Science Societies

Burned homes, contaminated ground: the aftermath of wildfire

As wildfires increasingly engulf the built environment, scientists are uncovering how heat, ash, and debris transform soils

By Megan Sever

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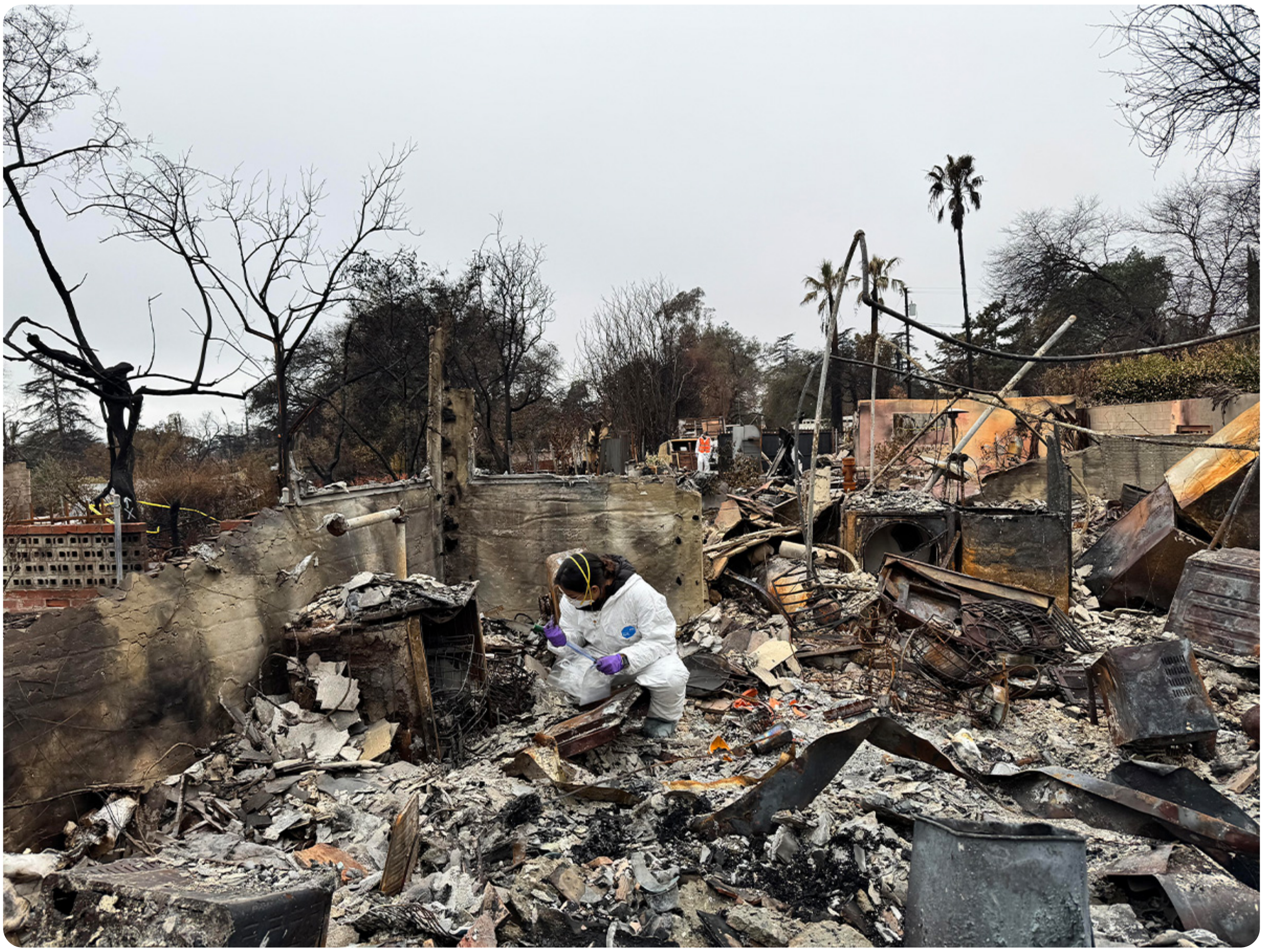


Photo courtesy of Frida Garcia-Ledezma.

When a wildfire destroys homes, the damage doesn’t end when the flames are extinguished. New research is revealing how heavy metals and other pollutants can persist in soils long after a fire, even at properties that escaped direct damage. Discover how scientists are tracking these hidden risks and developing new tools to guide recovery efforts.

Check out the short video below summarizing the main points of this article and last month's companion article.

If your home was one of the roughly 2,000 structures lost in the 2023 Lahaina wildfire or among the tens of thousands of buildings destroyed in 2025 Southern California wildfires, soil is probably the last thing on your mind. In the aftermath of a wildfire, attention understandably turns to safety, housing, insurance, and rebuilding. But beneath the ash and debris, the ground itself has changed. What lingers after the fire—in the soil underfoot and the water moving through it—can shape what comes next, and it's something scientists say can't afford to be an afterthought.

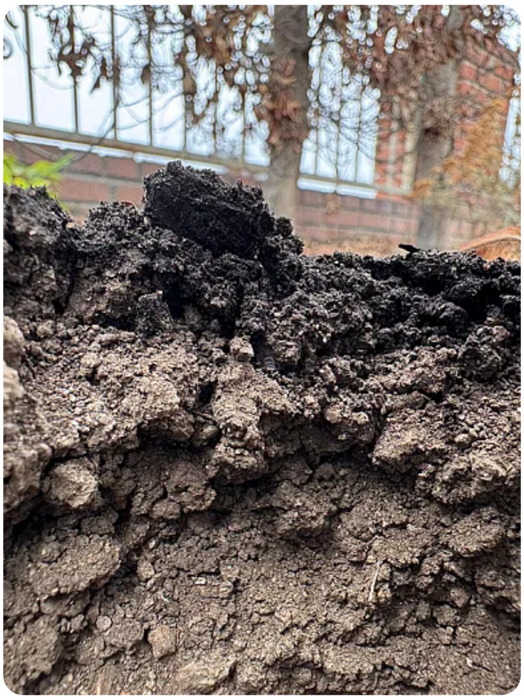
Wildfires are becoming more frequent, longer lasting, and more intense as the climate changes, increasingly pushing into the wildland-urban interface where homes and fire-prone landscapes meet, especially in the West. As more structures burn, the built environment itself becomes fuel, transforming everyday materials into sources of contamination that persist in soil and water long after the flames are out. Understanding what remains in soil, water, and the spaces in between is becoming as essential as understanding how fires spread. To get a better picture, scientists are beginning to treat burned neighborhoods not just as damage zones, but as inventories of materials that have been transformed by fire.

Pretty much the only way to determine what's in the soils is to go out and sample it, burned house by burned house, says Frida Garcia-Ledezma, a doctoral student in soil biogeochemistry at Stanford University. That's what she and her team from Stanford and Colorado State University did for months after the 2025 Eaton and Palisades fires. That's what Duke pedologist Daniel Richter's team did in the California neighborhoods as well. It's a tried-and-true method that works. But it's also time consuming, labor intensive, and relies on locating homeowners—many of whom have scattered after their homes burned—and getting permissions. This method also lacks prefire baselines, making it difficult to isolate what the fire actually changed.

Some scientists are turning to new approaches to categorize what happened after a fire, from determining what may have been in the soil before fire struck to using a new nationwide dataset of combustible mass (COMBUST).

How fire reshapes the vadose zone

As we explored last month, beneath our feet lies a largely unseen system that quietly shapes the quality of the air we breathe, the water we drink, and the food we eat. Known as the vadose zone, it spans the space between the land surface and the water table—a mostly unsaturated layer where water moves downward through soil and fractured rock, filtering and transforming contaminants along the way. Though hidden from view, it plays a central role in sustaining modern life, says Ryan Stewart, a soil hydrologist at Virginia Tech University, and is too important to ignore.



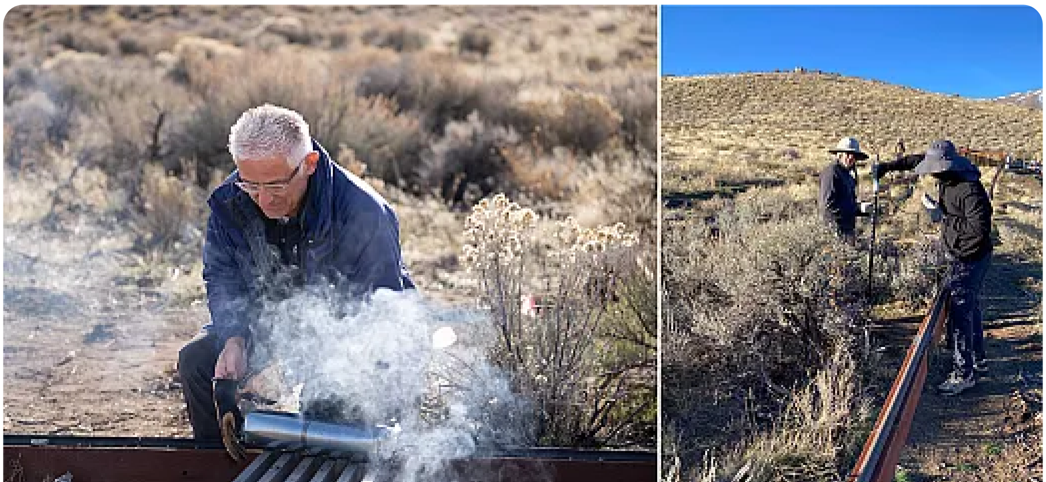
A soil profile sampled in September, a few months after the 2025 LA wildfires. Photo courtesy of Frida Garcia-Ledezma.

At its upper edge, the vadose zone includes the soil beneath our homes—the ground we walk and drive on and where gardens grow, children play, and pets track dirt indoors. This story focuses on that overlooked interface, where everyday human activity meets the subsurface systems that ultimately determine what reaches our groundwater.

Wildfire can fundamentally reshape the top layer of soil, altering how water moves through it, how much it can hold, and how easily it soaks in. Heat can form a thin, water-repellent seal at the surface, reducing infiltration and sending more water and debris downslope as surface runoff. The severity and persistence of these changes vary widely over many orders of magnitude.

Hundreds of studies have shown that fire-exposed soils repel water, says Markus Berli, a soil physicist at the Desert Research Institute in Nevada. “So if you go out and measure the absorption rate for water by a burned soil, and you find water repellency, the conclusion typically is it’s fire-induced,” he says. But water absorption by the soil varies significantly in time and space, he says. You can’t just assume fire caused water repellency—you’d have to know what the soil was like before the fire and compare it to after. In most wildfires, that baseline simply doesn’t exist, he says.

Berli’s lab is working to change that. At 20 soil plots outside of Reno, NV, Berli’s team has been measuring water repellency of unburned soil across a range of vegetation and soil moisture conditions. In fall 2025, they burned 10 out of these 20 plots and are now repeating those water repellency measurements to compare soil water repellency under burned and unburned conditions.

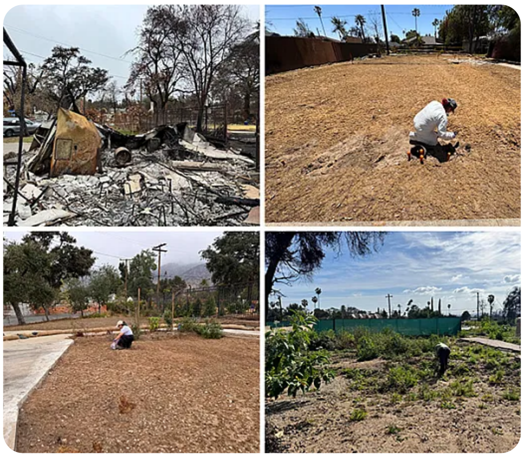


*Markus Berli **(left)** and team **(right)** at prescribed burn plots, directly measuring the effects of fire on soil. Photo courtesy of Markus Berli.*

"What's really fascinating is that the soils—especially under shrubs—are already quite water repellent even though they haven't burned since 1984," he says. By capturing both pre- and postfire conditions, the team hopes to isolate the fire's true effects, something that's rarely possible in real wildfire settings. "It could be that in areas we find water repellency after a fire, it's because the soil was already water repellent before. You don't see that unless you have a before-and-after comparison."

Repellency is important because it affects rain infiltration, runoff, and flooding as well as debris flow risk, in addition to contaminant movement, Berli says. In the San Gabriel Mountains in Southern California, floods and debris flows are common after fires as more water rapidly runs off the burned areas compared with the unburned areas. Berli's work aims to use the repellency data to predict how much more water will run off soils after fires to help with hazard predictions. But he also wants to know the chemistry side: It's not just pure water running off, he says, it's a mix of ash, sediment, and chemicals from everything that burned. After a wildfire, the built environment also becomes a patchwork of chemical sources. Scientists are just beginning to understand what chemicals are left in the soil and whether they stay there or wash away, he says.

Inside burned neighborhoods: what the soils reveal



As structures burn, materials—from treated wood, paints, and wiring to plastics and household goods—are transformed, concentrating heavy metals and generating new contaminants that can persist in soils or move into waterways.

In the months following the 2025 Eaton and Palisades fires, Garcia-Ledezma and her colleagues sampled houses affected by the fires. Pictured are sampling sites taken in February 2025, just after the fires ***(top left)****, May 2025* ***(top right)****, September 2025* ***(bottom left)****, and December 2025* ***(bottom right)****. Photos courtesy of Frida Garcia-Ledezma.*

In the wake of the fires, Frida Garcia-Ledezma and her team connected with colleagues at the Jet Propulsion Laboratory to connect with people whose houses had been affected by the fires to inquire about sampling. They picked 33 houses throughout the Eaton fire zone in Altadena to sample—some houses that had burned to the ground, others that were damaged by smoke but otherwise unburned. Of the houses that burned completely, the team sampled the zones of particular rooms, front yards, backyards, and garages/driveways, identifying contamination patterns one month, four months, and eight months after the fires. Of smoke-impacted houses, they sampled yards.

Within the burned homes, the teams identified office spaces, bedrooms, kitchens, and living rooms, and then further delineated walls from furniture and appliances. What they found surprised them, Garcia-Ledezma says. First, there was tremendous variation between homes. “It’s crazy. You’re in the same neighborhood, but the contamination is very different.” Second, lead levels at many properties were far above safe, including at smoke-impacted properties.

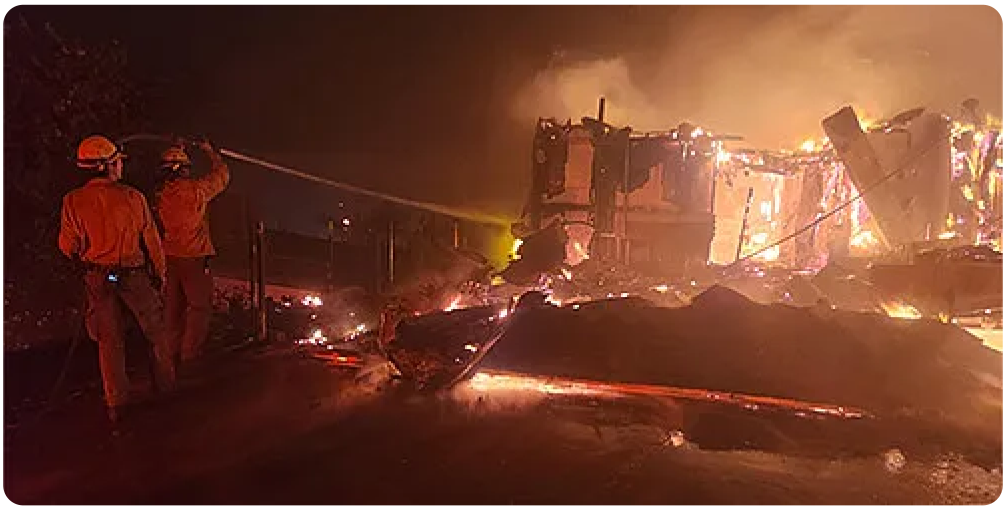
After the fire: What cleanup removes—and what it doesn’t

After recent wildfires, cleanup protocols have varied but typically have unfolded in two phases led by the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (USACE). In Phase 1, USEPA crews remove household hazardous waste—paints, batteries, and other chemicals. Phase 2, led by USACE, focuses on clearing debris, ash, and contaminated soil to prepare properties for rebuilding.

The most extensive cleanup can involve removing several feet of soil and even replacing it, but more commonly, crews scrape away the top 6 inches of structural ash and soil from the house foundation. In some cases, remediation is even lighter, removing only an inch or two of debris or covering the surface with mulch to create a buffer between contaminated soil and people, says Frida Garcia-Ledezma, a doctoral student in soil biogeochemistry at Stanford University. Chemical treatments are sometimes used as well.

Federal agencies typically step in after a wildfire is declared a federal disaster and the state requests federal assistance. Not all properties qualify for funded cleanup, even in a disaster zone. Generic, large-scale estimates are used to decide the qualification threshold. Research by Garcia-Ledezma and Daniel Richter show contamination can vary widely from house to house. Even homes damaged by smoke alone may require costly remediation. “Homeowners are rebuilding or fixing their homes while also trying to figure out how to clean up their soil, often on their own,” Garcia-Ledezma says. “Some don’t have the money to fully remediate, and the contamination can stay for a long time after the fire.”

Even then, surface cleanup doesn’t tell the whole story. Contaminants can move deeper into the vadose zone or wash into waterways after storms. What remains below—and where it goes next, especially in areas with frequent heavy rains like Southern California—are questions scientists are still working to answer.



United States Forest Service (USFS) members fighting the 2025 Eaton fires. Photo courtesy of Wikimedia Commons.

In burned homes, lead in the soils and ash where walls would have been—predominantly in those homes built before 1978—exceeded 940 (ppm). For reference, the U.S. Environmental Protection Agency (USEPA) defines 200 ppm as the screening level above which remediation may be required. Burned soils in yards in Altadena sometimes exceeded 400 ppm. Burned cars left 1,500 ppm of lead behind in the debris.

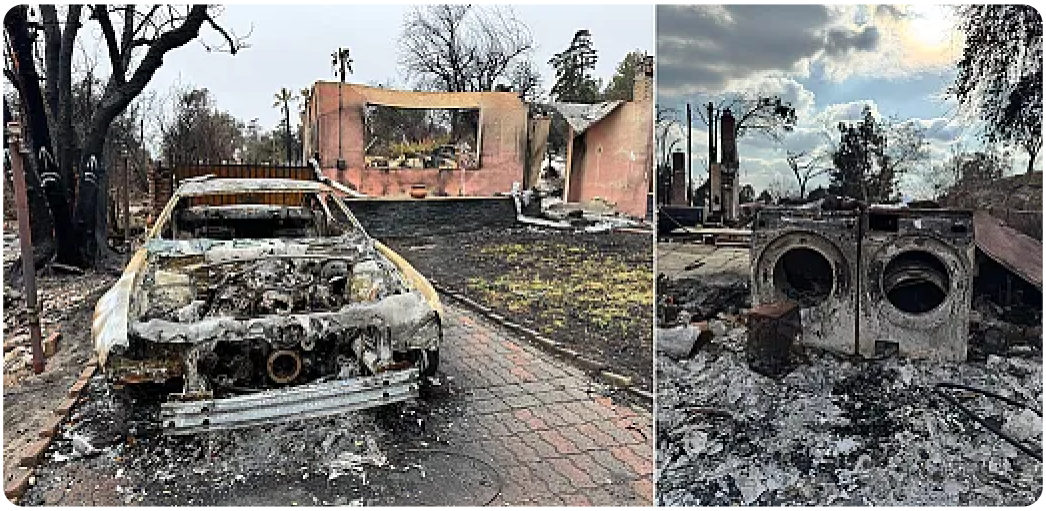
Dan Richter’s team also found wide variation among the homes they sampled, especially older homes, both immediately after the fires and after two phases of remediation by the USEPA and U.S. Army Corps of Engineers. Like the Stanford team, Richter’s team found highest lead levels in the soil, ash, and debris of older homes. Before cleanup, about 28%

of structural ash exceeded USEPA screening levels (200 ppm), with 50% exceeding California's screening levels of 80 ppm and 10% exceeding 650 ppm. After the second round of remediation, less than 5% of soils exceeded 200 ppm, with 24% still exceeding 80 ppm (see sidebar). Those levels are within the range of many urban unburned soils in various U.S. cities, Richter says.

Richter's team also examined the intercorrelations of lead, arsenic, calcium, copper, iron, potassium, manganese, rubidium, strontium, and zinc in structural ash, and reported on these at the 2025 CANVAS conference in Salt Lake City.

Garcia-Ledezma's team also looked at chromium, a particularly concerning metal common in steel and several household products. They found that chromium levels—reaching up to nearly 700 ppm—in the burned debris were highest at point sources of appliances in the houses. Burned cars also exceeded 400 ppm chromium, they reported at the same CANVAS conference.

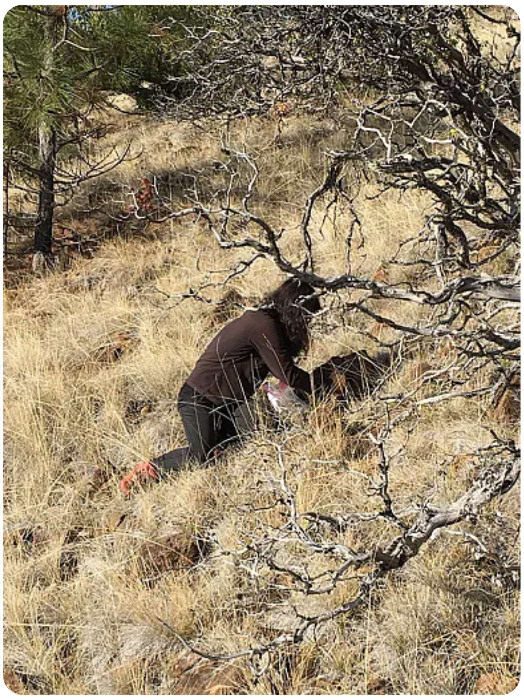
Previous studies suggest that elements such as chromium and arsenic found after fires come from the geology—geogenic sources, Garcia-Ledezma says. But when they sampled the burned areas, the team found that the bulk of the elements were coming from anthropogenic materials. The team is still analyzing the chromium samples, but the hypothesis is that it comes from stainless steel appliances.



Burned cars and household appliances were high point sources of chromium. Photos courtesy of Frida Garcia-Ledezma.

When fire turns chromium toxic

Most chromium naturally found in rocks and soils—and used in steel—is inert and relatively safe. But new research from the Soil and Water Lab at the University of Oregon shows that wildfire heat can transform it into chromium VI (hexavalent chromium), a highly toxic and mobile form.



Chelsea Obeidy sampling Eight Dollar Mountain in southern Oregon for heavy metal contamination. Photo courtesy of Chelsea Obeidy.

Soil chemist Chelsea Obeidy, now at Cal Poly Humboldt, and her adviser Matthew Polizzotto sampled soils in southern Oregon, where serpentine bedrock contains high levels of chromium along with lead, nickel, cobalt, and manganese. After simulated fires, they found hexavalent chromium was leached at hazardous concentrations—up to 10 times above drinking water standards—along with elevated nickel and manganese. Levels varied sharply with landscape position and persisted from months to more than two years, with elevated chromium concentrations lingering longer from ridgetop soils. Another factor was temperature: At lower temperatures, like in cultural fires or other prescribed burns, less chromium III could be converted to chromium VI, Obeidy says.

The findings, published in *Environmental Science & Technology* last November, highlight both the risk of fires converting stable metals into toxic forms and how unevenly that contamination is distributed. Even in serpentine-rich regions, Obeidy notes, post-fire contamination can't be predicted from soil maps alone.

For now, boots-on-the-ground, door-to-door sampling is the only reliable way to determine how much remediation a property needs.

Can data speed cleanup after wildfire?

Such sampling and analysis, however, are limited by how much scientists can do on the ground. The future, many say, lies in technology development.

"The role of the GPS-enabled and portable XRF instrument is largely untapped," Richter says. An XRF (X-ray fluorescence) is a device that within seconds (instead of weeks) measures the composition of many metals in soil, rock, or dust on site. "Although not systematically used by USEPA or USACE following the Eaton or Palisades Fires, portable XRFs are rugged, precise, and accurate, well suited for rapid field screening," he says. "The widespread adoption of portable XRF in mining, manufacturing, and metal recycling industries suggests the technology has a potential for improving post-fire cleanup."

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> *industries suggests the technology has a potential for improving post-fire cleanup.”*

Existing datasets may help fill in the gaps. Tools like the USDA’s Web Soil Survey or state geological maps can offer clues about underlying soils and potential hazards, Obeidy says. Pairing those with experimental work—like Berli’s studies on how soils change after burning—could further refine predictions.

Another new resource is the COMBUST dataset, which estimates how much combustible material—building materials, contents, even vehicles—was present before a fire at a 250-meter resolution. Built from satellite remote sensing, real estate data, and statistical models, it provides a starting point for understanding what may be left behind.

Together, these tools are reshaping how scientists think about wildfire. It’s not just an ecological disturbance, but a chemical one that redistributes contaminants from burned structures into fly ash and smoke, structural ash, and soils, and the vadose zone. By combining datasets like COMBUST with material inventories, researchers can begin to estimate what chemically was released, what was transformed by heat, and what remains. They can then pair material composition data with known contaminant concentrations—metals such as lead, copper, and chromium; organics like PAHs (polycyclic aromatic hydrocarbons); and emerging contaminants such as PFAS (per- and polyfluoroalkyl substances)—and better contend with issues of environmental risk.

> The million-dollar question is how far these tools can go on their own—whether what we see from space and these datasets is sufficient or whether we still need ground

truthing, Berli says. We probably still need both, he adds.

“The COMBUST dataset is an incredible resource and will be very useful for predicting soil contamination,” Garcia-Ledezma says. “Testing it against our on-ground data could … help us identify potential contamination hotspots and prioritize intervention strategies.”

That may be where the science is headed: building enough predictive power from data to guide faster, more targeted remediation the next time a wildfire reaches the wildland-urban interface.

Dig deeper

“The Science of the In-Between: Why the Vadose Zone Matters” *CSA news* magazine article, July 2026

“Sources and Persistence of Heavy Metals in Residential Soils Following the Eaton Fire,” CANVAS 2025 presentation by Frida Garcia-Ledezma

“Lead and Metal Contamination of Post-Fire Ash and Soil Following the Urban Conflagrations in Altadena and Palisades, California,” CANVAS 2025 presentation by Daniel Richter

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