tions, disaster victims may gain psychologically from legal recognition of their cause or by winning an admission of guilt from their victimizer.

See Also: Bhopal Chemical Disaster (1984); Ethnicity and Minority Status Effects on Preparedness; Gender and Disasters; Hurricane Katrina (2005); Indian Ocean Tsunami (2004); Political Economy of Food; Poverty and Disasters.

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Volcanoes

In 2005, the U.S. Geological Survey (USGS) released a comprehensive review that the United States and its territories contain 169 geologically active volcanoes, 54 of which are a high threat to public safety: "As populations increase, areas near volcanoes are being developed and aviation routes are increasing. As a result, more people and property are at risk from volcanic activity. Future eruptions can affect hundreds of thousands of people." The report established a framework for a National Volcano Early Warning System.

Worldwide, more than 50 volcanoes erupt each year. Approximately 500 million people on Earth live close to volcanoes. In the past 100 years, nearly 100,000 people have been killed by volcanic eruptions. Densely populated countries with many active volcanoes, such as Mexico, Japan, the Philippines, and Indonesia, are particularly vulnerable. When volcanic hazard mapping, monitoring, forecasting and early warning, and emergency plans are in place, it may be possible to evacuate populations and save lives before disaster strikes. However, a sudden event will be a disaster in the absence of mitigation and preparedness, despite monitoring and warning preparations, such as Mount St. Helens in Washington State in 1980.

A volcanic hazard refers to any possible volcanic activity. A volcanic risk is any potential loss or damage as a result of the volcanic hazard. Risk also includes a population's vulnerability. The increased number of deaths is not due to increased volcanism, but rather, to an increase in the population near those active volcanoes. The volcanoes that surround Mexico City have shown signs of increased activity. If a sudden eruption took place, a catastrophe could result; for example, El Popo is located within 60 miles of more than 20 million people in the Mexico City region.

About two-thirds of 1,500 active volcanoes on Earth are located in the Ring of Fire that surrounds the Pacific Ocean. Particularly, the Cascade Range, with more than a dozen active volcanoes, is close to various critical infrastructure, air routes, and populated areas in Washington, Oregon, and California. Outside the Ring of Fire, Mauna Loa in Hawaii is the world's largest active volcano. In western Central America, Nicaragua, Guatemala, Costa Rica, the Caribbean, Colombia, Ecuador, and along the Andes, Peru, and Chile, the population is exposed to volcanic activity. Europe has a number of active volcanoes, including Santorini (Greece), Surtsey and Heimaey (Iceland), Pompeii and Etna (Italy), which have erupted many times.

The volcanic molten (magma) materials (lava flow and ash) ejected from volcanoes during eruptions are extremely hot (around 1,830 degrees Fahrenheit). Such high-temperature lava flows burn and damage any object in their path. Volcanic ash is a powdery material that can affect people hundreds of miles away from a volcano. In 1980, when Mount St. Helens erupted, it killed 58 people and caused more than $1 billion in property damage. Hot lava created fires, many buildings were buried, and more than 200 houses were destroyed. The eruption of Mount Asame in 1783, which is called Japan's Pompeii, killed 1,400 people in a single day. In 1902, a lava flow from Mount Pelée in the West Indies killed 30,000 people in the nearby town of St. Pierre in a matter of minutes. After the Mount Unzen (Japan) eruption of 1991, hot ashfall and large rock fragments killed 43 people and burned schools and homes. The 1992 eruption of Mount Pinatubo in the Philippines caused 932 deaths, and more than 250,000 people had to be evacuated. More than 100,000 houses and several hospitals and schools were destroyed and damaged. *Lahars* (a lava pyroclastic flow, mud, and water mixture) can move down valleys to great distances from the volcano. In 1985, the eruption of the Nevado del Ruiz volcano in Colombia sent mud and ash flows down into the valley below where people were sleeping. Within 15 minutes, the city was buried under a 30-foot blanket of hot ash and mud, and more than 23,000 people perished.

Secondary Hazards

Volcanic eruptions can be accompanied by other hazards, including earthquakes, landslides, fires, tsunamis, environmental pollution, acid rain, climate change, and famine. Earthquakes can accompany or precede volcanic eruptions. Volcanic earthquakes and rapidly moving volcanic material that enters the sea may generate catastrophic tsunamis. During the giant Krakatou eruption in 1883, a tremendous explosion produced huge waves that reached as high as 115 feet and killed more than 30,000 people.

Volcanic events may also create toxic spills and environmental emergencies. Ashes have toxic consequences, and can cause a temporary increase in the acidity of the water, which may last for several hours after an eruption ceases. Volcanic gases on plants cause absorption or storage of toxic chemicals. Potential contamination of food and water supplies, as well as sanitation problems and health challenges, may require displacements of large populations for a period of time. In Montserrat, a small island in the Caribbean, the population was displaced for over five years after a volcanic eruption. Falling ash, even in moderate amounts, can destroy, bury, or hamper the photosynthesis of crops and trees, which can result in famine. Famines are the largest secondary hazard produced by volcanic eruptions. During the world's largest-ever volcanic eruption—Indonesia's Mount Tambora in 1815—93 cubic kilometers of ash were ejected into the atmosphere, 11,000–12,000 people were killed by the explosion, and approximately 60,000 more starved due to famine. In addition, the eruption created a global cloud of sulfuric acid droplets (aerosols), that caused regional cooling of up to 34 degrees Fahrenheit and resulted in the 1816 "year without a summer" in New England. Climate change from the eruption caused major hardships in North America and Europe, including crop failures and famine.

Impact of Volcanic Disasters

During the volcanic trauma, crush-type injuries and burning can be caused by explosions and contact with volcanic mass. Studies have shown health hazards on contact with hot volcanic ash and breathing poisonous volcanic gases. These include burns and irritation of the skin and eyes (watery eyes, conjunctivitis or corneal abrasion); headaches, sore throats, and flu-like symptoms; and breathing difficulties, such as acute respiratory distress, asthma attacks, and damage to the lungs of small children and people with respiratory problems. In addition, ash can cause poisoning from direct contact, inhalation, and digestion.

Ashfall can disrupt human activities, including communication (ash create serious interference), and transportation due to total darkness, poor visibility, and slippery roads. The lava can block water supply lines and clog natural drainage and sewers, cover roadways, damage electric cables, contaminate the environment, and create large cleanup problems. Damage to infrastructure, airports, harbors, and emergency services can be severe. Ash accumulations mixed with water become heavy, and may cause the collapse of roofs and structural damage to buildings and historic monuments. Volcanic ash can damage machinery, including engines, equipment, electronic devices, and airplanes.

Public Awareness: Risks and Response

The communication, cooperation, and coordination of the public, local government officials, and scientists about volcanic risks can save lives, and includes planning for emergency response, improvement of evacuation (roads, ports, and harbors), and mass care (shelters and other refuge facilities), search and rescue systems, emergency communication, and mitigation. The wide range of volcanic hazard-mitigation techniques include risk assessments (volcano monitoring, volcanic zonation, eruption prediction, and early warning); land use

Redoubt Volcano is the second highest of the 76 major volcanoes of the Alaska Peninsula and Aleutian Islands. An active stratovolcano, Redoubt began spewing ash in multiple eruptions in March 2009, nearly 20 years after its last major eruption.

planning and regulations; relocation; infrastructure, property, and socioeconomic protection; and public disaster awareness and preparedness plans.

Volcanic hazard zonation and risk maps are useful for evacuation planning, land use planning, community protection, and reducing the social and economic impacts in these areas. Volcanic monitoring is one of the most important methods to detect and measure changes caused by movement of magma and allow for forecasting (hours to months) of possible volcanic activity. The USGS operates five volcano observatories that monitor volcanic activity in Hawaii, the Cascade Range, Alaska, Long Valley in California, Yellowstone National Park, and the Northern Mariana Islands (the USGS Volcano Hazards Program), and analyze events for the public and government officials. Forecasting volcanic eruptions uses information gained by monitoring and studying geologic history. The agency also developed a lahar-detection system for several volcanoes in the Philippines, Indonesia, Ecuador, Mexico, and Japan. These systems detect ground motion from rapidly approaching lahars, when people must be alerted and evacuated immediately. At the Cascade Volcano Observatory in Vancouver, Washington, continuously monitoring Mount St. Helens includes a network of seismographs and global positioning system (GPS) satellite receivers with Webcams to detect earthquakes and ground motion; thermal, magnetic, and hydrologic conditions; mudflow movements; and release of volcanic gases. Steve P. Schilling and researchers from the USGS Cascades Volcano Observatory recently created a geographic information system (GIS)-based method called LAHARZ to map hazard zones and develop new ways of forecasting what are termed *hot ash hurricanes* induced by volcanoes.

This method has already been used at Mount Merapi in Java, Indonesia, in 2006 and in the Montserrat volcano in the Caribbean in 2006–09 to quickly and effectively create volcanic flow maps. Penn State geoscience professor Barry Voight noted that this method was expected to make a difference in volcano hazards mitigation by saving time and thus saving lives, avoiding an insufficient and untimely mitigation response.

Volcanic Disaster Reduction

Various facilities are installed to control lava and minimize damages. In Japan, various techniques are being developed to prevent and reduce the impacts of volcanic ash, including the design of ash-resistant houses; ash removal systems for buildings, roads, agricultural concerns, forestry, and fishery facilities; and measures for traffic safety on roads in volcanic areas. Another option is to regulate the character of construction in areas of possible ash accumulation, and provide buildings of greater roof load capacity, as well as special provisions for power, water supplies, and drainage systems. Terracing and vegetation are also methods of promoting slope stability to prevent debris flow and *lahar* mobilization on the flanks of volcanoes. Relocation is one way of avoiding volcanic hazards, by permanently evacuating settlements from the hazard zones into safer locations.

Economic losses can be reduced by insurance, distributing and transferring risks, and establishment of reserves. Insurance, as an incentive to mitigation, can be relied on during and after a disaster for rebuilding or reinvestment proposes, and can be used in the form of cash savings, food banks, resources, or product reserves. During the first stage of the eruption of Heimaey (Iceland) in 1973, people and livestock were all successfully evacuated. When the eruption took place, the island was covered by at least one foot of hot ash and caused enormous losses. The island had grown in area as lava cooled down, and people were able to construct additional geothermal heating systems. Although permanent settlements had been built on the mainland, the majority of people returned to the island within a year. The town has now been rebuilt, and people turned the eruption to their own advantage. The reaction of the people of Vestmannaeyjar is a good example of the community responding to and coping with volcanic disasters.

People need to be prepared for volcanic ash during an eruption. This includes stocking up on water and food supplies; avoiding buildings that are flat-roofed; preparing to be without telephones, electricity, and gas; and planning for careful cleanup of heavy ash from flat or low-pitched roofs and rain gutters. Those caught indoors are advised to stay inside until the ash settles, unless there is a danger of the roof collapsing. A wet cloth or some sort of filter over the mouth and nose is advisable for going outdoors in an emergency. All doors, windows, dampers, and all ventilation in the house (chimney, air conditioners, fans, and other vents) should be closed. All machinery should be brought inside, and animals and livestock brought into closed shelters. Some neighbors may require special assistance, such as children, people with disabilities, and those with respiratory problems. A battery-powered radio or television should be kept on hand for the latest emergency information. Those trapped outdoors are advised to protect the head if caught in a rockfall. During ashfall, recommended protection items include long-sleeved shirts and long pants; goggles to protect the eyes (eye glasses instead of contact lenses), and a dust mask or a damp cloth over the face to help breathing. Protective measures also include avoiding areas downwind of the volcanic ash and keeping car or truck engines off (driving can stir up volcanic ash that can clog and damage engines). If driving is unavoidable, vehicles should be driven very slowly, avoiding river valleys (vehicles should move upslope); lava flows (especially when the roar of lava is audible); and bridges, especially if a flow is approaching.

People in volcanic eruption zones are advised to follow the evacuation order announced by authorities, and evacuate immediately from the area to avoid flying hot rocks, ashfall, and gases. In case of lava flows, the health impact is minimal; lava moves slowly, and gives plenty of time for people to evacuate. USGS established the Volcanic Activity Alert-Notification System, which helps to establish successful evacuation and inform government officials and the public when they face a real and immediate threat. In an evacuation, improved communication between scientists, emergency managers, officials, and the public is particularly important. Community-based education and training of health and firefighter personnel, and voluntary public groups, play an important role in reducing physical damage and sacrifice of human and animal lives. A successful response and mass care during and after an evacuation will be based on mitigation and preparedness measures and plans that should include: establishing evacuation centers, providing food safety and water supplies, basic sanitation and personal hygiene measures, solid-waste management; donation and volunteer management, activating medical collaboration network, emergency medical centers (remote hospitals), alternative transportation measures (via air or sea), burial of the dead, public information and the media, and establishing emergency communication hotlines.

See Also: Early Warning and Prediction Systems; El Chichón Eruption (1982); Famine; Krakatoa Eruption (1883); Mitigation, Benefits and Costs of; Mount Pelée Eruption (1902); Mount St. Helens Eruption (1980); Nevado del Ruiz Eruption (1985); Ring of Fire; Tsunami.

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Vulnerable Populations

The effectiveness of governments, humanitarian workers, and agencies with regard to the needs of vulnerable populations has increasingly become a measure of effective emergency planning and disaster management. Yet the term *vulnerability* conjures up a range of interpretations. The words *vulnerable* and *vulnerability* are notoriously elusive to define and open to interpretation, with different professions attributing their own meanings to these terms. The word *vulnerability* is derived from Latin, for which the equivalent in English is "to wound." *Vulnerability* is a term that is used in disasters to suggest the level of a person's susceptibility to hazard risk. However, it would be too simplistic to assume that there is a finite list of people who belong to the vulnerable population. Perhaps the most important aspect in the discussion about vulnerable populations relates to issues that make people vulnerable. A person's capacity to deal with their susceptibility and exposure to risk could suggest the level of their potential vulnerability. Thus, social, economic, political, cultural, and environmental factors, separately or collectively, contribute to the level of a person's vulnerability. Vulnerability and the susceptibility to hazard risk can increase, remain stable, or decrease over time, depending on a range of other critical factors. These factors may relate to livelihoods, which are essentially about the strengths which people individually or collectively possess. These strengths are generally known as assets, and include the following:

- Natural assets, such as water, minerals, land, and forests
- Human assets, such as health, skills and knowledge
- Financial assets, such as income, savings, access to credit, credit, and remittances
- Physical assets, such as water and sanitation, shelter, and other infrastructure like roads and transport.
- Social assets, such as family affiliation, reciprocal arrangements based on trust, and community networks

Resiliency, Capacities, and Vulnerabilities

Increasingly, the discussion about vulnerability is shifting toward the capability of disaster-prone people. It is about recognizing people's abilities while examining factors that contribute to their vulnerability, the reduction of which has the potential to make them more resilient and less prone to disasters. For example, if healthy people who are equipped with swimming knowledge and skills found themselves in a capsizing boat, they would be less vulnerable than people without these skills.

However, if the same people who are equipped with swimming knowledge and skills were in poor physical health when the boat capsized, they would be more vulnerable than the people without swimming skills. Even in this situation, the availability of lifejackets may help save lives. Thus, it would seem important to consider a person's capabilities and resources available—in this example, the presence of lifejackets—and how they