ENVIRONMENTAL IMPACTS OF VOLCANIC ERUPTIONS

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Summary

Volcanoes are one of the most spectacular and beautiful features of the physical world. On the other hand, great volcanic eruptions in historic times have brought death and destruction to many areas around the world. Erupting volcanoes have claimed more than 80 000 lives in the twentieth century and over 260 000 since AD1700; at least 300 000 casualties have been ascribed to volcanism in human history. This means that every year an average of 1000 people become the victims of eruptions. This number includes not only those that are killed by pyroclastic flows, mudflows, and ash falls but also those that die from starvation after crop failures because of volcanic eruptions. Furthermore, relatively small amounts of ash can be fatal to animals because of the loss of vegetation and the ingestion of poisonous ash on what vegetation remains.

Volcanoes are so widely considered to be agents of destruction that their contribution to the development of Earth is often overlooked. Volcanoes have been a major contributor to the building of continents as well as the ocean floor. The waters of the ocean and gases of the atmosphere are believed to have been derived from the cooling of magma and to have reached the surface through volcanoes and hot springs. Volcanic eruptions are the surface expression of deep Earth processes.

Volcanic ash contains components that can stimulate biological production in the marine and aqueous environments. Volcanic ash is also a good fertilizer and contains many elements that increase soil fertility. Volcanism can change the gas composition of the atmosphere, increase the temperature of the atmosphere, and cause a decrease in solar radiation reaching Earth's surface. Climate cooling at Earth's surface attributed to volcanic eruptions is primarily a result of the formation and spread of stratospheric H_2SO_4 aerosols. These small droplets are formed from sulfur volatiles (largely SO_2) injected into the atmosphere by convective plumes rising above volcanoes. Volcanism is thus one of the factors that can influence the earth's climate.

1. Introduction

The impact of volcanic eruptions, one of the most powerful display forces of nature, was poorly understood until recent developments in volcanology. The impact of large eruptions on climate is a major reason that an understanding of volcanic phenomena is important for society today. The relationship between people and volcanoes is as old as the human race. Sometimes eruptions can be a catastrophically destructive force and greatly influence changes of global environment. Every year, about 50 volcanoes throughout the world are active above sea level, threatening the lives and property of millions of people. Ash fallout from large-scale explosive eruptions can cover large areas of Earth. Eruptions can produce such features as floods, pyroclastic flows, and mudflows that can cause major loss of life and property burying towns and villages within minutes (Figure 1). Eruptions can rapidly change productive landscapes to virtual deserts. The number of people living in volcanic areas is growing and impact of volcanic eruption on humans will be evaluated next.

Figure 1. Waha'ula visitor center in Hawaii Volcanoes National Park burns from an advancing lava flow in 1989
Photo from the archive of the Hawaii Volcano Observatory

2. Influence of Eruptions on Humans

Erupting volcanoes have claimed more than 80 000 lives in the twentieth century and over 260 000 since AD 1700; at least 300 000 casualties have been ascribed to volcanism in human history. Thus, every year an average of 1000 people become the victims of eruptions. This number includes not only those that are killed pyroclastic flows (Figure 2), mudflows, and ash falls but also those that die from starvation after crop failures due to volcanic eruptions (Figure 3). Despite their awe-inspiring,

spectacular, and even deadly fireworks, volcanic eruptions have not been nature's most deadly hazard in living memory. Over the period 1947–1981, the average number of deaths per volcanic disaster totaled 525; this compares with 190 in landslides, 856 due to tsunamis, and 2652 during earthquakes. Between 1980 and 1990, around 620 000 people were affected by volcanic activity compared, for example, to over 28 million affected by earthquakes, and 525 million by floods.

Figure 2. Pyroclastic flows descends the flank of Mayon volcano, Philippines
Photo by C. Newhall on 23 September 1984; archive of USGS

Figure 3. Defoliated plants after the 1960 Kapolei eruption of Kilauea volcano, Hawaii
Photo from the archive of the Hawaii Volcano Observatory

Of all the volcanic hazards, gas releases are among the most important. The large-scale fissure release of fluorine-containing gases over 8 months at Laki, Iceland, in 1783–1784, killed 22% of the country's population. Lethal gas bursts also occurred at Ding, Indonesia, in 1979 and at Lake Nios, Cameroon, 1986.

Pliny the Younger in his famous letter mentioned the strong eruptions of Vesuvius in 79 BC that destroyed the Roman cities of Pompeii, Herculaneum, and Stacie. Pliny the Younger wrote that the ash fall was so heavy that, at distance of several kilometers from the volcano, it was necessary to constantly shake the ash from his body; in other cases, ash buried entire villages and their inhabitants like a snowfall. In Pompeii, where ash thickness was greater than 3 m, more than 2000 people were killed. In the sixteenth century, a similar tragedy occurred in Leon, the former capital of Nicaragua, following the eruption of Momotombo volcano.

A catastrophic eruption of Tambora volcano on Sumbawa Island in 1815 in three days deposited a thick layer of volcanic ash over an area the size of France that was inhabited by several million people. According to various reports, the death toll ranged from 75 000 to 92 000 people and large areas of Sumbawa and Lombok Islands were covered by so much ash as to prevent crop production for many years. The abnormal climate conditions in 1816, the next year after the eruption, have frequently been proposed as an important factor in the first worldwide cholera epidemic. The bad weather also caused a series of crop failures in India.

One of the most powerful eruptions of recent centuries, at Krakatau (Indonesia) on 27 August 1883, produced lethal tsunamis, killing about 36 000 people. The largest wave, an estimated 15 m in the open ocean, reached heights to 40 m on the heavily populated coast.

One of the most tragic volcanic disasters in the world took place at Montagne Pelee volcano, Martinique, West Indies, on 8 May 1902. The city of St. Pierre, with a population of 28 000 people, was destroyed by pyroclastic flows and surges from Montagne Peel volcano. A series of violent explosions took place on the morning of 8 May. A great black cloud of ash rose above the volcano, and simultaneously another cloud shot southward from the crater. Hot pyroclastic ash wave engulfed city within several minutes. Only two people survived.

For the decade of the 1990s, deaths from pyroclastic flows and surges occurred at Unseen volcano (Japan) in 1991, Pinatubo (Philippines) in 1991, Serape (Indonesia) in 1994, and Montserrat (Lesser Antilles) in 1997.

The large volumes of unconsolidated tempura that accumulate on the steep slopes of the volcano are unstable, especially following heavy rains or the melting of snow and ice on the slopes of the volcano during eruption. As a result, mudflows travel down the slope of the volcano (Figure 4). Catastrophic eruptions of Kelut volcano in Indonesia in 1586, accompanied by mudflows from a crater lake, killed about 10 000 people. The mudflows formed during the eruption of Ruiz volcano in Columbia killed about 29 000 people. The effect of the 1980 catastrophic explosive eruption of Mount St. Helens volcano (USA) were cataclysmic in some places near the volcano. Following the

eruption of Mount St. Helens volcano, 68 people were killed or missing, mostly in the 600 km^2 devastated area.

Figure 4. Lahars
A series of pyroclastic flows from Redoubt volcano in Alaska between December 1989 and April 1990 rapidly melted snow and ice that generated lahars in Drift River. Photo by C.Gardnier on 28 June 1990; archive USGS.

The blast destroyed or damaged 169 lakes. Destruction or damage to civil works was extensive, both near and far from the volcano. Most roads, bridges, and buildings immediately north of the volcano were destroyed. Mudflows resulted in extensive property loss along some rivers. In a zone extending nearly 10 km from the summit, much of which had been densely forested, virtually no trees remained. Beyond the zone of total devastation, in the area extending 18–24 km from the volcano, old-growth timber was blown down and lesser vegetation was killed by the blast, buried by airborne debris, or both. In this zone, falling trees caused extensive damage to recreational and roads and operations. The effect of the eruption were tremendous. Although the volcano was located in a relatively remote area, an estimated $1.8 billion of damage was inflicted; this included damages in the vicinity of the volcano as well as those areas that suffered from the ash fall.

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Biographical Sketch

Vladimir Kirianov is Deputy Director of the Institute of Volcanic Geology and Geochemistry, Russian Academy of Sciences (Petropavlovsk-Kamchatsky, Russia). His research interest has focused on the study of volcanic ashes, reconstruction of volcanic activity, impact of volcanic eruptions on climate, and volcanic hazards. He has also studied volcanic ash and aviation safety problems across the North Pacific working in close cooperation with the Alaska Volcano Observatory for the past 10 years. He has been the leader of KVERT (Kamchatka Volcanic Eruption Response Team) since 1993. Dr. Kirianov has conducted fieldwork in many volcanic areas around the world including Russia, Nicaragua, Mexico, USA, Japan, and Iceland. At the present time, Dr. Kirianov works at the INTAARI Company (St. Petersburg) and teaches at St. Petersburg State University (Geological Department).