o The majority of ash particles (> 90 per cent by count) were ⩽ 10 μm in aerodynamic diameter, respirable in size, and belonged to the plagioclase (glass) mineral class of aluminium silicates and other oxides.[30]

o A small percentage of the respirable-size particles consisted of potentially hazardous polymorphs of free crystalline silica (about 4 per cent cristobalite and 3 per cent quartz by weight) which can cause pulmonary fibrosis (silicosis) if inhaled over prolonged periods of time at airborne concentrations greater than about 50 $\mu g/m^3$ (i.3., ambient concentrations of respirable size volcanic ash ⩾ 700 $\mu g/m^3$, containing ⩾ 7 per cent free silica). [27,30,58]

o No harmful amounts of respirable-size asbestiform fibers were detected and no excessive amounts of leachable toxic metals or acids (e.g., mercury, fluorides, and arsenic) were noted. [30]

Air Sampling

Between June 3 and 13, 1980, a team of four NIOSH industrial hygienists collected personal ("breathing-zone") and general area samples of airborne dusts in ash-affected communities of Washington Idaho, and Oregon. Indoor samples were collected in homes, schools, and other public buildings. Outdoor samples were collected in a variety of occupational settings in which workers were likely to be exposed to resuspended volcanic ash (e.g., clean-up crews, forest and agricultural workers, and law enforcement personnel). Standard occupational air sampling methods were used to collect respirable-size (< 10 μm in diameter) dusts suspected of containing toxic and inert minerals. [14(4,12,16–18)]

Geometric mean concentrations of respirable mixed dusts ranged from 30 to 100 $\mu g/m^3$ for nonoccupational exposures, while most community occupational exposures ranged from 50 to 570 $\mu g/m^3$. [14/4,14,16-18),27] 7 The results of NIOSH air sampling indicated that only the occupational exposures for certain categories of workers in heavy ashfall areas exceeded 800 $\mu g/m^3$ in a significant number of samples taken during dry weather. However, even these exposures were transient, and the per cent of volcanic ash in environmental dusts was likely to decrease with time if there were no further major ashfalls. Because of the potential for more intense, frequent, and prolonged exposures, workers involved in operations that created a visible dust cloud (e.g., certain job categories in logging and agriculture) were advised to wear goggles and NIOSH-recommended single-use or multiple-use high-efficiency face masks. 14,55

For reasons discussed below, it was considered unlikely that the adult general population exposed to volcanic ash from the eruptions of Mount St. Helens would be at risk of developing pulmonary fibrosis or new onset of obstructive airways diseases. 14,27,28 However, it was considered possible that those with preexisting bronchial hyperreactivity of chronic lung disease might experience exacerbations of their problems. In addition, the risks for exposed children could not be predicted from available data, and avoidance of exposure was generally recommended. 14,55

Toxicity Studies

Laboratory studies were initiated to determine the toxicity of the volcanic ash. Several different *in vitro* biologic tests indicated the ash to be mildly fibrogenic in a fashion which was dose-dependent[59] and proportional to the surface area or particle count in the test media. 30,60,61 The fibrogenic potential of volcanic ash was also observed *in vivo* in short-term animal experiments 30,62,63 and supported in the pulmonary histological findings of autopsy studies of two loggers who died in hospital following thermal injuries and heavy exposures to ash on May 18.51,63,64

Ash extracts were not mutagenic in two microbial assay systems and particulate ash had no effect on interferon production by monkey kidney cell monolayers or on the human complement system *in vitro.* 14(9),30 Marked inhibition of the antibacterial substance superoxide anion from ashexposed and zymosan-stimulated alveolar macrophages suggested that volcanic ash may impair antibacterial lung defense mechanisms. 30,65

The results of the above NIOSH toxicology studies and those of investigators in other laboratories are reviewed in more detail in chapter 6. In order of decreasing likelihood, the following adverse respiratory health effects were deemed biologically plausible if individuals received intense, frequent, or prolonged exposures: 14,27-30, 32,33,51

1. Acute irritation of the eyes, nasopharynx, and airways;
2. For individuals with preexisting or ash-induced bronchial hyperreactivity, more severe forms of respiratory distress and pulmonary impairment;

3. For individuals with preexisting chronic mucus hypersecretion or obstructive airways diseases, exacerbation and/or acceleration of these diseases and related impairment;

4. Potential for delayed-onset of ash-induced mucus hypersecretion or obstructive airways disease;

5. Potential for delayed-onset of ash-induced pulmonary fibrosis or "pneumo(vol)coniosis."

Epidemiologic Studies of High-risk Groups

Surveillance or "numerator" data alone could not be used to assess the adverse respiratory health impact of volcanic ash exposures on high-risk groups. For example, such data could not be used to evaluate the effectiveness of media directives advising patients with chronic respiratory disease to remain indoors or use respiratory protection. Additional information was obtained by cross-sectional, case-control, and longitudinal studies of high risk groups—those who were presumed to be hypersusceptible because of risk factors such as pre-existing chronic respiratory disease, or those who were heavily exposed to volcanic ash at work.

Hypersusceptible Individuals

To examine the possible etiologic relationships between as exposure and acute onset or exacerbation or pre-existing respiratory problems, two studies were conducted—a case-control study, and an exposure-referent study.24 For both studies, data on personal exposures were estimated from the EPA's rooftop monitoring of TSP levels because it was not possible to obtain or reliably estimate data on breathing-zone concentrations of respirable-size dust. In the study community which had received the heaviest ashfalls (Yakima), TSP levels varied as described in Table 1 and Figure 2. Over 90 per cent of the ash particles which sedimented to the ground in central and eastern Washington were < 10 m in diameter and thus were within the respirable range. Presumably, the vast majority of excess TSP, collected by EPA monitoring devices at rooftop levels, consisted of this highly respirable volcanic ash.

For the case-control study, patients with symptomatic asthma and acute bronchitis were identified from surveillance hospitals located in the most heavily impacted communities and one control was selected for each patient: a person of the same age (adults ± 5 years, children ± 1 year), race, and sex who lived in the same neighborhood was selected in order to match for socioeconomic status and neighborhood levels of ashfall. Cases were selected from among those patients who attended the ER during the four weeks following the May 18 eruption.

In the exposure-referent study, lists of all patients known to have attended thereapeutic classes for asthma and chronic bronchitis (prior to the eruptions of 1980) were obtained from the Washington Lung Association. The experiences of residents of the ash-exposed communities of Yakima and Ellensburg were compared with those of residents from a referent (unaffected) rural community, to determine the extent to which volcanic ash exacerbated chronic lung problems for patients who may not have been seen at the surveilance hospital ERs.

All participants were interviewed in their homes by interviewers trained in the use of the questionnaire and in the selection of matched controls. The questionnaire was based on the British Medical Research Council Respiratory Symptom Questionnaire[66] which was extended to include questions on:

o exposure to ash (time spent outdoors, involvement in house and community clean-up, wearing of masks, incidents when heavy exposure may have occurred);

o onset and duration of respiratory symptoms before and after the May 18 ashfall, including visits to medical facilities and use of medications; and

o housing information (location, number of rooms and occupants use of storm windows and doors, and type of home heating, cooking, and ventilation).

The results of these studies supported the *a priori* hypothesis that pre-existing chronic respiratory diseases (primarily asthma and chronic bronchitis) are important risk factors [24,47] for adverse respiratory reactions[51] to levels of TSP (largely volcanic ash) exceeding EPA's Emergency (875 $\mu g/m^3$) and Significant Harm (1000 $\mu g/m^3$) NAAQ Standards (Figure 2). About one-third of the patients with chronic lung disease who were registered with the Lung Association stated that their respiratory problems had been worsened by volcanic ash exposure, and one-half of these patients were sufficiently affected so that they curtailed their usual activies for at least three months afterwards. It is likely that widespread adverse respiratory effects among people with chronic lung problems were averted to some extent because most of these people had followed the official advice, issued through the media, to stay indoors and wear respiratory protection when exposure to volcanic ash could not be avoided.[24]

It was not possible to use surveillance or case-control methods to evaluate the occurrence of new onset of asthmatic bronchitis in previously non-asthmatic individuals (which had been reported after the eruption of Soufriere volcano on St. Vincent[67]). Valid, reliable, objective data on the preeruption clinical status (e.g., the severity of any pre-existing asthma[47] or asymptomatic bronchial hyperreactivity [68,69]) and actual breathing-zone levels of respirable dust exposures were not available in either setting. Chapter 8 provides a review of several studies [70-72] which addressed this question with pulmonary function testing and environmental exposure measurements.

Loggers with Heavy/Prolonged Exposures

On June 4, 1980, the International Woodworkers of America (IWA) and the Weyerhaeuser Company (Weyco) made a joint request of Niosh for a Health Hazard Evaluation of the potential health risks for loggers from intense, frequent, or prolonged occupational exposures to volcanic ash. Prior to this request, Weyco industrial hygienists had collected and analyzed sedimented bulk and airborne respirable dusts in six ash-affected logging areas in Washington.[73]

The Weyco industrial hygienists found that sedimented and resuspended dusts, including newly deposited volcanic ash, were highly respirable in size and contained 1 per cent to 5 per cent quartz and 1 per cent to 10 per cent cristobolite in the respirable fraction in logging areas affected by ashfalls. The results of air-sampling by Weyco were confirmed by NIOSH investigators: breathing-zone exposures for certain job categories of logging operation exceeded the 50 $\mu g/m^3$ NIOSH-recommended exposure limit for free silica in a substantial portion of samples. As a result of these findings, NIOSH conducted a cross-sectional study of the respiratory status of the Weyco/IWA loggers in Washington and a comparison group of nonexposed loggers in Oregon which provided baseline data for a longitudinal follow-up. [27-29] The results of the baseline and follow-up studies are described in detail in chapter 8.

Dessemination of Public Health Information

Immediately following the May 18 eruption, the news media, government authorities, and members of the public in areas affected by ashfalls sought information and advice about the health effects of volcanic ash from several different sources: local and state public health, environmental quality, and occupational health officials, as well as university affiliated and private practice physicians. There was wide-spread confusion and disagreement about certain common questions that had to be answered rapidly with valid and consistent responses. The questions asked most often concerned the necessity to remain indoors, the advisability of limiting outdoor exercise and sporting events, the risk of exposure for individuals with pre-existing lung disease, the need for respirators outdoors, and the use of automobiles.

Providing answers to these questions was difficult because of the paucity of directly relevant literature.[1 2] This difficulty was compounded during the first days after the May 18 eruption by a lack of data regarding the concentrations of toxic substances in the ash, such as respirable-size crystalline free silica. Even weeks later, the wide variation in "silica" levels determined by different laboratory method hampered efforts to formulate consistent advice to the public. Finally, the potential duration of ash exposure could not be predicted

TABLE 6—Consensus Recommendations to the Public from the Oregon Public Health Committee on Volcanic Ash Fallout, Summer 1980

1	When airborne volcanic dust levels are high, avoid activities which would lead to dust exposure. Examples include jogging, lawn mowing, and dry clean-up of fallen ash.
2.	Persons who must work in dusty situations should wear a mask, recommended by the National Institute for Occupational Safety and Health (coded by the designation, "TC-21-C"), for filtering out small ash particles. Goggles should be considered for eye protection as well.
3.	Remove fallen ash from your property by wetting it first to avoid raising unnecessary dust during clean-up
4	Take caution to avoid motor vehicle accidents and falls caused by slippery or dusty conditions from wet volcanic ash.
5	If you have chronic lung or heart disease and experience an increase in symptoms, consult your physician
6	Don't drive unnecessarily when conditions are dusty.
7	Avoid smoking The hazards of smoking are far greater than any known to be caused by volcanic ash

because no one could reliably predict how long the airborne concentration of respirable-size ash particles would remain elevated from a particular ashfall, or how long new ashfalls would continue to occur.

After the Presidential designation of the disaster area on May 21, 1980, FEMA established an interagency center for coordination of disaster response efforts, dissemination of scientific information, and control of rumors. The center was in Vancouver, Washington where the USGS volcano monitoring and state and local search and rescue operations were located. A NIOSH medical epidemiologist was assigned to work full time with USGS, USDS, and other federal, state, and local disaster response personnel at the FEMA coordinating center in Vancouver. Several other CDC professionals worked with state health department officials in Seattle, Washington and consulted with state officials in Portland, Oregon.

In Oregon, an ad hoc committee was eventually established to provide sound and consistent advice, in spite of early limitations on data concerning ash toxicity. This committee included representatives of state and local public health agencies, both private and university-based physicians, and concerned voluntary health organizations. The committee met to consider available data and to develop consensus recommendations for the public on health questions related to the ashfalls (which first affected the Portland area on Juni 12, 1980). These consensus recommendations, developed in cooperation with federal experts in the FEMA coordinating center, were then communicated to the media and the public (Table 6). This effort successfully reduced the earlier confusion that had resulted from separate, sometimes contradictory, recommendations issued by the various organizations with which committee members were affiliated.

By May 26, 1980, the FEMA Coordinator began publishing a series of Mount St. Helens Technical Information Network Bulletins. 54(1–33)) Field staff from CDC collaborated with FEMA on the health aspects of these bulletins and also published series of CDC Mount St. Helens Volcano Health Reports, initiated on May 30, 1981 and distributed nationally to state and country health officials. 14(1–23) These reports included technical advice on driving and vehicle maintenance in heavy ashfall areas; descriptive and analytical data on the occurrence and distribution of morbidity and mortality due to volcanic hazards; results of bulk ash analyses, area air

TABLE 7—Indices of Centers for Disease Control (CDC) Public Health Bulletins and Federal Emergency Management Agency (FEMA) Technical Bulletins: Information Resources on the Evaluation and Control of Volcanic Hazards

Subject Area	CDC Report Numbers*	FEMA Report Numbers*
Disaster planning	4, 12, 14, 23	4, 25, 28, 34
Deaths, injuries near eruption	10, 15, 16, 19, 23	32
Public health aspects of volcanic eruptions, ashfalls	1–23	1–4, 10, 12, 14, 18, 19, 20, 26 32
Socioeconomic aspects of volcanic eruptions, ashfalls	4, 9–11, 13, 14, 16–18, 20, 23	2b, 5–7, 9, 11, 16, 17, 21–24, 29–31
Collection, analysis of ash	3, 7–9, 12, 13, 16, 23	1, 8, 13, 32, 34
Monitoring and controlling ash, gas exposure in air/water/food	3, 4, 9–12, 14, 15, 17, 18, 22, 23	15, 18, 19, 26, 27, 30, 32
Literature review	8, 10, 13, 18, 21	33

*Copies of CDC reports[14] may be available upon request to: Dr. Henry Falk, CDC/CEH/DEHHE, Atlanta, GA 30333, USA; request FEMA reports[55] from: Bill Brown, FEMA Region 10, Bothell, WA 98101, USA.

sampling, and personal exposure monitoring; results of water and food quality testing; updated descriptions of current and potential volcanic hazards; and guidelines for further predisaster planning and post-disaster reponses, including control of flooding and resuspended ash in affected areas (Table 7). These FEMA and CDC publications provided health professionals and the public with valid, reliable, and timely information about the nature and impact of volcanic hazards and appropriate control measures. Federal, state, and local safety and health officials reported that these publications and daily news briefings at the FEMA Coordinating Center were extremely helpful.[74,75]

Conclusions

Continuing volcanic activity at Mount St. Helens[76] and premonitory activity at other volacanoes in the northwestern United States[77] raise the remote, but serious, threat of further widespread environmental damage and the potential for widespread morbidity and mortality.[78] This chapter has outlined the range of public health concerns and the methods and actions involved in responding to the explosive eruptions of a volcano in a relatively isolated area of western North America.

In developing countries, the human and technical resources available for disaster response effrots are considerably more limited. However, in the West Indies, Indonesia, Japan, and certain other areas, the magnitude and frequency of hazards from volcanic eruptions may rival those associated with other natural disasters which are somewhat more predictable (e.g., severe weather) or less predictable (e.g., earthquakes).[34,79] Considering the expansion of world populations into potentially hazardous volcanic areas and current limitations in the reliability, precision, and availability of predictive monitoring technology, there is a growing need to develop appropriate pre-disaster planning and response measures. Resources for epidemiologic surveillance and epidemic field investigations of suspected outbreaks are needed following widespread environmental damage, mass evacuation, refugee resettlement, and disruption of routine public health services.[33–38]

It is hoped that the experiences following the eruptions of Mount St. Helens described here can serve as a case study in secondary preventive measures for use by populations which are more vulnerable and more often exposed to volcanic hazards.

Summary

A comprehensive epidemiological evaluation of mortality and short-term morbidity associated with explosive volcanic activity was carried out by the Centers for Disease Control in collaboration with affected state and local health departments, clinicians, and private institutions. Following the May 18, 1980 eruption of Mount St. Helens, a series of public health actions were rapidly instituted to develop accurate information about volcanic hazards and to recommend methods for prevention or control of adverse affects on safety and helath. These ***public health actions*** included:

o establishing a system of active surveillance of cause-specific emergency room (ER) visits and hospital admissions in affected and unaffected communities for comparison;

o assessing the cause of death and factors associated with survival or death among persons located near the crater;

o investigating reported excesses of ash-related adverse respiratory effects by epidemiological methods such as cross-sectional and case-control studies; and

o controlling rumors and disseminating accurate, timely information about volcanic hazards and recommended preventive or control measures by means of press briefings and health bulletins.

Surveillance and observational studies indicated that:

o excesses in morbidity were limited to transient increases in ER visits and hospital admissions for traumatic injuries and respiratory problems (but not for communicable disease or mental health problems) which were associated in time, place, and person with exposures to volcanic ash;

o excessive mortality due to suffocation (76 per cent), thermal injuries (12 per cent), or trauma (12 per cent) by ash and other volcanic hazards was directly proportional to the degree of environmental damage—that is, it was more pronounced among those persons (48/65, or about 74 per cent) who, at the time of the eruption, were residing, camping, or sightseeing (despite restrictions) or working (with permission) closer to the crater in areas affected by the explosive blast, pyroclastic and mud flows, and heavy ashfall; and

o *de novo* appearance of ash-related asthma was not observed, but transient excesses in adverse respiratory effects occurred in two high-risk groups—hypersusceptibles (with preexisting asthma or chronic bronchitis) and heavily exposed workers.

Laboratory and field studies indicated that:

o volcanic ash had mild to moderate fibrogenic potential, consisting of > 90 per cent (by count) respirable size particles which contained 4–7 per cent (by weight) crystaline free silica (SiO_2);

o importantly, community exposures to resuspended as only transiently exceeded health limits normally applied to entire working lifetime exposures to free silica; and

o there were no excessive exposures to toxic metals, fibrous minerals, organic chemicals, radon, or toxic gases of volcanic origin in community water supplies or air.

Recommended preventive measures include: avoidance of areas of predicted hazards during premonitory and ongoing volcanic activity and use of respiratory protection and wetting methods to control unavoidable exposures to ash. In densely populated countries with relatively frequent explosive volcanic activity, resources for epidemiological surveillance and investigation are needed following widespread environmental damage, mass evacuation, refugee resettlement, and disruption of routine public health services.

ACKNOWLEDGMENTS

A large number of local, state, and federal government health professionals and scientists, as well as professionals in academia, private industry, and labor, contributed to the efforts described herein. While we can not list all the individuals and the credit which they deserve, we wish to acknowledge their cooperation and assistance. We are particularly grateful for the advice and support of the following individuals: George Rodgers and Drs. Jack Allard, Jean Freach, Clark Health, James Merchant, Gary Stein, John Horan, and Danielle Haber. Previous drafts of this chapter were considerably improved as a result of comments by Drs. Karl A. Western and Christopher Newhall, and other peer reviewers. The editorial assistance of Eillen Kuempel was essential in the preparation of the final manuscript.

REFERENCES

1. Moulton C. Auston I, Kenton C; Biomedical Effects of Volcanoes 138 Selected Citations. USDHHS Pub. No. SBS 1980-1. Bethesda MD: National Library of Medicine, July 1980.
2. MacDonald GA: Volcanological Aspects. *In:* Disaster Prevention and Mitigation: A Compendium of Current Knowledge, Vol. I, Pub. No. GE.77-6194 (7828). Geneva: United Nations Disaster Relief Coordinator (UNDRO), 1976.
3. Blong RJ: Volcanic Hazards. North Ryde, New South Wales, Australia: Academic Press, 1984.
4. Walker GPL: Volcanic Hazards. Interdisc Sci Rev 1982; 7:148–157.
5. White GF (ed): Natural Hazards: Local, National, Global. London: Oxford University Press, 1974.
6. Sheets PD, Grayson DK: Volcanic Activity and Human Ecology. New York: Academic Press, 1979.
7. Crandell DR, Mullineaux DR, Rubin M: Mount St. Helens volcano: recent and future behavior. Science 1975; 187;438–441).

8. Simkin T, Siebert L. McClelland L., Bridge D, Newhall C, Latter JH: Volcanoes of the World: A Regional Directory, Gazeteer, and Chronology of Volcanism during the Last 10.000 Years. Stroudsburg, PA: Hutchinson Ross Publishing (for Smithsonian Institution), 1981.
9. Crandell DR, Mullineaux DR: Potential Hazards from Future Eruptions of Mount St. Helens Volcano, Washington, Geol Sur Bull No. 1383-C. Washington, DC: Govt Printing Office, 1978.
10. Findley R: Eruption of Mount St. Helens. Nat Geographic 1981; 159:3-65.
11. Baxter PJ, Stoiber RE, Williams SN: Volcanic gases and health: Masaya volcano, Nicaragua, Lancet 1982; 2:150-151.
12. Rosenfeld CL: Observations on the Mount St. Helens eruption. Am Sei 1980;68:494-509.
13. Decker R, Decker B; The eruptions of Mount St. Helens, Sci Am 1981;244:68-80.
14. Falk H. Baxter PJ, Ing R, French J, Heath CW, Bernstein RS, Merchant JA: CDC—Mount St. Helens Volcano Health Reports =1-23, Atlanta: Centers for Disease Control, May 30, 1980 to February 23, 1981.
15. Dillman DA, Schwalbe ML, Short JF: Communication behavior and social impact following the May 18, 1980, eruption of Mount St. Helens, *In:* Keller SAC (ed): Mount St. Helens: One Year Later Cheney, WA: Eastern Washington University Press, 1982;173-179.
16. Findley R: Mount St. Helens aftermath. Nat Geographic 1981; 160:713–733.
17. The Columbian Inc: Mount St. Helens Holocaust: A Diary of Destruction. Lubbock, TX: C.F. Boone Publishers, 1980.
18. Anderson J: Mount St. Helens May 18 ashfall: the human ecology of an unanticipated natural hazard. *In:* Keller SAC (ed): Mount St. Helens: One Year Later, Cheney, WA: Eastern Washington University Press, 1982; 181–189.
19. Murphy SA: After Mount St. Helens: disaster stress research. J Psychosoc Nurs Ment Health 1984; 22:8–18.
20. Dillman JJ, Roberts ML: The impact of the May 18 Mount St. Helens ashfall: eastern Washington residents report on housing-related damage and cleanup. *In:* Keller SAC (ed): Mount St. Helens: One Year Later. Cheney, WA: Eastern Washington Uni-

versity Press, 1982; 191–198.

21. MacCready JS: Some economic consequences of the eruptions. *In:* Keller SAC (ed): Mount St. Helens: One Year Later. Cheney, WA: Eastern Washington University Press, 1982; 215–224.
22. Buist AS: Are volcanoes hazardous to your health? West J Med 1982; 138:294–301.
23. Nania J, Bruya TE: In the wake of Mount St. Helens. Ann Emerg Med 1982; 11:184–191.
24. Baxter PJ, Ing R, Falk H, Plikaytis B: Mount St. Helens eruptions the acute respiratory effects of volcanic ash in a North American community. Arch Environ Health 1983; 38:138–143.
25. Shy CM, Goldsmith JR, Hackney JD, Lebowitz MD, Menzel DB: Health Effects of Air Pollution. New York: American Thoracic Society, 1978.
26. Baxter PJ, Ing R, Falk H, French J. Stein GF, Bernstein RS, Merchant JA, Allard J· Mount St. Helens eruptions, May 18 to June 12, 1980: an overview of the acute health impact. JAMA 1981; 246:2585–2589.
27. Merchant JA, Baxter PJ, Bernstein RS, *et al:* Health implications of the Mount St. Helens eruption: epidemiological considerations An Occup Hyg 1982; 26:911–919.
28. Bernstein RS. McCawley MA, Attfield MD, *et al:* Epidemiologic assessment of the risk for adverse pulmonary effects from persistent occupationaal exposures to Mount St. Helens' volcanic ash (tephra). *In:* Keller SAC (ed): Mount St. Helens: One Year Later. Cheney, WA: Eastern Washington University Press, 1982; 207–213.
29. Bernstein RS: Health effects of exposures to volcanic ash from Mount St. Helens. *In:* Johnson RH, Segal E (eds): A Continuing Education Course Hopkins University School of Hygiene and Public Health, 1982.
30. Green FHY, Bowman L, Castranova V, *et al:* Health implications of the Mount St. Helens eruption: laboratory investigations. Ann Occup Hyg 1982; 26:921–933.
31. Gregg MB· The principles of an epidemic field investigation. *In:* Holland WW, Detels R, Knox G (eds): *Oxford Textbook of Public Health: Investigative Methods in Public Health* (Vol. 3). New York: Oxford University Press, 1985; 284–299.
32. Baxter PJ, Bernstein RS, Falk H, French J, Ing R: Medıccal as-

pects of volcanic disasters: an outline of the hazards and emergency response measures. Disasters 1982; 6:268–276.
33. Baxter PJ: Health hazards of volcanic eruptions. J R Coll Phys Lond 1983; 17:180–182.
34. Bernstein RS, Buist AS: Public health aspects of volcanic hazards evaluation and prevention of excessive morbidity and mortality due to natural disasters. Disasters 1984; 8:6–8.
35. Western KA: Epidemiologic Surveillance after Natural Disaster. PAHO Sci. Pub No. 420. Washington, DC: Pan American Health Organization, 1982.
36. Seaman J, de Ville de Goyet C. Donaldson D. Bulle W: Emergency Health Management after Natural Disaster. PAHO Sci. Pub. No. 407. Washington. DC: Pan American Health Organization, 1981.
37. Pan American Health Organization: Emergency Vector Control after Natural Disaster. PAHO Sci. Pub. No. 419. Washington, DC: Pan American Health Organization, 1982.
38. Pan American Health Organization: Environmental Health Management after Natural Disaster. PAHO Sci. Pub. No. 430. Washington, DC: Pan American Health Organization, 1982.
39. US Public Health Service: Promoting Health/Preventing Disease: Objectives for the Nation. Washington, DC: Govt Printing Office, 1980.
40. Bernstein RS, Lee JS: Recognition and evaluation of occupational health problems. *In:* Rom WN (ed): ***Environmental and Occupational Medicine.*** Boston: Little, Brown 1983; 7–19.
41. Fraunfelder FT. Kalina RE, Buist AS, Bernstein RS, Johnson DS: Ocular effects following the volcanic eruptions of Mount St. Helens. Arch Ophithalmol 1983; 101:376–378.
42. Weniger BG. Blaster MJ, Gedrose J, Lippy EC, Juranek DD: An outbreak of waterborne giardiasis associated with heavy water runoff due to warm weather and volcanic ashfall. Am J Public Health 1983; 73:868–872.
43. Ferris BG: Health effects of exposure to low levels of regulated air pollutants: a critical review. J Air Pollut Control Assoc 1978; 28:482–497.
44. Holland WW, Bennett AC, Cameron IR, *et al:* Health effects of particulate pollution: reappraising the evidence. Am J Epidemiol 1979; 110:525–659.

45. Shy CM: Epidemiologic evidence and the United States air quality standards. Am J Epidemiol 1979; 110: 661–671.
46. Thibodeau LA, Reed RB, Bishop YMM, Kammerman LA: Air pollution and human health: a review and reanalysis. Environ Health Perspect 1980; 34:165–183.
47. Whittemore AS, Korn EK: Asthma and air pollution in the Los Angeles area. Am J Public Health 1980; 70:687–696.
48. Samet JM, Hishop Y, Speizer FE, Spengler JD, Ferris BG: The relationship between air pollution and emergency room visits in an industrial community. J Air Pollut Control Assoc 1981; 31: 236–240.
49 Ferris BG, Dockery DW, Ware JH, Speizer FE, Spiro R: The Six-City Study: examples of problems in analysis of the data. Environ Health Perspect 1983; 52:115–123.
50. Lebowitz MD: Utilization of data from human population studies for setting air quality standards: evaluation of important issues. Environ Health Perspect 1983; 52:193–205.
51. American Thoracic Society, Committee of the Scientific Assembly on Environmental and Occupational Health: Guidelines as to what constitutes an adverse respiratory health effect, with special reference to epidemiologic studies of air pollution. Am Rev Respir Dis 1985; 131:666–668.
52. Langmuir AD: The surveillance of communicable diseases of national importance. N Engl J Med 1963; 268:182–192.
53. Eisele JW. O'Halloran RL, Reay DT, Lindholm GR, Lewman LV, Bradv WJ: Deaths during the May 18, 1980 eruption of Mount St. Helens. N Engl J Med 1981; 305:931–936.
54. Parshley PF, Kiessling PJ, Antonius JA, Connel RS, Miller SH, Green FHY: Pyroclastic flow injury: Mount St. Helens, May 18, 1980. AM J Surg 1982; 143:565–568.
55. Federal Emergency Management Agency (FEMA): Mount St. Helens Technical Information Network Bulletins #1-33. Bothell, WA: FEMA, May 27, 1980 to July 1, 1980.
56. Langran K, Terich T. Government response to the Mount St. Helens disaster: a study of perceptions and attitudes in the Longview-Kelso and Yakima areas. *In:* Keller SAC (ed): Mount St. Helens: One Year Later. Cheney, WA: Eastern Washington University Press, 1982; 167–170.

57. Hull AN: Mount St. Helens: The value of preparing a meteorological and hydrological contingency plan for a highly unlikely event—volcanic eruption. *In:* Keller SAC (ed): Mount St. Helens: One Year Later. Cheney, WA: Eastern Washington University Press, 1982; 171–172.
58. Criteria for a Recommended Standard, Occupational Exposure to (Respirable) Crystalline (Free) Silica. DHHS (NIOSH) Pub. No. 75-120. Washington, DC: Govt Printing Office, 1974.
59. Vallythan V, Menthnech MS. Stettler LE, Dollberg DD, Green FHY: Mount St. Helens' volcanic ash: hemolytic activity. Environ Res 1983; 30:349–360.
60. Vallyathan V, Reasor M, Stettler LE, Robinson V, Bernstein RS: Comparative in vitro cytotoxicity of volcanic ashes from Mount St. Helens, El Chichon, and Galunggung, J Toxicol Environ Health 1984; 14:641–654.
61. Nolan RP, Langer AM, Harington JS, Oster G. Selikoff IJ: Quartz hemolysis as related to its furface functionalities. Environ Res 1981; 26:503–520.
62. Vallyathan V, Mentnech MS, Tucker JH, Green FHY: Pulmonary response to Mount St. Helens' volcanic ash. Environ Res 1983; 30:361–371.
63. Green FHY, Dollberg DD. Tucker JH, Kiessling P: Toxicity of Mount St. Helens volcanic ash and relevance to mining populations. *In:* Wagner WL, Rom WN, Merchant JA (eds): Health Issues Related to Metal and Nonmetallic Mining, Boston: Butterworth Publishers, 1983; 105–121.
64. Green FHY, Vallyathan V, Menthnech MS, *et al:* Is volcanic ash a pneumoconiosis risk? Nature 1981; 293:216–217.
65. Castranova V, Bowman L, Shreve JM, Jones GS, Miles PR: Volcanic ash: toxicity to isolated lung cells. J Toxicol Environ Health 1982; 9:317–325.
66. Medical Research Council's Committee on the Aetiology of Chronic Bronchitis: Standardized questionnaires on respiratory symtpoms. Br Med J 1960; 2:1665.
67. Leus X, West CM: Asthmatic bronchitis associated with a volcanic eruption in St. Vincent, West Indies. Disasters 1981; 5:67- 69
68. Boushey HA, Holtzman MJ, SHeller JR. Nadel JA: Bronchial hyperreactivity. Am Rev Respir Dis 1980; 121:389–413.
69. Weiss ST, Tager IB, Weiss JW, Munoz A, Speizer FE, Ingram RH:

Airways responsiveness in a population sample of adults and children. Am Rev Respir Dis 1984; 129:898–902.
70. Buist AS, Johnson LR, Kanarek PH, Sexton GJ, Killian DM: Acute effect of Mount St. Helens Ash on children. Chest 1982; 81S:70S.
71. Hewett P, Bernstein RS: Evaluation of personal exposures to volcanic ash at the Gales Creek Camp for Diabetic Children, Glenwood, Oregon. DHHS (NIOSH) Technical Assistance Report No. MTA 80-116-34M. Morgantown, WV: National Institute for Occupational Safety and Health, 1980.
72. Johnson KG, Loftsgaarden DO, Gideon RA: The effects of Mount St. Helens volcanic ash on the pulmonary function of 120 elementary school children. Am Rev Respir Dis 1982; 126: 1066–1069.
73. Lewis DP: An evaluation of worker exposure to Mount St. Helens' volcanic ash in logging operations. Master of Science Thesis in Public Health. Seattle, WA: University of Washington, 1981
74. Brown WL: Areas of controversy. *In:* Keller SAC (ed): Mount St. Helens: One Year Later. Cheney, WA: Eastern Washington University Press, 1982; 165–166.
75. Shearer C: United States Geological Survey Programs. *In:* Kerr JW (ed): Mount St. Helens Scientific Workshop. NSF Pub. No. RA-800552. Washington, DC: National Science Foundation, 1981; 11–14.
76. Swanson DA, Casadevall TJ, Dzurisin D, Malone SD, Newhall CG Weaver CS: Predicting eruptions at Mount St. Helens, June 1980 through December 1982. Science 1983; 221:1269–1376.
77. Bailey RA, Beauchemin PR, Kapinos FP, Klick DW: The Volcano Hazards Program. Objectives and Long-Range Plans. US Geological Survey Open-File Report 83-400, 1983.
78. Kerr RA. Volcanoes to keep an eye on. Science 1983; 221: 634-635
79. Tomblin JF: Earthquakes, volcanoes, and hurricanes: a review of natural hazards and vulnerability in the West Indies. AMBIO 1981; 10:340--345.