PREVENTIVE HEALTH MEASURES IN VOLCANIC ERUPTIONS

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Introduction

Major volcanic eruptions are often preceded sufficiently far in advance by premonitory events to enable geologists and emergency workers to plan for a possible disaster. However, some of the severest eruptions have occurred without apparent warning; such an explosive eruption in populated areas will inevitably lead to a heavy loss of life in the vicinity of the volcano. It is fortunate that these eruptions are rare because it is impossible for all dormant as well as active volcanoes to be continually monitored by geologists. Hazard evaluation and emergency planning for an eruption should therefore be done for all volcanoes in populated areas irrespective of their apparent state of activity.

The following general recommendations are based on experience with Mount St. Helens and are intended for health workers who become involved in either the planning for or management of volcanic disasters. They are intended to be applicable in both affluent and developing countries. Specific advice on relief and rescue operations, including medical treatment, is not included. The emphasis is on prevention: medical treatment has only a limited place in alleviating the worst consequences of volcanic disaster. The reader is advised to consult the general references 1–3 and other parts of this Supplement, using this chapter as a check-list when preparing a plan.

Assessment of the Volcano (Table 1)

Volcanologists will predict the way a particular volcano will behave from information on its previous behavior (if known) and its

geological characteristics. The key geological information required by health workers is summarized in Table 1. In general, volcanoes which are mainly effusive pose the least risk: lava flows tend to be slow moving and little ash is produced, most of which is coarse-grained (non-respirable) and contains little, if any, crystaline silica with potential to cause silicosis. Volcanoes with explosive characteristics are, on the other hand, the most dangerous. Furthermore, after a catastrophic explosive eruption, further eruptions (usually of decreasing violence) must be anticipated.

Emergency Measures in the Vicinity of the Volcano (Table 2)

Explosive eruptions usually cause most damage within a few kilometers of the volcano, the main agents being explosive blast, mud flows, and glowing avalanches. Because gravity plays the greatest part in the movement of mud flows and glowing avalanches, low-lying areas and river valleys draining the mountains may be at risk for distances of many kilimeters. Geologists should be able to predict the relative importance of these and the other hazards listed in Table 2.

The only effective protection against these devastating forces is to demarcate restricted areas and evacuate communities and workers at most immediate risk. Long-term evacuation may obviously result in severe socioeconomic disruption and should never be recommended without sound reasons. Decisions on the boundaries of restricted zones, including the need for evacuation, are essentially political judgments to be taken by government officials on the basis of advice received from volcanologists. The views of emergency services and health officials among others also need to be considered. However, despite the paucity of available data from previous eruptions, it is evident that the expected number of injured survivors who could benefit from emergency medical treatment is likely to be quite small compared with the number of people killed within minutes of a catastrophic eruption. A similar ratio of dead to injured also applies to the flooding which may result from mud flows or melting snow and ice. Neverthless, a few survivors suffering from severe burns and trauma must be anticipated.

Urgent planning measures may include:

o Welfare of evacuees who may have to be relocated for many months;

o Precautions, including emergency warning and evacuation plans for communities at risk of floods along rivers draining the volcano;

o Search and rescue plans for the dead and any marooned survivors;

o Sites of emergency field morgues and their staff;

o Rehearsal of local hospital emergency plans for sudden influx of victims with body surface burns and lung damage from the inhalation of hot ash, and all kinds of trauma;

o Informing local communities of action to be taken when an eruption becomes imminent and after it has occurred;

o Advice and equipment for people who are temporarily permitted to work in restricted areas, including devising an alert system for emergency evacuation if an eruption is imminent, and survival measures in the event of an eruption in which workers could become marooned for days. This information should be encapsulated in a hand-out (Figure 1).

In the rare event of a ground-level release of toxic gas (e.g., from a vent in the volcano's flanks) equipment for emergency air monitoring for SO_2, H_2S and CO_2 and other gases (Table 2) should also be available.

Emergency Measures at a Distance from the Volcano

Ashfall can have health implications for populations as far as hundreds of kilometers away from a massive eruption (Table 3). The period when exposure to respirable ash particles will be at its greatest is during the ashfall and in the few days, or even weeks, after an eruption, a period when many outdoor activities will, in any case, be inevitably curtailed. Rainfall is a key factor in clearing the air of ash and minimizing resuspension by winds and traffic. In addition, rain will wash out soluble toxic elements from settled ash in a matter of weeks. It is, therefore, in dry areas that ashfalls may pose the greatest problems.

Ash Collection and Analysis

Laboratory tests for toxicity are essential to protect human and animal life. Specimens of ash must be carefully collected from each eruption at different distances from the volcano and in relation to the likelihood of human exposure, preferably by a pre-arranged net-

TABLE 1—Health and Safety Hazards According to Characteristics of Volcano, Magma, Eruption

Characteristics	Main Hazards
Volcano	
Effusive (little or moderate danger)	Lava flow; gases
Explosive (very dangerous)	Blast, heat: Destruction around volcano, perhaps for many miles, especially low lying areas and valleys Fine ash: Respiratory illnesses Eye irritation Toxicity Destruction of habitat Gases Tidal waves (Tsunami)—rare
Effusive and explosive	All of the above
Magma	
Total content of silicon containing minerals:	
<55% (effusive)	Little if any risk of silicosis
>55% (explosive)	Risk of silicosis if ash particles of respirable size (<10 μm) and containing crystalline silica
Eruption	
Effusive:	
Hawaiian	Gases, lava flow
Explosive:	
Strombolian	Explosions
Vulcanian	Explosions, ash and gases
Peleean	Glowing avalanches (burns, asphyxiation)
Plinian	Explosions, ash
Phreatic	Explosions, ash

work of collaborators. A clean plastic sheet laid on a flat roof, e.g., a hospital, is best, with the ash being transferred to a clean glass jar for dispatch to the laboratory together with details of the location, time, weather, and mode of collection (Table 4). A specialized laboratory is required for analysis of the ash for particle size and shape and crystalline silica content, but studies of leachable toxic elements adherent to the surface of the ash can be done by general chemical laboratories. It is essential to exclude the presence of high concentrations of leachable fluoride which may contaminate food and water and poison livestock. There should be a local laboratory capable of performing this test as transport of specimens to a central laboratory may be impossible for several days after a heavy ashfall. Inexpensive portable equipment for fluoride estimations in water is available commercially.

Respiratory and Eye Protection

Inexpensive, disposable, high efficiency masks (i.e., capable of filtering particles sub-micrometre size) are now available which can be stocked locally before an eruption for immediate distribution to communities after an ashfall. Halfmask respirators or airstream helmets (powered visor respirators) and goggles should be available for emergency and other outdoor workers and clean-up crews. Residents should be advised that weatherproofing their homes will reduce infiltration of fine ash. North American housing generally provides an effective barrier. Airborne ash will mostly affect persons with asthma and other respiratory diseases, but everyone should be advised to stay indoors when the ash is falling or being resuspended by strong winds. In developing countries where poor nutrition and infectious diseases are important causes of premature mortality, children may also be at special risk; little is known about the respiratory effects of ash in such communities. Silicosis is a potential problem to outdoor workers if they are exposed for long periods to high concentrations of ash with an elevated crystalline silica content. Silicosis is not a major consideration for the general community or emergency workers, but for others whose regular occupation is outdoors (e.g., farmers, loggers) special recommendations may be necessary. These should ideally be based on laboratory analyses of ash, and field studies incorporating measurements of total and respirable levels of ash in the breathing zone of workers.

In our opinion, recommendations on occupational exposure levels for respirable volcanic ash should be based on regarding this substance as any other siliceous dust, for which there are agreed methods of calculating exposure limits in industrial settings, usually over 8-hour periods. There is currently no scientific basis for guidance on ambient air levels or 24-hour exposures to lower concentrations of fine ash in the general community which, of course, includes the sick, the elderly and children; air quality standards in industrialized countries for fossil fuel pollutants (i.e., total suspended particulates and SO_2) are not applicable.

Air Monitoring

Measurement of levels of airborne ash in cities is nevertheless useful for monitoring local conditions and relating these to morbidity and mortality. Some cities in industrialized countries which

TABLE 2—Principal Health Effects of Eruptions in Vicinity of the Volcano and Main Preventive Measures

Eruptive Event	Consequence	Health Impact	Preventive Measures
Explosions	Lateral blast, rock fragments	Trauma, skin burns	Evacuation
	Air shock waves	Lacerations from broken windows	Minimize exposure to flying glass
Hot ash release	Glowing avalanches	Skin and lung burns	Evacuation
	Ash flows and falls	Asphyxiation	
	Lightning	Electrocution	
	Forest fires	Burns	
Melting ice, snow and rain accompaning eruption	Mudflows, floods	Engulfing, drowning	Evacuation, Diversion barriers
Lava	Lava flow	Engulfing and burns (rare)	Evacuation, Diversion barriers
	Forest fires	Burns	Evacuation
Gas emissions:			
SO_2,CO,$CO_2$$H_2$S,HF	Pooling in low lying areas and inhalation	Asphyxiation	Evacuation
		Airways constriction	Respiratory protective equipment for geologists
Radon	Radiation exposure	Lung cancer	Evacuation
Earthquakes	Building damage	Trauma	Evacuation

Scientists cannot predict when or if Mt. St. Helens will have a major eruption. Although many federal, state, and local officials are monitoring the mountain's activities, it is uncertain whether there will be adequate time to warn people in the area if a major eruption should occur. The following information is provided so that you will be aware of emergency procedures and information should they become necessary.

Remember, Mt. St. Helens is now considered to be a major hazard. You are assuming a risk by entering the Mt. St. Helens area.

WARNING

Instruments have been placed on the mountain that could provide advanced notice of a major eruption. If these instruments indicate an eruption is imminent, emergency services personnel will immediately notify local radio and television stations serving the Mt. St. Helens area.

While in this high hazard area you should:

STAY TUNED TO YOUR LOCAL RADIO OR TELEVISION STATION

The following radio stations transmit to the immediate Mt. St. Helens area.

KGW	KWJJ	KGAR
62—AM	1080—AM	1550—AM
24 hours	24 hours	24 hours
226-5096	228-4398	256-9043
Portland	Portland	285-5575
		Vancouver

The following television stations are received in the Mt. St. Helens area.

Channel 2, (in Cougar area).

Channel 2, 6, & 8 (in the Pinecreek area).

During periods of high density ash eruptions, the ash particles become highly charged with static electricity. Clouds of highly charged ash may temporarily disrupt telephone, television, and radio communications. If your television, radio, and telephone doesn't work during an eruption, you may be notified of emergency procedures by:

Ground vehicles with PA warning announcements

or

Aircraft with PA warning announcements

WHAT TO DO IF NOTIFIED THAT AN ERUPTION IS OCCURRING

DON'T PANIC. REMAIN CALM.

If you live or work in the area, you should be prepared to leave your house or work place and relocate immediately via evacuation routes as directed. When evacuating, please bring the following with you:

—Special medicines or foods required by members of your family.

—Blankets and adequate clothing for each family member.

—A battery powered radio, a flashlight and extra batteries.

Relocation centers will be provided by local governments and volunteer agencies.

You may experience heavy ash fall while in this high hazard area. If you do, STAY INDOORS. If you are outside, seek shelter such as in a car or building. If you cannot find shelter, breathe through a cloth to filter out the ash and keep your eyes closed as much as possible. Heavy ash may cause darkness during daylight hours and temporarily interfere with radio, television, and telephone communications. STAND BY. The interruption will probably be temporary. Heavy ash fall may impair visibility. DO NOT TRY TO DRIVE unless instructed to do so by emergency personnel.

Thawing temperatures combined with the activity on Mt. St. Helens has increased the potential for mud flows, avalances, and floods.

WHAT TO DO IF A MUD FLOW OCCURS

Mud flows generally originate on steep slopes when shallow soil layers are transformed to a liquid state. The liquefied soil flows like streams of water down gulleys, canyons, and valley bottoms. Large mud flows may spill out of stream channels and spread out across adjacent low grounds.

Mud flows can move faster than you can walk or run, but you can drive a car down a valley faster than a mud flow will travel. Your car should be equipped with an automobile emergency preparedness kit (see last section).

While driving along a valley that heads on a volcano, watch the river channel and parts of the valley floor for oncoming mud flows. Before crossing a highway bridge, look upstream. DO NOT CROSS A BRIDGE WHEN A MUDFLOW IS MOVING BENEATH IT.

REMEMBER: The danger of mud flows increases as you approach a river channel and decreases as you move to higher ground. If you become isolated DO NOT STAY NEAR THE RIVER CHANNEL—MOVE UP SLOPE.

The risk of mud flows decreases the farther you move away from the volcano.

WHAT TO DO IF CAUGHT IN AN AVALANCHE

If you are caught in an avalanche, you should immediately try to get out of the slide path or grab a hold of trees, shrubs, or other anchorages. If escape is impossible, try to discard skis, pack or other impediments and make a swimming motion with your arms and legs. Your only hope at this time is to try to stay near the surface and work toward the edges of the slide. It may be possible to escape by reaching the sides of the slide path, rather than attempting to outrun it.

WHAT TO DO IF FLOODING OCCURS

Leave the area. Do not attempt to cross a flowing stream where the water is above the knees. Do not drive over a flooded road, you may get stranded or trapped. If trapped, KEEP CALM. Go to the highest, safest location and remain there. NEVER TRY TO SWIM TO SAFETY IN FLOOD WATERS. Try to provide a distress signal.

BE PREPARED BEFORE YOU GO INTO THE MT ST HELENS HIGH HAZARD AREA should an emergency occur, you may have to be self-sufficient until help arrives.

For personal comfort, safety and life support, your automobile should contain an emergency preparedness kit containing:

- —blankets for each passenger
- —extra clothing for each passenger
- —first aid kit
- —basic tool kit
- —water
- —fire extinguisher
- —emergency food rations
- —flashlight (extra batteries)
- —portable radio (extra batteries)
- —shovel, axe
- —road map
- —matches, candle
- —emergency flares
- —waterproof tarp
- —heavy rope or tow cable
- —survival manual

As in any wilderness emergency situation, when you enter this high hazard area, it will be you against nature.

WARNING

MT. ST HELENS
IS AN ACTIVE VOLCANO

You are entering a
High Hazard Area

YOU DO SO AT YOUR OWN RISK

PLEASE READ THE FOLLOWING
INFORMATION BEFORE PROCEEDING

BE PREPARED FOR POSSIBLE:

ASH FALL
MUD FLOWS
FLOODS
LAVA FLOWS
AVALANCHE

Prepared in the interest of public safety and preparedness by:

WASHINGTON STATE DEPARTMENT OF EMERGENCY SERVICES

Dixy Lee Ray
Governor

Edward Chow Jr
Director

FIGURE 1—Example of brochure for workers entering restricted areas
SOURCE: Washington State Department of Emergency Services

monitor air pollution may already have facilities for measuring suspended particulates. Static samplers should otherwise be provided in key locations and, if possible, sited at a height corresponding to the breathing zone rather than on rooftops.

Water and Food Contamination

Fluoride, and possibly other toxic elements, might contaminate drinking water from ash falling in rivers and reservoirs. Alternative sources of potable drinking water should be planned and homes should stockpile water in advance. Outdoor crops may be safe to consume after ash is washed off, but laboratory tests to exclude contamination of food and milk, including the bioavailability of toxic elements, should be done. The health of outdoor foraging animals should be monitored for evidence of toxic effects and emergency food supplies stockpiled at farms. The pH of the ash is an important factor as heavy ashfalls may result in surface water quality becoming impaired.

General Measures

Pre-planning should also allow for the following effects of widespread disruption of communities and public utilities:

Transport and Communication

Road and railways can be destroyed by mud flows, lava flows and floods; driving is almost impossible through suspended ash. Dark-

TABLE 4—Ash Collection Information Form

1. (a) Time Collection began: _____ AM PM
   (b) Time Collection ended: _____ AM PM
2. Date of Collection: _____
3. Physical location of point of collection (ground, rooftop, etc.):
   _____
4. Address point of collection (building, city and county; zip code if known):
   _____
5. Weather conditions during collections:
   dry _____ any rain occurring _____
   wet _____
   approximate speed and direction of wind _____
6. Weight of ash (to the nearest gram): _____
   Area of the sample collection surface (in m^2) _____
7. Other comments (e.g., potential sources of contamination):
   _____
8. Name of person collecting: _____
   Address (include zip code): _____
   _____
   Telephone number: _____

TABLE 3—Principal Health Effects of Eruptions at a Distance from the Volcano, and Main Preventive Measures

Eruptive Event	Consequence	Health Impact	Preventive Measures
Ashfall	*Respiratory*		
	Inhalation of fine ash (<10 μm diameter)	Asthma, exacerbation of pre-existing lung disease	Laboratory test for particle size; Wear high-efficiency masks; Protect homes/offices from ash infiltration
	Inhalation of siliceous dust (presence of crystalline silica, e.g., quartz)	Silicosis, if exposure heavy and continuous (years): outdoor occupational hazard	Laboratory tests for crystalline silica, respiratory protective equipment
	Toxic		
	Ingestion of water contaminated with fluoride, possibly also heavy metals (e.g., cobalt, arsenic)	Gastrointestinal upset, even death in vulnerable (chronic sick)	Laboratory tests for leachable toxic elements; Avoid surface waters for drinking supplies (i.e., use well water)
	Ingestion of contaminated food (as above), including milk	As above	Laboratory tests for bioavailability of toxic elements; Observe health of foraging animals, laboratory analyses of milk
	Ocular		
	Foreign bodies in eyes	Conjunctivitis, corneal abrasions	Goggles for heavily exposed (e.g., outdoor workers)
	Mechanical		
	Roof collapse and falls from roofs	Trauma	Prevent build-up of ash; exercise care if danger of falling from a roof
	Automobile accidents (slippery roads and poor visibility)	Trauma	Traffic control
	Aircraft engine damage	Trauma	Radar warning of eruption
	Radio and TV interference	Unable to receive warnings	Pre-eruption: advisory leaflets to all homes
	Electricity outages (moist ash on horizontal insulators)	Breakdown of public utilities, home heating, etc.	Cover insulators or organize emergency repair crews
	Poor visibility	Cessation of emergency transport; Stranded homes and travelers	Designate emergency shelters
Gaseous Emissions	Acid rain	Eye and skin irritation; Possible toxic contamination	Protection during rainfall; Avoid collection of rainwater for drinking, especially from metal roofs, etc.
Explosion/Earthquake	Tsunami (Tidal wave)	Drowning	Rare and unpredictable

How to be Prepared for an Ashfall

Whether in a car, at home, at work, or play you should always be prepared. Based on past Mount St. Helens volcanic activity, intermittent ashfalls may continue over several years.

Your Home

- Extra face masks. Check your local emergency services office for the nearest source.
- Food stored for two weeks
- Water (one quart per day per person) in clean plastic containers
- Medicines
- First aid kit
- Battery operated radio with extra batteries.**
- Candles, lanterns, or flashlight with extra batteries.**
- Extra wood, if you have a fireplace or wood stove
- Extra blankets
- Extra vacuum cleaner filters and cleaning supplies

**Ash may interrupt telephone, TV and electricity.

Your Auto

Any vehicle can be considered a movable second home. Always carry a few items in case of delays, emergencies, or mechanical failures.

- Face masks (should be coded "TC-21C")
- Blankets
- Fire extinguisher.
- Extra clothing
- Emergency food ration
- First aid kit
- Flashlight (extra batteries)
- Basic tool kit
- Portable radio (extra batteries)
- Water
- Shovel, axe
- Road map
- Matches, candle
- Emergency flares
- Waterproof tarp
- Heavy rope or tow cable
- Survival manuals
- Extra air filter
- Extra oil filter
- Extra oil
- Extra windshield washer water
- Window wiper blades in good condition

Your Children

- Have quiet games and activities available
- Explain what a volcano is and what they should expect
- Teach children safety procedures if they are caught in an ashfall
- Consider organizing a community or neighborhood day-care center to relieve economic and other stresses on working parents during ashfall clean-up, and to keep children in a cleaner environment.

Your Pets or Animals

- Extra dry and clean food

What to do During an Ashfall

Your Home

- Close doors and windows.
- Close dampers
- Place damp towels at door thresholds and other draft sources
- Do not run exhaust fans or clothes dryers
- Remove ash from flat or low pitched roofs and from rain gutters to prevent thick accumulation.
- If you are engaged in ash clean-up, logging or farming activities, have your work clothes laundered at work or outside the home.
- If water source is contaminated, use clean stored water in your hot water heater or toilet tank (turn off main water valve). To purify water, use 10 drops of chlorine bleach per gallon of water. Let sit 30 minutes, or purify by boiling for 5 minutes.
- You may eat vegetables from the garden, but wash them off first. The grit is harmless.
- Dust often — using vacuum attachments rather than dust cloths, which may scratch.
- Vacuum furniture, carpets, etc., and try not to wipe as ash will scratch.
- Clothes — brush, shake, and pre-soak. Use detergent, not soap, as soap will gum up.
- Use extra detergent in washer.
- Use full load of water and two rinse cycles. Front loaders are more effective than top loaders.
- Keep refrigerator closed.
- Bagging lawn clippings and mowing lawns when damp will cut down on dust. Blades will dull faster.
- Use battery operated radio to receive information.

Your Auto

- If possible do not drive.
- If you must drive, drive slowly (15 mph). Remember ashfall will decrease visibility. Do not follow the car ahead too closely.
- Use windshield washer and wipers.
- Change air filter**
- Change oil and oil filter.
  - Every 50 to 100 miles in heavy dust. (Less than 50 feet visibility.)
  - Every 500 to 1,000 miles in light dust. (Up to 200 feet visibility.)
- Do not drive without air filter.
- If car stalls, push it off the road to avoid collisions, and stay with the auto.

**Do not change air filter until you notice a loss of power in your car's engine. A dirty filter is more effective as long as it allows air to reach engine. If you cannot change air filter, clean by blowing air through from the inside out.

Note: Ash is abrasive rock; therefore it will clog engine, damage motor and scratch finish of auto.

Your Children

- Do not attempt to pick your children up at school. Schools will be apprised of emergency procedures to take.
- Keep children indoors.
- Minimize exertion to reduce inhaling ash.
- If possible maintain normal routines for children.
- If prolonged ashfall — take children outside as weather conditions permit. (Use protective masks. Some approved masks which may be adjusted to fit children include: 3-M #8710, #8983 and #85501.

Your Pets or Animals

- Keep pets indoors.
- Get clean water to livestock as soon as possible.
- If pets go out, brush or vacuum them before letting them inside. Don't let them get wet or try to wash them.
- Keep extra dry and clean food available.

This brochure was prepared by the Federal Emergency Management Agency, Region X, Bothell, WA, with the assistance of the Washington State Department of Emergency Services, Olympia, WA.

What is volcanic ash?

Volcanic ash is not ash at all. It is pulverized rock. A one inch layer of dry ash weighs ten pounds per square foot as it lands. It often contains small pieces of light expanded lava called pumice or cinders.

Fresh volcanic ash may be harsh, acid, gritty, glassy, smelly, and thoroughly unpleasant. Although gases are usually too diluted to constitute danger to a normal person, the combination of acidic gas and ash which may be present within a few miles of the eruption could cause lung damage to small infants, very old and infirm, or those already suffering from severe respiratory illnesses.

- ***A heavy ashfall blots out light.*** Sudden heavy demand for electric light may cause power supplies to 'brown out' or fail.
- ***Ash clogs water courses, reservoirs, sewers, sewage plants and machinery of all kinds.***
- ***Ash drifts onto roadways, railways, and runways like snow,*** but resembles soft wet sand.
- ***Fine ash may be slippery.***
- ***The weight of ash may cause roofs to collapse.***

What to do if Volcanic Ash is Falling

- Don't panic, stay calm.
- Stay indoors.
- If outside, seek shelter (e.g., car, building), use mask — or a handkerchief/cloth (dampened cloth most effective).
- If at work, go home if possible before ash begins to fall. If ash is already falling, stay indoors at work if possible, until the heavy ash is settled.
- Go directly home; do not run errands.
- Unless an emergency, do not use the telephone.
- Use your radio for information on the ashfall.

Federal Emergency Management Agency
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Bothell, WA 98011

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HOW TO PREPARE FOR
AND WHAT TO DO DURING A

VOLCANIC ASHFALL

- *What Volcanic Ash is*
- *What to do when Ash is Falling*
- *How To Be Prepared for an Ashfall*
- *Tips for Protection of your Children, your Home, your Pets and Animals, your Automobile.*

FIGURE 2—Example of brochure distributed to residents in volcanic areas in anticipation of ashfall
SOURCE: Federal Emergency Management Agency

ness is a feature of ashfalls and can last for several days in a gigantic eruption. Aircraft and helicopters may be unable to fly for days after heavy ashfall due to poor visibility and the risk of engine damage from the ash. Elaborate precautions may be needed to protect automobile engines. Ashfalls can also interfere with radio and TV communications, and damage telephone switchgear. Local telephones should not be relied upon for emergency communications–the system becomes rapidly overloaded with callers. Electrical outages may also occur.

Water Supplies, Sewage and Infectious Diseases

Water intakes at rivers and reservoirs can be destroyed. Power outages may close down pumping stations. Water supplies can be severely depleted by cleaning-up activities, e.g., washing ash off sidewalks, streets, and rooftops. Sewage and water treatment plants can break down in heavy ashfalls and contamination of water supplies with sewage and animal carcasses may occur. Adequate chlorination of water supplies should therefore be ensured. Still water areas created by the devastation and flooding may promote endemic diseases such as malaria and leptospirosis. As in other natural disasters, vaccination programs should never be undertaken except on firm epidemiological indications, e.g., the findings of a disease surveillance system (see below).

Emergency Shelter and Food Relief

In remote and devastated areas, particularly in developing countries, deaths from extreme environmental exposure may occur. The risk is highest in the first few days after the disaster has struck, particularly if the transportation system breaks down. It is doubtful whether such deaths can be readily prevented. Evacuation centers should have roofs strong enough to withstand large collections of ash. In developing countries the death of livestock and disruption of habitats may cause food shortages and relief food distribution may be required, at least for a short period; historically, even famines have occurred after volcanic eruptions.

Psychological Reactions

There is some evidence for psychological problems arising from the Mount St. Helens eruptions (chapter 9). How severe psychological reactions associated with the threat or the aftermath of severe

eruptions can be best prevented by intervention measures by health professionals is currently not clear on available evidence and we are reluctant to speculate here, especially as the guidance available from other types of disaster is conflicting (see, for example, Ref 3, Chapter 5).

Advice to Residents

Personal protection measures to be adopted during a volcanic emergency should be given to all people in at-risk areas well in advance. A brochure containing information was mailed to all homes before the Mount St. Helens disaster (Figure 2).

Preventive Measures Once A Disaster Has Occurred

Many local and governmental agencies will be involved in the emergency so it is essential that a coordinating center be established by the national government without delay. Here, representatives from numerous key agencies can be co-located with the geological team responsible for predicting future activity of the volcano. An important function of the center is to issue authoritative information on health and survival matters. Initially, assessments of the size of the disaster (area and population affected) and the needs for rescue and evacuation in anticipation of a further eruption must be undertaken.

The preventive health team has four main functions in a volcanic disaster:

1. Collaborate with other agencies in the coordinating center to provide:

o Advice on health matters, e.g., to government officials community and occupational groups (including volcanologists) and media;

o Advice on appropriate health resources for disaster relief;

o Information for relief planning and immediate relief action;

o Information on the surveillance and control of disease after the disaster (e.g., in affected communities and evacuation camps).

2. Provide a field survey team to collect data on the dead and survivors in the vicinity of the volcano in collaboration with rescuers and the staff of emergency centers and field morgues.

3. Provide a field survey team to travel as soon as conditions permit into areas of heaviest ashfall to make rapid assessments of the

TABLE 5—Emergency Room and Field Morgue Volcano Questionnaire
MEDICAL—CONFIDENTIAL

_____ No.
Date: _____ Time: _____ AM/PM

A. *IDENTIFICATION:*
Name of ID Number: _____ Sex: M F Age:_____
Last First M. Initial
Address or Location when Found_____
City State Zip
Phone: _____ Usual Occupation:_____

B. *EXPOSURE TO VOLCANIC HAZARDS (Check all that apply).*
1. Victim _____ or Survivor _____of:
Blast ____, Pyroclastic flow ____, Mudflow/Flooding ____, Ashfall____
Other_____
2. (a) Lived in ashfall area: Yes _____ No_____
(b) Worked outdoors in ashfall area: Yes _____ No_____
(c) Average time exposed to ash per day (e.g., in clean-up activities):
_____Hours
(d) Regular use of industrial mask Yes _____ No_____

C. *PAST MEDICAL HISTORY, HOSPITAL ADMISSIONS, AND MAJOR CHEST ILLNESSES:*
1. *Past Medical History:*

Asthma	No _____ Yes _____	Duration: _____	Years
Chronic Bronchitis	No _____ Yes _____	Duration: _____	Years
Heart Disease	No _____ Yes _____	Duration: _____	Years
Other	No _____ Yes _____	Duration: _____	Years

2 *Past Hospital Admissions* *Year* *Illness* *Surgery*
_____
_____
3. Illness in Previous Four Weeks:_____
4 Cigarette Smoker: Never ____ Ex ____ When stopped_____
Current _____ Pks/day_____

D. *PRESENT DIAGNOSIS:*
1. Onset: (a) Time: _____ am/pm: Date:_____
(b) Activity:_____
2. Relationship with ash/blast. _____ Yes _____ No
If yes, specify:
3. Outcome: Admitted/Discharged/Referred to_____

E. CLINICAL, AUTOPSY AND OTHER NOTES—USE BACK SIDE
Signature_____
_____

health needs of affected communities, including food and shelter, and the condition of medical services. Rapidly executed household surveys may be required to provide immediate assessment of the health impact of the ash.

4. Establish a health surveillance system.

Key medical facilities, (hospitals, emergency rooms) in areas affected by the devastation and ashfalls should be coordinated into information networks supplying information to the preventive health team on the daily number of patients attending with disorders of interest, and including deaths. By comparing the results with data for the period before the eruption, or the previous year, or from an unaffected area, any unusual trend would be highlighted and appropriate investigations instituted, e.g., to determine if a true increase

in disease incidence is occurring. Preventive measures can then be rapidly put in hand. As an example, a list of diagnostic labels and number of patient visits to a hospital emergency room in Moses Lake, WA is shown in chapter 3. Baseline population and health statistics should be collected before an eruption if possible.

An all-purpose recording form to facilitate data collection from patients while they are actually attending emergency departments is suggested in Table 5; it could also be used for data collection on survivors and victims recovered from devastated areas. The advantages of such instantaneous data collection are obvious, but it does need to be planned before an eruption if it is going to be workable.

Additional Studies

The rapidly executed surveys mentioned above can be conducted using questionnaires and medical records and with the minimum of apparatus. More detailed studies involving lung function tests and computer analysis of results may suggest themselves, e.g., studies of lung function and morbidity among groups of workers or patients with chronic lung disorders exposed to volcanic ash. However, such studies need to involve experts in their planning and execution and more rightly belong to the recovery phase after the disaster.

Information gathering will add to knowledge for the mitigation of disasters in the future as there is a remarkable dearth of studies on the health impact of volcanic eruptions. Deficiencies in current knowledge include:

1. Special problems of eruptions in developing countreis, e.g., morbidity and mortality after heavy ashfalls, especially in areas with inadequate housing and shelter, and a high prevalence of infectious diseases; effects of extreme environmental exposures and food shortages; and health of evacuees.
2. Characterization of ash from different volcanoes: particle size and shape, crystalline silica content and leachable toxic elements.
3. Cos-effectiveness of disposable industrial face masks for the prevention of respiratory disorders in ashexposed communities.
4. Profiles of volcanic gases, including radon, and their concentration in air at the crater and ground level, including personal monitoring and medical surveillance of geologists in active craters.
5. Special problems of volcanism in technologically advanced societies, e.g., power outages and computer circuit damage following

volcanic ashfall.

6. Causes of death and injury in relation to eruptive phenomena in the vicinity of volcanoes.

7. Psychosocial effects arising from:

   o the loss of life and property following an eruption; and

   o disruptions caused by the long-term threat of volcanic activity.

8. Epidemiologic evaluation of the overall management of volcanic hazards, e.g., the study of a series of threatened and actual eruptions to assess the effectiveness of public health measures (including the advice given in this chapter) in countries with different health and economic infrastructures.

Conclusion

Compared to other natural disasters, volcanic eruptions offer good prospects for prevention. Volcanoes are, by human standards, permanent and often majestic features of the landscape which challenge investigators and those who dwell by them to learn of their behavior and plan accordingly. Future advances in technology, e.g., volcano surveillance using satellites, will undoubtedly improve the predictive power of volcanologists in determining when, how, and for how long a particular volcano will erupt; these gains need to be matched by scientific studies of the impact of eruptions on populations so that innovative and rational approaches to disaster management can be devised. Until then, careful planning and coordination of all the involved agencies and officials well in advance of an eruption is the essential key to prevention.

Summary

Medical treatment has only a small role in severe volcanic eruptions and so preventive measures are paramount if injuries and loss of life are to be reduced. The health team must be incorporated in emergency planning and response at the earliest stage. Guidance on the interpretation of geological information about a volcano and the appropriate health measures that should be adopted before and after an eruption are summarized for the benefit of health workers.

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