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The Hidden Hazards of Fire Soot

By Dawn Bolstad-Johnson, MPH, CIH, CSP

The documented hazards of fire soot date back to 1775 when Percivall Pott, an English surgeon, discovered an association between exposure to soot and a high incidence of scrotal cancer in chimney sweeps. This was the first occupational link to cancer, which ultimately led to the science of epidemiology and the Chimney Sweeper's Act of 1788.

Exposure to soot may not be an obvious health hazard to conservators who are exposed to soot during the treatment of fire-damaged materials. However, the term "fire soot" refers to smoke residue on surfaces, a complex mixture of substances that is often representative of what was in the fire smoke. Fire soot should not be treated simply as "dirt."

What is in Fire Smoke?

Smoke is a complex mixture of different gases and particles, which results from the various materials that burn during a fire event. A typical structure fire (residential home or business) may involve the destruction of plastics, foams, fabrics, carpets, wood products, synthetic fabrics, wool, and asbestos-containing materials. Respiratory hazards connected with exposures when working in an environment that has been sullied by a fire event differ from those from the past, because the materials that our belongings are made from have changed over the years. For example, plastics and other synthetics are much more prevalent in our homes and studios today. It is important to recognize that these materials undergo pyrolysis during a fire and become the deposits that are identified as soot.

What is Soot?

Smoke is the result of incomplete combustion, which produces tiny particles of carbon in the air. When deposited, these particulates are identified as soot. Put simply, the particle size of smoke residue on a surface can present a respiratory hazard.

The particle size of soot is approximately 2.5 microns, a size that is associated with deep lung penetration. Particles that are approximately 10 microns or larger get trapped in the upper respiratory tract. Particles that are 5 microns or smaller can make it down to the lower lung where the gas exchange occurs in the alveoli. In order to offer some perspective on the size of these particles, the dust you see flying in the light coming through a window is about 40 microns in size. Airborne soot present within the breathing zone of workers is too small to be seen with the naked eye and can easily be inhaled.

Soot will usually adhere to a wall or any other surface that is cooler than the heart of the fire. In fire investigations, a wall free from soot may be an indicator of where the fire began because the fire would burn at a higher temperature in this area. As a fire dies down, the smoke it has caused will disperse leaving behind a residue of quickly cooling particles which is generally referred to as soot.

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What is in the Smoke Residue/Soot?

All materials involved in a fire cause odors. Typically, soot is representative of what has burned, but may include byproducts that at first seem unrelated to the original material. For example, hydrogen cyanide is a byproduct of burning wool. When wood burns it can produce manganese and benzene. As many products as there are in the world, there are an equal number of byproducts produced in a fire. Each fire is different based on the contents of what has burned during the event.

Organic and inorganic materials produce different types of smoke residue or soot. These residues may be present on surfaces that conservators may be tasked with treating. Burnt organic material produces soot that is hard to see and often has a very pungent odor. This is known as protein smoke. It can discolor paints and varnishes. Protein smoke can disperse over large areas and attach itself to everything.

How the fire burns and how much moisture is in the air while the fire burns, plays a role in soot deposition on articles. The amount of moisture in the air is a key component in whether the smoke that is produced is wet or dry.

There are several types of smoke or soot, which may be present on a surface that conservators might be tasked with treating:

Wet Smoke—can present as a sticky residue or soot, and is often associated with a smoldering type of fire and often will have a strong odor.

Dry Smoke—associated with a fast-burning fire and occurs at high temperatures.

Protein—often present in soot, usually invisible, it can discolor paints and varnishes and often has a very pungent odor. Protein odors could be caused by food on the stove burning slowly or other sources. The slow burn allows the protein to disperse and attach itself to everything, producing a strong odor.

Potential Exposures

Soot is in the general category of airborne particulate matter. While we would not expect most volatile organic compounds (VOC) to survive a fire and still be present on the soot, there may be metals present as well as some chlorinated compounds. There are not many studies that address what compounds could be associated with soot particles, essentially using the particles as a “magic carpet” to get into the lungs. The Phoenix Fire Department examined this phenomenon during a study focused on firefighter exposures after the fire was extinguished and their findings indicated that some chlorinated products become attached to airborne particulate matter. This is an important study because it points to the fact that exposure to airborne vapors and residues during a post-event time frame is much more complex than our current understanding allows. However, the important point to glean from this is that soot may be more than just a particulate hazard; it can potentially carry other chemical residues that are potentially harmful to the respiratory system. More research is clearly needed in this area.

Currently, the main health hazards potentially associated with soot would be irritant hazards. Soot can be both irritating to your lung tissue and to your skin.

Case History: Studio Precautions When Treating Smoke Damaged Paintings



Outside the Harold Golen Gallery after the fire. Photo courtesy of the Harold Golen Gallery.

In the early hours of December 13, 2007, fire erupted in the Harold Golen Gallery in Miami, Florida. The fire was believed to have started when an advertising balloon attached to the gallery for Art Basel week came in contact with electrical wires overhead. Despite the intensity of the fire and the collapse of the ceiling, 178 Pop-Surrealist paintings were rescued from the building. Some of the works were charred beyond redemption, but 108 of the works were deemed potentially salvageable and were transported to the Florida branch of the Rustin Levenson Art Conservation Studio.

Fortunately the warm, dry winter weather allowed the initial treatment of the works to be undertaken outdoors. The frames and the backing boards were removed from the paintings and discarded. The paintings were then vacuumed several times with a vacuum cleaner that was equipped with a HEPA filter. The reverse of the works, tacking margins, and the stretchers were cleaned with vulcanized rubber sponges. During this part of the operation, conservators wore air purifying (cartridge) respirators, nitrile gloves, and disposable cover-alls.

Rather than risk contamination of the studio, two rooms in a separate building were isolated for these paintings. One room was set up for storage, with tarps covering all surfaces and cardboard to interleave the paintings. Tables were set up in an adjacent room where the treatments took place. Both rooms had individual wall air conditioning units. Portable HEPA air purifying units were installed, one in the storage area, and two in the work room. Filters on all units were changed regularly. Once the loose particulate matter was removed from the paintings outdoors, they were moved into the prepared spaces for further treatment. Weather permitting, folding tables and easels were used so paintings could be treated outdoors. Conservators wore latex gloves and air purifying respirators (3M N-95 particulate) during this part of the process.

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Some Observations: Removing Soot Residue from Contemporary Paintings

Soot removal treatments on the 108 paintings that were in the fire at the Harold Golen Gallery met with varying results. Ultimately, 85 of the painting were successfully cleaned. The treatments and research were presented in a paper with my associates Veronica Romero and Kelly O'Neill at the Paintings Specialty Group session at the 2010 AIC meeting in Milwaukee.

We found that working with Groomstik or with vulcanized rubber sponges on the face of the paintings was unsatisfactory. Any pressure on the paint surface drove the soot into the paint layer, with little hope of removal. The exceptions to this were the handful of varnished paintings where dry methods successfully removed some soot without affecting the paint layer. Additionally, we observed that the presence of accretions from the collapsed ceiling on the face of the paintings could have caused scratching if the sponges were rubbed across the paint surface.

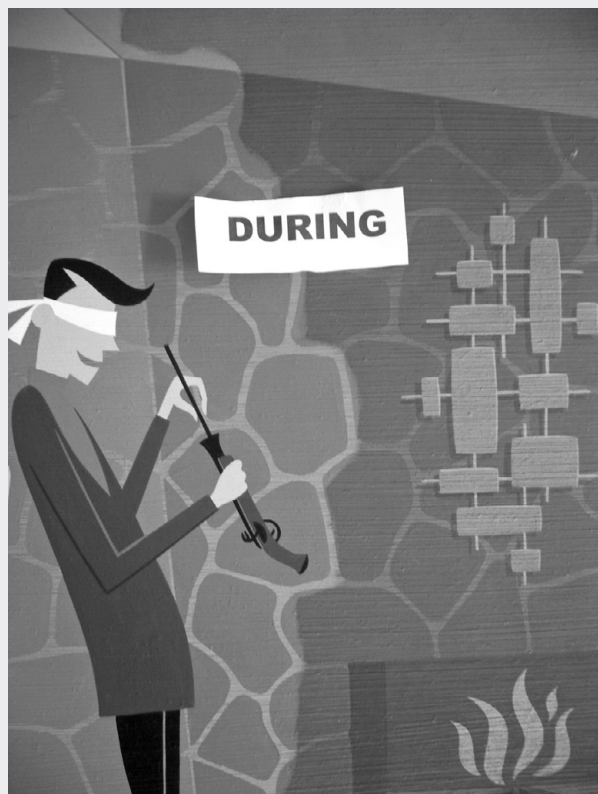
Traditional wet cleaning mixtures for soot removal, dibasic ammonium citrate in water and naphtha emulsions, were the first solutions tested. Combinations of these solutions were successful on 24 oil paintings.

Other solvents were also tested. For one acrylic painting, soot was released by a solution of mineral spirits and trimethylpentane followed by an application of VM&P Naphtha. A xylene emulsion was successful with another work.

Ultimately, there were a number of paintings that did not respond to traditional conservation treatments. Although the insurance company would have discarded these paintings, they offered a unique opportunity for research. Solvents and commercial products were tested. Further success was realized with stronger chelating agents such as EDTA(ethene, diamine, tetra acidic acid) and Versenol. Soot was removed from some works with the addition of detergents such as Vulpex to the conservation solutions. The soot solvent, ethylene glycol monobutyl ether, was found to be a useful component in cleaning some of the acrylic paintings.

In summary, if a conservator is confronted with soot damaged paintings we can offer the following advice.

- Wear appropriate personal protective equipment (PPE). Consult with an industrial hygienist or health professional about what type of filtration is needed for respirator use.
- Vacuum the reverse and clean it with a vulcanized rubber sponge.
- Vacuum, without pressure, near the paint surface. Forego the vulcanized rubber sponge on the paint surface except in cases of very light soot or heavily varnished paintings.



Detail, during cleaning, *Best Party in Palm Springs*, by Shag. Photo courtesy of Rustin Levenson Art Conservation.

- Try traditional solutions of chelating agents such as ammonium citrate in distilled water and naphtha emulsions.
- Other solutions to test could include other petroleum distillates, alone or in emulsions, xylene emulsions, ethanol, or mixtures of Versenol, VM&P Naphtha, and distilled water.
- Detergent mixtures such as Vulpex in distilled water or VM&P Naphtha could also be tested.
- The use of carbon solvents/degreasers such as ethylene glycol monobutyl ether, diluted, alone, or combined with detergents such as Vulpex could also increase success in removing these residues.
- Careful rinsing of all solutions is also recommended, blotting or using a PVOH sponge for the final rinse so that no residue is left on the surface.

This information is shared in the hopes that other conservators and conservation scientists will undertake further testing and research into these materials.

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The most common route of exposure during the conservation and restoration process is inhalation due to the proximity of your breathing zone to your work area. This is assuming that the work is not occurring under a hood or with some other form of capture exhaust ventilation.

The second most common route of exposure is self-inoculation. Consider this scenario, you are working on a piece, the piece is covered in soot, wearing gloves will protect your skin but what happens when you get an itch in around your eyes or nose? How clean is the back of your hand or the second knuckle on your finger?

How Can You Protect Yourself?

Protecting yourself from the potential hazards associated with working soot-contaminated items is simple:

- Do not eat or drink in the area where the soot contaminated items are stored or being restored.
- Wear an air purifying respirator.
 - CBRN (chemical, biological, radiological, and nuclear) canisters will provide the most protection against chemical vapors and particulates.
 - An N95 respirator is appropriate where particulates are the only concern.

(Note both types of respirators require annual fit testing.)

- Wear nitrile gloves.
- Do not bring your hands to your face while your gloves are on.
- Wear safety glasses.
- If possible, do all conservation work using a local exhaust or fume extractor such as a chemical hood.
- Use a HEPA/UPLA vacuum to remove the residue from the article.
- Wash your hands thoroughly after removing gloves.

Perspective

Most of this article addressed soot hazards under the assumption that the fire soot contaminated article has been brought to you for conservation treatment. If you are asked to enter a fire damaged building to conduct an assessment, or commence with conservation work on fire-damaged materials or other articles in the building that may be too large to move, the situation is completely different with regards to what is considered the best protection for you. Consultation with a health and safety professional is always recommended in these circumstances.

The presence of debris piles that may contain many other materials will probably present other chemical hazards. For example, formaldehyde, a known human carcinogen, is found in the glues that comprise plywood and oriented strand board (OSB), as well as many plastics, carpets, textiles, and other materials commonly found in typical structure fires. The geometry of the debris pile can often trap toxic chemicals like formaldehyde for days. The recommended personal protective equipment for working in a fire damaged building, includes the following:

- Wear a full-face, air purifying cartridge respirator,

equipped with CBRN canisters. These are the only canister cartridges that offer some protection from formaldehyde. Formaldehyde is one of the most pervasive toxic chemicals and is found at nearly every fire due to the content load. Note that organic vapor cartridges will not work for formaldehyde.

- Wear breathable disposable clothing.
- Wear nitrile gloves.
- Wear safety glasses.

Conclusion

It is important to note that soot is not simply a form of dirt that needs to be removed from an article. Soot can be a respiratory or skin irritant, and there may be chemicals or metals riding on the soot particles that are small enough to enter into your lungs. Be respectful of what chemical constituents can be represented in fire soot and take the time to wear personal protective gear.

Be Safe!

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Are you concerned about the health and safety of yourself and others?

Do you want to be part of a great team?

AIC's Health & Safety Committee is seeking one member for a 4-year term, with the possibility of renewal for a second term. Health & Safety is one of the most active AIC committees, with members contributing articles and guides to the AIC Newsletter, hosting an informational booth and workshops at the Annual Meeting, and regularly addressing questions and issues related to health and safety in our field. The ideal candidate will have a strong interest in these issues, and a desire to participate and learn. If you are interested, please contact Jane Klinger at jklinger@ushmm.org or Joanne Klaar Walker at jklaar22@hotmail.com.

AIC News



Staff Transitions

Morgan Gilpatrick joined AIC as the new communications director on July 16. Morgan holds a BFA in painting and is currently working on a MFA in integrated design at the University of Baltimore. Before coming to AIC she served as creative services manager for the in-house graphic design studios of The George Washington University and Prince