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Contributions of covering materials to indoor radon concentration in buildings in Ogbomoso, Nigeria

Oni O. M[1], Oladapo O.O[2*] and Oni E.A[1]

[1]Department of Pure and Applied Physics, Ladoke Akintola University of Technology, P.M.B. 4000 Ogbomoso, Nigeria.
[2]Department of Science Laboratory Technology, Ladoke Akintola University of Technology, P.M.B. 4000 Ogbomoso, Nigeria.

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ABSTRACT

The contributions of different covering materials used on internal building surfaces including walls, ceilings and floors to indoor radon concentration in 36 buildings were measured using an active electronic device, the Safety Siren Pro Series 3 Radon Detector (Model HS71512). The three commonest combinations of covering materials in Ogbomoso are (A): paint, paint, carpet; (B): paint, fibre board, plastic tile; (C): paint, fibre board, ceramic tile. The buildings with combination (C) contributed the highest to the indoor radon concentration in buildings investigated in Ogbomoso while buildings with combination (A) contributed the least. The mean value for combinations (B) and (C) were found to be slightly greater than the world average of 40 Bqm^{-3} (UNSCEAR, 2000). A person living in building with combination (A) receive an annual dose to the lungs smaller than someone living in a building with combination (B) and (C) by 2.0216 x 10^{-8} Svy^{-1}

Introduction

Until the 1970s radon (UNSCEAR, 2000) and its progeny were regarded as radiation health hazards encountered only in the mining and processing of uranium ore. This notion has changed markedly as a result of increasing efforts made in many States to measure radon in dwellings, mines other than uranium mines, and workplaces suspected of having high atmospheric radon levels.

In lung dosimetry models, in which deposition sites of radioactive material and locations of target cells are taken into account, the risk per unit of inhaled radioactive material is considered to be much greater for radioactive material in the unattached state than for radioactive material in the attached state (NRC, 1991). While it is the radon progeny rather than radon gas itself that presents the greater risk, the word 'radon' is also used generally as a convenient shorthand for both the gas and its progeny. Radon has been recognized as a radiation hazard causing excess lung cancer among underground miners (ICRP, 1981). Consequently radon has been classified as a human carcinogen (IARC, 1988). Since the 1970s, evidence has been increasing that radon can also represent a health hazard in non-mining environments (WHO, 1993; ICRP, 1993). Since environmental radon on average accounts for about half of all human exposure to radiation from natural sources (UNSCEAR, 2000), increasing attention has been paid to exposure to radon and its associated health risks in both industrialized and developing countries.

In buildings with high radon levels, the main mechanism for the entry of radon is the pressure driven flow of gas from soil through cracks in the floor. This flow arises because buildings are normally at a slight with respect to their surroundings. This under pressure is a consequence of the air inside buildings being warmer than that outside, especially in temperate and cold regions, and also of the drawing effect of the wind blowing over chimneys and other openings. However, various other mechanisms can affect the concentrations of radon in dwellings. Most building and covering materials for walls, ceilings and floors have been discovered to produce some radon but building materials of certain types can act as significant sources of indoor radon. Such materials have a combination of elevated levels of ^{226}Ra and a high porosity that allows the radon gas to escape. Examples are lightweight concrete made with alum shale, phosphogypsum and Italian stuff.

Most of our time is spent indoors; therefore, the measurement and evaluation of radon concentrations in buildings are important (Risica, 1998; Hamori *et al*., 2004). Worldwide measurements of radon activities in the indoor air of dwellings are continuously presented all over the world (Singh *et al*., 2002; Iyogi *et al*., 2003; Magalhaes *et al*., 2003) including Nigeria (Obed *et al*., 2010). The numerous measurements of the activity concentrations of radon in different countries along with epidemiological studies regarding the indoor radon and risk of lung cancer have been published in recent years (Papastefanou *et al*., 1994; Bochicchio *et al*., 1998; Field *et al*., 2000; Nsiah-Akoto *et al*., 2011)

In a previous investigation (Yu, 1993), the effects of typical covering materials used in Hong Kong on the radon exhalation rate from concrete surfaces were studied in the laboratory. These covering materials were wall paper, plaster, ceramic mosaics and glazed ceramic. It was found that some covering materials could satisfactorily inhibit the radon exhalation and reduce the corresponding indoor radon concentration. Nevertheless, it was remarked that care should be taking in transferring the result to real building and we should not be over-optimistic that the result will be as good as expected when such covering materials are actually applied to internal surfaces of real buildings.

In this present work, the contributions of typical covering materials on internal building surfaces, including walls, ceilings

Tele:
E-mail addresses: mixwealthacada@yahoo.com

and floors will be investigated in order to identify realistic effects of covering materials on the indoor radon properties. There were three objectives. First, the major combinations of covering materials for the walls, ceilings and floors in Ogbomoso were identified. Second, the differences in the average indoor radon concentrations for sites with different combinations of covering materials for the walls, ceilings and floors were found. Third, the average annual equivalent dose to the lungs were calculated.

Materials and Method

Measurement

In this work, an active electronic device, the Safety Siren Pro Series 3 Radon Detector (Model HS71512) of dimension 4.7" x 3.1" x 2.1" with an accuracy of ± 20% was employed. The detector is designed to be plugged into a standard household main outlet. The detector consists of an ionization chamber sensor with sensor. It has a full scale reading display ranging between 0.0 to 999.9 showing the level of radon gas. The detector is designed to take sample for two days (48 hrs) before an accurate result can be displayed. Subsequently, for the same location, reading are updated every hour if there is a change in the level of radon gas.

Sampling

The Safety Siren Pro Series 3 Radon Detector (HS71512 model) was placed on a flat surface where the ventilated slot will not be blocked such that the detector is at least 3 feet from windows, doors, or any other potential openings in the exterior walls. The detector was also located at least at least 1.2 m above the floor i.e in the breathing zone of a seated person. No other objects was placed within 4 inches of the detector. Since radon level depend remarkably on the sampling position (Katase et al, 1988; Doi et al, 1994), the sampling inlet of the detector was fixed at a point throughout the this work.

A total of 36 buildings with different covering materials cladded on internal building surfaces, including walls, ceilings and floors in Ogbomoso were measured on a radom basis. The three commonest combinations of covering materials in Ogbomoso were (A): paint, paint, carpet; (B): paint, Fiber board, plastic tile; (C): paint, Fiber board, ceramic tile. At each building, the radon concentration were measured.

Result and Discussion

In order to estimate the annual effective dose rate received by the population, one has to take into account the conversion co-efficient from the absorbed dose and the indoor occupancy factor. According to the UNSCEAR (2000) report, the committee proposed 9.0 x 10^{-6} mSv/h per Bqm^{-3} to be used as a conversion factor, 0.4 for the equilibrium factor of Rn-222 indoors and 0.8 for the indoor occupancy factor. Calculating the annual effective dose to the population, the equation below is used (ICRP, 1993). At a certain radon concentration C_{Rn} in Bqm^{-3}, the annual absorbed dose, D_{Rn} is usually expressed in the unit of mSv from the following relation below:

$$D_{Rn}\ (mSvy^{-1}) = C_{Rn}.D.H.F.T \qquad (1)$$

Where

C_{Rn} is the measured Rn-222 concentration (in Bqm^{-3}),

F is the Rn-222 equilibrium factor indoors (0.4),

T is the indoor occupancy time 24 h ×365 = 8760 h/y

H is the indoor occupancy factor (0.4), and

D is the dose conversion factor (9.0×10^{-6} mSv/h per Bqm^{-3}).

To calculate the annual equivalent dose and effective dose, a tissue and radiation weighting factors has to be applied according to ICRP, 1991. The equivalent dose is the radiation-weighted absorbed dose. The radiation weighting (W_R) factor for alpha particles is 20 (ICRP, 1991). With the effective dose, a tissue weighting (W_T) factor is applied. According to ICRP, the tissue weighting factor for lung is 0.12. The annual effective dose is then calculated according to the equation below:

$$H_E\ (mSv/y) = D_{Rn}.W_R.W_T \qquad (2)$$

where,

D_{Rn}= Annual Absorbed dose rate

W_R = Radiation Weighting Factor for Alpha Particles, 20

W_T= Tissue Weighting Factor for the Lung 0.12

It is, however, apparent that the time spent by individuals in the home varies widely globally. The occupancy factor of 0.8 (ICRP, 1993) over estimates the excess lung cancer risk in the tropical regions but may be valid for the inhabitants of the cold climate zone. In this present study, the occupancy factor that was used for the annual absorbed dose calculation will be 40% (0.4).

In the case of the annual equivalent dose to the lungs, the radon content of the lung air has to be taken into account, which results in the equation below according to UNSCEAR, 2000.

$$H_{lungs}\ (Sv) = 8 \times 10^{-10}\ \chi_{Rn,air}\ Bqm^{-3} \qquad (3)$$

Table 1: The different covering materials for walls, ceilings and floors

Combination	Wall	Ceiling	Floor
A	Paint	Paint	Carpet
B	Paint	Fiber board	Plastic tile
C	Paint	Fiber board	Ceramic tile

Table 2: Indoor radon concentration for different combination of covering materials

S/N	COMBINATION A Paint, Plastic. carpet Concentration (Bqm^{-3})	COMBINATION B Paint, Fiber board, plastic tile Concentration (Bqm^{-3})	COMBINATION C Paint, Fiber board Ceramic tile Concentration (Bqm^{-3})
1.	37.00	33.30	51.80
2.	33.30	33.30	55.50
3.	29.60	37.00	59.20
4.	33.30	40.70	62.90
5.	29.60	37.00	59.20
6.	25.90	40.70	55.50
7.	29.60	44.40	55.50
8.	29.60	48.10	55.50
9.	33.30	44.40	
10.	33.30	48.10	
11.	33.30	44.40	
12.		40.70	
13.		40.70	
14.		37.00	
15.		37.00	
16.		40.70	
	31.62 ± 3.03	**40.47 ± 4.38**	**56.89 ± 3.39**

The result of this study highlights the contributions of different combination of covering materials on internal surfaces to indoor radon concentration in the district of Ogbomoso. Table 1 shows the three commonest covering materials for walls, ceilings and floors in Ogbomoso while Table 2 shows the indoor radon concentration for different combinations of covering materials. The experimental data of the radon concentration obtained from direct indoor measurement for 36 buildings are shown in Table 3, from which the annual effective dose and the annual equivalent dose to the lungs were calculated.

Table 3: The radon concentration, annual effective dose and annual equivalent dose to the lungs for different combination of covering materials

Combination	Sites	Radon Concentration (Bqm^{-3})	Annual Effective Dose (mSv/y)	Annual Equivalent Dose to the Lung (Sv/y)
A	11	31.62 ± 3.03	0.9574	2.5296×10^{-8}
B	16	40.47 ± 4.38	1.2252	3.2376×10^{-8}
C	8	56.89 ± 3.39	1.7222	4.5512×10^{-8}

The radon concentration of buildings with combination (A) ranges from 25.90 to 37.00 Bqm^{-3} with a mean value of 31.64 ± 3.03 Bqm^{-3} while that of combination (B) ranges between 33.30 and 48.10 Bqm^{-3} with a mean value of 40.47 ± 4.38 Bqm^{-3}. The radon concentration for buildings with combination (C) lies within 51.80 to 62.90 Bqm^{-3} with a mean value of 56.89 ± 3.39 Bqm^{-3}. The mean value for all the combinations of covering materials used for internal surfaces were found to be lower than the recommended action level of 200 Bqm^{-3} (ICRP, 1993) and lower than the reference level set by USEPA for USA and the reference level set by WHO and ICRP (WHO, 2009; ICRP 2007). The buildings with combination (C) contributed the highest to the indoor radon concentration in buildings in Ogbomoso while buildings with combination (A) contributed the least. The mean value for combinations (B) and (C) were found to be slightly greater than the world average of 40 Bqm^{-3} (UNSCEAR, 2000). The result of the study with different combination of covering materials for the internal surfaces in most of the buildings were significantly low.

The annual effective dose $mSvy^{-1}$ estimated for the covering materials of combination (A), (B) and (C) which were 0.9574, 1.2252 and 1.7222 $mSvy^{-1}$ respectively have been found to lie below the range of action level (3 – 10 $mSvy^{-1}$) recommended by ICRP. The annual equivalent dose to the lung for all the three different combinations of covering materials are shown in Table 3 to be 2.5296×10^{-8}, 3.2376×10^{-8} and 4.5512×10^{-8} Svy^{-1} for combination (A), (B) and (C) respectively. From the result obtain in Table 3, a person living in building with combination (A) receive an annual dose to the lungs smaller than someone living in a building with combination (B) and (C) by an amount as large as 2.0216×10^{-8} Svy^{-1}.

Conclusion

This work assess the contributions of different covering materials for internal surfaces of building to the indoor radon concentration in Ogbomoso.

The three commonest combinations of covering materials for the walls, ceilings and floors in Ogbomoso were (A): paint, paint, carpet; (B): paint, asbestos, plastic tile; (C): paint, asbestos, ceramic tile.

The buildings with combination (C) contributed the highest to the indoor radon concentration in buildings in Ogbomoso while buildings with combination (A) contributed the least.

A person living in building with combination (A) receive an annual dose to the lungs smaller than someone living in a building with combination (B) and (C) by an amount as large as 2.0216×10^{-8} Svy^{-1}.

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