



18. VOLCANIC GAS

18.1 HAZARD PROFILE

18.1.1 HAZARD DESCRIPTION

Overview

The City does not include volcanic eruptions among its hazards as all volcanic structures on O‘ahu are extinct. While Hawaii Islands and possibly Maui do have active volcanos that post risk to those counties, a volcanic eruption from one of those sources would not directly impact O‘ahu. A secondary impact of an eruption that could impact O‘ahu is volcanic smog or vog. Eruptions from the active Kīlauea Volcano on Hawaii island can result in vog conditions impacting O‘ahu.

Types and Causes

The term “vog” refers to the hazy air pollution caused by the volcanic emissions, which are primarily water vapor, carbon dioxide (CO₂), and sulfur dioxide (SO₂) gas. As SO₂ is released from the volcano, it reacts in the atmosphere with oxygen, sunlight, moisture, and other gases and particles and, within hours to days, converts to fine particles, which scatter sunlight, causing the visible haze that is observed downwind. Vog contains mostly the following (IVHHN 2016):

- SO₂ is a colorless, irritating gas that has an acrid odor like fireworks or a struck match. It is also emitted from other sources, such as fossil fuel power plants and motor vehicles.
- Fine particles consisting of particulate matter less than 2.5 micrometers in diameter are referred to as “PM2.5.” PM2.5 in vog is mainly composed of acid and neutral sulfate particles. Other sources of PM2.5 include vehicle exhaust and smoke from fires.

Potential Impacts

The risk posed by vog varies based on proximity to the eruptive vents and wind conditions. Individuals vary in their sensitivity, and vog exposure may worsen symptoms for people who have pre-existing health conditions.

SO₂

Areas closer to the eruptive vents can be exposed to both SO₂ gas and fine particles during periods of vog. Physically active asthmatics are most likely to experience serious health effects from SO₂. Even short-term exposures can cause narrowing of the airways (bronchoconstriction), causing asthma symptoms. Potential health effects increase as SO₂ levels and/or breathing rates increase. At SO₂ levels considered “unhealthy” for



the general population, even non-asthmatics may experience breathing difficulties. Short-term SO₂ exposure is connected to increased visits to emergency departments and hospital admissions for respiratory illnesses, particularly in the sensitive groups. No one knows the long-term health effects of exposure to volcanic SO₂. Short-term health symptoms include:

- Eye, nose, throat, and/or skin irritation
- Coughing and/or phlegm
- Chest tightness and/or shortness of breath
- Headache
- Increased susceptibility to respiratory ailments
- Some people also report fatigue and/or dizziness

PM2.5

Areas far downwind of eruptive vents are mostly affected by the fine particles in vog. Both long- and short-term particle exposures have been linked to various health problems. High levels of particle pollution are linked to increased hospital admissions and emergency room visits, and even to death from existing heart or lung disease. Low levels of PM2.5 are not considered as problematic for asthmatics as low levels of SO₂ gas. The vog impacts O'ahu experiences is mostly low levels of PM2.5 its distance from the source. Particle pollution can cause temporary health symptoms such as:

- Eyes, nose and/or throat irritation
- Coughing and/or phlegm
- Chest tightness and/or shortness of breath

18.1.2 LOCATION

The primary source of vog is Kīlauea volcano on Hawaii Island, which has experienced a series of eruptions in recent years. Other active volcanoes, such as Kīlauea and Mauna Loa on Hawai'i Island, or Haleakalā on Maui, could produce vog that impacts to O'ahu were they to erupt.

Vog concentrations are primarily dependent on the amount of volcanic emissions, the distance from the source vents, and the wind direction and speed on a given day. In the Hawaiian Islands, the predominant wind direction is from the northeast (trade winds). Consequently, the areas southwest of Kīlauea are most frequently affected by vog on Hawai'i Island. When trade winds are absent, which occurs most often during winter months, the entire state can be impacted by vog.



18.1.3 EXTENT

Hazard extent refers to the potential severity or magnitude of hazard events in a given area. This section describes measurements used to indicate the extent of this hazard and the systems in place for monitoring severity and providing warnings as necessary.

The extent of vog varies by proximity to the volcano's source vents. Areas of Hawaii Island closer to the eruptive vents can be exposed to both SO₂ gas and fine particles during periods of vog. Under certain wind conditions, SO₂ can reach levels considered 'unhealthy' for the general population. For Kīlauea Volcano, this would be limited to Hawai'i Volcanoes National Park and surrounding areas. Downwind areas relatively near Kīlauea on Hawaii Island under certain wind conditions, SO₂ can reach levels considered "unhealthy for sensitive groups."

Areas far downwind of Kīlauea, and other islands in the state like O'ahu, are mostly affected by the fine particles in vog. In most areas of the state PM_{2.5} concentrations only occasionally reach levels considered 'unhealthy for sensitive groups.'

Monitoring and Warning

Monitoring systems have been established to inform the public when vog levels are anticipated to increase, enabling individuals to take appropriate measures to safeguard their health.

The Hawaiian Volcano Observatory (HVO) conducts gas monitoring to track changes in emission rates of gases like SO₂ and CO₂. These changes are analyzed alongside other monitoring data to assess magma supply and eruption rates, issue eruption warnings, improve gas-hazard assessments and vog forecasts, and enhance the understanding of Hawaiian volcanoes.

In addition, HDOH monitors air quality across the state, including the effects of vog on residents. On O'ahu, stationary air quality monitors measure particulate levels (PM_{2.5} and PM₁₀) and SO₂. The specific monitoring stations on O'ahu include Honolulu, Kapolei-Ncore, and Sand Island (HDOH 2024). These monitoring stations are part of a broader network that includes locations on Hawai'i Island, Maui, and Kaua'i.

The Hawai'i Interagency Vog Information Dashboard (IVHHN) at <http://weather.hawaii.edu/vmap/new/> displays real-time air quality data and vog forecasts to keep the public informed of any locations where they are potential health risks due to vog.

The warning period can fluctuate based on various factors, including the volume of volcanic emissions, as well as wind direction and speed. These forecasts can provide advance notice that ranges from a few hours to over a day, depending on the conditions.

To aid in the identification of risks linked to different levels of vog exposure, advisory levels are established for short-term exposure. These advisory levels serve to inform the public about the potential adverse effects of exposure. Figure 18-1 provides the advisory levels established by the State of Hawai'i Department of Health (HDOH).



Figure 18-1. State of Hawai'i Department of Health Guidance on Short-term Sulfur Dioxide Advisory Levels

SO ₂ Conc. (ppm) ¹	Color Code & Air Quality Condition	Air Quality Description	Recommended Action/Activity ²		
			Sensitive Groups ³	People Experiencing Health Effects ³	Everyone Else
0 – 0.10	Green (Good)	Considered satisfactory & poses little or no risk	Highly sensitive individuals may be affected at these levels		Potential health effects not expected
0.11-0.20	Yellow (Moderate)	Acceptable, however, may be moderate health concern for small number of people	Be aware that levels are slightly elevated	If you experience breathing difficulties, such as chest tightness or wheezing, stop activities, use a rescue inhaler and find a place to sit down and rest.	Potential health effects not expected, however actions to reduce exposure to vog may be useful
0.21–1.00	Orange (Unhealthy for Sensitive Groups)	Members in sensitive groups, including healthy individuals with mild asthma, may experience health effects. They may be affected at lower levels than general public. Toward the upper end of this range, most asthmatics who are active outdoors are likely to experience some breathing difficulties. General public not expected to be affected in this range.	Avoid outdoor activities that cause heavy breathing or breathing through the mouth ⁴	If you experience breathing difficulties, such as chest tightness or wheezing, stop activities, use a rescue inhaler and find a place to sit down and rest.	Potential health effects not expected, however actions to reduce exposure to vog may be useful
1.01–3.00	Red (Unhealthy)	Everyone may begin to experience health effects. Members of sensitive groups may experience more serious health effects.	Avoid outdoor activities & remain indoors	Consider leaving the area	Avoid outdoor activities that cause heavy breathing or breathing through the mouth ⁴
3.01–5.00	Purple (Very Unhealthy)	Triggers health alert, meaning everyone may experience more serious health effects.	Avoid outdoor activities & remain indoors	Leave the area & seek medical help	Avoid outdoor activities & remain indoors
> 5.01	Maroon (Hazardous)	Triggers health warnings of emergency conditions. Entire population is more likely to be affected.	Avoid outdoor activities & remain indoors. Leave the area if directed by Civil Defense	Leave the area & seek medical help	Avoid outdoor activities & remain indoors. Leave the area if directed by Civil Defense

Source: (State of Hawaii Department of Health 2020)

18.1.4 PREVIOUS OCCURRENCES

This section provides an overview of hazard occurrences since the publication of the previous LHMP, covering the period between January 2020 and February 2025. It identifies events that resulted in federal disaster declarations and/or state or local emergency proclamations. For events prior to 2020, refer to the 2020 LHMP.

Recent Events

The Kīlauea volcano was active in 2020, 2021, 2022, 2023, and 2024 (NPS 2025); the Mauna Loa volcano was active in 2022 (NPS 2023). Table 18-1 details the eruption length and locations as described by HVO. Vog emissions were referenced for only the September 2023 eruption.



Table 18-1. Active Volcanic Periods (2020 to 2024)

Event Date	Disaster Declaration/ Proclamation			Description
	Federal	State	Mayoral	
December 20, 2020 to May 23, 2021	N/A	N/A	N/A	On December 20, as lava cascaded into Halema'uma'u crater, it instantly vaporized the growing lake of water that had been developing in the crater since 2018. By December 24, it was replaced by a lava lake more than 500 feet deep. After 5 months of activity, the eruption ceased on May 23, 2021.
September 29, 2021 to December 14, 2022	N/A	N/A	N/A	On September 29, three fissures opened within Halema'uma'u crater. The new fissures generated lava flows on the surface of a previous lava lake surface, creating a new lava lake eventually growing to nearly 300 acres in size. Over the next 14 months, lava flows continued to fill in the crater, ultimately effusing over 29 billion gallons of lava and raising the crater floor to nearly 500 feet higher than before the eruption.
November 27, 2022 to December 13, 2022	N/A	N/A	N/A	Mauna Loa, erupted in late 2022, the first eruption since 1984. The eruption began in Moku'āweoweo, the summit caldera of Mauna Loa. After several hours, new fissures opened some distance away from the summit along the Northeast Rift Zone. Fissure 3, the only active fissure, was producing between 50 and 100 cubic yards of lava per second. The eruption ceased on December 13.
January 5, 2023 to March 7, 2023	N/A	N/A	N/A	On January 5, a surge of lava burst from the floor of Halema'uma'u crater. Lava fountains reached 164 feet (50 meters) into the air on the first day. Lava flows inundated the crater floor within hours and filled a 277-acre area. On March 7, the eruption paused after 61 days of volcanic activity.
June 7-19, 2023	N/A	N/A	N/A	On June 7, the Halema'uma'u crater began erupting with lava fountains up to 200 feet tall. The eruption paused on June 19.
September 10-16, 2023	N/A	N/A	N/A	On September 10, Fissures emerged from the eastern edge of Halema'uma'u crater. At the beginning of the eruption, the main fissure's base, furthest to the west, measured about 230 feet wide and reached heights of roughly 65-82 feet. As the six-day eruption progressed, the lava fountains gradually subsided to an average of 32 to 50 feet). Initial volcanic gas emissions amounted to 209,000 tons of sulfur dioxide per day, with the eruption plume consisting primarily of sulfur dioxide and minor volcanic particles, rising to altitudes of 8,000 to 10,000 feet above sea level. Eruptive activity ceased on September 16.



Event Date	Disaster Declaration/ Proclamation			Description
	Federal	State	Mayoral	
June 3, 2024	N/A	N/A	N/A	Kīlauea’s Southwest Rift Zone erupted in the early hours of June 3. While the East Rift Zone has dominated headlines over the past four decades, with Pu’u’ō’ō’s continuous eruption, the 2018 Leilani Estates eruption, and recent summit eruptions, the Southwest Rift Zone has often been overlooked. The lava flows, though limited, covered a modest area of a few thousand square meters.
September 15-20, 2024	N/A	N/A	N/A	On September 15, Kīlauea began a new eruption along the middle East Rift Zone, about eight miles from Kaluapele, the summit caldera. The new eruption came after nearly three months of heightened unrest and hundreds of earthquakes along the East Rift Zone, indicating that magma was on the move just below the surface. Eruptive activity came to an end on September 20.
December 23, 2024	N/A	N/A	N/A	On the morning of December 23, Kīlauea volcano began erupting. Fissures opened on the caldera floor, releasing lava fountains up to 295 feet high. The eruption was mainly confined to the southwest side of the caldera, and by 9:30 a.m., the lava fountains had decreased to about 230 feet in height.

Source: (NPS 2025)

Federal Disaster Declarations

Under the Stafford Act, the President of the United States may issue an Emergency Declaration (EM) or Major Disaster Declaration (DR) for health related events and activate certain federal assistance programs based on factors related to the magnitude of the hazard threat or impacts.

Vog, as a standalone hazard, would not qualify for a federal disaster declaration.

State and Local Emergency Proclamations

State law authorizes the Governor to issue emergency proclamations if an emergency or disaster has occurred, or there is imminent danger or threat of an emergency or disaster in any portion of the state. County Mayors have the authority to issue local emergency proclamations when such conditions exist within any part of their respective jurisdictions.

No state or local emergency proclamations related to this hazard were issued for the City during this period.



18.1.5 PROBABILITY OF FUTURE OCCURRENCES

The probability of future occurrences of vog affecting O’ahu depends on several factors, including the frequency, intensity, and elevations of eruptions on Hawai’i Island and prevailing wind patterns. Historically, significant eruptions on Hawai’i Island have led to periods of elevated vog levels on O’ahu, particularly when trade winds are weak or absent. Given the ongoing volcanic activity in Hawai’i, it is reasonable to expect that O’ahu will continue to experience vog events in the future.

According to the HVO, vog occurrences in the City are not tracked. Therefore, the number of volcanic eruptions as tracked by NPS was used to calculate the probability of future occurrence of such events. Table 18-2 lists the number of events from various sources over the 156-year period from 1868 to 2024 which is the most complete period of record for all sources reviewed. Based on these records, the probability of occurrence for volcanic gas in the City is considered “occasional.”

Table 18-2. Probability of Future Vog Hazard Events in the City and County of Honolulu

Hazard Type	Number of Occurrences Between 1868 and 2024	Percent Chance of Occurring in Any Given Year
Volcanic Gas	29	18.6%

Source: (NPS 2025)

Note: The time period presented in this table is the most complete period of record for the various data sources reviewed.

18.2 VULNERABILITY AND IMPACT ASSESSMENT

18.2.1 LIFE, HEALTH, AND SAFETY

Overall Population

The health impacts from vog on the overall population on O’ahu are very minor as there are no elevated levels of SO₂ and SO₄, which are the main contributors to adverse health effects. The most likely impacts O’ahu will experience are from low levels of PM_{2.5} particle pollution, which can cause temporary health symptoms such as the following:

- Eye, nose and/or throat irritation
- Coughing and/or phlegm
- Chest tightness and/or shortness of breath

Socially Vulnerable Population

Sensitive groups include the following:



- People with asthma or other respiratory conditions
- People with cardiovascular disease
- Older adults
- Infants and children

The IVHHN recommends that those sensitive to unusually high vog levels take the following precautions (IVHHN 2024):

- Do not smoke, and avoid secondhand smoke
- Stay hydrated and drink warm or hot fluids
- Manage congestion or irritation
- Limit outdoor activities
- Stay indoors and use air conditioning, if possible
- Have medications close at hand

In the event of a vog occurrence, individuals concerned about its impact on their health can use the vog prediction model to anticipate when vog might affect them. This tool can be found here: <http://mkwc.ifa.hawaii.edu/vmap/>.

18.2.2 ECONOMY AND GENERAL BUILDING STOCK

Vog does not directly impact structures, including the general building stock. The general building stock, as defined for this plan, would continue to be functional during a vog event.

18.2.3 COMMUNITY LIFELINES AND OTHER CRITICAL FACILITIES

Vog does not significantly impact community lifelines and other critical facilities in the City. The levels of SO₂ and particulate matter from volcanic emissions are generally below thresholds that would cause serious operational disruptions or health effects for the general population and critical infrastructure.

18.2.4 NATURAL, HISTORIC, AND CULTURAL RESOURCES

Natural Resources

The sulfuric acid or sulfur dioxide in vog has been shown to have some effects on plants. However, SO₂ levels are not elevated on O'ahu; there is no evidence that concentrations are high enough to have an impact on O'ahu. Therefore, it is unlikely that SO₂ will have any direct effect on natural resources (City and County of Honolulu 2020).



Historic and Cultural Resources

While there is not extensive information specifically addressing the impact of vog on historic resources in O‘ahu, it is reasonable to infer that vog could potentially affect these resources. Vog, which contains SO_2 and other pollutants, can lead to acid rain. Acid rain can cause deterioration of building materials, including those used in historic structures.

Although detailed information on the impact of vog on cultural resources on O‘ahu is limited, it is plausible that vog could have adverse effects. The presence of SO_2 and other pollutants in vog can result in acid rain, which may contribute to the deterioration of materials used in cultural sites. This can affect the preservation and integrity of these important resources.

18.2.5 FUTURE CHANGES THAT MAY AFFECT RISK

Understanding future changes that affect vulnerability can assist in planning for future development and ensure establishment of appropriate mitigation, planning, and preparedness measures. The following sections examine potential conditions that may affect hazard vulnerability.

Potential or Planned Development

Potential or planned development within the City will not be affected by vog events.

Projected Changes in Population

As the age distribution of the population changes resulting in an increase in the number of elderly and young persons in the City, vulnerability to the impacts of vog may increase as these populations tend to be more susceptible to negative impacts.

Climate Change

Climate change is not expected to increase the probability of vog or its associated risks.