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Flavors of Fire: Assessing the Relative Toxicity of Smoke from Different Types of Wildfires

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From afar, wildfire smoke looks like a dingy, homogeneous blur rising into the air or smudged across the sky. Yet, when analyzed chemically, wildfire smoke is in fact a complex, highly variable mixture: Its chemical makeup depends on the fuel, and when and how it burned.[1] A study published in *Environmental Health Perspectives* helps illustrate why human health impacts of wildfire smoke may vary based on the chemical makeup of the smoke. In other words, all wildfires should not be expected to have the same effects.

Researchers from the U.S. Environmental Protection Agency (EPA) studied smoke produced from the combustion of different tree species at different temperatures. "We wanted to ask, 'If you burn different fuels, are they going to have different health effects, qualitatively or quantitatively?'" says senior author Ian Gilmour, chief of the Cardiopulmonary and Immunotoxicology Branch within the U.S. EPA's Environmental Public Health Division. "What we did show was that different fuels, when burned, have different chemistries and different toxicological effects."

To perform their analysis, the researchers used an enclosed furnace to burn samples of five different biomass fuels representing distinct woodland types—red oak for forests of the eastern and central United States, lodgepole pine wood and ponderosa pine needles for the West, eucalyptus for Southern California chaparral, and pocosin peat for the Midwest and Southeast. They used temperatures conducive to both open flames (approximately 640°C) and a steady-state smoldering phase (approximately 500°C) to assess whether different combustion conditions affected the chemistry and toxicity of the smoke.

The researchers extracted particulate matter (PM) from the smoke samples. Then, they administered the PM to *Salmonella* and to mice to assess mutagenicity and lung injury, respectively.

When considering total emissions, PM from smoldering pine wood and needles was by far the most mutagenic of the samples assessed, and thus potentially more carcinogenic.[2] Compared with previously reported values of mutagenicity for other types of burning materials, the pine needle emissions were considerably more mutagenic than smoke generated by the open burning of agricultural plastic[3] or wood-burning cookstoves,[4] and approximately half as potent as smoke generated by burning rubber tires,[5] based on mass of fuel consumed.

To evaluate lung toxicity, the researchers counted the number of neutrophils—white blood cells that migrate to sites of infection or injury[6]—present in lung fluid extracted from mice following exposure to the different PM extracts. They determined that in terms of the mass of fuel consumed, smoldering eucalyptus demonstrated the greatest lung toxicity of all the fuels tested.

Investigators used plant matter from different parts of the United States to measure differences in the toxicity of the smoke they produced under different combustion conditions. The results of the laboratory studies suggest that wildfires in some regions may cause worse health effects than fires in others, in part as a function of the local vegetation. Image: © ruig/iStockphoto

Relative to the amount of PM produced, flaming pine and peat released the most mutagenic smoke, whereas smoke from flaming eucalyptus and peat was the most toxic to the lungs. "We were surprised that on a [PM] mass basis, the flaming samples were actually more toxic than the smoldering samples," Gilmour said. "That was something that heretofore hadn't been known and has implications for the relative health impact of smoke, depending on the combustion intensity and level of particulate exposure."

The study is limited by the fact that combustion in the field is much more complex than laboratory conditions allow, says Rodney Weber, a professor of atmospheric chemistry at the Georgia Institute of Technology, who was not affiliated with the study. Applicability of the findings to human health is further limited by the fact that the study could not account for how smoke changes over time in the atmosphere. "The chemical composition and likely toxicity of the smoke can vastly change with age," Weber says. "In studies of widespread health effects from smoke, [the] actual composition of what one is exposed to is what matters—not what is initially emitted by the fire."

These are valid criticisms, the authors say, and they hope to address them through future research. The study's sequestration of fuel types and phases was intended not to simulate real-world fires but rather to look for differences among smoke from distinct biomass types that may act as surrogates for others, says coauthor Michael Hays, a physical scientist in the U.S. EPA's Air Pollution Prevention and Control Division. "We were trying to get contrast," he explains, "but I think much more could and should be done to discriminate different fuels."

University of Iowa professor of analytical chemistry Betsy Stone, who was not involved in the research, says separating out flaming and smoldering emissions, even if an artificial construct, is the study's greatest strength. "In the real word, smoldering and flaming combustion occur simultaneously. Breaking them up is not necessarily a problem because by finding each one individually, you can start to put the results together," she says. "I think this is an important step forward in making these connections between combustion, chemistry, and health effects."

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