Experimental simulations of the weathering of volcanic ash – a case study to better understand short - and long-term impacts of ash-leachable elements on the environment

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Alexander Robert Greig

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Abstract

The aim of this project is the development and testing of a new methodology for the investigation of the short- to long-term leaching behaviour of volcanic ash. Previous research has demonstrated that volcanic eruptions can have strong impacts on the environment, which result from elements that have been leached from volcanic ash. To date, there is relatively little understanding of the minor and trace element composition of ash-leached brines, and how this varies over time. These gaps in knowledge currently preclude an estimate of both the detrimental and the beneficial impacts of volcanic ash fall due to leaching on the environment, agriculture, as well as on human and animal health.

An adaption of a soxhlet reactor was found to be an adequate experimental technique for the constant flushing of volcanic ash samples with deionised water. This was designed to accelerate the weathering of a volcanic material in a laboratory setting. A number of shortcomings in the experimental method could be identified through the course of this research and should be considered in future investigations.

In this experiment nine volcanic ash samples from four different and highly active volcanoes have been tested. These volcanoes are Mt. Ruapehu and White Island in New Zealand, Mt. Kelut in Indonesia and Mt. Sakurajima in Japan. All volcanic ash samples were found to release elements into brine over the experimental time in a strongly non-linear fashion. Based on the current data set of nine ash samples, three main classes of time-variant element release behaviour are here suggested and defined, whose characteristics are primarily controlled by the element, rather than volcanic source or ash characteristics. A preliminary interpretation of these different element release pattern is that their temporal changes are most likely restrained by the strength of chemical and mechanical bond of elements to the surface of juvenile and non-juvenile ash material. Moreover, significant controls on the long-term leaching concentrations of elements were found to be by the style of eruption as well as the nature of the volcano plumbing system, confirming results of earlier batch leaching experiments. The 1995-96 Mt. Ruapehu eruption sequence in particular illustrated some significant variability in leaching behaviour as a result of specific eruption parameters. Volcanic ash samples that have been derived from a phreatomagmatic style eruption have been found to have a higher short-to long-term impact than those volcanic ash samples derived from dry magmatic eruptions.

A simple method was developed to estimate the real–world equivalent weathering time corresponding to the duration of a soxhlet reactor leaching experiment. The method, which is

primarily based on the total volume of water percolating through an ash sample, and to relate this to local annual rain fall data, was found to estimate real-world weathering times in the natural environment fairly accurately. Based on these natural time constraints, detrimental short-term impacts (months to years) are concluded for lead and fluoride, and beneficial short-term impacts for calcium and manganese. Long-term beneficial effects (up to 20 years) are seen for zinc, copper and iron, while long-term detrimental impacts are concluded for the cases of lead and fluoride.

The strong dependence of the leaching rate on the effective ash surface area precludes that future forecasts of short- and long-term impacts should be made by considering local soil permeability and ash grain-size characteristics. In that way future modelling approaches via reactive and non-reactive porous media flow of ash-leached brines into soil and groundwater may form an interesting avenue for future developments of this pilot study. This approach may hold potential to give quantitative advice to regional councils, the agricultural industry and governmental agencies on detrimental and beneficial short- to long-term impacts of volcanic ash.

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