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How future volcanic eruptions will impact Earth's ozone layer

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The next major volcanic eruption could kick-start chemical reactions that would seriously damage the planet's already besieged ozone layer.

The extent of damage to the ozone layer that results from a large, explosive eruption depends on complex atmospheric chemistry, including the levels of human-made emissions in the atmosphere. Using sophisticated chemical modeling, researchers from Harvard University and the University of Maryland explored what would happen to the ozone layer in response to large-scale volcanic eruptions over the remainder of this century and in several different greenhouse gas emission scenarios. The research was published recently in *Geophysical Research Letters*.

The Earth's stratosphere is still recovering from the historic release of chlorofluorocarbons (CFCs) and other ozone-depleting chemicals. Even though CFCs were phased out by the Montreal Protocol 30 years ago, levels of chlorine-containing molecules in the atmosphere are still elevated. Explosive volcanic eruptions that inject large quantities of sulfur dioxide into the stratosphere facilitate the chemical conversion of chlorine into more reactive forms that destroy ozone.

Researchers have long known that when concentrations of chlorine from human-produced CFCs are high, ozone depletion will result following a volcanic eruption. When levels of chlorine from CFCs are low, volcanic eruptions can actually increase the thickness of the ozone layer. But exactly when this transition happens—from eruptions that deplete ozone to eruptions that increase ozone layer thickness—has long been uncertain. Previous research has put the window of the transition anywhere between 2015 to 2040.

The Harvard researchers found that volcanic eruptions could result in ozone depletion until 2070 or beyond, despite declining concentrations of human-made CFCs.

"Our model results show that the vulnerability of the ozone column to large volcanic eruptions will likely continue late in to the 21st century, significantly later than previous estimates," said David Wilmouth, who directed the research and is a project scientist at the Harvard John A. Paulson School of Engineering and Applied Sciences and the Department of Chemistry and Chemical Biology.

So, why is this shift happening so much later than previously thought?

"Previous estimates did not take into account certain natural sources of halogen gases, such as very-short lived bromocarbons originating from marine plankton and microalgae," said Eric Klobas, lead author and Harvard chemical physics PhD candidate.

Accounting for these emissions fine-tunes the timing of the shift from eruptions that cause ozone depletion to eruptions that increase the thickness of the ozone layer. These natural sources of bromine become especially important in the lower stratosphere after concentrations of human-emitted CFCs have declined.

"We found that the concentration of bromine from natural, very short-lived organic compounds is critically important," said Klobas. "Even small, part-per-trillion changes in the amount of bromine from these sources can mean the difference between a late 21st century volcanic eruption resulting in ozone column depletion or ozone column enhancement."

The researchers then explored how a volcanic event the size of the Mount Pinatubo eruption, which shot about 20 million metric tons of sulfur dioxide into the stratosphere in 1991, would impact the ozone layer in 2100. The team modeled four different greenhouse gas emission scenarios, ranging from very optimistic to what is commonly considered the worst-case scenario.

The team found that the most optimistic projection of future greenhouse gas concentrations resulted in the most ozone depletion from a volcanic eruption. Conversely, in the pessimistic scenario in which greenhouse gas emissions continue to increase rapidly throughout the 21st century, a Mount Pinatubo-size eruption would actually lead to a slight increase in ozone. The researchers found that the colder stratospheric temperatures and higher methane levels in this scenario would curb important ozone-depleting chemical reactions.

But, here's the kicker: all of the above scenarios assumed that the volcanic eruption would only inject sulfur into the stratosphere, like the 1991 eruption of Mount Pinatubo in the Philippines. If the eruption were to also inject halogen-containing chemicals such as hydrogen chloride (HCl) into the stratosphere, the results could be dire.

"If volcanic halogens, which are commonly present in large quantities in volcanic eruptions, were to partition substantially into the stratosphere—in any greenhouse gas emission scenario, at any point in the future—it would potentially cause severe losses of stratospheric ozone," said Klobas.

In such a case, the United States could see a prolonged and significant decrease in ozone layer thickness - upwards of 15 to 25 percent in the highest halogen scenario modeled. Even small reductions in the thickness of the ozone layer, which shields the surface of the Earth from DNA-destroying ultraviolet radiation, can adversely impact human health and other life on this planet.

"These eruptions are highly unusual events but the possibility does exist, as evidenced in the historical record," said Wilmouth.

Provided by Harvard John A. Paulson School of Engineering and Applied Sciences

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