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TECHNICAL NOTE

THE EFFECTS OF TYPICAL COVERING MATERIALS ON THE RADON EXHALATION RATE FROM CONCRETE SURFACES

K. N. Yu
Department of Applied Science, City Polytechnic of Hong Kong
Tat Chee Avenue, Kowloon Tong, Kowloon
Hong Kong

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Abstract — The ability of typical covering materials used in Hong Kong to reduce the radon exhalation rate from concrete surfaces has been studied using EPA standardised activated charcoal canisters and gamma spectroscopy. These covering materials are plastic lined wall paper, plaster, ceramic mosaics and glazed ceramic. It is found that plastic lined wall paper and glazed ceramics can satisfactorily reduce the radon exhalation rates. Considering a concrete room of a typical size for Hong Kong, the possible reduction in the indoor radon concentrations and the corresponding reduction in the internal dose equivalent have been calculated. In doing so, it has been shown that applying some common covering materials to internal building surfaces can be a simple and economical way to mitigate the indoor radon concentrations and the corresponding internal dose. However, care should be taken that the calculated reduction in the indoor radon concentration be treated as an upper limit that is unlikely to be achieved in practice because of other entry routes and sources of radon.

INTRODUCTION

Surveys on the level of environmental radon in Hong Kong[1,2] have shown that the levels there are higher than the global average value. It is therefore necessary to identify efficient mitigation methods to remedy the situation. In general, there are many sources for indoor radon, e.g. from the ground, from the building materials and outdoor radon. Previous investigations have revealed that the main contribution to the indoor radon concentration in Hong Kong comes from radon exhalation from building materials[1,3,4]. Furthermore, most of the buildings in Hong Kong are high rise, and people seldom work or live on the ground floor, so the indoor radon concentrations are not measured on the ground floor. In this way, the main contribution of indoor radon concentration should come from the building materials.

The present work focused mainly on two subjects. First, the power to inhibit radon exhalation of different covering materials for concrete surfaces typically used in Hong Kong was determined. Previous works (e.g. Ref. 5) have investigated a similar subject. However, the intention here was to investigate the properties of covering materials that are typical of the local area. Furthermore, in these investigations, use was made of the activated charcoal canister method, which may be different from some of the methods employed in previous work. The covering materials chosen are plastic lined wall paper, plaster, ceramic mosaics and glazed ceramic, which are those most commonly used in Hong Kong. Second, the possible reduction of indoor radon concentrations and the corresponding reduction in the internal dose equivalent will also be discussed.

METHODOLOGY

The radon exhalation rate of a surface (in units of $Bq.m^{-2}.s^{-1}$) is defined as the activity of ^{222}Rn exhaled from a unit area of that surface in a unit time.

In the present work, standardised charcoal canisters with a diameter of 4 in and containing 70 g of activated charcoal were used to collect the radon atoms exhaled from such surfaces, which were then analysed using a NaI gamma spectrometer. The radon activity was determined by measuring the γ ray peaks emitted by the radon daughters RaB and RaC at 295 keV, 352 keV and 609 keV. This method was developed by Cohen and Cohen[6] and is one of the standard methods recommended by the EPA (USA) for measuring concentration of environmental radon[7]. In making the measurements, the charcoal canister was placed against the surface with the open end facing the surface, and the points of contact sealed with silicone sealer to fix the canister and to prevent leakage of air[3].

In the ideal case that the radon atoms are completely collected, i.e. back diffusion and leakage of radon atoms can be neglected, and the relationship between the activity A of radon inside the collector and the time elapsed t can be written as:

$$\frac{dA}{dt} = \varepsilon S - \lambda_o A \quad (1)$$

where ε is the radon exhalation rate of the surface, S is the area of the measured surface and λ_o is the physical decay constant of ^{222}Rn; the term εS represents the increase in the activity due to radon exhalation and the term $-\lambda_o A$ represents the decrease in the activity due to radon decay. If the collection time is t = T, and if we assume that the initial activity $A_o \sim 0$ at t=0, the solution of Equation 1 becomes

$$A = \frac{\varepsilon S}{\lambda_o} (1 - e^{-\lambda_o T}) \quad (2)$$

From Equation 2, the radon exhalation rate from the surface is

$$\varepsilon = \frac{\lambda_o A}{S(1 - e^{-\lambda_o t})} \quad (3)$$

After collection of radon for two to three days, the charcoal canister was removed from the surface, sealed, and stored for three hours to allow the radon decay to reach equilibrium. It was then put into the radon measuring system for measurement for 10 to 30 min depending on the counting statistics. From the measuring method described by Cohen and Cohen[6], the radon activity in the canister is given by

$$A = \frac{(NET)}{E\,(DF)} \quad (4)$$

where NET is the net measured area (cpm) (i.e. after subtraction of the background) under the three characteristic γ ray peaks of the radon daughters; E is the detection efficiency of the system calibrated using a standard canister; DF is the correction factor for decay which is

$$DF = e^{-\lambda_o t} \quad (5)$$

where t is the time elapsed from the end of collection to the start of measurements.

Substituting Equations 4 and 5 into Equation 3, the radon exhalation rate ε from the surface is given by

$$\varepsilon = \frac{\lambda_o (NET) e^{\lambda_o t}}{SE\,(1 - e^{-\lambda_o T})\,3600} \quad (6)$$

where ε is in units of $Bq.m^{-2}.s^{-1}$, $\lambda_o = 0.00756\ h^{-1}$, and 3600 is the conversion factor from hours to seconds.

REDUCTION IN RADON EXHALATION RATES

Cubic concrete blocks of suitable size (such that covering materials can fit onto every surface and charcoal canisters can be stuck onto all these surfaces at the same time) have been constructed. Subsequent experiments have been carried out in the same laboratory, in which the temperature is maintained at 23°C and the relative humidity at 60%, to avoid significant effects due to changes in ambient conditions.

The radon exhalation rates from the concrete surfaces before and after all surfaces were clad with covering materials were measured. By comparing these radon exhalation rates, the effects of different covering materials was determined. The results are shown in Table 1. It is found that the radon exhalation rates from concrete surfaces covered by plastic lined wall paper and glazed ceramics are lower than the minimum detectable limit. It is therefore believed that these covering materials can satisfactorily reduce the radon exhalation rates.

The results are as expected. Since the wall paper is plastic lined, and since plastic has a very small permeability, it should provide a considerable barrier to radon transmission. Plaster has large porosity so it is no wonder that the effects on radon exhalation are small. The porosities of ceramic mosaic and glazed ceramic are similar so the difference in the power to inhibit radon exhalation depends greatly on the presence of gaps, and the results obtained support this assertion.

Table 1. Summary of the percentage reduction of radon exhalation rates of the chosen covering materials.

Covering material	Number of measurements	Range of reduction (%)	Mean (%)	S.D. (%)
Plastic lined wallpaper	10	>66.4 - >80.0	—	—
Plaster	5	21.0 - 27.3	24.7	2.25
Ceramic mosaics	7	16.2 - 23.8	20.5	2.30
Glazed ceramics:				
no gap	7	>68.3 - >85.5	–	–
with gap	6	38.1 - 55.4	46.4	6.85

POSSIBLE BENEFITS

In showing the ability of covering decorative materials to inhibit radon exhalation rates, we have indicated a simple, effective and economic method to decrease indoor radon concentration and the corresponding internal dose. However, care should be taken in transferring the above results to buildings, because if some surfaces in the buildings are not sealed, radon will find its way out from these surfaces and radon reduction will not be efficient.

For calculation purposes, a concrete room of a typical size and typical parameters for Hong Kong has been adopted[4]. These parameters are as follows. The dimensions of the room are $V = L{\times}W{\times}H = 4{\times}3{\times}3\ m^3$. Therefore the volume is 36 m^3 and the total wall area S_w (excluding the ceiling S_c and the floor S_f, both being 12 m^2) is 25.2 m^2 if we introduce a correction factor $f_s = 0.6$ for windows and doors. The air exchange rate λ_v is taken to be 1 h^{-1}. The outdoor radon concentration is denoted as $C_{Rn,o}$ (in $Bq.m^{-3}$) which will not affect the numerical results of our calculations.

It can easily be shown that, at equilibrium, the indoor radon concentration $C_{Rn,i}$ (also in $Bq.m^{-3}$) of a concrete room, of which the internal surfaces are all uncovered, is given by

$$C_{Rn,i} = C_{Rn,o} + \varepsilon\,[S_w+(S_c + S_f)]\left(\frac{3.6}{\lambda_v V}\right) \qquad (7)$$

where ε is the radon exhalation rate (in $Bq.m^{-2}.s^{-1}$) from the uncovered surfaces (assumed to be the same for all surfaces). As regards the application of decorative covering materials, we are normally talking about the walls and the ceiling; the floor is usually left as it is. First, we consider the decorative materials that apply only to the walls but not to the ceiling (e.g. ceramic mosaics and glazed ceramics), which we refer to as case A. In this case, we assume the ceiling to be covered by plaster. If r_w and r_c are the reduction factors of radon exhalation rates from the walls and the ceiling respectively, we obtain the reduction in the indoor radon concentration $\Delta C_{Rn,i}$ ($Bq.m^{-3}$) to be

$$\Delta C_{Rn,i} = \varepsilon\,(r_w S_w + r_c S_c)\left(\frac{3.6}{\lambda_v V}\right) \qquad (8a)$$

Substituting typical values, we have

$$\Delta C_{Rn,i} = \varepsilon\,(2.52 r_w + 1.2 r_c) \qquad (8b)$$

If the covering material is also applied to the ceiling (e.g. plaster and plastic lined wall paper), which we refer to as case B, we have $r_w = r_c = r$, so

$$\Delta C_{Rn,i} = 3.72\,\varepsilon\, r \qquad (8c)$$

For reference, ε is taken to be the mean radon exhalation rate from uncovered concrete internal building surfaces, previously measured to be 16 $Bq.m^{-2}.s^{-1}$[3]. The reduction in indoor radon concentration by using different kinds of covering materials is shown in Table 2. For glazed ceramics, the data is used assuming gaps. The average indoor radon concentration in Hong Kong is about 45 $Bq.m^{-3}$ [1,2,4] but this is an average of sites with all kinds of covering materials cladding internal surfaces (only a small number have uncovered internal surfaces).

Table 2. Estimated reduction of the indoor radon concentration and the internal dose equivalent by the use of different covering materials.

Covering material	Case	$\Delta C_{Rn,i}$ ($Bq.m^{-3}$)	SD	ΔH_{Rn} ($mSv.y^{-1}$)	SD
Plastic lined wallpaper	B	>39.5	–	>0.96	–
Plaster	B	14.7	1.3	0.36	0.03
Ceramic mosaics	A	12.2	1.4	0.30	0.03
Glazed ceramic	A	27.6	4.1	0.67	0.10

According to the model and parameters for estimation in the UNSCEAR 1982 report[8], the fraction f_p of unattached radon daughters is taken to be 0.05 and the aerosol activity median diameter (AMD) to be 0.2 μm. The conversion factors from indoor unit radon daughter concentration to annual effective dose equivalent are taken to be 0.061 $mSv/(Bq.m^{-3})$. From these, the reduction in the annual effective dose equivalent ΔH_{Rn} (in mSv) received by the Hong Kong population due to inhaled radon and radon daughters can be calculated from

$$\Delta H_{Rn} = 0.061\,\Delta C_{Rn,i} F_i \qquad (9)$$

where F_i is the indoor equilibrium factor of radon daughters, the typical value of which for Hong Kong is 0.4[4]. The reduction in the annual effective dose equivalent by using different kinds of covering materials is also shown in Table 2. The estimated annual effective dose equivalent due to indoor radon and the estimated total annual effective dose equivalent from natural background radiation are about 1.32 and 3.24 mSv respectively[4].

From the above calculations, it can be seen that using effective covering materials on internal building surfaces can be a simple and economical way to mitigate the indoor radon concentrations and the corresponding internal dose. However, it should be noted that estimated reduction of the indoor radon concentration and the internal dose equivalent by the use of the various covering materials shown in Table 2 are theoretical maximum reductions in the absence of other sources. Furthermore, once again, one should bear in mind that if some surfaces in the buildings are not sealed, radon will find its way out from these surfaces and radon reduction will not be efficient, and the above calculations will not hold true completely.

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