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*Research Paper*

# Estimation of Indoor Radon from Concrete Blocks Used In Construction of Wall in Typical Nigerian Dwellings

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**ABSTRACT**

Radon gas is the most important source of natural radiation. Indoor radon concentration is the main path of human exposure to high radon concentration. Radon contribution from concrete block walls of typical Nigerian dwellings has been estimated from gamma ray spectroscopy measurements of radium concentration using generic equation. The radon concentrations varied from 11.27 Bq $m^{-3}$ for a dwelling of dimensions 4.8 m × 4.8 m and 18.52 Bq $m^{-3}$ for a dwelling of 3.6 m × 3.6 m. The effective dose varied from 0.28 to 0.47 mSv. All the results obtained are lower than the world average radon concentrations. The radiological hazard associated with the samples of building blocks considered in this study is not significant.

**Keywords:** radium, radon concentration, concrete blocks, dwellings

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## INTRODUCTION

Radon and its short-lived decay products in the atmosphere are the most important contributors to human exposure from natural sources of radiation. The inhalation of the short-lived decay products of $^{222}$Rn and their subsequent deposition along the walls of the various airways of the bronchial tree provide the main pathway for radiation exposure in the lungs (UNSCEAR 2000)

In recent years, awareness of the health risk due to exposure to radon and its progeny has led to numerous surveys to establish radon concentrations within domestic buildings. Radon is a noble gas produced by the alpha decay of $^{226}$Ra which is present in all terrestrial materials. It has a half life of 3.82 days. Radon produces a series of short-lived radioisotopes, known as radon daughter or progeny as it undergoes further radioactive decay. Radon itself is inert and causes little damage, since most of it is exhaled with breath. However, the progeny, Po-218 and Po-214, are electrically charged species and can be inhaled either directly or through their attachment to airborne particles. Once inhaled, the radon progeny tend to be retained in the lungs, where they may ultimately cause cancer (Hines et al, 1993).

Since radium is widely distributed in the earth's crust, it is present in trace amounts in all earth-based building materials. According to UNSCEAR (1977), the main contribution to radon indoors is from building materials. Other sources of significance may be the soil under the building, natural gas and radon-rich water. The radium content of building materials constitutes the

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source of the emanation of radon. High radon levels may be found in dwellings with high content of radium in the building materials (UNSCEAR, 1977). However, it is not possible on a general basis to correlate the radon levels in a building to radium content because of the influence of ventilation conditions.

To evaluate the contribution from building materials to indoor Rn concentrations, the most important factor is emanation rate (i.e. the rate at which the atoms are released into the atmosphere) of Rn from the material. One method for evaluating the emanation rate involves placing a sample of building material in a closed container and determining the buildup of Rn inside the container. In a situation where there are no facilities to determine the $^{222}$Rn emanating from building materials, there should be a way of making an estimate from the $^{226}$Ra content for the purpose of radiation protection at local level. In this study, the contribution of a basic building material, concrete building blocks, to indoor Rn concentrations from $^{226}$Ra content is evaluated using generic model given in UNSCEAR, 1977.

## MATERIALS AND METHODS

### 1. *Measurement of activity concentrations of $^{226}$Ra*

Concrete building blocks were collected from manufacturers in nine cities of Nigeria. The concrete building block consists of a mixture of cement, sand and water in an appropriate proportion. Five samples from each city were analysed for activity concentration of $^{226}$Ra. The samples were pulverized and dried. A mass of 100 g of each sample was placed in a cylindrical container of height 28 mm and diameter 70 mm. The containers were sealed and left for more than 4 weeks in order to allow for Ra and its short-lived progeny to reach radioactive equilibrium.

The activity concentrations of $^{226}$Ra in the samples were measured using coaxial HPGe (Hyperpure Ge) detector of model GC3018 – 7500SL (serial number 693085). The relative efficiency of the detector is 30% and has a resolution of 1.8 keV at 1.33 MeV (0.875 keV at 122 keV). The detector is maintained in a vertical position in a lead cylindrical shield of 10 cm thickness. The detector is coupled to a computer through a preamplifier base (model 2002CSL).

The energy calibration of the detector was performed using point sources of known energy from Amersham Buchier GmbH & Co. KG. Calibration was done for gamma energy range of 20.0 keV to 2.87 MeV. The efficiency calibration was done using reference sources R6/120/85 (QCY-48 solution) from Amersham, 97-273 (Cr-51 solution) and 12024 (Cs-137 solution). These are aqueous solution which contains well known concentrations (Bq kg$^{-1}$) of several isotopes emitting gamma- rays in a wide range of energies between 60 keV and 2 MeV. Dry quartz sand was used as sample matrix in order to simulate soil sample. This is almost free of natural radioactivity. The quartz sand was carefully mixed with the nuclide solutions and dried at low temperature until its initial mass was attained. The activity concentrations of $^{226}$Ra was determined from the photopeak of $^{214}$Pb (295.21 keV) and each sample was counted for 43200 s (12 h).

### 2. *Evaluation of indoor $^{222}$Rn*

The method used in this study involves combining the knowledge of Ra content in the building material, based on gamma spectrometry, with an assumed Rn emanation rate (Quindos et al., 1988). The conversion factors used to calculate the emanation rate for different building materials are given in the report by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 1977). Three dimensions of dwelling were considered in this study (Osasona, 1991);

1. 4.8 m × 4.8 m × 3.0 m
2. 4.8 m × 3.6 m × 3.0 m
3. 3.6 m × 3.6 m × 3.0 m

These dimensions are types inhabited by most low/middle income groups in Nigeria (Osasona, 1991). For the calculation of the emanation rates, the estimated emanation rate per unit activity concentration of $^{226}$Ra, 0.072 Bq m$^{-2}$ s$^{-1}$ per Bq kg$^{-1}$ given in UNSCEAR, 1977 was used.

Using the dimensions of room stated and the data from Table 1, the contribution from concrete to the indoor Rn concentrations were calculated by the expression (UNSCEAR, 1977);

$$C_{in} = C_o + \frac{e \times A}{(\lambda + \nu)V} \qquad (1)$$

where

$C_{in}$ = indoor Rn concentration (Bq m$^{-3}$)
$C_o$ = outdoor Rn concentration (Bq m$^{-3}$)
$A$ = area of room (m$^2$)
$\lambda$ = decay constant of $^{222}$Rn (0.00755 h$^{-1}$)
$\nu$ = ventilation rate and
$V$ = volume of room (m$^3$)

The outdoor Rn concentration was taken as 10 Bq m$^{-3}$, the world average reported by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000). Ventilation rate of 1 h$^{-1}$ was assumed. This according to Quindos et al., 1988 is more common for houses that are less energy efficient and covers a wide spectrum of houses seen throughout the world.

The annual effective dose was calculated using the following equation (UNSCAER 2000);

$$E = C_{in} \times EF \times T \times DC \qquad (2)$$

where $E$ is annual effective dose, $EF$ is equilibrium factor, $T$ is the occupancy and $DC$ is the dose coefficient.

## RESULTS AND DISCUSSION

The mean activity concentrations of $^{226}$Ra in the concrete building blocks ranged from 24.9 ± 1.9 to 120.7 ± 85.4 Bq kg$^{-1}$ (Table 1). The errors quoted are the standard deviations from the means. The means of $^{226}$Ra content of the samples examined in this work are less than the world average for building material, 50 Bq kg$^{-1}$ (OECD 1979, UNSCEAR 1993), with the exception of the samples collected from Jos.

**Table 1:**
Activity concentrations of $^{226}$Ra and emanation rates of concrete building blocks

| Town | $^{226}$Ra (Bq kg$^{-1}$) | | Emanation rate (Bq m$^{-2}$ h$^{-1}$) |
|---|---|---|---|
| | Range | Mean± Std. Dev | |
| Abeokuta | 16.7– 73.5 | 42.7 ± 25.2 | 3.07 |
| Ado Ekiti | 27.7 – 42.3 | 35.9 ± 5.8 | 2.58 |
| Akure | 35.7 – 51.4 | 40.6 ± 6.4 | 2.92 |
| Jos | 36.2 – 238.3 | 120.7 ± 85.4 | 8.69 |
| Ibadan | 13.6 – 61.6 | 31.8 ± 20.6 | 2.29 |
| Lagos | 7.7 – 43.8 | 28.5 ± 15.1 | 2.05 |
| Ogbomoso | 23.3 – 28.2 | 24.9 ± 1.9 | 1.79 |
| Osogbo | 43.9 – 53.5 | 48.1 ± 3.5 | 3.46 |
| Oyo | 22.5 – 30. | 25.7 ± 3.8 | 1.85 |

Based on the Ra-226 content of concrete building blocks the contribution of Rn-222 due to concrete building blocks to indoor radon concentration had been estimated for different dimensions of room. The results are presented in Table 2. Corrections were made for windows and doors. The results obtained ranged from 11.27 to 16.15 Bq m$^{-3}$ for room of dimensions 4.8 m × 4.8 m, 11.56 to 17.59 Bq m$^{-3}$ for room of dimensions 4.8 m × 3.6 m and 11.76 to 18.52 Bq m$^{-3}$ for dimensions 3.6 m × 3.6 m. The results show that for same amount of $^{226}$Ra in a concrete block, the Rn concentration increases with decrease in the dimensions of room. All the results obtained in this study are lower than the world average of 40 Bq m$^{-3}$ for indoor radon (UNSEAR 2000). However, there could be contributions from other sources, but it is not likely that these contributions would be more than those from the concrete building blocks since they are the major component of the room

**Table 2:**
Estimated indoor radon concentration contribution due to concrete walls

| Town | Indoor Radon concentration (Bq m$^{-3}$) | | |
|---|---|---|---|
| | 4.8 × 4.8 ×3.0 m$^3$ | 4.8 × 3.6 × 3.0 m$^3$ | 3.6 × 3.6 × 3.0 m$^3$ |
| Abeokuta | 12.17 | 12.68 | 13.01 |
| Ado Ekiti | 11.83 | 12.25 | 12.53 |
| Akure | 12.07 | 12.55 | 12.86 |
| Jos | 16.15 | 17.59 | 18.52 |
| Ibadan | 11.62 | 12.00 | 12.25 |
| Lagos | 11.45 | 11.79 | 12.01 |
| Ogbomoso | 11.27 | 11.56 | 11.76 |
| Osogbo | 12.45 | 13.02 | 13.39 |
| Oyo | 11.31 | 11.62 | 11.81 |

To quantify the effect of radiation hazard, the radon concentrations were converted to effective dose. Using equilibrium factor for indoor radon, 0.4, occupancy, 7000 h and dose coefficient, 9 nSv per Bq h m$^{-3}$ (UNSCEAR, 2000), the annual effective dose was calculated. The annual effective dose varied from 0.28 mSv for a dwelling of dimensions 4.8 m × 4.8 m to 0.47 for a dwelling of 3.6 m × 3.6 m. All the results are lower than the world average of 1.0 mSv (UNSCEAR 2000).

**Table 3:**
Annual effective dose due to indoor radon concentrations from concrete walls

| Town | Annual effective dose (mSv) | | |
|---|---|---|---|
| | 4.8 × 4.8 ×3.0 m$^3$ | 4.8 × 3.6 × 3.0 m$^3$ | 3.6 × 3.6 × 3.0 m$^3$ |
| Abeokuta | 0.31 | 0.32 | 0.33 |
| Ado Ekiti | 0.30 | 0.31 | 0.32 |
| Akure | 0.30 | 0.32 | 0.32 |
| Jos | 0.41 | 0.44 | 0.47 |
| Ibadan | 0.29 | 0.30 | 0.31 |
| Lagos | 0.29 | 0.30 | 0.30 |
| Ogbomoso | 0.28 | 0.29 | 0.30 |
| Osogbo | 0.31 | 0.33 | 0.34 |
| Oyo | 0.29 | 0.29 | 0.30 |

## Conclusion

Indoor radon concentration has been estimated from the radium content of concrete building blocks using generic equation. Typical Nigerian dwellings were considered in this study. The radiological hazard associated with the samples of building blocks considered in this study is not significant. This method could be used to estimate indoor radon concentration for radiation protection purpose in a situation where there are no facilities for the determination of emanation rate of the materials.

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