Volcanic soils and health: what are the risks?

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Background

With more than 800 million people living on volcanic soil, managing the risk of prolonged exposure to volcanic particles is a major public health issue, and one that is critical to achieving the Sustainable Development Goals. Although holistic approaches are becoming more widespread (in particular to include sociocultural aspects), the health-related challenges involved in quantifying the parameters and mechanisms of toxicity operating at the organism level are not yet sufficiently understood and do not provide a basis for developing sustainable actions to protect human health in volcanic environments.

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Further reading

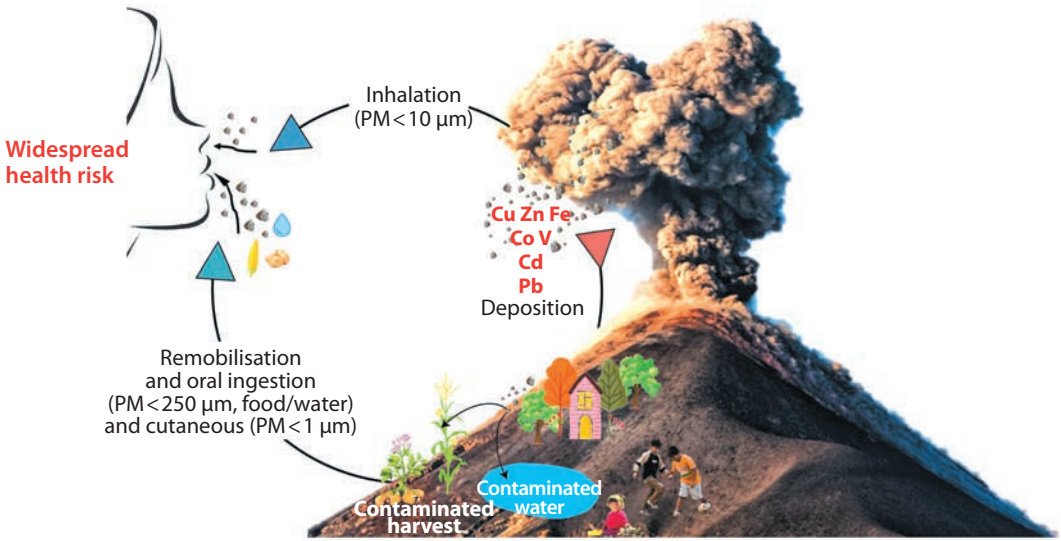
Sauzéat L. *et al.*, 2022 – Metallome deregulation and health-related impacts due to long-term exposure to ground-deposited volcanic ash: new chemical and isotopic insights from la Soufrière de Guadeloupe volcano. *SSRN Electronic Journal* [http://dx.doi.org/10.2139/ssrn.3982115 | 10.2139/ssrn.3982115].

The volcanic environment: balancing benefits and dangers

Soils, and the volcanic environment more generally, offer a range of benefits that contribute to the socioeconomic well-being of local populations. For example, volcanic soils are fertile lands that help to ensure that agriculture flourishes. They are also a rich source of metal deposits (such as gold) that could be mined. The geothermal activity of some volcanoes also provides clean and sustainable energy (for example, green electricity). Volcanic soils are therefore very attractive environments, and more than 800 million people currently live atop them, mostly in developing countries. However, the flip side of all these advantages is that volcanic soils are also rich in certain heavy metals (such as Cu, Zn, Fe, Cd, Mo), which may be harmful if they are in constant contact with our bodies. Metals such as copper (Cu) and zinc (Zn) are involved in the activity of a large number of proteins and enzymes and are common catalytic and structural cofactors in several metabolic pathways of living organisms. These metals are vital to life, but only if their concentration is regulated in the body. In a volcanic setting, metals initially present in the soil can accumulate in the body, not only through food (water and nutrients enriched in metals drawn from the soil), but also through other absorption routes, some of which are still poorly understood (inhalation and oral and cutaneous ingestion of volcanic particulate matter [PM]). This accumulation in the body can lead to major metal homeostatic disturbances and therefore become a major health risk factor. However, not all volcanic soils have the same degree of toxicity, as this depends on their specific physico-chemical properties and on the sociocultural practices of local populations.

Developing an interdisciplinary approach

Understanding the risk from prolonged exposure to metals from volcanic soils requires an integrated scientific understanding of the mechanisms of action and the biological effects induced at the whole-body level. To date, given the complexity of the biological processes and metabolic pathways regulated by metals, our understanding of metal pollution resulting from exposure to volcanic particles and its impact on health is still incomplete. Furthermore, the only studies that have reported a proven causal link between health and direct exposure to volcanic particulate matter (PM) focused on the impact of exposure via inhalation or intratracheal injection of fine particles (PM <10 µm). Although adverse effects on the respiratory and pulmonary tracts have been identified, both the exposure conditions and the biological functions investigated in these studies are restricted, limiting our overall understanding of volcanic risk at the organism level. To assess the dangers of chronic exposure of a population to volcanic particles and to identify the vital functions most affected by this toxicity



The volcanic environment: a complex system with multiple sources of metal contamination.

at the whole-body level, it is now essential to adopt a systemic approach based on interdisciplinary research at the interface between (I) the social sciences (to take into account the socioeconomic factor in health vulnerability) (II) isotope geochemistry (to quantify the toxic potential of volcanic soils and the metallomic imbalances induced at the organism level) and (III) health (to identify the associated physiological dysfunctions and, subsequently, to consider appropriate solutions for promoting the health of the most vulnerable populations).

What if isotopes could take us further?

Until recently, measuring stable isotopes such as copper (Cu), iron (Fe) and zinc (Zn) was used exclusively in the earth sciences to quantify major geological processes. It has now been extended to the medical field. This innovative approach, at the interface between geology and health, has provided a better understanding of the complexity of certain biological processes (such as the body's ageing process, cancers, neurodegenerative diseases) and has

also shown promise for the diagnosis, prognosis and monitoring of a range of liver diseases. Recently, measuring copper and zinc isotope ratios for medical purposes in volcanic environments has also highlighted the potential benefit of using these biomarkers as new diagnostic tools specific to pathophysiological disturbances developing these environments. Although the factors governing these isotopic fractionations still need to be explained, these findings once again highlight the growing interest in using isotopic measurements in medicine and hint at new, post-diagnosis therapeutic avenues aimed at promoting the health of populations most exposed to this volcanic risk.

KEY POINTS

Because soils are enriched with certain metals, ongoing exposure to soils, and volcanic particles in general, poses a real danger to human and animal health. Volcanoes cannot be moved, nor can the 800 million people living on these volcanic lands, but there are potential alternative and sustainable solutions to support the health of these populations. This requires the development of interdisciplinary research to (I) quantify the toxic potential of volcanic soils and (II) identify the biological mechanisms and functions predominantly affected by chronic exposure to volcanic metals. Consideration of these health issues is now essential to support a holistic approach to risk management in volcanic environments.

SUSTAINABILITY SCIENCE

UNDERSTAND, CO-CONSTRUCT, TRANSFORM

Collective thinking coordinated
by Olivier Dangles and Claire Fréour

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