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Evaluation of radon separation and measurement by using membrane air-water separator for radon in water

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1. Introduction

Radon-222 (hereafter referred to as radon) is well known to radioactive nuclide gas in nature by decay of 238U. Previously measured radon concentrations in the water in the world by liquid scintillation methods or bubbling method on the sample was reported with highly variable, ranging from 0 to 1,200 kBq/m^3 [1-3], and areas with high radon concentrations are important for monitoring and investigation. When measuring multiple sites with a single detector, it takes a considerable amount of time to release the radon in the detector and for deposited radionuclides decayed. Therefore, in order to shorten the preparation time for considering these points with high radon concentration, it is necessary to treat the high concentration of radon in water to minimize effect to detector so that the intermediate ventilation time can be reduced properly.

In this study, a radon measurement method is proposed by using water-radon separator and an air mixer with a membrane to treat high concentration of radon appropriately. By using this method, it is possible to protect the detector by appropriately diluting the high concentration radon suitable for the proper analysis. For the performance evaluation of the fabricated detection system, the theoretical relation between the radon concentration, the concentration decreased with the mixing ratio, and the change of the radon concentration with time was analyzed.

2. Methods and Results

In this section some of the techniques used to measure radon in water using air-water separator is described. The measurement system includes a separator, mixer, and detector.

2.1 measurement system

Water-radon measurement system consist of water separation system, mixer, and radon measurement system as figure 1.

The basic mechanism is to suck up a water sample or a monitoring object using a water separation system, separate the water from the water, and send the separated water to the mixer to mix with the external air. Finally, the mixed air is sent to the detector to measure the radon concentration in the water.

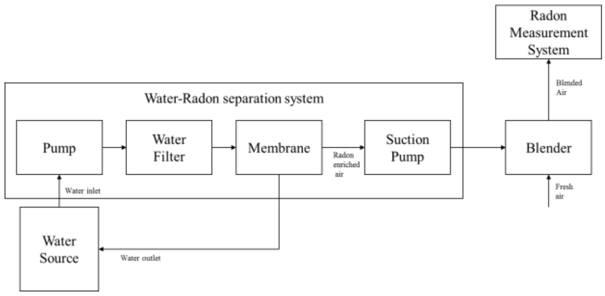

Fig. 1. Radon in water measurement system

RAD-7 was used to measure radon concentration in water, and it measures radon in water sample in 30 minutes, and it is possible to monitor water continuously. If measurement time increased, precision would increase so it is suitable to use to correspond various situation [4].

2.2 Theoretical calculations

According to the three components of the water radon detection system, the radon moves in the order of water separation system, mixer, and detector. The concentration of radon in each component is shown in Equation 1-3.

$$\frac{dN_W}{dt} = -\lambda_w N_{w0} \quad (1)$$

$$N_m = \frac{1}{a+i} N_w \rightarrow \frac{1}{a+i} N_{w0} e^{-\lambda_w t} \quad (2)$$

$$\frac{dN_D}{dt} = \lambda_m N_m - \lambda_D N_D = \frac{\lambda_m}{a+i} N_{w0} e^{-\lambda_w t} - \lambda_D N_D \quad (3)$$

N_w =Radon concentration at water (Bq/m^3)
λ_w=Radon separation rate at water(s^{-1})
N_{w0}=Initial Radon concentration at water (Bq/m$_3$)
N_m =Radon Concentration at mixer (Bq/m^3)
a =Air mix ratio
i =external air inflow ratio
λ_m=Radon transfer rate from mixer (s^{-1})
λ_D=Radon reduction rate at detector (s^{-1})
N_D=Radon concentration in detector(Bq/m^3)

2.3 Radon measurement test

Radon source was made by 226Ra source because Radon has short half-life of 3.823 days. 3.7 kBq, 226Ra source (Eckert & Ziegler, 01-Oct-2016, 3.1%

uncertainty) was used to made radon source, half radioactivity 1.85 kBq is diluted to 4 L distilled water. Source was kept for 20 days in glass bottle to make secular equilibrium with ^{226}Ra in bottle.

To find actual ratio of radon concentration in water and external air, mixer was tested by 3 sources is prepared. The basic source was prepared in the same way as the radon separation experiment, and the basic source was evaluated as 13,000 Bq/m^3 which was derived by aeration test of RAD-7. An estimated source of radon was divided into 2L bottles. Each source was measured with different mixing ratio, only radon rich water, 1:1, and 1:3 of radon in water and external air ratio. Each sample was measured 5 minutes with 9 cycles when radon in water was exhausted. In the case of the existing radon in air or water concentration measurement by using RAD-7, the radon concentration is derived by converting the calculated value using the theoretical and experimentally proven efficiency. The detector constructed here, measurement was performed in units of CPM instead of Bq/m^3, because the detection environment such as the target volume, detection time, and introduction air mixer were changed.

The measured and the theoretically derived values are compared in figure 2-4, and each graph shows the change in radon concentration in no air mixed, 1:1, and 1:3 of air from water and external air mixed.

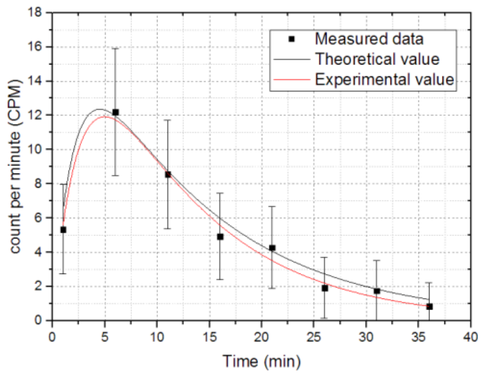

Fig. 2. Comparison of experimental and theoretical data (case: no air mixed)

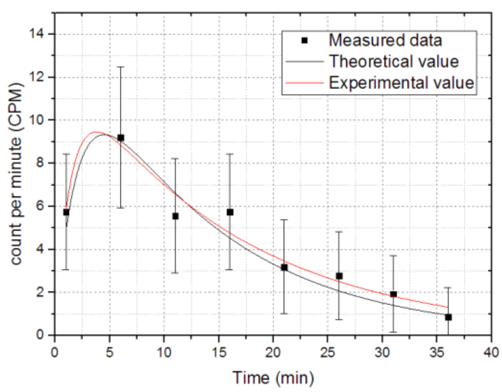

Fig. 3. Comparison of experimental and theoretical data (case: 1:1 air mixed)

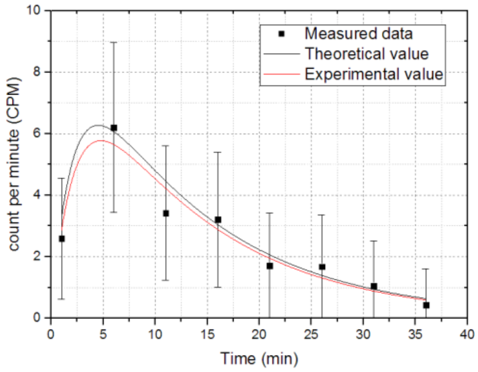

Fig. 4. Comparison of experimental and theoretical data (case: 1:3 air mixed)

In all results, the radon is separated from the water sample and introduced into the detector, increasing the concentration of radon. After two cycles, as the radon in the water is depleted, so the radon inflow is reduced. The amount of radon released from the detector is increased, resulting in a gradual decrease in the concentration of radon. Comparing each result, the measurement value is decreased to 12.2 CPM, 9.2 CPM and 6.2 CPM according to the air mixing ratio, and it is confirmed that the radon concentration measured according to the increase of the air mixing ratio was decreased. The error is found to be large because the count value per hour was small due to the counting error of the coefficient measured at 5 minutes.

3. Conclusions

Theoretical calculations confirm that the experimental results agree with the values within the tendency with R-square of 0.95, 0.92, and 0.98, and it is confirmed that the linearity of the radon concentration change according to the radon concentration in water and air mixing ratio. This detection system can be useful when mixing outside air to reduce the radon concentration in the detector, reducing ventilation time after measurement, and quickly measuring multiple points in a high concentration radon in water measurement area. If the ratio of the two airs can be automatically controlled according to the radon concentration, excessive contamination of the detector by the sample can be expected.

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