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## Determination of Radon-220 and Radon-222 Concentrations in Fumarolic Gases\*

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The Rn-222 concentrations in the soil gas, fumarolic gas, atmosphere, and in the underground water have been measured extensively for the studies of seismology, uranium mining, environmental science and geochemistry. It has been known that its concentrations are often very high in fumarolic gases and in the underground water, the reason for which is, however, not clarified yet.

Rn-220 is another isotope of radon and belongs to the thorium decay series. Due to its short half life of 55.6 s, reports on its concentrations in those gases and in natural water are still scant. They are also important for a better estimate of our exposure to natural radioactivity and also for the geochemical study of the formation of those radon isotopes and their underground movement.

In the previous paper (Yoshikawa *et al.*, 1986), we proposed a method for the direct determination of Rn-220 and Rn-222 in fumarolic gases.

In the present work, an indirect method for the determination of Rn-220 in fumarolic gases has been studied that measures essentially the activity of Pb-212, the progeny of Rn-220, together with a further investigation on Rn-220 and Rn-222 concentrations at various sites. An attempt is also made for understanding of the Rn-220 and Rn-222 data, namely, the formation and transport of the radon gas underground.

An advantage of this method is that the gas sampling does not have to be carried out fast. Thus the gas volume can be made large so long as the condensed water as well as the non-condensing gas is collected into a sampling bottle quickly. Moreover, the radioactivity measurement does not have to be performed at the sampling site. However, the disadvantage is the decreased sensitivity in the activity measurement due to the longer half life of Pb-212, i.e., the half life of 10.64 hr is about 690 times larger than that of Rn-220. The measurement of Pb-212 actually has a meaning somewhat different from the direct measurement of Rn-220, and it is expected to give some information on the amount of Rn-220 initially drifted from the source into the up-stream of the gas if the decay products of Rn-220 stay in the gas stream and come up to the surface.

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In the present work, lead isotopes were chemically separated from the sample gas as lead sulfide since the formation of lead sulfide was inevitable under the presence of  $\text{H}_2\text{S}$  in the fumarolic gas. The lead sulfide was then dissolved in a small amount of concentrated  $\text{HCl}$  and mixed with the Insta Gel (emulsion scintillator solution, Insta Gel, Packard inc.) for the liquid scintillation counting. The chemical yield and the volume of the collected non-condensing gas were obtained from the measurement of the activities of  $\text{Pb-214}$  and its progeny which were in radioequilibrium with their precursor  $\text{Rn-222}$  whose concentration was determined separately by the direct method.

Comparison of the direct and indirect method

Location		TAMAGAWA HOT SPRING		HAKONE HOT SRING
		Ohbuki	Higashimori	Goemon-Jigoku
Temperature ( $^{\circ}\text{C}$ )		96	97	84
Gas collection method		orifice of hot spring	gas vent	orifice of hot spring
Direct Method	Sampling time (s)	79	135~140	4~8
	Rn-222 (kBq/l)	$0.048 \pm 0.003$	$0.085 \pm 0.003$	$0.066 \pm 0.003$
	Rn-220 (kBq/l)	$5.6 \pm 0.4$	$1.4 \pm 0.4$ $1.1 \pm 0.2$	$0.03 \pm 0.07$ $0.06 \pm 0.04$ $0.09 \pm 0.03$ $0.05 \pm 0.07$
	Rn-220/Rn-222	$115 \pm 12$	$16 \pm 4$ $13 \pm 3$	$0.5 \pm 1.1$ $0.9 \pm 0.6$ $1.3 \pm 0.5$ $0.8 \pm 1.1$
Indirect Method	Rn-220/Rn-222	$136 \pm 13$	$11 \pm 1$ $9 \pm 1$ $11 \pm 1$	$1.5 \pm 0.3$ $2.0 \pm 0.3$
	Rn-220 (kBq/l)	$65. \pm 0.7$	$0.93 \pm 0.07$ $0.78 \pm 0.07$ $0.93 \pm 0.07$	$0.10 \pm 0.02$ $0.13 \pm 0.02$