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Volcanic Gases Effects on Human Health; Case of Mazuku on The Population of the Goma City

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ABSTRACT

Each year in the city of Goma, cases of death are reported in the western part. These spontaneous and sudden deaths are either reported early or late to the local administrative authorities. Since the conditions of death and causes are unknown, the local administration looks to the institution that has a good and accurate idea of the effects of the gases in the region. In order to elucidate and prepare a warning system for the places (depressions) related to mazuku, we conducted investigations to document the damage of this "monstrous" gas in the city of Goma. Our investigation covered the past five years from 2015 to 2020. It appears from our investigations that during these last five years, more or less thirty eight (38) people have lost their lives in the mazuku areas. These deaths were reported to the Goma Volcano Observatory via its scientific direction. It is noted that on average 6 people die in mazuku each year. The victims of this gas are from diverse origin. The neighborhoods (quarters) of Kyeshero, Lac Vert and Mugunga are the most famous in this sense. On the spot (in the three neighborhoods), the carelessness of passers-by as well as the lack of mazuku warning signs would be at the root of these deaths.

Keywords: Mazuku, Goma, CO_2, volcanic hazard, mazuku deaths.

Introduction

Health impact assessment (HIA) is a linked set of approaches and tools for estimating, in advance of their occurrence, the implications for human health of proposed policies, programs, actions, or events.

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 organisations 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. Due to a lack of rigorous exposure assessment and a scarcity of powerful context specific epidemiological studies, there are no ash specific concentration response functions (CRFs). The uniqueness of ash properties, which can vary by individual eruptions and among volcanoes, adds to the lack of data.Furthermore, ashfall from explosive eruptions has the potential to disrupt life in large populated regions in two ways, both of which pose issues to the use of standard air pollution HIA methodologies (**Mueller et al., 2020**).Due to the resuspension of ash by wind and cars, single, major eruptions can result in towns being blanketed in deep deposits of ash, causing devastating air pollution episodes capable of bringing regular life to a halt for days or weeks.

During such an episode, daily ambient airborne concentrations of PM2.5 and PM10 are much higher than those normally encountered from traffic and other common outdoor sources, and may greatly exceed regulatory air quality standards for particles, while being time limited, with natural rainfall and weathering processes, as well as official clean-up measures, removing the deposits from inhabited areas (**Moore et al., 2002; Searl et al., 2002**).

Special steps to protect human health and decrease exposure until the ash deposits are gone include ash clearing, counselling to stay indoors for susceptible groups, and mask use, with special attention paid to adults and children with pre existing respiratory disorders **(www.ivhhn.org**). It's possible that recommendations to evacuate afflicted areas, at least for the most vulnerable groups, will be necessary.

The second scenario occurs when smaller eruptions produce sporadic or continual emissions of smaller amounts of ash, which can influence air quality for months (or even years) while the volcano is active, but without halting transportation or other important services. Ground deposits may accumulate in the absence of, for example, daily cleaning of ash from streets and areas around houses. People will try to maintain normal activities as much as possible under these conditions, but questions may arise about the long-term health risks from this more prolonged or chronic exposure to the moderately elevated average ambient concentrations of PM10 and PM2.5, based on the now well-recognized morbidity and mortality effects from epidemiological studies from anthropogenic sources of particulate matter (PM) (World Health Organization (**WHO, 2013b).**

Health Effects from Exposure to Volcanic Ash

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 carbondioxide (CO_2); sulphur dioxide(SO_2); hydrogen chloride (HCl); hydrogen fluoride (HF); hydrogen sulfide (H_2S); 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 fluxescan be substantial in terms of atmospheric source strengths. Investigating the health effects of a volcanic eruption is laden with difficulties, such as outward and changeable migration, as well as fearful communities and officials, all of which can lead to skewed information and outcomes (**Baxter et al., 2014**). With the eruption of Mount St. Helens (USA) in 1980, health research of ash exposure began in earnest. Since then, studies have mostly identified reversible, short-term respiratory outcomes, with less clear results in longer-term research, where few such studies have been conducted, and where the majority of the studies were conducted prior to the development of more recent research on CRFs for fine PM.

A small number of mortality studies have been conducted, mostly in Japan, however these studies lacked sufficient power and other methodological flaws to give persuasive evidence of elevated risks (**Horwell & Baxter, 2006**). Most volcanic eruptions are unpredictable and occur over a short period of time (days to months), making it difficult to conduct a long-term cohort study, or at least one with chronic exposure, in contrast to the continuous duration of exposure addressed in outdoor air pollution studies (e.g., **Pope et al., 2002**). Rather, some research have attempted to track down individuals who were exposed at a specific point in time, as discussed below. Horwell & Baxter provide a more complete evaluation (2006). Individuals in specific subgroups within the at-risk population, such as those with respiratory disorders like asthma or bronchitis, may be particularly vulnerable to the health impacts of volcanic ash inhalation.

The 1980 eruption of Mount St. Helens (USA) resulted in high PM10 concentrations for a month, ranging from 30–100 g/m3 for nonoccupational exposures and 50–570 g/m^3 for occupational exposures (**Bernstein et al., 1986**). Pre-existing respiratory disorders are substantial risk factors for unfavourable respiratory reactions to volcanic ash, according to a study of people with symptomatic asthma and acute bronchitis and healthy controls from towns heavily damaged by the eruption (**Bernstein et al., 1986).**

Similarly, after the 2004 eruption of Mount Asama in Japan, a survey of 236 asthmatic adults found that 43% experienced exacerbations, compared to 8% in an unexposed control area; those with more severe asthma did not experience such changes, as these individuals apparently tended to reduce their exposure by staying indoors with closed windows; those with more severe asthma did not experience such changes, as these individuals apparently tended to reduce their exposure by staying indoors with closed windows (**Shimizu et al., 2007**).

Degassing is more abundant from volcanoes where magma convections are significant. Effective degassing occurs before the magma reaches the surface, that is, when the magma is fluid. Volcanic gas in the atmosphere can affect the population or the vegetation around volcanoes (**Le Guern, F., 1982).**

Nyiragongo is a stratovolcano (3470 m a.s.l.) located on the floor of the western branch of the East African Rift. Nyiragongo along with Nyamulagira shield volcano (3058 m a.s.l.) are the presently active volcanoes in a group of eight major edifices forming the Virunga Mountains, though Visoke also erupted in 1957 (**Global Volcanism Program, accessed in June 2016).** Both Nyiragongo and Nyamulagira have active lava lakes within their major craters, which have been active since May 2002 and early April 2013, respectively.

Since its first discovery in the late 1800s, Nyiragongo has only erupted twice (**on January 10, 1977, and January 17, 2002**), both times while the volcano was holding a closed up lava lake, i.e. a lake with a hardened surface (**Tazieff 1977; Pottier 1978; Ueki 1983; Durieux 2004a, b; Komorowski et al. 2004; Tedesco et al. 2007).** Nyiragongo's third and most recent eruption occurred on May 22-23, 2021. This eruption, which erupted from the southern flank, wreaked havoc on extensive regions of farmland and homes. It came to a halt outside the Goma city gate, leaving almost nothing in its wake.The Nyiragongo volcano threatens 1.5 million people in the towns of Goma (DR Congo) and Gisenyi (Rwanda), as well as those living in nearby communities. As a result, residents regularly monitor Nyiragongo volcanic activity, and any report of increased activity agitates residents in the area, particularly those in Goma. 2016 (**Balagizi Charles et al**.).

Health hazards from volcanic gase

Magma contains dissolved gases, which provide the driving force that causes most volcanic eruptions. Water vapour is by far the most abundant volcanic gas, yet it is completely safe. Volcanoes can, however, produce substantial volumes of carbon dioxide, sulphur dioxide, hydrogen sulphide, and hydrogen halides. These gases are all potentially dangerous to people, animals, crops, and property depending on their concentrations. (USGS,https://www.usgs.gov) Nearly the last 600 years, volcanic gases have claimed the lives of over 2000 people (Auker et al. 2013).

Carbon dioxide (CO_2) trapped in low-lying areas can be lethal to people and animals

Carbon dioxide makes up about 0.04 percent of the air we breathe on this planet. Volcanoes emit between 180 to 440 million tonnes of carbon dioxide per year on average. When this colourless, odourless gas is produced by volcanoes, it is immediately diluted to low concentrations and poses no hazard to human life. Cold carbon dioxide gas, on the other hand, is heavier than air and can flow into low-lying places, where it can reach much higher concentrations under specific, highly stable atmospheric circumstances.

People and animals may be at risk as a result of this. Breathing air that contains more than 3% CO_2 can cause headaches, dizziness, an increase in heart rate, and trouble breathing. Carbon dioxide causes unconsciousness and death at mixing ratios greater than roughly 15%.

Volcanic CO_2 emissions have the potential to alter the global climate in addition to its direct hazard, however scientific studies show that the average worldwide volcanic production is small when compared to emissions from human activities. (U.S. Geological Survey, https://www.usgs.gov).

CO_2 volcanic hazards in Goma

Accumulations of H2S and CO_2 from volcanic and geothermal sources have caused fatalities from asphyxiation (**Anna Hansell& Clive Oppenheimer, 2004**). It's critical to minimise minor depressions and low places that could act as CO_2 traps in volcanic or other areas where CO2 emissions occur. The distinction between healthy air and poisonous gas can be razor-thin; simply a single step upslope may be enough to save your life. Three ski patrol workers at Mammoth Mountain ski resort were killed in 2006 after falling into a snow depression surrounding a volcanic fumarole that was filled with cold CO2 gas. As shown in various spots on Mammoth Mountain, high CO_2 gas concentrations in soils can damage or destroy flora. (**USGS, https://www.usgs.gov**) In the city of Goma there is a phenomenon known as « mazuku ».

In Swahili, the word "mazuku" means "bad wind." It correlates to lowland (depressions) where carbon dioxide is emitted and accumulates at high – often dangerous – amounts since it is heavier than air (10 vol. percent of CO_2 in atmosphere can be considered as the deadly threshold, even for a short time exposure). Mazuku may be found in abundance in Goma and the neighbouring areas, particularly south of the enormous volcanic edifices of Nyiragongo and Nyamulagira volcanoes, which are located in the most eastern section of the Democratic Republic of Congo, on the W branch of the East African Rift System (EARS). (**Benoît Smetset and colleagues, 2010**) Every year, mazuku kills a large number of people. The risks linked with mazuku are increasing as a result of political and social upheaval, as well as significant demographic and urban growth in the Goma area. Mazuku are currently the area's most significant natural risk in terms of human loss, and greater study, systematic mapping and monitoring of mazuku, as well as adequate risk management, are urgently needed. **(BenoîtSmets and colleagues, 2010)**

Volcanic activity in the central crater resumed in May 2002 (**e.g., Tedesco et al., 2007b**), with a lava lake that continues to generate a permanent gas plume with high levels of acid gases, SO2, HF, and HCl (**Carn, 2002/2003, Sawyer et al., 2008, Vaselli et al., in press**). Due to local dominating winds, this plume is responsible for continuous and significant acid rains in neighbouring areas with a pH of 1–4, primarily west of Nyiragongo. Damage to plants, crops, and human infrastructure is one of the consequences, as is air, soil, and water pollution, which causes health concerns (**e.g. Baxter and Ancia, 2002, Vaselli et al., in press**). **Vaselli et al., 2002/2003, Smets, 2007, Tedesco et al., 2010**) discovered another another well-known threat among the indigenous population: the mazuku. CO2-rich dry gases are emitted by vents that are typically found in morphologically depressed locations. **(BenoîtSmets and colleagues, 2010)** Nyiragongo is a major contributor of CO_2 and SO_2 to the troposphere. It is also known for its "mazukus" (evil's winds). These are CO_2 trapping zones located in fractures, lava tunnels and topographic depressions (carbon dioxide being heavier than air). These gas accumulations would be responsible for the death of a hundred people per year by asphyxiation; the colorless and odorless CO_2 escapes any olfactory detection**.(Michel Detay; 2011)**

Material and methods

This study has been conducted on six (6) years, from 2015 to 2020. For the data collection of our investigations, we carried out descents on the ground; the districts/quarters considered rich in carbon dioxide (mazuku). We interviewed some administrative authorities at their offices for interviews and open discussions. Some data were taken from the archives of the scientific direction of the Goma volcano observatory.

Results

The western area of the city of Goma contains many mazuku points. These killer gases do not leave months without being talked about in and around Goma.Surveys conducted in the city of Goma prove that every year, deaths by mazuku are recorded in the general population. Investigations carried out in different neighborhoods in the western part of Goma, such as Kyeshero, Lac Vert and Mugunga, have shown that an average of six (6) people lose their lives in this gas. As evoked above, the mazuku being depressions with high concentration of CO_2, of whatever origin, causes the scarcity and/or the decrease of the saturation in oxygen in these depressions. This hypoxia leads the subjects (living beings: humans and animals) to a respiratory failure which affects the respiratory, circulatory and nervous systems. The brain being deprived of oxygen-rich blood supply, the subject presents headaches, dizziness, sometimes vomiting, numbness of the limbs…, up to hypotonia. Most of the victims of mazukus, being affected by hypotonia and/or numbness of the lower limbs followed by dizziness, do not know how to save themselves from the phenomenon and fall into the depression hypersaturated in carbon dioxide.

Table 1: Distribution of the number of deaths due to mazuku in the last six years

Years	Deaths	Percentage
2020	8	21.05
2019	4	10.53
2018	6	15.79
2017	6	15.79
2016	5	13.16
2015	9	23.68
Total	**38**	**100**
Average	**6.33**	

Source: Scientific direction of the Goma volcano observatory.

It can be seen, reading this table, that every year more than 6 people die in mazuku. The year 2015 recorded more deaths caused by mazuku than others during this period of investigation, with a percentage of 23.68; on the other hand, 2019 was the least affected year of this period.

Conclusion

Focusing on the harmful effects of volcanic gases in the region of Goma in general and the western part of this city in particular, this study revealed the enormous damage caused by carbon dioxide (CO_2). This study focused on the deaths reported in depressions containing high concentration of this gas (Mazuku).

During these investigations, it was found that every year, in the city of Goma, an average of 6 people died as a result of the effects of mazuku. Over the past six years, a total of 38 cases of death from mazuku have been reported in the western part of Goma, people from different origin.

The totality of these victims, once taken in the zone of the mazuku, succumb in the same zones a few minutes after their exposure to this gas by lack of oxygen; this last being driven out by the high concentration of CO_2.

These gases make their packages in certain districts of the extreme west of the town of Goma; of which the quarters ofKyeshero, Lac vertand Mugunga.

Conflict of Interest Statement

All the authors do not have any possible conflicts of interest.

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