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RESIDENTIAL RADON LEVELS IN HONG KONG

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ABSTRACT

Hong Kong is made of concrete, which emits radon continuously. The radon concentration in a domestic apartment is controlled, to a great extent, by natural ventilation. At night, when outside natural convection dies away, the ventilation rate inside a closed room can drop to near zero. The radon concentration then increases at a steady rate, often to unacceptably high levels.

In a poorly ventilated room, the equilibrium radon level can actually give a measure of the ventilation rate. The results in this paper provide a case study for such an approach. The method described also provides a means to determine the minimum ventilation rate necessary to keep the radon concentration below the recommended level. For the room studied, an air change rate of 0.5 changes per hour would keep the radon level less than 100 Bq/m^3 (2.5 pCi/L) above ambient.

INTRODUCTION

Even with all windows and doors closed, the average apartment, with its loose fitting windows, gaps round the air conditioners and gaps under doors, will be subject to infiltration of outside air. Infiltration is driven by pressure differences across the building, caused by wind. Sometimes, however, particularly at night when the ground is cooled, all convective activity ceases, and winds drop to zero. There is an English expression describing this .. "In the Still of the Night".

Hong Kong is a concrete city. Almost all the high-rise buildings are of ferro-concrete construction. Everybody spends most of their time surrounded by concrete walls, floor and ceiling. The granite aggregate in the concrete contains Uranium and its daughter, Radium, which thus provides a continuous, unchanging source of Radon gas (1).

Infiltration normally provides sufficient natural ventilation to keep radon levels below the Environmental Protection Department's action level of 200 Bq/m^3 (5.4 pCi/L) (2). On several occasions in a bedroom in my own apartment, however, levels climbed steadily overnight, to peak above 400 Bq/m^3 and once, at least, exceeded 600 Bq/m^3 (16.2 pCi/L) (3). It was observed that, during the steady climb of radon level, the rate of increase was always around 40 Bq/m^3 (1.1 pCi/L) per hour. This compares with 60 Bq/m^3 per hour observed elsewhere in Hong Kong (4).

Measurements of ventilation rate by tracer gas may not always be feasible, especially for domestic occupants. In this study, an alternative method is suggested for estimating ventilation rate from time-resolved measurements of the radon concentration.

METHODS

Methodology

The radon concentration was measured continuously in a bedroom. Typically, each measurement run lasted 2 to 3 days and the cycle time was 1 or 1.5 hours. During the early stages of the experiment, measurement runs were started without particular preparation, other than making sure the windows and door were shut. Later in the series, before each measurement run, the room was opened up fully, with windows and door wide open. So the initial radon concentration in the room was the same as outside air (which was in most cases less than 40 Bq/m^3 (1 pCi/L)).

When infiltration ceases, radon concentrations outside the room being studied do not effect the level in the room. If infiltration does occur it will have the effect of slowing and limiting the increase of radon concentration in the room. By focusing on the maximum slew rate, it becomes unnecessary to monitor levels outside the room being studied. The effect observed is generated entirely within the room under study. Measurements of concentrations both outside the room and outside the apartment were made, but are not of direct relevance to the conclusions of the study.

A measurement was made of the radon emission from the wall of the room. A container was sealed against the wall and the air in the container was drawn through the radon monitor. A linear increase in radon concentration was observed for over twelve hours before the rate of increase started to slow down. The initial slope provided a measure of the radon emission. The measurement was repeated several times with nearly identical results.

Instrumentation

It was necessary to find a radon monitor which would give good time resolution of the measurements. In the radon decay chain the first daughter, Polonium 218, has a half-life of 3.05 minutes and decays with a 6.00 MeV alpha particle. The Polonium 214 daughter appears some 45 minutes later and generates a 7.69 MeV alpha particle. An instrument was required, therefore, which (a) filtered out all pre-existing radon daughters and accepted only radon gas into the measurement chamber, (b) captured the Polonium 218 atoms created in the measurement chamber and © could discriminate between the 6.00 MeV alpha particles from the Polonium 218 and the 7.69 MeV alpha particles arising from the Polonium 214 much later.

The NITON RAD7 radon monitor provided the functionality required. It has several modes of operation and in one, "Sniff Mode", it counts only the 6.00 MeV alpha particles produced by the short-lived Polonium 218 and thus has a response time of only about 10 minutes for a 90% response to a step change in radon concentration, either up or down. During a linear ramp lasting several hours, the ten-minute response time has the effect of delaying the readings by ten minutes but does not alter the slope of the ramp, which is the parameter of interest (5).

Location

The room chosen for the investigation, in an apartment occupied by the author, was on the fifth floor of a 43-floor apartment building in Tseung Kwan O, East of Kowloon, Hong Kong. The building is made of reinforced concrete and has eight apartments on each floor.

The room had an emulsion paint on the walls that is probably quite porous to radon. It is a small bedroom with casement windows and a small air conditioner. During the measurement, the windows and door were closed, but no attempt was made to hermetically seal the room. Thus the occasional cessation of infiltration, occurring at night, was typical of what may be observed in any of millions of other similar rooms with their windows and doors closed.

RESULTS

Radon concentrations

A typical run inside the room with door and windows closed, starting late on 24 October 1995, shows apparently random variations. Note that even on just a typical day the radon level is often close to or even above 200 Bq/m^3 (5.4 pCi/L), the EPD level of concern (2), although a charcoal test would show the average to be acceptable.

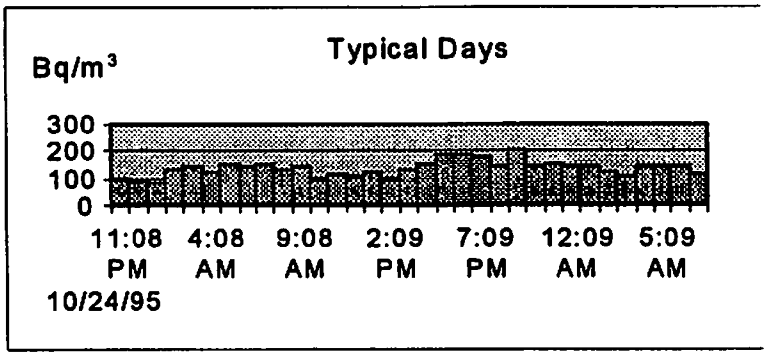

Figure 1. Radon concentration in bedroom ventilated by natural infiltration.

Outside air at the height of the apartment (about 30 m) was invariably very low in radon (less than 20 Bq/m^3 or 0.5 pCi/L). On July 25 & 26, 1995, it looked like this:

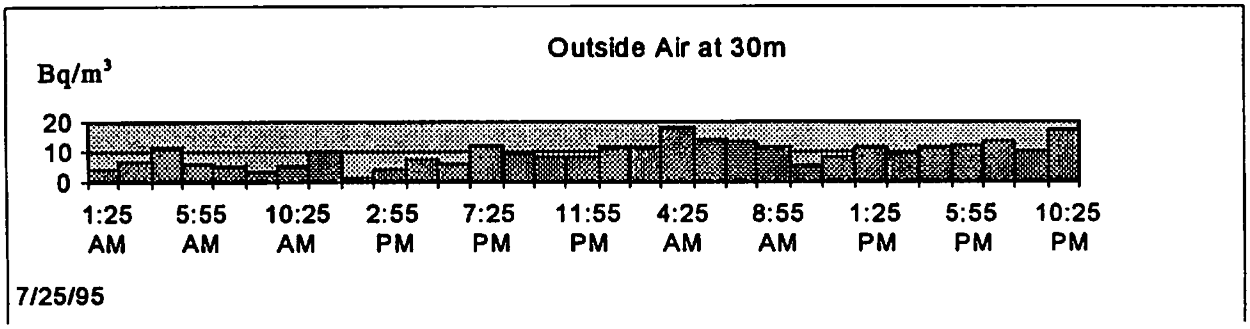

Figure 2. Outside air radon concentration at 30m height

There were many occasions where the results demonstrated the linear ramp in radon concentration inside the closed bedroom after dark. A few follow:

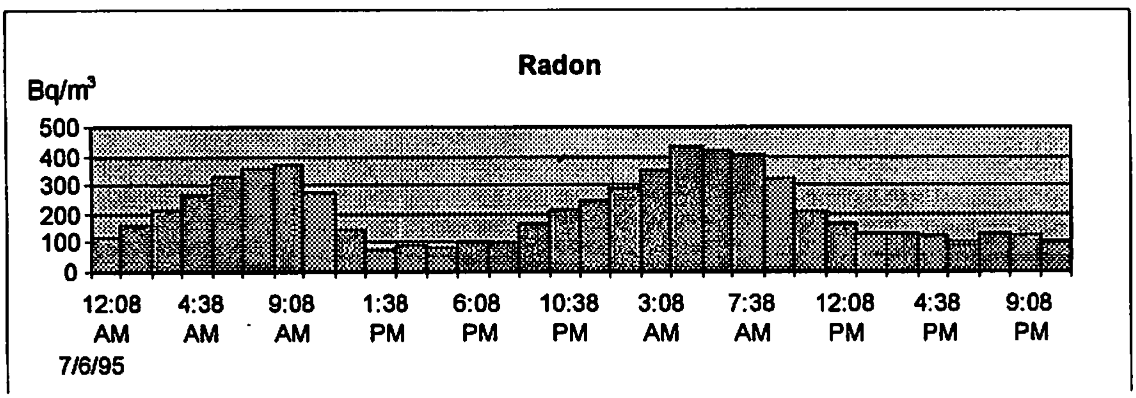

Figure 3a. Examples of linear ramps in radon concentration after dark

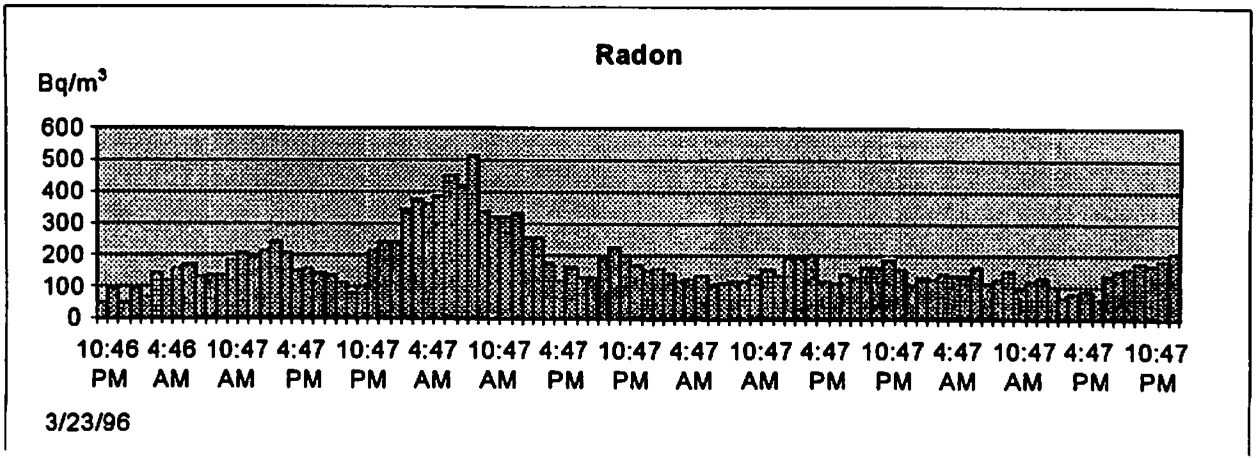

Figure 3b. Examples of linear ramps in radon concentration after dark

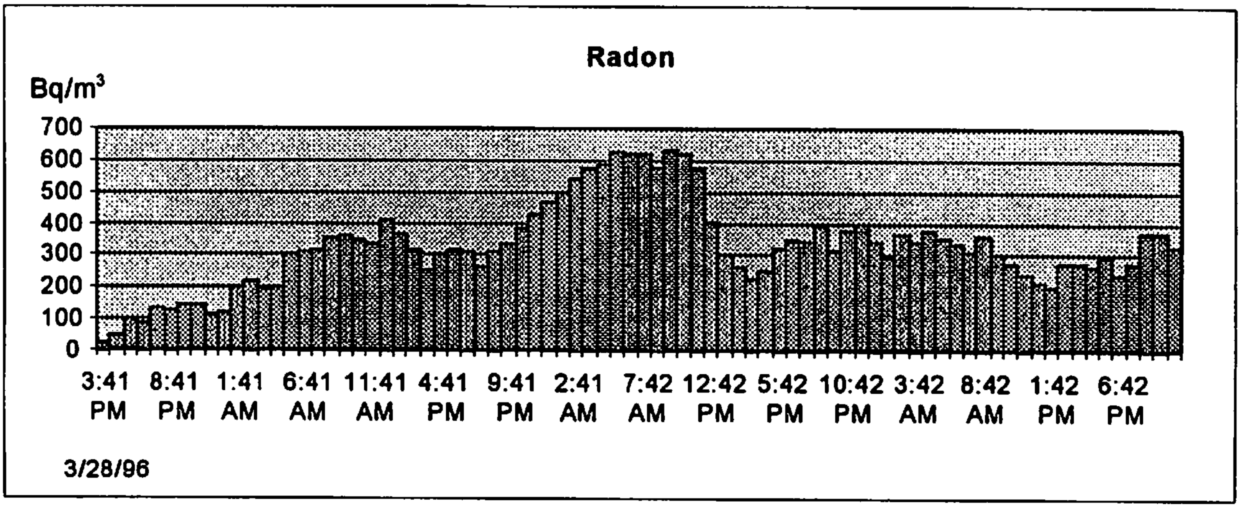

Figure 3c. Examples of linear ramps in radon concentration after dark.

The mean slope of the four ramps illustrated is 38 Bq/m³ (1 pCi/L) per hour with a standard deviation of less than 10%.

The room dimensions were 1.8 m x 2.1 m x 2.4 m. The window at one end took up wall space but was placed protruding 500 mm beyond the face of the wall. The extra surface created around the window just about compensated for the loss of concrete surface due to the window. The floor was covered in wood blocks and heavily sealed with polyurethane. It was considered to be sealed against the emission of radon from the concrete floor beneath the surface. The volume of the room with the window recess was 10 m³. The surface area of radon-emitting concrete was 23 m².

Radon emission

To measure the emission of radon from the wall, a container with an aperture of 0.17 m² and a volume of 0.044 m³ was sealed against the painted, concrete wall. Tubes to and from the RAD7 radon monitor were attached to "feed-throughs" mounted in either side of the container. The RAD7 and tubes added a further 0.001 m³ to the effective volume of the container.

Several runs were made in the emission measurement configuration. One such follows:

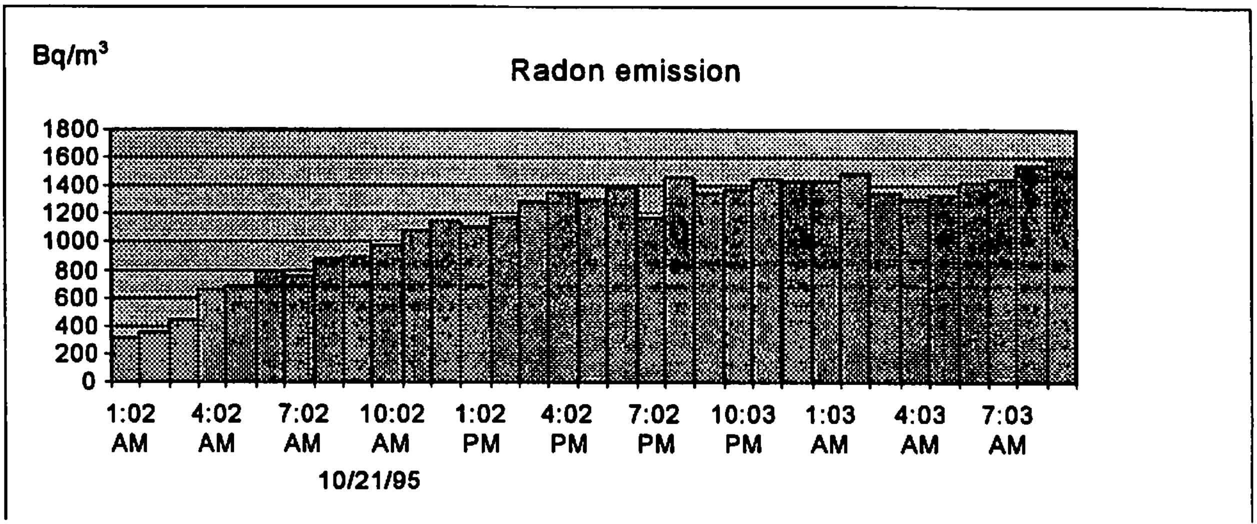

Fig 4. Measurement of radon emission from the wall.

The initial slope, averaged over the first ten hours, is 80 Bq/m^3 (2.2 pCi/L) per hour.

<u>Calculation</u>

A room of 10 m^3 experiencing a rate of increase in radon concentration of 38 Bq/m^3 per hour must have 380 Bq/hr entering it. If there are 23 m^2 of wall space emitting radon at the same rate and if that is the only source of radon, then each square metre must be emitting 380/23, or 17 Bq per hour.

A container of 0.045 m^3 experiencing a rate of increase in radon concentration of 80 Bq/m^3 per hour must have 3.6 Bq/hr entering it. If there is an emitting surface of 0.17 m^2 then the rate of emission must be 21 Bq/m^2 per hour.

DISCUSSION

Within the uncertainties of the experiment, the deduced rate of emission from the walls and the measured emission from the walls are in reasonable agreement. The wall emission measurement was made at a place where a major construction pillar of the high-rise building was situated. It is likely that the surface there, with the thick concrete behind it, will emit more radon than a concrete wall separating two rooms. Further study would show whether or not there is much variation from place to place around the walls and ceiling of the room. If there is variation, it is likely that the room average would be lower than the 21 Bq/m^2 per hour measured, in which case the agreement between the two investigations would likely be even more close.

In a high-rise concrete residential building in a hot climate, without central HVAC, it may be concluded, therefore, that the radon levels in a closed room are caused by emission from the walls and pillars of the building itself and are normally limited by infiltration of outside air. However, occasionally, when outside convection dies away and there is no wind, infiltration will cease and radon levels in the room will climb at a rate determined by the emission of radon from the walls. These circumstances may cause highly elevated radon levels which are hazardous to the health of the occupants. The maximum rate of rise of radon concentration, or maximum slew rate, is an indirect measure of the radon emission rate from the walls, floor and ceiling of the room.

Ventilation

It may be noted that if the radon concentration stabilises at some steady level, then the rate of supply of radon by emission is equal to the rate of removal by ventilation. We may see, therefore, that the air change rate causing the stabilization will equal the maximum ramp slope at zero ventilation (in this case 38 Bq/m^3 per hour) divided by the equilibrium, excess radon concentration in Bq/m^3.

Air Change Rate = (Maximum ramp slope)/(Equilibrium radon - outside radon levels)

If the outside air is presumed zero Bq/m^3 then the calculated air change rate is a lower limit.

The same equation may be used to calculate the ventilation necessary to keep the radon level below a given threshold. For example, if we choose a maximum of 100 Bq/m^3 (2.5 pCi/L) above the ambient as the target concentration and 40 Bq/m^3 (1 pCi/L) per hour as the observed maximum slew rate with zero ventilation, then 40/100 (1/2.5) or 0.4 ACH is the minimum air change rate necessary to meet the target.

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