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Atmospheric mercury depletion and mercury photoreduction in snowpack at a mid-latitude coastal island

JU HYEON LEE[1], YOUNGGWANG KIM[1], SEUNG HYEON LIM[1], MOONKYOUNG CHO[1], KITAE KIM[2], YEONGCHEOL HAN[2] AND SAE YUN KWON[1,3]

[1]Pohang University of Science and Technology
[2]Korea Polar Research Institute
[3]Yonsei University

Presenting Author: jhl329@postech.ac.kr

During polar springtime, the atmospheric mercury depletion event (AMDE) is considered an important mechanism driving photo-oxidation of elemental mercury (Hg^0) via halogens and subsequent deposition (Hg^{2+}) and re-emission (Hg^0) from snowpack. While this atmospheric-snowpack interaction for mercury has been extensively studied in the coastal regions of the Arctic and Antarctic, only a few studies have characterized Hg exchange at mid-latitude coastal regions. We collected surface snow and atmospheric total gaseous Hg (TGM) at Mountain Halla, located at a coastal island of Jeju, South Korea, to characterize sources and mechanisms responsible for atmospheric-snowpack Hg exchange at mid-latitudes. Our TGM exhibited a δ^{202}Hg range of –2.33 to –0.80‰, consistent with TGM evaded from the oceanic surface [1]. The snow samples collected at multiple elevations exhibited surprisingly consistent Hg isotope ratios (δ^{202}Hg = -0.26 ± 0.33‰, Δ^{199}Hg = -1.06 ± 0.74‰, 1SD) with fresh snowfall (δ^{202}Hg = 0.25 ± 0.42‰, Δ^{199}Hg = -1.08 ± 0.18‰) and aged snow affected by the AMDE in the Arctic (δ^{202}Hg = 0.04 ± 0.61‰, Δ^{199}Hg = -2.51 ± 0.11‰) (Figure 1). Our snow halogen concentrations (Br^- = 1.00 ± 0.72µM, Cl^- = 476 ± 559µM, Na^+ = 547 ± 603µM, 1SD) reveal levels that are similar to snow collected over the first year ice in the Arctic Ocean (Br^- = 0.7 ± 0.5µM, Cl^- = 342 ± 159µM, Na^+ = 194 ± 100µM), known to be heavily influenced by coastal halogens. Over the course of three days, we observed an increasing trend in Hg isotope ratios in the snow (3rd day; δ^{202}Hg = 0.34 ± 0.03‰, Δ^{199}Hg = 0.03 ± 0.02‰). The slope of Δ^{199}Hg/Δ^{201}Hg, used to distinguish between Hg^{2+} photo-reduction and methylmercury photo-degradation, displayed a value (1.05 ± 0.15) reflecting aqueous Hg^{2+} photo-reduction caused by snow melting. Our study provides preliminary evidence that coastal halogen induced Hg^0 photo-oxidation followed by deposition may be an important mechanism driving Hg deposition to snowpack in mid-latitude coastal mountains. The frequent melting of the snow, however, supplies photo-reduced Hg^{2+} to both the mountain ecosystem and the atmosphere.

[1] Rolison, Landing, Luke, Cohen & Salters (2013), *Chemical Geology* 336, 37-49.

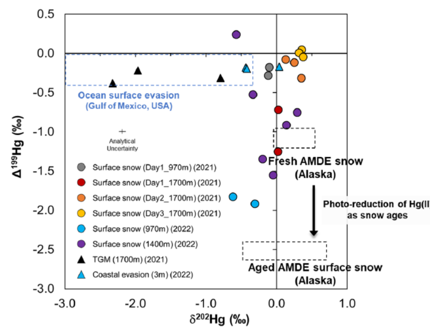

Figure 1. Mercury isotope ratios (δ^{202}Hg and Δ^{199}Hg) of surface snow and total gaseous mercury (TGM) collected at low (970m) and high altitudes (1400m and 1700m) of Mountain Halla, Jeju Island, South Korea in 2021 and 2022. Snow samples are plotted in circles and the colors signify varying sampling sites and days. TGM samples are presented in triangles and the colors indicate varying sampling sites.