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Building and Environment, Vol. 29, No. 1, pp. 1–3, 1994.
Printed in Great Britain.

0360–1323/94 $6.00+0.00

Mitigation of Indoor Radon Pollution in Buildings in Hong Kong: Covering Materials on Internal Building Surfaces

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The effects of typical covering materials used in Hong Kong on the radon exhalation rate from concrete surfaces have been studied. These covering materials are wallpaper, plaster, ceramic mosaics and glazed ceramic. Concrete blocks have been constructed in the laboratory. The radon exhalation rates from their surfaces, first without the covering materials and then with the covering material we want to investigate, are then measured using EPA-standardized activated charcoal canisters and γ-spectroscopy. By comparing these radon exhalation rates, the effects of the covering materials can be determined. It is found that the radon exhalation rates from concrete surfaces covered by wallpaper and glazed ceramics are lower than the minimum detectable limit. It is therefore believed that these covering materials can satisfactorily inhibit the radon exhalation and reduce the corresponding indoor radon concentration.

1. INTRODUCTION

FOLLOWING the linking of radon and induced lung cancer, more and more studies on the source and the health effects of environmental radon have been carried out in recent years [1]. Surveys on the level of environmental radon in Hong Kong [2, 3] have shown that the levels here are significantly higher than the global average value. It therefore seems important to identify efficient mitigation methods to remedy the situation. Our previous investigations have revealed that the main contribution to the indoor radon concentration in Hong Kong comes from radon exhalation from building materials [2, 4, 5].

In this work, therefore, the power to inhibit radon exhalation of different covering materials for concrete surfaces typically used in Hong Kong will be determined. The covering materials chosen are plastic-lined wallpaper, plaster, ceramic mosaics and glazed ceramic.

2. METHODOLOGY

Materials containing ^{226}Ra will exhale radon from their surfaces following α-decays and diffusion of the recoil ^{222}Rn atoms. The radon exhalation rate of a surface (in units of Bq . m^{-2} . s^{-1}) is defined to be the number of ^{222}Rn atoms exhaled from a unit area of that surface in a unit time. The process of radon exhalation is complicated. Besides depending on the radium content of the material, it also depends on the properties and the structure of the material (such as porosity, size and distribution of pores and cracks, etc.) and on environmental parameters (such as temperature, humidity and air pressure, etc.).

A collector is used to collect the radon atoms exhaled from such a surface. Under 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:

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

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 $A_o \simeq 0$ at $t = 0$, the solution of equation (1) becomes

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

From equation (2), we can obtain the radon exhalation rate from the surface to be

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

There are a number of methods of collecting radon atoms and of measuring the activity A. In the present work, charcoal canisters are used to collect radon and are then analyzed using a NaI gamma spectrometer (Fig. 1). The radon activity is 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

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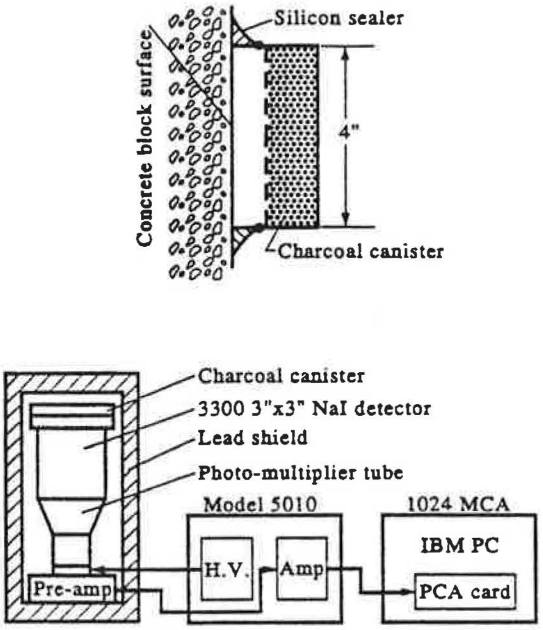

Fig. 1. Charcoal canister and radon counting system.

developed by Cohen and Cohen [6] and is one of the standard methods recommended by the EPA of U.S.A. for measuring concentration of environmental radon [7]. Standardized charcoal canisters with a diameter of 4 inches and containing 70 g of activated charcoal are used. In making the measurements, the charcoal canister is 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 [1, 4]. After collection of radon for two to three days, the charcoal canister is removed from the surface, sealed, and stored for three hours to allow the radon decay to reach equilibrium. It is then put into the radon measuring system for measurement for 10 to 30 minutes depending on the counting statistics. From the measuring method described in [6], the radon activity in the canister is given by

$$A = \frac{(NET)}{\mathrm{E(DF)}} \tag{4}$$

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

$$\mathrm{DF} = e^{-\lambda_o t} \tag{5}$$

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

Substituting equations (4) and (5) into equation (3), we can obtain the radon exhalation rate ε from the surface to be given by

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

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.

3. RESULTS AND DISCUSSION

Cubic concrete blocks of suitable size (such that covering materials can fit onto every surface and charcoal canisters can be sticked onto 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 temperature and relative humidity.

The radon exhalation rates from the concrete surfaces before and after all surfaces being cladded with covering materials have been measured. By comparing these radon exhalation rates, the effects of different covering materials can be determined. The results have been shown in Table 1. It is found that the radon exhalation rates from concrete surfaces covered by wallpaper and glazed ceramics are lower than the minimum detectable limit. It is therefore believed that these covering materials can satisfactorily inhibit the radon exhalation and reduce the corresponding indoor radon concentration.

The results are as expected. Since the wallpaper is plastic lined, and since plastic has a low permeability, it should provide greater barrier to radon transmission. Plaster is porous so there is no wonder why 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.

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. However, care should be taken in transferring the above results to buildings, because if

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. (%)
Wallpaper	10	> 66.4– > 80.0	—	—
Plaster	5	21.0–27.3	24.7	2.25
Ceramics mosaics	7	16.2–23.8	20.5	2.30
Glazed ceramic				
no gap	7	> 68.3– > 85.5	—	—
with gap	6	38.1–55.4	46.4	6.85

some surfaces in the buildings are not sealed, radon will find its way out from these surfaces and radon reduction will not be efficient. Furthermore, we should not be over-optimistic that results will be as good as expected when such covering materials are actually applied to internal surfaces of real buildings. It is hoped that further work can be developed in future to quantify the effect in real buildings.

Acknowledgements—This research is partially supported by an indicated grant from the City Polytechnic of Hong Kong. S. F. Shi is thanked for participation in the experimental work.

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