A LABORATORY FOR STUDYING RADON MITIGATION METHODS IN HIGH-RISE OFFICE BUILDINGS IN HONG KONG

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ABSTRACT

A territory-wide survey of indoor radon level in 1993 showed that 17% of offices in Hong Kong have radon concentrations above 200 Bq m^{-3} compared with 4% for dwellings. Consequently, the Radioisotope Unit Radon Analysis Laboratory (RURAL) is being built for studying radon mitigation methods applicable to high-rise office buildings. The laboratory consists of three rooms; the main exposure room is built of concrete and is surrounded by the buffer room; and all controls and operations are done inside the control room.

The exposure room can, with the aid of the buffer room, simulate any environmental conditions that can be faced by a real building. The pressure, temperature and humidity can be adjusted to any meteorological conditions that can be found in Hong Kong. Pressure differential and temperature differential can be adjusted to simulate the arrival of fronts, troughs or typhoons. Aerosol concentration and distribution inside the exposure room are controllable as well as the ventilation conditions.

Various mitigation methods will be tested under different conditions. Passive methods include application of radon barriers to building structures and active methods include the use of air cleaners; techniques to increase radon daughters plateout or reduce their attachment to aerosols; and various modifications to the ventilation systems. Mitigation techniques involving modifications to the building strictures and building services will also be developed with the help of the RURAL.

INTRODUCTION

Building materials containing naturally occurring ^{232}Th and ^{238}U, which decay to ^{220}Rn and ^{222}Rn respectively, are the major sources of indoor radon, especially in poorly ventilated environment (1). Some European and U.S. countries have proposed regulations to control the use of building materials in order to minimize their hazards to the people. Hong Kong is a densely populated city, most people spend a lot of time, both living and working, in high-rise concrete buildings; and owing to the hot and humid weather, the use of air-conditioning systems with limited air change rate is very common. According to the territory-wide indoor radon survey conducted in 1993, 17% of offices in Hong Kong have radon concentrations above 200 Bq m^{-3} compared with 4% for dwellings. Moreover, the contribution of ^{220}Rn in Hong Kong is significant, since the predominant geological material is decomposed granite that has a higher content of ^{232}Th. According to another previous survey conducted in 1986 (2), the hazard of ^{220}Rn is almost half of that of ^{222}Rn. Because of the potential high radon dose, there is a necessity to build the RURAL to investigate radon mitigation methods under situations in Hong Kong.

STRUCTURE OF RURAL

The RURAL consists of three rooms, the Exposure Room, Buffer Room, and Control Room. The total area is 8 m x 5 m, and the overall height is 3 m. A schematic diagram of the RURAL is given in Fig. 1.

The Exposure Room is the room where indoor environment of high-rise building is simulated, and where most of the measurements will be done. Its is 3.5 m x 2.4 m x 2 m (L x W x H) and is built of 10 cm thick concrete. The Exposure Room is completely isolated from outdoor environment by the Buffer Room which completely encloses it. The floor of the exposure Room is also isolated from the floor of the Buffer Room by raising the Exposure Room with supports underneath it. Entrance to the Exposure Room is through double air-tight doors which minimize disturbance to the exposure condition.

The Buffer Room is 5 m x 5 m x 3 m (L x W x H) and is built of bricks. Its main function is to simulate all sorts of meteorological conditions external to the Exposure Room. Hence by changing the pressure and temperature inside both the Exposure Room and Buffer Room, the arrival of fronts, troughs or typhoons can be simulated and their effects to indoor radon concentration can be studied. Entrance to the Buffer Room is again guarded by double air-tight doors. All the walls, ceiling and floor of the Buffer Room are coated with polyurethane paint which reduces the generation of radon from the building material of the Buffer Room thus keeping the radon concentration at the low outdoor level.

The Control Room is where all controls and operations take place. Sample of air in the Exposure Room can be taken here through ducts connected to the Exposure Room. The room also contains a stainless steel radon exposure chamber (3) where radon related experiments are done.

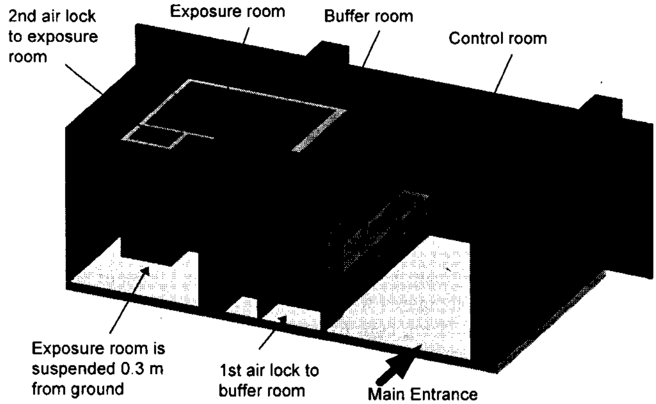

Figure 1. The RURAL (Radioisotope Unit Radon Analysis Laboratory)

FEATURES OF RURAL

The followings are brief descriptions of major equipment installed in the RURAL.

1. Aerosol generator

To create a steady concentration of monodispersed aerosol, a high output atomizer (model 3076, TSI Inc., USA) and a diffusion dryer (model 3062, TSI) are installed. The aerosol particle size can be altered by changing the concentration of solute in the solution of the atomizer. Typical particle size ranges from 0.02 m to 0.3 m. By adjusting the injection duration and interval, a wide range of aerosol concentration can be achieved.

2. Aerosol measurement

The size distribution of the aerosols are measured by two equipment. The Scanning Mobility Particle Sizer (SMPS) from TSI selects particle size with an electrostatic classifier (model 3071A, TSI) and then measure their concentrations with a condensation nuclei counter (model 3052A, TSI). The SMPS can measure the size distribution of aerosols from 5 nm to 1 μm. Above 1 μm, the aerosols are measured by a laser optical particle counter (model LASAIR 510, PMS) which has eight particle size channels from 0.5 μm to 10 μm.

Activity size distribution of ^{222}Rn daughters is determined by six wire screens-filter-detector assemblies (3). By varying the number of the 400 mesh stainless steel wire screen on each assembly, different sizes of aerosol particles will be collected on the six filter papers. By stripping the recorded activities on the filter papers by an iterative nonlinear algorithm (4), the activity size distribution in the range 0.002 μm - 0.5 μm can be obtained.

3. Ventilation measurement

Ventilation and air flow in the Exposure Room is monitored by a SF_6 tracer gas monitor (model 5302, B&K). The monitor detects SF_6 based on the photoacoustic infra-red absorption method.

4. ^{220}Rn & ^{222}Rn gas measurement

The gas inside the exposure room is continuously pumped through two Radiation Systems (model AB-5, Pylon Enc.) with scintillation cells, connected by a long delay tube. The first AB-5 measures the concentration of ^{220}Rn and ^{222}Rn, and the second measures that of ^{222}Rn alone after most ^{220}Rn decays inside the delay tube. In both AB-5 systems, the ^{220}Rn and ^{222}Rn daughters are first removed by a filter paper and only gas that decays inside the scintillation cells are recorded. The continuous radon concentration in the second AB-5 system is calculated by an algorithm (5) which takes into account of activities of previously deposited ^{222}Rn daughters and which also corrects for different humidity and flow rates. Concentration of ^{220}Rn is obtained by noting the difference in activities of the two scintillation cells.

5. Radon daughters measurement

The ^{220}Rn and ^{222}Rn daughters are sampled intermittently by a filter and Si detector assembly. The energy spectra of the radon daughters collected in the filter paper are recorded in a multichannel analyzer. Alternatively, three-count method (6) and five-count method (7) are used to determine the daughter activities and working levels. Unattached fraction of ^{222}Rn daughters are measured by computing the collected activities on 2 filter papers, one of them is preceded by a single 400 mesh wire screen that collects the unattached daughters.

6. Radon Chamber (3)

The chamber is made of stainless steel and has a volume of 1.46 m^3. It is connected to the Exposure Room where samples of air can be taken for conducting experiments. Similar to the Exposure Room, radon gas and radon daughter concentrations, aerosol size distribution, activity size distribution, etc. in the chamber can be controlled and monitored.

METEOROLOGICAL CONDITION

According to information provided by the Hong Kong Royal Observatory, the mean atmospheric pressure is 101.3 kPa, ranging from 95.3 kPa to 105.3 kPa, being maximum in winter during the cold fronts, and minimum in middle of the year during troughs and typhoons. The mean temperature ranges from 8 °C to 32 °C, being hottest in July and August, and coldest in January.

The exposure room can, with the aid of the buffer room, simulate any environmental conditions that can be found in Hong Kong. The designed pressure can range from 96 kPa to 103 kPa and temperature from 10 °C to 35 °C. The ventilation systems in both the Exposure Room and Buffer Room contain pressure sensors which automatically maintain the pressure by varying the input and output air flows. Similarly, the air change rate can be controlled and maintained automatically.

MITIGATION METHODS

It is well known that some paints or wall papers are effective radon barriers and provide an economic passive method to reduce indoor radon level. In addition to that, the RURAL is designed to study active mitigation methods such as controlling the ventilation system. Since change in pressure and temperature will result in change of radon exhalation rate, so by quantifying this change with respect to temperature and pressure differential between the two sides of the walls or between interior and exterior of the walls, the reduction of indoor radon can be accessed. Plate out of radon daughters can be increased by use of air cleaners or ionisers (8). Devices using similar principle will be installed and tested in the ventilation system. The air flow pattern in wall surface is also known to affect deposition rates of radon daughters, hence air flow system will be studied and adjusted to provide maximum reduction of suspended radon daughter concentration.

Radon-220 daughters attract less attention in other countries but they are certainly important contributors to the total radon dose in Hong Kong. Mitigation methods aiming to reduce ^{220}Rn exhalation and working level will be studied.

CONCLUSION

Rather standard mitigation methods have been developed in western countries for the detached or semi-detached houses but little was done for high-rise buildings. In places such as Hong Kong where the population density is high and ^{220}Rn and ^{222}Rn exhalation from local building materials are also high (9), the population exposure to radon is significant. Though indoor radon can be removed efficiently by increasing ventilation, there are many situations where this is not economically feasible, such as inside commercial buildings, so other methods have to be used and these may involve modifications to the building structures and building services.

With the help of the RURAL, reduction of indoor ^{220}Rn and ^{222}Rn hazards in high-rise buildings under situations in Hong Kong can be investigated. It is hoped that appropriate mitigation methods can eventually be developed.

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