# Cold conspirators: Ice crystals implicated in Arctic pollution

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Close-up of frost flowers.

Frost flowers. Diamond dust. Hoarfrost. These poetically named ice crystal forms are part of the stark beauty of the Arctic. But they also play a role in its pollution, a new study by scientists at the University of Michigan, the Cold Regions Research & Engineering Laboratory and the University of Alaska has found.

After collecting and analyzing hundreds of samples from the Alaskan Arctic, the researchers determined that ice crystals that form from vapor clouds billowing up from cracks in sea ice help concentrate mercury from the atmosphere, and that certain types of crystals are more efficient than others. Their results appear in the cover article for the March 1 issue of *Environmental Science & Technology*.

"Previous measurements had shown that in polar springtime, the normally steady levels of mercury in the atmosphere drop to near zero, and scientists studying this atmospheric phenomenon had analyzed a few snow samples and found very high levels of mercury," said Joel Blum, the John D. MacArthur Professor of Geological Sciences at U-M. "We wanted to understand what's controlling this mercury deposition, where it's occurring and whether mercury concentrations are related to the type and formation of snow and ice crystals."

Mercury is a naturally occurring element, but some 150 tons of it enter the environment each year from human-generated sources in the United States, such as incinerators, chlorine-producing plants and coal-fired power plants. Precipitation is a major pathway through which mercury and other pollutants travel from the atmosphere to land and water, said lead author Thomas Douglas of the Cold Regions Research & Engineering Laboratory in Fort Wainwright, Alaska.

"Alaska receives air masses originating in Asia, and with China adding a new coal-fired power plant almost every week, it's not surprising that we find significant amounts of mercury there," Douglas said. "The concentrations we measured in some snow are far greater than would be found right next to a waste incinerator or power plant in an industrialized location."

Once mercury from the atmosphere is deposited onto land or into water, micro-organisms convert some of it to methylmercury, a highly toxic form that builds up in fish and the animals that eat them. In wildlife, exposure to methylmercury can interfere with reproduction, growth, development and behavior and may even cause death. Effects on humans include damage to the central nervous system, heart and immune system. The developing brains of young and unborn children are especially vulnerable.

Douglas, Blum and co-workers discovered that certain types of ice crystals—frost flowers and rime ice—contained the highest concentrations of mercury. Because both types of crystal grow directly by water vapor accretion, the scientists reasoned that breaks in the sea ice, where water vapor rises in great clouds, contribute to Arctic mercury deposition.

"The vapor that rises through these openings in the ice brings with it bromine from the sea water. That gets into the atmosphere, where sunlight plus the bromine cause a catalytic reaction which converts mercury gas into a reactive form. If any ice crystals are present, the mercury sticks to them and comes out of the atmosphere," Blum said.

The greater the surface area of the crystals, the more mercury they grab, which explains why frost flowers and rime ice, both delicate formations with high surface areas, end up with so much mercury. The mercury-tainted crystals aren't, however, confined to the edges of breaks in the ice, the researchers determined. Bromine can travel great distances, resulting in mercury deposition in snow throughout the Arctic coastal region.

Collecting the samples was an undertaking that required a spirit of adventure as well as scientific savvy.

"It's kind of a scary place to work," Blum said. "It's freezing cold, and you're out on the sea ice as it's breaking and shifting. You can very easily get stuck on the wrong side of the ice and get stranded. Our Inupiat guides would listen and watch, and when they told us things were shifting, we'd get out of there quickly."

In one experiment the research team used Teflon containers filled with liquid nitrogen, attached to kites or long poles, to collect newly condensed frost over the open water. They also flew a remote-controlled airplane through the vapor cloud and collected ice from its wings.

Even getting out to the ice to do the work was a challenge. After flying to Barrow, Alaska, the northernmost settlement on the North American mainland, the team took off on snowmobiles, led by their Inupiat guides. That may sound like a lark, but traveling over sea ice was not exactly smooth sailing, Blum said. Though the ice freezes flat, it breaks up, smashes back together and refreezes, forming high ridges through which the team had to chip their way with ice-axes to make pathways for their snowmobiles.

But the results are worth the effort and the risks, Douglas said.

"Research like this will help to further the understanding of mercury deposition to a region that is generally considered pristine," he said. "In the next phase of our work, we are expanding our knowledge by tracking the mercury during and following snow melt and studying its accumulation on the tundra."

In addition to Blum and Douglas, the paper's authors are Matthew Sturm of the Cold Regions Research & Engineering Laboratory in Fort Wainwright, Alaska; William R. Simpson and Laura Alvarez-Aviles of the University of Alaska, Fairbanks; Gerald Keeler, director of the U-M Air Quality Laboratory; Donald Perovich of the Cold Regions Research & Engineering Laboratory in Hanover, N.H.; U-M post-doctoral fellow Abir Biswas and U-M graduate student Kelsey Johnson.

Source: University of Michigan