HEALTH HAZARDS DUE TO AIR POLLUTION FROM VOLCANIC ERUPTIONS

A guide for the public

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LANDSPÍTALI
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These guidelines is intended to explain the potential effects of air pollution on people's health and to provide information on how to protect yourself and your loved ones against air pollution during volcanic eruptions. It is partially translated and adapted from The International Volcanic Health Hazard Network´s (IVHHN) brochure: *The health hazards of volcanic and geothermal gases*.

Agencies involved in the Icelandic version:

The Chief Epidemiologist, landlaeknir.is
The Environment Agency of Iceland, ust.is
Icelandic Met Office, vedur.is
Department of Civil Protection and Emergency Management, almannavarnir.is
Landspitali – The National University Hospital of Iceland, landspitali.is
Icelandic Food and Veterinary Authority, mast.is
Association of Public Health Authorities in Iceland, shi.is

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Hazardous Gases in the Vicinity of Volcanic Eruptions

Each volcano exhibits its unique characteristics, and the impacts of volcanic eruptions can vary. Explosive volcanic eruptions occur when magma disintegrates due to the expansion of magmatic gases, while other eruptions can take place underwater or through glaciers. Lava eruptions, which are most common in Iceland, tend to flow through cracks. Volcanic eruptions release a variety of gases, which are dispersed in the direction of the prevailing wind. However, their concentration is highest in close proximity to the volcano. This air pollution can pose significant dangers to individuals, animals, vegetation, and property.

Volcanic gases are colorless, but have different odors:

SO_2	A similar smell to fireworks, or a struck match.
H_2S	Smells like a hot spring ('rotten egg').
HF and HCl	Strong, irritating, pungent odor. This gas pollution occurs mainly when lava flows into the ocean.
CO_2 and CO	Odorless and therefore particularly dangerous.

Air Pollution Resulting from Volcanic Eruptions

Volcanic eruptions release various types of pollutants in the form of gases and solids. The most prevalent gas emitted is sulfur dioxide (SO2), which disperses in the direction of the prevailing wind. However, the highest concentration of sulfur dioxide is found near the volcano. The finest particulate matter from volcanic eruptions (PM 2.5) can be particularly harmful to health, as it can easily penetrate deep into the lungs and accumulate there, potentially entering the bloodstream.

Monitoring Air Pollution during Volcanic Eruptions

During a volcanic eruption, monitoring of air pollution is significantly intensified, and the number of pollution meters is increased in both urban areas and the vicinity of the erupting volcano. The Icelandic Met Office measures pollution levels in close proximity to the volcano and develops a distribution model that predicts the spread of eruptive substances. The pollution forecast is published on Met Office´s website. Air pollution travels with the prevailing wind direction, and the concentration of pollution is directly related to the volume emitted by the volcano and the distance from the eruption site. The Met Office website also features a form that allows the public to report any odors associated with volcanic eruptions, such as the smell of sulfur.

The Environmental Agency maintains the website loftgaedi.is, where data is collected from various sites around the country. Visitors can view the concentration of chemicals in the atmosphere and access real-time assessments of air quality in urban areas.

Can Air Pollution Have Immediate Effects on Health?

The table "Short-term Effects of Sulfur Dioxide (SO_2) - Effects and Recommendations" provides recommendations for dealing with air pollution resulting from volcanic eruptions. These recommendations assume exposure to polluted air for 10 to 15 minutes. Prolonged exposure may lead to more severe health effects. It is important to note that the health protection limits for SO_2, according to Icelandic regulations, are 350 µm/m³ for hourly averages and 125 µg/m³ for 24-hour averages. These limits also apply during volcanic eruptions. The table offers guidelines for pollution across a wide range of concentrations, aiming to facilitate daily activities while minimizing harm to people's health.

Short-term effects of SO2

Descriptions of effects are based on 10-15 minutes spent in polluted air

Concentration of SO_2 for 10–15 minutes		Descriptions of air quality and its effect on individuals	Recommendations on response	
µg/m³	ppm		All children, individuals with underlying medical conditions and vulnerable individuals *	Healthy individuals
		Excellent		
0–20	**0–0.1**	Generally no effect on health.	Effects on health unlikely. Young children can sleep outside in baby carriage.	Effects on health unlikely.
		Good		
20-350	**0–0.1**	Generally no effect on health.	Effects may be felt. Young children should not sleep outside in baby carriage.	Effects on health unlikely
		Fair		
350–600	**0.1–0.2**	**Vulnerable individuals:** Can cause respiratory tract discomfort (cough) in susceptible individuals. **Healthy individuals:** Can cause irritation of eyes, nose and throat.	Show caution, follow measurements performed. Limit outdoor activities if you experience symptoms. Young children should not sleep outside in baby carriage. Older children should avoid exerting themselves outdoors. Turn off ventilation systems.	Effects on health unlikely. Turn off ventilation systems.
		Unhealthy for vulnerable individuals		
600–2.600	**0.2–1.0**	**Vulnerable individuals:** Cough. Irritation of eyes, nose and throat.	Limit strenuous outdoor activities. Children should not be outdoors except to commute between home and school.	Effects on health unlikely but sensible to limit strenuous outdoor activities. Try to breathe only

		Healthy individuals: Can cause respiratory tract symptoms or irritation to eyes, nose and throat.	Turn off ventilation systems.	through your nose. Turn off ventilation systems.
		Unhealthy		
2,600–9,000	**1.0–3.0**	**Vulnerable individuals:** Cough. Irritation of eyes, nose and throat. **Healthy individuals:** Same symptoms but milder, or none.	Stay indoors and close the windows. Turn off ventilation systems.	Avoid outdoor exertion. Those who can, stay indoors. Try to breathe only through your nose. Close the windows and turn off ventilation systems.
2,600	**1.0**	Occupational safety limits 15 min.	All outdoor work is prohibited except if using a suitable gas mask and gas meter.	All outdoor work is prohibited except if using a suitable gas mask and gas meter.
		Very unhealthy		
9,000–14,000	**3.0–5.0**	All are likely to experience moderate or severe respiratory tract symptoms.	Stay indoors and close the windows. Turn off ventilation systems. Follow the advice of the authorities.	Stay indoors and close the windows. Turn off ventilation systems. Follow the advice of the authorities.
		Hazardous		
> 14,000	**> 5.0**	Severe respiratory tract symptoms are very likely in both healthy and vulnerable individuals.	Stay indoors and close the windows. Turn off ventilation systems. Follow the advice of the authorities.	Stay indoors and close the windows. Turn off ventilation systems. Follow the advice of the authorities.

* All children. Adults with asthma (history of wheezing and/or chest pain, or diagnosed asthma), bronchitis, emphysema, and cardiovascular disease. These instructions also apply to pregnant women.

In the Vicinity of a Volcanic Eruption

Before embarking on a trip to the vicinity of a volcanic eruption, it is crucial to take the following precautions:

- **Educate yourself about the type of eruption and potential hazards, including air pollution.** Follow the guidance of local authorities and check the weather forecast, paying close attention to wind direction and air pollution forecasts. It's important to note that children and individuals with pre-existing medical conditions are more susceptible to the effects of pollution from an erupting volcano.
- **Familiarize yourself with the route to the volcano**, considering the physical demands and available hiking trails. It is advisable to choose a hiking trail based on the prevailing wind direction.
- **Inform your family and/or friends about your travel plans before depature.** You can also share your itinerary on safetravel.is, which can be useful in case of any unforseen circumstances during your trip.
- **Keep in mind that children are more vulnerable to air pollution**. Chilren should not spend more than 15 minutes in an area where air pollution exceeds health protection limits. This also applies to pregnant women, people with underlying heart or lung conditions, and individuals over the age of sixty.
- **As pollution is carried by the wind, it is safest to observe the eruption with the wind at your back.** Exercise extra caution during light wind conditions, as pollution tends to accumulate in valleys. **Follow the instructions of emergency personnel if they are present at the scene.**
- **If you hear a warning from a gas meter, immediately move uphill and maintain a safe distance from the eruption.** It is unnecessary for the public to use gas masks during volcanic eruptions. In the event of heavy pollution, it can be helpful to breathe through a damp cloth and inhale slowly through the nose.
- **Avoid valleys in the area and, if possible, follow ridges.** Magmatic gases are colorless but may have distinct odors. Near to a volcanic eruption, these gases can reach life-threatening concentrations. Carbon dioxide (CO_2) is particularly noteworthy, as it is odorless and it can lead to sudden death if you are exposed to high levels of this gas.
- **Do not linger for an extended period near a volcanic eruption. Leave the area promptly.** Have your own evacuation plan in case a warning is issued. Stay calm and move away from the eruption, heading towards the nearest ridge or hill while maintaining higher ground. Remember to breathe

through your nose, and that engaging in strenuous activity may result in increased inhalation of pollutants.

Extremely High Levels: Acute Pollution from Substances Other than Sulfur Dioxide (SO_2)

Hydrogen Sulfide (H_2S)

This gas emits a smell like that of a hot spring or rotten eggs, but at very high levels, it can affect the sense of smell, causing people to stop perceiving the odor. Elevated levels of H_2S can lead to fatigue, loss of appetite, irritation of the respiratory tract, and acute confusion. Concentrations of 2-5 ppm can cause respiratory tract irritation, headaches, nausea, and eye irritation. Individuals with pulmonary conditions may have trouble breathing. Very high levels (above 500 ppm) can result in fainting and sudden death.

Carbon Dioxide (CO_2) and Carbon Monoxide (CO)

These gases are odorless. The atmospheric concentration of CO_2 is approximately 400 ppm, and exposure to around 50,000 ppm can cause headaches, sweating, and an increased heart rate. Higher concentrations of CO_2 can lead to dizziness, breathing difficulties, muscle weakness, acute confusion, tinnitus, nausea, or vomiting. At extremely high concentrations (over 100,000 ppm), CO_2 can induce fainting, suffocation, and sudden death. Gas masks do not provide protection against high levels of CO_2 unless they are connected to a source of oxygen.

Hydrogen chloride (HCl) and Hydrogen fluoride (HF)

These gases have an irritating, strong, pungent odor. High levels of HCl (50—100 ppm) and HF (>50 ppm) can cause life-threatening pulmonary edema. Special attention should be given to HCl and HF when lava flows into the sea. Even short-term exposure to HF concentrations above 50 ppm can be dangerous (minutes).

Indirect Health Effects of Acute Air Pollution

- **Driving.** High levels of air pollution affect concentration and extremely high levels of SO_2 can lead to loss of consciousness.
- **Water Pollution.** Follow the instructions of local authorities.
- **Effects on Wildlife and Plants.** Crops may be at risk. Wash vegetables and fruits before consumption. Animals may experience respiratory problems. Ensure they have access to clean water and feed. The Food and Veterinary Agency strongly advises against bringing dogs or other pets to eruption sites due to the high levels of pollution, which can harm animals. For more information, visit their website.

What Can Individuals Do to Protect Themselves and Their Loved Ones from Air Pollution during a Volcanic Eruption?

- Familiarize yourself with the air quality map from the Environmental Agency, the pollution forecast from the Met Office, and follow the advice of health authorities.
- Be aware of general principles, such as staying indoors and closing windows during periods of high pollution. Minimizing time spent in polluted areas is beneficial. Conventional face masks provide little to no protection against air pollution from volcanic eruptions. If it becomes necessary to be outdoors briefly in heavy pollution, it can be helpful to breathe through a damp cloth. Breathe slowly through the nose. There is no need to use gas masks in populated areas.
- Individuals who are vulnerable should consult with healthcare providers regarding medications and other measures that may be useful.

Measures to Prevent Indoor SO_2 Pollution

- Close windows and limit the opening of doors to the outside.
- Turn off ventilation systems, if applicable.
- Ventilate the indoor space as soon as the air quality outside improves.

The Fagaradalsfjall volcano Photo: Dept of Civil Protectio