Public Health Surveillance after a Volcanic Eruption: Lessons from Cerro Negro, Nicaragua, 1992[1]

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The eruption of the Cerro Negro volcano near León, Nicaragua, on 9 April 1992 distributed an estimated 1.7 million tons of ash over a 200 square kilometer area. An assessment was conducted to evaluate the health effects on approximately 300 000 residents, using routine data obtained by the national epidemiologic surveillance system. It was found that rates of visits to health care facilities for acute diarrheal and respiratory illnesses increased in two study communities, one within and one near the disaster zone. Specifically, visits for acute diarrhea were nearly 6 times more numerous than before the eruption in both communities, while visits for acute respiratory diseases were 3.6 times more frequent in Malpaisillo (the community near the disaster zone) and 6.0 times more frequent in Telica (the community within it). Most of the visits were for infants and children less than 5 years old.

Increased diarrheal disease morbidity, which commonly occurs after volcanic eruptions, demands detailed investigation of the type and quality of water supplies following heavy ashfall. Ash-related respiratory problems should be further examined to determine the spectrum of such diseases and the timing of illness onsets among infants and other special population subgroups. Data collected on health conditions before and after an eruption by passive surveillance can be used to detect eruption-related morbidity. Systems already in place, such as Nicaragua's national epidemiologic surveillance system, can be modified or extended so as to increase their sensitivity to new cases and hence their ability to provide appropriate notification to medical relief agencies.

Investigation of the health effects of disasters with acute impacts has tended to employ active surveillance systems—ones that actively solicit information as opposed to passive (routine) surveillance systems that do not (*1–6*). Such active systems can permit immediate assessment of disaster-related problems for the purpose of mounting relief operations (*7*). However, the work reported here made use of a passive surveillance system, Nicaragua's national disease surveillance system, to detect health effects following a volcanic eruption and identify issues whose resolution could re-

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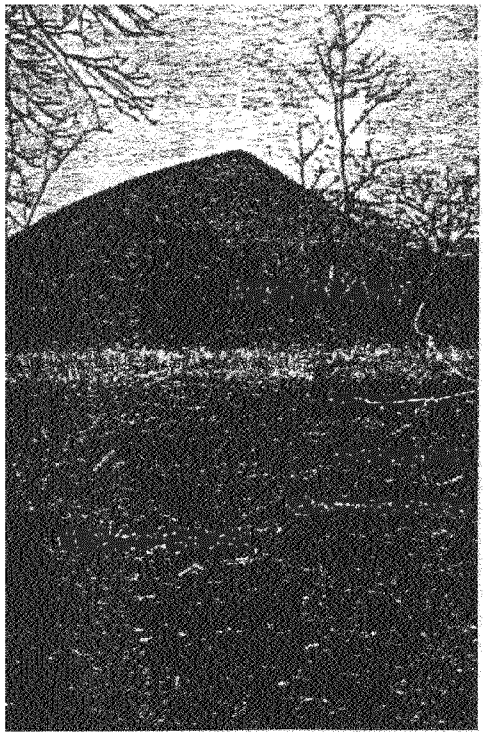
duce morbidity from volcano-related hazards. The results obtained served to demonstrate that, with modification, routine health information systems such as the nationwide surveillance system employed can provide reasonable estimates of post-disaster health problems.

BACKGROUND

Nicaragua's Cerro Negro volcano (12.51° N, 86.70° W), located approximately 25 kilometers northeast of the provincial capital of León, erupted at 11:30 p.m. on 9 April 1992 (*8*). Over the next three days an eruption plume deposited an estimated 1.7 million tons of ash in a west-southwesterly direction over an area of 200 square kilometers extending beyond León, some 80 kilometers northwest of Managua (Figure 1). Initially, local health authorities expressed concern about hazards posed by toxic gases—because sulfur dioxide concentrations were reported nine times higher than normal. Although no casualties were reported, 300 000 people living in the affected zone were at risk, more than 10 000 of whom required some emergency assistance (*9, 10*).

Damage from volcanic ashfall within the study area.



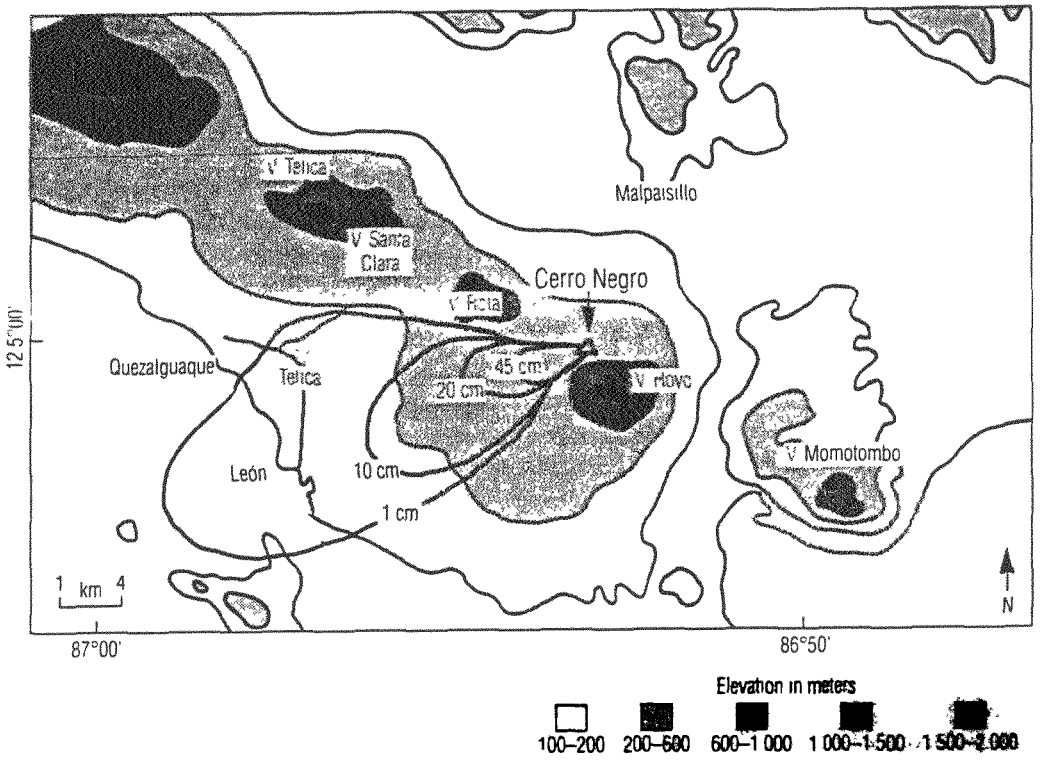
MATERIALS AND METHODS

Weekly summaries of reportable illnesses and deaths for the month before the eruption were obtained from the *Informe diario de vigilancia epidemiológica*, the reporting vehicle of the Local System of Integral Health Care (*Sistema Local de Atención Integral en Salud—SILAIS*), this latter being the health information reporting unit of León Province. Using the same information source, we also obtained daily reports of illnesses and deaths for a one-week period following the eruption.

Each day, nine provincial municipalities and the city of León reported morbidity and mortality statistics from all of their respective hospitals, health clinics, and health posts. From among these 10 reporting subdivisions we selected two, Malpaisillo (population 35 692) and Telica (population 22 378), that encompassed about 48% of the province's area and included most of its population outside the city of León. Age-specific breakdowns of these two municipalities' populations were readily available (*11*).

We determined morbidity only for acute diarrheal and respiratory illnesses in these communities, because we observed only sporadic instances of other conditions (such as conjunctivitis, measles, and suspected cholera cases) during the study period. For purposes of the study, we examined cases said to have occurred during the epidemiologic reporting period of 8 March–4 April 1992 (before the 9 April eruption) and those reported for 12–18 April after the eruption. Case definitions for acute diarrheal disease

Figure 1. A map showing levels of ashfall from the 9 April 1992 eruption of the Cerro Negro volcano, the altitude of surrounding territory, and the locations of the principal capital, León; the two study communities, Malpaisillo and Telica; other nearby towns; and other nearby volcanoes, indicated by "V".



Source: Nicaraguan Institute of Territorial Studies (*Instituto Nicaraguense de Estudios Territoriales*)

and acute respiratory infections were not available from the surveillance system.

RESULTS

Weekly rates of health care visits for acute diarrheal disease were highest among children younger than 1 year of age, with visit rates increasing from 13.8 per 1 000 during the month before the eruption to 45.1 per 1 000 one week after the eruption. In terms of age, the next highest weekly rates for such visits occurred among children 1 to 4 years old, among whom these visit rates increased from 2.3 per 1 000 during the month before the eruption to 23.2 per 1 000 one week after the eruption. Weekly rates of health care visits for diarrheal disease in the community of Malpaisillo tended to be considerably higher than in Telica (Figure 2).

Before the eruption, weekly rates of health care visits for acute respiratory illness were higher in Malpaisillo than in Telica. Noteworthy increases in these rates were observed in both communities after the eruption, that in Telica being more than fourfold. During the study period, infants (especially) and children under 5 years old consistently exhibited higher rates of acute respiratory infection than all other age groups in either community. Among in-

Figure 2. Weekly rates of reported health care visits per thousand for acute diarrheal diseases among infants and young children in the municipalities of Malpaisillo and Telica, Nicaragua, from 8 March through 18 April 1992.

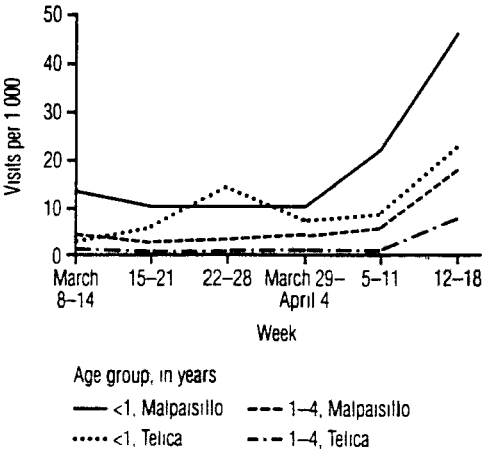
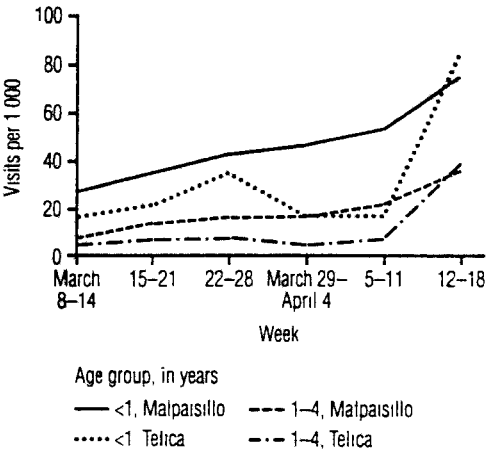


Figure 3. Weekly rates of reported health care visits per thousand for acute respiratory diseases among infants and young children in the municipalities of Malpaisillo and Telica, Nicaragua, from 8 March through 18 April 1992.



fants, the weekly rates of health care visits in Malpaisillo for acute respiratory illness ranged from 27.7 per 1 000 four weeks before the eruption to 79.9 per 1 000 one week after the eruption. In Telica, these rates ranged from 17.4 per 1 000 four weeks before the eruption to 83.6 per 1 000 one week after the eruption (Figure 3).

We compared diarrheal and respiratory morbidity before and after the eruption for proportional increases in the rates of disease associated with the eruption. Tables 1 and 2 show standardized morbidity ratios (SMR) and 95% confidence intervals (CI) for acute diarrheal and respiratory illnesses among those in the study communities (*12*). Using preeruption age-specific morbidity in each community as a standard, we found that morbidity from acute diarrheal disease after the eruption in both communities was 5.8 times higher than expected. Similarly, observed morbidity from acute respiratory illness after the eruption was 3.6 times higher than expected in Malpaisillo and 6.0 times higher in Telica.

Among infants, observed acute diarrheal disease morbidity was roughly three to four times greater after the eruption in both study communities. However, among children 1 to 4 years old, the observed morbidity was 5.9 times higher after the eruption in Malpaisillo (95% CI: 4.3, 8.2) and 17.3 times higher in Telica (95% CI: 7.1, 42.1). For all other age groups, the relative risk of experiencing acute diarrheal disease after the eruption ranged from 10 to 30 in Malpaisillo and 3 to 7 in Telica. In general, the apparent risk of acute diarrheal disease was higher in Malpaisillo than in Telica for all age groups, except for children between the ages of 1 and 4.

Compared to preeruption morbidity, the apparent relative risk of experiencing acute respiratory illness (ARI) after the eruption was 3.6 in Malpaisillo and 6.0 in Telica. Within the specific age groups studied (see Table 2), observed ARI morbidity increased by factors ranging from 2 to 10. The relative risks of ARI after the eruption (as compared to before the eruption) were consis-

Table 1. Acute diarrheal disease cases among people visiting Malpaisillo and Telica health facilities before and after the eruption, showing standardized morbidity rates (SMR) and 95% confidence intervals derived from these data.

Age group, in years	Population projection, 1992	Preeruption morbidity per 1 000	Expected No. of cases*	Observed No. of cases†
Malpaisillo:				
<1	1 374	11.1	15.3	62
1–4	5 218	2.9	15.3	90
5–14	10 240	0.2	2.5	26
15–49	15 797	0 03	0.5	15
50+	3 063	0.2	0.5	5
Total			34.0	198
SMR (95% confidence interval). 5.8 (5.0, 6.7)				
Telica:				
<1	861	7.6	6.5	20
1–4	3 272	0.5	1.5	26
5–14	6 420	0.04	0.3	1
15–49	9 905	0.03	0.3	2
50+	1 920	0.0	0.0	0
Total			8.5	49
SMR (95% confidence interval) 5 8 (4 3, 7.5)				

*Based on data for 8 March–4 April 1992
†12–18 April 1992

tently higher for all age groups in Telica than for their counterparts in Malpaisillo, these risks ranging from 3.7 (95% CI: 2.7, 5.0) to 10.0 (3.1, 31.9). We also detected cases of acute diarrhea, ARI, and conjunctivitis among persons living in evacuation camps; but no noteworthy trends in daily morbidity were found during the 10 days immediately after the eruption.

DISCUSSION

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 under 4 years old. These weekly rates of health care visits provided only an approximation of disease incidence, since some disease cases may not have prompted visits and there could have been repeat visits to the health care facilities involved.

Even though residents were evacuated from affected areas, the numbers of health care visits increased during the week after the eruption. Since the evacuated people had not yet returned to their homes in these areas, the numbers of health care visits after the eruption probably underrepresented diarrheal and respiratory disease morbidity.

More specifically, residents of the municipalities of Malpaisillo and Telica were evacuated to an estimated 20 shelters outside the affected zone, along with people from León, La Paz Centro, Quezalguaque, Corinto, Chichigalpa, and several areas within a 12-kilometer radius of the volcano. These residents went to temporary shelters in León within three days after the erup-

Table 2. Acute respiratory disease cases among people visiting Malpaisillo and Telica health facilities before and after the eruption, showing standardized morbidity rates (SMR) and 95% confidence intervals derived from these data.

Age group, in years	Population projection, 1992	Preeruption morbidity per 1 000	Expected No. of cases*	Observed No. of cases†
Malpaisillo:				
<1	1 374	37.9	52.0	103
1–4	5 218	14.3	74 8	194
5–14	10 240	3.0	31.0	187
15–49	15 797	2 3	36.8	193
50+	3 063	1 4	4.3	33
Total			198.8	710
SMR (95% confidence interval): 3.6 (3.3, 3 8)				
Telica:				
<1	861	22.9	19.8	72
1–4	3 272	6.4	21.0	129
5–14	6 420	1.5	9.8	73
15–49	9 905	0.7	6.8	68
50+	1 920	0.5	1.0	10
Total			58.3	352
SMR (95% confidence interval). 6.0 (5.4, 6.7)				

*Based on data for 8 March–4 April 1992.
†12–18 April 1992

tion and were moved a day later to encampments in surrounding areas. Evacuees received medical attention provided by four health posts that were established within these encampments (*9*).

Although gastrointestinal illnesses are not caused directly by volcanic eruptions, such illnesses have been reported as secondary effects arising from unfiltered, inadequately chlorinated surface water. Waterborne giardiasis has been associated with heavy water runoff resulting from warm weather and volcanic ashfall on snow (*13*). 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 (*14*). In rural settings, 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. These conditions, coupled with poor sanitation and hygiene in rural areas, could explain the increased diarrheal disease rates observed.

Ash-related ocular and respiratory problems have been reported in the aftermath of volcanic eruptions (*3, 14–21*). Immediate effects have included transient, acute irritation of the mucous membranes of the eye and respiratory tract by volcanic ash and gases as well as exacerbation of existing chronic lung diseases by heavy ashfall during and for some time after the eruption (*15*). Within one hour of the beginning of volcanic activity at Cerro Negro, ash began falling in León. By the next day, depos-

its of up to 1 cm were recorded. As of 12 April, changes in wind direction from the west-southwest to the west (see Figure 1) led to accumulations of an estimated 2.5 cm of ash in Telica (22).

Overall, the eruption led to a two- to tenfold increase in health care visits for acute respiratory disease among residents of Malpaisillo and Telica within the age groups studied. High rates of ARI observed among study population infants could be attributable to a number of circumstances, including infections in crowded shelters that may have been treated at clinics in the study areas soon after the eruption, before health posts were established in the evacuation settlements. It is also conceivable that a new onset of respiratory illness may have occurred. (Following a 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—*15, 23.*)

Before the eruption, weekly rates of visits to health care facilities indicated higher diarrheal and respiratory disease morbidity in Malpaisillo than in Telica. After the eruption, apparent increases in nonspecific diarrheal and respiratory illnesses were noted in both communities; however, potentially confounding factors related to the characteristics of the study communities and coverage by the health centers serving them 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 in the path of the ashfall (see Figure 1). Compared to Telica, the municipality of Malpaisillo is located several kilometers north of Cerro Negro, outside the perimeter of major ashfall. Even so, the increased diarrheal and respiratory disease morbidity in Malpaisillo that was indicated by higher rates of health center visits may have been partly due to the eruption. Health centers may have treated both residents living within the path of the ashfall and evacuees at nearby encampments who may have received medical attention outside of health posts established within the encampments. At the same time, Malpaisillo's health facilities continued providing services to surrounding communities that were not affected by the eruption. This population could have contributed to increased visit rates as a result of events other than the eruption.

Ideal comparison periods for assessing the impact of the eruption would have been epidemiologic reporting periods from previous years, particularly the last five years, that were identical to the posteruption study period. However, these data were not available at the time of the investigation, and thus we were unable to determine excess morbidity. Overall, it was difficult to determine from the data gathered whether increased health visits for respiratory and diarrheal diseases, as detected by the surveillance system, were due to health effects of the eruption rather than to increased visits by persons who availed themselves of health services after the eruption. Nevertheless, the results of this investigation point up the potential usefulness of routine health information systems in obtaining worthwhile information about the incidence of selected diseases after a disaster.

CONCLUSIONS

Obviously, volcanic eruptions can have both direct and indirect, as well as immediate and delayed impacts upon health and safety (15). The effects of these events can be actively monitored via existing national surveillance systems to provide useful information about health changes in the populations at risk. Concurrently, passive surveillance—such as that performed by the national surveillance system in the work reported here—can be used to supplement active surveillance in monitoring health effects over a wider area or for a longer time period.

In view of the findings reported here, we recommend further investigation of the following matters:

(a) Ash-related respiratory diseases. Detailed studies should be conducted to assess the spectrum of such diseases and determine their time of onset among special subgroups such as infants within the population.

(b) The type and quality of water supplies in rural areas. The marked increase in acute postdisaster diarrheal diseases, particularly among young children, calls for further study of the water supply.

(c) The national epidemiologic surveillance system. The system could be modified or extended so as to increase its sensitivity to new cases and hence its ability to provide appropriate notification to medical relief agencies. The system could also be modified to examine the long-term effects of exposure to ash in a particular community.

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Sanitary Engineering Congress to Meet in Mexico

The XXV Inter-American Congress of Sanitary Engineering and Environmental Sciences will be held 3–7 November 1996 in Mexico City. Sponsored by the Inter-American Association of Sanitary Engineering (AIDIS), the meeting is expected to draw over 1 500 participants from the countries of the Americas.

One of the main events at the XXV Inter-American Congress will be Expo Environment '96, where individuals as well as private and public institutions will display the latest in technical developments, programs, products, and services in the field of environmental protection. In addition, there will be panel discussions and plenary sessions featuring technical papers in the fields of water and wastewater treatment and reuse, solid waste management and disposal, air pollution control, and environmental impact assessment.

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