A volcanic issue – lessons learned in Goma

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When Mount Nyiragongo erupted in 2002 it sent lava through the town of Goma and into Lake Kivu. Relief operations focused on how to treat biological pollution in water from Lake Kivu and to manage the water's chemical contamination from lava flows. Either form of contamination would have been less of a problem if lessons learned from earlier eruptions had been more readily available.

Mount Nyiragongo in the Democratic Republic of Congo is one of Africa's most active volcanoes. On 17 January 2002 Nyiragongo erupted, sending lava across the town of Goma 10 km away into Lake Kivu. Goma has a population of approximately 400 000. Years of conflict, displacement and poverty have rendered Goma's population particularly vulnerable to disease and malnutrition. Chief causes of mortality include malaria, measles, tuberculosis and diarrhoeal diseases. Epidemics such as cholera, meningitis, dysentery and bubonic plague are frequent. Water and sanitation infrastructure and health services in Goma are limited, and largely supported by external aid agencies.

Because Goma's health situation is already precarious, volcanic eruptions can easily prompt medical crises. In 1977 lava flow from Mount Nyiragongo killed more than 2000 residents. In 1994 conflict and displacement triggered cholera and dysentery epidemics, resulting in 50 000 deaths.[1] The eruption in January 2002 led to the displacement of over 300 000 to Rwanda and neighbouring areas. Lava flows destroyed an estimated 13 per cent of the town, including water supply and electricity systems, local health centres, hospitals, local residences and foreign aid offices. Goma's population suffered dehydration, respiratory and ocular infections, burns, ionizing radiation and mental health disorders as a consequence of the eruption and subsequent displacement. Risks of morbidity and mortality were heightened by the uncertain quality of water sources and unhygienic living conditions.

Chemical and biological contamination

Lake Kivu is the only source of water for drinking, cooking and hygiene in Goma and the surrounding areas. During the crisis, humanitarian agencies became concerned that the water would not be safe for consumption owing to chemical contamination. Following lava flows into the lake, vulcanologists and water and sanitation specialists noticed that the temperature of the lake had risen in localized areas and was releasing large amounts of gas. Dead fish floated to the surface, and flames reportedly glowed above the water. Vulcanologists studying Mount Nyiragongo have long known that Lake Kivu holds large amounts of carbon dioxide and methane. Scientists feared that lava flow into the lake would destabilize the gases and cause either a fatal explosion resulting from methane or the spread of lethal low-lying carbon dioxide, as happened by Lake Nyos in Cameroon in 1986. In addition to disquiet over the destabilization of carbon dioxide and methane in the lake, specialists were concerned about two other key water supply issues: the lake's fluoride pollution and the threat of a cholera outbreak. Water quality assessments and appropriate disinfection techniques were considered crucial to avoid wide-scale loss of life.

Many factors must be taken into consideration during assessments of water quality, such as source protection, treatment efficiency and reliability, and protection of the distribution network. Water quality can be affected by organic faecal pollution (e.g. bacteria, viruses, protozoan pathogens, helminth parasites, etc.), suspended matter

Houses were submerged by the lava flows

(e.g. mineral solids, algae, protozoa, bilharzia cercaria, etc.), acid and alkaline substances, toxic metals, pesticides and nitrates, and concentrations of salts. Of these, faecal pollution is generally considered the most severe since it can lead to rapid and widespread outbreaks of communicable infectious diseases and mortality.

Cholera control and chlorination

Drainage systems in Goma were badly damaged by the lava flows. Heavy rainfalls caused water pooling, flooding and risks of associated faecal-oral diseases. Cholera (infectious *Vibrio cholerae*) has been endemic in Goma for years; it is transmitted through the ingestion of faecally contaminated food or water, and is preventable through a safe water supply and hygiene measures.

The International Committee of the Red Cross (ICRC) had provided a local water and sanitation NGO, Ami-Kuvi, with training, finances and equipment in the past. During the crisis, Médecins Sans Frontières (MSF) began to collaborate with Ami-Kuvi (under agreement with ICRC) to monitor, train and expand the NGO's activities and to ensure a safe water supply to Goma's population. This involved the establishment of new chlorination points next to the lake, and the rehabilitation and monitoring of long-standing ones. Trained staff performed bucket chlorination (i.e. on-site injection of chlorine proportional to the capacity of individual water containers).

Chlorine is considered appropriate for the disinfection of water in emergency situations since it is powerful enough to kill all viral and bacterial pathogens. In order for disinfection to be successful, however, it is imperative that sufficient amounts of chlorine be used. Chlorine is absorbed by oxidizable substances present in water, such as organic matter, minerals, pathogens, etc. The effectiveness of chlorination is dependent on the presence of the Free Residual Chlorine (FRC), and water quality must be assessed daily, or even hourly, in order to adapt chlorine dosages appropriately. Chlorination requires good logistics (i.e. reliable chlorine product, appropriate storage, etc.), properly trained staff and regular monitoring. This is particularly the case for bucket chlorination.

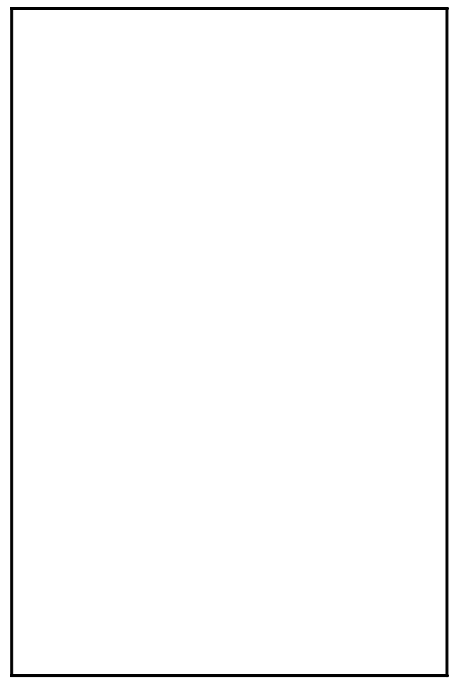
Standard protocol for chlorine treatment calls for the preparation of a 1% chlorine stock solution, which is then mixed with raw water. An FRC of 0.2–0.5 mg/l of chlorine is considered necessary in emergency settings in order to prevent possible recontamination (e.g. during handling). Water pH levels are known to influence the effectiveness of chlorine disinfection, and chlorine dosages must be modified according to pH levels; water with a high pH requires a higher FRC (0.4–1 mg/l). Lake Kivu has always had a high pH (8.5). Monitoring local chlorination procedures revealed that treated water did not have any FRC, either due to incorrect dilution procedures, a lack of monitoring equipment or insufficient training. Local staff had not always been properly trained about assessment and monitoring techniques, and the need for regular modifications of chlorine content. Chlorination points around the lake were using a 0.1 per cent stock solution, rendering the treatment totally ineffective. The combination of poor chlorination techniques and the fact that infectious *Vibrio cholerae* proliferates in waters with high pH greatly heightened the risk of cholera outbreak.

In addition to concerns about cholera prevention, WATSAN experts were also preoccupied with the chemical (i.e. fluoride) contamination of Lake Kivu.

Fluoride contamination

The World Health Organisation (WHO) stipulates 1.5 mg/l as the safe level of fluoride content in drinking water. Concentrations above 2 mg/l have been associated with the mottling of tooth enamel (dental fluorosis) and concentrations greater than 4 mg/l with joint problems and skeletal deformities. Populations in hot climates are considered particularly at risk, since fluoride concentrations in water are increased by evaporation. Furthermore, local diets may already be rich in fluoride or nutritionally deficient.[2]

Fluoride concentrations in Lake Kivu have always been slightly higher than the WHO recommendation, at 1.6 mg/l. A water sample taken by Goma's water control board a few days after the eruption revealed a drastic increase to 4.0 mg/l. It is supposed that volcanic lava and acidic ash affect the pH content of water and cause fluoride contamination. However, scientific knowledge about the relationship between lava, acidic ash and fresh water toxicity are inconclusive, and the extent to which chemical modification of water high in fluoride could be harmful to populations in the short term is unclear. Water and sanitation specialists working in Goma discussed several options: forbid everyone to drink water from Lake Kivu (unrealistic, given it is Goma's only water source); allow everyone to drink lake water in spite of high fluoride content; or treat the water with appropriate defluorination techniques.



Chlorination requires properly trained staff and regular monitoring

Over a few days, water samples were taken at regular intervals and sent to Rwanda for analysis. In the meantime, WATSAN specialists from humanitarian agencies held daily meetings to exchange assessment findings and discuss possible options. The most frequently employed fluoride removal techniques include ion adsorption (using activated alumnia or charred bone meal) and coagulation (using aluminium sulphate). Full-scale activated alumnia facilities and household defluoridators using charred bone meal have been shown to decrease fluoride levels from 5–8 mg/l to less than 1 mg/l.[3]

Water from Lake Kivu is used for bathing, washing and cooking

Meanwhile, coagulation using aluminium sulphate can reduce fluoride content by 10–60 per cent.[4] These technical options were never discussed in detail, however, since they would have been logistically unfeasible in the context of Goma. Furthermore it was assumed that the impact of water high in fluoride content on the population would not be immediate.

Before humanitarian agencies had the time to discuss an appropriate solution, new water samples showed a decrease in fluoride concentration to 2.0 mg/l. The agencies decided to leave the chemical content of the water untreated.

Lessons learned

Confusion about the consequences of fluoride contamination and incomplete chlorination procedures brought home several lessons:

International protocols and appropriate training for bucket chlorination. Unlike sustainable development organizations, humanitarian organizations are not focused on long-term capacity building and participatory programme implementation. The goals of MSF, for example, are to prevent widespread mortality, alleviate suffering, prompt a restoration to health and restore dignity. Implicit in the humanitarian approach is a 'quick in and quick out' response, which means there is a tendency to overlook the need for transferring knowledge and technical expertise to relevant local NGOs.

The incomplete chlorination assessment, dilution and monitoring techniques witnessed in Goma could have been prevented if local NGOs had received adequate training in, and monitoring of, water disinfection. Special attention needs to be paid to explaining:

- why chlorination techniques are used in emergency contexts
- what factors influence disinfection protocol (e.g. pH levels, turbidity, presence of iron and organic matter, etc.)
- which types of biological pollution chlorine is capable of eliminating (e.g. bacterial and viral) and not (e.g. protozoa, helminths, etc)
- how to disinfect water properly (e.g. pH assessment, contact time, calculation of FRC, etc.).

Humanitarian agencies need to strengthen their institutional memory. Relief agencies constantly encounter new emergency situations and have to employ new staff. Institutional memory is often either held by individuals, or contained in archives that are not accessible to the public, and agencies are forced to 're-invent the wheel' every time they encounter an unusual emergency situation, such as the chemical destabilization of lake waters due to lava flow.

Confusion over fluoride pollution could have been avoided if WATSAN experts had had access to the lessons learned from earlier volcanic eruptions. UNHCR had devised a contingency plan about chemical water modification and appropriate management techniques after Mount Nyiragongo's previous eruption, but this document was never readily available to all organizations. Inter-agency collaboration and communication during the humanitarian crisis was excellent. However, humanitarian organizations also need to take a shared responsibility for the assimilation, recording and dissemination of relevant operational information, so that decision-making and programme implementation in future emergency contexts is efficient.

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Further reading

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