News and Perspectives

Wearable Air Samplers Reveal How Wildfire Shapes the Exposome

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Key Takeaways

- Wearable silicone-based devices are increasingly being used to measure chemical exposures, notably following wildfires.
- Indoor air exposures linger far longer than outdoor exposures.
- Researchers are working to correlate environmental exposures with health outcomes.

Just over 1 year ago, devastating fires raged in Los Angeles (LA), California, killing 29 people [1]. The blaze destroyed 16,000 structures—homes full of computers, plastic, and furniture—subjecting roughly 20 million people to toxic smoke and ash [1,2]. Winds helped clear the air significantly by mid-January, but researchers have found that hazardous compounds lingered indoors for weeks—possibly longer.

Tracking the Exposome

To collect a profile of the chemicals residents were exposed to following the LA wildfires, Krystal Pollitt, PhD, PEng—an associate professor at the Yale School of Public Health—deployed a wearable passive air sampler to 30 standing homes between February and April 2025 [3].

Pollitt's *Fresh Air Clip* is one of a number of wearable devices—typically made of silicone polymers—that can collect a wide range of organic chemicals from the air or skin. These devices are designed to offer insights into the "exposome"—a term first described 20 years ago [4] as the environmental counterpart to the genome. Exposome research aims to quantify how environmental exposures translate into health outcomes. Wearables are increasingly being deployed after natural hazards to help researchers document chemical exposures from air pollution, as well as water contaminants, occupational hazards, or pathogens.

Ongoing Exposure

Pollitt's rapid response study found that once these chemicals permeate the home, residents can continue to be exposed as they slowly release from furniture, carpets, and even drywall [3].

Combustion byproducts were detected in all of the homes tested 2 to 3 months after the fire; even homes 12 km away from the burn zone had byproduct levels only 1.2 times lower than those in homes closer to the burn zone. Further, levels of the vast majority of combustion-related chemicals, such as flame retardants, petroleum products, plastics, and tire particulates, were elevated indoors compared to outdoors.

Pollitt explains that hundreds of chemicals that settled indoors stayed put, and they will continue to be released off surfaces slowly over time. She uses a nontargeted gas chromatography–high-resolution mass spectrometry approach able to detect volatile and semivolatile organic chemicals, including those not necessarily expected to be collected by silicone. "There's so many obscure products that were burning, and were transformed through the pyrolysis process, that to come in with a targeted method would be like looking for a pin in a haystack," she says.

In addition to obscure products, Pollitt found a wide range of building materials and household products that released numerous chemicals that have not been well characterized, especially following combustion. "There's tons of plastics present, but we don't know which specific plastic types yet," she says.

"This was a first pass study, done in collaboration with colleagues at University of California in Los Angeles, that required immediacy to understand how acute exposures evolved," says Pollitt. She and colleagues are now analyzing hundreds of different soft materials from the fires, including carpet swatches, blankets, pillows, and stuffed animals, to determine which remediation efforts would work best to reduce long-term exposures.

It has become clear that wearables will be a key component of exposomics research going forward. "Especially with the fires, people have realized there's a huge need to be able to do personalized exposure monitoring," says Mary Margaret Johnson, MD, PhD—principal research scientist at Harvard T.H. Chan School of Public Health—who coauthored a review paper of exposomics methodologies and future directions [5].

"We're realizing more and more that what is in the smoke needs to be accounted for," says Johnson. "There is a realization that the toxicity of the smoke depends on what is being burned in the home or area. Metals in the smoke vary from fire to fire," she says.

Measuring Health Impact

Other researchers are conducting similar studies using silicone wristbands—even broaches—that can typically be worn for a few hours to 1 week to collect exposome samples. Heather Stapleton, PhD—distinguished professor of Environmental Chemistry & Exposure Science at Duke University in Durham, North Carolina—has conducted numerous studies using silicone wristbands in diverse communities. One group she has focused on is structural and wildland firefighters, given their increased risk of cancer and other health conditions compared to the general population.

Stapleton's preliminary research found that, compared to structural firefighters, wildland firefighters appear to have higher exposure to combustion byproducts and some brominated flame retardants.

As Stapleton's previous research has shown [6], the risks aren't just from the fires either. Contaminated firefighting equipment can also expose workers to a mixture of different chemicals. As well, they can be exposed to per- and polyfluoroalkyl substances (PFASs) used to extinguish the fire or treat their gear. Stapleton found that blood PFAS levels were positively correlated with years working as a firefighter.

Stapleton and Pollitt agree that the utility of wearable exposure capture devices is still in the early days, but they look very promising. "I am collaborating with a colleague to modify the wristband's ability to absorb and detect metals," Stapleton says.

Other researchers are pairing wearable air quality sensors with Apple Watch data to assess long-term impacts of wildfires on cardiovascular health. One recent study [7] found that, for each 10-µg/m^3 increase in particulate matter, firefighters' resting heart rates rose by an estimated 0.38 beats per minute before the 2024 Park Fire in California and by approximately 1.4 beats per minute following the fire.

Stapleton says that, while likely too cost-prohibitive to replicate on a large scale, this study is a first step toward the larger questions that researchers must now tackle, like determining how wristband results correlate with chemical levels in the body. "We know how to take blood or urine measurements, and put those into a risk assessment framework," says Stapleton. "We aren't quite there yet with wristbands." Stapleton says that the next steps include creating a machine learning model to predict what wristband exposures mean for internal doses. "I think that's key to making sure this tool is successful and can be used more broadly," says Stapleton.

Beyond Acute Exposure

Johnson and her colleague—Harvard physician-scientist Kari Nadeau, MD, PhD—are conducting several experiments to pair what is found in blood with external exposure measures, including those from wearable wristbands. "In our lab, we are trying to use blood as the exposome window," she says. "We also heavily focus on multi-omics approach, looking at inflammatory markers being produced, or on epigenetic changes, by looking at immune functioning, and associating them with various environmental exposure levels simultaneously," says Johnson.

"Since the silicone wristbands are relatively cheap, researchers are trying to incorporate with the general population to estimate different chemical exposures," she says.

Pollitt, too, is now collecting biological samples to look beyond acute exposures, as part of the LA Fire Health Consortium—a decade-long study of fire impacts. "Now we're starting to understand persistence," she says. Pollitt was one of many scientists presenting their research at the LA Fire Health Consortium conference in January to mark the 1-year anniversary of the fire. The saddest thing from the meeting, she described, was the realization of "what does this mean for the next fire? It will happen again—hopefully not on that scale."

In the meantime, researchers' continued adoption of silicone-based wearable devices will provide a unique lens into the exposome and how it is altered by growing climate change–related wildfire risk.

Keywords: wildfire smoke; exposome; air pollutants; environmental; wearable electronic devices; environmental monitoring; firefighters; combustion products; polycyclic aromatic hydrocarbons; particulate matter; cardiovascular diseases

Conflicts of Interest

None declared.

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