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A Rapid Method for Radon Determination

N. Enkhbat[a], N. Norov[b], S. G. Shin[a], Y. U. Key[a], M. H. Cho[a*], G. Kim[c], W. Namkung[d], H.S. Lee[d]
[a]*Division of Advanced Nuclear Engineering, POSTECH, Pohang 790-784, Korea*
[b]*Nuclear Research Center, National University of Mongolia, Ulaanbaatar, Mongolia*
[c]*Department of Physics, Kyungpook National University, Daegu 702-701, Korea*
[d]*Pohang Accelerator Laboratory, Pohang 790-834, Korea*
[*]*Corresponding author: mhcho@postech.ac.kr*

1. Introduction

Research carried out in last decades has shown that more than 70% of a total annual radioactive dose received by people originates from natural sources of ionizing radiation, whereby 40% is due to inhalation and ingestion of natural radioactive gas radon ^{222}Rn and its progeny [1, 2]. Radon has 3.5 days of half-life. However, its progeny is dangerous than Radon in the view of radiation protection. Radon measurement is commonly used in controlling radon concentration in underground mine, closed room and in forecasting earthquake.

The difference between methods for determination of radon and its progeny is determined by a small number of variables, notably a selection of the time of air drawing on filter and filter counting on alpha counter. Generally, methods derive their names, such as one-count, two-count and three-count methods, from numbering how many times filter paper counts on alpha counter.

In this paper, we will discuss a rapid method for radon determination and present measurement result of mine environment using by this method.

2. Materials and Methods

Two commonly used one count methods are the modified Kuznets method and the Rolle method, which differ only in the choice of sampling and counting times. Air is drawn through a filter at a rate of 2–10 L/min for a sampling time of 5–10 min. After a waiting time of up to 90 min, the gross alpha activity is integrated over a counting time of 5–10 min using scintillation counter. Another one count method employs alpha spectroscopy combined with gross beta counting using single ‘passivated implanted planar silicon’ (PIPS) detector [4]. This method has been extended to a semi-continuous method involving 3 min grab samples taken at 15 min intervals. The method does not need cumbersome vacuum systems for alpha spectroscopy and therefore allows the use of lightweight portable instrumentation suitable for mine environments.

Various methods are applicable for determination of radon concentration in the air based on gross alpha activity [3-7], including:

a) sampling using alpha scintillation cells (Lucas cells);
b) sampling using pulse ionization chambers;
c) sampling using the charcoal canister (activated carbon);
d) time integrated measurements using nuclear track detectors (radon cup) – CR39;
e) time integrated measurements using thermoluminescent dosimeters;
f) continuous monitoring using sampling methods.

Measurement of concentration of radon progeny is generally active air sampling in which a known volume of air is drawn through a filter. Alpha and/or beta activity on the filter is counted during and/or after sampling. Some methods determine gross activities, while others determine the individual radon progeny concentrations. Alpha spectroscopy is used to determine the activity of individual radon progeny.

2.1 Testing and calibration of detection system

TM372 scintillation counter (Environmental Instruments Canada Inc.) and Model 224-PCXR4 pump (SKC Inc., PA 15330 USA) are applied for this method. The counting efficiency of alpha scintillation counter was determined using a calibrated mixed nuclide of ^{241}Am+^{241}Cm+^{239}Pu (Amersham). Pall 61630 type filter paper was used for our study. The fig. 1 shows radon detection system.

Fig. 1. Radon Detection system.

Calibration curve for pump flow rate was shown in Fig.2. Average pump flow rate was determined based on

10 sampling average. Adjusted pump flow rate found to be as 2.25 l/min.

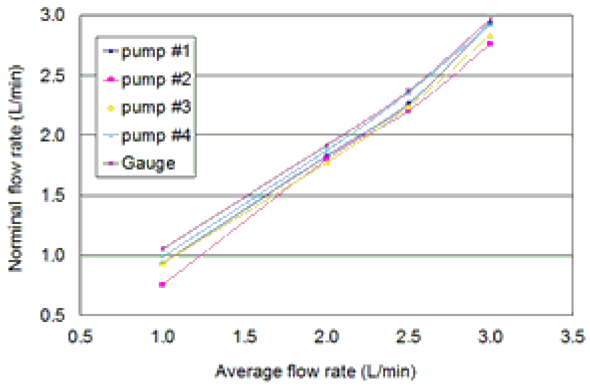

Fig. 2. Calibration curve for pump flow rate.

2.2 Modified Markov Method

Advantage of Markov method comparing to Roll and Kuznets is 2 times counting of activity on filter and estimating of radioactive equilibrium. In Markov method, alpha particles from short decay products of radon on air sampled filter are measured on alpha-radiometer.

Modified Markov method in which air sample is taken for 5 min on a filter at a rate of 2.25 L/ min and two times counting of filter activity for 3 min after 1 and 5 min since sampling, is used to calculate a concentration of radon progeny in air.

$$\left.\begin{aligned} C_{RaA} &= \frac{4.4}{\varepsilon\eta\upsilon}(N_1 - N_2) \\ C_{RaB} &= \frac{1}{\varepsilon\eta\upsilon}(1.1 \cdot N_2) \\ C_{RaC} &= \frac{1}{\varepsilon\eta\upsilon}(2.2 \cdot N_2 - 0.91 \cdot N_1) \end{aligned}\right\} \quad (1)$$

Where: C_{RaA} ,C_{RaB},C_{RaC} – specific activity of radon progeny, RaA(^{218}Po), RaB(^{214}Pb), RaC(^{214}Bi) respectivily in air, Bq m^{-3}; N_1 - the giving counts per 3 min in alpha counter after 1 min delay since sampling, N_2 - the giving counts per 3 min in alpha counter after 7 min delay since sampling, η – the collection efficiency for Rn progeny of the filter paper, ε - the efficiency of alpha scintillation counter, υ - air flow rate (L/ min). For our study, ε = 0.41, υ = 2.25 L/min and η =0.98.

Radon equilibrium activity in air, C_{Rn} (Bq m^{-3}) is calculated the following expression using values of radon progenies obtained from Equation 1.

$$C_{Rn} = 0.105 \cdot C_{RaA} + 0.516 \cdot C_{RaB} + 0.379 \cdot C_{RaC} \quad (2)$$

3. Results

Radon gas emission rate in the immediate opening of the west ventilation shaft depends on the operation of the ventilation system, duration of ventilation system operation, and the air flow rate through the underground development.

Specific activity of radon progeny in air (RaA (Po-218), RaB (Pb-214) and RaC (Bi-214)) and Ra-222 in radioactive equilibrium was calculated by formula 1 and 2, respectively. We include result of measurement carried out in the air around a mining. In Fig.2 shown that the distribution of Po-218, Pb-214, Bi-214 and Ra-222 isotopes releasing from west ventilation shaft in Gurvanbulag underground uranium mine in the eastern part of Mongolia.

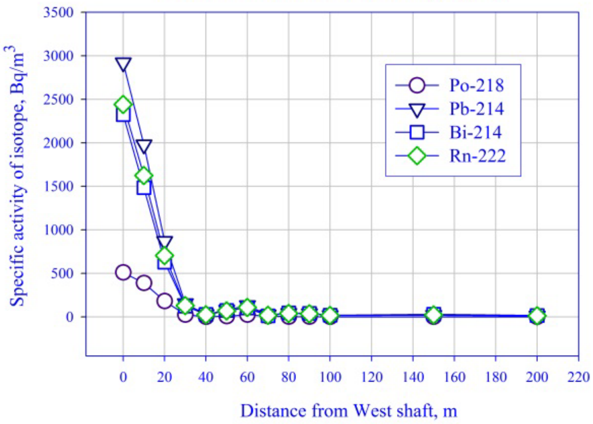

Fig. 2. Radiation distribution of radon and its progeny from mine shaft.

In summary, this method provides rapid determination of radon.

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