Suggested Guidelines for Wildfire Smoke Damage Investigations and Remediation

>> by **Brad Kovar, Martin L. King and Dr. Priyotosh Chakravarty**

Devastating wildfires are becoming more common; nine of the ten largest fires in U.S. history have occurred in the last decade. Between 60,000 and 80,000 wildfires occur in the United States each year, burning 3 to 10 million acres. The proliferation has captured national attention and brought renewed interest to fire science and fire suppression technology. These wildfires have awakened the need for a coherent multi-disciplinary approach to individual evaluation of smoke damage due to wildland and forest fires.

A major challenge in forest fire investigations has been the absence of an objective standard relating combustion particles to damage. Settled combustion particles in the form of char and ash can be identified, counted and measured in a laboratory. Damage, however, is subjective: a level of particle contamination acceptable in a machine shop would not be tolerated in a hospital.

Damage has been defined as *an alteration resulting in a loss in appearance, utility, life expectancy or value.* When do combustion particles cross the threshold of normal background and become damage? After forest fires, property owners differ in their perceptions of heat damage, particle contamination and smoke odor. Since insurance is often involved, large sums may hinge on the opinions of owners and investigators. Objectivity may be in short supply.

This paper combines the views and disciplines of an environmental hygienist, an accredited damage appraiser and a professional researcher. The paper is not intended to constitute a detailed analysis of property damage from settled combustion particles, nor is it a risk assessment procedure. The authors are attempting to combine scientific principles with practical procedures for investigating claims of wildfire damage. In the process they have tried to adhere to the discipline and impartiality that science requires.

Wildfire

Smoke Distribution

Wildfires create their own weather patterns. The fire's intense heat generates updrafts that drive combustion particles thousands of feet into the air, where prevailing winds can carry them great distances. At the same time, air rushing in to feed the updrafts picks up other debris, such as sand and granular particles that also become part of the air stream.

The extreme heat generated by the combustion process reduces vegetation to ash, which is feather-light and easily transported in the environment. Other fuels, such as vehicles, buildings and building contents may burn and contribute to the mix of chemicals and particles that are found in wildfire smoke, soot, and ash. Winds generated by larger weather patterns may transport smoke great distances. Particles of charred debris often continue to deposit long after the fire was extinguished.

Understanding wildfire smoke can be useful when explaining some of its effects, but more precise knowledge is needed when evaluating a wildfire's impact on a community or a specific site. Satellite images of the smoke plume, official weather and fire department reports and local news sources provide support for eyewitness accounts of the smoke's location, intensity and duration.

General evidence of a smoke-laden environment does not automatically mean that damage has occurred. That can only be demonstrated by direct inspection of the property.

Exterior Particle Distribution

Exterior surfaces sustain the direct impact of wildfire smoke and heat, so exterior building components may provide essential information on damage or its absence. All things considered, external damage is usually greatest on surfaces facing the fire source.

Forest fires may be remote or proximate. Particles from remote fires tend to diffuse over a general area, such as a town or community, where many properties are affected in a similar way and to a similar degree. In contrast, wildfire that approaches a subject property becomes a point source, and damage tends to be oriented towards that source and is specific to the site in question. A greater variation of impact between different sides of a structure can be expected from point-source fires. The inspector must be conscious of this distinction because it determines the thrust of the investigation, even if elements of both types are present. Factors to be considered include:

- Location of the fire relative to the subject site.
- Proximity of the fire.

Executive Summary

Devastating wildfires are becoming more common; nine of the ten largest fires in U.S. history have occurred in the last decade. Between 60,000 and 80,000 wildfires occur in the U.S. each year. These wildfires have awakened the need for a multi-disciplinary approach to their evaluation.

This paper is not a detailed analysis of property damage from settled combustion particles or a risk assessment procedure; it is an attempt to combine scientific principles with practical procedures for investigating claims of wildfire damage.

Wildfires create their own weather patterns. Understanding wildfire smoke can be useful when explaining some of its effects, but evidence of a smoke-laden environment does not mean that damage has occurred.

Exterior surfaces sustain the direct impact of wildfire smoke and heat, so exterior building components provide essential information on damage. Wildfire particles infiltrate buildings through visible apertures as well as unperceived gaps in the building envelope. They tend to settle evenly.

Wildfire smoke causes damage when combustion particles alter the appearance of building surfaces or personal property. Wildfire particles may penetrate electronic devices or other equipment. Smoke odors create an environment that may be intolerable.

No standards or exposure limits exist for settled combustion particles (char or ash) in indoor environments, and there are no standards for laboratory analysis. Investigators need benchmarks to compare results, but there may be no published data against which field data may be compared. Determining prior background levels are key to attributing combustion particles to wildfires.

In wildfire investigations, the investigator develops a working hypothesis for the degree of exposure and damage to the property. The hypothesis steers the inspection toward specific areas where sampling confirms or discounts wildfire particle accumulation. The complexities associated with these investigations necessitate that investigators have appropriate training and experience. Investigative procedural guidelines help ensure vital evidence is not lost or red flags overlooked:

- Information gathering/occupant interviews.
- Visual inspection.
- Sampling protocols.
- Obtaining background samples.

Investigators should exercise prudence when selecting an analytical laboratory. Laboratories offer an array of methods for determining the intensity and composition of sub-micron soot particles, and are useful in distinguishing alternative sources of combustion particles. However, laboratories sometimes attempt to adapt asbestos or carbon black protocols to combustion particles, yielding misleading results.

The goal of restoration after wildfires is to return properties as closely as possible to their predamage state. Removal of loose combustion particles is a universal first step. The HEPA vacuum is an essential tool. Early and thorough removal of combustion particles is crucial. Detergent-water solutions release particles that adhere electrostatically.

Cleaning of absorbent materials such as carpeting, upholstery or clothing should be performed by restorers familiar with current technology and materials. HVAC filters should be replaced or cleaned. Ventilation systems operating during a fire event may be impacted throughout, with deposits generally greater on the return side.

Swimming pools and hot tubs may be heavily impacted by forest fire particles. Restoration is usually performed by those who customarily service them. Siding, decks, driveways, railings and cast decorations will benefit from timely air washing or spray rinsing. This may mitigate the need for more intensive work.

Wildfire smoke is often accompanied by a pungent, disagreeable odor. Generally, the most effective remedy is the full and complete removal of combustion products.

Because only new or recently-painted surfaces would have been free of dust and combustion residues before the wildfire, the removal of visible combustion particles is often considered sufficient for restoration.

- Wind direction during the fire and subsequently.
- Topography of the subject area relative to the fire source, presence of significant geographic elements such as valleys, peaks, bodies of water, prevailing winds, rainfall and built obstructions.
- Past smoke exposures, other fire history.
- Alternate particle sources, such as highways, industrial facilities, airports, business centers, schools or sports facilities.
- Building orientation relative to the fire; slope or hillside construction, nearby trees and vegetation.
- Structural details of the subject property, including orientation of windows, doors, attic vents, garage doors as well as exterior surface materials, trims, lighting and HVAC equipment.
- Appurtenant structures such as retaining walls, swimming pools, hot tubs, barbecue grills, storage sheds, patios, decks and porches.
- Building age, history, recent painting, repairs and condition prior to the fire; occupancy, whether condominium, rental or owner-occupied.
- Remediation or other repairs performed since the wildfire event.

Interior Particle Distribution

Though not as dramatic as external conditions, buildings have interior "weather" that consists of air currents, seasonal and daily temperature changes, and variations in humidity. Air currents cycle continuously, induced by pressure differences that arise from temperature gradients in individual rooms, entire floor levels, or the building as a whole. Interior weather is moderated by the ventilation system and individual heating and cooling appliances. However, air circulation patterns exist independent of ventilation systems and continually distribute airborne particles. These particles may accumulate to a visible degree, a phenomenon sometimes called *filtration soiling.* Air infiltration and thermal exchange from the exterior are significant contributors to interior weather.

> "The distribution of wildfire particles within buildings differs from interior fires, where heat drives combustion particles upwards and the smoke path can be visually traced back to the source."

The character of wildfire particles also influences their distribution. Their polarity attracts combustion particles to TV and computer screens as well as to each other when they form long strands called *smokewebs.* Electrostatic bonding causes fine particles to adhere to walls and ceilings.

The distribution of wildfire particles within buildings differs from interior fires, where heat drives combustion particles upwards and the smoke path can be visually traced back to the source. Wildfire particles infiltrate buildings through visible apertures such as windows, doors and air vents, as well as through unperceived gaps in the building envelope. No longer propelled by heat, wildfire particles are transported by air currents and settle or fall when the air velocity is no longer sufficient to transport the particles. Forest fire particles tend to settle evenly on interior surfaces. Irregular concentrations, for example in a kitchen or vented attic, may point to other sources.

Background Particles

Particles of various types are always present in exterior air and inevitably find their way into buildings, where they join insulation particles, fiber fragments from clothing and carpets, hair, epithelial (skin) fragments, and combustion particles from cooking, smoking, candles and fireplaces. These particles combine as "dust." Everyone is aware that removing accumulated dust is a part of normal living. However, not everyone is aware that combustion particles are usually an ingredient of dust. In contrast, wildfire emissions impact a surface similar to other major particle-producing events, such as remodeling, earth-moving activity, volcanic eruption, etc., eventually settling as a distinct upper layer blanketing the normal assemblage of dust.

Composition of Wildfire Smoke

It is generally accepted that the chemistry of wildfire emissions is not stable. Fuel layers, available oxygen, weather conditions and fire temperatures produce a variable mix of compounds that may impact human health and property. Additionally, combustion particles may undergo chemical change in the atmosphere.

Although there may be commonalities, the broad range of potential wildfire products requires that their impact be studied on a case-by-case basis. Some research studies have attempted to generalize impacts from disparate wildfires, resulting in conclusions that do not withstand scrutiny. This suggests a need for caution in wildfire analysis. Because of uncertainties in particle chemistry, this subject will not be further discussed here. In the authors' experience, wildfire smoke damage is best approached through its observed effects.

Wildfire Damage

Damage has been defined as *"an alteration resulting in impairment or loss of function, appearance, utility or value."*

These elements of damage are subjective concepts which are usually negotiated between the interested parties. The investigator should not attempt to relate the presence of combustion particles to property damage or value. The objective of the investigation is to determine the presence or absence of wildfire-related particles and, if appropriate, to determine if the settled particles exceed background levels.

Wildfire smoke causes damage when combustion particles alter the appearance of building surfaces or personal property, or when they constitute a nuisance by transferring dark residues to hands and clothing. Wildfire particles may penetrate electronic devices or other equipment and interfere with their operation. Ash is a common form of wildfire residue. Ash crumbles easily into superfine particles that resemble normal household dust but have been found to contain toxic elements. Fine granular material may accompany and settle out with combustion particles.

Smoke odors create an obnoxious environment that occupants may find intolerable. Smoke odors may contaminate hair and clothing to a degree that is detectable away from the site. Remedies for these and other forms of wildfire damage are discussed in "Remediation Procedures" below.

Standards and Guidelines

No standards, guidelines, regulations or exposure limits currently exist for settled combustion particles (char or ash) in indoor environments. Further, with the exception of ASTM D6602-03b *Standard Practice for Sampling and Testing of Possible Carbon Black Fugitive Emissions or Other Environmental Particulate, or Both,* which does not address wildfire soot particles, there are no standards for laboratory analysis. Qualified laboratories may have different methodologies that may produce different findings for the same sample.

Similarly, IESO/RIA 6001 *Standard for the 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* is specific to HVAC systems and structural fires, but the collection and laboratory methods described may apply to some aspects of settled wildfire particles.

As with any type of testing or sampling, investigators need benchmarks or thresholds to which they compare their results. There may be no published data against which field data may be compared. Comparison data may be based on in-house research or other published information. However, in many cases internal research and published information may not be appropriate, as this data may not account for regional variations, site-specific characteristics, variations in collection media or the presence of alternative combustion sources. Therefore, determining prior background levels are key to attributing combustion particles to wildfires.

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Investigations

Working hypothesis

Based on the fire and site information described above, the investigator develops a working hypothesis for the degree of forest fire exposure and the likelihood of fire-related damage to the subject property. The hypothesis steers the inspection toward specific areas where properly performed sampling can confirm or discount wildland/forest fire particle accumulation.

The complexities associated with wildfire smoke damage investigations and the plethora of laboratory methodologies necessitate that investigators and laboratory analyst have appropriate training and experience.

The following investigative procedural guidelines will help ensure vital evidence is not lost or red flags overlooked when processing and analyzing a smoke damage claim.

Information Gathering/Occupant Interviews

The collection of relevant data, including the statements of building occupants and other observers, is a basic requirement of wildfire smoke investigations.

Building occupants can provide information that will supplement the sample evidence and investigator's observations. Occupant accounts of airborne particles and smoke odors within the interior and exterior of the property should be recorded, along with information of post-fire cleaning procedures and repairs. Occupants' living habits, such as smoking, fireplace or candle use, should be included in a signed written statement when feasible.

Visual Inspection

Visual inspection of the subject property is the most important part of any investigation. It should have a clear and specific purpose. In the immediate aftermath of a forest fire event, resolving the source of dark-colored particles is not difficult. However, the processing of an insurance claim may require distinguishing wildfire particles from other combustion sources. During the site inspection, the investigator(s) should document evidence of a fire event, such as heat and smoke damage, visible combustion particles, and smoke odors. Key observations should be documented with photographs. During the site inspection, the investigator(s) should document, including photograph validation, evidence of a fire event, such as heat and smoke damage and visible combustion particles. The presence of any perceived smoke odors should also be acknowledged.

Since there are a host of forces and principles that govern particle movement and their relative interaction with surfaces, the investigation should include all interior and exterior spaces and surfaces where accumulation of combustion particles are likely.

The inspection should extend to furniture, flooring, baseboards, structural ledges, art works, window treatments, interior contents, knick-knacks, attic spaces, garages and detached structures.

Sampling Protocols

Sampling is critical to assessing potential smoke damage. Any given location or surface is visited by volumes of air which can propel combustion particles. Confidence levels in the outcome of the investigation is linked to appropriate sampling strategies. The investigator must consider the size of the subject property, points of entry and layout of the structure when determining the locations and number of samples to collect.

Any sampling plan should include areas where accumulation of dark particulates are visible, exterior openings, attics, interior and exterior surfaces, as appropriate.

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Instructions should accompany laboratory samples that describe the objective of the investigation and recommend a specific test or tests appropriate to that objective. A laboratory that finds itself unable to meet the request should be instructed to return the unprocessed samples.

Suggested Sampling Methods

Tape-Lift samples are preferred for evaluating char, the primary indicator of wildfire smoke impact. Char generally consists of particles in the 1µ to 500µ range, making them readily visible with standard light microscopy at 100-200× magnification. The tape-lift technique preserves the relative positions of all the particles on the original surface, as well as the population per unit area.

Testing for soot, a secondary indicator, may be unnecessary, as soot is usually not found in wildfire investigations. However, if appropriate for the investigation, wipe samples for soot can be collected pursuant to the method detailed in ASTM International Standard Method D6602-03b.

Discouraged Sampling Methods

Composite Sampling Collecting multiple lifts on a single tape or wipe is strongly discouraged. Composite samples obscure the particle layers and dilute the ratio of combustion particles to background particles. It is not possible to reconstruct information lost when sample sites are combined. The most likely result will be a misleadingly low proportion of combustion particles.

Micro-vacuum sampling The Micro-vacuum method is not validated for collecting settled combustion particles. ASTM D6602 specifies only two sampling methods: Section, 6.3.1, reads: "Remove particulates and solids from surfaces by placing an appropriate length of sticky tape on the surface to be sampled". Section 6.3.2 states: "Collect the other type of sample by rubbing the surface to be sampled with a polyester ball or glass filter pad with a light back-and-forth motion to remove surface particulates and solids."

ASTM D5755 (Standard Test Method for Micro-vacuum Sampling and Indirect Analysis of Dust…) acknowledges "the collection efficiency of this technique is unknown and will vary among substrates. Properties influencing collection efficiency include surface texture, adhesiveness, electrostatic properties and other factors." Since surface textures and character vary, micro-vacuum comparisons are likely to be unreliable.

Obtaining Background Samples

EPA 838/08, *Site Contamination – Determination of Background Concentration and EPA 540/F-94/030 Estab-*

lishing Background Levels, specifies that background sampling locations must be selected from areas on the site or in the vicinity of the site not known to be impacted by combustion particles from the (wildfire) event. Combustion particles from everyday activities, such as wood-burning fireplaces, stoves, candles, cigarettes and vehicular source particles, are part of the background.

The location and number of background samples depends on several factors, including the objectives of the investigation, the size of the site, the number and type of alternative combustion sources, as well as particle intensity and pathway considerations. If it is necessary to collect multiple background samples, it is recommended that background and test samples be collected concurrently, but remain clearly distinguished. Composite samples from multiple surfaces should not be collected for determining particle concentrations.

To permit comparison, background and investigation samples should be collected using the same method (e.g., tape or wipe). Similarly, the subjective nature of visual estimation methods practiced by laboratories requires the use of identical analytical procedures, and preferably by the same laboratory and analyst.

Interpretation of Background Sample Data

Once background samples have been collected and analyzed, the information must be interpreted to establish background concentration(s) for the subject site. This background data must then be compared with actual site data in order to determine if investigative sample concentrations equal or exceed background levels. Average background concentrations may be applied if sufficient background samples have been collected from a relatively homogeneous environment and if alternative sources of combustion particles are insignificant or absent. While this method of comparative analysis can be challenged because of incorrect assumptions of ambient conditions, it can be useful in determining the scope of restoration if that is warranted.

Other challenges include the absence of publications on acceptable concentrations for settled combustion particles, scant agreement among hygienists and their organizations on a concentration level that would constitute "damage," levels that would necessitate remedial action, or levels that would constitute a clean environment. It should be understood that damage has no objective criteria.

Delayed Sampling

Circumstances sometimes dictate that inspections be conducted long after the wildfire event, when sample sites may have been cleaned or dust has accumulated on top of the wildfire particles. These factors must be stated as qualifications to the sample analysis. It should be clearly stated that the inspection is valid only for the date on which it was conducted.

> Independent of a wildfire event, most properties will have some degree of settled combustion particles as part of the background generated from numerous alternative sources.

Samples represent specific test locations, whereas wildfire particles generally settle as a somewhat uniform coating throughout the site with individual differences due to building air currents. Recommendations that confine remediation to specific positive test areas overlook the general condition that existed immediately after the fire.

Analytical Methods

Investigators should exercise prudence when selecting an analytical laboratory. Qualified laboratories may offer an array of techniques that include Polarized Light Microscopy (PLM), Transmission Electron Microscopy (TEM), Scanning Electron Microscope (SEM) and Electron Dispersive X-ray analysis (EDX). Further options may include Fourier Transform Infrared Spectrometry (FTIR), Gas Chromatography/Mass Spectrometry (GC/MS) and High Performance Liquid Chromatography (HPLC).

Most of these analytical methods are used for determining the intensity and composition of submicron soot particles and are useful in distinguishing alternative sources of combustion particles. However, laboratories sometimes attempt to adapt asbestos or carbon black protocols to combustion particles, yielding results that are irrelevant and misleading. References to published standards often fail to mention that they do not relate to combustion particles. Laboratories should be reminded that no published standards exist for assessing the visual and other impacts of settled combustion particles.

PLM analysis is a primary method for characterizing settled particles, but can show bias. Under PLM scrutiny, some char particles will appear the same as other opaque particles and may lead to false negatives or positives.

Reflected Light (Episcopic) Microscopy permits an evaluation of color, texture and other particle characteristics. Episcopic examination against white and black backgrounds permits the microscopist to differentiate combustion particles from other materials.

A measuring reticle or scale within the microscope may assist in estimating the size and quantity of combustion particles present in the sample.

Particle Assemblage Analysis

Independent of a wildfire event, most properties will have some degree of settled combustion particles as part of the background generated from numerous alternative sources. In cases where the source of particles is desirable, typical PLM analysis of combustion particles rarely identifies their origin. Assemblage analysis is a unique and fundamental technique not many laboratories or analyst perform or are even qualified to execute. It is a mental process that provides a framework into which the complexity of an environmental particle sample can be reduced to a relevant set of well-defined source related assemblages. Assemblage analysis is based on the concept of "contextual assemblages." A contextual assemblage is defined as a group of objects or features that in combination establish a fact or context not established by any individual feature or object. In any significant event there are assemblages of particles that are created by the event. In other words, assemblages suggest sources. For a wildfire, the assemblage consists of charred wood/plant that are indigenous to the area where the fire took place, fire retardant, burnt clay from the soil, and pyrolized calcium oxalate phytoliths from the bark and leaves of the various plants and trees. Particle Assemblage Analysis will detect the characteristic particle signature and unique assemblage of particles created by a specific wildfire event.

In summary, it is important to recognize that accepted laboratory techniques for particle analysis may involve metrics and standards that were not intended for evaluating combustion particles after a wildfire event. Laboratory extrapolations of combustion particle impact may appear to be authoritative, but in fact lack a verifiable basis.

Investigators must exercise professional judgment, evaluate the analytical methods available and select a method that is appropriate to the situation and the purpose of the study.

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Impartiality and Ethics

Bias in sampling can exert a profound influence on test results. It is not unusual to encounter investigations that were conducted with inappropriate methodology, sloppy technique or intentional misconduct. Some reports appear to be little more than advocacy documents. To be credible, hygienists must have verifiable experience in smoke investigations. Most importantly, hygienists that consistently offer similar conclusions should expect to be greeted with skepticism.

Remediation Procedures

Introduction

This section provides an overview of restoration procedures that may be applied after wildfire damage. It is not a comprehensive procedural guide and should not be used as a basis for recommendations or repair specifications. These are properly prepared by persons directly experienced in professional damage repair.

Purpose of Restoration

The goal of restoration after wildfires is to return properties as closely as possible to their predamage state. To accomplish this, restoration specialists match their procedures to the type and intensity of damage. The character of the impacted surface usually determines which procedures can be safely employed. For example, pressure washing that is safe for plain brick may damage antique brick or an EIFS system. In the absence of heat damage, major consideration is given to whether a surface absorbs water (stucco, textiles, unfinished wood) or is impervious (glass, vinyl siding, painted wood).

Initial steps

Removal of loose combustion particles is a universal first step. Freshly settled ash and char are lightly bonded and preexisting dust insulates the surface. Removal of particles at this stage simplifies later procedures and may prove sufficient in itself. The HEPA (High Efficiency Particle Air) vacuum is an essential tool. HEPA filters capture fine particles that household vacuums exhaust back into the air. In order to remove combustion particles to the fullest degree possible, repeated slow HEPA vacuuming may be required. High-velocity blowers may supplant vacuuming on sensitive exterior surfaces. The importance of early and thorough removal of combustion particles cannot be overemphasized.

Because settled combustion particles can redistribute, effective restoration often requires professional assistance for particle removal from attics, duct chases, roof overhangs and other inaccessible areas.

Additional procedures

HEPA vacuuming may be supplemented by other dry removal techniques such as soft brushing, wiping with cellular rubber sponges, or applying adhesive rollers. This may include the use of air scrubbers to prevent redistribution of fine particles. If dry removal procedures do not adequately restore the original condition, application of a solvent may be required. If the introduction of moisture might alter or damage the surface, restoration should be suspended until additional approval is obtained.

Detergent-water solutions release particles that adhere electrostatically to smooth and textured surfaces. Dissolved particles should be removed rather than redistributed, which requires specific extraction techniques and frequent changes of collection media. Premoistened absorbent wipes are often effective for this process. Exterior surfaces may respond to washing/rinsing with a soft water spray, in contrast to pressure-washing, which may change surface appearance or inject water into the wall system.

Intensive cleaning

Intensive or immersion cleaning of absorbent materials such as carpeting, upholstery or clothing requires professional equipment and training, but should be preceded by thorough HEPA vacuuming and evaluation. Trial cleanings in inconspicuous areas can establish effective procedures and avoid costly errors. In general, less aggressive procedures are preferred over one-size-fits-all cleaning systems. Remediation should be performed by experienced fire damage restorers who are familiar with current technology and materials. It should be noted that extremely small opaque particles in textiles may be visible under high magnification (e.g., Scanning Electron Microscopy [SEM]) but cannot be presumed to originate in a specific fire event unless valid comparison samples are available.

Ventilation systems

HVAC filters should be replaced or cleaned. Air return plenums and blowers should be wipe-tested and cleaned if necessary. Ventilation systems operating during a fire event may be impacted throughout, with deposits generally greater on the return side. Sampling of supply registers may establish or preclude more extensive duct cleaning. In evaluating air systems, it should be understood that its surfaces were not free of particles before the fire. Professional experience and the use of comparison samples may help in attempts to distinguish preexisting combustion particles from recent additions.

Exterior structures

Swimming pools and hot tubs may be heavily impacted by forest fire particles. Restoration is usually performed by the parties who customarily service these facilities for the owner. However, siding, decks, driveways, concrete railings and cast decorations will benefit from timely air washing or spray rinsing, which may mitigate the need for more intensive work.

Smoke odors

Wildfire smoke is often accompanied by a pungent and (to many) disagreeable odor. Smoke odors vary in their strength and persistence. Human sensitivity to odors is known to vary; an odor imperceptible to one person may be obnoxious or irritating to another. Further, odor response may be colored by association with a traumatic experience. No known laboratory test can match human odor sensitivity. For these reasons it sometimes is not possible to validate the perception of smoke odor in buildings or other property. However, smoke odors are known to be emitted by combustion products and often are proportional to the presence of charred material. In many cases the removal of charred material is accompanied by abatement of smoke odors. Thus, as a general rule, the most effective remedy for smoke odor is the full and complete removal of combustion products from impacted surfaces. Other “deodorization” methods are sometimes employed whose effects may not have been fully explored or documented.

Evaluation and Confirmation

It was stated earlier that the goal of restoration is to return property to its predamage state. It should be understood that only new or recently-painted surfaces would have been free of dust and combustion residues before the wildfire. For this reason the removal of visible combustion particles is often considered sufficient evidence of restoration. Other facilities and circumstances may impose different standards. Tape-lift sampling may be used at any point to evaluate the results of restoration procedures, and should be conducted by investigators trained in this process. Before-and-after lift sampling may be useful, but is not part of a normal wildfire investigation. Properly performed post-treatment samples may be archived for future reference.

Disclaimer

This paper offers a technical discussion based on a review of scientific literature and the best professional judgment of the authors. It does not necessarily represent the official policy of the Environmental Protection Agency (EPA), Indoor Air Quality Association (IAQA), Indoor Environmental Standards Organization (IESO), Restoration Industry Association (RIA) or any other organization or government health agency. The paper is intended to serve as a vehicle for discussion on the subject of wildfire smoke damage investigations and remediation, and serve as a basis for future research and training activities.

Editor’s Note

The Restoration Industry Association (RIA) together with the Indoor Air Quality Association (IAQA) and ASHRAE are developing a standard titled *Fire and Smoke Damage Standard: Characterizing and Documenting the Impact of Combustion Particles on Buildings and Personal Property*. Two of the authors of this paper, Martin King and Brad Kovar, participated in the development of the standard. For updates on the release of the public review of the standard or to get involved please contact standards.section@ashrae.org.

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>> ABOUT THE AUTHORS

BRAD KOVAR , CIEC, CEICC, REPA, is the founder, president and CEO of Safeguard EnviroGroup, Inc. He holds board certified accreditations, State of California and OSHA certifications in several indoor environmental disciplines. Kovar has participated in the investigation and analysis of hundreds of wildfire smoke damage claims involving every major Southern California wildfire in recent history. He acts as a scientific advisor and environmental consultant for state and municipal agencies, insurance companies on major loss claims and provides expert testimony and pretrial forensic case development for litigation.

MARTIN L. KING, CR, ASA, is the founder and CEO of Martin Churchill Associates, Inc., damage investigators and appraisers. He is a Certified Restorer and a Senior Accredited Appraiser in the American Society of Appraisers, serving for 20 years as Technical Advisor to the Restoration Industry Association. He has published numerous articles on restoration technology and appraisal including the popular *RIA Guidelines for Fire and Smoke Damage Repair.* Over the past ten years he has performed hundreds of microscopic particle analyses and currently serves as a damage investigator, appraiser and expert witness.

DR. PRIYOTOSH CHAKRAVARTY is a renowned environmental scientist with many years of experience as a laboratory director. He has published over 75 papers in scientific journals, chapters in books, and government reports. He was a research scientist for the National Resources Canada, Canadian Forest Service and the National Forestry Institute. Dr. Chakravarty is presently collaborating with researchers in an array of plant studies as well as soil science, chemistry, bio-chemistry, pesticide science, land reclamation and reforestation.