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HEALTH IMPLICATIONS OF THE MOUNT ST. HELENS' ERUPTION: EPIDEMIOLOGICAL CONSIDERATIONS

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Abstract—The devastating 18 May 1980 eruption of Mount St. Helens presented an opportunity to evaluate the acute and potential chronic health effects associated with a major volcanic event. Investigations included assessment of immediate deaths around the volcano, surveillance of hospital visits and admissions in two ash exposure areas in the State of Washington, environmental dust exposures in five affected communities, free silica determinations on several respirable ash samples, and a cross-sectional epidemiological and environmental study of loggers (and unexposed control loggers) likely to have high and prolonged ash exposures. Sixty-three people were killed or missing; an important cause of death was asphyxia from dense ash exposure. Total suspended particulate concentrations in Central and Eastern Washington were quite high in the week following 18 May, but quickly fell to lower levels, except for workers involved in clean-up. Hospital visits and admissions for respiratory disease, especially for asthma, increased following the major eruption, but were not markedly increased in areas affected by a milder second eruption. Loggers were found to have moderate ash exposure which, within six weeks of the major eruption, was associated with an increase in acute respiratory symptoms, but no measurable difference in lung function. Free silica levels of 3 to 7%, as determined from respirable ash samples, suggest some potential for lung damage which is being assessed prospectively.

INTRODUCTION

MOUNT ST. HELENS has long been regarded as among the most beautiful of the volcanically active Cascade mountains in the northwestern United States. In the Spring of 1980, that changed dramatically. In March, volcanic activity was first noted in Mount St. Helens and on 27 March the initial, but very small, eruption occurred. Several more small eruptions and earthquakes followed over the next several weeks and an ominous bulge formed over the north face. With the possibility of a major volcanic event, the area around the mountain was largely evacuated. On 18 May, a devastating eruption occurred. Within seconds, an earthquake over the bulging north face laid open the mountain in a lateral devastating hurricane extending 180° and 30 km from west to east and out more than 20 km from the volcano's summit. Approximately 2.5 km^3 of ash, lava and stone was displaced, leaving a huge crater. Virtually everything within 10 km of the blast was destroyed; mudflows and deposits of pyroclastic flow left a crater-pocked moonscape.

An estimated one billion board feet of prime timber over an area of 125 square miles and valued at 500 million dollars was destroyed or blown down. Several additional millions of dollars worth of logging equipment, roads, railroads and bridges was lost.

Damage to lakes and rivers was extensive. An estimated 70 million trout and salmon were lost together with several thousand elk, deer, bear, cougar and mountain goat. Millions of cubic yards of silt clogged the Cowlitz river, the North and South forks

of the Toutle river and the Columbia river, trapping 30 ocean going vessels and requiring extensive dredging.

Within the first week of the 18 May eruption, the State of Washington requested the Centers for Disease Control and the National Institute for Occupational Safety and Health to provide technical assistance in the evaluation of health effects arising from the eruption. As a result, a series of epidemiological and laboratory investigations was begun.

METHODS AND RESULTS

Surveillance efforts initially concentrated on the volcano's exigent casualties. Depicted in Fig. 1 is the proximal blast area extending directly from the summit northward. The large area where timber was blown down and a fringe of a few kilometers in which further timber was destroyed are also shown. No bodies were removed in the immediate mud flow area. Many of the 32 persons officially missing are thought to be in the immediate blast area. Thirty-one bodies were recovered; 25 of these were in the tree blown down area. The most frequent cause of death was asphyxiation. Details are given in Table 1.

A dense cloud of volcanic ash extended eastward over the States of Washington, Idaho, Montana and North Dakota where measurable levels of ash were deposited. The ash thickness in some areas of Central Washington reached as much as 2–4 inches. From the Environmental Protection Agency stationary air sampling stations, indications of total suspended particulate concentrations are available. In Yakima, one of the most heavily hit cities in Central Washington, dust concentrations reached as high

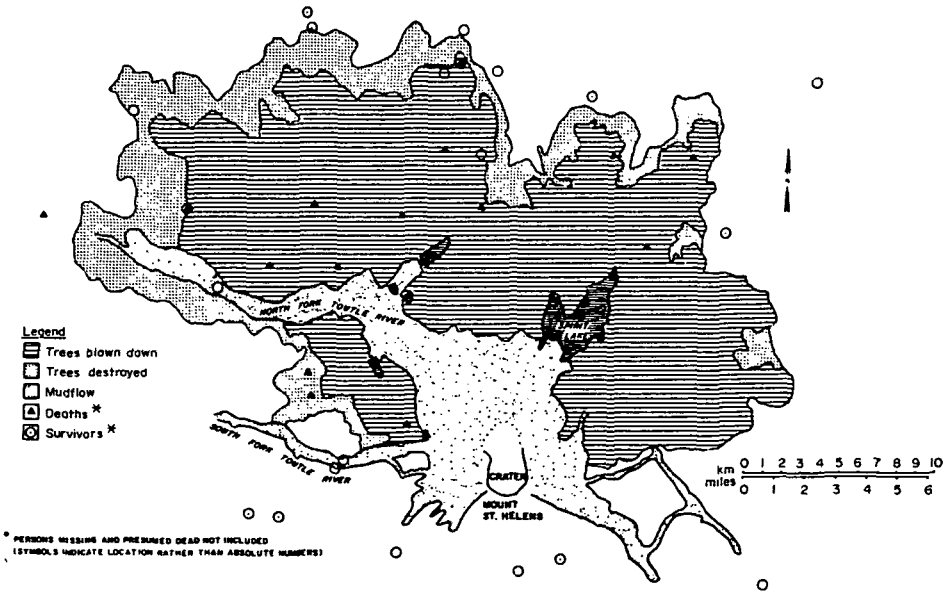

FIG. 1. Deaths and survivors from the 18 May eruption of Mount St. Helens. Source: CDC—Mount St. Helens Volcano Health Report No. 19.

TABLE 1. DEATHS AROUND THE VOLCANO (AS OF 22 AUGUST 1980)

Officially missing	32
Recovered dead	31
In blast area	0
In tree blown down area	25
Severe blast injury	1
A fall	1
Flying rock	1
Falling trees	3
Asphyxia	16
Severe burns	3
Burn complications	2*
In tree destruction area	2
Asphyxia	1
Burns (gasoline?)	1
Outside tree destruction area	
Asphyxia	2

* Hospital deaths.

Source: CDC—Mount St. Helens Volcano Health Report.

as 35.6 mg/m^3 and averaged 13.3 mg/m^3 over the first week; it was not until rain occurred on the 26th that dust levels dropped abruptly, but still remained somewhat elevated, averaging 0.22 mg/m^3 from 26 May to 23 June.

A five community environmental survey evaluated respirable dust exposure in a number of jobs dealing directly with the clean up operation or in workers likely to be heavily exposed (such as forest workers or agricultural workers) and revealed moderate dust exposure (Table 2a). Some individual concentrations reached as high as 5 mg/m^3 among forestry workers, and in some communities as many as a third of the samples on clean-up crews exceeded 0.8 mg/m^3. Area sampling in schools, homes, commercial establishments, and in enclosed automobiles found dust concentrations to be quite low. A good deal of variation occurred in dust level from community to community (Table 2b). A number of samples were studied extensively for their 'free silica' content, for fibres and for trace metals. X-ray powder diffraction, infrared spectrophotometry, light microscopy and electromicroscopy, together with utilization of a wet chemical method developed by Talvitie, revealed there were low concentrations of quartz, cristobalite and possibly tridymite in all samples studies: Table 3 describes the per cent of free silica from 10 μm samples collected in a number of communities in eastern and central Washington; it varied from 3–7%. No fibres were identified nor were levels of trace metals found to be unusual.

Within the first week of the 18 May eruption, a hospital surveillance system was instituted in order to assess potential health effects among community residents. Both emergency room visits and hospital admissions were monitored by telephone in ten hospitals in central and eastern Washington and in eight hospitals in western Washington, an area spared by the initial eruption. Shown in Table 4a are hospital pulmonary admissions in eastern Washington hospitals. There was a clear increase in pulmonary admissions beginning the week of 18 May, the day of the major eruption. It should be noted, however, that these findings may be somewhat misleading: physicians'

TABLE 2. FIVE COMMUNITY ENVIRONMENTAL SURVEY OF VOLCANIC ASH—WASHINGTON AND IDAHO, JUNE 1980

(a) *Average concentration of respirable dust, by job*

Job	mg/m^3
Clean-up crews	
hand-shoveling and sweeping	0.46
sweeper truck or broom truck drivers	0.64
front end loader operators	0.50
grader operators	0.56
water truck drivers	0.21
truck drivers	0.19
manual hosing	0.05
Rubbish workers	0.67
Idaho forest worker	0.48
Agricultural worker	0.55
Law enforcement personnel	0.10
Area samples	
homes	0.03
schools	0.06
commercial establishments	0.09
autos	0.10

(b) *Differences between communities (personal samples)*

Area	Respirable (mg/m^3) $\bar{x}_g$ (s_g, n)	Total (mg/m^3) $\bar{x}_g$ (s_g, n)
Spokane	0.17 (2.56, 37)	1.18 (3.58, 7)
Moses Lake	0.48 (2.65, 30)	2.43 (4.86, 17)
Longview Area	0.14 (4.02, 29)	0.40 (7.34, 17)
Centralia–Chehalis	0.12 (3.46, 31)	0.44 (4.95, 12)
Yakima	0.35 (2.68, 26)	0.68 (7.47, 9)

$\bar{x}_g$ = geometrical mean, s_g = geometrical standard deviation, n = number of samples.
Source: CDC—Mount St. Helen's Volcano Health Report no. 12.

offices and clinics were necessarily closed in many of these communities because of the dense dust cloud and some individuals were probably admitted to a hospital, who might otherwise have been treated as outpatients. Alternatively, in western Washington hospitals little change in hospital pulmonary admissions was noted with the exception of a very slight increase following the 25th May ash fall (Table 4b).

Generally, emergency room visits followed the same pattern as did hospital admissions. Shown in Table 5 are respiratory diagnoses in the two hospitals in Yakima, which had a heavy ash fall. A clear increase in respiratory diagnoses began the week of 18 May but diminished somewhat during the three succeeding weeks. Although all respiratory diagnoses appeared to increase, prominent among the increases of 18 May, and not surprisingly, was a diagnosis of asthma. Again it should be noted that the data from 18 May may be confounded by the closing of some physicians' offices in Yakima during that week.

Of principal concern was ash exposure to forestry workers in the immediate area of Mount St. Helens. Early exposures of respirable dust reached as high as 5 mg/m^3 among forestry workers. Immense dust clouds were generated when felling the douglas

TABLE 3. PER CENT 'FREE SILICA' DETERMINED BY X-RAY DIFFRACTION IN WASHINGTON COMMUNITIES

Sample	Per cent Silica XRD untreated	Talvitie colorimetric	XRD treated*
Ellensburg 1	6.98	7.69	4.55
Yakima 3	7.68	5.96	5.50
Spokane 4	6.10	5.42	5.26
Centralia 5	10.20	7.82	6.82
Chehalis 6	8.26	6.50	4.69
Moses Lake 7	4.00	4.76	3.38
Moses Lake 8	3.70	3.23	3.16
Spokane 9	3.50	4.47	2.63
Spokane EPA	6.85	4.87	5.20

*Sample treated with hot phosphoric acid to remove plagioclase silicates using method developed by Talvitie.

Source: DOLLBERG, D. D. SWEET, D. V., BOLYARD, M., CARTER, J. W., STETTLER, L. E., GERACI, C. L., JR. (1980). Mount St. Helens Volcanic Ash: Crystalline Silica Analyses. Division of Physical Sciences and Engineering, National Institute for Occupational Safety and Health, Centers for Disease Control, Public Health Service, Department of Health and Human Services.

fir, which usually reach 4–5 ft in diameter. These dust clouds persisted for up to 15 min, delaying further cutting. As a result, a prospective study of loggers was begun in an area adjacent to the blow down area between the north and south forks of the Toutle river (Fig. 1).

A total of 471 ash exposed loggers and 226 control loggers, well away from the ash exposed area, were studied in June 1980 using a standard respiratory questionnaire, spirometry, chest radiography and environmental sampling. Airborne samples of the loggers' personal exposures to 'volcano dust' were collected for respirable and total dust using tared polyvinyl chloride filters and battery-operated personal sampling pumps. Respirable samples were collected using 10 mm cyclones with pulsation dampened pumps and total dust samples were collected using 2-piece cassettes sampling 'closed face'. Choker setters and cutters were found to have the highest dust concentrations (Table 6). Dust concentrations, however, did not differ greatly between control and exposure areas.

In Table 7a it is noted that the ash exposed group and the non-ash exposed control group are similar in regard to demographic, smoking and work history. Crude prevalence rates of 'chronic symptoms' reveal the two groups also had similar frequencies of persistent cough and phlegm, dyspnea, wheezing and chest illness (Table 7b). However, when questions were asked concerning symptoms since the 18 May eruption, nearly all respiratory symptoms were increased in the ash exposed group (Table 7c). This may be related in part to the intense interest of the media in potential health effects from ash exposure. Eye irritation was a frequent complaint and has continued to be a principal complaint of the loggers working in the ash exposed area.

TABLE 4. HOSPITAL PULMONARY ADMISSIONS

(a) EASTERN WASHINGTON

Location	11–17 May	18–24 May*	25–31 May	1–7 June	8–14 June
Ritzville	2	13	1	1	1
Moses Lake	3	5	7	1	5
Othello	9	17	4	6	2
Yakima 1	8	19	12	13	10
Yakima 2	7	14	7	8	6
Pullman	2	1	4	2	0
Soap Lake	0	0	1	1	0
Ellensburg	1	5	4	5	4
Ephrata	3	1	5	0	6
Spokane 1	9	17	14	9	NA

* First volcanic eruption with area ashfall: 18 May, 1980.

(b) WESTERN WASHINGTON

Location	11–17 May	18–24 May	25–31 May*	1–7 June	8–14 June
Centralia	5	4	6	0	NA
Chehalis	1	3	3	5	3
Longview 1	21	10	17	13	14
Longview 2	10	4	8	3	2
Aberdeen 1	4	5	12	10	NA
Aberdeen 2	6	7	7	10	5
McCleary	1	0	5	1	3
Shelton	5	4	1	3	4

* Second volcanic eruption with area ashfall: 25 May 1980.
Source: CDC–Mount St. Helens Volcano Health Report No. 8.
NA = Not available.

Lung function tests revealed that both the ash exposed and comparison groups had excellent lung function relative to accepted standards and did not differ (Table 7d). Changes in lung function over a working shift were studied in a subgroup of cutters in the ash exposed area and in the control area (Table 7e). Although total dust concentrations were measured as twice as high among those with ash exposure, no difference in lung function over a working shift was noted between groups and the declines in lung function were quantitatively small.

CONCLUSIONS

Although much remains to investigate, a number of lessons have already been learned from the Mount St. Helens eruption.

(1) Undoubtedly, preparedness greatly reduced the immediate loss of life from the initial blast. Detailed plans for evacuation, monitoring of ash concentrations, surveillance for health effects and public education should be made well in advance in such situations.

TABLE 5. EMERGENCY ROOM VISITS FOR RESPIRATORY DIAGNOSIS FOR TWO HOSPITALS IN YAKIMA 4 MAY–14 JUNE 1980

Respiratory diagnosis	4–10 May	11–17 May	18–24 May*	25–31 May	1–7 June	8–14 June
Hyperventilation	0	0	10	4	2	1
Airway irritation	0	0	9	2	1	1
Cough	2	5	11	8	5	3
Wheezing	1	1	3	1	3	3
Shortness of breath	4	8	23	8	5	6
Asthma	17	4	38	15	17	17
Bronchitis	20	12	27	20	21	24
Chronic bronchitis/ COPD/emphysema	5	4	12	9	3	8
Subtotal	49	34	133	67	57	63
Other respiratory†	102	78	99	103	109	138
Total	151	112	232	170	166	201

* First eruption, 18 May had primary impact in eastern Washington.

† Other respiratory symptoms include epistaxis, fever only, hay fever–allergy, URI–cold–viral syndrome, tonsillitis, oral thrush, pharyngitis–laryngitis, sore throat, pneumonia, penumonitis, pneumothorax, hemoptysis, and other upper respiratory and pulmonary syndromes.

Source: CDC—Mount St. Helens Volcano Health Report No. 17.

TABLE 6. DUST CONCENTRATIONS AMONG LOGGERS BY JOB, JUNE–JULY 1980

Job	Exposure (mg/m³). $\bar{x}_g(s_g, n)$ Ashfall area—Washington Respirable	Ashfall area—Washington Total	Control Area—Oregon Respirable	Control Area—Oregon Total
Cutter	0.77 (2.55,53)	5.97 (2.95,10)	0.52 (1.83,20)	2.81 (1.46,5)
Choker setter	1.20 (3.16,11)	8.31 (5.50,2)	0.57 (6.23,3)	—
Truck driver	0.11 (3.12,9)	0.49 (—,1)	0.20 (1.97,6)	—
Yarder and loader operators	0.09 (2.64,19)	0.13 (3.84,6)	0.16 (1.81,3)	0.17 (1.04,2)
Landing man	0.19 (3.06,14)	1.52 (5.24,5)	0.16 (1.49,2)	—

$\bar{x}_g$ = geometrical mean, s_g = geometrical standard deviation, n = number of samples.

(2) The hospital surveillance network provided a rapid assessment of immediate health effects in affected communities. Results from this surveillance system suggest that many of the afflicted persons in heavy ashfall areas were those with pre-existing airways diseases.

(3) The occupational group which appears to be at greatest potential risk to continued ash exposure is loggers working in the immediate area of Mount St. Helens. Cross-sectional data suggest some increases in acute respiratory and eye symptoms, but no effect on lung function. As these loggers move into the tree blow down area to recover that timber, their dust exposures and silica levels, together with their lung function, will be followed prospectively.

TABLE 7. CHARACTERISTICS, SYMPTOMS PREVALENCE AND LUNG FUNCTION OF LOGGERS, WASHINGTON–OREGON, JUNE–JULY 1980

	Ash exposed	Not ash exposed
(a) Demographic, smoking and exposure characteristics—mean values		
Number	471	226
Age (years)	37	36
Height (cm)	176	176
Smokers (%)	35	35
Packs per day (all workers)	21	23
Tenure (years)	12	14
Other exposure (years)	1	2
(b) Crude "chronic symptom" prevalence (%)		
Persistent cough	12	18
Persistent phlegm	16	16
Dyspnea	4	3
Wheeze	26	26
Chest illness	8	7
(c) Crude symptom prevalence since 18 May (%)		
Day cough	31	15
Day phlegm	32	14
Dyspnea	4	3
Chest tightness	16	8
Wheeze	18	11
Stuffy nose	49	24
Headaches	37	18
Dizziness	6	4
Chest pain	10	5
Eye irritation	62	15
(d) Lung function (mean values)		
Observed FVC (L)	5.3	5.4
Predicted FVC (L)*	4.8	4.8
Observed FEV_1 (L)	4.0	4.0
Predicted FEV_1 (L)*	3.9	3.9
(e) Shift changes in lung function among cutters and fellers (mean values)		
	($n=39$)	($n=25$)
Δ FVC (L) (post-shift—pre-shift)	−0.036	−0.032
Δ FEV_1 (L) (post-shift—pre-shift)	−0.036	−0.041

* Values from Knudson *et al.* (1976).

DISCUSSION

BARBARA D. BECK: At the Harvard School of Public Health, we have also carried out some tests on the volcanic ash from the Mount St. Helens' eruption on 18 May 1980, in an attempt to predict the potential health effects on exposed populations. The ash was collected on 20 May from the Moses Lake region and a respirable-size fraction was prepared in the laboratory by water sedimentation. The ash was tested in a short-term bio-assay system using hamsters exposed by intra-tracheal instillation. The animals were sacrificed 24 h after exposure and their lungs were lavaged with physiological saline. Several biochemical and cytological components were estimated quantitatively on the lavage fluid; these included lactate dehydrogenase (a cytoplasmic enzyme), peroxidase and glucosaminidase (lysomal enzymes), albumin (a serum protein) and cell numbers and types. In addition, *in situ* particle clearance was determined. Basically, we found that the response was much less than that to α-quartz (a highly toxic dust) and to granite although greater than that in saline-exposed controls. The response to volcanic ash was comparable to that produced to a challenge by aluminium oxide, a relatively biologically inert dust. We therefore agree with Dr Green's conclusions that the volcanic ash exhibits only mild toxicity and may not prove a severe threat to public health. A fuller description of the hamster bio-assay system is given in the presentation by T. J. SMITH *et al.* (pp. 435–448), this symposium).

J. L. ABRAHAM: I would like to comment briefly on my experience with a comparison of the ashes from two volcanic eruptions (Mount St. Helens, 1980, and Mount Augustine, Alaska, 1976) and a human lung biopsy specimen taken 2 yr after exposure to the dust of the earlier eruption. The man from whom the lung-biopsy specimen was taken had several weeks' exposure while collecting geological samples near Mount Augustine during which time he reported heavy dust exposure and respiratory 'irritation'. Approximately 2 yr later he had an open lung biopsy for evaluation of progressive shortness of breath. No other toxic exposures have been identified to date. The biopsy showed focal end-stage fibrosis and focal accumulation of dusty macrophages. Dust particles from the lung tissue and in the ash samples of both eruptions were analysed using scanning electron microscopy (SEM) and energy-dispersive X-ray analysis (EDXA). The results showed virtual identity between the ash from the two different sources, each having 2–5% free silica, 80–85% silicates (Na, Al, K, Ca, Fe, Si constituents indicating feldspar group) and 10–15% of other material (Fe, Ti, etc.). There were very few fibrous magnesium silicates in the five samples examined (less than 0.1% of the individual particles). The particles from the lung sample were of basically the same materials. Previous studies of silicate pneumoconiosis in man and animals have shown almost complete agreement between particles from tissue and the corresponding environmental source.

F. H. Y. GREEN: You showed electron micrographs of fibrous particles in sedimented samples of volcanic ash from the recent eruption of Mount St. Helens volcano. The studies conducted by NIOSH and by others (FRUCHTER *et al.*, *Science N Y* 1980, **209**, 1116, and HOOPER *et al.*, *Science N Y* 1980, **209**, 1125) have failed to reveal fibrous minerals in a large number of samples from each of the eruptions. In view of the public health importance of your observations I would like to ask, firstly, what is the likelihood of the sample being contaminated at source? Secondly, do you have crystallographic data on these fibres? And, finally, what proportion of the sample(s) (by count or weight) was fibrous?

J. L. ABRAHAM: I did not mean to imply any imminent health hazard from the fibrous minerals in the volcanic ash. As I said, the percentage of fibrous particles in the ash samples was very small and it would be surprising to find no fibrous silicates in the various geological formations fragmented and aerosolized during a major volcanic explosion. The answers to your specific questions are as follows:

(1) The sample collections were not under my control, but I examined several different Mount St. Helens' samples (taken hundreds of miles and weeks apart) in addition to the Mount Augustine sample and the lung-biopsy specimen. Since I have not had similar analytical results from dozens of other soil and air samples, it seems unlikely that the constancy of composition of the volcanic ash samples is a result of contamination. The method of examination I used (SEM) probably accounts for the fact that I found some fibres; it is a more efficient means of searching particle preparations than methods used in other laboratories (e.g. TEM).

(2) As the number of fibres was so small, I have not been able to obtain any diffraction data. The Mg:Si:Fe elemental ratio would suggest that some of the mineral is an amphibole such as amosite. Some sort of fibre-enrichment procedure would be necessary before crystallography could be carried out on these samples.

(3) I would estimate the proportion of fibrous particles in the whole, by number, to be from 0.01 to 0.1% in the settled ash, small particle fraction (i.e. less than 10 μm).