INDOOR RADON MEASUREMENTS IN THE SHENZHEN REGION, THE PEOPLE'S REPUBLIC OF CHINA

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INTRODUCTION

In recent years there has been a growing concern about radon level indoors. Measurements of indoor ^{222}Rn concentrations of residential buildings in the People's Republic of China are organized. The indoor ^{222}Rn survey program in the Shenzhen region was completed in 1986. The purpose of this paper is to present the results and to discuss the indoor radon variations. The dose estimation is also presented.

METHODOLOGY

Shenzhen is a special economic region of China. It is located between 113°46'E and 114°37'E, 22°27'N and 22°57'N. It faces the Daya Bay on the east and the Pearl River estuary on the west. Hong Kong is on its south. The climate is typically maritime with average annual rainfall of 1948mm. The temperature is between 1.4°C and 36.6°C, no significant seasonal variation.

In order to obtain representative data, many measurements have been made in different types of dwellings and at widely distributed locations. Dwellings investigated were typical in each location. The multi-family dwellings selected were constructed with brick and fabricated concrete blocks. In each apartment there was water supply but no mechanical ventilation. Most of the high-rise buildings were morden hotels, or commercial buildings built with concrete, and morden building materials with central or separate mechanical ventilation system. Most of investigated detached houses were in the old area of the city or in the rural area. They were mainly built of brick or stone with brick or concrete floors. Almost all dwellings measured were less than 5 years old except for some detached houses.

Most of the measurements were conducted with a dual-filter environmental radon monitor, with decay volume of 15 lit.. The lower limits of detection (LLD) were 1.2 Bq m^{-3} for ^{222}Rn. Another grab sampling technique used was scintillation flask radon monitor with a volume of 0.7 lit., the background was 0.04 counts per minute and the LLD was 1.2 Bq m^{-3}. It mainly used for checking and for rural area measurement. We also employed integrated activated carbon detectors for comparison. Its LLD was 5.9 Bq m^{-3} for exposure period of 3 or 4 days (Re86). All these instruments were calibrated with liquid radium sources. The in situ intercomparison showed that the results of these three methods were agreeable within ±24%. By the end of 1986, 222 dwellings were investigated. Since there is no significant reasonal variation, the investigation covers half a year, from March to September.

RESULTS

Radon-222 concentration

Radon-222 concentration have been obtained from 19 multi-family apartments, 50 detached houses and 147 high-rise apartments. The frequency and cumulative frequency distributions of indoor ^{222}Rn are approximately log-normal, though the existence of high ^{222}Rn levels in some dwellings makes the distribution skewed.

The measured ^{222}Rn concentrations, extremes, arithmetic and geometric means in several types of buildings and outdoor are given in Table 1.

Table 1 Measured ^{222}Rn concentration in different types of dwellings in Shenzhen (Bq m^{-3})

Types of dwellings	Number of dwellings	Extreme value	Arithmetic mean	Standard deviation	Geometric mean	Geometric standard deviation
High-rise buildings	147	1.5 - 14.2	31.1	22.9	25.2	1.96
Multi-family dwellings	19	3.33- 52.5	15.5	11.8	11.8	2.16
Detached houses	50	4.07- 54.0	17.8	11.8	14.4	1.93
Basement	6	77.7 -142	108	26.3	106	1.27
Outdoors	10	2.78- 35.9	13.7	11.1	20.4	2.24

Statistical analyses indicate that ^{222}Rn concentrations in detached houses and multi-family apartments are no difference, with arithmetic means of 15.5 Bq m^{-3} and 17.8 Bq m^{-3}, respectively. The average concentration in high-rise buildings is 31.1 Bq m^{-3}, significantly higher than that in the other two types of buildings. One of the probably explanation for the fact is that the air exchange rate is much lower in high-rise buildings as mentioned above. In basement the mean is 108 Bq m^{-3} about 2.5, 5.1 and 6 times higher than in high-rise, detached and multi-family dwellings, respectively.

For comparison, the outdoor ^{222}Rn concentration is also listed in Table 1. The arithmetic mean is 13.7 Bq m^{-3}, much higher than the world average, 5 Bq m^{-3}, given by UNSCEAR (Un82). The measured specific activity of ^{226}Ra in soil of Shanzhen region is, on average, 85 Bq kg^{-1}, much higher than the world average, 25 Bq kg^{-1} (Un82). This may explain the higher outdoor ^{222}Rn level.

Radon-222 daughter concentration

Alpha potential energy concentrations of ^{222}Rn daughters have been measured in 181 dwellings. Their frequency and cumulative frequency distributions are similar to the distributions of indoor ^{222}Rn. Statistical analyses shows that the daughters' concentrations in detached houses and multi-family apartments are statistically the same with arithmetic mean of 1.02 mWL and 0.81 mWL, respectively. The concentration, however, in high-rise buildings is significantly higher than in detached and multi-family dwellings.

Equilibrium factor

From the measured activity concentrations of polonium-218, lead-214, polonium-214 and ^{222}Rn, equilibrium factors F were calculated. Table 2 listed the equilibrium factors in different types of dwellings as well as outdoors. It indicates that there are no significant differences and 0.20 is representative for all types of dwellings. It is much lower than the UNSCEAR estimated values, 0.5 for indoors and 0.6 for outdoors (Un82). The main reason for the low value might attribute to the high air exchange rate and low aerosol concentration in this subtropical city.

Table 2 Equilibrium factors in different types of dwellings

Types of dwellings	Number of dwellings	Extreme values	Arithmetic mean	Standard deviation
High-rise buildings	105	0.04-0.79	0.22	0.13
Multi-family apartments	18	0.02-0.46	0.16	0.10
Detached houses	21	0.07-0.47	0.22	0.09
Basement	5	0.11-0.19	0.14	0.03
Outdoors	4	0.06-0.25	0.17	0.08

DISCUSSION

Variations of ^{222}Rn concentration with heights above ground: in naturally ventilated buildings, ^{222}Rn concentration is higher on lower floors, then it lows gradually as the altitute goes up. However, in centrally or separately ventilated buildings, this trend is not observed, even in a 53 story building, where the correlation coefficient between radon concentration and floor height is -0.43, it means no significant correlation exists. The variation of ^{222}Rn daughters concentration with height is about the same.

The influence of ventilation: The influence of ventilation on concentrations of indoor ^{222}Rn and its daughters is demonstrated. The concentrations in centrally and separately ventilated buildings are significantly higher than in naturally ventilated. The main reason may probably be the difference in air exchange rate. In fact if we use the measured air exchange rate, ^{226}Ra specific activities in building materials, and an appropriate model (Un86), the radon concentrations predicted are reasonably agreeable to the means measured. It means that air conditioning may raise indoor ^{222}Rn and its daughters concentrations and the inhancement of indoor air exchange rate is only way to reduce ^{222}Rn concentration indoors.

Dose estimation: If the assumption is made that the radon equilibrium factor is 0.2 and that the UNSCEAR's occupancy factor and effective dose equivalent conversion factors, 0.061 and 0.031 mSv $(Bq\ m^{-3})^{-1}a^{-1}$ for indoor and outdoor are used (Un82), then the absorbed dose to T-B region and P region and effective dose equivalent for different types of dwellings caused by ^{222}Rn daughters can be calculated, as given in Table 3. Calculation indicates that effective dose equivalent caused by ^{222}Rn is about 12 times less than that listed in Table 3.

Table 3 Estimation of annual dose caused by ^{222}Rn daughters in different types of dwellings*

Types of dwelling	EEC concentration ($Bq\ m^{-3}$)	Absorbed dose (uGy) T-B region	P region	Effective dose equivalent (mSv) Indoor	Indoor plus outdoor
High-rise buildings	6.53	255	32.7	0.40	0.49
Multi-family apartment	3.25	127	16.3	0.2	0.29
Detached houses	3.74	146	18.7	0.23	0.32
Basement	22.7	885	114	1.39	1.48

*The doses are estimated based on arithmetic mean.

It is evident that due to low radon and its daughter concentrations, the population weighted average annual effective dose equivalent is about 0.3 mSv in this subtropical region. It is about one third of the world average estimated by UNSCEAR. For comparison, the effective dose equivalent from external radiation, including cosmic ray, is about 1.1 mSv a^{-1} in this region, roughly 3.7 times that caused by ^{222}Rn and its daughters.

REFERENCES

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