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Measurement of radon in air using a radon-^{218}Po calibration curve determined by an absorptive non-volatile liquid scintillator

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HIGHLIGHTS

- This determination method for ^{222}Rn in air was using a radon-^{218}Po calibration curve.
- This curve was performed with measurements in a radon calibration chamber at the National Institute of Radiological Science.
- The ability of this method was detectable atmospheric radon at its low natural concentration at the region of less than 500 Bq/m^3.
- A used non-volatile liquid scintillator for this measurement of radon combines as an absorbent for radon collector.

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ABSTRACT

This work reports a novel method for determining ^{222}Rn (radon) in air using a radon-^{218}Po calibration curve constructed by an absorbable non-volatile liquid scintillator (NVLS). The ability of this method to detect low natural concentrations of radon was confirmed from linear extrapolation of the curve between 500 and 8000 Bq/m^3. The calibration curve was created from data obtained from measurements performed in a radon calibration chamber at the National Institute of Radiological Science (NIRS) by using the least-squares method. The line had high precision and stability, and the required detection time was less than that of ^{214}Po. An absorptive NVLS was used to collect radon and was found to be highly advantageous for α-spectrometry liquid scintillation measurements. Variations of the Ostwald coefficient due to changes in temperature and humidity, which affect radon absorption, were investigated and discussed.

1. Introduction

Liquid scintillation spectrometers (LSS) are suitable for measuring α-particles and β-emitters (Salonen, 2005). Radon, thoron and their decay chain nuclides disintegrate primarily through α- and β-disintegration. LSS has an extremely high (nearly 100%) counting efficiency for the α-particles of those progeny.

Generally, the radioactive equilibrium for radon is calculated and the efficiency of ^{214}Po radioactivity based on the α-spectrum is used to determine the radon concentration in air (Prichard, 1983; Vitz, 1991). This method is commonly used because the overlap of the radon spectrum disturbs the calculation when the α-spectra of ^{220}Rn (thoron) and the progeny of ^{226}Ra are combined in a scintillator for standardization (Salonen, 2010, 1993). However, the ^{214}Po α-spectrum does not overlap with radon, thoron, their decay nuclides or ^{226}Ra. Therefore, when radioactive equilibrium between radon and ^{214}Po is reached after 4 h lapse (Standard Methods for the Examination of Water and Wastewater, 1998; Möbius Ramamonjisoa and Möbius, 2002), the radioactivity of radon must be determined in either air or water. However, we believe that a delay time of approximately 10–20 min is achievable when determining radon concentrations in air if the sample air is saved in a bag, decreasing both the thoron and disintegrated radon concentrations, which is preferable. In this study, we suggest an airborne-radon-determination method that is based on a

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radon-^{218}Po calibration curve that can be applied after thoron has almost completely decayed and when the amount of radon remains unaffected.

The radon-^{218}Po calibration curve in the region of 500–8000 Bq/m^3 was determined in the radon chamber at the National Institute of Radiological Science (NIRS) (Janik et al., 2009). The curve was a proportional relation in the region of 500–8000 Bq/m3 between the absorbed radioactivity in the NVLS and the radon concentration in air. The curve was extrapolated to the region of less than 500 Bq/m^3. We measured the actual radon concentrations in the atmosphere using the linearly extrapolated region of the radon-^{218}Po calibration curve of less than 500 Bq/m^3. This measurement confirmed that the extrapolated straight line was proportional in the region of less than 500 Bq/m^3, similar to the 500–8000 Bq/m^3 region.

We used a non-volatile liquid scintillator (NVLS) to sample airborne radon. The NVLS contained a collector for airborne radon and a liquid scintillator (Kato, 1983). NVLSs are attractive devices because they use a non-volatile solvent, the components of the cocktail must remain unchanged during an extended sampling period (Kato and Hatagami, 1980), because the quenching index measured by the external standard source ^{133}Ba remained unchanging before and after sampling. The cocktail was transparent and colorless. Therefore, using an NVLS does not increase quenching. Radon was collected from the air using an NVLS, with the entire volume (10 mL) of the NVLS in the 20-mL scintillation vial constituting the sample. Here, we present a measurement method that enhances the quality attained previously (Cassette

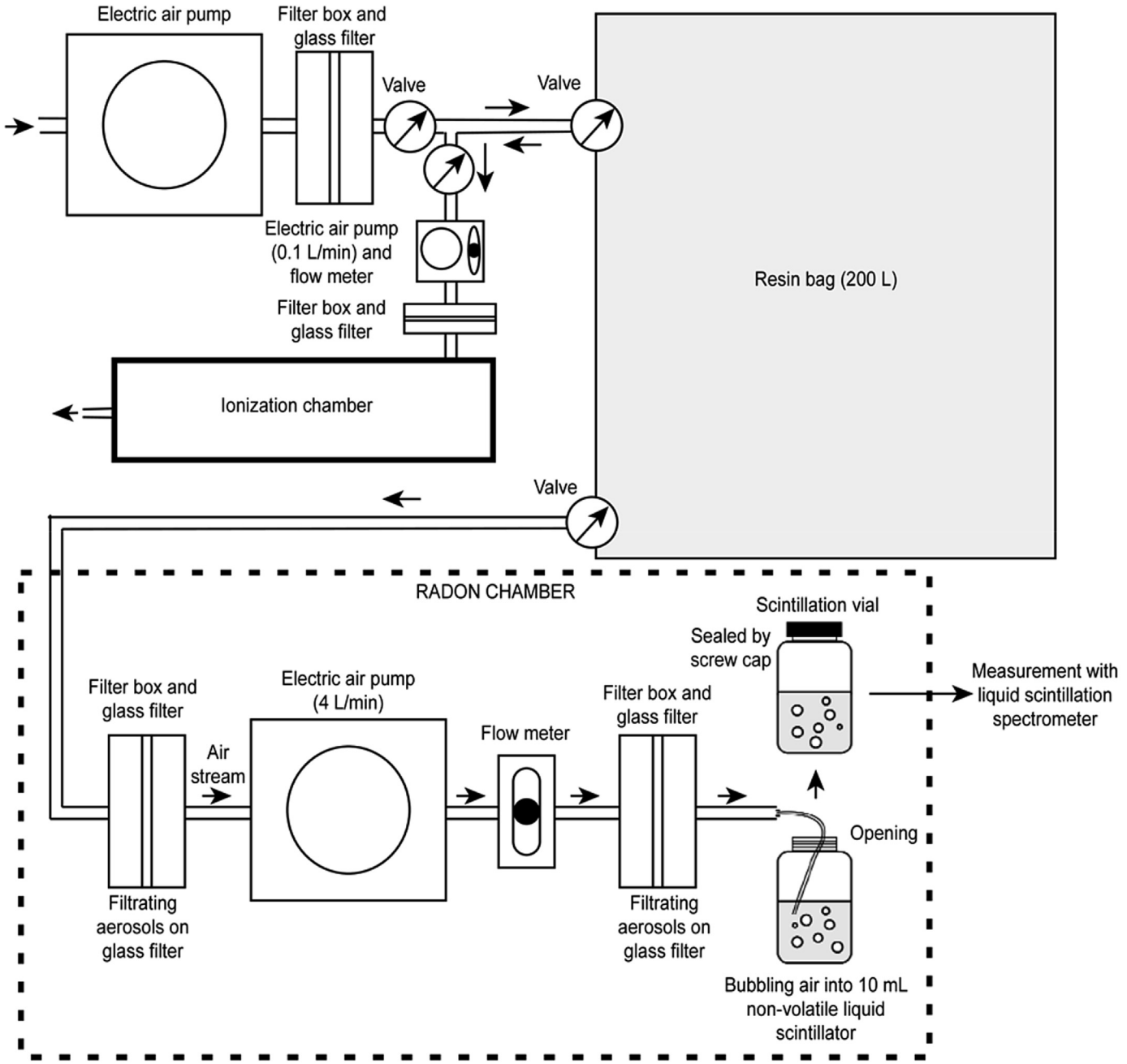

Fig. 1. Illustration of sampling and ^{222}Rn measurements in an absorptive NVLS with bubbling air and a gas flow ionization chamber.