EGU2020-19656
https://doi.org/10.5194/egusphere-egu2020-19656
EGU General Assembly 2020

Self-limiting atmospheric lifetime of environmentally reactive elements in volcanic plumes

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Volcanoes are a large global source of almost every element, including ~20 environmentally reactive trace elements classified as metal pollutants (e.g. selenium, cadmium and lead). Fluxes of metal pollutants from individual eruptions can be comparable to total anthropogenic emissions from large countries such as China.

The 2018 Lower East Rift Zone eruption of Kīlauea, Hawaii produced exceptionally high emission rates of major and trace chemical species compared to other basaltic eruptions over 3 months (200 kt/day of SO_2; Kern et al. 2019). We tracked the volcanic plume from vent to exposed communities over 0-240 km distance using in-situ sampling and atmospheric dispersion modelling. This is the first time that trace elements in volcanic emissions (~60 species) are mapped over such distances. In 2019, we repeated the field campaign during a no-eruption period and showed that volcanic emissions had caused 3-5 orders of magnitude increase in airborne metal pollutant concentrations across the Island of Hawai'i.

We show that the volatility of the elements (the ease with which they are degassed from the magma) controls their particle-phase speciation, which in turn determines how fast they are depleted from the plume after emission. Elements with high magmatic volatilities (e.g. selenium, cadmium and lead) have up to 6 orders of magnitude higher depletion rates compared to non-volatile elements (e.g. magnesium, aluminium and rare earth metals).

Previous research and hazard mitigation efforts on volcanic emissions have focussed on sulphur

and it has been assumed that other pollutants follow the same dispersion patterns. Our results show that the atmospheric fate of sulphur, and therefore the associated hazard distribution, does not represent an accurate guide to the behaviour and potential impacts of other species in volcanic emissions. Metal pollutants are predominantly volatile in volcanic plumes, and their rapid deposition (self-limited by their volatility) places disproportionate environmental burdens on the populated areas in the immediate vicinity of the active and, in turn, reduces the impacts on far-field communities.

Reference: Kern, C., T. Elias, P. Nadeau, A. H. Lerner, C. A. Werner, M. Cappos, L. E. Clor, P. J. Kelly, V. J. Realmuto, N. Theys, S. A. Carn, AGU, 2019; https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/507140.