Note

THE VARIATION OF RADON EXHALATION RATES FROM BUILDING SURFACES OF DIFFERENT AGES

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Abstracts—**Standardized activated charcoal canisters (according to the U.S. EPA) have been used to collect radon exhaled from concrete surfaces covered with thin plaster (categorically different from thick plaster) of 32 buildings of different ages (0.5–31 y) in Hong Kong. Concrete surfaces covered with thin plaster is the commonest wall configuration in Hong Kong. The canisters are analyzed using gamma spectroscopy to obtain the radon exhalation rates. The results show that the radon exhalation rate decreases with the building age.**
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Key Words: radon; charcoal canisters; exhalation rate; ^{222}Rn, indoor

INTRODUCTION

RECENT studies on radon have shown that the levels here in Hong Kong are significantly higher than the global average value (Yu et al. 1992a; Yu 1993a). It has also been established that the main source of indoor radon in Hong Kong comes from the exhalation from the building materials (Yu et al. 1992a,b). The contribution from soil beneath the buildings are minimal as most of the buildings in Hong Kong are high rise and people rarely work or live on the ground floor. Yu et al. (1992a) have measured the indoor radon concentrations at 71 sites in different buildings in Hong Kong and have found that the indoor radon concentration varies with the building age, which immediately leads us to think about the possibility of a variation of radon exhalation rates from building surfaces with the building ages.

Therefore, in this paper, *in-situ* measurements have been made of radon exhalation from surfaces of buildings of different ages in Hong Kong to study the existence of such a variation. The radon exhalation rates from surfaces of building materials have been widely studied (e.g., Colle et al. 1981; Abu-Jarad and Fremlin 1983; Folkerts et al. 1984; Mustonen 1984; Samuelsson and Pettersson 1984; Lettner and Steinharsler 1988; Chen et al. 1993).

MATERIALS AND METHODS

The method employed to measure the radon (^{222}Rn) exhalation rate from building surfaces has been described by Yu (1993b). Standardized charcoal canisters (according to the U.S. EPA) with a diameter of 10.16 cm (4 in) and containing 70 g of activated charcoal are used to collect the radon atoms exhaled, which are then analyzed using a NaI gamma spectrometer. The radon activity is determined by measuring the gamma-ray peaks emitted by the radon progeny ^{214}Pb and ^{214}Bi at 295 keV, 352 keV, and 609 keV. The charcoal canister method was developed by Cohen and Cohen (1983) and is one of the standard methods recommended by the EPA for measuring concentrations of environmental radon (Gray and Windham 1987). In making the measurements of radon exhalation rates, the charcoal canister is sealed against the surface with silicone sealer to fix the canister and to prevent leakage of air (Yu 1993b). 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 for measurement for 10 min.

The radon exhalation rate ϵ (in units of Bq m^{-2} s^{-1}) can be calculated using eqn. 6 from Yu 1993b:

$$\epsilon = \frac{\lambda_o(\mathrm{NET})e^{\lambda_o t}}{\mathrm{SE}(1 - e^{-\lambda_o T})3{,}600}, \qquad (1)$$

where λ_o (=0.00756 h^{-1}) is the physical decay constant of ^{222}Rn, NET is the net measured area (cpm) (i.e., after subtraction of the background) under the three characteristic gamma-ray peaks of the radon progeny mentioned above, S is the area of the building surface covered by the charcoal canister, E is the detection efficiency of the system calibrated using a standard canister, T is the radon collection time, t is the time elapsed from the end of collection to the start of measurements, and 3,600 is the conversion factor from hours to seconds.

The radon exhalation rate from surfaces covered with thin plaster of 32 randomly chosen buildings of different ages in Hong Kong have been measured in the same season (from October to December 1993). Only those surfaces covered with thin plaster are measured because the different covering materials have different abilities to inhibit the radon exhalation (Yu 1993b). Thin plaster is used to describe the wall material when most apartments are first sold in Hong Kong. It is also the most

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common wall material used in Hong Kong, since most of the apartments are not re-decorated (e.g., lined with wall paper, etc). The description of "thin plaster" is used for the differentiation from the "thick plaster," which is a wall material commonly used in humid environments such as bathrooms or kitchens. In this way, thin plaster and thick plaster are different for their different categories rather than for their numerical thickness. Moreover, a concrete surface covered with thin plaster is the commonest wall configuration in Hong Kong. Multiple measurements are taken on different walls of the same building. The age of the buildings range from 0.5 y to 31 y.

RESULTS AND DISCUSSION

The results are shown in Table 1 and Fig. 1. At each site, at least two and normally three measurements have been made. In some cases, radon activities lower than the minimum detectable activities (MDAs) have been recorded. For the sake of convenient calculations and comparisons, these activities are taken to be half of the MDAs. In the third column of Table 1, we have given the number of detections (i.e., where the recorded activities are greater than the MDAs) and the total number of measurements. From Fig. 1, we can see a rather clear anti-correlation between the radon exhalation rate and the age of building.

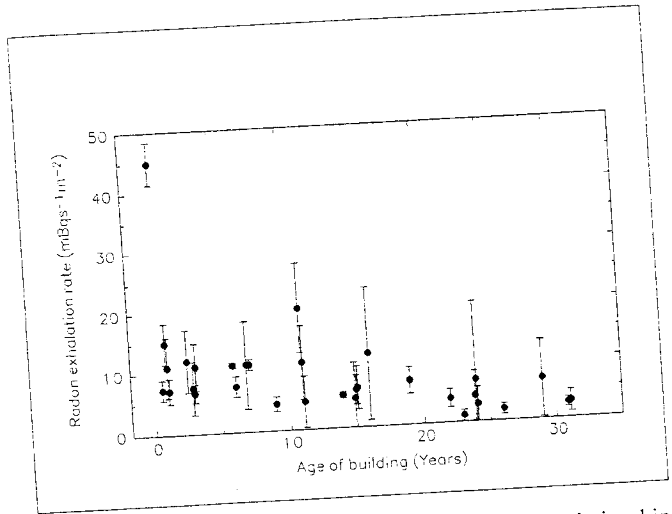

Fig. 1. The individual data of our samples showing the relationship between the radon exhalation rates and the age of the buildings.

Table 1. The radon exhalation rates from internal wall surfaces of 32 buildings. The values associated with the means are statistical deviations of the set of individual values.

Age (yr)	Usage of building	Detection/ total	Mean radon exhalation rate (mBq s^{-1} m^{-2})
0.5	residence	2/2	45 ± 3.5
0.5	office	3/3	7.3 ± 1.7
1	office	7/7	15 ± 3.4
1	office	3/3	11 ± 5.0
1	office	3/3	7.1 ± 2.1
2.5	office	3/3	12 ± 5.2
3	school	3/3	7.5 ± 4.4
3	office	3/3	6.6 ± 1.5
6	office	2/2	11 ± 3.9
6	residence	2/2	11 ± 0.4
6	residence	3/3	7.5 ± 1.7
7	residence	3/3	11 ± 7.3
7	school hall	3/3	11 ± 0.9
9	office	3/3	4.3 ± 1.2
11	school hall	3/3	20 ± 7.4
11	school hall	3/3	11 ± 6.1
11	office	3/3	4.5 ± 4.2
14	church	3/3	5.3 ± 0.5
15	office	2/3	4.7 ± 5.9
15	residence	4/4	6.1 ± 2.4
15	residence	3/3	6.4 ± 3.5
16	school hall	3/3	12 ± 11
19	school hall	3/3	7.2 ± 2.2
22	school hall	3/3	3.9 ± 1.5
23	residence	1/3	1.0 ± 0.9
24	residence	3/3	4.2 ± 4.1
24	residence	2/3	6.8 ± 13
24	residence	3/3	2.8 ± 2.8
26	office	3/3	1.8 ± 0.9
29	residence	2/4	6.6 ± 6.4
31	residence	3/3	2.5 ± 0.8
31	residence	3/3	2.7 ± 1.8

It might also be helpful to separate the building ages into small groups, i.e., 0–5, 6–10, 11–15, 16–20, 21–25, and >25 y. For the first group, i.e., 0–5 y, the age is accurate to 0.5 y. In other groups, the ages are specified only to an integral number of years. The mean value of radon exhalation rates in each group has been calculated and shown in Table 2 and Fig. 2. From these calculations, the anti-correlation is more evident.

From the above discussions, we may say quite confidently that the radon exhalation rates from building surfaces decrease with the building ages. This is unlikely to arise from the radium contents of the concrete used because the radioactivity contents of the concrete used for newer buildings and older buildings are likely to be similar. For the building materials in Hong Kong, granite is the main source of radon and constitutes the essential part of the radionuclide concentrations. Over the years, the source of granite has not changed; most of the granite is imported locally and from the nearby Shenzhen in

Table 2. The mean radon exhalation rates from internal wall surfaces of buildings in different age groups.

Age group (y)	No. of sites	Mean radon exhalation rate (mBq s^{-1} m^{-2})
0–5	8	10.13 ± 0.87
6–10	6	10.32 ± 0.34
11–15	7	5.43 ± 0.48
16–20	2	7.38 ± 2.16
21–25	5	1.93 ± 0.73
>25	4	2.28 ± 0.57

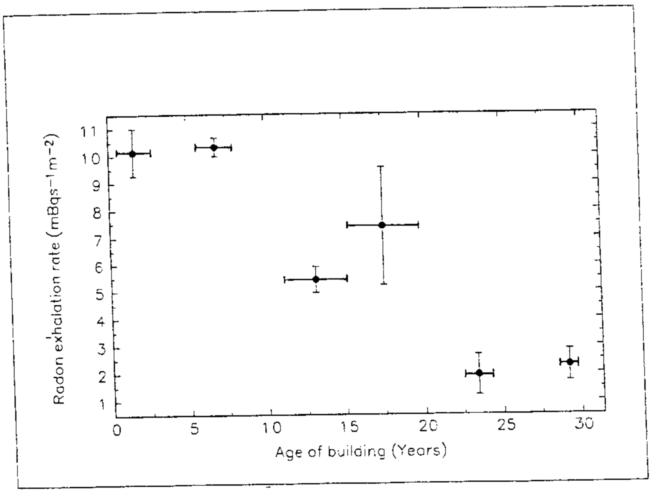

Fig. 2 The clustered data of our samples showing the relationship between the radon exhalation rates and the age of the buildings.

China. Our investigations (Yu et al. 1992b) show that the granites from these two sources are similar in ^{226}Ra concentrations. The constancy in the radionuclide concentrations is further supported by the constancy in the gamma dose rates (Yu et al. 1992a). For 69 sites, Yu et al. (1992a) have measured the absorbed gamma dose rate in air using two types of LiF TLDs. The mean absorbed gamma dose rate in air at sites <15 y and >15 y are respectively 202.8 and 207 nGy h^{-1}, which are rather similar. From the above results, it is quite safe to say that the radium contents of walls with different ages do not have large differences. A possible explanation for the variation is that the extrinsic characteristics such as the water content of the concrete have been changing over the years, which affects the radon exhalation.

In order to identify the real factors affecting the radon exhalation, it is planned to monitor the exhalation rates from concrete blocks fabricated in the laboratory at short intervals for a longer time. These concrete blocks have fixed radium contents and provide opportunities for a longitudinal study, which might show clearer results than those obtained in the latitudinal studies described in the present investigation.

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