IN–SITU MEASUREMENTS OF RADON EXHALATION RATE FROM BUILDING SURFACE IN HONG KONG

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(Received February 1993)

ABSTRACT

EPA–standardized activated charcoal canisters were used to collect radon exhaled from building surfaces and analyzed using γ–spectroscopy to obtain the radon exhalation rates. More than 120 samples were analyzed in more than 10 buildings situated in different areas of Hong Kong. Variations were identified in the exhalation rates at different levels in a building, for different covering materials and for the presence of cracks in walls. The radon exhalation rate from the most common concrete walls and covering materials was found to be approximately 13 $mBq \cdot m^{-2} \cdot s^{-1}$. This may be the cause of a relatively high indoor radon concentration in Hong Kong.

Keywords: Charcoal canisters Radon exhalation rate Building surfaces Building materials

1 INTRODUCTION

Following the linking of radon and induced lung cancer, more and more studies on radon[1, 2] showed that the levels here are significantly higher than the global average value. Most scientists agree that indoor radon generally comes from soil beneath and around buildings and from building materials. The geographical material of Hong Kong is mainly volcanic rocks such as granite, making both the outdoor and the indoor radon levels high. Nevertheless, most of the buildings in Hong Kong are high rise, which would suggest that the contribution from building materials may be more significant[3]. Therefore, in–situ measurements of radon exhalation from different building surfaces such as concrete floors, walls and ceilings, and the change of exhalation rate with different covering materials were made.

2 PRINCIPLES AND METHODOLOGY

Materials containing ^{226}Ra will exhale radon from their surface following α–decays and diffusion of the recoil ^{222}Rn atoms. The process of radon exhalation is very 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, air pressure, *etc.*). Generally speaking, there are two types of radon exhalation rates associated with indoor surfaces of a building. The first is determined by the radium content and the internal structure of the building materials, which can be measured by investigating prepared samples of building materials[4] in the laboratory. The second includes the additional contribution of radon from soil or other media in contact with the building materials, which can only be investigated through in-situ measurements[5,6]. In this paper the second radon exhalation rate is measured, in order to lind directly to indoor radon levels.

A collector is used to collect the radon atoms exhaled from building surfaces. 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:

$$dA/dt = \varepsilon S - \lambda_o A \tag{1}$$

where ε is the radon exhalation rate of the building surface, S is the area of the measured surface and λ_o is the physical decay constant of ^{222}Rn; εS represents the increase of the activity due to radon exhalation and $-\lambda_o A$ the decrease of the activity due to radon decay. If the collection time is $t=T$, and one assumes that the initial activity $A_o \approx 0$ at $t=0$, the solution of Eq.(1) becomes

$$A = (\varepsilon S/\lambda_o)[1-e^{-\lambda_o T}] \tag{2}$$

From Eq.(2), one can obtain the radon exhalation rate from a building surface

$$\varepsilon = \lambda_o A/S\ [1- \exp(-\lambda_o t)] \tag{3}$$

There are a number of methods to collect radon atoms and to measure A. In the present work, charcoal canisters are used to collect radon and they are then analyzed

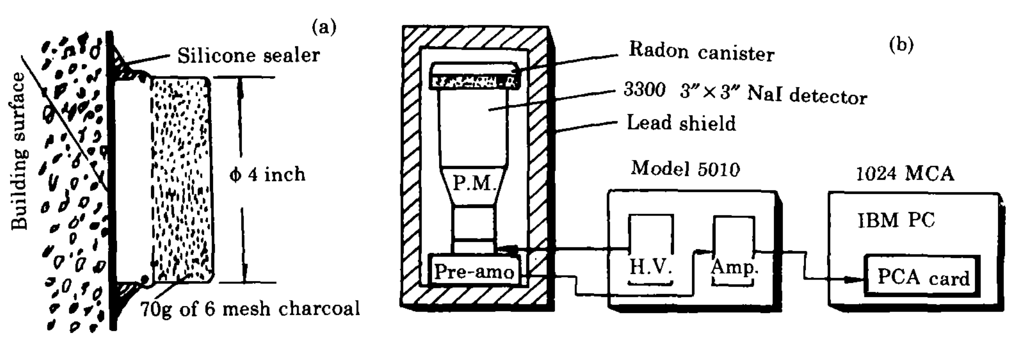

Fig.1 Charcoal canister and radon counting system

using a NaI gamma spectrometer. The radon activity is determined by measuring the γ-rays emitted by the radon daughters RaB and RaC at 295 keV, 352 keV and 609 keV[7,8]. US EPA 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 (Fig.1a). After collection of radon for 2—3 d, the charcoal canister is removed from the surface, sealed, and stored for 3 h to allow the radon decay to reach equilibrium. It is then put into the radon measuring system (Fig.1b)[9] for measurement for 10 to 30 min depending on the counting statistics. From themeasuring method described in Ref.[7], the radon activity in the canister is given by

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

where NET is the net measured area (cpm) (*i.e.*, after subtraction of the backgroud) under the three characteristic γ-ray peaks of the radon daughters; E is the detection efficiency of the system calibrated using a standard canister found to be about 7.3 cpm • Bq^{-1}; DF is the correction factor for decay which is given in Ref.[8] to be

$$\mathrm{DF} = \exp(-\lambda_o t) \tag{5}$$

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

Substituting Eq.(4,5) into Eq.(3), one can obtain ε

$$\varepsilon = [\lambda_o(\mathrm{NET}) \exp(\lambda_o t)] / \{SE\,[1-\exp(-\lambda_o T)]\,3600\} \tag{6}$$

where ε is in unit of $Bq \cdot m^{-2} \cdot s^{-1}$, $\lambda_o = 0.00756\ h^{-1}$.

The overall efficiency of the system is mainly determined by the background level and the detector efficiency. The background for a fresh charcoal canister is about 170 cpm. According to a 3σ threshold, the minimum detectable count rate will be about 7 cpm (counted for 30 min) and the corresponding minimum detectable radon exhalation rate will be about 0.64 $mBq \cdot m^{-2} \cdot s^{-1}$ (collection for 3 d and measurement after 3 h). The radon absorption power of the charcoal canisters is extremely high and the effective volume of air absorbed is more than 3 orders of magnitude of the volume of the canisters (calculated for two days of collection). Therefore back diffusion and leakage can be neglected. However, some care must be taken that the contact between the canister and the building surface is totally sealed, especially for coarse surfaces and for powdery surfaces.

3 RESULTS AND DISCUSSIONS

More than 120 in-situ measurements have been made of radon exhalation rates from building surfaces in more than 10 buildings in Hong Kong.

3.1 Comparison among the radon exhalation rates from concrete floor surfaces at different levels in a building

Table 1 shows that the radon exhalation rate on the ground floor is found to be much greater than those on other levels. The rates at other levels are more or less the same and are thus grouped under one single item. The results are expected and are similar to those obtained by other workers. The cause for the difference is the significant additional contribution to the exhalation rate from the soil underneath and around the building on the ground floor.

Table 1

Radon exhalation rate from concrete floors on different levels of a building $mBq \cdot m^{-2} \cdot s^{-1}$

Level	Number	Range	Mean	SD
Ground floor	4	15—42	28	13
Other levels	10	1.7—27	10	8.0

3.2 The effect of covering materials on the radon exhalation rate

The radon exhalation rate is lowered by varying amounts when a concrete surface is covered by different decorative materials. The results are shown in Table 2. From Table 2, it can be seen that some covering materials are very efficient at inhibiting the radon exhalation and are thus economical and practical materials for reducing indoor radon concentration. In addition, the measurements show that at places where the covering material is removed or where cracks exist, or at junctions between covering materials the radon exhalation rates are comparatively higher.

Table 2

Radon exhalation rate from concrete surface with different covering materials $mBq \cdot m^{-2} \cdot s^{-1}$

Surface type	Covering material	Number of samples	Range	Mean	SD
Floor	Naked	10	1.7—27	10	8.0
	Mosaics	10	0.5—6.7	2.0	2.2
	Wooden strips	4	4.9—8.0	6.5	1.6
	Carpet	8	0.6—3.7	2.2	1.3
	Terrazo	8	<MDA—1.5	0.7	0.5
	Plastic	12	<MDA—1.7	0.7	0.5
Wall	Naked	21	12—28	16	3.7
	Wall paper	3	<MDA—1.7	<MDA	-
	Thin plaster	14	8.8—21	15	3.4
	Thick plaster	3	<MDA	<MDA	-
	Glazed ceramic (thin)	8	<MDA—8.4	4.5	3.2
	Glazed ceramic (thick)	5	<MDA	<MDA	-
	Glazed ceramic (thick) (at junctions)	6	3.4—11	7.4	3.1
	Ceramic Mosaics	6	7.4—11	9.7	1.5
	Stone set tiles	3	3.3—6.6	5.5	1.5
	Exposed aggregate	3	8.5—14	12	3.0

MDA: Minimum detectable activity

4 CONCLUSIONS

a. The method of using charcoal canisters to make in-situ measurements of radon exhalation rates from building surfaces is both simple and practicable. The results in fact give the effective radon exhalation from a mixture of building materials in and beneath the surface. In general, the efficiency of the method meets requirements.

b. Differences in the radon exhalation rates from floor surfaces on different levels of a building agree with the results obtained by other workers.

c. In showing the ability of covering decorative materials to inhibit radon exhalation rates, the results are very important and indicate an effective and economic method to decrease indoor radon concentration.

d. The weighted mean value is 13 mBq • m^{-2} • s^{-1}. This value is higher than the average value (3.3 mBq • m^{-2} • s^{-1}) for building in Beijing[6] by a factor of 4, higher than the average value (4.6 mBq • m^{-2} • s^{-1}) for buildings in Norway[11] by a factor of 3, and higher than the typical value (2 mBq • m^{-2} • s^{-1}) quoted in the UNSCEAR-82 report[10] by a factor of 6.5. This may be the main reason for high indoor radon concentrations in Hong Kong.

ACKNOWLEDGEMENTS

This research is partially supported by an indicated grant from the City Polytechnic of Hong Kong. H. M. Mok and S. Y. Kee are thanked for their participation in some of the experimental work.

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