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The CO_2 and SO_2 from Nyiragongo Volcano and Considerations Over Related Risks among Displaced Persons in the Camps of Rusayo and Bulengo

Mirimo Rachel Munpfano [a]*, Kyambikwa Albert Milungu [b], Bizimungu Laurent Kagabo [a], Minani Abel Shamwesi [a]

[a.] *Department of Geochemistry, Goma Volcano Observatory, GVO, DR Congo*
[b.] *Department of Seismology, Goma Volcano Observatory, GVO, DR Congo*

A B S T RA C T

This study looked at considerations on carbon dioxide in Mazuku, on sulfur dioxide in the volcanic plumes of Nyiragongo and Nyamulagira by displaced persons in Bulengo and Rusayo camps. A survey aided by simple random sampling coupled helped to gather information from the study population. Results showed that the majority feared volcanic CO2 in the Mazuku more than Sulphur dioxide, SO2 in the volcanic plume. Those considerations are understandable since they rely on recurrent death toll of Mazuku as reported. But sulfur dioxide cannot be underestimated if we consider the fact that all health effects of volcanic gases are yet to be determined for more indirect deaths due to complications of respiration associated with volcanic gases to be known. While an important portion of participants testified not to have considered any safety measures against the carbon dioxide in the Mazuku, it is observed that the majority reported to have considered a safety measures like ventilating their dwelling places, choosing safer places but observations and interviews have shown that most of the scientific recommendations are still far from being applied properly either by displaced people nor their host community. In addition, the majority of our respondents declared that they did not consider any safety measure against sulfur dioxide from Nyiragongo volcanic plume. People were considering to choose safer places, avoiding rain water and building accordingly but observations revealed that both residents and displaced people were not really applying the recommended practices. The authors recommend a reinforcement of information and preventive campaigns.

Keywords: Considerations, Carbon Dioxide, Mazuku, Sulphur Dioxide, Volcanic Plume, Nyiragongo

Introduction

The release of volcanic gases, earthquakes, expulsion and lava flow in the vicinity of the volcano are some of the specific signs that show the level of volcanic activity and warn of future eruptions (Lindell, 2018; Pesicek, Ogburn, & Prejean, 2021). Not all of these signs are necessarily followed by a volcanic eruption. Statistics from global eruption data reveal trends that may not be evident in more limited data sets where errors and uncertainties have greater effects (Pesicek et al., 2021). However, monitoring seismicity, the degassing of volatile substances from volcanic systems is a useful tool to monitor volcanic activity in order to characterize geochemistry, predict and prevent changes in the level of volcanic activity (Inguaggiato et al., 2021). These geochemical tools have been successfully applied by the Goma Volcano Observatory, GVO, to measure Sulfur Dioxide, SO2 in the plume emitted by the Nyiragongo volcano a scanning system installed in the area since 2007 (Galle et al., 2010). At the same time, a repetitive measurement of Carbon Dioxide, CO2 has also been conducted in the fractures and Mazuku in the Southern flanks of the said Volcano shortly after its eruption on January 17, 2002. The measurement of volcanic gases is interesting to prevent the eruptions and the danger that these ones present for human health and the environment.

Carbon dioxide, invisible, odorless, and heavier than the surrounding air, flows in hidden layers in the valleys and low points around the volcano. Such accumulations of carbon dioxide in fractures and depressions are called Mazuku ("evil breaths"). They are observed in the lava fields at the foot of Nyiragongo and Nyamuragira, near Lake Kivu. CO2, of mixed origin (magmatic and organic), constitutes a significant danger, as populations and their livestock can be victims of asphyxiation(Balagizi et al., 2016; Smets et al., 2010; Tedesco et al., 2007). CO2 is present in the atmosphere in a proportion approximately equal to 0.0375% by volume. It is produced in particular during aerobic fermentation or the combustion of organic compounds, and during the respiration of animals and plants (Faustin Safari Habari et al., 2021). For the latter, photosynthesis absorbs much more CO2 than their respiration produces. From a certain concentration in the air, this gas is dangerous or even fatal. The exposure limit value is 3% over a period of 15 minutes. This value must never be exceeded. Beyond this, the health effects are all the more serious as the CO2 content increases. Thus, at 2% CO2 in the air, breathing amplitude increases. At 4%, the respiratory rate accelerates. At 10%, visual disturbances, shivers, and sweating may appear. At 15%, there is sudden loss of consciousness. At 25%, respiration arrest leading to death (Smets et al., 2010). CO2 is also the second most important greenhouse gas in the atmosphere

after water vapor, H2, but also and above all the most associated with climate change. As such, the reduction of anthropogenic industrial emissions is targeted by the Kyoto Protocol; its long-term geological sequestration is the subject of ongoing projects. Furthermore, CO2 emissions from volcanic origin remain insignificant as a contribution to climate change (Trevor M Letcher, 2019:8).

It is well known that sulfur-bearing species released by volcanic eruptions can degrade air quality, affect the environment and human health (Shroder John F. and Paolo Papale, 2015:378). Reliable observations reported that SO2 can persist longer in the atmosphere than ash particles subject to gravitational settling and fall down (Shroder John F. and Paolo Papale, 2015:99). Laki eruption in Iceland released 120 Megatons (Mt) of sulfur dioxide (SO2) into the atmosphere over the course of 8 months which is about the same as the current annual anthropogenic SO2 flux to the atmosphere of about 116 Mt. Contemporary records of the 1780s imply that the Laki eruption induced severe environmental stress well beyond the shores of Iceland(Shroder John F. and Paolo Papale, 2015:378).

According to studies on natural hazards around Nyiragongo (e.g. Balagizi et al., 2018), the effects of volcanic gases on human health are yet to be fully determined. However, it is clear that in humans, exposure to high concentrations of SO2 can cause respiratory problems, respiratory diseases, and worsening of pulmonary and cardiovascular diseases. People suffering from asthma or chronic heart or lung diseases are necessarily more vulnerable. In the atmosphere, sulfur dioxide transforms into sulfuric acid, which is deposited on the ground and on vegetation. In combination with other pollutants, this acid contributes to the acidification and impoverishment of natural environments and the deterioration of materials used in building construction (stone, metals). SO2 also damages trees and crops. Aside from nitrogen oxides, it is one of the gaseous constituents of acid rain, which is associated with corrosion of metal parts of buildings, acidification of lakes and rivers, and reduced visibility. Furthermore, SO2 causes the formation of microscopic acid aerosols that have adverse health effects and contribute to climate change.

At Nyiragongo Volcano, the total destruction of vegetation on the northwest, west, and southwest flanks is observed as a result of acid rain produced by sulfur dioxide. It should be noted that this volcano is among the most polluting volcanoes in the world and alone is estimated to produce nearly half of the sulfur dioxide produced worldwide by active volcanoes. Its damage not only extends to the destruction of vegetation but also to the attack on the roofs of houses towards the western part of the city of Goma, particularly in the city of Sake. Certainly, there are also health damages from this gas, especially on the respiratory tract, but these have not yet been archived by the people of the North Kivu Health Inspectorate. These natural hazards have already caused several losses of human life directly during and after the eruption through the gaseous emissions, particularly the Mazuku (Bahati rusimbuka et al., 2021; Balagizi et al., 2018; Kasereka et al., 2017; Lisa, Christian, Karen, & Blake, 2021). Despite the scale of the crisis linked to more or less punctual gas emissions, a mass of people displaced by the war relaunched by the M23 in February 2022 and estimated at more than 600,000 people are flocking in the Nyiragongo volcanic areas to end up being settled in the camps of Bulengo, Lushagala, Kanyaruchinya, Elohim, Munigi and Rusayo where they are exposed to hazardous environment, hunger and epidemics (MSF, 2023) The population's ignorance of these risks increases human vulnerability and the likelihood of further volcanic disasters. This article aims to establish an overview of the human considerations of these risks and provide an opportunity for necessary precautions.

Methods and Materials

Data Collection

Using purposive technique, snowballing and interview guide, key informants were identified for in-depth interviews on their considerations regarding the settlement of displaced people around active volcanoes and particularly the Nyiragongo volcano (Sharma, 2017). Key informant refers to political, scientific and technical authorities responsible for preventive guidance, protection and other stakeholders selected by deliberate choice, including a sample of internally displaced persons themselves. Apart from the knowledge already at our hand, the investigations were guided by one participant towards another who could provide relevant information. The in-depth interview being based on a non-probabilistic approach (David Silverman, 2014:112; Virginia Braun, 2017:152), the number of participants was increased for a survey assisted by a more probabilistic simple random sampling technique. Our survey population was estimated at 250,000 people, including 150,000 people in Bulengo and 100,000 people in Rusayo, according to reports from organizations in charge of displaced people in these two camps (AGIR RDC, 2024; Radio Okapi, 2024), and then we drew a representative sample of 384 people according to the pre-calculated sample table on a population between 250,000 and 2,500,000 people and following a confidence level of 95% and 5% as an acceptable margin of error (Orban, 2021; S Singh Ajay and Masuku Micah B, 2014). Both informal, documented fears and awareness regarding risks related to volcanic carbon dioxide in Mazuku and sulfur dioxide were the focus of our investigation carried out from September 2024 to January 2025.

Study Area

There are many camps of displaced persons installed in the eruptive areas of Nyamulagira and Nyiragongo Volcanoes. This study was specifically focused on Bulengo and Rusayo camps which are directly exposed to the most threatening volcanic gases including Carbon dioxide, CO2 in Mazuku and Sulfur Dioxide from the volcanic plume as presented in Figure 1 below.

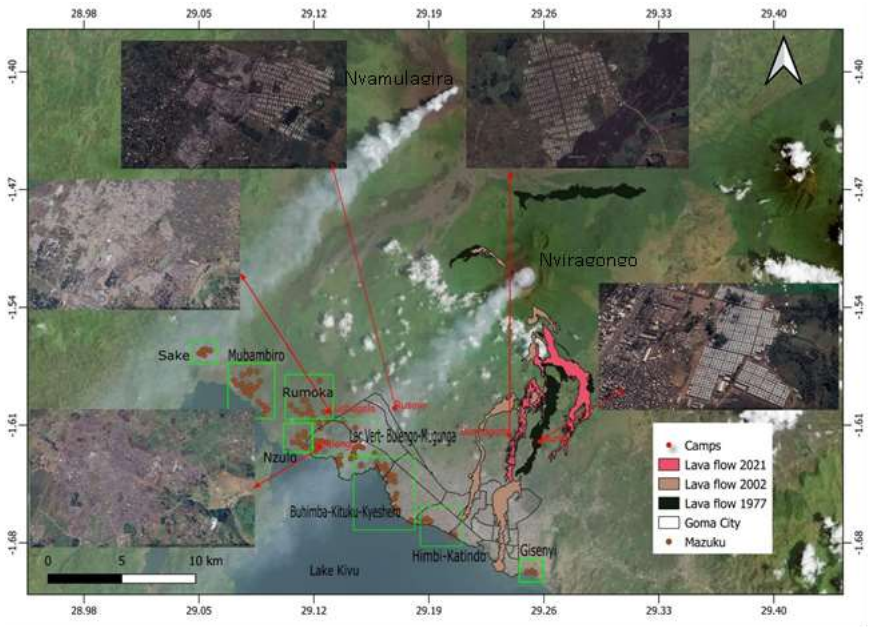

Figure 1. Camps of Displaced Persons, CO2 in Mazuku, volcanic plume with SO2 and Lava flows from Nyiragongo Volcano

Results & Discussion

The main motivation of this article was to know the considerations of the community over volcanic gases; particularly carbon dioxide in Mazuku and sulfur dioxide in the volcanic plumes of Nyiragongo and related risks to war displaced people in Bulengo and Rusayo camps. The following graphs present the essential results of the study.

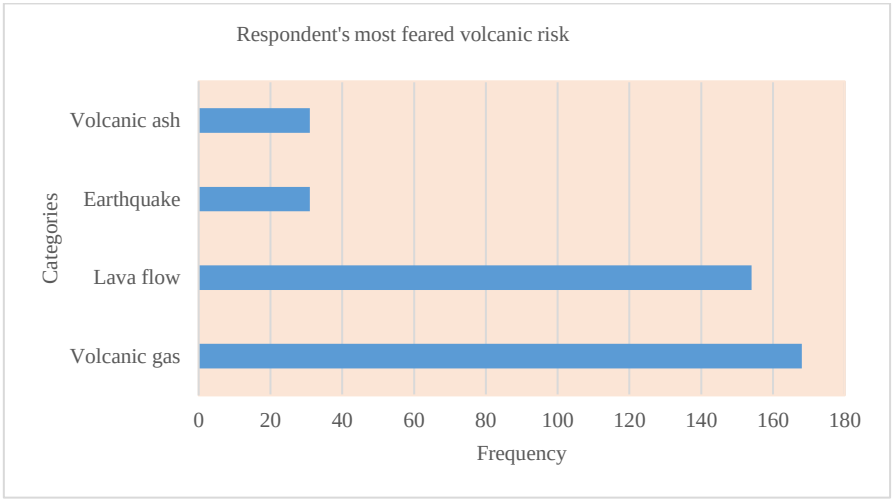

Figure 2. Most feared volcanic risk

The graph above shows that the majority of our respondents, i.e. 44% (n=168) fear volcanic gas than other volcanic risks. While another important portion, i.e. 40% (n=154) of our participants testified that they fear the lava flow, only 8% (n=31) attested that they fear Earthquake. And only 8% (n=31) said that they fear volcanic ash. During the interview, it was also revealed that volcanic gases are the most feared volcanic risks, especially sulfur dioxide, SO2, because its direction is subject to more uncertainty as it is guided by the prevailing wind direction. This had even been previously revealed that sulfur dioxide is occasionally perceived in Goma city through a smell like the one of rotten eggs (Balagizi et al., 2018).

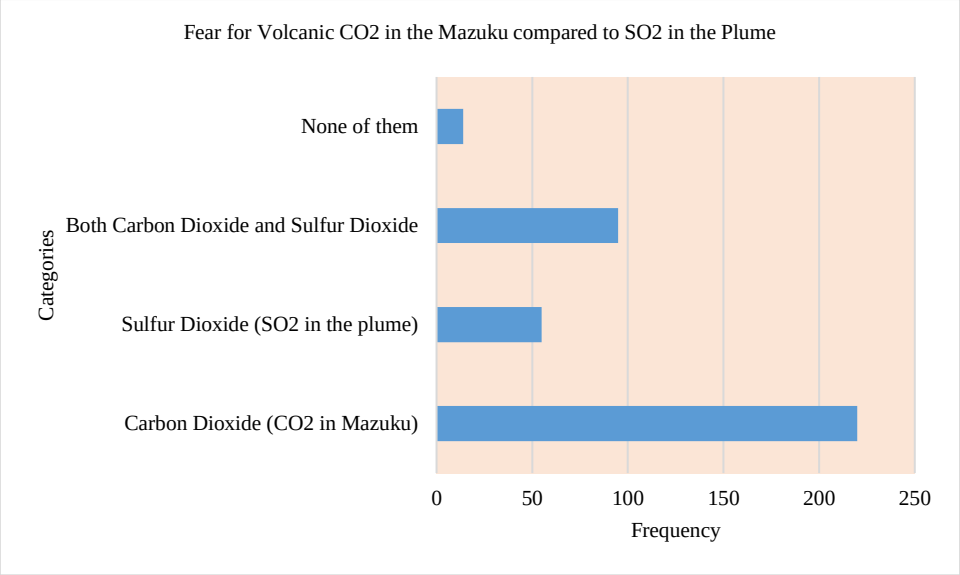

Figure 3. Respondents' fear for volcanic carbon dioxide, CO2 in the Mazuku compared with SO2 in the plume

Upon examination of the graph above, the majority of our respondents, i.e. 57% (n=220) said that they feared volcanic CO2 in the Mazuku more than sulfur dioxide, SO2 in the volcanic plume. While 25 % (n=95) feared both Mazuku and sulfur dioxide, 14% (n=55) feared Sulfur dioxide more than Mazuku and 4% (n=14) of participants testified that they neither feared none of the two gases. These are understandable considerations since they rely on recurrent death toll of Mazuku (Bahati Rusimbuka et al., 2021) but volcanic sulfur dioxide if we consider the fact that all health effects of volcanic gases are yet to be determined (Balagizi et al., 2018) for more indirect deaths due to complications of respiration associated with volcanic gases to be reported.

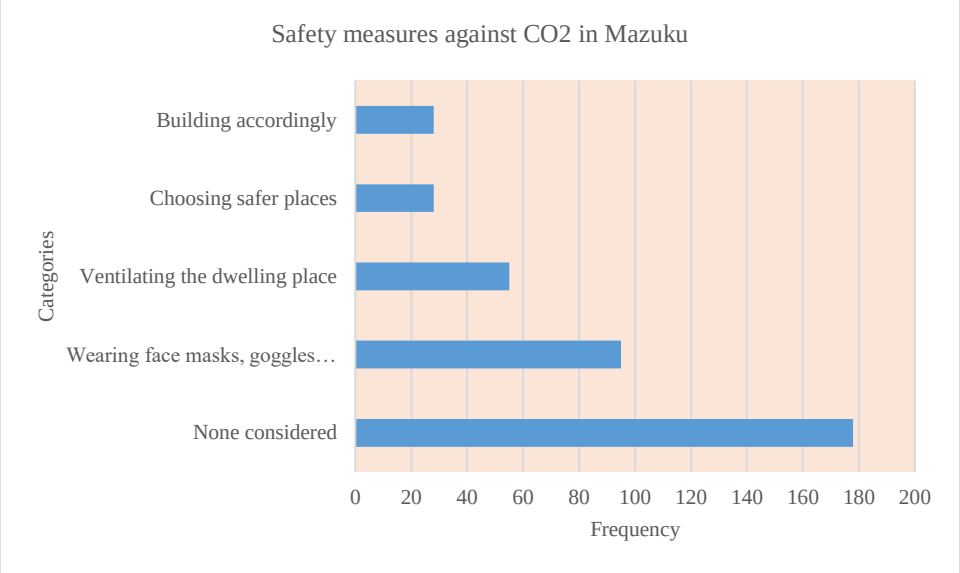

Figure 4. Respondents' consideration on safety measures against CO2 in Mazuku

The results above show that an important portion of participants to our study, i.e. 46 % (n=178) testified not to have considered any safety measures against the carbon dioxide in the Mazuku. However, it is observable that the majority of the respondents reported to have considered a safety measure. While 24% (n=95) said that they considered bearing face masks, goggles, etc., 14% (n=55) declared that they considered ventilating their dwelling places, 8% (n=28) said that they considered choosing safer places and 8% (n=28). It is key that people would be able to consider safety measures but observations and interviews have shown that most of the scientific recommendations are still far from being applied properly either by displaced people or their host community. As CO2 is heavier than air, for instance, a raised, if possible non-porous, and bulging ground with ventilation openings along the walls would drastically reduce the risk of lethal concentration inside the house(Smets et al., 2010).

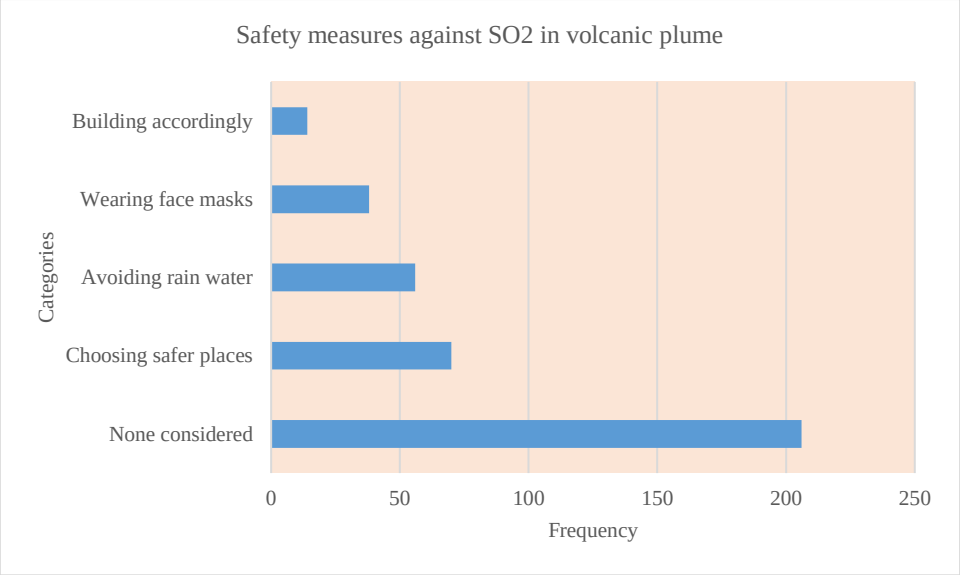

Figure 5. Respondents' consideration on safety measures against SO2 for the volcanic plume

The graph above shows that the majority of our respondents, i.e. 53% (n=206) declared that they did not consider any safety measure against sulfur dioxide in Nyiragongo volcanic plume. Only 18% (n=70) considered to choose safer places, 14% (n=56) said that they deliberated to avoid rain water, 10% (n=38) said that they considered to bear face masks, goggles, etc., and 4% (n=14) considered to build accordingly. It is really interesting that people are considering choosing safer places, avoiding rain water and building accordingly. However, observations revealed that both residents and displaced people are not really applying the recommended practices. It is hard to determine the safer places since the volcanic plume can be occasionally diverted by the wind, and they may build accordingly while being exposed to amounts of volcanic sulfur dioxide that could affect their health in a long run.

4. Conclusion

The main purpose of this article was to know the considerations of the community over volcanic gases; particularly carbon dioxide in Mazuku and sulfur dioxide in the volcanic plumes of Nyiragongo and related risks to war displaced people in Bulengo and Rusayo camps. Observations had showed that volcanic CO2 in the Mazuku is feared more than sulfur dioxide, SO2 in the volcanic plume. Those considerations are understandable since they rely on recurrent death toll of Mazuku as reported. But sulfur dioxide cannot be underestimated when we consider the fact that all health effects of volcanic gases are yet to be determined for more indirect deaths due to complications of respiration associated with volcanic gases to be known. While an important portion of participants testified not to have considered any safety measures against the carbon dioxide in the Mazuku, the majority reported to have considered a safety measures like ventilating their dwelling places, choosing safer places but observations and interviews have shown that most of the scientific recommendations are still far from being applied properly neither by displaced people nor their host community. In addition, the majority of our respondents declared that they did not consider any safety measure against sulfur dioxide from Nyiragongo volcanic plume. People were considering to choose safer places, avoiding rain water and building accordingly but observations revealed that both residents and displaced people were not really applying the recommended practices. The authors recommend a reinforcement of information and preventive campaigns for a proper application of safety measures against volcanic gases in the camps of displaced people.

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Disclosure of conflict of interest

No conflict of interest recorded

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