Measurement of Radon Exhalation Rate from Soils Around Daegu, Korea

Jihye Seo, Seongjin Maeng, Nur Syamsi Syam, Myo Gwang Kim, Sang Hoon Lee *
School of Architectural, Civil, Environmental and Energy Engineering, Kyungpook National Univ.
80 Daehak-ro, Buk-gu, Daegu, Korea
**Corresponding author: lee@knu.ac.kr*

1. Introduction

Radon (^{222}Rn), a noble gas and one of radioactive progeny of uranium-238 (^{238}U) decay chain, is present in soil and rocks and can easily escape from the soil/rock grains, so it can spread in the air. It is also released from building materials mainly made of soils and concretes, causing indoor air pollution. Radon is considered as a second major contributor to lung cancer because radon and its daughters floating in the air can enter into the human lung through inhalation and cause internal radiation exposure through alpha energy deposition to lung cells[1]. For indoor air, the radon concentration is recommended to be below 4 pCi/L. Since it is well known that radon, from the view point of public radiation dose studies, contributes more than half of the radiation dose from natural environment, it seems necessary to monitor radon exhalation rates directly from soil surfaces.

There are studies to measure and model the radon concentration in soil gas and some studies have been carried out in the field to confirm regional and seasonal characteristics. However, studies measuring and modeling radon exhalation from soil mainly have been conducted in indoor chambers using soil samples taken from outdoor[2,3]. So, in this study of radon exhalation rate from soil around Daegu, measuring radon concentration in a detector volume as a function of time and getting the initial increase rate from fitting were conducted outdoor by using RAD7 detector and its surface emission chamber. The measured radon exhalation rates were compared with ^{226}Ra, ^{238}U activity in the soil. The soil activities were obtained through HPGe gamma spectrometry and alpha spectrometry for soil samples

2. Methods and Results

2.1 Radon measurement

The measurement location was Kyungpook National University(KNU) in Daegu and Geochang(GC) located in Gyeongsangnam-do near Daegu. RAD7 radon detector and its surface emission chamber (Durridge co.) were set up for the measurement of radon activity concentration versus time, using sniff-mode, pump-auto options. After purging the RAD7 system for one hour with fresh air to return radon concentration back to near zero, radon measurements were taken for twelve hours with the emission chamber on the soil surface. During the 12 hours, 36 data of radon activity concentration in RAD7 chamber were collected with 20-min measurement period. Additionally, environment factors like soil temperature, soil water content, air temperature, air humidity were also collected.

2.2 Radon exhalation rate

The radon exhalation rate can be derived in two ways, one from the saturated or equilibrium radon concentration using parameters affected by leakage and back diffusion effects, or the other way from the initial increase rate which should be proportional to the exhalation rate. In this study, we calculated it using initial increase section's data far before equilibrium.

So, for the calculation of radon exhalation rate from soil, we used the equation (1).

$$Y = at + b = \left(\frac{SE}{V}\right)t + b \quad (1)$$

Y represents the activity concentration obtained with RAD7 [Bq/m^3], S is the soil surface area of emission chamber [0.03664 m^2], E is the exhalation rate [Bq/m^2-sec], V is total system volume including RAD7, emission chamber, drying unit and connecting tubes [0.001931 m^3], t is time [sec], and a/b are fitting parameters. By comparing fitting parameter a and (SE/V), one can get the exhalation rate. Measured data Y versus t are presented in Figure 1. Fitting to get increase rates were performed for initial 1 hour and the fitting results are included in Table I.

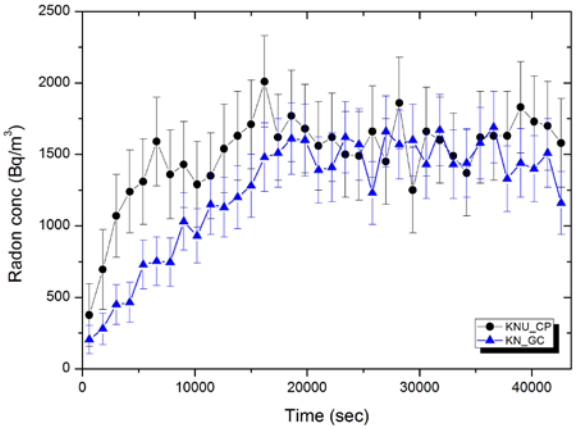


Fig. 1. Measured radon concentration versus time

Table I: Fitting Parameters and Derived Exhalation Rates

Sample Location	KNU	GC
a [Bq/m^3s]	0.29±0.01	0.097±0.023
b [Bq/m^3]	197.54±23.32	133.68±42.26
Exhalation rate [mBq/m^2s]	15.14±0.87	5.13±1.25
Exhalation rate [$atoms/cm^2s$]	0.72±0.04	0.24±0.06

The estimated uncertainties were about 1% for the area S, 3% for the volume V, 14% for the increase rate from the fitting and all combined to get the final exhalation rate uncertainties of about 5~ 24%.

2.3 Measurement of ^{226}Ra, ^{238}U activity in soil

To check the relation between radon exhalation rate and parent nuclides (^{226}Ra, ^{238}U) concentration, soil samples were taken for HPGe gamma spectrometry. In addition, thoron (^{220}Rn) exhalation rate was calculated and also compared with its parent nuclide, ^{228}Ac, concentration.

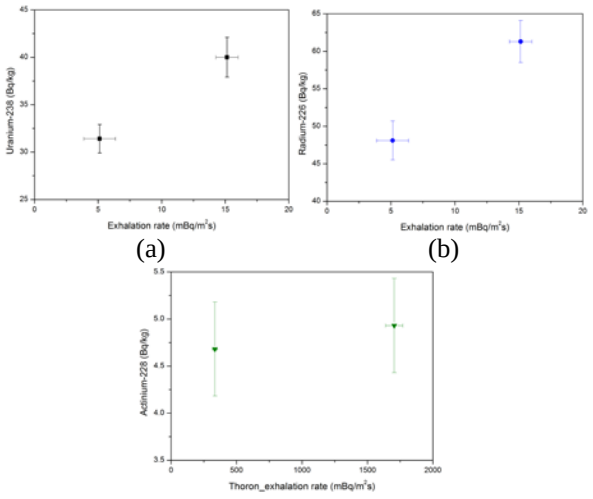
ORTEC company's P type HPGe (High Purity Germanium gamma spectroscopy, efficiency: 20%) and Alpha spectroscopy (efficiency: 21%) are used. Measurement time for HPGe was 100,000 seconds for a good detection ability and a low MDA. The concentration of ^{238}U was obtained by alpha measurement and the concentrations of ^{236}Ra and ^{228}Ac were determined with gamma measurement by appropriate deduction of ^{235}U peaks.

Table Ⅱ: Parent Nuclides Activity in Soil [Bq/kg]

	KNU	GC
^{238}U	40.0±2.1	31.4±1.5
^{226}Ra	61.3±2.8	48.1±2.6
^{228}Ac	4.93±0.5	4.68±0.5

2.4 Comparison between exhalation rate and ^{226}Ra, ^{238}U activity in soil

The correlation between the exhalation rate and the radioisotopes concentrations can be seen in Figure 2. It is clear that radon exhalation from a soil has a very strong linear relation with ^{226}Ra, ^{238}U activity in the same soil. For thoron exhalation rate and its parent ^{228}Ac the relation is not clear at this point. For future studies we are planning to include more soil data for better conclusions for radon and thoron exhalation rates and soil activities of parent nuclides.



(a) (b) (c)

Fig. 2. Comparison between radon exhalation rate and (a) uranium-238 concentration, (b)radium-226 concentration, (c)thoron exhalation rate and actinium-228 concentration.

3. Conclusions

In this study, for two locations near Daegu, radon was measured outdoor and radon exhalation rates were calculated from the increase rates. In KNU, radon exhalation rate from soil was 15.14±0.87 Bq/m^2s, in GC, 5.13±1.25 Bq/m^2s. And radon's parent nuclides' concentration in KNU was also higher than GC's. But as for thoron, correlation between thoron exhalation rate and parent nuclide concentration can't be seen clearly.

Afterward the measurement will be made in more sites and exhalation rate will be analyzed in association with parent nuclides activity in soil and spatial gamma dose rates or gamma exposure rates from monitoring ion chambers.

REFERENCES

[1] H zeeb, F Shannoun, WHO handbook on indoor radon: a public health perspective, World Health Organization, p. 3-16, 2009.

[2] Y Tan, D Xiao, Revision for Measuring the Radon Exhalation Rate From the Medium Surface, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, Vol.58, p.209-213, 2011.

[3] Z Weihai, I Takao, F Masahide, Modeling Radon Flux Density from the Earth's Surface, Journal of NUCLEAR SCIENCE and TECHNOLOGY, Vol.43, p.479-482, 2006.