A long-term investigation of the atmospheric radon concentration in Beijing, China

2009 J. Radiol. Prot. 29 263

(http://iopscience.iop.org/0952-4746/29/2/012)

IOP PUBLISHING JOURNAL OF RADIOLOGICAL PROTECTION

J. Radiol. Prot. **29** (2009) 263–268 doi:10.1088/0952-4746/29/2/012

A long-term investigation of the atmospheric radon concentration in Beijing, China

Liang Zhang[1], **Liguo Zhang**[2] **and Qiuju Guo**[1,3]

[1] State Key Laboratory of Nuclear Physics and Technology, School of Physics, Peking University, Beijing 100871, People's Republic of China
[2] Institute of Nuclear and New Energy Technology, Tsinghua University, Beijing 100084, People's Republic of China

E-mail: qjguo@pku.edu.cn

Received 18 August 2008, in final form 27 November 2008, accepted for publication 28 November 2008
Published 19 May 2009
Online at stacks.iop.org/JRP/29/263

Abstract

To investigate the levels and behaviour of the atmospheric radon concentration in Beijing, a continuous measurement was carried out and recorded hourly over a five-year period from January 2003 to December 2007. Levels and variations were studied on the basis of 36 731 data points, and the trends of diurnal and yearly variations were also analysed.

The range of average concentration of atmospheric radon each year was from 11.2 to 13.0 Bq m^{-3}, while the average concentration over the five years was 12.1 ± 4.9 Bq m^{-3}. The average diurnal pattern of radon concentration showed that the daily maximum appears between 6:00 and 8:00 in the early morning, and the daily minimum appears between 16:00 and 18:00 in the late afternoon. The frequencies of both the maximum and minimum during this period were 30% overall. The yearly pattern features a maximum around October and November and a minimum around April and May.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

Radon (^{222}Rn) is a naturally occurring gaseous radioactive decay product of the radium isotope ^{226}Ra, which is present in all terrestrial materials. As radon is a naturally radioactive element, it is necessary and important to know the levels and behaviour of atmospheric radon concentrations. At the same time, as a radioactive inert gas, radon is relatively chemically stable and can be sensitively detected. The study of radon concentration in the atmosphere can give information on the state of turbulence and the stability of the lower atmosphere and can highlight the movements and origin of air masses. Studies on atmospheric radon as an

[3] Author to whom any correspondence should be addressed.

0952-4746/09/020263+06$30.00

Figure 1. The electrostatic radon monitor (ERM-B1) device.

environmental tracer have been reported in recent years (Taguchi *et al* 2002, Iida *et al* 1996, Sesana *et al* 2003, 2006).

In China, national surveys on natural background radiation have been performed, and many local investigations on atmospheric radon have been reported previously (Pan *et al* 1992, Cheng *et al* 2002); however, nearly all the measurements were carried out by grab sampling. Considering the variation of atmospheric radon concentrations, a continuous measurement was essential for the evaluation of atmospheric radon behaviour.

A project called Measurement of Radon as a Tracer of Air Pollutants in East Asia was started several years ago, and measurements of the atmospheric radon concentrations at various locations in East Asia have been carried out. As a member of the project, our laboratory put an electrostatic radon monitor (ERM) into use in 2003, and a continuous measurement of the atmospheric radon concentration has been carried out since. This paper reports the results of a study conducted from January 2003 to December 2007. The results of data from the first year, 2003, were reported previously (Zhang *et al* 2004).

2. Methods and materials

2.1. Observation site

Atmospheric radon concentrations have been continuously measured in the author's laboratory at Peking University, which is located on the fourth floor (15 m from the ground) of a university building (39.59 °N, 116.19 °E). Outdoor air is pumped continuously into the radon monitor (electrostatic radon monitor, ERM-B1). There are no tall buildings located in the close vicinity.

Beijing is a large city located in the North China Plain in northern China. The North China Plain has a continental climate typical of a temperate zone. The weather can be generally described as: dry and cold winters; hot summers; dry and windy springs; short and stable autumns.

2.2. Continuous radon measurement equipment

Atmospheric radon concentrations were sampled and measured with the electrostatic radon monitor (ERM-B1), developed by the Iida group (illustrated in figure 1) (Iida *et al* 1991).

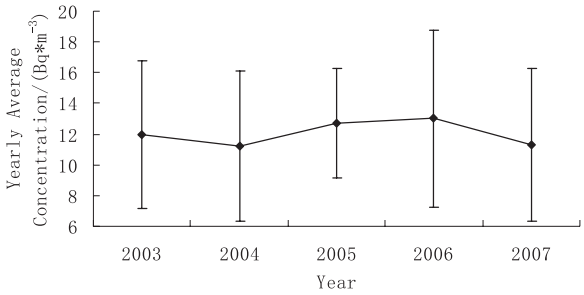

Figure 2. Yearly average concentrations of atmospheric radon in the five years.

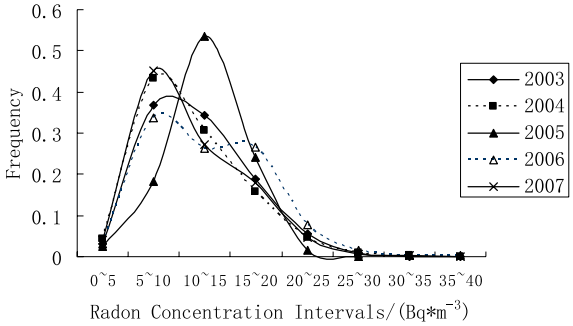

Figure 3. Frequency distribution of radon concentrations for each year.

Outdoor air was pumped continuously into the monitor and filtered with a cellulose nitrate membrane filter (pore size 0.8 μm) to remove aerosols and atmospheric radon decay products and then dried with P_2O_5 powder before being passed into a 16.8 l hemispheric vessel. Radon decays inside the vessel and positive ^{218}Po ions were collected electrostatically on the electrode of aluminised Mylar coated with a ZnS (Ag) scintillator. The scintillations due to alpha particles were detected by a photomultiplier tube. The scintillation pulse, which was amplified and processed, was then fed into a computer. Radon concentrations were calculated automatically every hour from the accumulated alpha counts. The flow rate was around 1.1 min^{-1}, and the background of the monitor was 8.91 ± 2.81 counts per hour (cph), so the lower detector limit gwas calculated to be 0.48 Bq m^{-3} (with 2 standard deviations).

Calibration of the instrument was carried out in a system consisting of a 1.5 l ionisation chamber, radon source chamber, and a 108.7 l research chamber with P_2O_5 powder on the bottom of it. The calibration coefficient is 8.26×10^{-3} (Bq m^{-3})/cph.

3. Results and discussion

Atmospheric radon concentrations were continuously measured from January 2003 to December 2007, and hourly average concentrations were recorded. Parts of the data were absent due to some malfunctions; the effective data were 83.8% of the whole period.

3.1. General trend

Over the five-year period, 36 731 effective data points were obtained. The maximum atmospheric radon concentration was 49.81 Bq m^{-3}, and the minimum was 1.06 Bq m^{-3}. The average concentration during the five years from 2003 to 2007 in the Beijing area was

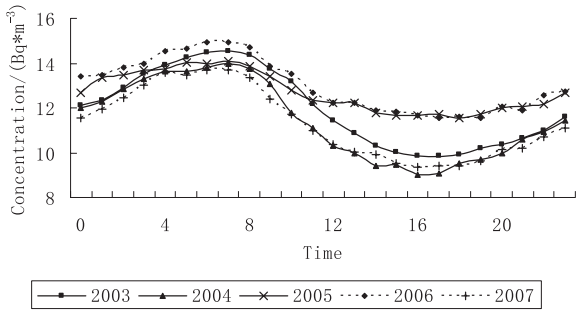

Figure 4. Diurnal variations of the whole year from 2003 to 2007.

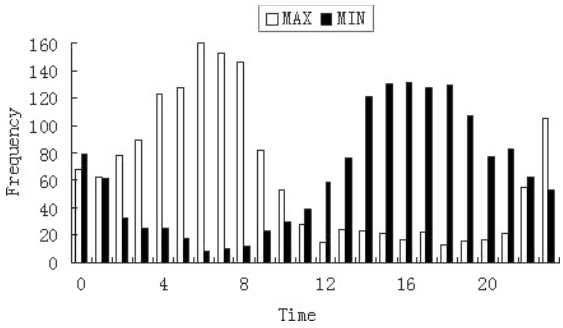

Figure 5. Frequency distribution of daily maximum and minimum appearances in the five years.

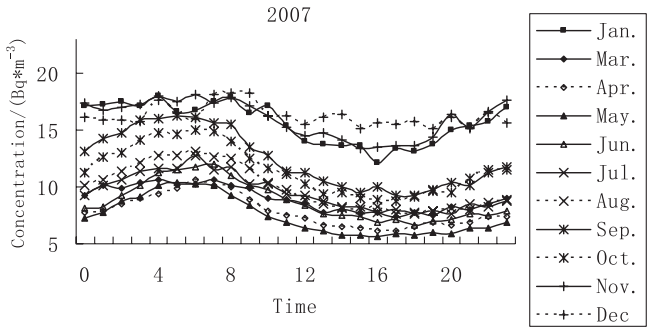

Figure 6. Diurnal variations of each month in 2007.

12.1 ± 4.9 Bq m^{-3} (arithmetic mean), which was slightly higher than the average world concentration (10 Bq m^{-3}) (UNSCEAR 2000). The yearly average concentrations were calculated and are shown in figure 2. The frequency distributions of radon concentration are shown in figure 3. No increasing or decreasing trend was observed during the five years.

3.2. Diurnal variation

The yearly average concentrations at each hour were calculated to evaluate diurnal variation; 24 data points on the average day were obtained to show the diurnal variation trends. The results are shown in figure 4. It can be seen that there was a minimum in the late afternoon (16:00–18:00) of each day followed by a maximum in the early hours of the morning (6:00–8:00). The frequency distribution of daily maximum and minimum appearances, as shown in

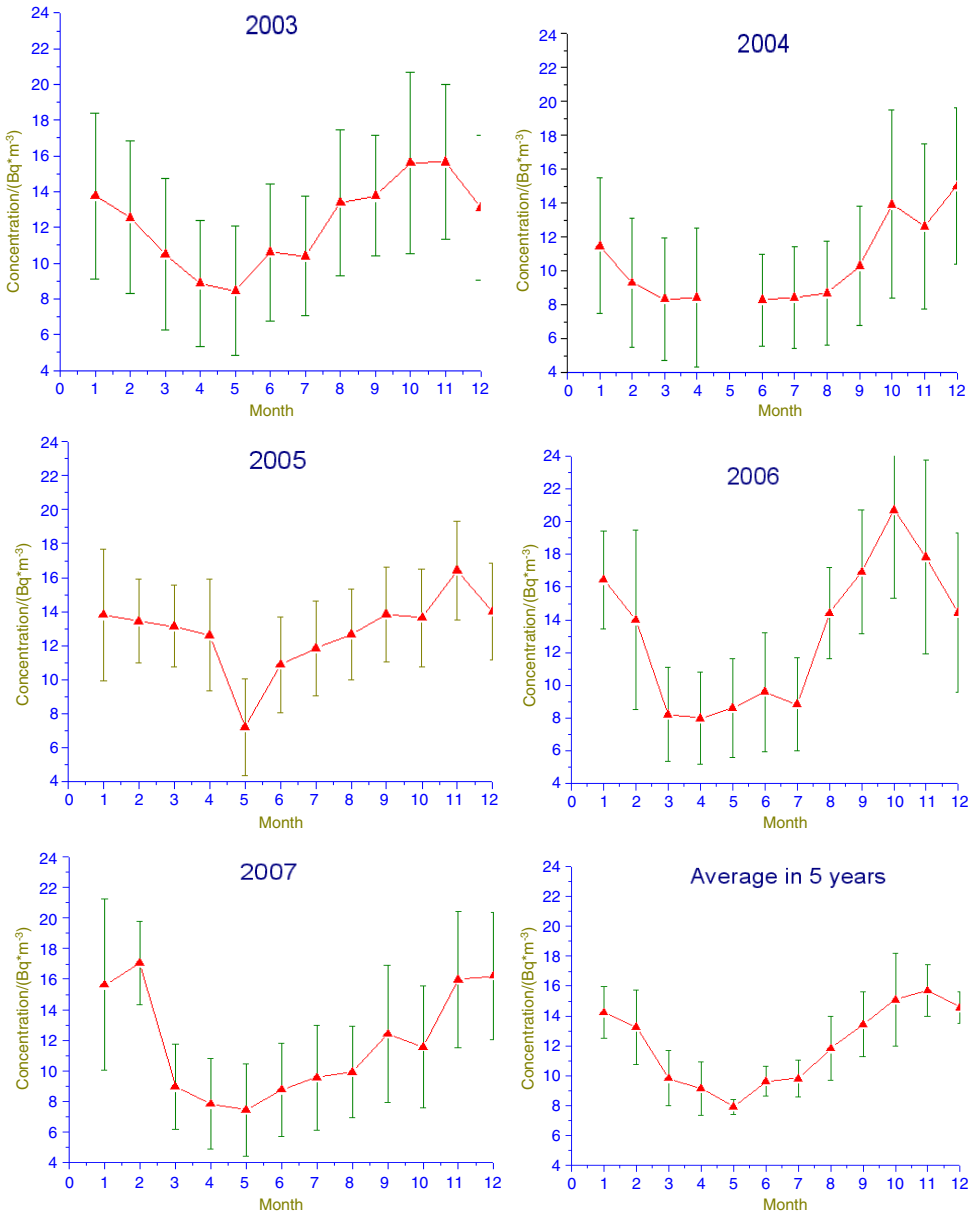

Figure 7. Monthly average concentration of atmospheric radon in the five years.

figure 5, also demonstrate the same results. One can see from figure 5 that the proportion of the maximum appearing between 6:00 and 8:00 was 30.2%, and the proportion of the minimum appearing between 16:00 and 18:00 was 25.6%. We suggest that the diurnal variation of radon concentration is affected by many complicating factors; only on some 1/3 of days did maximum or minimum concentrations appear during the periods of 6:00 to 8:00 in the morning or 16:00 to 18:00 in the afternoon.

Diurnal variation of each month was also observed; as an example, the results from 2007 are shown in figure 6. It appears that the diurnal variation pattern of each month was

quite variable; the peaks of maximum or minimum were not visible in some months, and the variational ranges were quite different between months.

3.3. Seasonal variation

The average concentration for each month in the five-year period, with standard deviation, is shown in figure 7. It seems that in Beijing, the maximum atmospheric radon concentration appeared around April or May, and the minimum appeared around November. During the five years investigated, the maximum monthly average concentration was 20.72 ± 5.40 Bq m^{-3} (appearing in October 2006) and the minimum was 7.22 ± 2.82 Bq m^{-3} (appearing in May 2005).

4. Conclusion

A continuous measurement of the atmospheric radon concentration in the Beijing area was carried out from 2003 to 2007. The five-year average concentration was 12.1 ± 4.9 Bq m^{-3}, which was slightly higher than the world average (10 Bq m^{-3}). The diurnal variation tends to be at a maximum in the early morning and at a minimum in the late afternoon. With respect to yearly variation, monthly average concentrations vary between a maximum in autumn and a minimum in spring.

Further analysis of the correlation between radon concentration and important meteorological conditions is necessary for a better understanding of the variation of atmospheric radon concentrations.

Acknowledgments

This work has been supported by the National Natural Science Foundation of China under Grant Nos 10775007 and J0730316.

References

Cheng J P, Guo Q J and Ren T S 2002 Radon levels in China *J. Nucl. Sci. Technol.* **9** 695–9

Iida T, Ikebe Y, Suzuki K, Ueno K, Wang Z and Jin Y 1996 Continuous measurements of outdoor radon concentrations at various locations in east Asia *Environ. Int.* **22** SI139–47

Iida T *et al* 1991 An electrostatic radon monitor for measurements of environmental radon *Res. Lett. At. Electr.* **11** 55–9

Pan Z *et al* 1992 Estimation of natural radiation background level and population dose in China *Radiat. Prot.* **12** 251–9 (in Chinese)

Sesana L, Caprioli E and Marcazzan G M 2003 Long period study of outdoor radon concentration in Milan and correlation between its temporal variations and dispersion properties of atmosphere *J. Environ. Radioact.* **65** 147–60

Sesana L, Ottobrini B, Polla G and Facchini U 2006 ^{222}Rn as indicator of atmospheric turbulence: measurements at Lake Maggiore and on the pre-Alps *J. Environ. Radioact.* **86** 271–88

Taguchi S, Iida T and Moriizumi J 2002 Evaluation of the atmospheric transport model NIRE-CTM-96 by using measured radon-222 concentrations *Tellus* B **54** 250–68

UNSCEAR 2000 *Report* (New York: United Nations)

Zhang L, Guo Q and Iida T 2004 Atmospheric radon levels in Beijing, China *Radiat. Prot. Dosim.* **112** 449–53