AN ELECTROSTATIC RADON MONITOR FOR MEASUREMENTS OF ENVIRONMENTAL RADON

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ABSTRACT. Authors developed a new field instrument for the measurement of environmental radon (^{222}Rn) concentrations. The collecting electrode located at the center of a 32-L cylindrical vessel consists of a light pipe covered with aluminized Mylar coated with ZnS(Ag) . Positive ^{218}Po (RaA) ions resulting from the decay of ^{222}Rn are electrostatically collected on the Al Mylar, and the α -scintillations produced in the underlying ZnS(Ag) are detected by a 52 mm photomultiplier tube. The ^{222}Rn concentrations are calculated from α -counts at one-hour intervals by using a personal computer, and stored on a floppy disk. The ^{222}Rn monitor is capable of measuring ^{222}Rn concentrations down to about $0.17 \text{ Bq}\cdot\text{m}^{-3}$.

1. Introduction

Ionization chamber (Budnitz, 1974), scintillation cell (Lucas, 1957), two-filter method (Thomas and LeClare, 1970) and electrostatic collection method (Dula and Dula, 1971; Wrenn et al., 1975) have been used for measuring environmental ^{222}Rn concentrations. These instruments and methods reported up to the present have low sensitivity or lack stability and availability. The authors constructed a new field instrument with high accuracy and sensitivity for measuring the ^{222}Rn concentration in grab sampling air collected at various environments. The ^{222}Rn monitor which was developed from the electrostatic continuous ^{222}Rn monitor (Iida, 1985) can also measure the outdoor ^{222}Rn concentrations every one-hour. The present paper describes the construction and the characteristics of the improved ^{222}Rn monitor and the some results of grab sampling and continuous measurements.

2. Electrostatic ^{222}Rn monitor

Figure 1 shows the schematic diagram of the electrostatic ^{222}Rn monitor for measuring the ^{222}Rn concentrations in grab sampling. The ^{222}Rn monitor consists of a cylindrical vessel of stainless steel which is able to be evacuated. The cylindrical vessel has a volume of about 32 L. The sampling air is passed through a membrane filter and a vapor trap to the 32-L cylindrical vessel. Then, aerosols, ^{222}Rn daughters and water vapor were removed in the air.

Radon-222 decays by emission of an α -particle to ^{218}Po (RaA), and most ^{218}Po atoms are positively charged (Dua et al., 1983). The positive ^{218}Po ions are collected electrostatically on the electrode of aluminized Mylar ($0.9 \text{ mg}\cdot\text{cm}^{-2}$) coated with ZnS(Ag) phosphor of $10 \text{ mg}\cdot\text{cm}^{-2}$. Alpha-particles emitted from the ^{222}Rn daughters are incident on the underlying ZnS(Ag) through the Al Mylar. The scintillations due to α -particles are detected by a 52 mm photomultiplier tube optically coupled to a light pipe. The scintillation pulse which is amplified and processed is fed into a personal computer (NEC PC-9801RX) through the interface. Using the personal computer, the ^{222}Rn concentrations are calculated from α -counts at one-hour

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Fig. 1. Schematic diagram of the electrostatic ^{222}Rn monitor.

intervals on the basis of Batemann equation (Iida, 1985). The obtained ^{222}Rn concentration data are stored on a floppy disk.

3. Characteristics of the ^{222}Rn monitor

Figure 2 shows the equipotential surfaces and the lines of electric force inside the ^{222}Rn monitor obtained by using a computer (Iida, 1985). From the electric field and the lines of electric force, the effective collection volume can be calculated to be 20.5 L.

The electrostatic collection of $^{218}\text{Po}^+$ ions depends on the humidity of the air and the collecting potential. In particular, the effect of humidity is an important problem for the electrostatic ^{222}Rn monitor (Dua et al., 1983). The air sample was passed through a vapor trap of phosphorus pentoxide (P_2O_5) to maintain the absolute humidity in the chamber less than

Fig. 2. Electric field calculated by iterative method.

$0.5 \text{ g}\cdot\text{m}^{-3}$. The dependence of the collection efficiency upon the applied potential was measured from 500 V to 5000 V in step of 500 V, keeping the humidity at about $0 \text{ g}\cdot\text{m}^{-3}$. The experimental result showed that the collection efficiency increased only 18 % from 500 V to 5000 V. Therefore, the applied potential has been determined to be 3000 V considering the possibility of electric discharge.

A calibration of the ^{222}Rn monitor was done as follows: after air containing ^{222}Rn had been introduced into a 1.5-L cylindrical ionization chamber to measure the ^{222}Rn concentration, the air was injected into the 32-L cylindrical vessel of the ^{222}Rn monitor. The ^{222}Rn concentration in the ^{222}Rn monitor was calculated considering the volume ratio of the 32-L vessel and the 1.5-L ionization chamber. The calibration factor between measured α -counts and ^{222}Rn concentration was derived to be $(53.7 \pm 0.9) \text{ counts}\cdot\text{h}^{-1}\cdot(\text{Bq}\cdot\text{m}^{-3})^{-1}$.

The measurement of the background count rate of the ^{222}Rn monitor was carried out by introducing radon-free air into the ^{222}Rn monitor. From this experiment, the mean background count rate was obtained to be $(5.0 \pm 2.0) \text{ counts}\cdot\text{h}^{-1}$. Using the values of the background count rate and the calibration factor, the detection limit defined by Currie (Currie, 1968) is found to be $0.17 \text{ Bq}\cdot\text{m}^{-3}$.

4. Sampling measurements

For example of the grab sampling measurements, the electrostatic ^{222}Rn monitor was applied to measure ^{222}Rn exhalation rate from the soil. The diagram of the sampling system is shown in Fig. 3. A 3.1-L stainless-steel cylindrical container (28 cm in diameter and 10 cm in height) is pressed into the soil to a depth of 1 cm and left for 15 min. There is no effect of back diffusion of ^{222}Rn into the soil for the accumulation time. After 15 min, the air in the 3.1-L container is passed to a 5-L polyvinyl fluoride (PVF) sampling bag with a diaphragm pump. The outdoor air in the vicinity of the sampling point is also collected in a 50-L PVF sampling bag. The ^{222}Rn concentration in the 5-L PVF sampling bag was measured as follows: The air in the PVF bag is dehumidified and injected into the 32-L vessel of the ^{222}Rn monitor which has been evacuated beforehand. Moreover, radon-free air is added into the 32-L vessel until its pressure reaches 1 atm. Then, the ^{222}Rn concentration is measured with the electrostatic ^{222}Rn monitor. The ^{222}Rn concentration in the 50-L PVF bag is also measured as shown in Fig. 1. The ^{222}Rn exhalation rate from the soil is given by

$$E = \frac{(Q - Q_{\text{air}})}{r \cdot S \cdot T} \quad (1)$$

where E ($\text{Bq}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) is the ^{222}Rn exhalation rate from the soil, Q ($\text{Bq}\cdot\text{m}^{-3}$) is the ^{222}Rn concentration in the 5-L PVF bag, Q_{air} ($\text{Bq}\cdot\text{m}^{-3}$) is the ^{222}Rn concentration in the 50-L PVF bag, r is the passing efficiency of ^{222}Rn from the 3.1-L container to the 5-L PVF sampling bag, S (m^2) is the base area of the 3.1-L cylindrical container, and T (s) is the setting time of the 3.1-L container. The passing efficiency r was determined to be (0.50 ± 0.9) on experiment.

The ^{222}Rn exhalation rates were measured from Aug. to Dec. 1988 at 14 locations in the campus of Nagoya University and its vicinities. Figure 4 shows the average and standard deviation of 10 measurements of the ^{222}Rn exhalation rate at each point. The analysis of variance indicates that there are significant differences in the exhalation rate at each point. The average ^{222}Rn exhalation rate of 14 locations was $(10 \pm 1.6) \text{ mBq}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$.

Fig. 3. Diagram of sampling system for the measurement of ^{222}Rn exhalation rate.

Fig. 4. Range of ^{222}Rn exhalation rates in the campus of Nagoya University and its vicinities.

5. Continuous measurements

A flow rate of $1 \text{ L} \cdot \text{min}^{-1}$ was used for continuous measurement, considering the exchange rate of the air in the ^{222}Rn monitor, the effect of ^{220}Rn concentration in the sampling air and the amount of drying agent in the vapor trap. Figure 5 shows the typical diurnal variation of outdoor ^{222}Rn concentrations measured with the electrostatic ^{222}Rn monitor. The ^{222}Rn daughters concentrations have also been measured by filter pack method during the same period. The ^{222}Rn daughters concentrations are lower than the ^{222}Rn concentrations, because of non-radioactive equilibrium between ^{222}Rn and its daughters in outdoor air. However, the ^{222}Rn and its daughters show similar variation as is shown in Fig. 5.

6. Conclusions

In the present study, a new type electrostatic ^{222}Rn monitor was developed for measuring not only outdoor ^{222}Rn concentration levels continuously but also the ^{222}Rn concentration in grab sampling air. From the relationship between measured α -counts and ^{222}Rn concentration, the calibration factor was derived to be $(53.7 \pm 0.9) \text{ counts} \cdot \text{h}^{-1} \cdot (\text{Bq} \cdot \text{m}^{-3})^{-1}$. The

Fig. 5. Comparison of ^{222}Rn concentrations measured with electrostatic ^{222}Rn monitor and by filter pack method.

detection limit of the ^{222}Rn concentration measured at one-hour intervals was found to be $0.17 \text{ Bq}\cdot\text{m}^{-3}$. Therefore, outdoor ^{222}Rn level can be measured with high accuracy.

The ^{222}Rn monitor was applied to the grab sampling and continuous measurements. The results show that the ^{222}Rn monitor has high sensitivity, stability and availability.

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