International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 11 Issue 4 ǁ April 2023 ǁ PP. 196-201

Indoor radon concentration in colleges and universities and its influencing factors

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Abstract
Radon is a radioactive element and has become the second leading factor in lung cancer. In order to explore the distribution of indoor radon concentration in universities, the indoor sampling conducted in this study in 2020~2022 mainly included four factors: indoor radon concentration distribution, building type, season, and floor, and classified the test rooms. The RAD-7 radon tester was used to measure the indoor radon concentration in the selected room and perform statistical analysis of the test results. The results showed that the maximum indoor radon concentration in a university in Shanghai was 65.5Bq/m3, the minimum value was 1.30 Bq/m3, the arithmetic average was 14.68 ±8.86Bq/m³, the geometric mean was 12.41 ±2.43 Bq/m³, and the median was 12.93 Bq/m³. Season is the main influencing factor, followed by season, floor, building type.
Keywords: *Indoor radon concentration; Indoor sampling; Statistical analysis*

Date of Submission: 01-04-2023 Date of acceptance: 12-04-2023

I. INTRODUCTION

Under normal temperature and pressure conditions, radon is a colorless and odorless gas, gas density of 9.96kg/m3, is 7.7 times the density of air, radon is the heaviest gas at room temperature, the concentration of radon in the atmosphere decreases with the increase of height [1], the increase of radon concentration will eventually cause lung cancer. Globally, lung cancer is one of the most common types of cancer, causing approximately 1.6 million deaths worldwide each year [2]. The World Health Organization (WHO) Global Burden of Disease (GBD) reports that tracheal, bronchial and lung cancers account for 19% of all cancer deaths and are the fifth leading cause of death worldwide [3]. Darby et al. (2005) [4] estimated that for every 100 Bq/m3, the risk of lung cancer increases by approximately 16% increased radon exposure, and that 3%-14% of global lung cancer deaths may be attributed to inhaled radon exposure (WHO, 2009) [5]. Therefore, radon exposure in the study chamber is of great significance for the evaluation of lung cancer.

Domestic sources of indoor radon are mainly reflected in the following aspects:

(1) Building characteristics

Building characteristics include factors such as the material, height, time of completion, heat exchange, decorative materials, and degree of decoration of the building. A domestic survey showed that the concentration of radon in caves in the northwest region was more than 10 times higher than the national average indoor radon concentration [6]. However, studies have found that under similar meteorological conditions, the main reason why radon concentrations in adobe houses are higher than in other houses is that the precipitation rate of radon in adobe houses is significantly higher, rather than the usual difference in building materials [7]. High-rise buildings with natural ventilation gradually decrease the concentration of radon with the increase of floors; However, the relationship between radon concentration and floor in high-rise buildings with system ventilation (such as air conditioning) is not obvious.

(2) Indoor and outdoor meteorological parameters

Indoor and outdoor meteorological parameters include relative humidity, air pressure, temperature and wind speed. When Jin Yihe et al. [8] studied the temporal representativeness of radon concentration measurement, they found that the indoor radon concentration changed with diurnal regularity, higher at about 6:00 a.m., gradually decreasing in the afternoon, and lower at 13:00-17:00. The reason may be related to the temperature, the temperature is low at about 6:00, accompanied by temperature inversion, and the doors and windows are closed, the ventilation is insufficient, the temperature rises in the afternoon, the temperature inversion is lifted, the doors and windows are opened, the ventilation is relatively sufficient, so that the indoor radon concentration is reduced. Tian Lixia et al. [9] found that the trend of indoor radon concentration with time was opposite to the indoor temperature, and that ventilation could greatly reduce indoor radon concentration in line with indoor air pressure and relative humidity.

(3) Radon in outdoor air

There is a linear correlation between outdoor radon concentration and indoor radon concentration with a correlation coefficient of 0.72 [10]. Chen Diyun et al. [11] studied radon in the atmosphere of two uranium mining areas in Xiazhuang and Nanxiong, Guangdong Province, and found that the atmospheric radon concentration above the tunnels of Xiazhuang and Nanxiong uranium mining areas in Guangdong Province was as high as 14800-20500Bq/m3, and the atmospheric radon concentration above the waste residue pile was as high as 350-280Bq/m3, resulting in indoor radon concentration near the mining area being 7-8 times that of normal indoor radon near the mining area.

This paper aims to obtain a single-factor study on indoor radon concentration in Shanghai universities by sampling indoor radon concentration in Shanghai universities, so as to obtain a single-factor study on building type, season and floor, so as to put forward constructive suggestions for reducing indoor radon concentration.

1.1 Indoor radon sampling

The sampling period was conducted in a university in Shanghai for two years from June 2020~June 2022. A total of 48 student dormitories, 10 classrooms, and 2 offices were tested. There was no complicated traffic and industry near the school, and the investigators accommodated third-year undergraduates, who lived in quadruple rooms with natural ventilation and individual air conditioning. All rooms are equipped with standardized loft beds, desks, chairs and storage space. In this experiment, the ventilation in the room was not strictly controlled, so the sampling process was carried out under natural ventilation conditions.

The parameters of indoor sampling included indoor and outdoor radon concentration, indoor and outdoor temperature and relative humidity. Among them, the instrument for testing radon concentration adopts the radon tester RAD-7 produced by Durridges in the United States. It is a universal multifunctional instrument for comprehensive radon measurement, it can work in many different modes, and has completed a variety of different test purposes, the specific test diagram is shown in Figure 1.

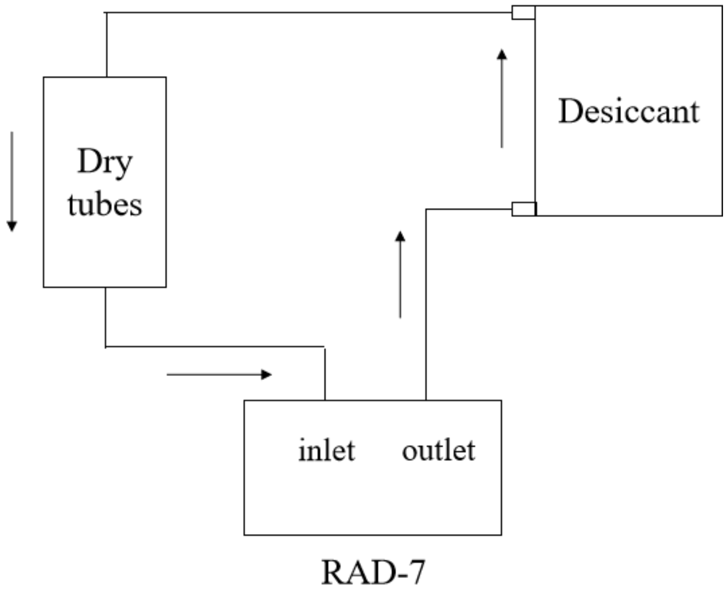

Figure1: Schematic diagram of the operation of RAD-7

1.2 Experimental design steps

The experimental design mainly includes the following steps：

1. Determine the radon measuring device. This test adopts the American Durridge RAD-7, which is a simple radon measurement method that can measure the atmosphere instantaneously and continuously; HOBO tester, measure indoor temperature and humidity, one data every 5 minutes, measurement data USB export; Measure the CO2 of the person in the room, one data every 5 minutes, and the measurement data is exported by USB.

2. Preparation. Fully charge various test instruments before measurement to ensure that the instruments can work normally without external power supply; Ensure that the dry silica gel in the drying tube is blue to ensure that the silica gel does not absorb moisture; Connect the filter membrane and drying tube to the air inlet of the instrument in turn. Check whether the indicators of the instrument such as relative humidity and temperature are within the normal value range to ensure the normal use of the instrument.

3. Measurement method. When measuring indoor air, in order to make the air in the measured room and the outside world as good as possible, the door and window of the room are closed tightly (or keep the indoor air clear and the personnel maintain normal living characteristics). Set the sampling time for 1h, the sampling period is 10/12 (classroom and office measurement 10h, bedroom measurement 12h) automatic mode, continuous measurement (20:00~8:00 the next day). To make the test data well representative, place the drying tube inlet on a tripod at a distance of 1.2m from the ground (the height of the person when sitting) and place the tripod in the center of the room. (If there are conditions, ensure that the doors and windows of the room are closed for 12~24h at the beginning of the experiment to reduce the exchange of air with the outside world.) Keep doors and windows closed during the beginning and end of the experiment).

4. Measure the location of the point. It should be 1.0m away from doors and windows, more than 0.5m from the wall, 0.5~1.5m from the ground, and more than 20cm from the surface of the object.

5. Measurement location and content. A total of 60 rooms with a total of 480 sampling points was selected in a university campus in Shanghai, including student dormitories, classrooms and offices, and the sampling situation was shown in Figure 3. The sampling content includes: indoor and outdoor radon concentration, CO2 concentration, indoor and outdoor temperature and humidity, personnel situation, basic parameters of room building, etc.

1.3 Data analysis

The factors that affect indoor radon are complex and diverse. In this paper, the influence of three factors (season, floor, and building types) on indoor radon is summarized, and the extent of the effect needs to be further verified. Artificially selected independent variables are not necessarily the variables that have a greater influence on the dependent variable, so in this paper, we establish a one-way variance model in SPSS to explore the degree of influence of independent variables on indoor radon based on statistical methods.

II. RESULT AND DISCUSSION

1.1 Indoor radon concentration

In order to explore the distribution of indoor radon and the correlation of its influencing factors, this test was carried out in a university in Shanghai in June 2020~August 2022, and a total of three different types of buildings were tested, including 8 bedroom buildings, 2 classroom buildings, and 1 office building, with a total of 60 rooms and 480 data points, as shown in Table 1. The campus radon concentration ranged from 1.32~65.5Bq/m3, the average concentration ranged from 11.4~17.28 Bq/m3, the arithmetic average was 14.68 ± 8.86Bq/m^3 , the geometric mean was 12.41 ± 2.43 Bq/m^3 , and the median was 12.93 Bq/m^3 . Overall, indoor radon conforms to a basic normal distribution, as shown in Figure 1. Only 0.9% of the data were concentrated in 60~70Bq/m3, which was lower than the average indoor radon concentration in Shanghai in 2002~2004[13] (the number of rooms was 183, the arithmetic mean was 37.7 Bq/m3, and the concentration was more than 100 Bq/m3 3.3%). The test found that the average indoor radon was far lower than the standard limit[14] 150Bq/m3 specified in China, and F=7.159, P<0.01, indicating that this sampling was statistically significant.

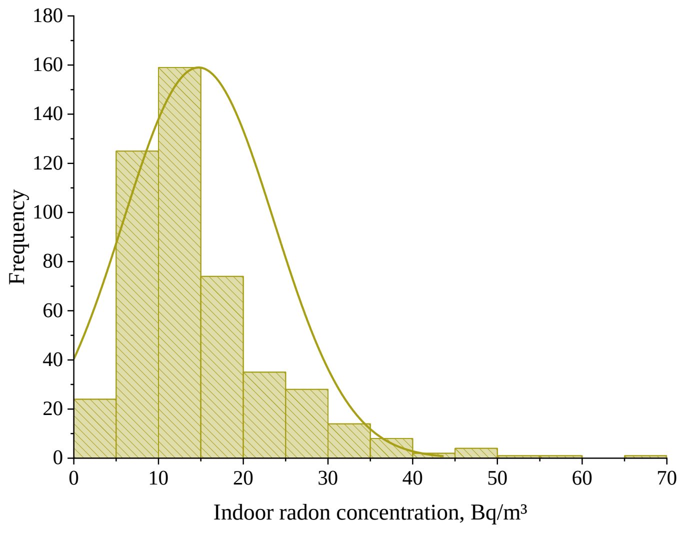

Figure2: Indoor radon concentration distribution

1.2 Radon and building types

The test involved a total of three building types, including: student dormitories, classrooms and offices, the average values of which were 14.8±9.21, 12.55± 6.71, 22.67±5.72Bq/m³, respectively, of which the maximum value was office buildings, about twice the indoor radon concentration in the classroom, and the average value of office buildings exceeded the total average by 342%, and the trend of indoor radon concentrations in classrooms and offices was similar, which may be caused by similar behavioral characteristics of personnel in the two types of buildings. The indoor radon concentrations in the three types of buildings are shown in Figure 3.

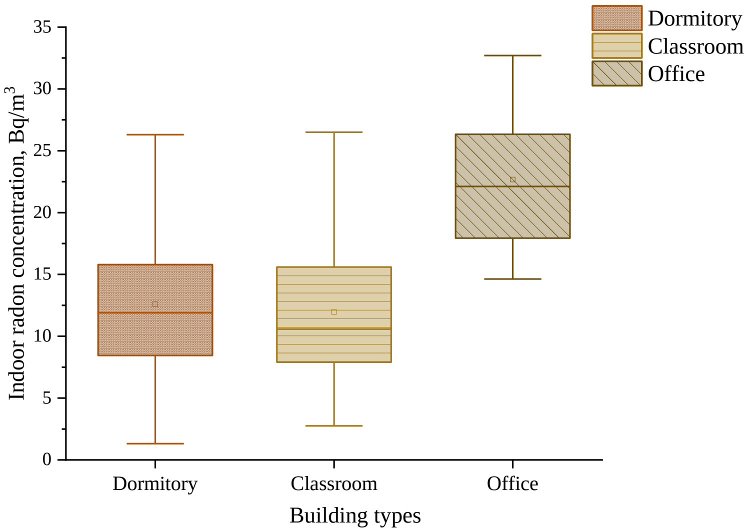

Figure3: Indoor radon concentrations in different building types

1.3 Radon with the seasons

The test season was divided into three categories: summer, winter and transition season, and after excluding outliers, their average values were 15.19±9.02 Bq/m³, 12.88± 6.79 Bq/m³, 10.97±4.16 Bq/m³, and the measurement range was 1.30~41 Bq/m³. The indoor radon concentration gradually decreases with the above three seasons, and the indoor radon concentration is the lowest in the transition season, which may be due to the similar ventilation habits of people in Shanghai, and people use ventilation more to reduce indoor radon concentration. In the winter and transition seasons, due to the low temperature and limited ventilation, the use of heating systems increases due to the lack of direct ventilation through the windows, so that the rising hot air is in direct contact with the radon gas on the surface, resulting in the accumulation of radon in the room [15].

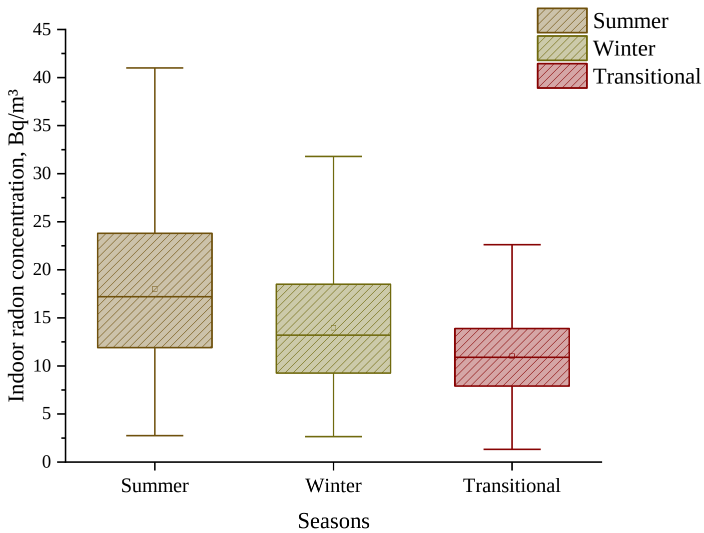

Figure4: Indoor radon concentrations in different seasons

1.4 Radon with the floors

The sampling involved a total of indoor radon concentration on 1~7 floors, with an average value of 13.67±7.19 Bq/m³ , a median of 11.90 Bq/m³ , a mode of 10.60 Bq/m³ , and an variance of 51.77, of which the maximum value was 46.3 Bq/m³ measured on the 1st floor, and the minimum value was 1.32 Bq/m³ measured on the 2nd floor. For rooms below the 3rd floor and above the 4th floor, with the increase of the number of floors, the indoor radon concentration showed a downward trend, and the average concentration of the first floor was 78% higher than that of the seventh floor, indicating that the radon concentration in the lower layer mainly came from the soil radon concentration [16], but because the radon concentration in Shanghai soil belongs to the low background, only limited radon enters the room through the gap.

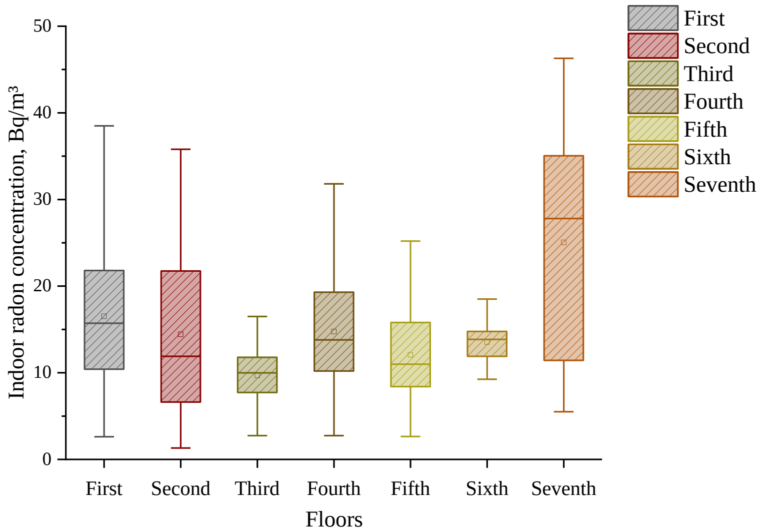

Figure5: Indoor radon concentrations in different floors

III. CONCLUSION

The sampling found that the indoor radon concentration level fluctuated in a university in Shanghai in the range of 2~65.5Bq/m³ , which was lower than the indoor radon standard value [17]. The concentration of offices is highest among the three types of buildings, with comparable concentrations in student dormitories and classrooms. The normal activities of people in the sampling room, the airtightness of the room was not strictly controlled, and the gas fluidity in the room was not strictly controlled, so the radon concentration in the sampling room only represented the indoor radon level of normal use in the room [18].

Among the three types of seasons, the indoor radon concentration in summer is the highest, which may be due to the high temperature and humidity in Shanghai in summer, and people prefer to use air conditioning to reduce indoor radon concentration, resulting in high indoor radon concentration; In the lower floors (1~3 floors), as the floor rises, the indoor radon concentration gradually decreases; However, the indoor radon concentration above the third floor showed a trend of first decreasing and then rising, which may be due to the weak ventilation degree of personnel in the upper floors, resulting in a significant increase in indoor radon concentration, indicating that the radon concentration on the upper floors is more susceptible to the influence of atmospheric pressure.

REFERENCES

[1]. LE Renchang, WU Yunping. Determination of adsorption saturation of radon in indoor and outdoor environments by activated carbon method[J].Geophysical and Geochemical Exploration,2004,28(1):39-40.
[2]. Sugawara E., Nikaido, H., World Cancer Report. International Agency for Research on Cancer, 2014.
[3]. Lozano R, Naghavi M, Foreman K, et al. 2012. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis, Global Burden of Disease Study,2010, 380(9859):2095﹣2128.
[4]. Darby S., Hill, D., Auvinen, A., et al. Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. BMJ 2005, 330-223.
[5]. WHO, WHO Handbook on Indoor Radon: A Public Health Perspective. World Health Organization, France, 2009.
[6]. Guan Qingchao. Effect of four types of building materials on indoor radon and its daughter concentration[J].China Radiation Health,1994,3(4):227.)
[7]. Wang Hua. Radon levels in ambient air[J].Radiation Health in China. 1996，5(3)：139.
[8]. Jin Yihe, Guo Qiuju. Temporal representation of radon concentration measurement. Chinese Journal of Radiation Medicine and Protection,2002,22(2):127-128.
[9]. TIAN Lixia, GE Liangquan, CHENG Feng, et al. Temporal and spatial variation characteristics of radon concentration[J].China Radiation Health,2006,15(4):385-387.)

[10]. Porstendörfer J. Radon: measurements related to dose[J]. Environment international, 1996, 22: 563-583.
[11]. CHEN Diyun, CHEN Zhiying, HU Ruiying, et al. Investigation of radon concentration in the surrounding atmospheric environment of Xiazhuang and Nanxiong uranium mining areas in Guangdong Province[J]. China Environmental Science,1999,19(1):91-96.
[12]. LIANG Baosheng, LIU Jianguo. Discussion on recommended values of carbon dioxide indoor air quality standards in China[J]. Chongqing Environmental Science,2003,12:198-200.]
[13]. XU Dongqun, SHANG Bing, CAO Zhaojin. Investigation and study on important pollutants in indoor air in some cities in China, [J].Health Research,2007,36(4):473-476.)
[14]. Standard for Indoor Environmental Pollution Control of Civil Construction Engineering GB 50325-2020, China Planning Press.
[15]. Dong X , Liao M , Kearfott K J . Influence of Environmental Factors on Indoor Radon Concentration Levels in the Basement and Ground Floor of a Building - A Case Study[J]. Radiation Measurements, 2015, 82:52-58.
[16]. LI Dongming,HU Hua,CHU Jun. Indoor radon concentration variation in high-rise buildings[J].Nuclear Techniques,2006,29(9):706-709.)
[17]. Code for indoor environmental pollution control of civil construction projects[J]. Urban Wind:Special Issue of Construction Management, 2002(17):5.
[18]. CHEN Xin, XU Jiyuan, HUANG Qianwen, et al. Investigation of indoor radon concentration level in a campus[J]. Science and Technology Wind, 2020(17):1.