New results and review of major and trace element output from worldwide passive degassing volcanoes

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Volcanic emissions represent one of the most important natural sources of trace elements into the atmosphere (e.g. As, Cd, Cu, Hg, Pb, Sb, Tl and Zn), sequentially influencing the other geochemical spheres (hydrosphere, lithosphere and biosphere). The human health hazard during episodic volcanic eruptions due to coarse and fine particles (2.5-10 and <2.5 μm) fall out like asthma and lung and respiratory disease is well documented. Regarding passive degassing volcanoes, the harmful effect of fluorine fumigation are known both for vegetation (foliar necrosis) and human/animals (fluorosis), but only few study have been focused on the effects of potentially toxic trace elements. From a literature review on metals output from active worldwide volcanoes, we found 37 publications (the first dating back to the 70's), 13 of which relate to the Etna and the other include some of the world's most active volcanoes: Mt. St. Helens, Stromboli, Vulcano, Erebus, Merapi, White Island, Kilauea, Popocatepetl, Galeras, Indonesian arc, Satasuma and Masaya. In general, the review shows that currently there are very few data available. We compiled a database both for concentrations and fluxes of 59 chemical elements (major and trace), that allow us to define the compositional and output range. In this study we present unpublished results from Etna (Italy), Turrialba (Costarica), Nyiragongo (Democratic Republic of Congo), Mutnovsky and Gorely (Kamchatka), Aso Asama and Oyama (Japan). Concentrations of major and trace elements were obtained by direct sampling of volcanic gases and aerosols on filters. Sulfur and halogens were collected by using filter-packs methodology, and analyzed by ion chromatography. Untreated filters for particulate were acid digested and analyzed by ICP-OES and ICP-MS. Sulfur to trace element ratios were related to sulfur fluxes to indirectly estimate elementar fluxes. Etna confirms to be one of the greatest point sources in the world. The Nyiragongo results to be also a significant source of metals to the atmosphere, especially considering its persistent state of degassing from the lava lake. Also Turrialba and Gorely have high emission rates of trace metals considering the global range. Only Mutnovsky volcano show values which are sometimes lower than the range obtained from the review, consistent with the fact that it is mainly a fumarolic field. The accurate estimation of individual and global volcanic emissions of trace metals is still affected by a high level of uncertainty. The latter depends on the large variability in the emission of the different volcanoes, and on their changing stage of activity. Moreover, only few of the potential sources in the world have been directly measured. This preliminary work highlights the need to expand the current dataset including many other active volcanoes for a better constraint of global trace metal fluxes from active volcanoes.