Beyond the tailpipe: UC Irvine Scientists Study Pollution From Vehicle Braking

New research reveals how brakes and tires contribute to air pollution, and what it means for our health.

Wednesday, April 23, 2025

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AirUCI researchers, pictured here in the UC Irvine School of Physical Sciences Machine Shop, are working to decipher the true nature of pollutants released from vehicle braking so they might understand how they affect disadvantaged communities.

Picture Credit:

Lena Gerritz / UC Irvine

When you imagine vehicle pollution, you might picture a car or truck spewing smoke out of its tailpipe. But that's not the only thing vehicles emit into the air.

A team of about three dozen researchers at UC Irvine that includes chemists, toxicologists and social scientists is working to better understand the growing threat posed by emissions from vehicle brakes and tires, something that may become the dominant source of road traffic pollution by 2035. The project, called "Beyond the Tailpipe: Health Impacts of Non-Tailpipe Vehicle Associated Pollutants Today and Tomorrow," launched in 2021 and is led by Barbara Finlayson Pitts, distinguished emerita professor of chemistry at UC Irvine and co-director of Atmospheric Integrated Research at UC Irvine (AirUCI).

The research has special relevance for Southern California – a place where traffic and congestion are synonymous with daily life. But while brake and tire pollutants might affect everyone, their impact isn't distributed evenly: residents in low-income neighborhoods often live close to busy freeways, and absorb a higher brunt of pollution. That's why the AirUCI-led team is partnering with local community and neighborhood organizations to uncover how overlooked brake emissions are affecting the health and well-being of those most vulnerable.

Finding answers

One big unknown surrounds the composition and behaviour of gases and particles released during braking. Brakes produce pollutants, but their exact nature, size, chemical makeup and electrical properties remain unclear, making it hard to fully assess the true impact of the pollutants on both the environment and our bodies.

To address this, the AirUCI team designed a custom dynamometer apparatus that simulates real-world braking conditions in a controlled laboratory environment. The team ran the dynamometer at an equivalent driving speed of 18 miles per hour under two different braking conditions. The first condition mimicked light breaking patterns typical of urban driving environments, while the second simulated heavy braking patterns common on rural roads and highways.

The team measured a wide range of airborne pollutants from the brakes, including greenhouse gases and a number of highly reactive molecules. The brake emissions, the team found, were similar to those emitted from biomass burning, suggesting heavy braking is akin to a continuous, slow-burning wildfire. Like the emissions that come out of an exhaust pipe, these emissions can react rapidly in air to form what we know as smog as well as other toxic ingredients, including ozone and airborne particles. The results appeared in the journal *Environmental Science: Processes & Impacts.*

An upcoming *Environmental Science & Technology* study by the team focuses on nitrogen compounds that can degrade air quality. This includes substantial quantities of gaseous nitrous acid (HONO) – a compound of importance to atmospheric scientists. Under many conditions, HONO can be a major source of hydroxyl radicals – often called the detergents of the atmosphere because they can help break down pollutants in the atmosphere, though they can also contribute to the formation of harmful compounds when interacting with those pollutants.

Despite its importance, sources of HONO remain poorly understood, as current models often underestimate HONO's impacts compared to real-world measurements. Brake emissions that were previously unrecognized could be responsible for some of the discrepancies, but more work needs to be done.

In addition to gaseous emissions, braking also releases tiny particles carrying surface charges. These particles can form hydroxyl radicals in water, which may have implications for human health in places where people breathe in those particles. The results appeared in *Proceedings of the National Academy of Sciences* and *Environmental Science & Technology Letters*.

The heavy metal iron was also found to be prevalent in brake particles emitted from the brake disc, which is the round metal plate attached to the wheel. Not only are chemicals like iron and nitrous acid harmful to the environment, they are also harmful to human health if inhaled. The team of toxicologists from the UC Irvine Wen School of Population and Public Health did experiments on exposure to brake wear using cell lines from human lungs and ovaries, and they found that exposure to brake wear particles can impact heart, lungs and reproductive health. In the lungs, DNA damage and cell death occurred for both male and female mice. The effects were sex-dependent, with female mice showing higher damage and cell death than male mice.

The team plans to extend the work to longer time periods, likely spanning months to years, to better understand how these chemicals persist in and affect the body. At present, most results come from studies that last days to weeks.

Community impacts

A cornerstone of the project is to investigate how non-tailpipe emissions impact disadvantaged communities. Given the health risks associated with such emissions, especially for residents living near major trafficked roads and multiple freeways like the city of Santa Ana in Southern California, the team partnered with GREEN-MPNA (Getting Residents Engaged - Madison Park Neighborhood Association), an environmental justice organization in Santa Ana to help assess and address these concerns. Aiming to incorporate social science perspectives into interdisciplinary environmental research and education, researchers from UC Irvine's EcoGovLab, led by Professor Kim Fortun of the Department of Anthropology, are working with members of GREEN-MPNA and the community to understand local air pollution sources.

“This project was designed from the outset to both incorporate community knowledge and to support community advocacy for stronger environmental protections,” said Fortun. “It was a uniquely interdisciplinary scientific study while also a concerted effort to address environmental injustice.”

The relationships and knowledge built through the project have had an enduring impact in Santa Ana, Fortun explained, bringing the city's most disadvantaged neighborhoods to the attention of both city and state officials.

“It is important to be able to tie the laboratory dynamometer measurements to real world exposures,” said Finlayson-Pitts. “In order to do this, a search for specific molecules that are markers for brake and tire emissions is underway both in the laboratory studies and then in the real world. These markers can then be used to estimate human exposures by measuring them in field studies in different locations, including in Santa Ana.”

Looking ahead

Replacement of fossil fuel vehicles with electric vehicles will not remove all vehicle-associated pollutants. EV's are zero exhaust emission vehicles (ZEEV), not zero emission vehicles (ZEV). Our currently-limited understanding of such emissions and their effects on the environment and health present significant challenges in developing cost-effective and health-protective policies and regulations.

The UC Irvine team is in the process of developing a mobile dynamometer that can perform in-field experiments on brakes and conduct studies on tire wear emissions. The new apparatus will facilitate deploying the dynamometer to various labs, including those that focus on toxicological impacts, so that emissions can be studied as they are generated. The setup will be able to fit full-sized tires in addition to passenger vehicle brakes.

“The mobile dynamometer will be a huge step forward for us. It will open up new areas of exploration and will allow us to more effectively collaborate with state and local air quality regulators,” said Jim Smith, UCI professor of chemistry. “Most importantly, it will allow us to more closely associate our lab measurements with real-world emissions.”

The brake research promises to contribute to new regulations for vehicles in California and beyond. Regulatory agencies like the California Air Resources Board and the South Coast Air Management District are already conducting research on understanding non-exhaust emissions in order to update their emission inventories, which in turn inform air quality regulations in the state. As the team’s findings grow, they will be used to inform new emissions standards for brakes and tires, and provide data on potential reformulations of brakes and tires as well as new technologies that control emissions.

“This project continues the ground-breaking research carried out by AirUCI researchers over a number of years, research that provides the foundation for developing cost-effective and health-protective control strategies.” said Finlayson-Pitts.

This article was written by Ph.D. student Sukriti Kapur from the UC Irvine Department of Chemistry. Kapur is a 2024-2025 UC Irvine School of Physical Sciences Science Communication Fellow.

About AirUCI: AirUCI is a world-renowned research institute dedicated to tackling issues of air pollution, climate change, sustainability and green technology on local to global scales. External reviewers recently rated AirUCI as one of the top institutes in the world, on par with the Max Planck Institute, Germany, ETH in Zurich, Switzerland and the Cooperative Institute for Research in Environmental Sciences (CIRES) at University of Colorado Boulder. This brakes project is one of many initiatives led by AirUCI to advance atmospheric research and improve public health.

The AirUCI brakes project was supported initially by the California Department of Justice through a $1.9 million grant made possible by a settlement with Volkswagen related to an emissions cheating scandal. Ongoing studies are funded by the National Science Foundation.

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