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A Method for Determining Concentrations of ^{220}Rn in the Field*

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Determining ^{222}Rn and ^{220}Rn concentrations in such environments as volcanic and hot spring areas, as well as in underground water, provides useful information for studies in geochemistry and environmental science. The ^{222}Rn concentrations in the soil gas and the underground water have been extensively measured from the view point of seismology. Human exposure to naturally occurring gaseous radioactivity is also an important problem from the radiological safety point of view in U mines and geothermal areas. Because of the relatively long half-life (3.82 d) of ^{222}Rn, many reports have been published on determining ^{222}Rn concentrations with an ionization chamber, α-track detectors, an electrometer, γ-ray spectrometry and a liquid scintillation counter. On the other hand, few studies have been published on determining ^{220}Rn concentrations, possibly because of the difficulty involved in rapid sampling and measuring of an isotope of short half-life (55 s, in this case).

In the present work, we examined a simple and reliable method for determining ^{220}Rn concentrations in fumarole gases by a rapid solvent extraction of Rn into a toluene scintillator solution, followed by activity measurement with a portable liquid scintillation counter especially designed for field work.

Rapid gas sampling and extraction of ^{220}Rn

Rapid gas sampling was carried out by a 100-ml syringe with two inlets. A glass or polyethylene funnel, immersed in spring water for the collection of gas bubbles, was connected to one inlet of the syringe through a plastic tube. The gas sampling was controlled by two cocks at the inlets. First, the spring water and gas were led into the syringe several times to warm it approximately to the temperature of the spring water. The spring gas was collected as quickly as possible, while the start and stop time of the sampling was recorded. The time required for the sampling of 100 ml of gas was dependent on the amount and the speed of the gas spouting. Sampling time ranged from 60 to 180 s at the Tamagawa Hot Spring, and from 8 to 40 s at the Kuroyu Hot Spring.

After the gas sampling, a 20-ml toluene-liquid-scintillator solution was rapidly sucked into the syringe from one of the inlets, and shaken vigorously for 30 s. The scintillator

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Determination of ^{220}Rn and ^{222}Rn concentrations in volcanic gases

Location	Data (1984)	Temp. (°C)	Concentration (kBq/1-gas) Tn*	Rn*	Tn*/Rn*
KOMATSU-JIGOKU I	Apr. 12	82.0	6.3	1.00	6.3
			6.9	1.05	6.6
II	Apr. 12	39.0	16.3	0.74	22
			22.0	0.92	24
III	Apr. 13	97.5	1.7	0.68	2.5
			1.8	0.84	2.1
IV	Apr. 13	92.5	3.0	1.14	2.6
			3.6	1.60	2.3
V	Apr. 13	—	<	0.41	—
OTAKE-JIGOKU I	Apr. 13	89.0	1.7	0.82	2.1
			1.8	0.77	2.3
II	Apr. 13	98.0	<	0.68	—
HATCHOBARU-KANNO-JIGOKU	Apr. 13	10.0	<	0.026	—
			0.27	0.048	5.6
MYOUBAN-JIGOKU	Apr. 15	96.0	<	0.37	—
NASU-CHAUSUDAKE I	June 07	90.0	0.60	0.096	6.2
			0.47	0.10	4.7
II	June 07	—	0.29	0.11	2.6
			0.44	0.12	3.6
III	June 07	91.0	0.48	0.12	3.9
HAKONE-OWAKUDANI BOUZU-JIGOKU	Sep. 10	94.5	0.71	0.36	2.0
			0.39		1.1
GOEMON	Sep. 10	88.0	0.40	0.27	1.5
KUROYU-HOT SPRING I-a	Aug. 01	55.6	0.95	0.80	1.2
			1.3		1.6
			1.6		2.0
I-b	Aug. 01	48.0	2.2	0.94	2.4
			1.3		1.4
			1.8		1.9
I-c	Aug. 01	54.0	1.4	0.84	1.7
			0.84		1.0
I-d	Aug. 01	56.5	1.9	1.1	1.8
			1.7		1.6
II	Aug. 01	73.5	1.4	0.75	1.9
			1.1		1.5
III-a	Aug. 01	82.6	1.1	0.57	1.9
			0.75		1.3
III-b	Aug. 01	79.0	0.94	0.63	1.5
			1.1		1.7
IV-a	Aug. 01	70.0	0.53	0.75	0.7
			1.1		1.4
IV-b	Aug. 01	50.1	0.54	0.90	0.6
TAMAGAWA-HOT SPRING YUKAWA-a	Aug. 02	97.0	7.7	0.078	99
			6.2		80
YUKAWA-b	Aug. 02	94.5	1.2	0.035	35
			1.1		32
YUKAWA-c	Aug. 02	91.0	11.8	0.15	80
			10.2		69
YUKAWA-d	Aug. 02	97.0	16.5	0.29	57
			15.6		54
YUKAWA-e	Aug. 02	96.0	23.1	0.21	110
			30.7		150
HIGASHIMORI	Aug. 02	99.0	1.4	0.083	17
			0.58		7
FUKENOYU-HOT SPRING	Aug. 03	92.0	4.6	3.04	1.5
			4.6		1.5

*Tn=^{220}Rn : Rn=^{222}Rn.

solution was, then, transferred to a standard measuring vial. The reproducibility of this extraction procedure was tested in the laboratory by using the gas containing ^{222}Rn. The coefficient of variation was 5.7%.

Detection system for in situ *measurement of* ^{220}Rn

To measure the radioactivity of ^{220}Rn in the field, a protable liquid scintillation counter was designed. The counting system consists mainly of one photomultiplier, three channel discriminators and a data print-out unit. A similar portable counter has been reported by Sato *et al.* but our equipment has an automatic printout unit and preset controls for the counting time and cycles, which are essential for measuring ^{220}Rn. With this system, the decay and growth of radioactivities were recorded as a function of time and analysed for the ^{220}Rn and ^{222}Rn components. For the absolute determination of the ^{220}Rn concentration, the volume of the hastily collected gas and the extraction efficiency of Rn into the toluene phase must be known. They were obtained by using the coexisting ^{222}Rn as a tracer.

Slow gas sampling for the determination of ^{222}Rn

For the actual sampling in the field, it is difficult to estimate the distribution coeffient of ^{220}Rn between the gas and the toluene scintillator solution since the temperature and the volume of the gas vary during the extraction. However, it can be known through the measurement of ^{222}Rn, with an assumption that ^{220}Rn is extracted in the same manner as ^{222}Rn–namely, the distribution coefficient being the same for both ^{220}Rn and ^{222}Rn. The ^{222}Rn concentration in the noncondensing gas was determined as follows. The spouting gas of 100 ml was slowly collected through a cooling condenser into the syringe, to which a 20-ml scintillator solution was added. After being shaken vigorously for 30 s, the scintillator solution was poured into a measuring vial. The remaining gas was shaken again with another 20 ml of the liquid scintillator solution. The radioactivities in the two extracted solutions were measured either by the portable counter in the field or by a liquid scintillation counter, at our laboratory.

The present method was used for testing the fumarole gases at Ohwaku-dani in the Hakone volcanic area (Kanto District), Kuroyu and Tamagawa hot springs in the Tohoku geothermal area, and Komatsu Jigoku (Kyushu District) in Japan.