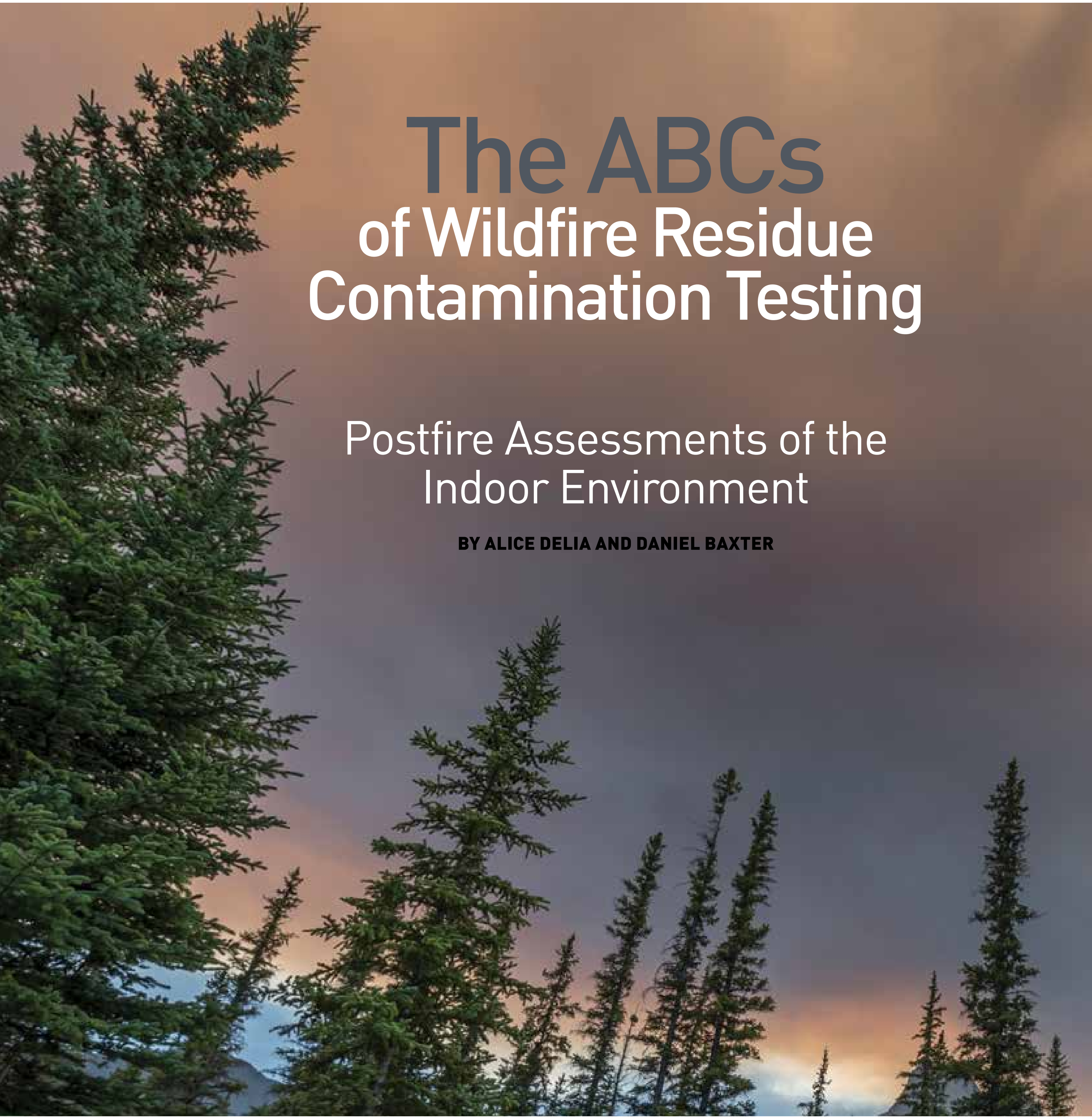


The ABCs of Wildfire Residue Contamination Testing

Postfire Assessments of the Indoor Environment

BY ALICE DELIA AND DANIEL BAXTER

We all know that postfire assessment and cleanup is a complicated issue. Although many assessments rely on known problems and a visual evaluation, testing can be an essential component in addressing “invisible” contamination concerns or determining if any residual contamination is above the “normal” or “typical background” levels. But what to test for and how to use the results are big questions without clear resolutions.

CONSIDERATIONS FOR TESTING

Concerns are typically centered on particulate residues, mainly char, ash, and soot, but chemical contamination of volatile (VOC) and semi-volatile (SVOC) compounds can be a large part of the picture. Metals can be a concern in post-wildfire assessments as well, although more typically in the outdoor environment. Table 1 outlines the usual concerns for testing.

Particulate and VOC contamination are critical in different areas. Testing or accounting for one does not necessarily address the other, but the two do share some traits.

Particles are a surface and dust contamination concern. A thorough cleaning of the surfaces and removal of dust may take care of the majority of particulate contamination. However, the biggest problem with particulate contamination is the possibility of recontamination, especially in an extensive wildfire situation in which the source material—the char, ash, and soot from the fire—remains in the outdoor environment, and

Table 1. What to Test for During Postfire Assessment

Test for	When the concern is ...
VOCs/SVOCs	Air and material contamination; smoke odor; contamination persistence
Soot/Ash/Char	Surface contamination; corrosion
Metals	Soil and water contamination

air movement as well as foot traffic can bring the fire residues back into the building. Ash, particularly from wildfires, can also create a corrosive environment that can cause additional damage.

VOCs are not primarily a surface concern, except in situations in which the less volatile organic compounds may "condense" onto surfaces or dust; however, the concentration from these avenues is typically low and may not account for larger sources of contamination. The bigger concern with VOCs is their penetration into porous materials in the building. Think of how long the smell of smoke or fire residue lingers in clothing and fabrics, even from a simple backyard barbeque. This is caused by the adsorption of VOCs into the fabrics during or shortly after the fire and the subsequent emission back into the indoor air.

The process of adsorption and emission, or off-gassing, is disproportionate in that the adsorption occurs in a very brief time period but the off-gassing can take months or even years to get to an undetectable level. So, why the disparity? Fundamentally, it comes down to equilibrium and the relative concentration proportions. The concentrations in the air during the fire are extremely high, while those in the materials in the building are low or nonexistent, so the materials quickly "soak up" the fire emissions. After the fire is out and the smoke has dissipated, the concentrations in the air are much more moderate; after a few days, they are very low compared with the concentrations during the fire. At this point, the opposite condition exists: the concentrations in the materials are now much higher than in the air. But instead of releasing the imbalance in short order—as occurred during the extreme conditions of the fire—the process is much slower due to the moderate "normal" conditions. Temperature, humidity, and air flow, as well as the amount and type of affected materials, are critical factors.

Another problem area after a wildfire that has not received much attention is the presence of metals. These are often released from natural static sources, or they are converted from non-biogenic materials, such as vehicles and buildings, burned during the fire. Lead and mercury are often present, but other metals such as antimony, copper, zinc, arsenic (naturally occurring in rock and soil), and chromium have been found as well. Both particulate and organic forms have been found, and although they are present in the air for short periods of time during and after a wildfire, the hazard is typically from high concentrations of metals in the local soil and water.

TESTING FOR PARTICULATES

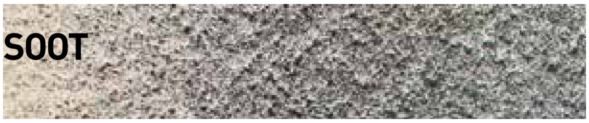
Several technologies and methods have been employed for assessing fire particulates. Published methods—such as IESO/RIA Standard 6001-2012 (Evaluation of Heating, Ventilation and Air Conditioning [HVAC] Interior Surfaces to Determine the Presence of Fire-Related Particulate as a Result of a Fire in a Structure), ASTM D1506-15 (Standard Test Methods for Carbon Black-Ash Content), and ASTM D6602-13 (Standard Practice for Sampling and Testing of Possible Carbon Black Fugitive Emissions or Other Environmental Particulate, or Both)—account for some aspects of wildfire contamination but are not suitable for all postfire situations. Therefore, it is often necessary to go beyond these methods for applicable information.

Optical microscopy is one of the most useful methods since it can provide information on several levels. Optical microscopy, including polarized and reflected light microscopy, can be used to identify soot, char, and ash, as well as "contextual assemblage particles" such as plant phytoliths, burned pollen grains, or carbonized or burned soil clay particles. The proportion of fire residue particles to biological and inorganic particles provides an estimate of the percentage of fire to non-fire particles. Although "normal" proportions of fire to non-fire particles have not been thoroughly defined or published, levels above approximately 5 percent likely indicate an increasing probability of fire residue contamination. Scanning electron microscopy can often assist in providing information on particle identification (especially ash constituent particles), chemistry, size distribution, and source. Transmission electron microscopy (TEM) is often suggested to identify the individual submicron

Soot, Char, Ash: What's the Difference?

The terms "soot," "char," and "ash" are often used interchangeably, but they have significantly different meanings:

- **Soot** is a fine carbonaceous material with aciniform structure; it is produced during incomplete combustion.
- **Char** comprises mostly carbonaceous, large, irregular fragments of burned material.
- **Ash** is the decarbonized (mostly inorganic) residue of cellulose material. It typically comprises mineral salts, carbonates, oxides, or metal/noncombustible compounds.



aciniform soot particles; however, complications exist with the reliability of this procedure for carbonaceous particles other than carbon black. “Semi-volatile” soot particles can dissolve in the solvents used in TEM preparation and essentially “evaporate” when placed under the high vacuum used in the TEM analysis process. These losses can be significant, especially with low-temperature, smoldering fires.

Ash can also be used to determine the pH, or corrosivity, of the fire residue. This is especially relevant in wildfire situations. Normal dust has a pH of 6 to 8, and concentrated fire ash can have a pH ranging from 9 to 13. When fire ash is present in indoor dust samples, diluting a small dust sample in distilled water will still yield pH readings above 9.

TESTING FOR VOCS AND SVOCS

Fire creates an incredible mix of chemical compounds. These range from light gases to condensable materials and from common hydrocarbons to unique fire breakdown products. Many compounds are far too common—for example, benzene or formaldehyde—to be reliable indicators. Therefore, the unusual or unique components must be the focus of any chemical assessment of fire and smoke contamination.

In a wildfire, the primary fuel source is plant material, so the breakdown compounds of the plant cell walls, primarily cellulose and lignin, are ideal choices.

Two classes of VOCs, guaicols (methoxy phenols) and syringols (dimethoxy phenols), are well-documented characteristic wildfire emissions. Both classes are produced from the pyrolysis of wood lignin. The guaicols are primarily produced by softwoods, while the syringols are released by both hardwood and softwood fuels.

Ambient air studies often use levoglucosan as a universal biomass indicator. It is produced from the pyrolysis of cellulose and has been found to be produced from all plant-based fuels. Although present during and after all wildfires, levoglucosan is less useful in indoor air assessments than in outdoor air assessments because of its low volatility.

Most fires produce less specific indicators as well. Cresols, creosol, and polycyclic aromatic hydrocarbons are commonly found in both wildfire and structure fire residues. These are produced from the oxidation of the many hydrocarbons that exist in most materials, including plant life.

In addition to their use as indicators of fire contamination, these chemical compounds are also responsible for much of the characteristic smoky odor. Identifying these compounds therefore provides information on both general fire contamination and specific odor concerns.

The guaicols, syringols, and levoglucosan are specific to biomass, so the presence of these compounds may be used to identify smoke contamination from wildfire and biomass sources. However, they are not specific between plant fuel sources, so a wood-burning fireplace will produce these compounds as well.

OTHER CONSIDERATIONS

Wildfire contamination evaluations rely heavily on the visual assessment and site-specific information. Some of the cleanup and remediation actions can be determined with only this information; however, testing provides a reference for pre- and post-remediation condition, can uncover less apparent problems, and incorporates an objectivity that increases the universality and limits the dependence on individual opinion. Although the last point is not directly related to assessment or remediation, standardized testing will reduce the number and extent of disagreements between occupants/owners, insurance representatives, assessors, and remediators.

Together, particulate and VOC/SVOC testing provide a comprehensive view of surface, air, and material (ingrained) contamination in the indoor environment. Although there are several ways to perform these evaluations, determination of fire versus other particulate by microscopy and corrosivity provides the broadest and most relevant information for particulate contamination. Plant-specific pyrolysis products, such as guaicols, syringols, and levoglucosan, are reliable indicators for biomass burning.

Metals are commonly released from both biogenic and anthropogenic sources during wildfires and can cause contamination of soil and water sources, which can have a large effect on the ecology and constitute a significant health hazard for humans and animals.

THE BOTTOM LINE

All laboratory results must be evaluated in context with the specific situation and environmental conditions, especially in such complex situations as fire. No single analytical test by itself can be used to definitively identify “contamination.” This determination must include the whole picture (visual inspection, site history, type of fire, sampling locations, and so on).

Currently there are no laboratory tests that can determine if a building is “safe.” This conclusion depends on the characteristics of the occupants, how much time they spend in the building, and their activities as well as the specific contamination to which they are exposed. Laboratory tests, however, can provide insight into the type and amount of fire-related contaminants that could be present, which can be used to make an informed evaluation. More detailed information will be available in the recently drafted “AIHA Technical Guide for Wildfire Impact Assessments: A Guide for the Occupational and Environmental Health and Safety Professional” (publication pending). Ⓢ

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