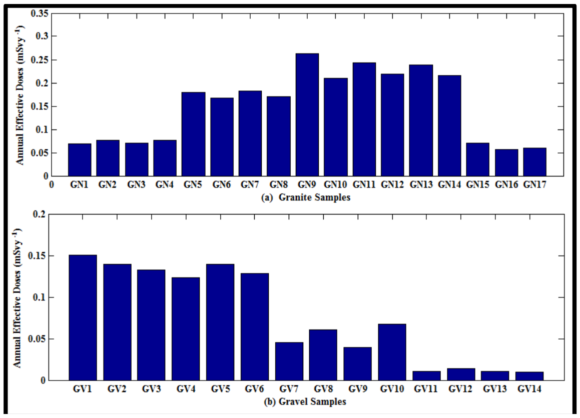

Figure 2 (a) Annual Effective dose in the surveyed granites (b) Annual Effective dose in the surveyed Gravels

4 Conclusion

Radon concentration, effective radium content, mass and surface exhalation rates in granites and gravels commonly used in south western Nigeria as building materials have been investigated using CR-39 radon detector in a Closed Can Technique. The results show that radon concentrations, mass exhalation rates, surfaces exhalation and the effective radium contents varied appreciably among the samples. The variation might be due to differences in the radium or uranium contents of the samples which is largely dictated by geological features of the origins of the materials. Porosity, permeability, texture and grain size of the materials were also suspected. The highest value of effective doses of all the materials falls below the lower limit of the range of recommended action level (3-10 mSvy^{-1}) as given by ICRP and from the radiological health point of view the materials under this study may be used for building construction without posing any radiological health hazards to the users.

Acknowledgement
I sincerely appreciate the efforts and the contributions of Prof. Pereira, Miss Filipa Domingos, Miss Jessica, Mr Nelson Simoes and the host of others in the Laboratory of Natural Radioactivity, Department of Earth Science, University of Coimbra, Portugal where the exposed radon detectors were analysed. Big thanks goes to Prof. O.S. Ajayi, Prof. A.M. Arogunjo and all the members of the academic staff of the Department of Physics, Federal University of Technology, Akure, Ondo State, Nigeria for their contributions in bringing this to reality.

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