The Second SREE Conference on Chemical Engineering

Surface Radon Exhalation Rates of Building Material and Soil Affect on Indoor Air Radon Concentration

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Abstract

By using RAD7 professional radon monitor which detecting data is reliable, selecting a one-story cottage in Shenzhen city area as the research object, the measurement results showed the radon concentration in the soil around the one-story cottage area was low background; the soil surface radon exhalation rate of soil was higher and was about two times that of cement floor of the room which indicated that the soil is the largest source of indoor radon; the surface radon exhalation rate of cement floor was higher than that of ceramic tile floor and was about 4 times that of the ceramic tile floor. The indoor radon concentration in the room covered with cement floor was higher than that of the ceramic tile floor due to the larger surface radon exhalation rate of cement floor. Therefore, in order to reduce indoor radon concentration, the laying floor material with low surface radon exhalation should be selected and windows should be kept open for ventilation.

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Keywords: Building materials; Soil; Surface radon exhalation rate; Indoor air radon concentration

1. Introduction

Indoor radon comes from the soil, building and decoration materials, outdoor air and natural gas for heating and kitchen equipment. Radon is a toxic, colorless, odorless radioactive gas. Radon is invisible and intangible, so people are not vigilant. Radon enters the body through breathing. The short-lived radionuclides from decay of radon will be deposited in the bronchial, lung and kidney tissue. When these short-lived radionuclides decay, they release α-particle which produces radiation injuries from internal

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exposure and damage respiratory epithelial cells. Long-term internal exposure may cause local tissue damage and even induce lung and bronchial cancer. Radon and its decay in the body will also release highly penetrating $\gamma$-rays on the human body and cause external radiation injuries.

China promulgated the “Code for indoor environmental pollution control of civil building engineering (GB 50325-2001) (2006 edition)”. This standard stipulates [1]: The concentration of radon should be controlled and limited. The indoor radon concentrations in I class civil engineering (residential, hospital, old buildings, kindergartens, schools, classrooms, etc.) $\leq 200$ Bq/m$^3$; The indoor radon concentrations in II class civil engineering (office buildings, shops, hotels, public place of entertainment, bookstores, libraries, exhibition halls, gymnasiums, public transport waiting rooms, restaurants, barber shops, etc.) $\leq 400$ Bq/m$^3$.

The world average soil radon concentration is 7400 Bq/m$^3$. In China, the area with soil radon concentration greater than or equal to 10000 Bq/m$^3$ is known as the high background area; the area with soil radon concentration greater than 5000 Bq/m$^3$ but less than 10000 Bq/m$^3$ is known as the middle background area; the area with the soil radon concentration is less than or equal to 5000 Bq/m$^3$ is known as the low background area. The bedrock of Shenzhen is granite. By the measurement, the Shenzhen average soil radon concentration is 50500 Bq/m$^3$. Therefore, Shenzhen is high background area of soil radon [2]. In this paper, the surrounding soil radon concentration and decoration material surface radon exhalation rate of a cottage in Shenzhen were investigated, which is very important for predicting indoor radon concentration levels, finding the source of radon, controlling and treating the indoor radon pollution.

Selecting a cottage as object investigated, by using a continuous RAD7 radon monitor, the soil radon concentration around this cottage and the soil surface radon exhalation rate were measured. The different material ground surface radon exhalation rate was determined in the room. Finally, the indoor air radon concentration in the room was measured and analyzed.

2. Measurement

2.1. Soil radon concentration measurement

The key point of measuring soil radon concentration is how to collect the air in soil. The soil radon concentration is generally greater than several hundred Bq/m$^3$. Such a high radon concentration is measured by RAD7 radon monitor with gold silicon surface barrier detector. Selecting a cottage in Shenzhen city area as object investigated, the soil radon concentration in seven-point in a small area around the cottage was measured by using a continuous RAD7 radon monitor. The sampling points were set about 1.5m far from the cottage wall. The distance between two points was 1.5 m or more. In each test point, the hole was made by using special drill rod. The hole diameter was 20 ~ 40mm and the hole depth was 500 ~ 800mm. The special sampler with the head pores was inserted into the hole. The sampler near the surface was closed to avoid the atmosphere into the hole. Then the RAD7 radon monitor began to exhaust. Before formal on-site sampling test, a series of different experiments should be done to determine the optimum pumping frequency. For each test point, measurements should be repeated 3 times and the arithmetic mean of radon concentration should be the test value.

RAD7 radon monitor was set sampling cycle for 10min, the number of cycles for 2 times, the measurement model for the sniff, the pump operating mode for Auto. The determination value of the second cycle is the test results [4]. Before the measurement, the humidity in air sampling measurement instrument system should be less than 10%. The sampling test should be carried out between 8:00 to 18:00 and not in the rain, in case of rain, should be carried out after 24h.
2.2. The surface radon exhalation rate measurement of soil and building material

The devices for measurement of the surface radon exhalation rate of soil and building material include measuring equipment and sampling equipment. Measuring equipment is RAD7 radon monitor and the sampling equipment is basin-like radon shield. In accordance with nuclear industry standards, “the surface radon exhalation rate measurement - the accumulation method (EJ / T 979-95)”, the standard devices for measurement of the surface radon exhalation rate of soil and building material will be set by connecting RAD7 radon monitor and radon shield.

The surface radon exhalation rate of soil and building material is radon amount released into the air per unit time per unit area on the surface of the soil and building material (Bq/m^2s). In this paper, the surface radon exhalation rate of soil and building material was determined by the accumulation method. The accumulation method is to test the soil and building material (precipitation medium) surface buckled by a gas-tight, radon insoluble shield, the radon was collected, radon concentration will increase with time growth, while radon leakage will increase, and finally precipitation with leakage and decay will get balance. When radon concentration in radon shield increases linearly within the time frame, radon concentration sampled and measured changes value, and the radon exhalation rate is calculated according to the volume of radon shield that covers radon, the area of radon shield and the accumulation time \[5\].

The formula is as follows:

\[
J = \frac{(C - C_0) \times V}{S \times t}
\] (1)

Where: 
- \(J\) - the surface radon exhalation rate of precipitation media measured (Bq/m^2s);
- \(C\) - the radon concentration in radon shield at accumulated time \(t\) (Bq/m^3);
- \(C_0\) - the radon concentration in radon shield at initial time (Bq/m^3);
- \(V\) - the volume of radon shield (m^3), \(V = 0.0048\) m^3;
- \(S\) - the bottom area of radon shield (m^2), \(S = 0.036\) m^2;
- \(t\) - the accumulation time of radon (s).

Selecting a cottage in Shenzhen city area as object investigated, the surface radon exhalation rate of soil was measured by using RAD7 radon monitor in the four points in a small area around the cottage. The sampling points for soil surface exhalation rate measurements and for soil radon concentration measurements were roughly same. Before measurement, in sampling points, the ground should be swept, the humus, weeds and stones should be removed. The sampler (ie radon shield) was put on the flat ground and was sealed with the soil to prevent leaks. When everything was ready, the measurement started and recorded the initial time. Measurement should be carried out in no wind or breeze condition.

When measuring the building material surface radon exhalation rate in cottage, the rooms covered with cement floor and ceramic tile floor were selected. The radon shield was sealed by gas-tight rubber mud. The surface radon exhalation rates of cement floor and ceramic tile floor were determined by the accumulation method.

RAD7 radon monitor was set sampling cycle for 10 min, the number of cycles for 10 times, the measurement model for the sniff, the pump operating mode for Auto. Before the measurement, the humidity in air sampling measurement instrument system should be less than 10%.

2.3. Indoor radon concentration measurement

Selecting a room in the cottage as object investigated, according to “Code for indoor environmental pollution control of civil building engineering (GB50325-2001) (2006 edition)” requirement, indoor
radon concentration should be measured by RAD7 radon monitor after keeping the external doors and windows in the room closed for 24 h. When the sampling time is not less than 30 min, air humidity is lower than 10%, the determination of indoor radon concentration will get satisfactory data, because the operator error is less and the equipment accuracy is better. [5]

Therefore, RAD7 radon monitor was set sampling cycle for 2 h, the number of cycles for 12 times, the measurement model for the sniff, the pump operating mode for Auto. The indoor radon concentration changes in the room were continuously determined for 24 hours in a day. Doors and windows were closed and minimized staff access during the measurement. The instrument was put in the center of the room and drying tube was set about 1 m high from the ground. The sampling points were arranged in the place where the indoor air rate is the lowest, away from the walls, vents, windows and air current, avoided direct sunlight.

3. Results and discussion

3.1. The area around the cottage is the low background area of soil radon

The high concentration radon can be found in soil and rocks containing uranium, radium, thorium in deep geological fault. The soil radon concentration in seven-point in a small area around the cottage was measured by using a continuous RAD7 radon monitor. The results are shown in Table 1. The data from Table 1 shows, the soil radon concentration around the cottage is 4716 Bq/m³, indicating that the area around the cottage is the low background area of soil radon, which is due to the soil around the cottage is not the original soil, but the backfill soil. So the soil radon concentration here is well below the average soil radon concentration 50500 Bq/m³ in Shenzhen.

Table 1. The measuring data of soil radon concentration and building material surface radon exhalation rate

| Measurement object | Measurement point | Soil radon concentration (Bq/m³) | Surface radon exhalation rate (mBq/m²s) |
|--------------------|------------------|---------------------------------|-----------------------------------------|
|                    |                  | Range of values                 | Range of values                        |
| Soil               | 7                | 1473 ~ 11033                    | 4716 ± 3207                             |
| Soil               | 4                | 6.1 ~ 7.8                       | 13.8 ± 9.8                              |
| Cement floor       | 3                | 3.7 ~ 10.2                      | 6.4 ± 3.4                               |
| Ceramic tile floor | 3                | 1.1 ~ 2.3                       | 1.5 ± 0.7                               |

3.2. The comparison of the surface radon exhalation rate between soil and building material

Soil, concrete, brick, sand, cement, gypsum board, granite, tile and other building material are the largest source of indoor radon. By using a continuous RAD7 radon monitor, the surface radon exhalation rate of soil was measured in a small area around the cottage and the surface radon exhalation rates of cement floor and ceramic tile floor were measured. Measurement results are shown in Table 1. The data shows the soil surface radon exhalation rate is maximum and about 2 times the cement floor, indicating that the soil is the largest source of indoor radon; the surface radon exhalation rate of cement floor is larger than that of ceramic tile floor, is about four times the ceramic tile floor. The radioactive material in
tiles (including ceramic tiles, polished tiles, colored glazed tiles) is mainly from the zirconia. In order to pursue the effect of natural marble of some ceramic tiles and increase the whiteness of the product, the most common approach is changing the formula by adding zirconia material.

3.3. The Indoor air radon concentration

Radon from the foundations of a building can enter the soil and atmosphere through ground fault. Radon will be spread through the ground cracks to the interior of the building. Because the absolute radon concentration of measurement sites can not be obtained, only the average is used as a reference level. By measuring, indoor radon concentration in the room covered with cement floor and in the room covered ceramic tile floor in the cottage are shown in Table 2.

Table 2. Measuring data of indoor air radon concentration

| Time  | Measurement results (Bq/m³) | Time  | Measurement results (Bq/m³) |
|-------|-----------------------------|-------|-----------------------------|
| 11:45 | 24.1                        | 11:05 | 15.6                        |
| 13:45 | 36.8                        | 13:05 | 31.1                        |
| 15:45 | 31.1                        | 15:05 | 9.90                        |
| 17:45 | 34.0                        | 17:05 | 17.0                        |
| 19:45 | 36.8                        | 19:05 | 12.7                        |
| 21:45 | 41.0                        | 21:05 | 11.3                        |
| 23:45 | 29.7                        | 23:05 | 8.48                        |
| 01:45 | 52.3                        | 01:05 | 7.07                        |
| 03:45 | 49.5                        | 03:05 | 14.1                        |
| 05:45 | 73.5                        | 05:05 | 9.90                        |
| 07:45 | 58.0                        | 07:05 | 15.6                        |
| 09:45 | 65.0                        | 09:05 | 22.6                        |

\[
\overline{x} \pm s = 44.3 \pm 14.7 \quad \overline{x} \pm s = 14.6 \pm 6.72
\]

Measurement results show the average indoor radon concentration in the room covered with cement floor is 44.3 Bq/m³ in 24-hour and the average indoor radon concentration in the room covered with ceramic tile floor is 14.6 Bq/m³ in 24-hour. Thus, the radon concentration in two rooms is far less than annual mean concentration 400Bq/m³ prescribed by “Indoor air quality standard (GB / T 18883-2002)”, and is far less than 200 Bq/m³ limits prescribed by “Code for indoor environmental pollution control of civil building engineering (GB50325-2001) (2006 edition)”. The results indicate that the indoor radon concentration in these two rooms do not exceed the national standard. However, the indoor radon concentration in the room covered with cement floor is larger because the surface radon exhalation rate of cement floor is higher.

4. Conclusion

The indoor air radon in cottage comes mainly from the foundation soil and rock. Radioactive radon gas in soil can enter into the room through ground, cracks or along the pipe. Therefore, selecting the building site should try to avoid the radioactive radon high background area and the fault area. When the
conditions are allowed, the radon concentration should be tested by relevant departments and the radon reduction measures should be taken. When build a house, the gap in the floor and walls should be eliminated to reduce radon precipitation.

Radon from building and decoration material precipitation can enter the room. Thus, in the construction and decoration of house, the building and decoration materials with lower surface radon exhalation rate and low content of radionuclide should be chosen. Real estate developers should pay particular attention to the radioactive material and delegate radiation protection security agencies to test in time. During home renovation, residents should pay attention to the selection of decoration material, purchase and choose the stones according to the radioactivity level. The radioactivity of radioactive stone is in the order of red, green, flesh red, gray, white and black. The radioactivity of granite is generally higher than that of marble. Of course, the most effective method is to detect and analyze the surface radon exhalation rate of building and decorative material, which can provide reference for selection and use material.

To reduce the harm of indoor radon, ventilation is effective way to reduce indoor radon concentration. According to expert’s test, the indoor radon concentration was 151 Bq/m$^3$ in a room and fell to 48 Bq/m$^3$ after 1 hour’s ventilation. Therefore, indoor radon concentrations can be reduced by opening the windows for natural ventilation, or by use of exhaust fans, air conditioners and other artificial ventilation methods. Indoor air purifier is also an effective equipment to reduce indoor radon concentrations.

Acknowledgements

The author wishes to thank Mr. Fu Shi and Mr. Su Hao from Shenzhen Institute of Building Research Co., Ltd, for their cooperation with experiments and the calibration of RAD7 radon monitor.

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