Precise flux measurements of soil diffuse gaseous elemental mercury on the surface of volcanoes

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1. Introduction

Earth's atmosphere contains an average of 1-3 ng/m^3 of mercury as gaseous elemental mercury (GEM). Mercury is one of the most important toxic gases emitted from industry, and also from natures including volcanoes. In addition to fumarolic gas at volcanoes, GEM is released from the surface of volcanoes as soil diffusion degassing. GEM is likely to be transported to the surface along relatively high permeable zones. In this case, the spatial distribution of GEM emission rates from ground surface is one of the clues for detecting fracture zones. Such fracture zones may correspond to areas where explosion occur in future. Thus, spatial distribution of GEM emission rate on the surface of volcano is important to mitigate the disaster risk from volcanic eruptions. However, the spatial distribution of GEM emission rates does not always reflect the gas release from the depths, because GEM emission from soil is usually strongly correlate with meteorological factors such as temperature. In this study we recorded temporal changes in GEM emission rate at a specific site at Kusatsu-Shirane volcano. On the basis of a relation between GEM emission rate and temperature, we modify a spatial distribution of GEM emission rates of Kusatsu-Shirane volcano.

2. Method

In-situ flux chamber measurements were carried out. To reduce the uncertainty originating from fluctuations of GEM concentration of the ambient air, all sample gas pumped from the chamber was returned to the chamber after all GEM in the sample gas is removed by mercury removal filter. GEM concentration was measured using the Lumex(R) RA-915M with a detection limit of 0.5 ng/m^3, corresponding to 1/4 of representative GEM concentration of earth's atmosphere. Our laboratory experiments using standard mercury gas show that our method records an average of 99 % of actual GEM emission.

Measurements were conducted at the site, RH, 500 m south of Yugama crater lake on 4-5 October 2021. Phreatic eruptions have repeatedly occurred in this area over the past 80 to 100 years, but is now mostly covered with vegetation and has no thermal features. GEM emission rates and temperature in the camber were recorded at intervals of 5 minutes. To further discuss the spatial distribution of GEM, measurements were carried out at 28 sites on the south of Yugama crater lake on 5-8 October 2021. Measurements were also performed at the site YM, 1.5 km northwest of Yugama crater, as a representative site where volcanic gas does not ascend from the depths.

3. Results and Discussion

The relation between GEM emission rates (ϕ) and temperature at the site RH was found to satisfy the Arrhenius equation, however, ϕ changes depending on the underground temperature (T_g), not the chamber temperature (T_c). T_c at the site RH varied between 8.1 and 25 degC while ϕ ranged between 4.0 and 10 ng/m^2/s, corresponding to 3-8 times higher than those at the site YM (area of no volcanic gas ascent). Although ln(ϕ) changes linearly with T_c^{-1} (Arrhenius equation), we can clearly see that the intercepts of the Arrhenius plot is different for the data recorded on morning (temperature increased with time) and evening (temperature decreased with time). The mechanism for the difference in intercept is interpreted as a delayed response of the subsurface temperature (T_g) to the change in chamber

temperature (T_c). On the basis of the consideration using the heat conduction equation, GEM emission rates (ϕ) changes depending on the ground temperature at a depth of two centimeters. Using the empirical relation obtained in this study, we modified the spatial distribution of GEM emission rate at Kusatsu-Shirane volcano. As result, we find GEM emission on the southern flank of the Shirane pyroclastic cone, which is 1.6-6.9 times higher than that at the site YM. The high GEM emission area corresponds to a locality of past fissure vents.

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