Effort to improve wintertime air quality in Fairbanks, Alaska, may not be as effective as intended

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Work led by University of Alaska Fairbanks and Georgia Institute of Technology researchers shows that the effort to improve Fairbanks' wintertime air quality by reducing the amount of primary sulfate in the atmosphere may not be as effective in the deep cold as intended.

The research is published in *Science Advances*, with UAF doctoral student James Campbell as the lead author.

The concern centers on a reduction in acidity, reflected in a higher pH, of fine atmospheric particles in Fairbanks' typically frigid winters, particularly around -40°F.

"We're worried that reducing the primary sulfate won't be enough for emission control, because more secondary sulfate would be formed because of the higher pH," Campbell said.

Campbell is a graduate student in associate professor Jingqiu Mao's research group at the UAF Geophysical Institute and studied through the UAF College of Natural Science and Mathematics.

Mao and Georgia Tech professor Rodney Weber oversaw the research. Other UAF co-authors include professor William Simpson and research assistant Meeta Cesler-Maloney. Additional co-authors are from Georgia Tech, Johns Hopkins University, University of Michigan, University of New Hampshire and institutions in France, Switzerland and Greece.

This collaboration has spanned several years and involved state-of-the-art thermodynamic tools used in the majority of the world's air quality models.

Acidity of atmospheric fine particles is largely controlled by the relative fraction of ammonium and sulfate. Sulfate is highly acidic, while ammonium acts as the base to neutralize it.

Campbell found that reducing primary sulfate makes atmospheric aerosol particles ammonium-dominated rather than sulfate-dominated. That change to ammonia-dominated particles raises the pH level of those particles.

Prior studies have identified residential fuel oil as the main source of sulfate particles in Fairbanks air but did not specify whether it occurred by direct emission from residential heating as primary sulfate or by post-exhaust atmospheric chemical reactions as secondary sulfate.

The state of Alaska required a switch to low-sulfur heating fuel in the portion of Fairbanks with bad air quality, defined as violating federal regulations regarding fine particulate matter, commonly referred to as $PM_{2.5}$. Particles of 2.5 micrometers or fewer can cause respiratory illnesses and heart ailments.

That higher pH from reducing primary sulfate and causing ammonium to be the dominant chemical of the two has a pair of consequences for Fairbanks wintertime air.

First, it increases formation of secondary sulfate during extremely low temperatures. Such temperatures make particles less acidic, which favors chemical reactions that lead to formation of the secondary sulfate.

Second, the higher pH increases the formation of hydroxymethanesulfonate, or HMS, which was discovered in Fairbanks winter air in 2019. Earlier research found that HMS accounts for a significant portion—3% to 7%—of the community's fine particulate pollution.

Little is known about the direct health effect of HMS on humans. Most of the concern about the compound relates indirectly through its role in air quality and its potential to contribute to atmospheric particulate matter.

Campbell wrote that the temperature effect on particle acidity is most obvious in extreme cold. The substantial HMS formation observed in Fairbanks winters during extreme cold periods "provides clear evidence

of it," he noted.

"This makes mitigation strategies a little more complicated, but hopefully this work will help reduce $PM_{2.5}$ pollution here in Fairbanks," Campbell said.

The U.S. Environmental Protection Agency has put Fairbanks in its "serious" category for air quality violations under the Clean Air Act and has threatened the state with sanctions.

Campbell's work stems from the 2022 Alaskan Layered Pollution and Chemical Analysis project, or ALPACA. It is part of an international air quality effort called Pollution in the Arctic: Climate Environment and Societies.

Nearly 50 U.S. and European scientists were in Fairbanks in January and February 2022 for the seven-week study of the chemical interactions that led to Fairbanks's air quality problem.

More information: James R. Campbell et al, Enhanced aqueous formation and neutralization of fine atmospheric particles driven by extreme cold, *Science Advances* (2024). DOI: 10.1126/sciadv.ado4373

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