In September 2014, a huge volcanic eruption in Iceland emitted up to nine times as much sulphur dioxide per day as all European industry combined. Anja Schmidt and Claire Witham explore what this did to air quality across Europe.

Air pollution from Icelandic volcanoes

Lava fountains, Holuhraun, Iceland.
Michelle Parks, University of Iceland.

In the early hours of 31 August 2014 a truly spectacular eruption began at the Holuhraun lava field in Iceland, 45km away from the Bárðarbunga volcano. Compared to the ash-producing 2010 Eyjafjallajökull eruption, the Holuhraun eruption was a rather different beast, producing very little volcanic ash but lots of lava and toxic volcanic gases that were detected at air quality monitoring stations as far away as Austria.

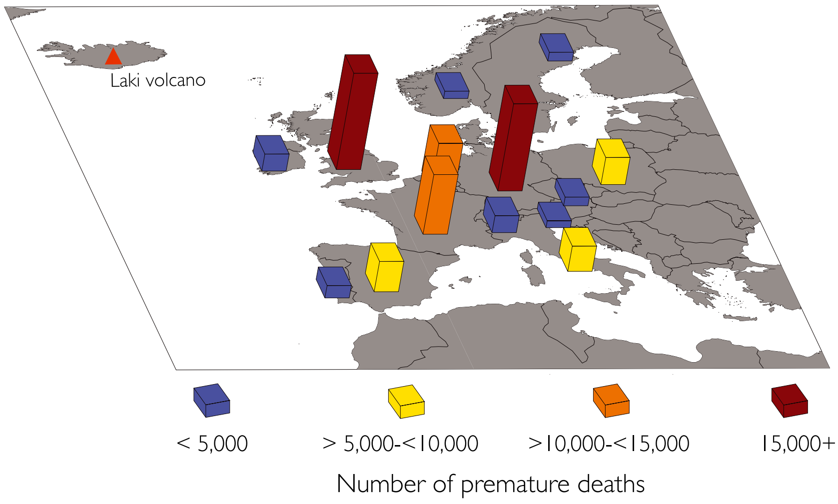
Events like Holuhraun are known as effusive eruptions, and specifically as fissure eruptions. The biggest of these produce enough lava to fill up to 100,000 Olympic-sized swimming pools per day for months to years. These big eruptions occur on average every 200 to 500 years, whereas smaller-volume fissure eruptions like Holuhraun occur every 40-50 years.

Less ash, more gas

During its first month, the eruption at Holuhraun was extremely powerful, spewing fountains of lava up to 150 metres high along a 1.5km long crack in the Earth's crust (putting the 'fissure' in 'fissure eruption'). By the time the eruption had ended six months later, it had produced about 1.5km^3 of lava, covering an area of around 86km^2 – about 50 times the area of Regents Park in London, or equivalent to covering Regents Park in 1km of lava.

It quickly became clear that the eruption was emitting truly staggering amounts of sulphur dioxide (SO_2) into the lower parts of the atmosphere. SO_2 is a toxic gas that is converted to sulphuric acid aerosol particles. Both of these can affect air quality, causing respiratory problems for people exposed to them, particularly those who already have asthma or other lung difficulties; sulphuric acid can also lead to acid rain. Due to the remoteness of the eruption site and the weather conditions in Iceland continuous ground-based monitoring and measurement of SO_2 was very challenging.

This is where satellite observations of the volcanic SO_2 plume came to the rescue. Our team analysed satellite data and combined it with computer modelling using the Met Office's NAME model. This let us track and compare the dispersion of the volcanic gas cloud, as well as estimate how much SO_2 was emitted. We found that at its most powerful the eruption emitted about 120 kilotons of SO_2 per day – eight times more than the total from all man-made sources in Europe. During September 2014, Holuhraun emitted a total of 2.0±0.6 million tons of SO_2, making it the largest volcanic sulphur pollution event in Iceland for more than 200 years. Its bigger sister, the Laki eruption, took place in 1783-1784AD and produced, over eight months, an order of magnitude more lava and about 60 times more SO_2 than Holuhraun did in 2014.



Estimated numbers of premature cardiopulmonary deaths in Europe which could potentially be caused by a Laki-type eruption in the future.

Detecting and monitoring volcanic pollutants

Over the course of the eruption, air quality monitoring stations in Iceland recorded unprecedented levels of SO_2, often significantly exceeding the current 10-minute mean air quality standard set by the World Health Organization (WHO) to protect public health. Yet the pollution was not confined to Iceland: we found the gas was transported over very large distances and detected by air quality monitoring stations up to 2750km away from Iceland.

Away from Iceland there was no risk of long-term detrimental health effects because exposure to volcanic pollutants was brief. For instance, on 6 September 2014, volcanic pollution reached Ireland, where monitoring stations recorded short-lived (up to 24 hours) spikes in surface SO_2 concentrations of just above 500µg/m^3. Air pollution regulations introduced in the 1980s mean that SO_2 levels from industrial emissions are very low nowadays, so the concentrations recorded on 6 September 2014 were particularly unusual.

Air quality monitoring stations across Europe were essential in detecting and characterising the pollution resulting from this eruption. These observations and our model simulations show that volcanic pollution from Icelandic fissure eruptions can easily reach Northern Europe and degrade air quality temporarily. Right now the number of SO_2 monitoring stations across Europe is steadily declining. SO_2 concentrations are usually very low as a result of new laws aimed at reducing man-made emissions since the 1980s, so constant monitoring doesn't seem as important as it once did.

We think existing air quality monitoring stations ought to be retained, or even extended to monitor volcanic pollutants from future eruptions in Iceland. This would help us characterise and mitigate volcanic gas and aerosol particle hazards, which could be severe in the event of a large-magnitude Icelandic eruption like a repeat of the Laki eruption. In a 2011 study, we calculated that a future Laki-type eruption could degrade air quality across Europe for several weeks potentially resulting in more than 100,000 premature deaths across the continent.

The next eruption…

Every eruption is different, and those of Holuhraun and Eyjafjallajökull have shown that future Icelandic eruptions will pose new hazards and challenges for science and society. With each event, we learn more about the volcanic processes involved and broaden our understanding of how to best use observations and computer models to understand these hazards and inform decision makers.

We cannot predict the next eruption, but recent activity proves that in Europe we should prepare for the impacts of not only volcanic ash but also volcanic gases and airborne particles. Work on this source of air pollution has informed UK Government policy and led to volcanic gas and airborne particle hazards being recognised alongside more established volcanic ash hazards. As a result there are now contingency plans in the event of a future eruption, which will make society better-prepared and more resilient. This in turn is expected to minimise disruption, costs and potentially save lives.

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To find out more about the NAME model, see www.metoffice.gov.uk/research/modelling-systems/dispersion-model.

Excess mortality in Europe following a future Laki-style Icelandic eruption – DOI:10.1073/pnas.1108569108

Satellite detection, long-range transport, and air quality impacts of volcanic sulfur dioxide from the 2014–2015 flood lava eruption at Bárðarbunga (Iceland) DOI:10.1002/2015JD023638