A study of Monitoring and Mapping for Radon-Concentration Distribution in Gyeongju-12201

Chan Hee Park, Jung Min Lee, So Young Jang, Shin Jae Kim, Joo Hyun Moon
Dongguk University, 707, Seokjang-Dong, Gyeongju, Gyeongbuk 780-714, Republic of Korea

ABSTRACT

Radon is one of the most important contributors to the radiation exposure in humans. This study measured the indoor radon concentrations at the 17 elementary school auditoriums that were sampled from those in the city of Gyeongju, Korea. The reason that an elementary school was selected as a measurement object is that many students and teachers stay for a long time in a day and it's easy to identify the characteristics of the auditorium building such as the essential building. The measurement shows that most of the indoor radon concentrations at the 17 elementary school auditoriums did not exceed 148 Bq/m^3 that is the action level recommended by U.S. Environmental Protection Agency.

INTRODUCTION

The city of Gyeongju is located in southeast of Korean peninsula and is about 360 km distant from Seoul. Gyeongju was the capital of the Silla dynasty that was a kingdom maintained over 1,000 years in Korean peninsula and has lots of historical heritage.

Radon gas is the natural radiation, which is known to secondary cause of lung cancer following smoking [1, 2]. Nowadays, the protection human against radon is considered to a worldwide issue. In this context, attention has to be paid to an elementary school since many young students and teachers stay for more 6 hours a day at it. For the auditorium at school, many students move in and out it several times a week because of gym classes or school assembly, but it tends to have poor ventilation as it is to be kept closed when not in use.

There has been no in-depth analysis of the indoor radon concentrations in the elementary school auditoriums in Gyeongju, considering the geological characteristics under them. Hence, this paper measured and analyzed the indoor radon concentrations at the 17 elementary school auditoriums.

MEASUREMENT METHOD

The elementary school auditoriums of measurement were selected by sampling one from the elementary school auditoriums in each administrative community with consideration of their location, age and geological characteristics under them. The auditoriums to be finally selected were marked in fig. 1. Measurements of the indoor radon concentrations for the 17 auditoriums were made from March to October 2011.

(a) The elementary school

(b) Examples of the elementary school auditorium

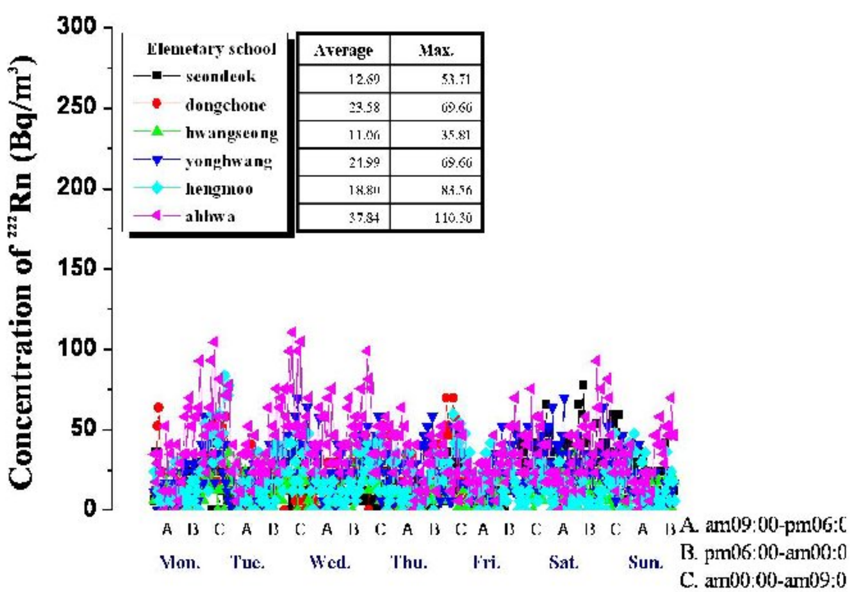
Fig.1. The locations of the elementary school auditoriums for measurement in the map of Gyeongju and outside or inside views of several auditoriums

In these measurements, a RAD7 detector (Durrridge Co.) was used because it allows continuous measurement. The procedure for measurement is as follows:

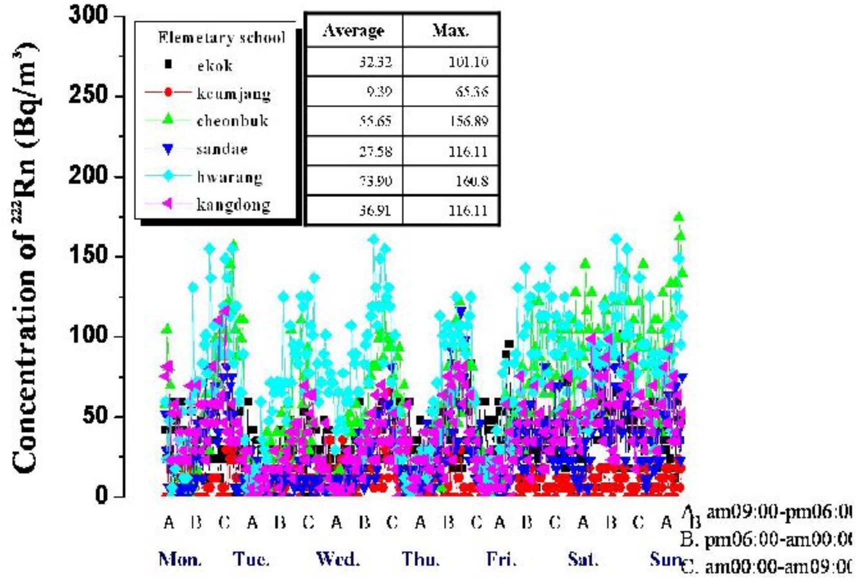
1) the detector is purged for 15 minutes before commencement of the measurement;
2) the radon concentration in the air outside the building is measured for 5 minutes;
3) for the measurement of the radon concentration inside the building, the detector is installed at the center and 1.5 m above the floor of the building;
4) the measurement was continuously made for 7 consecutive days;
5) In case that the indoor radon concentration exceeds 148 Bq/ m^3 or an abnormal value is recorded, re-measurement is made.

MEASUREMENT RESULTS

Fig.2 shows the indoor radon concentration variations for the 17 auditoriums over 3 time intervals per day; 09:00-18:00 (denoted as A), 18:00-24:00 (B), 00:00-09:00 (C). As shown in fig. 2, the indoor radon concentrations over time interval A was found to be generally lower than those over other time intervals B and C. This seems to be why all the auditoriums were kept to be closed during off-duty hours and they have poor ventilation conditions. For Hwarang elementary school auditorium, the radon concentration was measured to be higher than any other auditorium. This seems to be due to the underground bedrock type. The bedrock type of all the elementary school, except Hwarang elementary school whose bedrock type is volcanic rock, is fault-based sedimentary rock. The previous study found that the radon concentrations in the area whose bedrock was volcanic rock were found to be higher than those in the area of the other types of bedrock since the radon emanation rate from volcanic rock was higher than that from sedimentary or fault [3].



(a)



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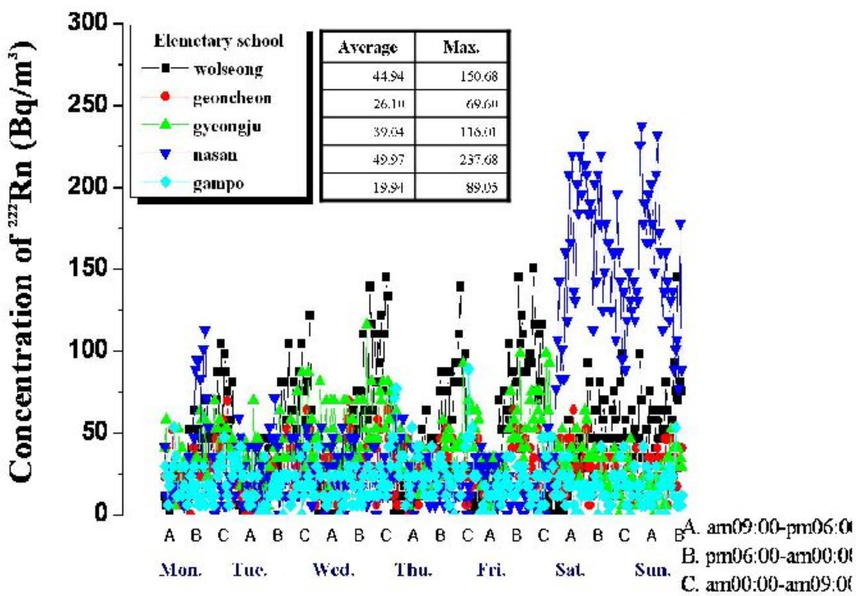


(c)

Fig.2. The indoor radon concentration in the elementary school auditorium according to 3 time intervals per day

Fig.3 shows the frequencies of the indoor radon concentrations exceeding 148 Bq/m^3, according to the time intervals; on-duty (09:00-18:00) and off-duty hours (18:00-24:00, 00:00-09:00). Irrespective of time intervals, there were few frequencies of the indoor radon concentration exceeding 148 Bq/m^3. The range of the indoor radon concentration with the highest frequency was from 20 to 70 Bq/m^3. Fig. 3 also shows some statistics of the indoor radon concentrations such as arithmetic mean, maximum and minimum value, according to the time interval. The arithmetic mean for off-duty hours was 0.7% higher than that for on-duty hours, and the maximum value for off-duty hours was 44% higher than for on-duty hours.

Fig. 4 shows the projected annual effective dose to an elementary school student due to the radon inhalation during the educational activities such gym classes or school assembly etc. in each elementary school auditorium. For this, it was assumed that an elementary school student stays 200 hours a year for the educational activities in the auditorium. And the estimation methods for an annual effective dose are the same as those in [4-6]. The standard of moving time calculated on multiply 5 hours per week which include the class and school assembly by 20 working week except in vacation and weekend. The radiation dose can be estimated using the working level (WL), which is a measure of the atmospheric concentration of radon and its progenies. 1 WL is defined as any combination of short-lived radon daughters in 1 L of air that will result in the ultimate emission of 1.3×10^5 MeV of alpha energy. This corresponds to an atmospheric concentration of 100 pCi of ^{222}Rn per liter (3,700 Bq/m^3) in equilibrium with its daughters. Using the indoor equilibrium factor (0.4 recommended by UNSCEAR), the annual effective dose can be calculated as follows :

$$WL = F_t \times C_{Rn}/100 \qquad \text{(Eq. 1)}$$

Where C_{Rn} = the average radon concentration in each building (pCi/L)

If the exposure resulting from inhalation of air with a 1-WL concentration for a period of 1 working month (170 hours) is 1 WML (Working Level Month), the actual exposure can be calculated as follows:

$$WLM = WL \times \text{exposure time (hours)}/170 \qquad \text{(Eq. 2)}$$

Using the effective dose conversion factor of 5.4 mSv/y/WLM, then the annual effective dose can be estimated as follows:

$$\text{Annual effective dose} = WLM \times 5.4\text{mSv/y/WLM}$$

Though the annual effective dose for the Hwarang elementary school was projected to be 1.3~8 times higher than any other school, it was much lower than 1 mSv/yr that is the dose limit for general population in Korea.

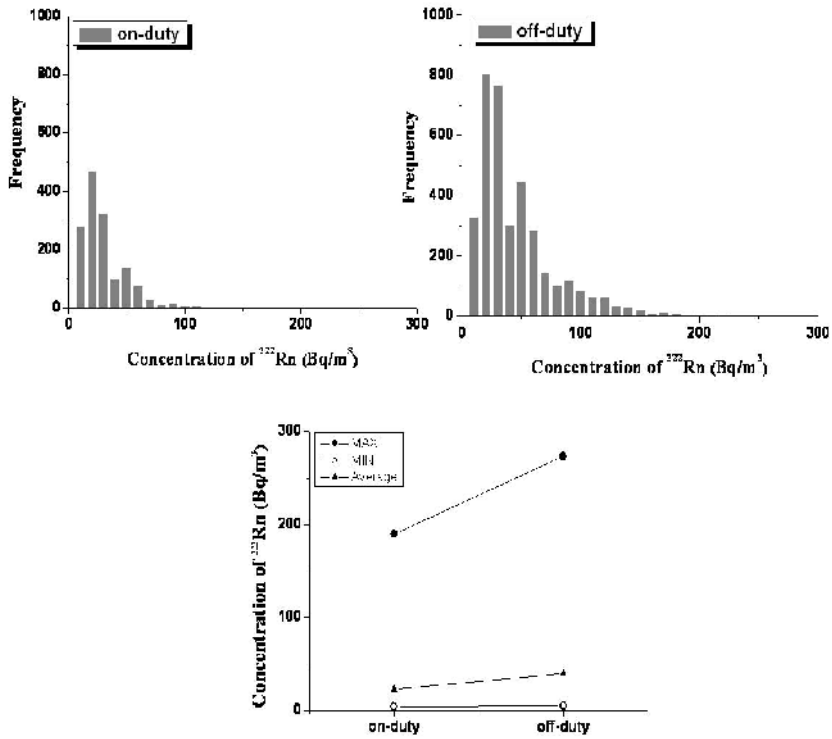
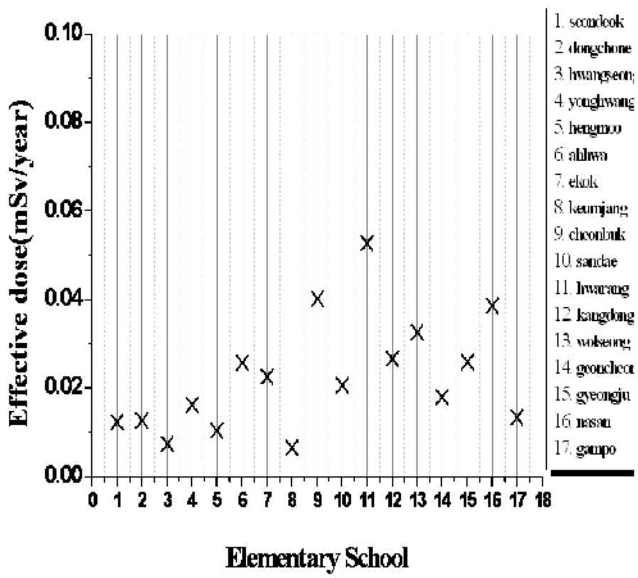


Fig.3. The frequencies of the indoor radon concentrations in the elementary school auditoriums according to 2 time intervals (on- and off-duty hours)



No.	point	mSv/y	No.	point	mSv/y
1	Seondeok	0.012	10	Sandae	0.021
2	Dongcheon	0.013	11	Hwarang	0.053
3	Hwangseong	0.0079	12	Kangdong	0.027
4	Yonghwang	0.016	13	Wolseong	0.033
5	Heongmoo	0.010	14	Geoncheon	0.018
6	Ahhwa	0.026	15	Gyeongju	0.026
7	Ekok	0.023	16	Nasan	0.039
8	Keumjang	0.007	17	Gampo	0.013
9	Cheonbuk	0.040			

Fig.4. The projected annual effective dose to an elementary school student due to the educational activities in the elementary school auditoriums

DISCUSSION

This study measured the indoor radon concentrations at the elementary school auditoriums in Gyeongju. The measurements were analyzed according to the bedrock type and the time intervals per day. In this study, it was found that the indoor radon concentrations over off-duty hours were generally higher that those over on-duty hours, and the indoor radon concentration in the area whose bedrock is volcanic rock was higher than those in the area of the other types of bedrock. As mentioned above, attention has to be paid to an elementary school since many young students and teachers stay for more 6 hours a day at it. Hence, it is necessary to continuously monitor and properly manage the indoor radon concentrations in the elementary schools.

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