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Analysis of Factors Affecting Indoor Radon Concentration in Zhuji City

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Abstract

At present, indoor radon pollution has become the focus of global environmental science and public health research. This study measured the indoor radon and soil radon concentrations in Zhuji City and analyzed the various factors affecting indoor radon concentrations. The research results show that the indoor radon concentration in Zhuji City is significantly lower than the national safety standard limit. The indoor radon concentration is affected by factors such as building age, floor height, seasonal changes and ventilation conditions. In addition, the study also found that there is a certain positive correlation between indoor radon and soil radon , and the soil radon concentration in Zhuji City is relatively high.

Keywords

Indoor Radon; Soil Radon; Influencing Factors.

1. Introduction

In modern society, people spend significantly more time indoors every day, and the quality of the indoor environment is increasingly closely related to human health . Indoor radon pollution has become a research focus in the fields of global environmental science and public health.

22Rn is a colorless,odorless, radioactive noble gas that is a product of the radioactive decay chain of uranium-238[1]. The half-life of 222 Rn is about 3.823 days . The radioactive daughters produced by its decay, such as polonium -218 and lead-214, are mostly solid particles that are easily attached to dust and aerosols in the air . Once inhaled by the human body, these radioactive daughters will continue to decay in the respiratory system and release alpha particles . Long-term exposure to such an environment will cause serious damage to human cells, greatly increasing the risk of lung cancer[2] . The International Agency for Research on Cancer (IARC) has long classified radon and its daughters as Class 1 carcinogens[3]. Darby et al. estimated that for every 100 Bq/m^3 increase in radon exposure, the risk of lung cancer increases by about 16%[4] . 3% to 14% of global lung cancer deaths may be attributed to inhaled radon exposure. Radon has also become the second largest cause of lung cancer in humans, second only to smoking[5] .

There are three main sources of indoor radon[6] . First, building materials. Many natural building materials, such as granite, shale, and some bricks and tiles, capture trace amounts of radioactive elements such as uranium and radium during their formation. These elements will continue to release radon gas into the room during their natural decay[7].Second, soil and rock are also important sources of indoor radon . Radon in soil and rock can enter the room through cracks and pores in the foundation of the building, as well as through the connection between pipes and the ground[8].This infiltration phenomenon is particularly evident in areas with high soil radon concentrations. Water supply and natural gas are also potential sources of indoor radon[9,10].When water is extracted from the ground and used directly as domestic water, radon in the water may be released into the indoor air.Natural gas may also release radon during combustion, but the amount released is usually relatively small .

Foreign countries started research on indoor radon at an early stage. Radon measurement began in the former Soviet Union in 1922 when it was exploring uranium mines. Later , radon measurement methods were used to determine the radon concentration in uranium mines and other mines and its relationship with the high incidence of lung cancer. After 1950, the application scope of radon measurement methods expanded to areas closely related to people's production and life. Subsequently, countries around the world began to actively carry out indoor radon investigations and studies . The changes in indoor radon concentrations abroad show that the average indoor radon concentration has generally shown a downward trend with the increase of years . The highest values in 90% of countries exceed the national standard limit of 150Bq/m3, but the average values are all lower than the standard limit[11] . In terms of measurement technology, a variety of mature and accurate measurement methods have been developed, such as the activated carbon box method and the track etching method. These methods can accurately measure radon concentrations according to different indoor environmental conditions, providing a solid data foundation for subsequent research. China’s research on indoor radon began in the 1980s , and three large-scale indoor radon surveys were conducted in 1983-1990, 1991-2002, and 2002-2004. A summary of literature data showed that China’s indoor radon concentration generally showed an upward trend in the 1980s, 1990s, and after 2000[12].

This paper measured the indoor radon concentration in Zhuji City and explored in depth the influencing factors of indoor radon in Zhuji City , which has important practical significance for reducing the risk of indoor radon exposure and formulating scientific and effective prevention and control strategies.

2. Measurement Scheme

Radon detector was used to measure soil radon around 11 residential buildings in Zhuji City that were comprehensively investigated. There were 16 measurement points around each residential building. Before the measurement, it was ensured that there was no rain within 24 hours and the soil radon detection of each building needed to be completed on the same day.There were a total of 62 effective measurement points.

Indoor radon measurement: Use a radon detector to hang at a position of 1.5-2.0m in the room, avoid placing it in a place with interference. According to the situation in Zhuji City , a total of 13 residential buildings with 36 households were selected for testing in four stages in different seasons. The test floors were selected from 1 to 3 floors, and 1 to 2 households on each floor were measured. The overall measurement results are shown in Table 1.

Table 1. Indoor radon measurement results in four stages

	average value	Median	Standard deviation	Minimum	Maximum
Spring	23.39	20.0	10.82	10.0	56.0
Summer	22.80	19.0	14.65	6.0	60.0
Autumn	18.0	16.0	8.80	6.0	32.0
Winter	44.7	45.0	12.75	27.0	69.0

Overall, the measured indoor radon range is 6.0-69.0Bq/m^3.According to the "Code for Indoor Environmental Pollution Control of Civil Construction Engineering" GB 50325-2010, the indoor radon concentration limit for Class I civil construction engineering is 200Bq/m^3. The indoor radon concentration measured above is relatively low, far less than the prescribed limit.

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3. Factors Affecting Indoor Radon

3.1. Analysis of the Correlation between Building Age, Floor, Season and Indoor Radon

The construction years are divided into before 2000 and after 2000. The results are shown in Table 2. The indoor radon concentration of buildings after 2000 has increased significantly compared with that before 2000. This may be because buildings after 2000 mostly adopt more rigorous sealing structures, such as the widespread use of double-glazed windows and high-efficiency insulation materials, which greatly reduces the natural ventilation efficiency of buildings, resulting in the continuous accumulation of radon. From the perspective of building materials, with the development of the construction industry, new building materials are constantly emerging, some of which contain radioactive elements such as uranium and thorium, which to a certain extent increase the potential risk of radon release.

It can be seen from Table 3 that as the floor goes up, the indoor radon concentration gradually decreases, and the indoor radon concentration on the first floor is the highest. This is because the first floor is mainly affected by the radon in the foundation soil, and this influence gradually decreases as the floor goes up.

Table 2. Average indoor radon concentrations in different building ages

	Before 2000	After 2000
Valid number	25	11
Indoor radon concentration (Bq / m^3)	19.84	31.45

Table 3. Average indoor radon concentrations in different building ages

	First floor	Second floor	Third floor
Valid number	14	9	9
Indoor radon concentration (Bq / m^3)	23	19	18

Four buildings were selected for continuous measurement in different seasons. The results are shown in Table 4. The average indoor radon value in Winter is much higher than in other seasons, reaching 42 Bq/ m^3. This is because Zhuji City does not have heating in Winter, and in order to maintain the indoor temperature, the window opening is reduced, resulting in the accumulation of indoor radon concentration. The indoor radon concentration is lowest in Autumn, only 17 Bq/ m^3. This is because the climate in autumn is suitable, the indoor ventilation is good, and the radon concentration is low.

Table 4. Average indoor radon concentration in different seasons

	A#	B#	C#	D#	average value(Bq/ m^3)
Spring	13	19	26	25	21
Summer	18	21	22	14	19
Autumn	17	20	15	15	17
Winter	42	38	40	47	42

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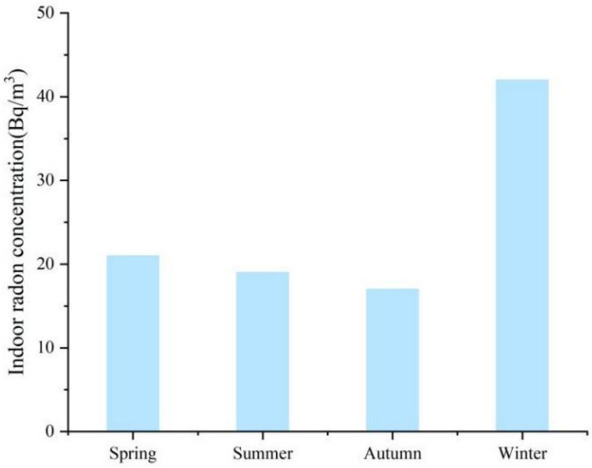

Figure 1. Variation of average indoor radon concentration in different seasons

3.2. Effect of Ventilation on Indoor Radon

A household was selected to use a RAD-7 radon detector to measure continuously for 48 hours in the transition season, summer, and winter. The first 24 hours were conducted under natural conditions, and the next 24 hours were conducted with doors and windows closed to explore the effect of ventilation on indoor radon. The results are shown in Figure 2. In natural conditions, the indoor radon concentration was highest in summer and increased significantly at night. This is because the air conditioner is turned on and the doors and windows are closed at night in summer. It reaches the maximum value at 7:00 in the morning and then decreases significantly . This is because people choose to open the doors and windows after getting up in the morning. When the doors and windows are closed, the indoor radon concentration is significantly higher than the concentration in the natural state. After closing the doors and windows, the indoor radon begins to accumulate gradually and then tends to stabilize.

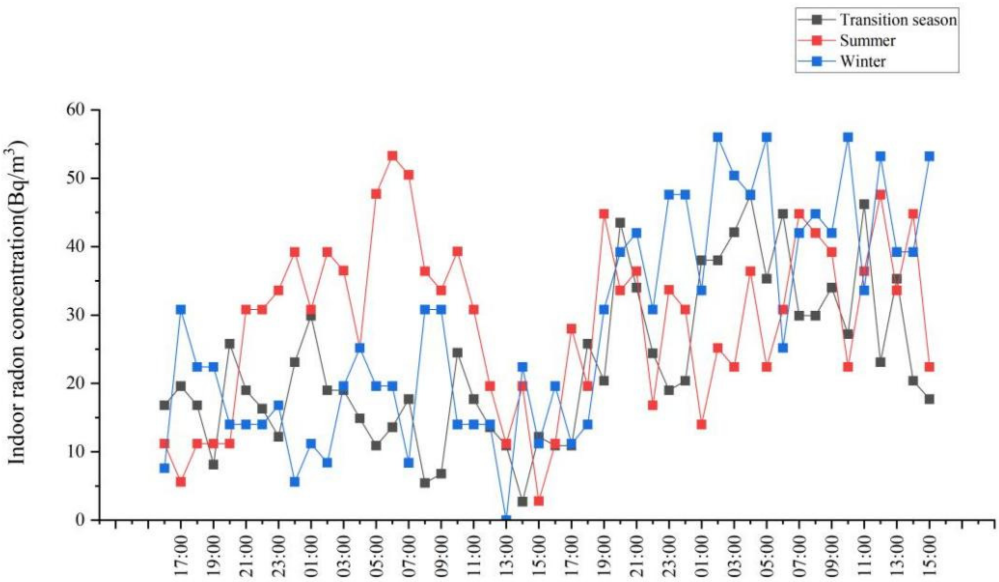

Figure 2. Changes in indoor radon concentration measured continuously for 48 hours in different seasons

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3.3. Correlation Analysis between Indoor Radon and Soil Radon

Soil radon was measured around 11 residential buildings, and the measured houses were numbered. The results are shown in Table 5. The correlation coefficient between indoor radon and soil radon is 0.16, indicating that there is a certain positive correlation between the two, but the indoor radon concentration is the result of the combined influence of multiple factors.

The average soil radon concentration in Zhuji City is 19200 Bq/m^3. Compared with the other 16 regions, as shown in Figure 3 , the soil radon concentrations in Zhuji City and Wenzhou City are close, which are much higher than those in other cities. The national urban soil radon concentration is 9614 Bq/m^3.The soil radon concentration in Zhuji City is twice that of the national urban soil radon concentration, which is generally at a high level.

Table 5. Correlation between indoor radon and soil radon concentrations

Measurement points	Soil radon concentration(Bq/m^3)	Indoor radon concentration(Bq/m^3)	Correlation coefficient
1	15949	17	0.16
2	5285	22	
3	13373	26	
4	7512	28	
5	8012	13	
6	31993	24	
7	16110	21	
8	18969	25	
9	7748	16	
10	9466	27	
11	17704	20	

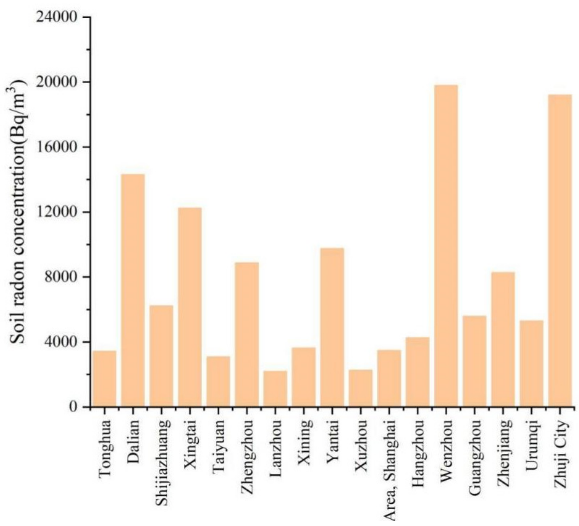

Figure 3. Comparison of soil radon concentrations in other 16 cities and Zhuji City

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4. Results

By measuring the indoor radon concentration of 13 residential buildings in Zhuji City and the soil radon of 11 surrounding residential buildings , the factors affecting the indoor radon concentration and the relationship between indoor radon and soil radon were explored, and the following conclusions were obtained:

(1) Through four phases of measurement, the overall indoor radon concentration ranged from 6.0 to 69.0 Bq/m^3, which is much lower than the prescribed limit of 200 Bq/m^3 ;

(2) Indoor radon increases with the age of the building, and is negatively correlated with the floor , with the highest on the first floor and the lowest on the third floor. Indoor radon was measured in four residential buildings over a span of one year, and the results showed that the highest level was in Winter and the lowest level was in Autumn.

(3) Through 48 hours of continuous measurement, the results showed that indoor radon with doors and windows closed was significantly higher than that in the natural state, indicating the importance of daily ventilation in reducing indoor radon;

(4) Through research, the correlation coefficient between soil radon and indoor radon is 0.16, indicating that there is a certain correlation between the two. The average concentration of soil radon in Zhuji City is 19200 Bq/m^3 , which is much higher than the average value of soil radon concentration in cities across the country.

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