# Continuous measurement of radon exhalation rate from the soil surface around an active volcano

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## INTRODUCTION

There are many active volcanos in Japan. In particular, the Sakura-jima volcano (**Fig. 1**), which is located in southern Japan, has been very active since 2009 (**Fig.2**). High $^{210}$Po concentrations were observed in air samples from Sakura-jima volcano collected in the 1980s. $^{210}$Po is one of the decay products of $^{222}$Rn which is a radioactive noble gas. Thus, high $^{222}$Rn may have been observed from Sakura-jima volcano when the high concentrations of $^{210}$Po were measured. On the other hand, the phenomenon of increasing outdoor $^{222}$Rn concentrations before earthquakes associated with diastrophism has been reported by many researchers. Thus, continuous measurement of $^{222}$Rn concentrations from the soil surface may be useful from the viewpoint of the prediction of volcanic activity. In this study, the $^{222}$Rn exhalation rate, which is often called flux density, from soil surface was measured together with meteorological data in order to discuss the possibility of the prediction of volcanic activity.

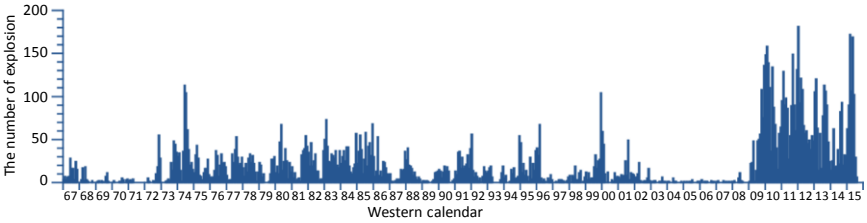


**Fig. 2** The number of explosion in Sakura-jima volcano. Ref. Website of the Kyoto University, Sakurajima volcano research center (http://www.svo.dpri.kyoto-u.ac.jp/new/wp-content/uploads/2015/08/GMonthly67.png)

**Fig. 1** Location of the Sakura-jima volcano.

## MATERIALS AND METHODS

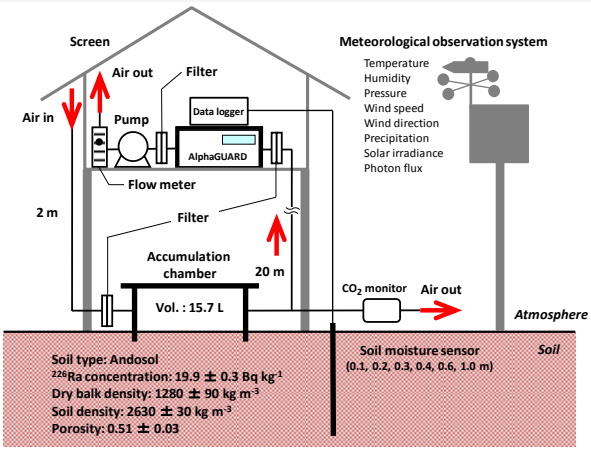


**Fig.3** The outline of the flow-through exhalation rate measurement system.

**Fig.4** Photo of the measurement point.

### Equation for flow-through method

Ref. Hosoda et al. ***Rev. Sci. Instrum.*** 82: 015101 (2011)

$$J_{Rn} = \frac{1}{S} \times \left[ \left\{ \frac{(\lambda + Q) \cdot V \cdot C}{1 - e^{-(\lambda+Q)t}} \right\} - \left( C_0 \times \frac{v}{60} \right) \right] \quad \text{Eq. (1)}$$

$J_{Rn}$ : Radon exhalation rate (Bq m$^{-2}$ s$^{-1}$)
$v$ : Sampling flow rate (= 0.0017 L s$^{-1}$)
$V$ : Chamber volume (= 15.7 L)
$Q$ : Air exchange rate ($Q = v/V$) (s$^{-1}$)
$C$ : Radon concentration in chamber after correction (Bq L$^{-1}$)
$C_0$ : Outdoor radon concentration (Bq L$^{-1}$)
$S$ : Sampling area (= 0.105 m$^2$)
$t$ : Elapsed time (= 3600 s)

$$C = \frac{(C_{cham} - C_{BG}) \times CF}{e^{-\lambda t_e}} \quad \text{Eq. (2)}$$

$C_{cham}$ : Radon concentration in chamber (Bq L$^{-1}$)
$C_{BG}$ : Background concentration (= 18 ± 7 Bq L$^{-1}$)
$CF$ : Calibration factor for AlphaGUARD (= 1.03 ± 0.01)
$t_e$ : Effective time from chamber to AlphaGUARD ($t_e = (V+V_1+V_2)/v$) (= 10491 s)
$V_1$ : Tube volume (= 0.0012 m$^3$)
$V_2$ : AlphaGUARD volume (= 0.00056 m$^3$)

## RESULTS AND DISCUSSION

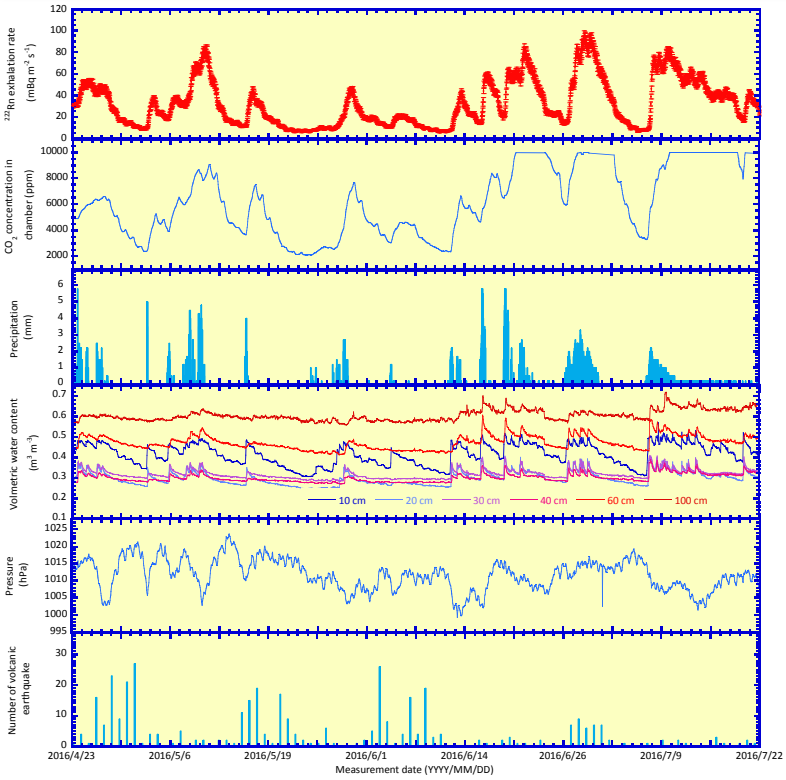


**Fig.5** The daily variations of $^{222}$Rn exhalation rate, $CO_2$ in the accumulation chamber and the meteorological parameters.

- The $^{222}$Rn exhalation rate showed its maximum value after rainfall. The soil surface around the accumulation chamber becomes wet due to rainfall. The rain water will permeate downward after a few hours. As a result, the water content around the accumulation chamber becomes higher. Thus, radon will be exhaled from the soil surface under the accumulation chamber which has a low-level water content.
- The daily variation of the $^{222}$Rn exhalation rate and $CO_2$ concentration in the accumulation chamber seem to be in good agreement. Thus, $^{222}$Rn will become a good tracer for $CO_2$ monitoring in environment.
- However, no relation between the $^{222}$Rn exhalation rate and volcanic activity has been found in this study due to the effect of rainfall. Thus, it is necessary to develop a correction method for the effect of rainfall on the $^{222}$Rn exhalation rate obtained by the flow-through method.

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