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Air Pollution in the Virunga Region: The Case of the Nyiragongo Volcano

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ABSTRACT

Nyiragongo Volcano, located in the Virunga region of the Democratic Republic of Congo, is one of the most active volcanoes in the world. The continuous eruption of its volcanic gases generates significant air pollution, affecting both the local environment and public health. Since pollutants are often carried by wind direction, the southwest part of Nyiragongo is the most affected by these various pollutants. During the last Nyiragongo eruptions in May 2021, significant amounts of ash were observed in the region. During times of normal activity of the Nyiragongo volcano, the atmosphere around Rusayo receives wind-borne pollutants, which contributes to significant environmental pollution.

Key words: Air pollution, Virunga, Nyiragongo Volcano.

Introduction

Pollution refers to the direct or indirect introduction of natural or artificial substances into an environment (water, air, soil) where they were absent, or present in different quantities. These pollutants can be physical (heat for example), biological (micro-organisms, parasites), or chemical (pesticides, heavy metals, etc.) in nature.[https://youmatter.world/fr]

Generally, it is not the presence but rather the overabundance of an element in an environment that creates pollution. Indeed, environments, thanks to the self-purification mechanism, are naturally capable of eliminating a certain quantity of substances without affecting the environment or human health.[https://youmatter.world/fr]

Air pollution is a major problem in many volcanic regions, where gas and ash emissions can cause significant environmental and health impacts.

During a volcanic eruption, the aerial dispersion of ash and gas can affect areas located hundreds of kilometers away and cause health consequences (effects on the population), but also environmental consequences (plants, water pollution) when the particles fall on the ground.[Cadelis, G., et al., 2013].Ash is composed of tephra particles smaller than 2 mm in diameter, tephra being the generic term used to designate any material emitted by the volcano during its eruption.[Hansel A, et al., 2006].

In general, it entails offering recommendations on how to amplify positive health impacts, reduce bad consequences, and enhance equity [WHO, 1999]. HIA has also been used to quantify the burden of mortality and disease caused by an environmental component at a specific moment in time; the methodology is particularly well established in regard to outdoor air pollution [Cohen et al., 2017]. Airborne, respirable emissions (ash particles, aerosols, and gases) from volcanic eruptions may harm human health, but epidemiological evidence is sparse [Gudmundsson, 2011; Hansell& Oppenheimer, 2004; Horwell& Baxter, 2006], and thorough exposure measurements from such events are rare. As a result, when calculating community health hazards, civil protection and public health organizations may need to depend on extrapolations from other evidence. Because anthropogenic sources account for a large portion of outdoor air pollution, widespread behaviour and policy changes to reduce emissions, such as encouraging public transportation and active travel (e.g., walking, cycling) and reducing private car use, may help to reduce ambient concentrations [Nieuwenhuijsen & Khreis, 2016]. These source prevention measures are clearly not practicable for volcanic emissions; consequently, it is critical to assess potential health hazards and, when appropriate, to intervene to reduce population exposure, which could be aided by HIA approaches.

However, there are a number of important factors to consider before doing a high-resolution analysis of a volcanic eruption and, if necessary, when interpreting the results.

Millions of people are potentially exposed to volcanic gases worldwide, and exposures may differ from those in anthropogenic air pollution [Anna Hansell& Clive Oppenheimer, 2004]. Volcanoes and geothermal areas are associated with emissions of a variety of gases that typically include carbon dioxide (CO2); sulphur dioxide (SO2); hydrogen chloride (HCl); hydrogen fluoride (HF); hydrogen sulfide (H2S); carbon monoxide (CO); radon (Rn);and heavy metals including lead and mercury [Bernstein RS et al., 1986 &Blong RJ, 1984]. Emission may occur in association with eruptions of all sizes. They are also common between eruptions on many volcanoes where they can be vented from fumaroles fields or diffusely through the soil [Baubron PJ, 1999 & Baxter PJ et al., 1999; &Beaudien SE et al., 2003]. Gas fluxes can be substantial in terms of atmospheric source strengths.

Acute respiratory manifestations reported after inhalation of particles from an ash cloud correspond to asthma attacks, acute bronchitis and exacerbations of COPD with the following predominant symptoms: cough, wheezing, dyspnea, chest pain.[Cadelis, G., et al., 2013]

Over 29 million people worldwide live within just 10 km of active volcanoes, and around 800 million people live within 100 km [Brown et al. 2015b], a distance within which there is potential for devastating volcanic hazards at some volcanoes. Understanding how volcanic threat varies with distance from the volcano and which groups of people are affected most can contribute to risk reduction by providing empirical data on which to forecast impacts or support evidence-based eruption planning and preparedness. Threat to life is influenced by distribution of both population and the footprint of volcanic products. [Brown, S. K., et all., 2017]

Volcanic pollution in the Virunga region

Air pollution refers to the presence of substances in the atmosphere that can harm human health, flora and fauna, and entire ecosystems. It can be of natural origin (such as volcanic eruptions) or human-caused (due to industrial activities, transport, agriculture, etc.).

The eruptions and/or re-suspension of deposited volcanic ash can result in high concentrations of suspended mineral dust in the atmosphere. Resuspension can occur naturally by wind picking up the fine particles of ash off the ground. [Bérubé, K. A., et all., 2004]

Volcanoes can have a major environmental impact, particularly due to the pollution they generate when they erupt. Here are some forms of environmental pollution associated with volcanoes:

Air pollution: Volcanic eruptions release enormous amounts of gases, such as:

- Sulfur dioxide (SO2): This gas reacts with water in the air to form acid rain, which can damage vegetation and contaminate water sources.
- Carbon dioxide (CO2): Although this gas is also emitted by fossil fuels, volcanoes also produce it. Although its effect is slower, it contributes to global warming.

Volcanic particles and ash: Ash emitted during an eruption is composed of fine particles that can spread over great distances. It can cause respiratory problems, damage crops, and contaminate water. It can also reduce visibility and affect daily life in affected areas. When this ash settles, it can alter the properties of the soil.

Ashfall, especially when it contains inhalable and irritating particles, can therefore have repercussions on health, particularly for asthmatics.[Cadelis, G., et al., 2013]

In general, particles >15 mm diameter will not penetrate the respiratory tract beyond the nose. Those between 10–15 mm diameter will settle in the upper respiratory tract and may cause irritation of the throat and nasal passage. Particles less than 10 mm diameter, the ‘thoracic’ fraction, may enter the bronchioles and it is thought that it is this fraction that causes lung irritation, inflammation, asthma and bronchitis. Fine particles less than 4 mm diameter are termed “respirable”. Respirable particles can penetrate the alveolar region of the lung where chronic, particle related respiratory diseases, such as silicosis, are activated. Ultrafine particles (sub-2.5 mm diameter, and particularly those in the nanoparticle range, sub- 0.5 mm) may have even greater disease-causing potential. [Horwell, 2007]

Climate change: On a large scale, volcanoes can influence the climate. Fine particles and aerosols generated by eruptions can reflect sunlight, reducing the amount of energy reaching Earth, which can lead to a temporary cooling of the planet. However, gases such as CO_2, released during eruptions, contribute to global warming.

Water degradation: Volcanic gases can dissolve in water, changing its pH and altering its quality. This can affect aquatic ecosystems and make the water unfit for consumption.

Beside respiratory health effect to human health, volcanic ash may result in short-term physical and chemical changes in water quality because of the existence of readily soluble material on freshly erupted volcanic ash which has been documented by many researchers [Smith et al., 1982].

Impact on biodiversity: Volcanic eruptions can lead to the loss of natural habitats for many animal and plant species. Lava, ash, and gases can destroy local flora and fauna, while terrain altered or covered by ash can become inhospitable to life.

Pollution of the Nyiragongo

Nyiragongo (3470 m) is a highly active volcano located in the western branch of the East African Rift System, in the Democratic Republic of Congo (DRC), near the border with Rwanda.[Lowenstern, et al., 2022]

Nyiragongo is a stratovolcano of the Great Rift Valley located in North Kivu Province, Democratic Republic of Congo. It is located in the Virunga mountain chain at about 20 km in the north of the Goma city and Lake Kivu and west of the border with Rwanda.

Spatial and temporal variations in soil CO_2 fluxes (f CO_2) have been measured in many volcanic and hydrothermal systems worldwide [Farrar et al.,1995; Koepenick et al., 1996; Salazar et al., 2001; Lewicki et al., 2003] and used as a tool for volcano and seismotectonic monitoring, geothermal exploration, delineation of fault and fracture zones, and estimation of the contribution of CO_2 from volcanic and hydrothermal sources to the global carbon cycle.

Nyiragongo, remains one of the most active volcanoes in the Virunga chain.[BAHATI R. Marcel et al., 2022]

Haroun Tazieff has long believed that the study of volcanic gases was an important key, if not among the principal keys, to understanding the mechanisms of eruptions and especially to predicting them. During an eruption, fluids often precede solids and are therefore "warning signs". Therefore, it would be important to control the threat from volcanic gases in the region. It depends mainly on the type of gas and its toxicity and concentration. [Yalire M., et al., 2022]

Since a volcano releases several types of gas, especially volcanoes that are permanently active such as Nyiragongo and Nyamulagira, the gases that affect the health of the population and are therefore harmful should be studied in depth [Cuoco et al., 2013].

Whether it is erupting or not, the Nyiragongo volcano emits, through its summit crater and through cracks in its flank, various gases including carbon dioxide (CO2) and sulfur dioxide (SO2). The quantities of these gases released by the Nyiragongo volcano give an indication, not only of the activity of this volcano but also of the degree of atmospheric pollution of its environment. Indeed, a significant increase in gases emitted by a volcano is one of the precursor signs of a possible upcoming eruption [18]. Furthermore, when these gases are injected into the atmosphere, they influence climatic parameters such as air temperature and precipitation with harmful or beneficial effects on the populations of human agglomerations located near the volcano. The two gases, CO2 and SO2, have antagonistic effects on the climate. The first is a greenhouse gas theoretically contributing to global warming. The second is a gas that forms aerosols in the air and theoretically contributes to the cooling of the atmosphere.[LUBEMBA Atchibiya Michel, et al., 2021]

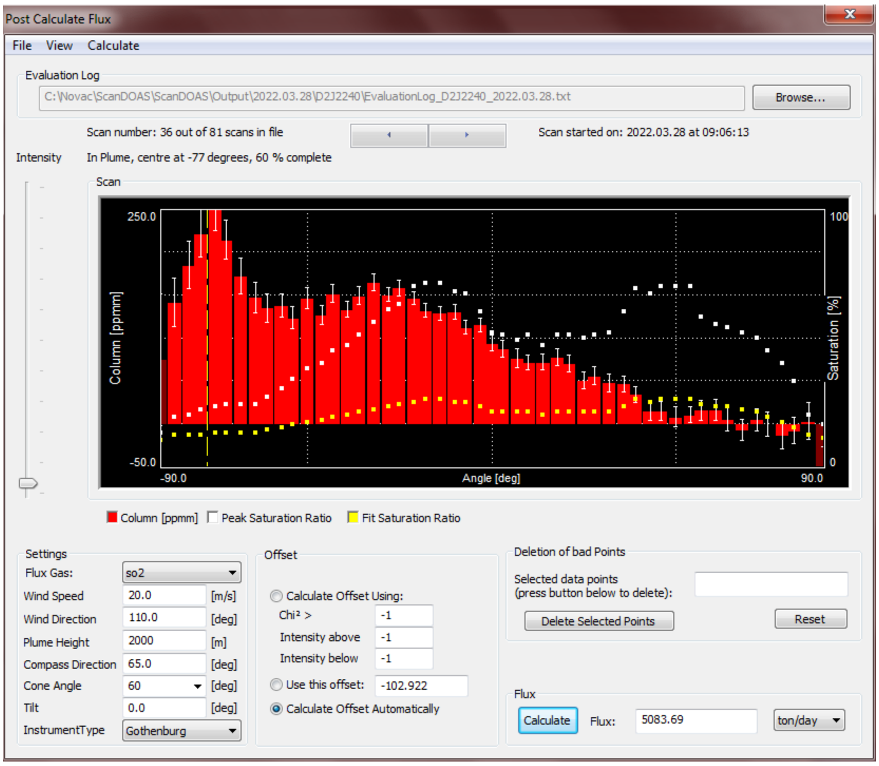

Fig1. Screenshot of the software calculating the SO_2 flux emitted by the Nyiragongo volcano on March 29, 2022 at 9:06:13 a.m

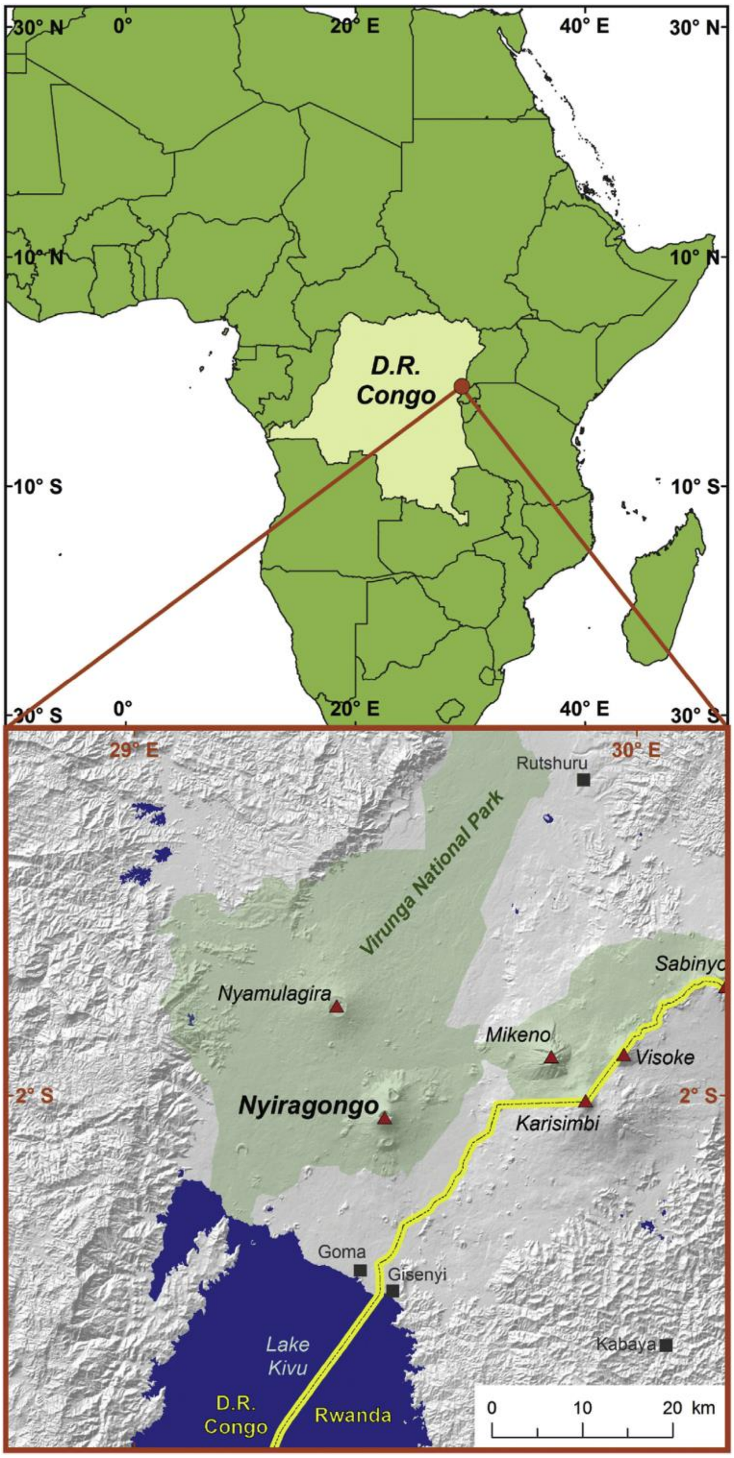

Fig. 2. Location map of the Nyiragongo volcano (North Kivu, Democratic Republic of Congo).[Benoît Smets, et al.,2016]

The Virunga region, known for its active volcanoes, particularly Nyiragongo, regularly experiences episodes of air pollution due to volcanic eruptions. Nyiragongo Volcano, in particular, is a continuous source of sulfur dioxide emissions, a corrosive gas that can have deleterious effects on human health and the environment.

Nyiragongo is well known for its large and long-lasting active lava lake and has been very active since May 2002[Balagizi et al.,2016].

Because the surrounding area is densely populated, Nyiragongo is considered one of the most dangerous African volcanoes [e.g.,Favalli et al., 2009]. Its eruptive activity since at least the early 20th century has been primarily characterized by the presence of a molten lava lake in its main crater, from which a SO2-rich gas plume continuously escapes [e.g.,Tedesco et al., 2007].

Nyiragongo's deadly reputation stems from a combination of factors. Due to the region's geological complexity, its lava is remarkably fluid and can travel up to 40 mph (64 km/h). Eruptions can also release large amounts of carbon dioxide, a lethal gas, to the surface. This is an extremely worrying situation given that six million people live within the volcano's boundaries.[https://www.nationalgeographic.fr]

The wide expanses of very hot and swift lava flows generated severe temperature gradients in the atmosphere, causing tremendous winds which, in several places unrooted big eucalyptus trees or torn off whole banana-groves. [Tazieff H., 1977].

The presence of CO2 emitted by the Nyiragongo volcano has the effect of raising the maximum air temperature on this volcano. Generally, positive anomalies in maximum temperatures correspond to positive anomalies in CO2 concentrations and vice versa. This highlights the warming power of CO2 on the climate around the Volcano. While the presence of SO2 emitted by the Nyiragongo volcano has the effect of lowering the maximum air temperature on this volcano. Generally, positive anomalies in maximum temperatures correspond to negative anomalies in SO2 concentrations and vice versa. This highlights the cooling power of SO2 around the Volcano.[LUBEMBA Atchibiya Michel, et al., 2021]

Conclusion

Nyiragongo Volcano, known for its continuous activity, emits enormous quantities of gas. DOAS records show that Nyiragongo releases an average of 5,000 tons of sulfur dioxide into the atmosphere every day. At times, this volcano can reach concentrations exceeding 40,000 tons per day. Pollutants are often carried by the direction of the wind; the southwestern part of Nyiragongo is the most affected by these different pollutants. During the last Nyiragongo lava flows in May 2021, significant quantities of ash were observed in the region. During normal activity of the Nyiragongo volcano, the atmosphere around Rusayo receives pollutants carried by the wind; which contributes to significant environmental pollution.

Further research should be conducted to elucidate the effects of volcanic air pollution on the environment.

There is an urgent need for air pollution control measures, such as expanding monitoring networks, early warnings, and raising awareness among local communities about volcanic risks. Future research could focus on assessing the long-term health impacts of exposure to volcanic gases and on environmental rehabilitation strategies for the region.

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