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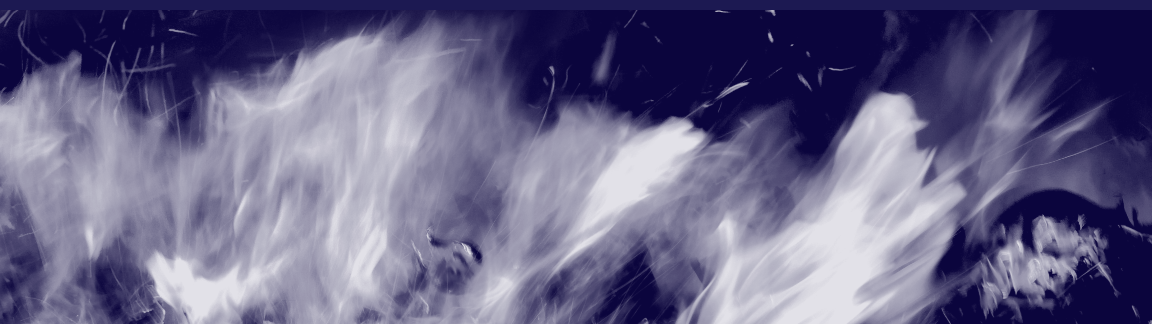
AIHA® Technical Guide for

Wildfire Impact Assessments

for the OEHS Professional

2nd edition



A practical guide for OEHS professionals and practitioners conducting wildfire impact assessments.

Edited by Enrique Medina, MS, CIH, CSP, FAIHA

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AIHA® Technical Guide for Wildfire Impact Assessments for the OEHS Professional

2nd edition

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Preface

The second edition of the *AIHA® Technical Guide for Wildfire Impact Assessments for the OEHS Professional* ("Technical Guide") updates and expands on the first edition published in 2018.

The impetus for the original Technical Guide started at the 2016 American Industrial Hygiene Conference and Exposition (AIHce) held in May in Baltimore, Maryland. The conference took place during the active phase of the Ft. McMurray wildfire in Alberta, Canada that burned 1,958 structures and more than 1.4 million acres (589,000 hectares) at a cost of CA$8.9 billion dollars. Fortunately, there were no human lives lost.

Coincidentally, a small group of industrial hygienists and laboratory experts presented a technical session on wildfire impact assessments. The positive response to the session reflected the profession's need for information and guidance on this subject. The group decided to form the "Wildfire Team" under the auspices of the Environmental Affairs Committee. Two years later, a team of 19 authors, editors, and contributors and five subject matter expert peer reviewers from the United States and Canada produced the first edition of the Technical Guide published by AIHA.

The Technical Guide is intended for use by industrial hygienists, analytical laboratories, restoration industry professionals and associations, insurance adjusters, government agencies, and law firms to address wildfire impacts. At the same time, the state of the practice has evolved in parallel with the experience of investigators, analysts, risk assessors, and restorers. Research on wildfire chemistry and atmospheric transport of air pollution has increased as global warming predicts more frequent and larger wildfires.

The second edition of the Technical Guide makes extensive use of the current published scientific research and established methods, protocols, and guidance found in AIHA publications, including *A Strategy for Assessing and Managing Occupational Exposures*; *The Occupational Environment: Its Evaluation, Control and Management*; *Recognition, Evaluation, and Control of Indoor Mold*; *The IAQ Investigator's Guide*; *Odor Thresholds for Chemicals*; *Principles of Good Practice,* and articles from *The Synergist*.

As in any emerging discipline, there are gaps in the peer-reviewed literature. The authors want the reader to know that the content of the Technical Guide represents the professional judgment, opinions, and advice of the expert authors based on current research, extensive firsthand practical experience, lessons learned, and good practice, in accordance with the AIHA *Principles of Good Practice Version* 5, October 2024. As with the first edition, the second edition of the Technical Guide has greatly benefitted from independent external peer review.

The Technical Guide was written by a multidisciplinary team of subject matter experts and practitioners in the areas of wildfire and structural fire assessments, industrial hygiene, medicine, toxicology, risk assessment, optical and organic laboratory science, professional restoration, statistics, and exposure assessment with literally hundreds of years of combined directly relevant experience and expertise. The updated Technical Guide is intended to serve as a practical guide for OEHS professionals and other practitioners on conducting evidence-based wildfire impact assessments.

Enrique Medina, MS, CIH, CSP, FAIHA
Editor and author
February 20, 2025

Executive Summary

The second edition of the *AIHA® Technical Guide for Wildfire Impact Assessments for the OEHS Professional* presents the current understanding of wildfire combustion processes and the chemical transformations that generate particulates, organic compounds, and metal residues.

The scope of this updated Technical Guide is on homes, buildings, and structures that were outside of the burn zone or survived a wildfire or a wildland-urban interface (WUI) fire and can be restored and reoccupied. The Technical Guide may be applied to wildfires that expand into conflagrations. However, caution is required to understand the myriad chemical and physical hazards that may exist in an extensive urban firestorm. Structure fires that consume buildings and property are outside the scope of the Technical Guide. They are only addressed when similar methods and techniques can be used to assess their level of impact. The primary purpose of the Technical Guide is to help occupational and environmental health and safety (OEHS) professionals and other investigators design and conduct wildfire impact assessments for exposure evaluations, forensic origin and cause investigations, or both.

Following the anticipate, recognize, evaluate, control, and confirm (ARECC) model used by OEHS professionals, forensic investigations of wildfire impacts on structures fit into the anticipate, recognize, and evaluate categories, whereas exposure assessment expands on the evaluation phase by characterizing human health hazards and risk. Forensic investigations are performed to assess the level of impact to the structure, evaluate contents from the wildfire residue, and develop a restoration plan. Exposure assessments seek to evaluate health risks to building occupants from infiltration and deposition of wildfire contaminants into a structure. Once damage or hazards are characterized, control and confirmation measures can be applied to restore property and/or protect the health of the occupants.

Whether the scope is a forensic investigation, a health exposure assessment, or both, the Technical Guide presents a framework for selecting a sampling strategy, choosing the appropriate sampling media and analytical methods, interpreting collected data to reach evidence-based conclusions, and preparing restoration specifications. This approach helps the OEHS professional and wildfire impact investigator work collaboratively with owners and restorers to determine the most appropriate approach for returning the structure as closely as possible to pre-loss conditions and controlling exposures.

Wildfires in the WUI burn homes, vehicles, and other structures in addition to vegetation. WUI fires generate a complex mixture of particulates, vapors and gases containing metals, volatile and semi-volatile organic compounds (VOCs and SVOCs), polycyclic aromatic hydrocarbons (PAHs), dioxins, furans, and other inorganic and organic compounds. These compounds can affect the indoor environment when they infiltrate a structure. The Technical Guide references studies from recent major wildfires to describe the factors that contribute to wildfire impact, whether from purely vegetation fires or mixed burns in the WUI. Many of the concepts, methods, and practices described in the Technical Guide may also apply to structure fires in a WUI fire.

The interrelated concepts of "time and distance" from the fire event are critical aspects that determine the fate and transport of particulates, organic chemicals, and metal constituents of wildfire residue. The Technical Guide describes how the effects of temperature, pressurization, and near-field and far-field distance from the fire perimeter determine the types, composition, and concentration of wildfire residue. The length of time elapsed after the fire significantly impacts the reactive chemistry, gas-to-particle partitioning, and decay rate of wildfire residue. Understanding the interplay between these factors is essential to defining the scope of the investigation.

The Technical Guide follows the investigative sequence, starting with a qualitative description of the initial exterior and interior site assessment, visual inspection, odor characterization, semi-quantitative and quantitative in-field testing, and assignment of preliminary impact levels. Criteria to evaluate when additional sampling may be required are presented. The sampling chapter explains how to develop a sampling strategy and sampling plan and describes the preferred sampling techniques, methods, and media for collecting particulates, organic compounds, and metals that will work for the intended analytical method. The chapter also introduces the uses of portable direct-reading instruments in wildfire impact investigations.

The chapter on microscopical and analytical chemistry methods explains how to select the most appropriate primary and secondary analytical methods to identify and quantify particulates associated with wildfire residue. A unique collection of optical and electron microscopy images illustrates the analysis of char, ash, soot, and signature fire-indicator particles using specific instrumentation to determine the origin and cause of the fire event. Organic and inorganic analytical methods are described for identifying organic indicator compounds associated with wildfire residue, identifying inorganic corrosive salts, or distinguishing similar organic and inorganic compounds unrelated to the wildfire that are present at background or typical levels in most structures.

Wildfire impact assessments often have practical and cost limitations on the numbers of locations and samples that can be collected and analyzed, which can constrain the statistical treatment of the data. Distribution of settled combustion particulates following a wildfire often deviates substantially from the "bell-shaped" normal or log-normal distribution used in classic exposure-based industrial hygiene statistics. This guide describes the application of the "permutation/randomization" or P/R model, a parallel inference model suited for wildfire data analysis and interpretation in forensic investigations. Some advantages of the P/R model are that it is not dependent on the mean or random sampling techniques. Examples of its application for wildfire impact assessments are described step by step in the Appendix section of the Technical Guide.

After characterizing the site, sampling and analyzing possible wildfire residue, and evaluating the resulting data for health exposure or forensic impact, the OEHS professional may be tasked with developing specifications for the restoration work plan. The Technical Guide explains how to develop prescriptive or performance-based specifications for those performing the restoration work, including the post-restoration verification conducted by the OEHS professional to confirm successful completion of the restoration goals.

The updated Technical Guide is intended to provide OEHS professionals, industrial hygienists, forensic investigators, laboratory analysts, restoration industry practitioners, and all other users with the knowledge, tools, and professional judgment to conduct wildfire impact assessments in order to help people who experience a wildfire return to a safe and healthy indoor environment.

1 Overview of the Potential Impact of Wildfires

WILDFIRES DIRECTLY AFFECT the property and environment in the immediate vicinity of the fire and can have regional or even international impacts (U.S. EPA, 2019). These impacts ultimately create potential exposures that could affect the health of building occupants and the public.

Wildfire impact investigations of structures that survived a wildfire and can be reoccupied involve professionals in a wide range of disciplines (e.g., OEHS professionals, forensic investigators, laboratory analysts, and restorers). Although the Technical Guide is primarily intended for OEHS professionals, the term "investigator" is used to refer to these professionals as a group.

The driving force behind the investigation is the impact from wildfire residues, which include not only particulate matter but also organic and inorganic chemical compounds. Time and distance from the fire event affect plume temperature and the chemistry of these compounds.

Impact-related concerns may include insurance claims, health and safety matters, legal items, or reoccupancy issues. These investigations can take place from days to months or longer after a fire. Most investigative, sampling, and analytical techniques are primarily intended for quantitative and qualitative analysis as well as source attribution to assist in determining the scope and degree of impact.

1.1. Types of Wildfire Impact Assessments

Wildfire impact assessments can be performed for a) forensic investigations, which are intended to confirm the presence or absence of wildfire residue and attribute the source, and b) exposure assessments to evaluate and control potential health hazards. Wildfire assessments can combine both goals.

The major difference is that a forensic investigation concentrates on whether the detected materials have an origin from the fire in question, whereas the goal of an exposure assessment is to assess the effects of the detected materials on human health to determine if the home or building is safe to occupy. These two goals are complementary.

Forensic investigations and exposure assessments are similar in their methods. Both must first define what the question is and develop a hypothesis to test it. Then, both must produce a sampling plan, select the appropriate statistical and inferential analysis for quantitative data, follow established quality assurance procedures, document data limitations, address confounders and uncertainties, and state evidence-based and supportable conclusions.

1.1.1. Impact Assessments for Exposure Evaluation

According to AIHA's *A Strategy for Assessing and Managing Occupational Exposures,* 4th edition, "exposure assessment is the process of defining exposure profiles and judging the acceptability of workplace exposures to environmental agents" (Jahn et al., 2015). Exposure assessment represents the evaluation portion of the fundamental industrial hygiene tenets of anticipation, recognition, evaluation, control, and confirmation (ARECC). In combination with hazard assessment and risk characterization, exposure assessment is an integral part of the risk assessment process. The ARECC concept can be adapted to wildfire impact investigations. Using this structured process, the OEHS professional is able to reach a conclusion on the acceptability of the exposure determination based on applicable criteria of human health risk and professional judgment (Jahn et al., 2015).

1.1.2. Forensic Impact Assessments

Forensic investigation is conducted when the presence, origin, and/or cause of combustion-associated materials in a building is uncertain. It describes the use of deductive reasoning to determine the level of wildfire impact to a building outside of the burn zone. This Technical Guide provides a framework for categorizing forensic impact on a continuum from Level 1 (Background) to Level 4 (Heavy).

In many cases, the overall inquiry may be less complex and not require a full forensic investigation. This may include investigation of a structure that was either visibly affected by a wildfire or exposed to contaminants generated by the wildfire (e.g., smoke). The initial assessment by the OEHS professional may be straightforward and not require items such as an origin and cause assessment. There are few unknown questions to answer, and the project may proceed using standard test methods (e.g., heavy metals, asbestos, char and ash concentration, etc.).

For example, to accurately address whether a structure has been impacted by a wildfire, an OEHS professional may have to determine whether materials found within the structure are consistent with the materials from the suspected point of origin. In the case of char and ash, the materials must be examined to determine whether the pyrolyzed materials detected are consistent with pyrolyzed materials from within the burn zone (i.e., fire perimeter). The OEHS professional must also take into account confounding factors that may influence the interpretation of their observed results. This would include accounting for other sources of combustion products that are similar to wildfire combustion products, such as fireplace ash, barbeque residue, smoking products, etc.

1.2. Wildfire Combustion Chemistry and Temperatures

A wildfire is a rapidly moving and uncontrolled fire that consumes specific parts of plants and other combustible materials in its path. Pyrolyzed and oxidized (burned) fragments and other products associated with the combustion of source fuels are distributed into the environment as components of the plume. Pyrolysis is the decomposition of a material into one or more other substances due to exposure to energy—typically driven by high temperatures—without oxidation (Larrañaga et al., 2016).

Wildfire fuels accumulate from the development of vegetation over time. Fuels are characterized by the establishment, growth, phenology, and mortality of the vegetation. The biomass on the ground, or necromass, becomes surface and ground fuel and is decomposed by microbes and soil macrofauna (e.g., worms, insects, slugs) over time. The development and decomposition processes continuously interact such that wildfire fuel properties and their distributions are a cumulative result of the vegetative development/decomposition cycle in space and time (Pritchard et al., 2022). Wildfire fuels exist in vertical layers defined as canopy, surface, and ground fuels. Canopy fuels are biomass above the surface fuel layer at approximately over two meters high; surface fuels typically include biomass from ground level to two meters high; and ground fuels are the necromass and vegetation on and below the ground (Pritchard et al., 2022).

Examples of ground fuels include partially decayed vegetation, tree roots, dead leaves, and fine deadwood. Surface fuels include downed logs, stumps, large limbs, low brush, grass, and seedlings. Canopy fuels include tree branches and crowns, dead trees, tree moss, and high brush.

During combustion, vegetative matter is decomposed due to the chemical reaction of fire, which is the rapid oxidation of organic material producing carbon dioxide, water, heat, and other components of smoke. During the incipient stages of the fire, pyrolysis begins, which dehydrates and converts fuel into combustible vapors and gases, providing fuel to the fire and allowing the fire to grow.

Flaming combustion follows pyrolysis, which burns the generated gases and vapors and increases the intensity of the fire. The fire will continue to grow due to convective or radiative energy, and flames will preheat and pyrolyze nearby fuels to generate gases and vapors available for burning and fire growth.

Flaming and smoldering combustion occur both sequentially and simultaneously as a fire front moves across a landscape, with smoldering combustion sometimes continuing for extended periods (weeks to months) after flaming combustion ceases (Pritchard et al., 2022). Smoldering combustion tends to occur in densely packed and highly lignified fuels in the necromass [e.g., organic soils, deep ground fuels (roots), peat, and decayed vegetation] due to fuel geometry that prevents oxygen from reaching the fuel in concentrations that support flaming combustion. In northern or southern subarctic ecosystems in the Northern Hemisphere, approximately 90% of wildfire emissions can be attributed to smoldering combustion of deep necromass (Pritchard et al., 2022).

Smoldering fires produce higher yields of some constituents (e.g., particulate matter, gases, and vapors, etc.) than flaming fires, where the yield is defined as mass of constituent per mass of fuel consumed. These types of fires have a lower mass loss rate. Although the yield is higher, the overall concentrations of constituents may not be significantly different from those produced by a flaming fire, which has lower yield but higher mass loss rate.

Wildfire Impact Assessment

2

WILDFIRE IMPACT ASSESSMENTS are typically performed for a) forensic investigations, which are intended to confirm the presence or absence of wildfire residue and attribute the source, b) exposure assessments to evaluate and control potential health hazards, or c) a combination of both. A comprehensive wildfire impact assessment should include a relevant history of events, general construction basics of the property of concern, and detailed sensory observations (e.g., odor evaluation, visible and physical impact) supplemented by sampling as needed. Knowledge of mechanical building ventilation and air movement inside a structure (especially during the fire event) can be helpful in anticipating particle deposition patterns and subsequently identifying sampling locations. The investigation should include interior and exterior spaces and surfaces where accumulations of combustion byproducts are likely.

2.1. Impact Evaluation

The primary role of the OEHS professional conducting a wildfire impact assessment is determining what has been impacted (and to what level) and establishing the source, origin, and cause of that impact.

If the evaluation is conducted for exposure assessment, the OEHS professional should follow the ARECC model of anticipation, recognition, evaluation, control, and confirmation. The OEHS professional should be able to select the appropriate site inspection, monitoring, sampling, and analytical methods to establish the presence and concentration of potentially hazardous agents.

In forensic investigations, the level of impact to properties is dependent on the location of the property relative to the wildfire, wind direction during the fire event and shortly thereafter, and opportunities for the wildfire residue to infiltrate into the structure.

The exterior surfaces of a structure generally sustain the most direct impact of wildfire residue and heat depending on the structure's location within the burn zone, near field, or far field from the fire perimeter. Exterior building components provide essential information on the level of impact. Wildfire particles can infiltrate buildings through visible penetrations as well as unperceived gaps in the building envelope and deposit and settle on proximal surfaces (Kovar et al., 2015).

The OEHS professional should understand that impact and damage are not synonymous terms. Evidence of wildfire residue impact to the environment does not necessarily mean that damage has occurred. "Impact" is a general term that indicates that the structure's condition, or portions thereof, is different than the background conditions that existed before the wildfire. "Damage" is generally defined as the alteration of appearance, utility, or value (Kovar et al., 2015). Although a change in appearance (e.g., a dirty window) indicates impact that requires cleaning, it is not considered damage by itself. It is not the role of the OEHS professional to determine or measure damage or ascribe a value to impacted structures and contents.

2.2. Pre-Entry Safety Considerations

OEHS professionals and other materially interested parties (MIPs) conducting an initial building inspection should exercise adequate caution to prevent exposure to potential health and safety hazards. The location of the structure and the time elapsed since the fire are important considerations. Structures located in the near field or a WUI fire area pose a greater risk of exposure than buildings located in the far field. At a minimum, foot covers should be worn when entering a building that has already been cleaned, ventilated, reoccupied, and returned to normal operations.

Initial inspections performed before the building or home is reoccupied or has been cleaned merit additional precautions. Personal protection equipment such as gloves and disposable coveralls may be recommended. N-95 masks are also advisable when accessing attics and crawlspaces or unoccupied spaces, such as sheds and warehouses. Upgrade to tight-fitting air-purifying respirators with N-95 and organic vapor cartridges may be necessary if volatile organic compounds (VOCs) or semi-volatile organic compounds (SVOCs) are detected or suspected.

Although not considered typical for a wildfire residue impact assessment, fire-impacted structural members may compromise the structural integrity of roofs, floors, walls, and foundations. In these cases, evaluation by a qualified engineer or building official is warranted prior to entry.

Other safety hazards to consider before entering a building regardless of its distance from the fire perimeter can also include fire risk, falling trees, electrical hazards, gas leaks, animals and uneven terrain, water damage, and mold, among others.

2.3. Information Gathering/Occupant Interviews

The collection of relevant data prior to or during the investigation is a fundamental component of wildfire residue impact investigations. Data collected should include the following:

- Details of the subject wildfire, including date(s) of wildfire occurrence, name, size of wildfire, location and proximity of wildfire relative to the property, prevalent wind direction(s), occupant observations during the wildfire, ambient air quality monitoring station data (e.g., $PM_{2.5}$, PM_{10}), relevant information from reliable sources (e.g., fire department, news media outlets, satellite imagery, video, etc.), cleaning or restoration performed to date, and building and site characterization and stabilization, if needed.

- Controls for confounding variables (e.g., sources of microscopic impact and chemicals other than from the wildfire that may skew testing results, such as smoking or fireplace use). The operating status of the building during the fire event (e.g., HVAC on or off, windows closed or open, water suppression system operating, etc.) will affect the level of impact and the fate, transport, and depositional patterns of wildfire residue.

2.4. Visual Inspection

Visual inspection of the subject property is the most important part of any impact investigation. Prior to arriving on site, the OEHS professional should have a clear and specific purpose and set objectives for the investigation. A comprehensive written inspection checklist is essential for accurately documenting the initial conditions observed. The checklist should be preserved as part of the permanent record. Appendix B presents example forms for exterior, interior, garage, attic/crawlspace, and HVAC system inspections.

In the immediate aftermath of a fire event, determining the level of impact at a structure located adjacent to the fire perimeter may not be difficult due to

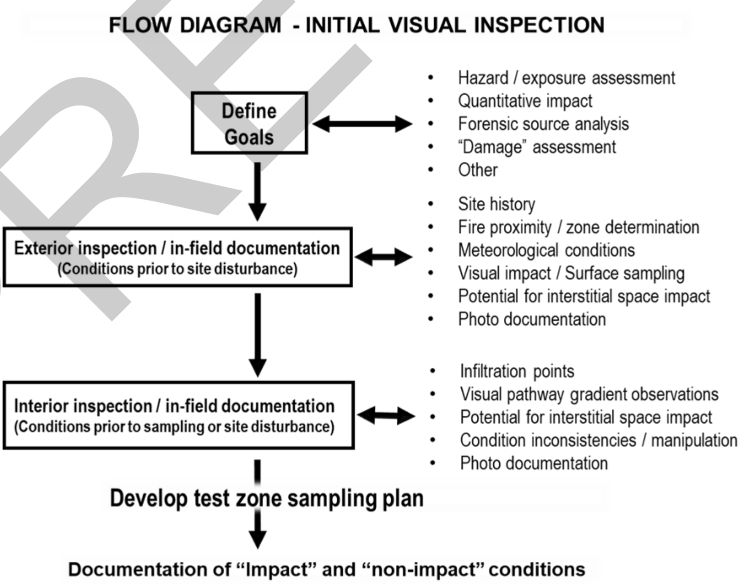


Figure 2.1: Forensic wildfire inspection flowchart.

Microscopical and Analytical Chemical Methods

4

4.1. Overview

As with the selection of sampling methods, the OEHS professional needs to select the appropriate analytical laboratory to perform forensic microscopy or analytical chemistry. Both particle and chemical fire residues are too complex to measure in their entirety. Therefore, suitable surrogates must be selected to support the project scope, which typically encompasses physical impact on structures, potential health risk of occupants, or both.

These laboratories must be capable of performing the appropriate analysis to test the desired hypothesis. This includes conducting forensic source and particle pathway identification using optical microscopy as well as organic and inorganic analyte testing for exposure assessment. The OEHS professional should also ensure the sampling methods used are compatible with the required analysis method.

Forensic analysis methods involving the origin, cause, and spread of the fire event may not be adequately defined by existing ASTM, U.S. EPA, NIOSH, or other analytical methods, which were originally designed for exposure assessment purposes. Standardized testing methods or accreditation programs do not encompass the full scope of these specific forensic laboratory requirements. In many cases, the existing methods may require modifications. The laboratory should be able to provide internal standard operating procedures (SOPs) specifically written for these particular purposes. By consensus, the Technical Guide authors developed a suggested analysis method framework for wildfire particulates , which is provided in Table 4.1 and Figure 4.6 (in Section 4.2.4). The guidelines are consistent with industry-accepted method formats for all analytical methods. They also provide minimum requirements for the laboratory to develop and use an internal laboratory SOP and test method.

The methods to be used include both primary and secondary methods. Primary methods are established consensus procedures relied on to provide both qualitative and quantitative impact evaluation and origin determination. Secondary methods are additional procedures that can be implemented to provide specific additional particulate, chemical, and elemental data to help resolve interferences. They may also be used in instances where the primary method(s) provides incomplete or inconclusive data for a specific investigative goal. Secondary methods may be based on experiential or experimental data, unpublished or in-house methods, or modification of an established method. Any deviation from a standard test method should be noted, and the OEHS professional should understand the deviation on the reported results.

4.2. Optical Microscopy

Optical microscopy is the primary method used to identify and quantify the surface impact from wildfire combustion residues. Optical microscopy of tape lift samples is used to address infiltration, pathway penetration, gas-phase particle deposition, and settling. The resulting particle assemblage is then used to help differentiate a wildfire-related impact from background sources. An advantage of light microscopy is that many thousands of particles can be quickly scanned, the combustion particles isolated and identified, and the source often characterized by the assemblage of identified particles. Optical microscopy can be used as a screening or surrogate method to determine if other chemical organic and inorganic testing and analytical methods may be required.

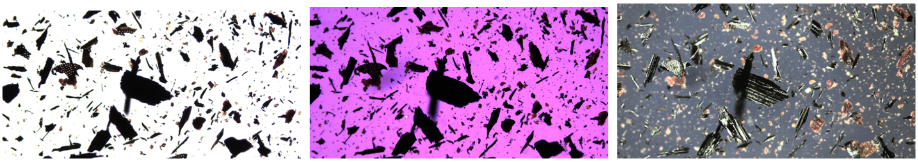
4.2.1. Optical Microscopy Transmitted and Reflected Light Illumination Method Requirements

Particle combustion residues carry the signature of the fuels consumed. Many of these products are opaque and characterized optically by their reflectivity and morphology using reflected light darkfield illumination. Some are transparent, optically active, and have characteristic morphology. Initial examination by low-magnification reflected light microscopy (50–100×) is first performed to help define and report the macroscopic texture and color of the sample. It is also used initially to determine the absence or presence of large fire residue particles and deposition patterns observed in the sample (char, suspect ash, or uniformly deposited soot clusters).

The high magnification (50–500×) quantitative portion of the light microscopy analysis is performed by examining each field of particles using both reflected and transmitted light illumination sources, specifically using brightfield, polarized light, and darkfield reflected illumination as a minimum capability. Differentiating between the optically "opaque" vegetative combustion char, decayed biomass, and other opaque debris such as commonly encountered corrosion particles (e.g., galvanized metals, iron oxide) within the same microscopic field of view requires both confirmation and quantification by the use of reflected light darkfield illumination. This minimum instrumental requirement to simultaneously differentiate between optically opaque "burned" particles and the most commonly encountered opaque environmental particles is illustrated in Figures 4.1 to 4.4.

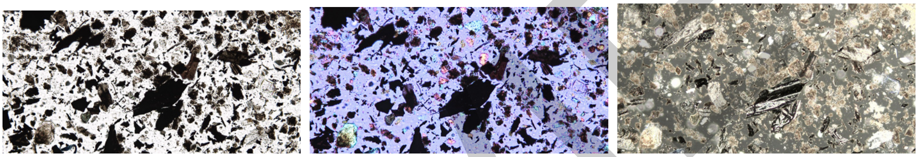
4.2.2. Optical Microscopy: Analysis of Char, Ash, Soot, and Fire-Indicator Signature Particles

The comprehensive analysis of wildfire particles encompassing the identification, origin, and distribution of indicator signature particles is best achieved by preserving the spatial distribution of settled particles using tape lift sampling for direct microscopical analysis. Indirect procedures such as wipes, solvents, and ultrasonication should be avoided where possible. Pyrolyzed vegetation char is



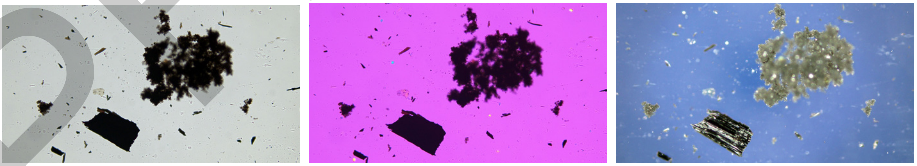
(A) Transmitted light brightfield (B) Transmitted polarized light (C) Reflected light darkfield

Figure 4.1: Mixed iron oxide corrosion particles and wildfire char. Images provided by Environmental Analysis Associates shown in (A) transmitted light brightfield, (B) polarized light with a full wave plate inserted, and (C) reflected light darkfield (RLDF) illumination in refractive index oil 1.550. For a reference point, the particles in the center are vegetation char particles and the orange iron oxide corrosion particles can only be differentiated in the RLDF illumination mode. Note the shiny black "reflective" surface of the char particles is visible in RLDF. All micrographs were collected at approximately 200×.



(A) Transmitted light brightfield (B) Transmitted polarized light (C) Reflected light darkfield

Figure 4.2: Mixed galvanized HVAC duct corrosion particles and wildfire char. Images provided by Environmental Analysis Associates shown in (A) transmitted light bright field, (B) polarized light with a full wave plate inserted, and (C) reflected light dark field illumination in refractive index oil 1.550. For a reference point, the large particles in the center of the micrograph are vegetation char. Galvanized metal particles (aluminum and zinc oxide) are the primary background particles and are highly reflective, showing a white-silver to light yellow-orange color in contrast to the shiny black and "reflective" surface of the char particles in reflected light darkfield. All micrographs were collected at approximately 200×.



(A) Transmitted light brightfield (B) Transmitted polarized light (full wave plate) (C) Reflected light darkfield

Figure 4.3: Mixed tire wear rubber and wildfire twig/leaf char. Images provided by Environmental Analysis Associates shown in (A) transmitted light brightfield, (B) polarized light with a full wave plate inserted, and (C) reflected light dark field illumination in refractive index oil 1.550. The reflective color of the silica matrix in the tire rubber allows immediate differentiation in reflected light (darkfield) illumination. The micrographs were collected at approximately 200×.

Appendix B. Wildfire Impact Site Investigation Forms

WILDFIRE INSPECTION - (General Property / Exterior Geographical Impact Conditions)

Page ______ *of* ______

Inspection	
Project #	
Client Project #	
Project Name	
Address	

Date(s) of subject fire event? ______ Days since fire event ______

Question Codes (U) Unknown (Y) Yes (N) No

Home in / near burn zone of fire (Y / N / U) ? →		Distance (miles) ____	Wind gusts ____
Home downwind of fire (Y / N / U) ? →		Distance (miles) ____	Wind gusts ____
Exterior pressurization (Y / N / U) ? →		Describe	
Interior pressurization (Y / N / U) ? →		Describe	
Windows open during fire (Y / N / U) ? →		Describe	
HVAC operating during fire (Y / N / U) ? →		Describe	
Cleaning post-fire (Y / N / U) ? →		Describe	
Firefighter property activity (Y / N / U) ? →		Describe	
Electronic issues post-fire (Y / N / U) ? →		Describe	
Vehicles impacted by fire (Y / N / U) ? →		Describe	
Homeowner photos (Y / N / U) ? →		Describe	
Inspection photos collected (Y / N / U) ? →		Describe	
Previous exterior fires (Y / N / U) ? →		Describe	
Pre-existing conditions (Y / N / U) ? →		Describe	

	Construction type				Age (if known) →	25
Construction	Single fam	Duplex	Townhome	Condo	High-rise	Other
Type/floors	1	1	1	1	1	1
	2 3	2 3	2 3	2 3	2 3	2 3
Foundation	Slab	Crawl	Pillar/stilt	Mid-floor	Other	
Siding	Wood	Stucco	Brick	Masonry	Other	
Roofing	Asphalt	Wood	Stone	Tile	Cement	

	Blank	Not addressed by inspection
Inspection	u	Unknown / Inconclusive
Conditions	y	Condition present
	n	Condition not present

Main Structure orientation			Ext. Fire Impact Level (0-3)					Ext. Garage Fire Impact Level (0-3)					Describe impacted landscaping features
Orientation	(N S E W)	Comments	Overall Impact	Vegetation	Wall	Window	Roof	Overall Impact	Vegetation	Wall	Window	Roof	Overall Impact
Front (entrance)	S												
Left side	W												
Right side	E												
Back entry	N												

	Blank	Not addressed by inspection
FIRE	0	Inspected - No visual or other / impact
IMPACT	1	Light fire residue impact
LEVELS	2	Moderate fire residue impact
	3	Heavy fire

Other Structure / ADU / Out-building		Other Structure - Fire Impact Level				
Orientation	Comments	Impact	Vegetation	Wall	Window	Roof
Front (entrance)						
Left side						
Right side						
Back entry						

Comments

Inspector______________________ Inspection Date________________

Figure B1: Example in-field investigation form to illustrate parameters for a systematic exterior evaluation applicable to wildfire and structure fire impact conditions.

Acronym List

Δf_d: difference in frequency distribution
µm: micrometers
AAS: atomic absorption spectrophotometry
ACAC: American Council for Accredited Certification
AIHA: American Industrial Hygiene Association
AIHce: American Industrial Hygiene Conference and Exposition (now AIHA Connect)
ANSI: American National Standards Institute
ARECC: Anticipation, recognition, evaluation, control, confirmation
ASTM: American Society for Testing and Materials
ATSDR: Agency for Toxic Substances and Disease Registry
CNCs: condensation nuclei counters
CO: carbon monoxide
CO_2: carbon dioxide
COPD: chronic pulmonary obstructive disease
CPCs: condensation particle counters
CRV: critical reference value
cts/mm^2: counts per square millimeter
CV: coefficient of variation
CZ: control zone
EAA: Environmental Analysis Associates
EDS or EDX: energy dispersive X-ray (analysis)
EPA: Environmental Protection Agency
ESAM: Environmental Sampling and Analytical Methods
FEMA: Federal Emergency Management Administration
FIDs: flame ionization detectors
FTIRs: Fourier-transform infrared detectors
GC/MS: gas chromatography/mass spectrometry
HEPA: high-efficiency particulate air (filtration)
HPLC: high-performance liquid chromatography
HUD: (Department of) Housing and Urban Development
HVAC: heating, ventilation, and air conditioning
IAQ: indoor air quality
IAQA: Indoor Air Quality Association
IARC: International Agency for Research on Cancer
ICP M/S: Inductively coupled plasma mass spectrometry
ICP-AES: inductively coupled plasma-atomic absorption spectrometry

IDLH: immediately dangerous to life or health
IICRC: Institute of Inspection, Cleaning, and Restoration and Certification
ISO/IEC: International Organization for Standardization and the International Electrotechnical Commission
IUR: inhalation unit risk (U.S. EPA IRIS database)
LOQ: limit of quantitation
LPCs: laser particle counters
mg/cm²: milligrams per square centimeter (of surface)
mg/cm³: milligrams per cubic centimeter (of air)
mg/kg: milligrams per kilogram (of bulk material)
MIPs: materially interested parties
NADCA: National Air Duct Cleaners Association
NASEM: National Academies of Sciences, Engineering, and Medicine
NESHAP: National Emission Standards for Hazardous Air Pollutants
NFPA: National Fire Protection Agency
ng/cm²: nanograms per square centimeter (of surface)
ng/g: nanograms per gram (of bulk material)
ng/L: nanograms per liter (of air)
ng/wipe: nanograms per wipe
NHST: null hypothesis significance test (statistical method for testing a hypothesis against an observation)
NIOSH: National Institute for Occupational Safety and Health
NMAM: NIOSH Manual of Analytical Methods
NOAA: National Oceanic and Atmospheric Administration
NOx: nitrogen oxides
NRC: Nuclear Regulatory Commission
NTP: National Toxicology Program
OEHHA: Office of Environmental Health Hazard Assessment (CA)
OEHS: Occupational and Environmental Health and Safety
OPCs: optical particle counters
P/R model: permutation/randomization
PAHs: polycyclic aromatic compounds
PDRIs: portable direct-reading instruments
pH: potential of hydrogen (measure of acidity or basicity)
PIC: products of incomplete combustion
PIDs: photoionization detectors
PM: particulate matter
$PM_{2.5}$: particulate matter, 2.5 µm
PM_{10}: particulate matter, 10 µm
POAs: primary organic aerosols
ppbv: parts per billion by volume
PPE: personal protective equipment
ppm: parts per million
PRE: post-restoration evaluation
PRV: post-restoration verification

PTR-TOF-MS: proton-transfer-reaction time-of-flight mass spectrometry
RfD: reference dose (inhalation, U.S. EPA IRIS database)
RI: refractive index
RIA: Restoration Industry Association
RLDF: reflected light darkfield
RSLs: regional screening levels (U.S. EPA)
RWP: restoration work plan
SEM: scanning electron microscopy
SO_2: sulfur dioxide
SOAs: secondary organic aerosols
SOPs: standard operating procedures
SPME: solid-phase microextractions
SVOCs: semi-volatile organic compounds
TD-GC-MS: thermal desorption-gas chromatography-mass spectrometry
TEM: transmission electron microscopy
TLBF: transmitted light brightfield
TO-15: Toxic Organics method number 15
TO-17: Toxic Organics method number 17
TPLM: transmitted and polarized light microscopy
TZ: test zone
UFPs: ultrafine particles or ultrafine particulates
µm/m^3: microgram per cubic meter (of air)
USDA: United States Department of Agriculture
U.S. DOI: United States Department of the Interior
U.S. EPA: United States Environmental Protection Agency
VAE: visual area estimation
VOCs: volatile organic compounds
WUI: wildland-urban interface
XAD™: trade name for a hydrophobic organic porous polymer sorbent
XRF: X-ray fluorescence

EMERGENCY PREP AND RESPONSE |
HAZARD RECOGNITION AND EVALUATION

AIHA® Technical Guide for Wildfire Impact Assessments for the OEHS Professional, 2nd edition

Edited by Enrique Medina, MS, CIH, CSP, FAIHA

This technical guide presents the current understanding of wildfire combustion processes and the chemical transformations that generate particulates, organic compounds, and metal residues. The scope is on homes, buildings, and structures that were outside of the burn zone and survived a wildfire or wildland-urban interface (WUI) fire and can be restored and reoccupied. The Technical Guide is intended to provide OEHS professionals, industrial hygienists, forensic investigators, laboratory analysts, restoration industry practitioners, and all other users with the knowledge, tools, and professional judgment to conduct wildfire impact assessments in order to help people who experience a wildfire return to a safe and healthy indoor environment.

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