MEASUREMENT OF ^{222}Rn AND ^{220}Rn EXHALATION RATES BY MEANS OF ALPHA SPECTROSCOPY

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Abstract

The measurement of ^{222}Rn and ^{220}Rn exhalation rates by means of alpha spectroscopy are presented. A metallic hemisphere cup with a hole at the bottom of the cup was used. A surface barrier detector is placed on the top of the hole and sealed with silicone in order to provide good insulation. Radon flux emitted from the surface of the material was measured by placing the inverted cup mentioned above on the top of the material. The increase of activity due to ^{222}Rn and ^{220}Rn inside the inverted cup was continuously measured by electrostatic deposition of ^{218}Po and ^{216}Po onto surface barrier detector. This method can also be applied in the measurement of radon exhalation rate from soil and building materials.

Introduction

The production of ^{222}Rn and ^{220}Rn in terrestrial materials depends on the activity concentration of ^{226}Ra and ^{228}Ra present. The UNSCEAR (1993) report indicates that the precursors of ^{222}Rn and ^{220}Rn have about activity in earth and building materials, and the rates at which the two isotopes are produced are also about equal. It is usually assumed that the emanation fraction is the same for both of them. The ratio for the potential alpha energy concentration of ^{220} Rn to ^{222}Rn is about 0.62, and the dose contribution from α decay of ^{220}Rn and its daughters is about 38.27 % of Rn isotopes(1). An instrumentation was developed to detect ^{222}Rn and ^{220}Rn by α spectroscopy with electrostatic collector and to measure ^{222}Rn and ^{220}Rn in some of the building materials available in Taiwan.

Experimental

A metallic hemisphere cup with a hole at the bottom of the cup was used. The hole has a diameter of 2.6 cm. A surface barrier detector was placed on the top of the hole and sealed with silicone in order to provide good insulation. The opening part of the cup connects to a fine metal net. The circuit between the metal net and the cup must be open. The whole device is shown in Fig. 1. The detector is connected to preamplifier, amplifier, analogy / digital converter, multiple channel analyzer and personal computer to analyze the data. When ^{222}Rn and ^{220}Rn decay to ^{218}Po and ^{216}Po, the daughters are mostly positively charged. This positive electricity creates an electrostatic field. Then they were expelled to the bottom of the cup and collected on the surface barrier detector by electrifying the cup with high voltage. The α spectrum analysis for the decay daughters can infer the radioactive concentration of ^{222}Rn and ^{220}Rn (2).

The Calibration of Detection Efficiency

The radioactive source used is a Pylon Model-1025, standard radon source. The activity of radium is 1147 k Bq. The equilibrium activity of radon is 1147 k Bq. As shown in Fig. 2 its detection efficiency is 23.2 % for ^{222}Rn and 17.4 % for ^{220}Rn. Because the decay daughters of

^{222}Rn and ^{220}Rn, namely ^{218}Po and ^{216}Po, are positively charged, the detection efficiency of them will be increased with the increasing positive electricity electrified to the metal cup. As shown in Fig. 2 when the voltage is higher than 3600 V, the detection efficiency for ^{218}Po will achieve a steady value, 87%. Meanwhile, when the voltage is higher than 4800 V, the detection efficiency for ^{216}Po will achieve a steady value, 52 %. Therefore, the collector has a higher collection efficiency for ^{218}Po. The half-life of ^{220}Rn and ^{216}Po is very short (55.6 and 0.15 respectively). Therefore, even the detection efficiency can be improved by electrifying, they can not reach the surface of the detector.

The measurement of ^{222}Rn and ^{220}Rn Exhalation rates in Building Materials

The voltage was set at 4000 V with relative humidity (R. H.) between 41.0 ± 0.2 % and temperature was placed 25 ± 2 °C. The building materials sample was placed in the cup. By measuring α-particle decayed from ^{222}Rn and ^{220}Rn and analyzing the α spectra, the concentration of ^{222}Rn and ^{220}Rn can be obtained. There are two exhalation rates: the initial exhalation rate and the equilibrium exhalation rate. The former is the instant exhalation rate after the building materials is airtight. It is influenced by the quantity of radium and the density of cracks in building materials. The latter is the exhalation rate while the production rate and the decay rate of ^{220}Rn and ^{222}Rn achieve equilibrium in the cup. In this experiment 8 different kinds of building materials were selected. The results obtained are listed in Table 1.

Results and Discussion

The detection efficiency can be raised gradually when the applied voltage is over 3600 V. The collection efficiency of ^{218}Po and ^{216}Po decreases as the R. H. increases and the latter has a greater influence on ^{216}Po rather than on ^{218}Po. While the R. H. varies from 10 % to 40 %, the collection efficiency declines from 40 ~ 50 % to 15 ~ 40 %. Table 1 shows the exhalation rate of building materials, and the equilibrium exhalation rate of ^{220}Rn is higher than that of ^{222}Rn. Inside the collector cup, air has the least amount, of ^{220}Rn with a concentration of 0.008 $kBqm^{-3}$. However, marble and granite have the highest amount, 2.78 $kBqm^{-3}$. The average concentration of ^{222}Rn in air tested by 8 different building materials is about two times greater than that of ^{220}Rn. The average concentration ratio of ^{220}Rn to ^{222}Rn is from 0.13 to 0.44 which means the quantity of ^{220}Rn is about one-third of that of ^{222}Rn. This result matches with the published documents in which the dose contribution of ^{220}Rn is about 30 % of radon(1,3,4). The experimental setup mentioned above can thus improve the detection efficiency, measure the amount of ^{222}Rn and ^{220}Rn, and detect them instantaneously or continuously.

References

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Table 1 The exhalation rates of ^{222}Rn and ^{220}Rn and radon concentration in the common building materials in Taiwan

Number	Name	Equilibrium exhalation rates ^{222}Rn ($\times 10^{-4}$ $Bqm^{-2}s^{-1}$)	Average	^{220}Rn ($\times 10^{-2}$ $Bqm^{-2}s^{-1}$)	Average	Average concentration ^{222}Rn $kBqm^{-3}$	^{220}Rn $kBqm^{-3}$	^{220}Rn / ^{222}Rn
1	Marble	0.07 ~ 0.13	0.10	0.24 ~ 1.32	0.78	0.06	0.008	0.13
2	Quartz brick	0.09 ~ 0.31	0.20	0.11 ~ 0.67	0.39	0.12	0.04	0.33
3	Floor brick	0.10 ~ 0.16	0.13	0.02 ~ 0.21	0.11	0.08	0.012	0.15
4	Red floor brick	0.07 ~ 0.16	0.12	0.02 ~ 0.27	0.14	0.07	0.015	0.21
5	Concrete	0.51 ~ 2.11	1.31	0.50 ~ 6.53	3.51	0.78	0.36	0.46
6	Terrazzo floor	0.17 ~ 3.23	0.27	0.16 ~ 0.82	0.49	0.16	0.05	0.31
7	Slate	0.09 ~ .23	0.16	0.08 ~ 0.31	0.39	0.09	0.04	0.44
8	Granodiorite	0.37 ~ 5.31	2.84	1.16 ~ 11.11	6.14	1.73	0.63	0.36

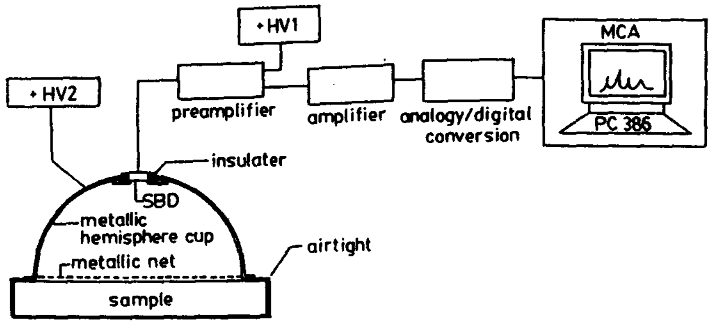

Fig. 1 Block diagram of experimental setup for measuring ^{220}Rn and ^{222}Rn.

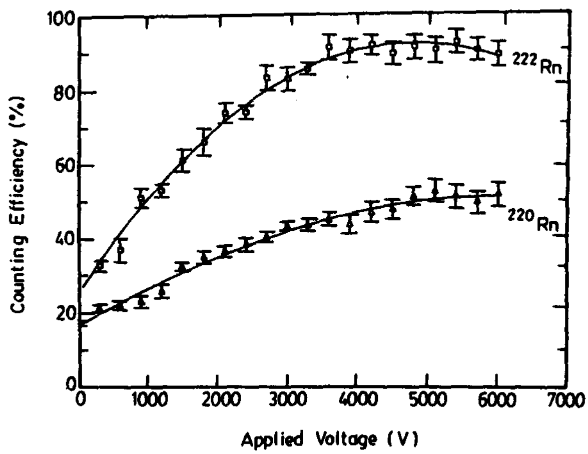

Fig. 2 Counting efficiency vs. applied voltage (Cup diameter 9.4 cm, Temperature 22 ± 2 °C, Relative Humidity 40.0±0.2%)