



Investigation of Radioactive Environment in Open Park in a City

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Abstract

Urban parks provide citizens with fitness and leisure space, and their radioactivity affects every surrounding resident. In this paper, seven typical open parks in a city were selected and 350 measuring points were arranged in total, where the field gamma air radiation absorbed dose rate was measured by a portable X-gamma dosimeter. The results show that the surface gamma radiation absorbed dose rate of air ranges from 73.0 nGy/h - 140.0 nGy/h, and the average value ranges from 96.0 nGy/h - 113.0 nGy/h. Meanwhile, the calculated annual effective dose per capita ranges from 0.12 mSv - 0.14 mSv, which is far less than the average level of China (0.54 mSv) and the global average level (0.48 mSv). And the external exposure index due to surface nuclides is less than the limits required by national standards.

Subject Areas

Nuclear Physics

Keywords

Open Park, Gamma Radiation Absorbed Dose Rate, Natural Radionuclides, Annual Effective Dose

1. Introduction

The radioactive environment is an important part of the natural environment, which is full of radiation. Thus, the public is exposed to ionizing radiation mainly from natural radioactivity in the environment (cosmic rays and proto-radionuclides) [1]. Due to various factors, the natural radioactivity levels in nature vary greatly in different regions [2].

Parks are the first choice, when people go for a walk outside, where are the

closest to nature in the city. Therefore, a scientific and reasonable evaluation of the content of radionuclides in the environmental media and in the typical open park of the city and the radiation dose caused by the public can provide a basis for the construction of the city in terms of the natural radioactive environment.

In this paper, the level of radioactivity in the open parks was studied to determine the source of the radiation, whether there were potential pollution hazards, and the impact on human health, by measuring the absorbed dose of air in the parks [3].

2. Research Contents and Methods

2.1. Research Contents

The surface gamma radiation absorbed dose rate of environmental radiation measurements were carried out in different open parks in various urban areas. By processing and analyzing these data (Table 1), the radiation environment in the open parks was preliminarily evaluated to determine the source of radiation and whether there were potential pollution hazards, and to understand the radiation level of some open parks in the city and the impact on the surrounding residents.

2.2. Research Methods

- 1) Select 7 open parks in the city as the target areas;
- 2) Process the stability test of the measuring instrument;
- 3) Determine the number of grid measuring points according to the size of the park and the functional area within the park, and conduct on-site gamma total measurement;
- 4) Analyze and process data, estimate experimental errors, and calculate annual effective dose.

2.3. Data Processing Method

According to the radiation Protection regulations of GB8703-1988, the annual effective dose equivalent of members of the public is 5 mSv per year as the dose limit. Estimation of the absorbed dose rate of environmental Gamma radiation the per capita annual effective dose generated by gamma radiation on the population is calculated by Formula (1) [4].

$$D_{aed} = D \times a_1 \times a_2 \times t \quad (1)$$

where: D_{aed} is average annual effective dose of external gamma radiation, unit:

Table 1. Radioactivity measurement content.

Environmental media	Measurement content	Number of measuring points	Survey target area
the earth's surface	Gamma radiation dose rate	350	7 parks

mSv; D is air absorbed dose rate value of external gamma radiation at 1 m above ground, unit: nGy/h; a_1 is the conversion coefficient between gamma absorbed dose and annual effective dose in the atmosphere is 0.7 Sv/Gy; a_2 is the average residence factor of residents is 0.2 according to the object of study; t is time spent in the environment, 1 a = 8760 h.

3. Natural Radioactivity Measurement Process

3.1. Survey of Target Areas

There are more than ten open parks in the central area of the city, which are resident public places for leisure and fitness. In order to ensure sufficient representativeness of the survey target, 7 representative parks were selected in the end, with a large number of people served by the target park and basically perfect surrounding facilities [3].

3.2. Layout of Survey Line in Survey Area

On the basis of the geological and hydrogeological conditions in the open parks, the grid point distribution method is adopted. According to the size of the park, different functional areas and different population density, different point distribution density is adopted to measure the vertical surface of the site. The distribution point is 40 m × 40 m grid for larger parks, and 15 m × 10 m grid, or 25 m × 25 m grid for smaller parks. Besides, properly encrypt measuring points at the area like rivers, ponds, buildings or closed areas in the park.

3.3. Quality Assurance Measures

The purpose of quality assurance is to ensure the authenticity of measuring data and the test area. Therefore, the following measures should be taken.

1) Instrument calibration.

The calibration of the instrument has been completed before leaving the factory, and the accuracy of the instrument was verified before this experiment.

2) Stability test of the instrument.

The radiation dose rate was measured at a fixed location in an open field, for two consecutive days, more than 20 groups were measured every day with an interval of 10 s and 180 s for each group containing 52 groups of data totally. The processing of test data is shown in **Table 2**.

3.4. Measuring Process

In accordance with the requirements of *Specification for the Measurement of Dose rate of Ambient Ground Gamma radiation* (GB/T 14583-1993) [5], *in-situ* gamma exposure air absorbed dose rate (D) was measured.

1) Set instrument parameters and preheat for 10 min;

2) Place the tripod, place the probe on the tripod, set the calibration line (measured height) on the probe at a distance of 1 m from the ground, and set the detection time to 60 s;

Table 2. Analysis of stability measurement data of portable X- γ dose rate meter.

Measurement data	First day measurement data	Second day measurement data
Average value $\times 10^{-8}$ Gy/h	31.79	32.23
Mean square error	0.37	0.34
Skewness coefficient	0.472	0.441
Kurtosis coefficient	0.918	0.858
Maximum standard deviation	0.02542	0.02715
Standard deviation	0.3763	0.3492
Relative standard deviation	0.01184	0.01083

Table 3. Information table of measuring points in each park.

Park name	Measuring time	Weather	Number of points	Serial number	Density of points
Park A	April 21	Sunny	50	SD01~SD50	40 \times 40 m
Park B	April 26	Sunny	50	SBQ01~SBQ50	40 \times 30 m
Park C	April 27	Sunny to cloudy	50	EXQ01~EXQ50	15 \times 10 m
Park D	April 28	Sunny to cloudy	50	BH01~BH50	35 \times 25 m
Park E	April 29	Cloudy	50	SH01~SH50	25 \times 25 m
Park F	April 30	Sunny	50	BHT01~BHT50	40 \times 40 m
Park G	May 1	Cloudy	50	NZ01~NZ50	40 \times 40 m

3) Measure and record data. (Record data for every three measurements)

The measurement points of each park are shown in **Table 3**.

4. Result

4.1. Present Situation of Dose Rate Distribution of γ Radiation

This survey covers the whole range of 7 open parks (some areas of the park are rivers, reservoirs or buildings), with a total survey area of 394,300 m² and 350 survey points in total. According to the measurement results, the contour map of gamma dose rate of each park was drawn, which shows the level of surface gamma dose rate in these 7 parks basically, and the results were shown in **Table 4** below.

According to the above data, the surface gamma dose rate of some open parks in a city ranged 7.3×10^{-8} Gy/h - 14×10^{-8} Gy/h, and the average value ranged 9.6×10^{-8} Gy/h - 11.304×10^{-8} Gy/h, which was within the normal value of natural radioactivity level. The surface gamma dose rate of park E was obviously slightly higher than that of other parks, reaching the maximum value of 14×10^{-8} Gy/h, while the value of other parks was basically the same.

The values obtained in this survey were all within the normal range of the province, while and the minimum values were increased, compared with the data from 1983 to 1990, and the measured values were slightly above the annual

average without exceeding the maximum, compared with the 2017 values. And the average gamma absorbed dose rate measured this time was $(3 - 4) \times 10^{-8}$ Gy/h, compared with the survey results of Zou Yulin *et al.* (6.77×10^{-8} Gy/h) [6].

4.2. Estimation of Annual Effective Dose of Public Natural Radiation

The per capita effective dose was calculated from Formula 1, as shown in **Table 5**.

As shown in **Table 5** that the per capita annual effective dose, by Formula (1), of some open parks in the city ranges from 0.12 mSv to 0.14 mSv, which is far less than the average level of China (0.54 mSv) and the global average level (0.48 mSv).

5. Conclusions

In this paper, the natural radiation level of the open parks was investigated and evaluated systematically, where the surface gamma dose rate was measured by setting up 350 measuring points with different grid density. Based on the statistical analysis of these measured data, the radiation level of residents caused by surface gamma dose rate of typical open parks in the city was evaluated and studied in detail. The specific conclusions are as follows:

1) The low natural radioactivity level and the gamma absorbed dose rate, which is lower than the national standard medium limit (1 mSv), in these typical

Table 4. Surface dose rate measurements (unit: 10^{-8} Gy/h).

Park name	Average value	Maximum value	Minimum value	Standard deviation	Coefficient of variation
Park A	10.1	10.8	8.5	0.434	0.043
Park B	10.5	11.5	8.3	0.684	0.065
Park C	9.9	12.1	7.3	1.042	0.105
Park D	9.6	10.6	8.6	0.548	0.057
Park E	11.3	14.0	8.7	1.471	0.130
Park F	10.4	11.8	9.4	0.520	0.050
Park G	10.6	12.7	9.2	0.722	0.068

Table 5. Annual effective dose per capita.

Park name	Average dose rate of γ air absorption (nGy/h)	Annual effective dose (mSv)
Park A	101.0	0.12
Park B	105.0	0.13
Park C	99.0	0.12
Park D	96.0	0.12
Park E	113.0	0.14
Park F	104.0	0.13
Park G	106.0	0.13

open parks environment of this city, indicate that the open park environment of this city is suitable for people to stay for a long time;

2) The residents' annual effective dose caused by environmental gamma radiation range between 0.12 mSv - 0.14 mSv, which is far less than the native average level (0.54 mSv), global average (0.48 mSv) and the national radiation protection standards (1.0 mSv), means the open parks of the city's environmental gamma radiation in the level of security;

3) The distribution of environmental surface gamma dose rate in the open park of this city was between 73.0 nGy/h and 140.0 nGy/h, with the average value between 96.0 nGy/h and 113.0 nGy/h, slightly higher than the national average (62.8 nGy/h), without exceeding the maximum value. And there was no abnormal area of the dose rate of environmental surface gamma radiation by statistical analysis of the data, indicating that the environmental surface gamma radiation from the city's open park was at a normal level.

Conflicts of Interest

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

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