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Case Studies

Exposures to Volcanic Emissions from the Hawaiian Volcanoes: A NIOSH Health Hazard Evaluation

Dawn Tharr, Column Editor

Case Report by Richard Stephenson, Gregory Burr, Melody Kawamoto, and Bruce Hills

Introduction

In March 1990, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the National Park Service to evaluate park employees' exposures to volcanic emissions (both gases and particulates) at the Hawaii Volcanoes National Park (HVNP) on the island of Hawaii. In response to this request, an initial industrial hygiene study was conducted at HVNP from March 25–30, 1990.

The exposure concerns which prompted the HVNP HHE request were multifaceted. Park employees were concerned about their exposures to sulfur dioxide emissions, to the asphalt decomposition products (when the lava covers the roadways and burns the pavement), to acid mists when lava enters the ocean, to VOG (volcanic caused smog), and to "Pele's hair" (a fibrous glass-like material that is formed both when lava enters the ocean and during periods of high lava fountaining). Unfortunately, except for sulfur dioxide emissions, none of these conditions were present during the NIOSH March 25–30 survey for the national park, either within the park boundary or outside the park; therefore, these exposures were not characterized during this initial survey.

Another similar but separate HHE request was received from the Hawaii County Civil Defense Agency, and a site visit was conducted from July 30 to August 2, 1990. Personal and general area air samples for hydrochloric acid and other inorganic acids were collected at

various locations surrounding the former village of Kalapana, Hawaii, and near the Kaimu black sand beach recreational area. The air sampling was conducted to assess the potential exposures of the Hawaii civil defense personnel to airborne contaminants.

Background

People in most volcanic regions of the world run in terror from an eruption, as most active volcanoes erupt violently and can be watched safely only from a great distance. Hawaii is one of the few places in the world where spectators rush to the eruption area instead of away from it because of the relative gentleness of eruptions and their accessibility.

Each year, millions of people visit the HVNP to view the natural beauty and unique and colorful sights of the volcanic mountains. Congress designated this national park in 1916, home of Kilauea and Mauna Loa, two of the largest and most active volcanoes on earth. The volcanoes within the park, such as Kilauea Volcano, have been continuously "active" since 1983. Volcanic activity, like forest fires, is quite variable, and the direction and quantities of lava and volcanic gas emissions can fluctuate hourly, daily, weekly, etc. The lava flows in 1990 were on the southeast side of the island, outside the park boundary, in the Kalapana area; they are part of the continuing eruptive series from the Pu'u O'o rift. To date, several roads and trails have been covered by the lava and over 166 structures/homes have been destroyed by lava, the majority of which were private residences in Kalapana. The lava flow has continued to flow in an easterly direction toward the ocean, across private and county land, toward the village of Kaimu.

Surveys

Hawaii Volcanoes National Park

On March 26–27, exposures to sulfur dioxide gas from vent sources within the park were measured by collecting personal breathing zone and general area air samples. Personal samples were collected on park employees whose job assignments required them to be at the following locations for varying lengths of time on March 26:

- Kamoamo Campground and Picnic Area.
- Both outside and inside the Hawaiian Volcano Observatory/Jaggar Museum.
- Kilauea Military Camp.
- Devastation Trail, Crater Rim Drive, Crater Rim Road, and the Chain of Craters Road near the Resource Management offices.
- Inside the Kilauea Visitor's Center and Museum.
- Adjacent to the park maintenance shop and the gravel pit area.

Park records were reviewed in an attempt to gather information concerning incidents in which tourists and/or park employees were exposed to volcanic emissions (gases/vapors and particulates) and reportedly experienced some health effects as a result of these exposures. In addition, 79 self-administered medical symptom questionnaires were given to park administrative representatives for distribution among the park workforce. A noteworthy finding was a 1987 park report that a park tourist (who was later reported to be asthmatic) collapsed and died in the Halemaumau Trail Area.

Hawaii County Civil Defense Agency

General area air samples were collected from July 30 to August 2 at locations where civil defense workers

were stationed for prolonged periods of time (usually at roadblock locations). In addition, samples were collected at locations on the old lava flow, at sites downwind of the laze plumes, and at locations along the beach and near the active lava flow from which the general public was restricted. One personal breathing zone air sample was collected on a geologist who routinely mapped the lava flow.

The U.S. Geological Survey has studied the explosive plume/steam clouds (laze) which are created when lava from the east rift zone of the Kilauea Volcano enters the ocean near Kupapa'u Point, Hawaii. In a journal abstract entitled "Acid Rain from the Heating and Evaporation of Seawater by Molten Lava: A New Volcanic Hazard" (*EOS Transactions of the American Geophysical Union*, October 24, 1989), it was determined that acid rain formed from the plume cloud is derived from HCl gas formed primarily by the hydrolysis reaction of steam with magnesium chloride salts, precipitated locally where magma (lava) evaporates seawater to dryness. In addition, calculations based on "irreversible mass transfer" indicate that evaporation of one liter of seawater to dryness at temperatures of 100–300°C will produce about a liter of hydrochloric acid condensate with a pH of 1.0.

Results

Hawaii Volcanoes National Park

Environmental

The direct-reading, long-term colorimetric detector tube samples collected on March 26, 1990, to characterize HVNP workers' personal full-shift exposures to SO₂ revealed no detectable levels. On March 27, stationary air samples were collected in the park along the Halemaumau Trail, at the Sulphur Bank Area and at the Steam Vent Area. Three long-term detector tube area samples for SO₂ taken on March 27 at the Halemaumau trail, revealed ambient concentrations of 0.8, 1.7, and 5.0 ppm, with the highest concentration measured in a parking lot. An area air sample collected at the Sulphur Bank, with the long-term detec-

tor tube positioned on top of a 3-foot high rock pile that covered a vent, indicated SO₂ levels of 4.1 ppm at the vent source. Direct-reading, short-term detector tube samples for SO₂ collected on this date, about three feet from the rock pile vent source, indicated ambient SO₂ levels of 1.2 ppm.

These area air samples measured concentrations which exceeded the NIOSH REL (0.5 ppm) and the OSHA

PEL (2.0 ppm) for SO₂. The evaluation criteria, however, are for personal exposures and, as noted, the personal samples were nondetectable. During the initial survey period, numerous park employees volunteered that they perceived the ambient volcanic emissions (gases/vapors) within the park to be minimal. Therefore, the SO₂ concentrations measured on March 27 could be considered minimal values and typ-

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ical of low volcanic emission periods.

Symptoms Questionnaire

Symptoms questionnaires were distributed to all park workers during the initial visit in March. Forty-three (approximately half) of the Volcanoes Park employees returned the symptoms questionnaire before May 1. Symptoms reported by more than half of the respondents included headaches, eye irritation, throat irritation, cough, and phlegm. Chest tightness or wheezing and shortness of breath were also frequently reported. Other reported symptoms included dizziness or light-headedness, skin rash or itching, nausea, nasal irritation, and, to a lesser extent, nose bleeds. Symptoms were often attributed to VOG, the steam cre-

ated when the lava mixes with seawater, sulfur compounds, and burning asphalt (when the lava crosses roadways).

These responses indicate that many park employees are experiencing acute irritant symptoms which are consistent with exposures to known irritants, e.g., SO₂ from volcano emissions or related to lava flows. However, symptoms of chest tightness, wheezing, and shortness of breath may be manifestations of bronchospasm and may indicate the possibility of more serious and potentially long-term respiratory impairment in some employees.

Hawaii County Civil Defense

Short-term detector tubes (sampling periods of approximately 5 minutes)

measured HCl concentrations of up to 10 to 15 ppm in the dense haze near the shoreline. Air samples collected over longer time periods (up to 8 hours) measured HCl concentrations up to 3.6 ppm. Area air samples, with sampling times up to 8 hours, were also collected at various civil defense roadblock locations and in areas where the general public or community residents had access. These HCl concentrations were significantly lower, ranging from not detectable to 1.1 ppm.

Future Studies

NIOSH investigators anticipate conducting a follow-up industrial hygiene/medical evaluation to characterize both national park and county civil defense workers' exposures to volcanic emissions, to further define areas of highest exposure, to medically assess workers' who have been exposed to the volcanic gases, acid mists, etc., and lastly, to find whether a correlation exists between exposures to the volcanic emissions and health effects (reported symptoms by questionnaire and measurable respiratory effects by baseline, pre/post spirometry, and peak flow). Air samples will be collected to verify that the spirometry controls are not exposed to volcanic emissions, and area samples will be collected in the Kalaupana coastal area to compare exposures across three shifts.

Editorial Note: Richard Stephenson, Gregory Burr, Melody Kawamoto, and Bruce Hills are with the Hazard Evaluation and Technical Assistance Branch of NIOSH. More information may be obtained by contacting the authors at NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, R11, Cincinnati, Ohio 45226, or by calling 1-800-35-NIOSH.