

Understanding the Hazards of Fire Residue Encountered During the Restoration Process

Michael A. Pinto, CSP, CMP
David A. Batts
Wonder Makers Environmental
Project GC15-13120

In conjunction with
Odorox Hydroxyl Group
April 2015

1.0 Abstract

In Part One of a proposed two-part project an extensive literature review was undertaken to determine the types and levels of contaminants that were present in a building following a fire loss. A thorough review of currently available literature uncovered significant research regarding the sorts of contaminants that are produced during building fires, as well as the type and extent of airborne and surface contaminants that are produced in such conflagrations. A wide variety of noxious materials were identified from multiple studies, with the consistent warning that attempts to fully characterize hazards associated with fire losses are inherently limited compared to the vast array of products that can be impacted by fire and the individual progression that each structure fire takes.

Identifying the large variety of hazardous products produced during a structure fire (including aldehydes, esters, halogenated alcohols, hydrocarbons, nitro-nitriles, ketones, aromatics, sulfides, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, dioxins, etc.) led to the recommendation that personal protective equipment should be utilized by restoration professionals working on such projects. Nevertheless, the study showed that there is little current research related to reducing the impact of airborne contaminants in such buildings by the use of hydroxyl radical generators or other oxidizers. As such, testing in actual or simulated fire conditions to determine if the cascade effect produced by hydroxyl radical generators as part of the contaminant/odor reduction process puts restoration workers at any further risk would offer valuable information to the restoration industry.

2.0 Introduction

Wonder Makers Environmental was contacted by the Odorox Hydroxyl Group to assist them in providing relevant information to the restoration industry regarding the air quality of post-fire environments and the potential risk to restoration contractors when working in such situations. In response, Wonder Makers Environmental suggested that a two-part approach be considered. It was recommended that the initial phase of the work be a review of existing literature related to indoor air quality (IAQ) and the risks associated with working in structures that have suffered fire and smoke damage.

The goal of the Part One research was to answer important questions about the types and quantities of residual contaminants that may be present in structures at the time that restoration work is undertaken. Specifically, given that smoke odor is often present and addressed through the restoration process, the research paper was suggested to answer relevant questions such as:

1. Does the available information suggest that certain harmful contaminants or intermediate compounds are typically present in a fire-damaged structure?
2. Is there any research that suggests that environments subject to fire restoration are generally safe during the various stages of restoration work, or does it suggest that most are potentially unsafe?
 - a. Understanding that every fire is different, and it will always make sense to err on the side of safety, are there certain types of fires or time periods after fires that are more dangerous?
3. Is there any consensus in the current body of knowledge regarding the use of personal protective equipment during the restoration of fire-damaged buildings—especially during the initial cleaning phases?
 - a. Is the risk to restoration workers and the utilization of personal protective equipment related to specific cleaning methods used during remediation?

Implementation of Part Two of the recommendation to address the concerns of the Odorox Hydroxyl Group would only be performed if the initial research indicated that there was some potential risk to workers during remediation of a fire-damaged structure. If the evaluation of the research regarding the air quality and safety of post-fire environments indicated that hazards were commonly present, then Wonder Makers would design and conduct a study to provide further information to the industry. Specifically, the goal of the "practical science" study would be to evaluate the use of hydroxyl technology and the possible impact it has in post-fire environments. In this case, the second part of the project would be the construction of a simulated finished interior space that would be contaminated with fire/smoke by-products. That space would then be used to simulate a real world post-fire environment in a laboratory setting to make further evaluations such as:

1. Do hydroxyl radicals and other oxidants produce harmful intermediates that are not otherwise present in the cleaning process using conventional methods?
2. Does a hydroxyl treatment process hasten the restoration to a natural balance and make the environment safer?

This research paper is the culmination of the Part One activities for this project.

3.0 Summary of Findings

There is no lack of information related to building fires. Codes and textbooks from organizations such as the National Fire Protection Association (NFPA) and the International Fire Service Training Association (IFSTA), research papers, restoration industry bulletins, and articles in the popular press all provide substantive information regarding fire science and firefighting. A

substantially smaller subset of information focuses on the fire residue, health effects from such residue, and potential issues related to the breakdown of those residual contaminants. At the time of this research, no information was located related to reduction of fire residue or odors using hydroxyl radical generators other than that which was supported or produced by one of the manufacturers or distributors of such equipment.

Although many documents were reviewed regarding the science of airborne fire residue, eight of them seem to provide the widest array of applicable information. The salient parts of those documents are summarized here. The material is organized from the most general to the most specific in order to build on individual concepts.

3.1 Institute of Inspection, Cleaning, and Restoration Certification (IICRC), *Why Professionals Should Clean Smoke Damage from a Fire*

As the title suggests, this basic document is designed to educate the public about the value of using professionals for fire restoration and cleaning. While it is promotional in nature, it does touch on some of the basics related to ash and smoke residue. Specifically, it notes that, generally, ash is acidic and if left on surfaces for even relatively short periods it can cause extensive corrosion, etching, and discoloration. It also emphasizes that ash residue is easily disturbed and can spread through a building, even into areas that were not originally impacted by fire or smoke.

From the standpoint of odor reduction, the IICRC clearly warns those dealing with fire damaged properties that lingering powerful odors are usually present. Although the use of oxidizers in general, and hydroxyl radical generators in particular, are not mentioned, the basic understanding that source materials that are off-gassing must be removed is emphasized. The document explains the difficulty of the task in many situations by noting that ash builds up in layers, and may eventually develop into a lacquer-like consistency.

3.2 American Institute for Conservation of Historic and Artistic Works (AIC), *The Hidden Hazards of Fire Soot; Dawn Bolstad-Johnson MPH, CIH, CSP*

Because it was written as a primer for art conservators, this paper lays out significant information related to the types and potential hazards of fire residue. It includes clarification of terminology, noting that the term “fire soot” refers to smoke residue on surfaces, which is a complex mixture of substances. Similar to the information summarized in section 3.1, this article also draws a connection between fire residue and the physical sciences, including the sense of smell. It notes that burnt organic material produces soot that is hard to see and often has a very pungent odor (known as protein smoke). The author explains that a number of hazardous products are created by the burning of different products.

Product	Hazardous Fire Residue
Wool	Hydrogen cyanide
Wood	Manganese and benzene
Carpet	Formaldehyde
Plastic	Chlorinated compounds
Rubber	Volatile organic compounds (VOCs)
Paint	Heavy metals

The AIC document also addresses the hazards of exposure to fire soot and repeatedly emphasizes that it should not be treated simply as “dirt”. It provides some historical context, noting that in 1775 Percivall Pott, an English surgeon, first documented an association between exposure to soot and a high incidence of scrotal cancer in chimney sweeps. The author builds on this by noting that some chlorinated products become attached to airborne particulate matter. This phenomenon of gases and vapors adhering to airborne and settled soot means that fire residue is more than just a particulate hazard, and that some attached chemicals can desorb from skin contact, inhalation, or ingestion.

A third major area of importance in the Hidden Hazards paper is the description of the burning process that produces smoke and discussion of the actual sizes of the tiny particles of carbon in the air. The author notes that smoke residue can present a respiratory hazard because of the size of these particles. A further explanation was provided, which states that, as a starting point, dust that is visible in a shaft of light coming through a window is about 40 microns in size. Particles 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. With the average particle size of soot being approximately 2.5 microns, most fire residue particulate is associated with deep lung penetration.

As a whole, the article written for conservation professionals provides a strong basis for understanding some of the hazards associated with fire residue. It identifies many specific hazardous components of soot, links exposure to those components to significant health effects, and details the mechanisms that produce dangers for the respiratory system.

3.3 Huffington Post.com, *Firefighters Sound Alarm on Toxic Chemicals*; Lynne Peoples

Written for the layperson, this press article is an investigation of the serious health effects experienced by active and retired firefighters. Although there are a substantial number of emotion-tugging accounts and language (e.g., “toxic soup of burning chemicals and their byproducts”), the article also provides a more expansive listing of the types of hazardous materials recovered from fire residue. It points out that some of the most toxic fumes

released in structure fires come from chemicals added to common contents in an effort to retard flames.

When flame retardant materials do burn, a variety of manmade byproducts are liberated, including dioxins, furans, and formaldehyde. Additionally, levels of polybrominated diphenyl ethers, or PBDEs—a common class of chemicals used as flame retardant, are so prevalent in smoke that they are recovered at elevated levels in the blood of firefighters.

Although the work focuses on firefighters, it has real relevance for the restoration industry. Studies are cited which demonstrate that hazardous chemicals present in soot may linger on skin, uniforms, respirators, helmets, and other gear. The article notes that transference of hazardous contaminants continues during the “overhaul” phase of work, when firefighters are moving debris and opening trapped spaces in order to confirm that no embers are active. This type of work closely correlates with the demolition and clean out phases of restoration work, where many companies begin the use of hydroxyl generators.

3.4 National Institute of Standards and Technology (NIST), *International Study of the Sub Lethal Effects of Fire Smoke on Survivability and Health (SEFS): Phase 1 Final Report*; Richard G. Gann, Jason D. Averill, Kathryn M. Butler, Walter W. Jones, George W. Mulholland, Julie L. Neviasser, Thomas J. Ohlemiller, Richard D. Peacock, Paul A. Reneke, John R. Hall Jr.

The NIST report is a massive study that provides data on many aspects of the composition and movement of fire residue. The document distinguishes between gaseous and particulate portions of smoke. As noted in previous documents, the compounds that are in the form of a gas dissipate rapidly, although some absorption into surfaces and airborne particulates does occur. The researchers documented that some types of fire gasses, such as halogen acids, actually dissolve into water droplets, which removes them from the air; but then that process changes the composition of the waste water used to fight the fire.

The NIST report identified a wide range of gasses produced by structure fires, which are considered dangerous.

- Acrolein from cellulosic materials like wood, cotton, paper, and polystyrenes
- Toluene diisocyanate from flexible polyurethane foams
- Formaldehyde from polypropylene materials
- Hydrogen cyanide from nitrogen-containing materials such as wool, silk, acrylic fibers, nylons, urea/formaldehyde, melamine, polyurethanes, and polyacrylamide
- Nitrogen dioxide from nitrogen containing products like those mentioned previously

- Hydrogen chloride from PVC plastics and chlorinated additives
- Hydrogen fluoride from PTFE plastics and other fluorinated compounds and additives
- Hydrogen bromide from brominated compounds and additives
- Sulfur dioxide from sulfur-containing materials such as wool and vulcanized rubbers
- Hydrogen sulfide also from sulfur-containing materials
- Ammonia from nitrogen-containing materials
- Styrene from polystyrenes
- Toluene from polystyrenes, PVC plastic, and polyurethane foams
- Benzene from polystyrenes, PVC plastic, polyesters, and nylons

Another aspect of fire residue investigated by the NIST team was the toxicology of ultrafine particles. They confirmed that the smaller size particles create more health problems because of their ability to penetrate deeper into the lungs. They noted that health problems occurred even with chemically inert materials due to the adsorption of the types of hazardous gasses detailed in their research.

3.5 National Institute for Occupational Safety and Health (NIOSH), *Polychlorinated Biphenyls (PCB's): Current Intelligence Bulletin 45*

Another concern with residue from fires is the potential for contamination by polychlorinated biphenyls (PCBs). Although PCBs were phased out of consumer products by 1977, commercial electrical service equipment was still found with these materials in North America up until 1990. Because of the effectiveness of these products and resiliency of the PCBs, houses and commercial structures can still be impacted by PCBs nearly 40 years after the products were initially banned.

Specifically, small capacitors containing PCBs were commonly used in household appliances such as television sets, air conditioners, and fluorescent light fixtures. Many of those products still reside in structures, and numerous fire-related incidents involving electrical equipment containing PCBs have resulted in widespread contamination of buildings with PCBs. The NIOSH bulletin also points out that a wide variety of chemical configurations were utilized and that secondary by-products can develop in reaction to the heat and flames such that fire residue may contain polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenzo-p-dioxins (PCDDs) in addition to standard PCBs.

By reviewing the data from a number of fires where electrical equipment was involved, NIOSH researchers were able to show that PCB contamination in fire residues can be extensive—up to 5,000 micrograms of PCBs per gram of soot. At such levels emergency response personnel, maintenance staff, restoration crew members, or building occupants

may be exposed to the compounds by inhalation, ingestion, or skin contact. Therefore, the government research group recommended that all workers who may be exposed to PCBs, PCDFs, or PCDDs should be equipped with chemical protective clothing to ensure their protection.

They strongly recommend disposable apparel because of the uncertainty of properly decontaminating reusable clothing. Specifically, the bulletin recommends that outer protective garments should consist of a zippered coverall with attached hood and draw string, elastic cuffs, gloves, and protective boots. If exposure to soot is anticipated, workers should wear outer coveralls made of a nonwoven fabric such as spunbond Tyvek[®] to exclude particulates. From a respiratory protection standpoint, they indicated that disturbance of burnt materials in large quantities of visible soot can create airborne exposure levels of PCBs. In such cases, a supplied air or powered air-purifying respirator should be used. They did note that when cleanup operations have advanced to a point where airborne PCBs can no longer be detected, air-purifying full facepiece respirators equipped with a high efficiency particulate air filter and organic vapor cartridge should be used as a precaution until final decontamination is completed.

3.6 Belfor, *Hazardous Substances after Fire Damage*; technical support pamphlet

This document provides an international perspective to the research as Belfor is a global restoration company with much of its technical support based in Germany. The bulletin provides a distinction between the gaseous contaminants mainly present while the fire is burning and the damaged structure is still hot, and those in a particulate form that are present after the fire scene is cold. The authors note that while the gaseous compounds are of a significant hazard to firefighters and others present in the building immediately after its control, restoration work is typically impacted by contaminants present in soot and particulates.

Specifically, the pamphlet notes that PCBs are still considered potential fire residue contaminants despite their phase-out from industrial operations many years ago, particularly from the burning of elastic expansion joints and sealing compounds in a building. The Belfor document also demonstrates that polycyclic aromatic hydrocarbons (abbreviated as PAH in some documents and PAK in others) and dioxins are possible contaminants as well.

The pamphlet notes that there are over 200 individual substances that fall into the dioxin category in addition to the most well-known of that chemical class, the polyhalogenated dibenzodioxins (PHDD). It also explains that the entire group of fire residues typically arises through incomplete combustion of chlorine and bromine-containing materials, in conjunction with other organic substances. As such, a source of dioxins, like old

containers of pesticides, does not have to be present in the structure for soot and other fire residues to contain dioxins. In addition, carbonic acids, aldehydes, alcohols, and aliphatic and aromatic hydrocarbons are also possible fire residue contaminants.

The bulletin also notes that both dioxins and PAHs are deposited in the condensate on surfaces and are also bound by adsorption to soot or fire residues. A large number of PAHs are known to be cancer-causing compounds, with benzo(a)pyrene as a marker. Benzo(a)pyrene itself is classified as a toxic, carcinogenic, mutagenic substance that also has a damaging effect on reproduction. It states that the acute and chronic toxicity of the large number of individual compounds varies considerably, by a factor of up to 10,000. Obviously, given the unstructured nature of the creation of dioxins (as well as many of the aromatic hydrocarbons) and the wildly varying toxicity of the contaminants, there is no safe approach other than to assume that such hazardous materials will be part of fire residue unless detailed testing is completed at each burned structure.

3.7 Chemosphere, *Toxic Chlorinated and Polyaromatic Hydrocarbons and Simulated House Fires*; Department of Environmental Sciences, University of Kuopio, Kuopio, Finland; Paivi Ruokojari, Marjaleenna Aatamila, Jubani Ruuskanen

This is another European document that looked at the presence of a number of toxic products, particularly those arising from chlorinated hydrocarbons. As in previous documents, the Finnish study identified polychlorinated biphenyls (PCBs), benzenes, and dioxins as hazardous contaminants of note. They also explain that furans (a class of chemicals so dangerous that they are often used as insecticides) are also present in combustion gas and deposited in soot collected from simulated house fires. Their measurements confirmed that large amounts of organic compounds may be released in house fires. As a result, there is a need for careful personal protection of firefighters and remediation workers against combustion gases during a fire and contaminated surfaces after it.

From their experiments the researchers made it clear that concentrations of toxic organic compounds released in residential fires are high even when there are no hazardous substances present in the fire, as the compounds are produced by incomplete combustion of building materials, surfaces, and contents typically found in homes. While they conclude that substantial amounts of toxic chlorinated and polyaromatic hydrocarbons may be released during fires, they explain that no emission factors could be estimated on the basis of their sampling, since the amount of material actually burned and the total amount of combustion gases in an uncontrolled setting like a house fire remain unknown. In actual structure fires the variety of furniture and interior decoration material available as the fire loads is much greater than in a simulated fire, thus PAH and dioxin

concentrations in the combustion gases may be even higher. They summarize that for firefighters and reconstruction workers who may be exposed to combustion gases, it is not only important to be equipped with respirators and protective clothing during the fire, but it is also necessary to be aware of the possibility of many types of toxic contamination from particulate soot on surfaces after the fire and of the need to use proper personal protective equipment during renovation work.

3.8 Oregon Office of State Fire Marshal, *A Study on Chemicals found in the Overhaul Phase of Structure Fires using Advanced Portable Air Monitoring available for Chemical Speciation*; Regional Hazardous Materials Team HM09-Tualatin Valley Fire & Rescue

This well-designed study used real-time portable gas detection instruments as well as corresponding sampling with laboratory analysis to validate the information from the portable equipment. Data was collected from 38 different fires over an eight month period, representing real world situations. Even so, testing at actual fire scenes during firefighting and overhaul activities (conducted after the majority of the fire has been put out but during a time when there may be smoldering materials and the possibility of small flare-ups) introduces variability into the research that cannot be controlled. As the authors noted:

...it was performed in the field with unpredictable conditions and circumstances. This was compounded by the fact that structure fires present a mixture of chemicals and synergistic effects. Concentrations, and even chemicals present, may depend on what's burning.

Because of the type of instrumentation that was used during the study, only 21 specific chemicals, along with miscellaneous unidentified particulates, were reviewed:

Acrolein	Hydrogen chloride
Total aliphatic aldehydes	Mercury vapor
Ammonia	Naphthalene
Arsenic	Nitrogen dioxide
Benzene	Nitrogen monoxide
Benzyl chloride	Ozone
Carbon disulfide	Phenol
Carbon monoxide	Sulfur dioxide
Formaldehyde	Styrene
Fufural	Toluene
Glutaraldehyde	

The researchers showed that many of these chemicals were present in various fires in concentrations that exceeded the established permissible exposure limits, with some

being greater than recommended short-term exposure limits. In a few cases, concentrations of specific chemicals—such as arsenic, carbon monoxide, mercury vapor, and nitrogen dioxide—exceeded levels that were considered to be immediately dangerous to life and health.

The Oregon report provides a great deal of useful information related to not only the types of hazardous materials involved in structure fires, but also to how fast the airborne concentrations of those materials dissipate. In this respect, it was unique among all the resources reviewed for this research effort.

Of particular interest was that the study showed there was a natural dissipation of chemical levels detected over the first 45 minutes after a fire was extinguished. As monitoring continued, once the fire was out the contents of the structures were cooling and either natural or mechanical ventilation had commenced. Somewhat surprisingly, the researchers noted that by one hour after the fire had been put out most of the measured hazardous contaminants had completely dissipated. Monitoring was typically discontinued about one hour after completion of the primary firefighting activities.

The key information regarding reduction in airborne levels of hazardous contaminants was summarized in the two tables reprinted here to allow a careful review of the data. It is interesting to note that concentrations of specific "toxic chemical levels" shown in the report's Figure 5 were measured in parts per million (ppm), with the illustrative graph scale describing a logarithmic fashion that presents concentrations from nearly 1,000 ppm to 1/1000 ppm. The accelerated decrease shown in the graph from 45 minutes to 65 minutes after the fire is put out is dramatic.

In a similar fashion, Graph 4 presents the airborne chemical data on a percentage basis from the various field instruments and laboratory results. It also confirms that there is a steep decline in airborne chemical concentrations as soon as the burning stops, with levels that are close to undetectable (utilizing field instruments and basic sampling protocols) by the time one hour has passed.

Despite the substantial majority of evidence showing that hazardous levels of airborne contaminants from fires dissipated rapidly after the burning had stopped, the study authors did note that in a number of the structures where samples were collected some specific residues were documented many hours, and sometimes days, after extinguishment. This prompted them to give a cautionary warning that even with strong evidence for rapid reduction of hazardous substances, time alone was not a reliable method of determining safe atmospheric levels.

Another interesting discussion in the study involved the impact of natural or mechanical ventilation on the airborne levels of some hazardous materials. The authors noted that ventilation seemed to improve conditions; however, the time lapse between the fire being extinguished and the collection of samples had a more pronounced effect in improving the quality of the air inside the structure.

Other germane aspects of the study dealt with personal protective equipment. Given the types and levels of hazardous materials identified in the air while the structures were burning, the authors were adamant that self-contained breathing apparatus should continue to be utilized as the primary respiratory protection for firefighters even when the blaze has been brought under control. They did note that other types of positive pressure supplied air respirators might be more feasible for overhaul and fire investigation activities, but cautioned against going to air-purifying respirators soon after a fire was put out or for any activity that might overturn hot spots or smoldering embers. These precautions have some validity for restoration workers that are involved in activities which take place immediately following a fire being extinguished, such as board-up, immediate pump out, initial content salvaging, etc. However, lower levels of personal protective equipment would seem to be indicated by the data collected for this report for individuals that are involved in restoration work taking place one or more days after the fire has been put out.

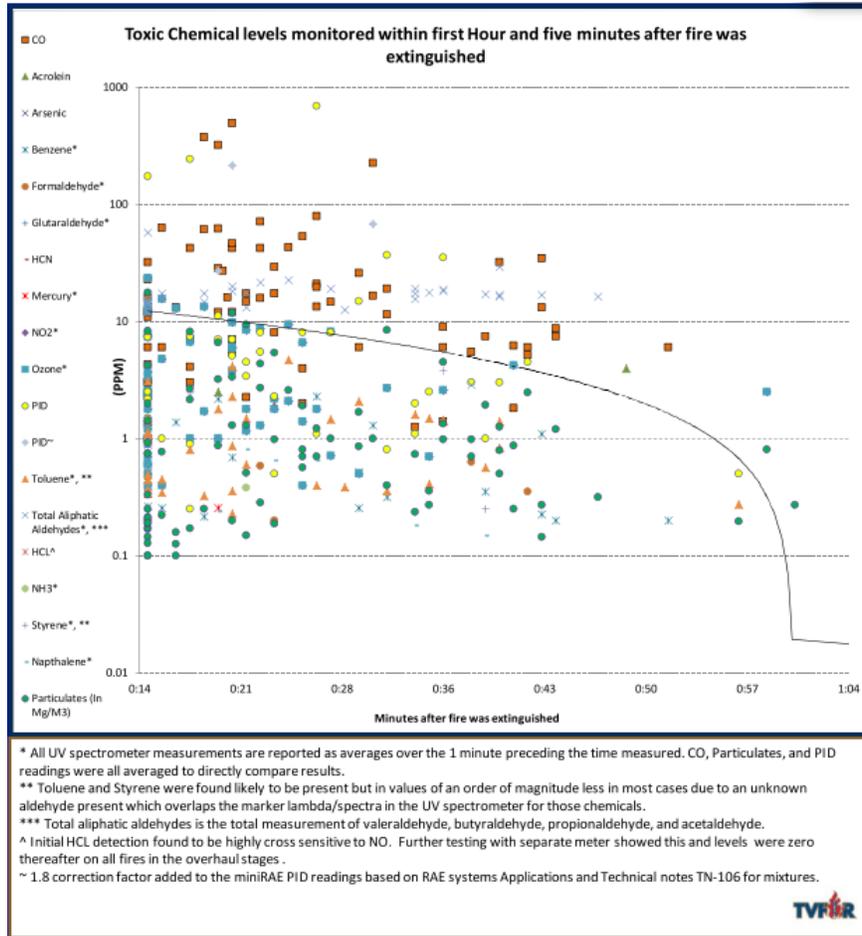
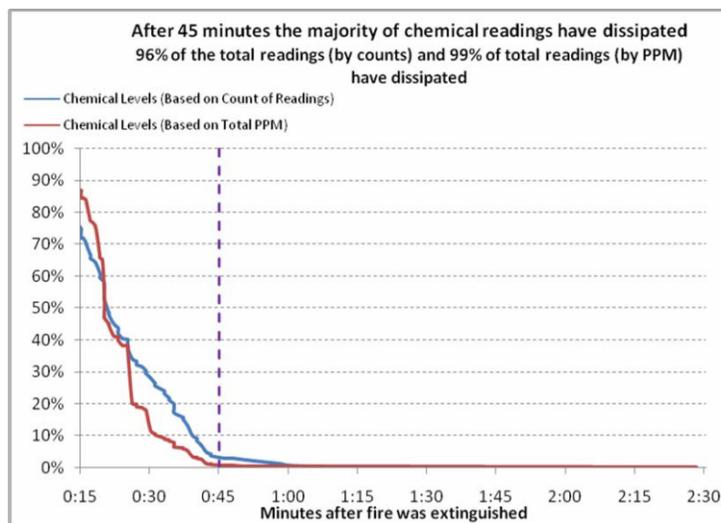


Figure 5. Graphical display of chemical levels as a function of time



Graph 4. Chemical levels measured as a function of time

4.0 Conclusions and Recommendations

As noted at the beginning of section 3, extensive research has been conducted regarding the sort of contaminants that are produced during building fires. Substantial scientific information also exists, explaining the types and extent of airborne contaminants as compared to surface contaminants. In general, several groups of chemicals were identified as potential airborne contaminants in fire-damaged buildings, including volatile organic compounds (aldehydes, esters, halogenated alcohols, hydrocarbons, nitro-nitriles, ketones, aromatics, sulfides, etc.), polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and dioxins. Although there are many different chemical processes that create this chemical mix of fire residue, the overall research is clear that most of the contaminants come from incomplete combustion of organic materials and, to a lesser extent, incomplete combustion of chlorine- and bromine-containing materials. Virtually all of the chemicals identified in the various studies as making up fire residue are considered hazardous by both regulatory agencies and safety/health professionals.

In addition to the specific types of compounds that have been identified as components of fire residue, the physical form of the residue is important to the individuals that come in contact with it. The small size particles created during a fire create the potential for more significant health problems than just exposure to the chemicals themselves because the tiny particles increase the ability of the airborne contaminants to penetrate deeper into the lungs. This respiration deep into the lungs has an added negative impact related to health, because hazardous gasses that might dissipate before being inhaled are adsorbed by many of the particulates and only released on contact with the fluid in lung sacs.

In addition to information describing the types of airborne contaminants following a fire, there are also studies that evaluate the dissipation of hazardous airborne contaminants after a fire has been put out. Of primary concern to firefighters and restoration professionals is how quickly some of the hazardous compounds off-gas, especially in regards to the time that elapses between the fire being extinguished and airborne levels of hazardous contaminants. While one of the primary studies showed that levels of hazardous components dropped off markedly within an hour of the fire being extinguished, the authors noted that many factors influence any particular case, including the amount of damage and subsequent natural airflow, use of artificial ventilation, firefighting methods, and how long the building is exposed prior to installation of protective coverings. Other credible references indicate that off-gassing is not the only process at work on fire residue following the suppression of the blaze as many of these chemical contaminants are broken down into other substances through oxidation, and even by sunlight.¹ However, the release and natural breakdown of components of fire residue does create other compounds, some of which can also be hazardous.²

Data garnered from the research does provide some information regarding the appropriate use of personal protective equipment when working in a fire-damaged building. However, most of the

research was directed toward firefighters who are in the structure not only during the actual conflagration, but immediately afterwards as well. Current literature, which focuses on fire suppression, overhaul, and investigation, continues to emphasize the importance of full scale personal protective equipment (supplied air respirator, bunker coat, gloves, etc.) both during and immediately after a structure fire. From that perspective, the need for personal protective equipment would appear to drop off substantially within an hour of the fire being struck. In contrast, there is a paucity of information about levels of contamination that may require protective equipment after the fire has been out for several days and/or the structure has been ventilated to remove a significant portion of the odors.

Although restoration professionals could look at the one study and feel justified in putting workers in such structures without personal protective equipment, such a decision clearly oversimplifies the actual situations encountered during such work. Virtually all of the reviewed literature emphasized that fire residue, and the hazards associated with it, is difficult to properly evaluate because of the incredible diversity in the types of materials that are burned and how the fire progresses.

The bigger picture that emerges from this literature review is that prudence should be the primary approach when restoration professionals determine whether personal protective equipment should be worn by restoration contactors working on fire damage projects. The levels and types of hazardous materials created during a structure fire lead to the recommendation that during the demolition and disturbance of burned materials, and during any activity that creates exposure to soot and other fire residue, and during initial cleaning activities that can liberate settled materials and propel smaller particles into the air, appropriate personal protective equipment should be utilized by workers. At a minimum, this should include respiratory protection and gloves to minimize the potential for inhalation and skin absorption of dangerous compounds.

This recommendation is based on the realization that it is nearly impossible for a restoration contractor to know the actual composition of the soot and fire residue that they are addressing. While many airborne volatiles may dissipate rapidly after a fire has been put out, other potentially dangerous chemicals could still be present. For example, even though PCBs are being phased out of electrical equipment, there are still many fires that impact mechanical components containing such chemicals. Since fire departments do not routinely test for the presence of PCBs and many other harmful contaminants, restoration contractors must do their best to comply with the occupational safety requirements/regulations that require them to take reasonable steps to protect their employees from harmful substances on the job site.

While the recommendation to utilize personal protective equipment for restoration of fire-damaged properties is based primarily on the types of hazardous materials that can be

encountered and the inability of the contractor to know with any precision the actual mix of chemicals to which his workers may be exposed, additional research in this area would be valuable. Since cleaning and the utilization of air scrubbers and hydroxyl radical generators has become a standard method for addressing fire residue and smoke odors, further research or testing is recommended to determine if the use of hydroxyl radical treatments to eliminate smoke odors may also create harmful intermediary compounds. As such, testing in actual or simulated fire conditions to determine if the cascade effect produced by hydroxyl radical generators as part of the contaminant/odor reduction process puts restoration workers at any further risk would offer valuable information to the restoration industry. Such testing should be supported as Part Two of this research.

5.0 References

1. *Hazardous Substances after Fire Damage*, Belfor; technical support pamphlet
2. *A Study on Chemicals found in the Overhaul Phase of Structure Fires using Advanced Portable Air Monitoring available for Chemical Speciation*, Regional Hazardous Materials Team HM09 – Tualatin Valley Fire and Rescue Office of State Fire Marshall
3. *Exposure to Smoke from Fires*, New York State Department of Health;
https://www.health.ny.gov/environmental/outdoors/air/smoke_from_fire.htm
4. *Fire Damage Repair and Restoration*, Servpro; www.servpro.com/fire-smoke-damage-restoration
5. *Fire Related Hazards Present During and After a Flood*, Suffolk County Government, Long Island, NY;
<http://www.suffolkcountyny.gov/Departments/FireRescueandEmergencyServices/FireMarshalsOffice/FireSafetyandDisasters/FireRelatedHazardsDuringandAfteraFlood.aspx>
6. *Firefighters Sound Alarm on Toxic Chemicals*, Lynne Peeples;
http://www.huffingtonpost.com/2014/03/27/firefighters-toxic-chemicals-regulation-flame-retardants_n_5034976.html
7. *Toxic Chemicals in Our Couches*, Natural Resources Defense Council;
<http://www.nrdc.org/health/flame-retardants/toxic-couch.asp>
8. *2nd Edition RIA Guidelines for Fire & Smoke Damage Repair*, Restoration Industry Association
9. *Handling Smoke Damage after a Fire – Getting Soot and Smoke Out*, The Disaster Handbook 1998 National Edition, Institute of Food and Agricultural Sciences, University of Florida
10. *The Consequences of Fire* from “A Reporter’s Guide to Fire and the NFPA”, National Fire Protection Association, <http://www.nfpa.org/press-room/reporters-guide-to-fire-and-nfpa/consequences-of-fire>
11. *Toxic Chlorinated and Polyaromatic Hydrocarbons and Simulated House Fires*, Chemosphere, Department of Environmental Sciences, University of Kuopio, Kuopio, Finland; Paivi Ruokojari, Marjaleenna Aatamila, Jubani Ruuskanen

12. *Home Fires*, FEMA/Ready, <http://www.ready.gov/home-fires>
13. *How to Clean Up Smoke and Soot from a Fire*, Los Angeles County Department of Public Health, www.publichealth.lacounty.gov
14. *Disaster Cleanup FAQ*, Odorox, <http://odoroxhg.com/disaster-cleanup-faq/>
15. *Polychlorinated Biphenyls (PCB's): Current Intelligence Bulletin 45*, National Institute for Occupational Safety and Health (NIOSH)
16. *Why Professionals Should Clean Smoke Damage From A Fire*, Institute of Inspection Cleaning and Restoration Certification, <http://www.iicrc.org/why-professionals-should-clean-smoke-damage-from-fire-a-38.html>
17. *International Study of the Sub Lethal Effects of Fire Smoke on Survivability and Health (SEFS): Phase 1 Final Report*, National Institute of Standards and Technology (NIST); Richard G. Gann, Jason D. Averill, Kathryn M. Butler, Walter W. Jones, George W. Mulholland, Julie L. Neviasser, Thomas J. Ohlemiller, Richard D. Peacock, Paul A. Reneke, John R. Hall Jr.
18. *The Hidden Hazards of Fire Soot*, American Institute for Conservation of Historic and Artistic Works (AIC), Dawn Bolstad-Johnson MPH, CIH, CSP
19. *Volatile chemicals found after house fire put out*, ABC Local, Samica Knight, <http://abclocal.go.com/story?section=news/local&id=7695482>
20. *Soot Damage: A challenge in any fire claim*, Laura Kupcis; Claims Canada, August 2011, U.S. Environmental Protection Agency, Health and Environmental Effects of Particulate Matter, New York State Department of Health, What You Should Know about Fires

6.0 Endnotes

1. US Agency for Toxic Substances and Disease Registry (ASTDR), *Public Health Statement for Polycyclic Aromatic Hydrocarbons (PAHs)*; accessed March 10, 2015 at <http://www.atsdr.cdc.gov/PHS/PHS.asp?id=120&tid=25>
2. ASTDR

7.0 Certifications

David A. Batts currently serves as Director of Environmental Services for Wonder Makers Environmental. His background includes education in the liberal arts and a variety of life experiences. Dave is a certified Mold Remediation Supervisor and also holds other certifications related to indoor air quality investigations and abatement. He has been involved in remediation of hazardous indoor environments as a contractor, inspector, project manager, asbestos instructor, and laboratory analyst since 1971.

Michael Pinto provided oversight and generated the report for this study. Mr. Pinto's post-graduate training is in Public Administration and Environmental Engineering, and, in addition to his scholastic achievements, he holds the titles of Certified Safety Professional and Certified Mold Professional. He is a member of the American Society of Safety Engineers, Restoration

Industry Association, American Industrial Hygiene Association, Indoor Air Quality Association, and the Cleaning Industry Research Institute. Mr. Pinto is the author of over 215 published technical articles and has successfully conducted industrial hygiene/indoor air quality investigations since 1988.

Michael A. Pinto, CSP, CMP
CEO



David Batts
Director of Environmental Services