

# Analysis of Indoor Radon Concentration Levels and Influencing Factors in Kunshan

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## Abstract

Radon is a natural radioactive gas widely existing, in order to study the indoor radon level and influencing factors in Kunshan City, the indoor radon concentration of three buildings was analyzed. It was found that all of them met the indoor radon concentration limit specified in the national standard, and the indoor radon concentration was mainly related to soil radon concentration, indoor ventilation and climate. Indoor radon can be controlled from the following points: (1) While building a new building, test the radon concentration in the soil and try to avoid areas with high concentrations. (2) Pay attention to daily window ventilation, especially in cold weather and poor air circulation in winter. (3) Find and prevent indoor radon sources, building materials will also release a certain amount of radon, and interior decoration materials must be selected to meet national standards.

## Keywords

Indoor Radon; Influence Factors; Exposure Level.

## 1. Introduction

Radon is a noble radioactive gas that originates from the radioactive conversion of  $^{238}\text{Ra}$  in the  $^{226}\text{U}$  decay chain, which is present in all terrestrial materials in the environment. It is an important source of natural human exposure to ionizing radiation, most of which is indoors [1]. There are three isotopes of radon ( $^{222}\text{Rn}$ ,  $^{220}\text{Rn}$ , and  $^{219}\text{Rn}$ ) in nature, from three naturally occurring radiation systems: uranium, thorium, and actinium. Uranium (radium) is a naturally occurring trace element found in all rocks and soils on Earth, with the highest concentration in granite, followed by shale, limestone, soil, igneous rock, and sandstone. Although there are several factors that influence the release of radon from rocks and soils into the air, such as radium content, porosity, humidity, air pressure and temperature, radon in ambient air comes mainly from the ground ( $7.6 \times 10^{19}$  Bq/a, 77.7% of all radon sources in ambient air), plants and groundwater ( $1 \times 10^{19}$  Bq/a, 10.2%), and the rest from the nuclear industry, the phosphorus industry, construction, and the combustion of coal and natural gas.

There are two main sources of indoor radon, one is when radon penetrates from the soil into the building directly, and the other is emitted from the building materials, both of which will pollute the indoor air [2]. Radon has been identified as one of the leading causes of adverse health problems in occupants due to its accumulation in indoor environments. Most people spend more than 90% of their time indoors in current, and many studies have demonstrated the relationship between long-term exposure to high radon concentrations and the incidence of lung cancer [3-5], which may also increase the risk of leukemia in children [6]. There isn't safe level of radon exposure now, and low concentrations of radon still increase the risk of lung cancer in exposed populations [7].

Globocan 2020 reported that lung cancer is the leading cause of cancer deaths worldwide (accounting for 18.0% of the total cancer deaths) and is also the most common malignant tumor in the Chinese population. According to field experiments in 26 provinces in China, the average

indoor radon level in China in the 80s of the 20th century was 22.5 Bq/m<sup>3</sup>[8]. In the 1990s, shang[9] et al. studied indoor radon levels and the distribution of buildings in 18 cities in China, with an average indoor radon concentration of 44.1Bq/m<sup>3</sup>[10, 11]. It can be found that indoor radon concentrations in China were on the rise. In this paper, the indoor radon concentration data in Kunshan City were used to analyze the influencing factors of indoor radon concentration and the prevention and control measures of indoor radon, which is of great significance for assessing the disease burden of lung cancer.

## 2. Measurement Method and Results

### 2.1. Measurement Method

Kunshan is located in the northern subtropical southern monsoon climate zone, with a mild and humid climate and four distinct seasons. In order to conduct to the test correctly, eight buildings were selected as the survey subjects. The measurement adopts the RAD7 radon meter, the operating principle of the instrument is to use a solid-state  $\alpha$  detector to measure the  $\alpha$  particles in the radon decay series, and convert them into radon concentration according to the built-in algorithm, and the number of measurements can be set according to the requirements. Its relative error is within 10%, which accord with the requirements that the uncertainty of the measurement results of the selected method in the "Code for Indoor Environmental Pollution Control of Civil Construction Engineering" should not be greater than 25%.

### 2.2. Measurement Results

In order to increase the representativeness and accuracy of the data, 30 measurement points were set up, and a total of 30 detectors were required. In order to obtain more reliable results, the measurement was carried out in four stages.

The measurement of the first stage is from February to May, and the measurement results are shown in Table 1, and the indoor radon concentration measured in the first stage is 9~80.7Bq/m<sup>3</sup>

**Table 1.** Results of the first stage of indoor radon concentration measurements

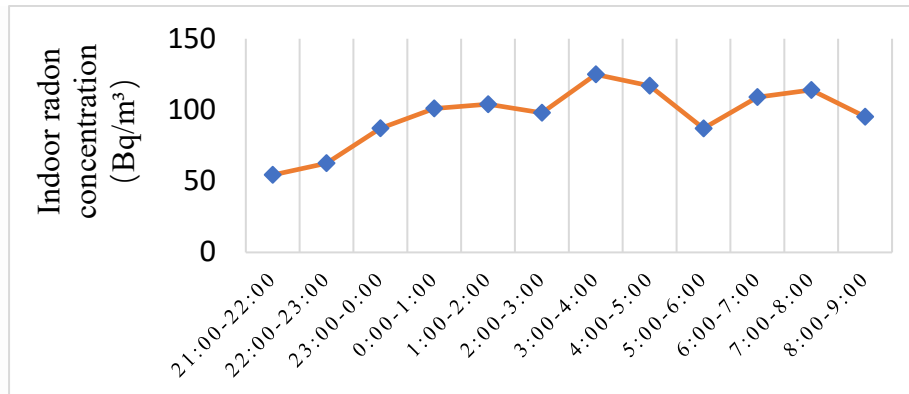
Buildings	Days	mean $\pm$ standard deviation/(Bq/m <sup>3</sup> )
1#	93	9 $\pm$ 1.53
2#	93	58.66 $\pm$ 11.83
3#	93	16.88 $\pm$ 3.5

The second stage is from May to August, the measurement results are shown in Table 2, and the indoor radon concentration measured in the second stage is 18~33.73 Bq/m<sup>3</sup>.

**Table 2.** Results of the second stage of indoor radon concentration measurements

Buildings	Days	mean $\pm$ standard deviation/(Bq/m <sup>3</sup> )
1#	94	18 $\pm$ 5.16
2#	94	33.73 $\pm$ 13.33
3#	94	16.24 $\pm$ 4.56

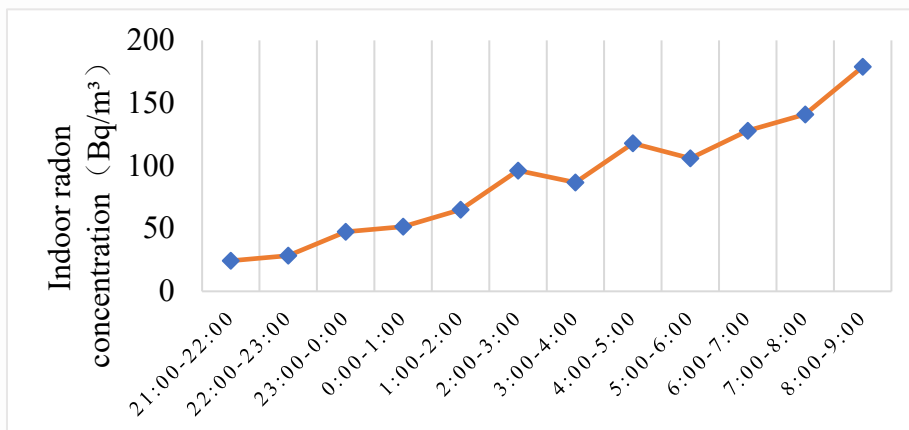
The third stage is from August to November, the measurement results are shown in Table 3, and the indoor radon concentration measured in the third stage is 13.21~33.55 Bq/m<sup>3</sup>.



**Figure 1.** 2 # Continuous measurement results of buildings from June 24 to June 25

**Table 3.** Results of the third stage of indoor radon concentration measurements

Buildings	Days	mean ± standard deviation/(Bq/m <sup>3</sup> )
1#	93	13.21±4.29
2#	93	33.55±8.79
3#	93	18.69±5.37



**Figure 2.** 2 # Continuous measurement results of buildings from November 24 to November 25

The fourth stage is from November to the next February, the measurement results are shown in Table 4, and the indoor radon concentration measured in the fourth stage is 24.21~101.72 Bq/m<sup>3</sup>.

**Table 4.** Results of the fourth stage of indoor radon concentration measurements

Buildings	Days	mean ± standard deviation/(Bq/m <sup>3</sup> )
1#	109	24.21±6.97
2#	112	80.72±8.26
3#	108	40.51±5.61

China's Code for Indoor Environmental Pollution Control of Civil Building Projects GB50325-2010 (2013 edition) stipulates that the limit of indoor radon concentration in class I civil building projects is 200 Bq/m<sup>3</sup>, and t. The indoor radon concentration measured above is below the prescribed limit of 200 Bq/m<sup>3</sup>.

### 3. Discussion

#### 3.1. Effect of Soil Radon Concentration

According to the normality test of soil radon concentration and indoor radon concentration, the results showed that the normal distribution, and Pearson correlation analysis, the correlation between soil radon concentration and indoor radon concentration was significant.

**Table 5.** Normality test

	Kolmogorov-Smirnov(K) <sup>a</sup>			Shapiro-Wilk		
	statistics	df	significance	statistics	df	significance
Indoor radon concentration/(Bq/m <sup>3</sup> )	.225	9	.200*	.782	9	.013
Soil concentration/(Bq/m <sup>3</sup> )	.325	9	.007	.743	9	.005
*. This is the lower limit of true significance.						
a. Lilliefors Significance correction						

**Table 6.** Correlation test

		Indoor radon concentration/(Bq/m <sup>3</sup> )	Soil concentration/(Bq/m <sup>3</sup> )
Indoor radon concentration / (Bq/m <sup>3</sup> )	Pearson correlation	1	.668*
	Significance (double-tailed)		.049
	N	9	9
Soil concentration / (Bq/m <sup>3</sup> )	Pearson correlation	.668*	1
	Significance (double-tailed)	.049	
	N	9	9
*. The correlation was significant at a confidence (double test) of 0.05.			

#### 3.2. The Influence of the Ventilation Factors

From the perspective of public health, the ventilation habits of the residents are more important than the other habits, and the ventilation also has a great impact on the indoor radon concentration[12].

In the process of testing the radon concentration in the room, the doors and windows are required to be closed. However, during the measurement period in Figure 1, it may be that residents cannot strictly close the doors and Windows, open Windows for ventilation, or people are in and out. Indoor radon concentration in figures 1 and 2.

#### 3.3. The Influence of Climatic Factors

The outdoor condition must also be considered when studying indoor radon concentration. In winter, high pressure is not conducive to gas diffusion; in summer, high temperature, low pressure and rapid gas diffusion in summer. Lin et al. found that the highest radon concentration in the atmosphere was between December and March, the lowest between June and September, and the annual average was generally low[13]. Kunshan city belongs to the southern monsoon climate zone of the north subtropical zone, with mild and humid climate and four distinct seasons. According to the table, the average indoor radon concentration in the fourth quarter is the highest, while the indoor concentration in the second quarter is the lowest, which is consistent with the results of previous studies.

## 4. Conclusion

This study about the indoor radon concentration and soil radon concentration in three buildings in Kunshan city, which can be found that indoor radon concentration is below the limit value and is affected by indoor radon concentration, ventilation and climate, mainly with the following conclusions:

(1) The Pearson correlation coefficient between indoor radon concentration and soil radon concentration was found to be 0.668 and  $p < 0.05$ .

(2) Through the analysis of the continuous measurement results of the indoor radon concentration in the 2 # building, it is found that the indoor radon concentration is generally rising when the doors and Windows are closed. Therefore, daily window ventilation is crucial to reduce indoor radon concentration.

(3) Indoor radon concentration is affected by temperature and air pressure, which is the highest in winter and the lowest in summer, that is, the highest in the fourth stage and the lowest in the second stage.

Prevention and control countermeasures of indoor radon pollution:

(1) Test for soil radon concentration and try to avoid areas with high concentrations before building new buildings.

(2) Pay attention to the daily window ventilation, especially in the winter cold weather and air circulation space.

(3) Find and prevent indoor radon sources, building materials will also release a certain amount of radon, indoor decoration materials must choose the materials that meet the national standards.

## References

- [1] Borgoni R, Tritto V, Bigliotto C, et al. A geostatistical approach to assess the spatial association between indoor radon concentration, geological features and building characteristics: The case of Lombardy, Northern Italy [J]. *International Journal of Environmental Research and Public Health*, 2011, 8(5): 1420-40.
- [2] Kirk K N, Vern C, Rogers. Radon penetration of concrete slab cracks, joints, pipe penetrations, and sealants [J]. *Health Physics*, 1997, 73.
- [3] Samet, Brenner, Brooks, et al. *Health Effects of Exposure to Radon* [M]. *Health Effects of Exposure to Radon*, 1999.
- [4] Only E, Longstaff C, Rigsby P, et al. *World Health Organization 2009* [J]. 2009, 50(1-2): 26-35.
- [5] Brauner E V, Andersen C E, Sorensen M, et al. Residential radon and lung cancer incidence in a Danish cohort [J]. *Environmental Research*, 2012, 118: 130-6.
- [6] Tong J, Qin L, Cao Y, et al. Environmental radon exposure and childhood leukemia [J]. *Journal of Toxicology and Environmental Health-Part B-Critical Reviews*, 2012, 15(5): 332-47.
- [7] Bochicchio F, Zunic Z S, Carpentieri C, et al. Radon in indoor air of primary schools: a systematic survey to evaluate factors affecting radon concentration levels and their variability [J]. *Indoor Air*, 2014, 24(3): 315-26.
- [8] Cheng J P, Guo Q J, Ren T S. Radon levels in China [J]. *Journal of Nuclear Science and Technology*, 2002, 39(6): 695-9.
- [9] Shang B, Qinghua H E, Wang Z. Studies of indoor action level of radon in China [J]. 2003.
- [10] Lubin J H, Wang Z Y, Boice J D, et al. Risk of lung cancer and residential radon in China: Pooled results of two studies [J]. *International Journal of Cancer*, 2004, 109(1): 132-7.
- [11] Blot W J, Xu Z Y, Boice J D, et al. Indoor radon and lung cancer in China [J]. 1990, 82(12): 1025-30.

- [12] Porstendorfer J, Wicke A, Schraub A. The influence of exhalation, ventilation and deposition processes upon the concentration of radon ( $^{222}\text{Rn}$ ), thoron ( $^{220}\text{Rn}$ ) and their decay products in room air [J]. Health physics, 1978, 34(5): 465-73.
- [13] Lin C, Zhu Y M, Lin H M, et al. Discussion on the relationship between atmospheric radon concentration and meteorological conditions [J]. 1989, (04): 31-3.