Evergreen needles act as air quality monitors

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Peter Lippert (left) and Grant Rea-Downing examine artificial pine branches being tested as passive air quality monitors. Photo from Sept. 2019. Credit: Paul Gabrielsen/University of Utah

Every tree, even an evergreen, can be an air quality monitor. That's the conclusion of researchers at the University of Utah who measured the magnetism of particulate matter on the needles of evergreen trees on the U campus. That measurement, they found, correlated to general air quality, suggesting that analysis of the needles—a relatively simple and low-cost process—could provide a high-resolution, year-round picture of air quality.

"Wherever you have a tree you have a data point," says Grant Rea-Downing, a doctoral student in geology and geophysics. "A tree doesn't cost $250 to deploy. We'll be able to map particulate matter distributions at a very high resolution for very little cost."

The results are published in *GeoHealth*.

How magnetic particles end up on leaves

Rea-Downing and his colleagues—associate professor Pete Lippert and fellow graduate students Courtney Wagner and Brendon Quirk—are all geoscientists in the Department of Geology and Geophysics whose regular research is on a much different scale than pine needles.

"Day to day," Lippert says, "we move mountains and close ocean basins by using the magnetism of rocks to figure out the geography of former continents."

In a course titled "The Magnetic Earth," Lippert introduced Rea-Downing, Wagner and Quirk to papers by U.K. researchers who measured the magnetism of deciduous leaves to assess air quality. "I knew the students would kind of have their minds blown by what the study showed, and what the implications of the findings were," Lippert says.

Particulate matter in the air comes from many sources, including natural windblown dust, brake dust and the byproduct of burning solid or fossil fuel.

"That's stuff in the air," Lippert says, "and it's got to come out sometime."

When it falls out of the air some of it, of course, falls on tree leaves and evergreen needles. Some of the particles contain iron, with enough to be detectable by the kind of high-precision magnetometers that Lippert uses in his geological work. The iron-bearing particulate matter in the air can be too small to see, but magnetism, he says, is a way to see the unseen.

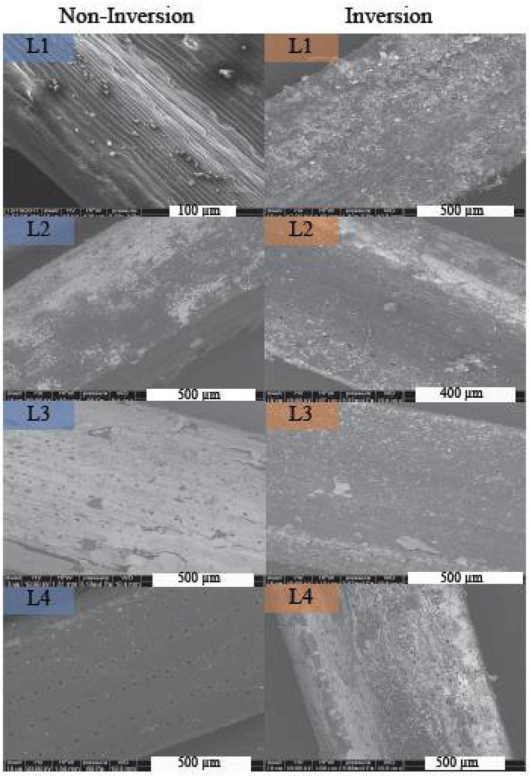
The papers made an impression on Rea-Downing, who saw Salt Lake City's air quality in stark contrast to the normally clean air of his native coastal California. He could easily apply the method in

Lippert's research lab.

"The kind of hill to climb to do this was actually quite flat," he says. "We have trees outside, we have seasonally bad air quality and we have a fully equipped paleomagnetic lab, which means that I literally just had to walk outside and pull some leaves off some trees and stick them in a magnetometer."

"We're not the first to explore the magnetism of pine needles to monitor air quality," Lippert says, "but no one had tried this to study winter inversions in the basins of the American West."

With financial support from the U's Global Change and Sustainability Center, the researchers went to work.



Scanning electron photomicrographs of evergreen needle surfaces. Images fromeach location are shown both during non-inversion (left) and inversion (right). Credit: University of Utah

Sylvan sentinels

The team selected four Austrian pine trees on the U campus to sample. Three of the trees were in a line perpendicular to North Campus Drive, a heavily used campus artery, with each tree successively farther from the roadway. The fourth was near the Union building, away from traffic. They collected pine needles twice: once in June 2017 after a summer of relatively good air and again in December 2017 during some of that winter's worst air quality.

With her particulate-matter-filtering dust mask on, Wagner collected the December samples in what she described as a "freezing death fog," as a temperature inversion throughout the valley had led to a thick yellowish fog and frost on the pine needles. Back in the lab, the team carefully cut the needles into short segments using ceramic scissors to avoid any metals contamination and put them in the magnetometers.

One of their experiments revealed that the magnetization of the December needles was nearly three times higher than the June needles. Another magnetic experiment, conducted at superlow temperatures, suggested the iron-bearing particles deposited during the inversion are extremely small (some as small as 1/5000 the width of a human hair) and found that they're composed of magnetite, an iron mineral that, as its name suggests, is naturally magnetic. The team also examined the needles under an electron microscope and confirmed that the December needles were significantly dirtier. The concentration, size and composition of the particles have all been linked by other studies to the health risks of air pollution.

They also looked at the elements present in the particulates. The amounts of iron in the dust correlated with amounts of other elements like titanium, vanadium and zirconium, "and a variety of other things that are associated with brake dust or fossil fuel combustion," Lippert says.

Other elements in the particulates were associated with catalytic converters, he says, which use chemical catalysts to detoxify exhaust. "And those concentrations, no surprise, are highest near the roadside."

Comparing the trees at various distances from the roadway showed a drop-off in the concentration of magnetic particles over a distance of 50 to 150 feet. That may be due to distance from the cars, the researchers say, but also possibly to elevation, as the transect of trees went up a slight hill.

Artificial pine

Now the team has joined forces with atmospheric scientist Gannet Hallar and chemical engineer Kerry Kelly to explore other questions that the study raised. They developed a new kind of passive air monitor—a 3-D printed, artificial pine branch with needles to catch particulates. The artificial needles are installed alongside natural needles and can serve as an experimental platform to more clearly understand how and when particles settle on evergreen needles, results they can compare directly to measurements of particle distributions measured by equipment in Hallar's and Kelly's labs.

"If we get a strong rain we can go and collect before and after that rain and see if this signal is just being washed away every time you have a rain event," Rea-Downing says. "Or are the biological needles actually absorbing material and actually holding onto that signal for longer than the synthetic needles?"

With every tree as a potential data point, pine needle analysis could give a more comprehensive insight into the what, when and why of air pollution in urban areas, showing variation in air quality on the scale of tens of feet. The analysis is straightforward and inexpensive, Lippert says.

"We have a lot of trees out on the landscape already," Lippert says. "They're a pretty low cost. So this democratizes our ability to monitor air pollution across the valley. This is easily exportable to any community. It allows us to do more with less, or that's our hope."

More information: Grant Rea?Downing et al, Evergreen needle magnetization as a proxy for particulate matter pollution in urban environments, *GeoHealth* (2020). DOI: 10.1029/2020GH000286

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