Health Consequences of the Cerro Negro Eruption, Nicaragua, 1992

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ABSTRACT

The eruption of Cerro Negro volcano near León, Nicaragua on April 9, 1992 resulted in the displacement of approximately 10,000 persons. An assessment was conducted in order to evaluate the health and medical response to the eruption, identify key means for reducing mortality or permanent disability, and recommend follow-up projects. Epidemiologic surveillance indicated that the rates of visits to health care facilities for acute diarrheal and respiratory illnesses increased in two communities at or near the disaster zone. Standard morbidity ratios showed that observed cases of acute diarrheal diseases were nearly 6 times higher than expected; observed cases for acute respiratory diseases were 3 to 6 times higher than expected based on pre-eruption rates. Children less than 4 years of age, specifically infants, were particularly vulnerable. Roof-related trauma associated with clean-up activities comprised 84.2 percent (85/101) of all hospital-treated injuries related to the eruption. Recommendations include determining appropriate warning and evacuation periods, sensitizing the national epidemiologic surveillance systems for detecting eruption-specific morbidity, and rapid damage assessments for relocating evacuees to pre-eruption homes.

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I. Introduction

Purpose

This report documents the result of an assessment of the public health consequences of the eruption of the Cerro Negro volcano in Nicaragua. Under terms of a contract between the Pan American Health Organization (PAHO) and the Centers for Disease Control and Prevention (CDC) for epidemiologic and operational research after a disaster, CDC was to evaluate the public health and medical response to the volcanic eruption, to identify key means for reducing mortality and permanent disability that later would be considered by national authorities and international agencies, and to prepare suggestions for future research projects and protocols.

Background

The Cerro Negro volcano (12.51° N, 86.70° W), located approximately 25 kilometers from the provincial capital of León, erupted at 11:30 p.m. on April 9, 1992 (Figure 1). An eruption plume rose 7,000 meters and deposited ash in a west-southwesterly direction past León, some 80 kilometers northwest of Managua, before ceasing at 6:00 p.m. on April 12 (1). The regional emergency committee of the country estimated that 1,700,000 tons of ash fell on a 200 square kilometer area (Figure 2). Local

health authorities expressed concern about hazards from inhalation of toxic gases because sulfur dioxide concentrations were reported to be nine times higher than normal. Although only a few casualties were reported, 120,000 people living in the affected zone were at risk, more than 10,000 of whom required some emergency assistance (2).

II. Methods

Field investigation was conducted from April 20 through 27, 1992. With assistance from the local medical epidemiologist and biostatistician, we obtained weekly information for the month before the eruption, and we also obtained information daily for 1 week after the eruption from the epidemiologic surveillance system of the local Ministry of Health reporting unit, or Sistema Local de Atención Integral en Salud (SILAIS), in the province of León.

Each day, nine municipalities and the city of León reported morbidity and mortality statistics from each of their respective hospitals, health clinics, and health posts. Of these 10 divisions, age-specific counts of the population were available for two: Malpaisillo (population 35,692) represented 29.7 percent of the affected population in the province of León and Telica (population 22,378) represented 18.6 percent (3). We determined morbidity rates only for acute diarrheal and respiratory illnesses in these communities, because we observed

only sporadic instances of other conditions, such as conjunctivitis and measles and suspected cases of cholera and rabies during the study period. Case definitions for acute diarrheal disease and acute respiratory infections were unavailable from the surveillance system.

We obtained morbidity data on an approximately 10,000 persons housed in an estimated 18 evacuation camps in the province of León. The data were abstracted from SILAIS, which modified routine data collection for evacuee camps. We also obtained a daily census report from the camps when it was available.

SILAIS also provided information regarding eruption-related injuries on persons hospitalized at Hospital Escuela Dr. Oscar Danilo Rosales A. (HEDRA) in León from April 10 through 21, 1992. The data included date of admission, age, sex, residential address, circumstances of injury, and mortality status. Results of a hospital-based study on eruption-related trauma that was conducted by the local Ministry of Health supplemented information on hospitalizations. On the basis of information obtained from HEDRA's emergency department logs, we categorized injuries by age, sex, cause, bodily location, and frequency by residential area for four days during the immediate postimpact phase.

III. Results

Epidemiologic Surveillance

Weekly rates of health care visits for acute diarrheal disease were highest among children younger than 1 year of age, with visitation rates increasing from 13.8 per 1,000 during the month before the eruption to 45.1 per 1,000 1 week after the eruption occurred. The next highest rates for such visits occurred among children of 1 to 4 years with morbidity rates increasing from 2.3 per 1,000 to 23.2 per 1,000. Weekly rates of health care visits for diarrheal diseases in the community of Malpaisillo tended to be 50 percent higher than those for the community of Telica (Figures 3 and 4).

Before the eruption, weekly rates of health care visits for acute respiratory illnesses were higher in Malpaisillo than in Telica. We noted a rise in these rates in both communities after the eruption occurred, with a more than fourfold increase observed in Telica. During the study period, children, particularly those younger than 1 year of age, consistently exhibited higher rates of acute respiratory infections than all other age groups in both communities (Figures 5 and 6). Among children younger than 1 year of age, the rates of health care visits in Malpaisillo for acute respiratory illness ranged from 27.7 per 1,000 4 weeks before the eruption to 79.9 per 1,000 the week after the eruption. In Telica, these rates ranged from 17.4 per 1,000 4

weeks before the eruption to 83.6 per 1,000 1 week after the eruption.

We compared diarrheal and respiratory morbidity between pre- and posteruption periods for proportionate increases in the rates of disease associated with the eruption. Pre-eruption cases included those that occurred during the 3-week epidemiologic reporting period before the week in which the eruption occurred; posteruption cases consisted of those that were observed during the week after the eruption. Tables 1 through 4 show standardized morbidity ratios (SMR's) and confidence intervals (CIs) for acute diarrheal and respiratory illnesses among those in the study communities (4). On the basis of pre-eruption age-specific morbidity rates, we found that cases of acute diarrheal disease during the posteruption period were 5.8 times higher than expected. Likewise, observed cases of acute respiratory illness occurring after the eruption were 3.6 to 6.0 times higher than expected for pre-eruption age-specific morbidity rates.

For persons living in Malpaisillo, the overall relative risk of experiencing diarrheal disease associated with pre- and posteruption periods was 5.82 (95% CI: 4.68, 7.24); for persons living in Telica, the relative risk was 5.76 (95% CI: 3.72, 8.93). Acute diarrheal disease was associated with a three- to-fourfold increase between pre- and posteruption periods among infants in both study communities (Figure 7). Children ages 1 to

4 years living in Malpaisillo were almost six times (95% CI: 4.27, 8.16) more likely to have experienced diarrheal illness after the eruption than before the eruption. An elevated relative risk was observed for their counterparts in Telica, where the risk was estimated at 17.3 (95% CI: 7.14, 42.08). Relative risks for experiencing acute diarrheal disease ranged from 10 to 30 for all other age groups living in Malpaisillo, whereas relative risks living in Telica ranged from 4 to 8. In general, the risk for acute diarrheal disease was higher in Malpaisillo than in Telica for all age groups, except for children between the ages of 1 through 4 years. Among children in that age group who lived in Telica, the risk was higher.

The overall relative risks of experiencing acute respiratory illness were 3.57 (95% CI: 3.23, 3.95) among those living in Malpaisillo and 6.06 (95% CI: 5.14, 7.14) among those living in Telica. Acute respiratory illness was associated with a 2 to 10-fold increase after the eruption when compared with pre-eruption levels (Figure 8). Relative risks for acute respiratory illness after the eruption were consistently higher for all age groups living in Telica than those living in Malpaisillo, with a range from 3.65 (95% CI: 2.67, 4.97) to 10.0 (3.14, 31.85). We also observed increased risks among persons older than 15 years living in Telica. We detected cases of acute diarrheal and respiratory diseases and conjunctivitis among persons living in evacuation camps, although we observed no trends in daily morbidity rates

during the 10 days immediately after the eruption.

Ashfall-related Trauma

We defined injuries as trauma for which medical attention was sought at HEDRA's emergency department in the city of León. Of the 157 people treated from April 10 through 14, 1992, 101 (64.3 percent) had injuries related to the eruption (5). Of these injuries, an estimated 84.2 percent (85) were attributed to roof-related incidents that occurred when residents removed the accumulated volcanic ash from their rooftops (Table 5). We attributed injuries not associated with the eruption to causes other than roof-related incidents.

Of the 85 roof-related injuries, more than 40 percent (37) involved trauma to the extremities; trauma to the thorax accounted for 16 injuries, and 10 injuries were the result of head trauma. An estimated 26 percent of the injuries was related to multiple trauma (Table 6). Roof-related trauma occurred predominantly in males (Table 7), although no significant association was detected between sex and roof-related cause of injury (Yates corrected Chi-square = 0.11, $p > 0.05$). Approximately 60 percent of the roof-related injuries occurred among persons ages of 15 through 49 years (Table 8).

Of the 101 persons treated for eruption-related injuries in the emergency department, 11 (10.9 percent) were hospitalized. These

patients ranged in age from 13 to 60 years (the median age was 30 years); approximately 82 percent (9) were male, and 38 percent (2) were female.

Of the 11 persons hospitalized with roof-related injuries, 9 (almost 82 percent) sustained injuries associated with the eruption (Table 9). Of the other two hospitalized patients, one was injured in a car crash due to poor visibility caused by heavy ashfall, and the other was injured at a swimming area in an evacuation camp. Head trauma and abdominal injuries each accounted for 45.5 percent of the injuries requiring hospitalization; one person was hospitalized for a fracture of the lumbar vertebrae.

We recorded 3 fatalities. Two persons died as a result of roof-related injuries: one, a 15-year old boy, sustained a cranial fracture, and the other, a 19-year old woman, died of a penetrating abdominal wound. A 60-year-old man died as a result of head trauma sustained while bathing in the swimming area of an evacuee camp.

Issues Relating to the Immediate Postimpact Phase

Key informants, including medical personnel and development workers in the affected communities of León, Telica, and Lechecuagos raised several issues concerning general posteruption public health conditions. Although the evidence is anecdotal,

the questions it raises provide a framework for developing future studies and for establishing emergency preparedness guidelines for use during volcanic disasters.

Evacuation

Although the Instituto Nicaragüense de Estudios Territoriales (INETER) warned of an impending eruption 2 hours before the event (6), evacuation of the affected zones was still continuing 16 hours after the eruption (7). Medical personnel involved in the evacuation of the area closest to the volcano (i.e., within 10 kilometers of the base of the volcano) described the events that ensued during evacuation.

Most people did not leave the disaster zone until they had experienced difficulty breathing, a symptom perhaps attributable to the emission and dispersion of volcanic gases. Those first at the scene reported that large rocks, then dust and ash, spewed from the volcano. When the quantity of tephra, mainly scoriae and fine ash, was knee-deep, people evacuated the area. Tephra particles, ranging in texture from dust to sand, were ejected continually during the period after the eruption and were particularly heavy the day after the eruption. Witnesses reported that "wet ash" hampered vehicles used to transport some evacuees from the disaster zone. Cases of dermatitis, possibly caused by the "wet ash," were reported although no verification of the cases had been made, nor any explanation for their

manifestation given or documented.

According to first responders, general patterns for evacuation indicated that the men moved livestock, primarily cattle, out of the area first, and then returned to evacuate women and children. Others observed the effects of gas emissions: the elderly had respiratory problems and livestock were disoriented. No human or animal deaths were reported during this time.

Immediate health effects

Residents in the affected communities raised concerns about the lack of public information regarding the immediate effects of the ash on their health. In particular, they had questions about the safety of ash-contaminated food and water and the potability of water with an unusual "post-eruption" odor. Two weeks after the eruption, however, public health advisories had yet to be communicated effectively if at all, to the general public (7,8). At that time, the general public did not know whether the ash had been tested for potential toxic elements.

Relocation to affected areas

The need for evacuation camps and the desire to prevent community dependence on outside sources for relief supplies and operations raised concern among observers about the timing and appropriateness of decisions to close the camps. Resettlement

began in disaster zone areas where possible although the general health effects of the ash had yet to be determined and the quality of water in wells, the main source of water had yet to be assessed. The desire to return evacuees to their homes preempted the question of when it would be safe to return. For example, the Isaza evacuation camp, which had no established procedures for returning people to their homes in the disaster zone, was given only 48 hours' notice that it would be closed (9).

IV. Discussion

The results of epidemiologic surveillance in municipal health clinics indicated that weekly rates of health care visits for acute diarrheal and respiratory illnesses increased after the eruption, particularly among children younger than 4 years of age. These weekly rates of health care visits represented an approximation of the incidence of disease, since repeat visits to the health care facilities were possible.

Although residents were evacuated from affected areas, the rates for health care visits nonetheless increased during the week after the eruption. People had not yet returned to their homes in affected areas. Thus, because of the evacuation of residents from affected areas, the rates of health care visits after the eruption probably underrepresented diarrheal and respiratory morbidity.

Although gastrointestinal illnesses are not caused directly by volcanic eruptions, such illnesses have been reported as secondary effects owing to unfiltered, inadequately chlorinated surface water that may cause infectious disease. Waterborne giardiasis has been associated with heavy water runoff resulting from warm weather and volcanic ashfall on snow (10). Heavy ashfall also has been known to affect the operation of sewage treatment plants by overwhelming filter beds, damaging machinery, and diverting raw sewage into surface water (11). In rural settings, however, where the main sources of water are wells, conditions predisposing to diarrheal diseases may be created or exacerbated indirectly by the effects of ashfall on water supplies. Inadequate water supplies and the need to travel long distances in order to obtain water were reported throughout the affected area of Lechecuagos (12). These conditions, coupled with poor sanitation and hygiene in rural areas, may explain the increased susceptibility of young children to diarrheal disease.

Ash-related respiratory problems have been described as occurring in the aftermath of volcanic eruptions (13-25). Immediate effects have included transient, acute irritation effects of the mucous membranes of the eye and respiratory tract by volcanic ash and gases as well as the exacerbation of existing chronic lung diseases because of heavy ashfall during and for some time after the eruption (14). Within 1 hour of the beginning of volcanic activity, ash began falling in León. By the next day, deposits

of up to 1 centimeter were recorded. By April 12, changes in wind direction from the west-southwest to the west led to accumulations of an estimated 2.5 centimeters of ash in Telica (26). The eruption led to a 2- to 10-fold increase in respiratory problems when compared with morbidity rates prior to the event. High rates of acute respiratory illnesses observed among infants in this population may be attributed to a number of events, including infections occurring in crowded camps. It is also conceivable that a new onset of respiratory illness may have occurred. After the 1979 eruption of the La Soufriere volcano on the island of St. Vincent, transient bronchospastic airway disease was observed for the first time among previously well infants (14, 27). Before the eruption, however, the prevalence of asymptomatic bronchial hyperreactivity was unknown (28, 29). Toxic gases, particularly sulfur dioxide, were initially reported to be associated with the eruption of Cerro Negro. None, however, were evident after the eruption of Cerro Negro (26).

Pre-eruption weekly rates of visits to health care facilities indicated a higher occurrence of diarrheal and respiratory morbidity in Malpaisillo than in Telica. Although we observed posteruption increases in non-specific diarrheal and respiratory illnesses in both communities, potentially confounding factors related to the characteristics of the study communities and coverage by health centers that serviced those communities must be noted. We attributed the higher posteruption rate of health

care visits for acute respiratory conditions in Telica, 16 kilometers west of the volcano, to its location which was in the path of the ashfall (Figure 2). In contrast, Malpaisillo is located several kilometers north of Cerro Negro and just outside the perimeter of the path. Increased rates in diarrheal and respiratory illnesses in Malpaisillo may have been due, in part, to the eruption, since the health center may have treated both residents living within the path of the ashfall and evacuees from a camp established in that community. Concurrently, Malpaisillo's health center continued providing services to surrounding communities that were not affected by the eruption. This population could have contributed to an increase in morbidity rates resulting from events other than the eruption.

Reports of past eruptions have included descriptions of roof collapse from heavy volcanic ashfalls after the 1971 and 1973 eruptions of Fuego in Guatemala (30). Ash, made heavier by rain, accumulated on roofs and led to building and roof collapse after the 1991 eruption of Mt. Pinatubo in the Philippines. Of the initial eruption-related fatalities, 61 percent were caused by roof collapse (31). During the eruption of Cerro Negro, roof collapses occurred in public buildings such as schools and businesses, including a large warehouse in León, where the cause of the collapse was attributed primarily to accumulated ash and scoriae that had not been cleaned (1). No injuries or fatalities were due to roof collapse.

In contrast, roof-related injuries and deaths resulting from falls from roofs were particularly noteworthy in the Cerro Negro eruption. All 85 persons treated for roof-related injuries in HEDRA's emergency department from April 10 through 14 were treated for falls associated with the eruption; these injuries accounted for 84.2 percent of all eruption-related injuries. Such falls were due to attempts to clean the ash and scoriae from roofs. People in the area roof their homes by laying single clay tiles over each other on a wooden frame so that their collective weight anchors the roof. Brushing off the ash requires the removal of all tiles, which can number several hundred per roof. Thus, the time spent cleaning the roof, the structural integrity of wooden frames that support the tiles, the roof's pitch, and the activities of the person cleaning the roof at the time of the fall may be predisposing factors for injury.

We expected the number of falls to increase once the ashfall had subsided and people attempted to clean their roofs. Data obtained during the 4-days immediately after the eruption show that although multiple trauma and trauma to the extremities and thorax accounted for most roof-related injuries, trauma to the head and abdominal area accounted for most hospitalizations for roof-related injuries. Although the injuries are few, these findings are point to the severity of roof-related injuries and are important in determining proper resources for treating such injuries. We discerned no significant patterns for age or sex

among persons hospitalized for roof-related trauma.

The increasing number of people living on or near volcanoes worldwide raises questions about emergency health management. Ideally, the only adequate preventive measures against the consequences of volcanic eruptions are evacuation and delineation of restricted zones when an area is threatened by an eruption (13). When Cerro Negro erupted, evacuation did not begin until several hours after the eruption had occurred, even though warnings had been issued several hours before the event. Because evacuation is time-consuming, (e.g., many people remained until all their farm animals were evacuated), perhaps warning messages should be transmitted earlier to vulnerable communities in Nicaragua and to other populations in Latin America with similar cultural concerns. To implement these earlier warnings, close monitoring of Cerro Negro should continue (32). The technical and logistical feasibility of warning systems requires further investigation by local emergency managers.

Collecting detailed information on the history and current activity of volcanoes provides a basis for determining appropriate warning and evacuation periods (33-35). In 1985, the eruption of Nevado del Ruiz in Colombia was similar to an eruption that occurred in the early 1800's (32). Armero, a town 48 kilometers from the volcano, was founded after the eruption in the early 1800's and before the catastrophic 1985 eruption in

which large numbers of townspeople died of suffocation from mudslides due to the eruption. No timely warnings were issued and followed (36). In formulating appropriate warning and evacuation systems, knowledge about the volcano's historical activity could have prevented many of these deaths. Given that Cerro Negro has erupted six times in the past 30 years, baseline data on the volcano could indicate the expected health effects from eruptions of this volcano. In particular, the 1968 eruption was one of the most violent, pelting the city of León with an almost continuous rain of ash (36).

After the eruption, people in affected areas clearly needed public information about the possible toxic effects of ash on food and water supplies. Indeed, such standardized guidance is needed and should be issued as soon as possible after any eruption.

Evacuees should not be permitted to return to their homes until public safety officials address health and safety issues. Although these officials may have concerns about increasing a community's dependence on outside resources, these officials should assure the availability of adequate and safe food, water, shelter and air quality before implementing plans to return people to their homes.

V. Recommendations

On the basis of the experience of the April 1992 eruption of Cerro Negro, we recommend further investigation of these topics:

1. Ash-related respiratory morbidity. Further detailed studies should be conducted to describe the spectrum of such diseases and to determine the timing of onsets of illnesses in special subgroups, such as transient bronchospastic airway disease in infants occurring among infants, of the population. In this study, questions arose about the uniformity of case definitions from different health care units (i.e., hospitals, clinics, and health posts) in the surveillance system. Moreover, health care coverage for these population units was expected to be low, because a fee-for-service system had recently been instituted and people could not afford the care. The PAHO epidemiologists from Managua planned to implement a household survey in the disaster zone within a month after the eruption.

2. The type and quality of water supplies in rural areas. The marked increase in acute diarrheal diseases, particularly among young children, that occurred after the eruption calls for further study of the water supply.

3. The national epidemiologic surveillance system. The system could be modified, extended, and its sensitivity increased

for detecting eruption-specific morbidity, particularly acute respiratory conditions. Categories for these conditions should be defined uniformly for all reporting units. The system should be able to detect new cases of respiratory illnesses so that medical relief agencies can respond appropriately. The system could also be modified for examining the long-term effects of exposure to ash in a particular community.

4. Roof-related injuries resulting from clean-up activities. Further evaluations to determine the risk of injury occurring during roof-cleaning are needed. Possible risk factors include type of roofing material, pitch of roof, and quality of the frame support.

5. Emergency health management. Hazard evaluation and vulnerability assessments should be based on historical data about the nature of a particular volcano, the types of gases and tephra emitted in the past, and prevailing climatological conditions. If possible, high risk areas should be demarcated to prevent people from settling in those areas. Warning and evacuation plans for the disaster zone should be developed and reviewed, if they already exist, and then exercised, evaluated, and revised. The appropriateness of noncivil defense personnel, such as medical personnel from the major hospital in León,

conducting evacuation in the disaster zone immediately after an eruption should be evaluated. The capability of rapidly evaluating the effects of ash on food, water, air, and shelter so that evacuees may return safely to their homes at the appropriate time should be developed.

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