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Background Environmental Radiation in a Museum in Chengdu

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Abstract

In order to grasp the radon concentration and γ-ray radiation level in a museum in Chengdu, and evaluate the radiation damage caused to the museum staff, the radon concentration and the instantaneous dose rate of gamma rays in the museum warehouse and exhibition room were monitored and estimated the annual effective dose caused by it. The results show that the radon concentration range in the museum is 24.12 - 78.9 Bq/m^3, the average is 36.17 Bq/m^3, far below China's 400 Bq/m^3 standard. The range of γ air absorbed dose rate is 7.1 - 13.6 × 10^{-8} Gy/h, the average is 10.8 × 10^{-8} Gy/h, it is the normal natural background range. The average annual effective dose of radon and its decay products was 8.68 × 10^{-3} - 2.84 × 10^{-2} mSv/a, the average annual effective dose of γ radiation was 0.100 - 0.192 mSv mSv/a, and the combined dose was 0.109 - 0.220 mSv/a, far less than 1 mSv/a standard.

Subject Areas

Environmental Sciences, Nuclear Engineering

Keywords

Radon Concentration, γ Radiation, Annual Effective Dose

1. Introduction

In recent years, people have realized the health effects of long-term exposure to natural radiation [1]. Radon is the only natural radioactive rare gas in nature produced by the decay of radionuclide radium. Because of its colorless and odorless, 1432 people will unknowingly inhale it into the body. After entering the body, it decays to produce progeny and alpha rays, and long-term exposure to high levels of radon can induce lung cancer [2]. A museum in Chengdu, Sichuan Province is a museum of geoscientific nature, which contains a variety of mineral. On the subject of radiation levels, the greatest concerns are external exposure from gamma radiation in mineral samples in museums and internal exposure from radon and its daughters [3]. The purpose of this study was to determine the radon concentration and gamma radiation levels in the air in the warehouses and exhibits of the museum, and to determine the annual effective doses of radon gas, its daughters and gamma radiation to the public and staff.

2. Materials and Methods

2.1. Monitoring Distribution

γ radiation monitoring is based on the principle of distribution: The survey area is divided into proper size grids, and a monitoring point is selected in each grid. In the end, there were 30 points in the warehouse, 30 in the exhibition room and 30 in the yard, which made a total of 90 points. Radon gas distribution principle also uses the appropriate size grid to divide the survey area, taking one point in each grid. In the end, there were 6 locations in the warehouse and 6 exhibition rooms, with a total of 12 locations. The plan of the museum is shown in Figure 1.

2.2. Methods

According to the "Standard Measurement Methods of radon in Ambient Air (GB/T 14582-93)", the sampling layout and solution requirements for indoor radon concentration measurement are as follows: 1) The sampling height is 0.8 - 1.5 m and the distance from the inner wall should not be less than 0.5 m; 2) Sampling work should be carried out normally under completely closed conditions, the outside doors and Windows must be closed, and the outside doors

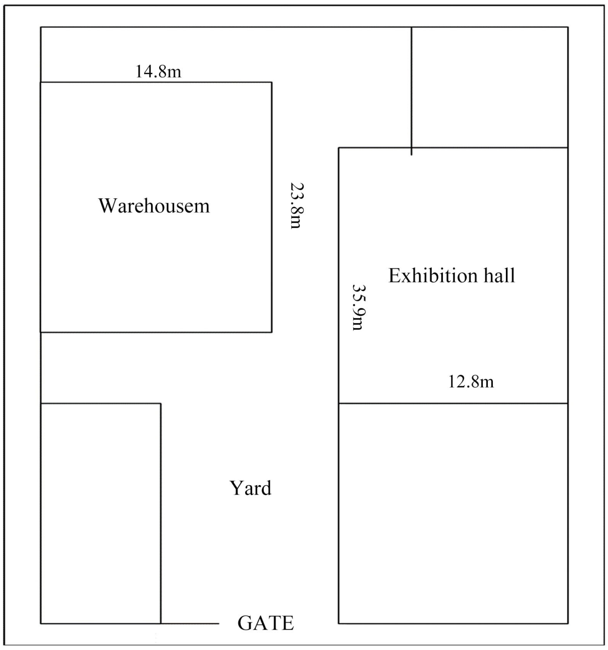

Figure 1. Plan of the museum.

should not be opened for more than a few minutes during normal access; 3) Internal and external air-conditioning systems such as ceiling fans and Windows must be stopped during sampling [4]. In this survey, the radon gas measurement instrument adopted the fixed-point measurement mode for 30 min. The inlet was 1.5 m from the ground and away from walls and corners. Each point was measured three times and the average value was taken as the radon concentration at the point.

According to the "Specification for The Determination of Dose rate of Environmental Surface gamma RadiationGB14583-1993", in this study, the γ air absorbed dose rate was measured by instantaneous measurement. The air dose rate of ambient gamma radiation at 1 m above the point was measured directly by the x-gamma dose rate meter. Each point is measured for 3 times, and the measurement time of each group of data is set at 270 s. If the data of the measurement point is abnormal, it can be measured for multiple times [5].

2.3. Materials

The radon concentration measuring instrument is fD-216 radon measuring instrument developed by Beijing Geological Research Institute of Nuclear Industry (Range of measurement: 3 - 100,000 Bq/m^3; Sensitivity: >1.5 $Bq{\cdot}m^{-3}$/cp20m; Background: ≤0.5 cpm). Gamma dose rate was determined using the BH3103B portable X-gamma dose rate manufactured by Beijing Nuclear instrument Factory (Range of measurement: 1 - 10,000 × 10^{-8} Gy/h; Cosmic-ray response: ±15%; Long-term stability: ≤ 7%; calibration factor: 1.00).

3. Result

3.1. γ Air Absorbed Dose Rate

The statistics of the measured data are shown in **Table 1**.

The measured data are compared with the upper and lower limits of the anomaly, and the values beyond the range are eliminated.

1) It can be seen from **Figure 2** that the measured data at the measuring points fall within the range of N + 3δ, all of which are reliable points, so the measured data can be used to evaluate the environmental radioactivity of the museum.

Table 1. γ Air absorbed dose rate data.

statistical magnitude	γ Air Absorbed Dose Rate (10^{-8} Gy/h)
The total number of measurements	268
Mean value	10.93
standard deviation	1.63
Range	13.6 - 7.1
Abnormal upper and lower limits*	15.82, 6.04

*Note: Determination of upper and lower limits of anomaly (Refer to geochemical correlation methods, N ± 3δ distribution is recommended as the limit of high anomaly and low anomaly, respectively).

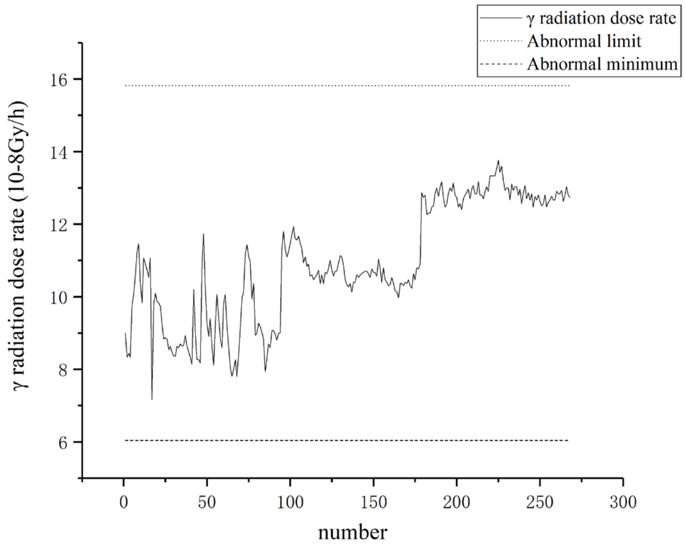

Figure 2. *γ* Air absorbed dose rate.

2) The content difference of different measurement points in the same measurement route is also very different, because of different geological structure, different ground materials, and different types of ore storage. The ground of some measurement points is concrete, while the ground of some measurement points is marble, and the ore type stored has a great impact on the measurement data.

The range of *γ* air absorbed dose rate is 7.1 - 13.6 × 10^{-8} Gy/h, the average is 10.8 × 10^{-8} Gy/h. Compare the results of this experiment with those of previous years: The range of *γ* air absorbed dose rate in Sichuan province in 1990 was 60.8 - 66.0 nGy/h, The average *γ* air absorbed dose rate of in China is 98.3 - 99.1 nGy/h [6]. The results were slightly higher than those of Sichuan and the whole country, and were in the natural background range.

3.2. Analysis of Radon Gas Measurements

The measurement results are shown in **Table 2**.

It can be seen from **Table 2** that the radon concentration ranges from 24.12 to 78.9 Bq/m^3, the mean value is 36.17 Bq/m^3, it can be seen that the radon concentration in the museum is far lower than the Chinese standard of 400 Bq/m^3.

It can be seen from **Figure 3** that the concentration of radon in the warehouse is higher than that in the exhibition hall. The reason is that the warehouse is in a closed state all the year round, and radon gas precipitated from it accumulates all the year round. However, the exhibition hall is in an open state all the year round, and the air ventilation is relatively good, so the concentration of radon in the warehouse is higher.

4. Dose Assessment

4.1. External Exposure Dose Estimation

The estimate can be made according to the following formula:

$$H_e = D_r \cdot K \cdot t \tag{1}$$

where H_e: annual effective dose equivalent (mSv/a); D_r: γ Air Absorbed Dose Rate (Gy/h); K: Ratio of effective dose equivalent rate to air absorbed dose rate, 0.7 Sv/Gy; t: Residence time in the environment, 2000 h.

According to the formula, the maximum, minimum and average of the measured air absorbed dose rate can be substituted into the formula, and the effective dose of external irradiation caused by γ radiation can be calculated, as shown in Table 3.

4.2. Estimation of Internal Exposure Due to Radon

For the estimation of internal exposure to radon, the formula for estimating the effective dose caused by radon in an equilibrium state is as follows:

$$H_E = 1.8\times10^{-10}\, C_{Rn} \cdot t \tag{2}$$

where H_e: annual effective dose equivalent (mSv/a); 1.8 × 10^{-10} Sv/(Bq/(m^3·h)); C_{Rn}: Radon concentration (Bq/m^3); t: The time of exposure to radon is 2000 h according to the international standard.

According to the above formula, the maximum, minimum and average value of radon concentration obtained can be substituted into it, and the effective dose of internal exposure caused by radon can be calculated as shown in Table 4.

5. Conclusions

In this survey, measurements were made of museum galleries, yard and warehouses.

The radon concentration in the museum ranged from 24.12 to 78.9 Bq/m^3, with an average of 36.17 Bq/m^3, it can be seen that the radon concentration in the museum is far lower than the Chinese standard of 400 Bq/m^3.

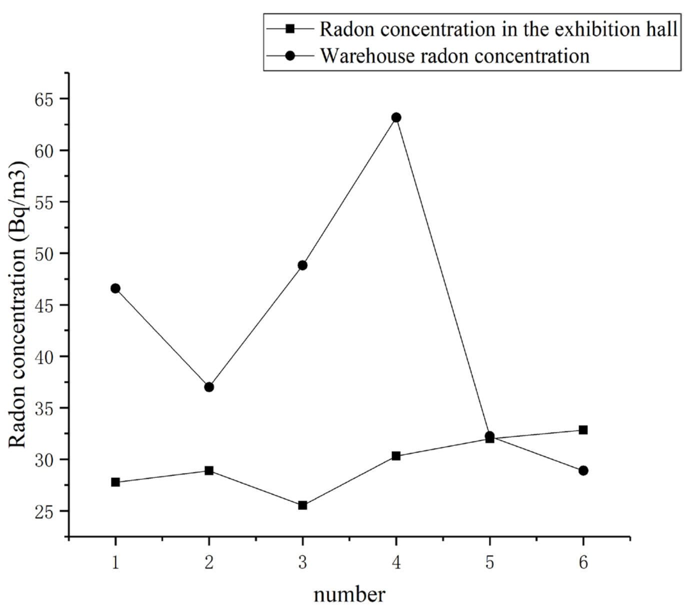

Figure 3. Radon concentration.

Table 2. Results of radon concentration data processing.

Statistical magnitude	Radon concentration (Bq/m^3)
The maximum	78.90
The minimum value	24.12
The average	36.17

Table 3. γ induced external effective dose.

Statistic	Annual effective dose (Sv/a)
The maximum	1.92×10^{-4}
The minimum value	1.00×10^{-4}
The average	1.53×10^{-4}

Table 4. Effective dose of internal exposure due to radon.

Statistic	Annual effective dose (Sv/a)
The maximum	2.84×10^{-5}
The minimum value	8.68×10^{-6}
The average	1.30×10^{-5}

The range of γ air absorbed dose rate is 7.1 - 13.6 × 10^{-8} Gy/h, the average is 10.8 × 10^{-8} Gy/h. Compared the results of this experiment with those of previous years, the range of γ air absorbed dose rate in Sichuan province in 1990 was 60.8 - 66.0 nGy/h, the average γ air absorbed dose rate of in China was 98.3 - 99.1 nGy/h. Comparing the two data, it can be seen that the gamma radiation level rate in the museum is higher than that in Sichuan province and the whole country, which belongs to the normal natural low range.

The effective doses of external irradiation caused by gamma rays and internal irradiation caused by radon ranged from 0.100 to 0.192 mSv and 8.68 × 10^{-3} - 2.84 × 10^{-2} mSv, respectively. Therefore, the total annual effective dose range of radiation received by staff is 0.109 - 0.220 mSv, which is far less than the national standard of 1 mSv for public individuals.

In summary, the environmental radioactivity level of the museum is normal and will not cause any harm to the staff of the museum.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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