

How Do Wildfires Affect Water Systems?

Cite This: *ACS Cent. Sci.* 2022, 8, 504–506

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New research shows that the heat causes volatile organic compounds to leach out of plastic pipes into drinking water.

In November 2018, a wildfire blazed through Paradise, California, a town of 26,000 in the forested foothills of the Sierra Nevada. Flames raged for more than 2 weeks, killing 85 people and incinerating many of the buildings, making the Camp Fire, as it was called, the state's deadliest and most destructive wildfire.

After the fire was extinguished, residents who wanted to return home and start rebuilding their lives were dealt another blow: testing revealed **toxic levels of benzene**, a carcinogen, in the drinking-water system. New research implicates plastic pipes as a key source of contamination.

Immediately after the fire, the Paradise Irrigation District, which supplies the town's water, didn't know how the pipes became contaminated, how to clean them up, or how to safeguard the system against future fires. So it asked environmental engineer Andrew Whelton, who leads Purdue University's Healthy Plumbing Consortium and Center for Plumbing Safety, to launch an investigation.

Most immediately, the district wanted to know how to get rid of the benzene. But it turned out that this was far from the only volatile organic compound (VOC) in the water system.

The state only asked the testing laboratory for the benzene results of its gas chromatography analysis. But Whelton asked for all the results and saw so many contaminants that "the chromatograph lit up like a Christmas tree," he says. Other VOCs in Paradise's water included naphthalene, styrene, toluene, and xylenes. "You need to know how to look for



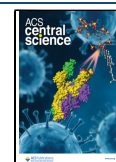
After a 2018 wildfire, residents of Paradise, California, relied on bottled water when toxic compounds were detected in the public water system. Credit: Brett Walton/Circle of Blue

unknowns," Whelton says. "The state didn't know what questions to ask—it's a gap in policy."

This gap can pose health risks for people who drink or shower in tainted water. For example, **benzene levels in Paradise's drinking water** reached 2,217 $\mu\text{g/L}$, far exceeding the US Environmental Protection Agency's standards of 200 $\mu\text{g/L}$ for acute exposure and 5 $\mu\text{g/L}$ for chronic exposure.

Scientists had seen wildfire-driven contamination of drinking-water systems the year before. In 2017, a resident of Santa Rosa, California, reported off-smelling water after a wildfire. When the city tested the water, **it found benzene**. This previously unrecognized problem has since been found in Oregon and Colorado and is likely to be widespread.

Published: May 12, 2022



“It’s probably been happening for decades, but nobody was testing for VOCs,” Whelton says, adding that lack of odor does not necessarily mean lack of contamination.

Most at risk are the many communities on the edge of fire-prone wildlands. In the continental US, about one-third of houses are near forests and other natural areas, and development along this [wildland-urban interface](#) is the fastest-growing land use. Meanwhile, climate change is making summers hotter and drier, exacerbating the threat of wildfires.

Contamination sources

In Paradise, Whelton’s team found a number of clues to how wildfires were contaminating drinking water. The town’s water distribution system includes a treatment plant, 277 km of large water pipes called mains, and more than 10,000 smaller pipes called service lines, which carry water from a main to water meters and then into buildings.

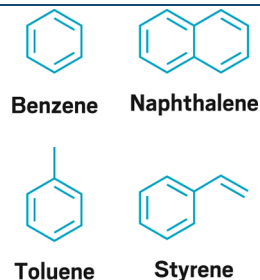
A key piece to the contamination puzzle was that the team found VOCs in service lines but not in the treatment plant or mains. Another was that many of Paradise’s service lines and water meters, both of which are commonly made of plastics like polyvinyl chloride (PVC) and high-density polyethylene (HDPE), burned and melted in the fire. These components are near or above the ground surface, making them more vulnerable to fire. Mains, in contrast, are buried deep enough to be protected from extreme heat.

Whelton’s investigation pointed to several potential mechanisms for Paradise’s water contamination. Maybe the burned plastic pipes released VOCs into the water. Or maybe smoke and soot, which contain VOCs, got “sucked backwards and into the distribution system” as it lost pressure because of fire damage, Whelton says. In both cases, VOCs could then spread to pipes that were undamaged but depressurized. Once in the system, VOCs can permeate PVC and HDPE, which Whelton likens to sponges where contaminants “get into spaces between [polymer] chains, hang out, and leach out.”

Whelton now believes all three mechanisms are at play, but the science was less certain when he began his inquiry. Although burning plastics were well known to contaminate air, little was known about their capacity to contaminate water. To learn more, Whelton decided to [test the latter in the laboratory](#) by heating and burning a variety of plastic pipes and then submerging them in water.

The study showed that plastic pipes can contaminate water and that they don’t even have to burn to do so—they just need to get tremendously hot. For example, PVC started degrading significantly by 300 °C, undergoing dehydrochlorination and forming polyene chains, as well

as benzene and toluene. PVC lost 40% of its mass by 400 °C and even more at 475 °C, as the double bonds in the polyene chains began to break and alkylated aromatics such as ethylbenzene and xylene formed. Likewise, by 300 °C, HDPE started degrading and generating VOCs.



After the Camp Fire, benzene, naphthalene, toluene, and styrene were the volatile organic compounds found in the greatest concentrations in a contaminated water sample from a service line in Paradise, California. Credit: C&EN

“Plastic pipes are an important primary source of contamination in drinking water after wildfires,” says Whelton, who continues to investigate and advise wildfire-ravaged communities, most recently those devastated by Colorado’s Marshall Fire in 2021–22.

The Plastic Pipes Institute (PPI), an industry trade association, disagrees with Whelton’s conclusion. “This study is not representative of what actually occurs during a fire—buried pipes are typically a few feet beneath the surface and are therefore insulated from the heat,” PPI president David Fink says, citing a [US Forest Service study](#) of soil temperatures at various depths during prescribed burns of trees. Houses as well as trees burned during the Camp Fire, however, and fire intensity can vary depending on the material burning.

New research supports Whelton’s conclusion that plastic pipes play a role in water contamination after wildfires. A study, led by California Department of Public Health research scientist William Draper, [analyzed a contaminated water sample](#) collected from a service line after the Camp Fire. Draper and his colleagues first identified VOCs in the water sample. Then, to find chemical fingerprints of possible sources of the contamination, they identified the VOCs emitted from burning plastic pipes in the laboratory and did a literature review of VOCs linked to burning biomass, building materials, and other aboveground sources.

The results suggest that the water sample was contaminated by a combination of fire-damaged plastic pipes and smoke intrusion. “We identified nine compounds that appear to be coming only from plastic pipes and 23 compounds associated only with smoke,” the California Department of Public Health says by email, with the caveats that they tested

just a single water sample and that finding specific sources of wildfire-related contaminants of drinking water is very difficult.

Wildfire-resilient water systems

Even after identifying the risks of plastic in water-delivery systems, Whelton is not opposed to such pipes, which are durable, inexpensive, and earthquake resistant. “There is a place for these materials,” he says, “but if you’re going to use them, you need to know where they’re vulnerable and where you need to protect them.” Protections for service lines include burying them deeper to insulate them against the heat of fires. Protections against contamination originating from both pipes and smoke include installing a network of isolation valves to keep contaminants from spreading throughout a water system, as well as devices to help keep contaminated water from moving from a burned house into the distribution system. As [part of the city’s plan](#) for rebuilding the community, the Paradise Irrigation District opted for the latter, replacing contaminated service lines with HDPE pipes outfitted with backflow preventers.



A comparison of a high-density polyethylene (HDPE) pipe (left) after the wildfire in Paradise, California, with HDPE pipes that were heated in the laboratory at 300 °C (center) and 400 °C (right). Credit: *Environ. Sci.: Water Res. Technol.* (CC by 3.0)

Erica Fischer, an Oregon State University (OSU) structural engineer specializing in hazard resilience, is developing a way to tell if a buried plastic pipe gets hot enough to release VOCs into water. She originally went to Paradise to evaluate the structural integrity of school and hospital buildings after the Camp Fire and began investigating drinking water when a local school employee mentioned the contamination.

“As an engineer, I looked at it through a heat transfer perspective,” Fischer says. “In wildlands, the fuel for fire is vegetation, but in communities, it’s our homes. They burn for hours, and the heat transfers through soil.” Heat may transfer deeper into soil when houses burn than when forests and other vegetation burn, she says.

Fischer co-leads an interdisciplinary team working to determine the temperature threshold for pipes and water contamination and to develop a fireproof sensor system that will alert communities when and where that threshold has

been reached. “When are buried plastic pipes hot enough to exceed standards for VOCs?” she asks. “It varies with the material, but they all kind of hover around 200 °C.” Next steps include burying pipes with sensors in small boxes of soil and heating the boxes to make sure the sensors work and can withstand the heat. The team will ultimately move on to testing the sensor system in larger-scale fire simulations.

Social vulnerability and public health

Engineering fixes like backflow preventers and heat sensors won’t be enough on their own to protect water systems from wildfires, though. “There’s never a silver bullet with hazard mitigation,” says OSU social scientist Jenna Tilt, who focuses on community resilience to disasters and is one of Fischer’s coleaders. “You need a tool kit.” For wildfires, the tool kit includes vegetation management; retrofitting houses that have flammable roofs and siding, such as wood shakes and shingles; and understanding a community and its vulnerabilities.

Tilt is developing a social vulnerability index that accounts for factors such as income, chronic disabilities, and whether people own or rent their homes, and will combine it with a model of hotspots for future wildfire-driven contamination of drinking water. This will help officials identify community members who may need extra assistance to prepare for or recover from wildfires. “If you’re worried about keeping food on the table or about where your next paycheck is coming from, you’re not going to be that worried about the probability of wildfire,” she says.

Safeguarding water systems will take time and money, in the meantime leaving many communities unprepared as the wildfire season begins in the American West. More immediately, water utilities should be tasked with testing for contamination house by house after a wildfire, says Gina Solomon, an occupational and environmental health physician who is a principal investigator at the nonprofit Public Health Institute and one of the coauthors of Draper’s report. “Most compliance testing is done in the water treatment plant,” not in distribution systems, Solomon says. “The most critical thing is to get in quickly after fires and test the water for VOCs, starting with service lines into burned homes.”

Robin Meadows is a freelance contributor to [Chemical & Engineering News](#), an independent news outlet of the American Chemical Society.