Environmental and health impacts of Nyiragongo and Nyamulagira Volcanoes, East Africa

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1. Introduction

Nyiragongo and Nyamulagira, only ~ 14 km apart (Fig. 1 & 2a), are the Africa's most active volcanoes, both located in the Virunga volcanic region, western branch of the East African Rift, in the eastern Democratic Republic of the Congo. The two volcanoes open systems that threaten ~1.5 million inhabitants of Goma (DR Congo) and Gisenyi (Rwanda) cities and people living in the surrounding villages.

2. Lava flows impacts

Since ~1880, Nyiragongo has erupted 2 times (1977 and 2002) and Nyamulagira ~ 44 times with eruptions that can last up to 26 months, and have both produced long lava flows, which have reached and destroyed cities and villages all-around and large forested areas (Fig. 1). Hence, Nyamulagira's eruptions for the period 1938 - 2010 lava flows covered ~ 600 x 10^6 km^2; while the Nyiragongo 1977 and 2002 eruptions covered ~ 15 km^2.

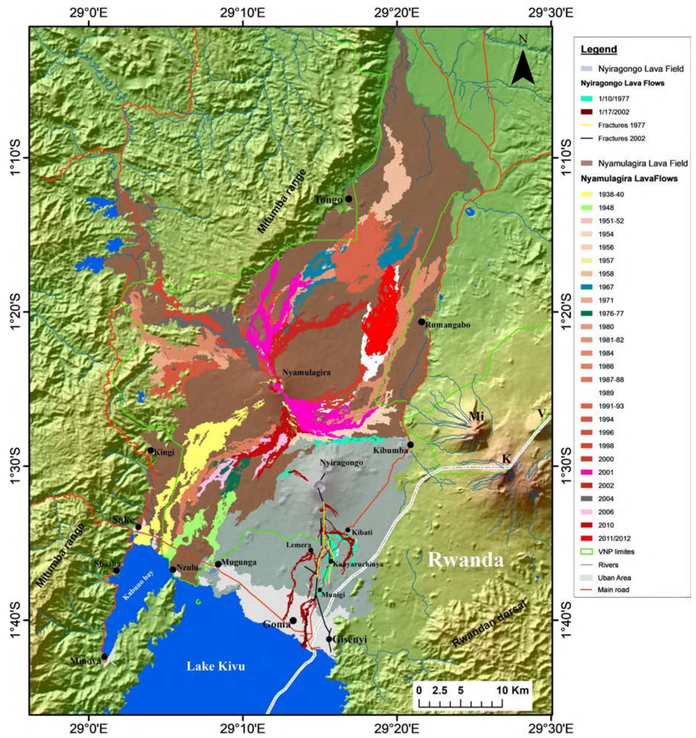
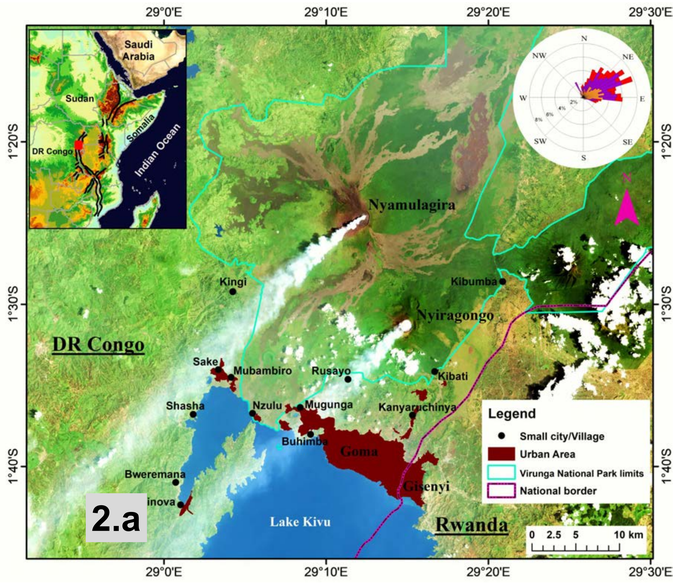


Fig. 1. Map showing the recent lava flows of Nyiragongo (1977 and 2002 eruptions) and Nyamulagira (from 1938 to 2012) after Thonnard 1965; Smets et al 2010 and Balagizi et al. 2018)

Poster based on the papers:

Balagizi et al. 2015; (https://doi.org/10.1002/2015gc005999);
Balagizi et al. 2017 (https://doi.org/10.1016/j.apgeochem.2017.03.018)
Cuoco et al. 2012 (https://doi.org/10.1016/j.gexplo.2012.11.008)
Cuoco et al. 2013 (https://doi.org/10.1016/j.jhazmat.2012)

3. Gas plume and ash emissions



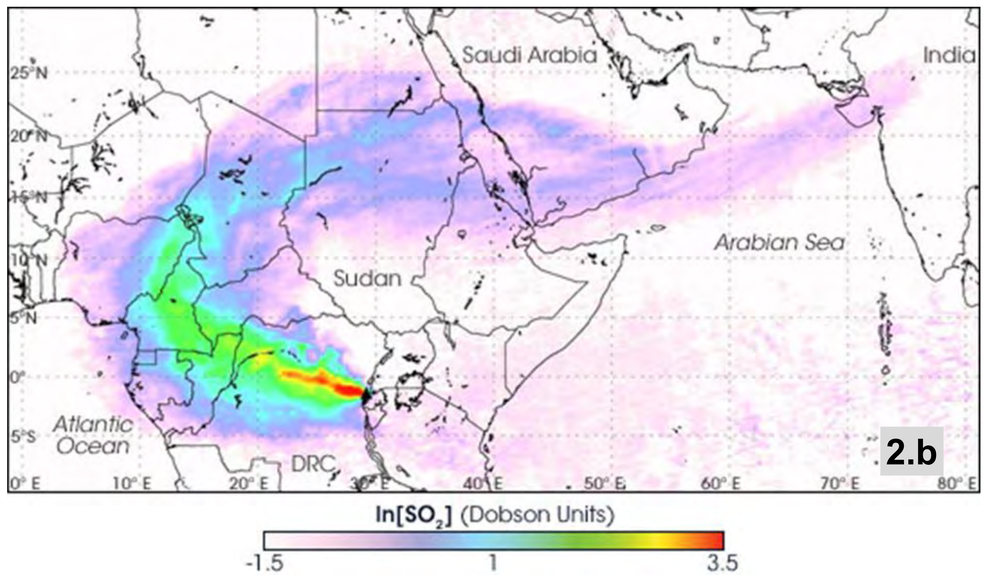


Fig. 2a. Plume venting from Nyiragongo and Nyamulagira permanent lava lakes hosted within their main craters on February 9, 2015 as captured by the NASA Earth Observatory (2015). **Fig. 2b**. Global distribution of the SO_2 plume from Nyamulagira's 2006 eruption between November 28 and December 4, 2006 tracked by the NASA (2006).

Nyiragongo and Nyamulagira emit huge gas plumes into the atmosphere (Fig 2a). During the 2002 eruption Nyiragongo released estimated fluxes of up to 147 kt/day of SO_2 and 9.3 kt/d of CO_2 while on the other hand, the cumulative SO_2 emissions from 15 eruptions of Nyamulagira between 1980 and 2006 are estimated to ~27 x 10^6 tons, which sets the Virunga among the SO_2 hot spots of the world. Virunga volcanic plumes can cross central and northeast Africa, Saudi Arabia and eventually reach India (Fig. 2b), and can therefore influence climate. Since May 2002 Nyiragongo's permanent lava lake has been emitting daily up to 5356.8 tons of SO_2, while since April 2013 Nyamulagira is characterized by intermittent presence of a lava lake which is presently showing higher activity and getting larger.

3. Rain and surface water pollution

The large amount of gases released into the atmosphere (Fig. 2a & 3a) are rapidly converted into acid compounds (Fig. 3b), leading to acid rain and air pollution, posing a hazard to people, animals, agriculture and seriously damage the environment. High bulk atmospheric deposition fluxes are observed in the region, with values up to 24.6 t km^{-2} yr^{-1} for fluoride, which is therefore at high concentration in rain and surface waters (Fig. 3c & 3d).

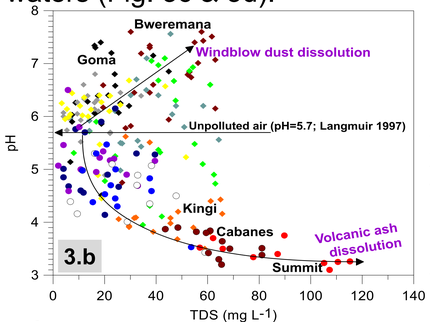


Fig. 3a. Plume venting from Nyiragongo and Nyamulagira permanent lava lakes scattered in the city of Goma.

Fig. 3b. Process of rain acidification around Nyiragongo and Nyamulagira volcanoes through the interactions of rain with volcanic plume and ash .

Fig. 3c. People washing in a river rich in both major and trace elements in Sake town, near Goma city

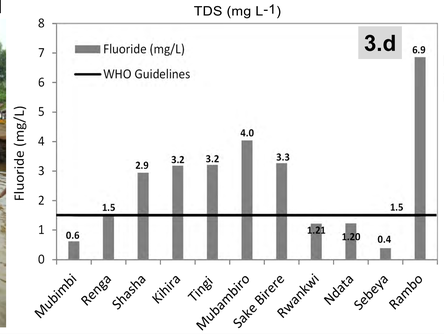


Fig. 3d. Fluoride concentration (mg/L) in the main rivers and springs in the area of Goma

4. Health impacts

Figure 4. Photos (A-F) showing young and adult people affected with dental fluorosis disease in villages around Nyiragongo and Nyamulagira active volcanoes, where rivers and rainwaters contain fluoride with concentrations greater than the WHO guidelines and recommendations.

The volcanic gases, ash and Pele's hair negatively impact the human health by damaging the respiratory system. The Virunga experiences high level of endemic dental fluorosis, which is linked to the use of F-rich water in all domestic activities, including as drinking water. Only the visible signs of fluorosis can be confirmed in the Virunga because the other related diseases cannot be diagnosed locally.