

Overhaul Danger: What are our Firefighters being Exposed to During Overhaul Operations?

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CERTIFICATION STATEMENT

I hereby certify that this paper constitutes my own product, that where the language of others was set forth, quotation marks so indicate, and that appropriate credit was given where I have used the language, ideas, expressions, or writings of another.

Signed: _____

A handwritten signature in blue ink, consisting of several overlapping loops and a long horizontal stroke extending to the right, positioned over a horizontal line.

Abstract

The Casper Fire-EMS department (CFEMS) has identified a problem within its operations that presents a significant danger to the firefighters. The problem was that Casper Fire- EMS does not know what toxic chemical exposures firefighters could encounter during real structure fire overhaul operations with positive pressure ventilation. The purpose of this research was to identify what toxic chemical exposures the Casper Fire EMS firefighters may be exposed to during real structure fire overhaul operations with positive pressure ventilation. Descriptive methodology was utilized to guide the following research questions: (a) What are the toxic chemical exposures to firefighters during real structure fire overhaul operations without positive pressure ventilation? (b) What are the toxic chemical exposures to firefighters during real structure fire overhaul operations with positive pressure ventilation? (c) What exposures have been discovered by other agencies on toxic chemical exposures to firefighters during real structure fire overhaul operations? Data was collected through analysis of sample results collected during overhaul operations and surveys of other organizations. The results indicated that there are toxic chemical exposures to firefighters during overhaul operations. The literature provided information on the confirmed presence of toxic chemical exposures in overhaul environments, but failed to identify the effects on exposures with positive pressure ventilation in place. The air sample analysis yielded proof of toxic chemical exposures, but failed to provide multiple data sets of before and after positive pressure ventilation. The survey provided good results on the attitude and scope that other agencies consider in the overhaul environment. The recommendations were to: (a) use all precautions in the overhaul stages, (b) continue comparative analysis of positive pressure ventilation effects, (c) partner with community stakeholders for support, and (d) ensure communication of the research information to all

members of the CFEMS.

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Overhaul Danger: What are our Firefighters Being Exposed to During Overhaul Operations?

At a glance, the dangers of firefighting may be apparent to those analyzing the risks. Unfortunately, firefighters are realizing some of the silent dangers that they are being exposed to in their line of duty. According to the International Association of Firefighters, cancer is the leading cause of death in firefighters at 63% (“Cancer: Killing our Hero’s,” n.d.). There are inherent risks with the profession of firefighting, and many of the risks are unknown. “Whether in a residence or chemical plant, firefighters have to deal with unknown exposures in every fire (“Firefighting and Your Health,” n.d.)” The CFEMS is aware that there are unknown dangers to toxic exposures during firefighting operations and has been focused on developing policies and procedures to address hazards and reduce exposures.

Typical structure fire operations for the CFEMS after fire extinguishment consist of the fire cause and origin investigation followed by overhaul operations. Overhaul operations focus on securing the structure and cleaning damaged debris and building components from the structure to ensure complete extinguishment and deliver excellent customer service to the community. The overhaul stage has been a growing concern for the CFEMS that has historically been a stage of the fire that many firefighters are working in the environment without respiratory protection or their full bunker gear ensemble.

The problem was that Casper Fire- EMS does not know what toxic chemical exposures firefighters could encounter during real structure fire overhaul operations with positive pressure ventilation. The purpose of this research was to identify what toxic chemical exposures the Casper Fire-EMS firefighters may be exposed to during real fire overhaul operations with

positive pressure ventilation. By identifying the exposures, protective measures can be implemented for preventative safeguards for Casper Fire EMS firefighters.

Descriptive methodology was used to guide the following research questions: (a) What are the toxic chemical and exposures to firefighters during real structure fire overhaul operations without positive pressure ventilation? (b) What are the toxic chemical exposures to firefighters during real structure fire overhaul operations with positive pressure ventilation? (c) What exposures have been discovered by other agencies on toxic chemical to firefighters during real structure fire overhaul operations?

Background and Significance

The Casper Fire-EMS (CFEMS) is an all hazards department servicing the City of Casper. The City of Casper has a population of 59,628, and is protected by the CFEMS department. The CFEMS covers a 27.24 square mile service area with five fire stations and 80 personnel (Casper Fire-EMS, n.d., p. 1). As the first responders in the community, CFEMS is the first line of defense for structure fires and any other emergencies. The personnel responding to the fires are repeatedly placed in hazardous environments with unknown toxic exposure consequences.

Outside of recent studies and cancer information in firefighters, the exposures to unknown toxic environments relative to causing cancers is a growing concern within the CFEMS due to two irreplaceable losses to the department. On September 11, 2014, Captain Jeffrey Atkinson passed away after his fight against cancer. Not three years later, on April 22, 2017, Captain Matthew Trott finished his battle with cancer and passed away. Two integral members of the department passing within a three-year period has heightened the department's concern for what may be the underlying causes. Both of the members served in the fire service for over 20

years, with countless operations on the fireground. The CFEMS has experienced several other members in the past that have fought cancer over the years. The two recent deaths identify the reality that there are hidden dangers the personnel face in the line of duty.

A National Institute for Occupational Safety and Health (NIOSH) update 2015 reveals that firefighting is considered one of the most hazardous occupations, and involves regular exposure to known carcinogens. Using data from 1998-2007, results found that firefighters have increased risks for several cancers, including: (a) melanoma, (b) acute myeloid leukemia, (c) multiple myeloma, and (d) cancers of the esophagus, prostate, brain, and kidney (NIOSH, 2015, para. 2). Throughout the US, almost every other workforce outside of the fire service has reduced exposures in the past 40 years, while firefighters continue to be exposed to high levels of carcinogens in smoke because fire suppression and overhaul activities occur in uncontrolled, hazardous environments (“Firefighter Exposure to Carcinogens,” n.d.).

The research was significant to CFEMS because it could provide substantial information to its members on the unknown toxic exposures throughout the overhaul stages of firefighting. This was a focus due to the historical practices of operating within this stage of the fire without all of the needed personal protective ensemble. Currently, the CFEMS is developing procedures to protect their firefighters from exposure hazards. The information from this research could provide further insight as to what and why protective measures are necessary to develop, implement, and maintain within the organization. Rather than continuing to operate in a reactionary manner, this could enable the CFEMS to proactively address and explore and address exposure concerns within overhaul operations.

The National Fire Academy’s Executive Leadership course goal is that: “the Executive Fire Officer (EFO) will develop the ability to conceptualize and employ key processes used by

effective executive-level managers in the exercise of adaptive leadership” (Federal Emergency Management Agency [FEMA], 2015, p. vii). The overhaul operational phase of fires on the CFEMS has historically been an operational period that does not require full personal protective equipment. Information on the inherent hazards is growing, yet personnel are still resistive to the idea of maintaining personal protective equipment through the overhaul operations. This is an adaptive challenge to change the hearts and minds of all CFEMS personnel and can begin by researching the facts relative to exposures in the overhaul phase.

This research was supportive of the third operational goal of the United States Fire Administration (USFA) (2014) that states: Enhance the fire and emergency services’ capability for response to and recovery from all hazards. Specifically, the third key initiative is to promote a culture of health, wellness and behavior that enhances emergency responder safety and survival (United States Fire Administration, 2014, pp. 1, 9, & 12). Identification of exposure vulnerabilities for the CFEMS, in the overhaul stage of firefighting, could provide information to promote a culture of health, wellness and behavior that enhances emergency responder safety and survival.

Literature Review

This research was focused on the discovery of the unknown toxic exposures throughout the overhaul stages of firefighting, analyzing the difference between using ventilation during the operations vs. not using ventilation. Literature provided references through research, while references relative to the data collected in the field, was cited in the appendices and included in the reference list. For full understanding, information was also researched on what cancer is and the dangers of toxic exposures to firefighters. The initial step in discovery was to define cancer

and the relationship to exposures. The National Cancer Institute's (n.d.) article *What is Cancer* defines cancer as the following:

Cancer is the name given to a collection of related diseases. In all types of cancer, some of the body's cells begin to divide without stopping and spread into surrounding tissues.

Cancer can start anywhere in the human body, which is made up of trillions of cells.

Normally, human cells grow and divide to form new cells as the body needs them. When cells grow old or become damaged, they die, and new cells take their place. When cancer develops, however, this orderly process breaks down. As cells become more and more abnormal, old or damaged cells survive when they should die, and new cells form where they are not needed. These extra cells can divide without stopping and may form growths called tumors. Many cancers form solid tumors, which are masses of tissue. Cancers of the blood, such as leukemia's, generally do not form solid tumors. (para. 1, 2, 3, &4)

The Center for Disease Control and Prevention's (CDC) (2016) article on Cancer, informs that more than 1.5 million people are diagnosed with cancer each year in the United States, with more than 500,000 dying from the disease. The information also predicts that cancer will soon be the leading cause of death in the United States and that by the year 2020, cancer cases are expected to increase to nearly 2 million per year (CDC, 2016, para. 1). Looking at this fiscally, national expenditures for cancer care in the United States was nearly \$125 billion in 2010 and could reach \$156 billion by 2020 ("Cancer Statistics," n.d., para. 12). Sollitto (2010), suggests that being diagnosed with cancer is one of the five costliest medical conditions, which forces patients to make decisions about their health care and cancer treatment based on finances rather than what is best for their health.

Brautbar (n.d.), published an article on chemicals and cancer that reveals that chemical exposures and cancer date back several thousand years. The article explains the importance of causation and epidemiology assessing causation in toxic exposure. Acceptable criteria that has been endorsed somewhat by the scientific community and utilized in the occupational medicine and medical toxicology, came from Sir Bradford-Hill who studied the cancerous effects of cigarettes, nickel and others, presented his aspects to establish medical causation in the 1960's (Brautbar, n.d., para. 5, 6, 8). In the article Brautbar (n.d., para. 15) gives information derived from the International Agency for Research on Cancer (IARC) Monograph Series, National Toxicology Program Report, and the Department of Health and Human Services' reports on carcinogens specifying chemicals shown to be carcinogenic to animals are carcinogenic to humans. According to Brautbar, information was provided on the scientific evidence for admissibility of animal carcinogenesis in addressing causation in human cancer:

Dr. David Rall from NIOSH clearly summarized the scientific evidence for admissibility of animal carcinogenesis in addressing causation in human cancer: Experimental evidence indicates that there are more physiological, biochemical, and metabolic similarities between laboratory animals and humans than there are differences. These similarities increase the probability that results observed in a laboratory setting will predict similar results for humans. (Brautbar, n.d., para. 13)

In understanding exposures, the literature review explores exposure limitations and the associated regulations with exposures. The *American Industrial Hygiene Association's (AIHA's) White Paper on Permissible Exposure Limits (PELs)*, (2002), gives the history of exposure limits, explaining that over 50 years of the industrial hygiene community's experience

has helped evolve the use of exposure limits as a means of protecting worker health. The limits established include the following:

Maximum Allowable Concentrations (MACs), Threshold Limit Values (TLVs), Workplace Environmental Exposure Levels (WEELs), Recommended Exposure Limits (RELs), and industry-developed Occupational Exposure Limits (OELs) have been essential tools of the practicing industrial hygienist. While the goals, where stated, may differ (2) (e.g., to limit occupational cancer to 1 case in 1000 exposed workers over a working lifetime or to protect "nearly all workers"), these exposure limits are all designed to reduce the occurrence of worker illness or impairment resulting from exposure to chemicals. The use of exposure limits to prevent occupationally-related illness has been an effective tool used by industrial hygienists for more than five decades. AIHA recognizes the controversies that are often involved in the setting of these limits both in the regulatory and voluntary arenas. In developing PELs the major concerns include scientific soundness, feasibility, timeliness, documentation, and opportunity for involvement of affected parties in the decision-making process. We believe that when these considerations are a part of the limit-setting process and when the limits are applied as part of a comprehensive occupational safety and health program they are a primary tool in disease prevention (American Industrial Hygiene Association's (AIHA's) *White Paper on Permissible Exposure Limits (PELs)*, 2002, para. 2).

Rosenbaum & Rosenbaum, P.C. (2017), has information revealing that OSHA has set regulations to assist employers with preventing needles exposure. Practices considered as optimal ways to minimize toxic exposure include: (a) personal protective equipment, (b)

changing out substances, (c) adjusting work schedules, and (d) changing process in an effort to reduce exposure.

The page on osha.gov's Chemical Hazards and Toxic Substances, *Controlling Exposure* (n.d.) gives an overview of controls for controlling exposures to protect workers. The primary means to reduce employee exposure to toxic chemicals is OSHA's longstanding policy of engineering and work practice controls.

Where possible, elimination or substitution is the most desirable followed by engineering controls. Administrative or work practice controls may be appropriate in some cases where engineering controls cannot be implemented or when different procedures are needed after implementation of the new engineering controls. Personal protection equipment is the least desirable but may still be effective. (*Controlling Exposure*, n.d., para. 4)

The *Controlling Exposure* (n.d.) page (Figure 1) also depicts the hierarchy of controls.

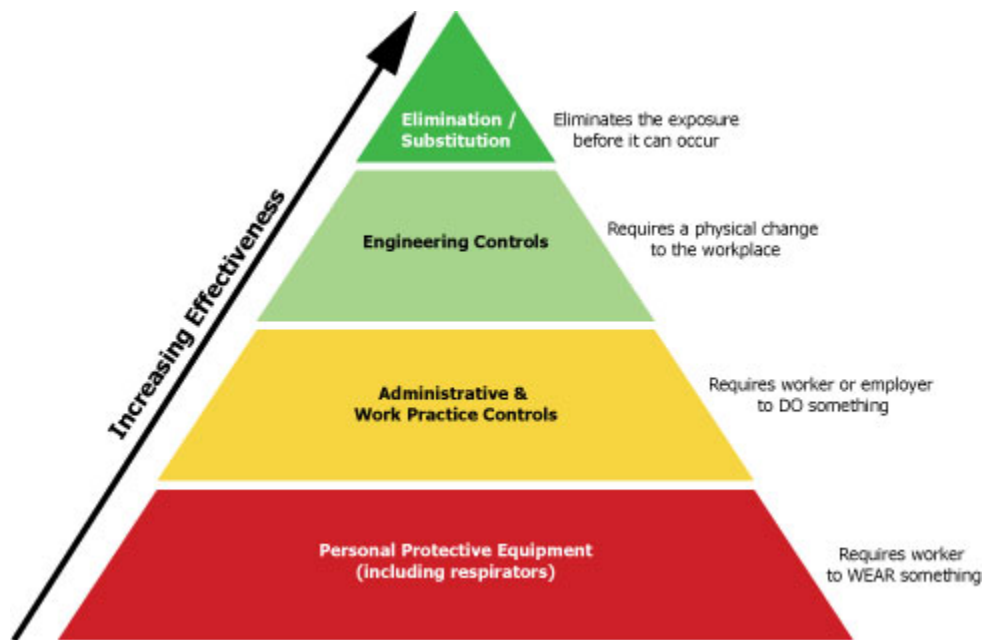


Figure 1. (*Controlling Exposure*, n.d.)

The osha.gov's page on *Chemical Hazards and Toxic Substances* (n.d.) has information regarding protective measures for workers through OSHA's Hazard Communication Standard (HCS). The standard is designed to ensure that workers are informed on the chemical and toxic substance hazards and associated protective measures within the workplace. The government's osha.gov page, *Hazard Communication* (n.d.), provides access to all the information relative to the HCS. Specifically informing the changes and alignment with the Globally Harmonized System of Classification and labeling of Chemicals (GHS). This is providing information that there will now be a common approach to classifying chemicals and communicating information and safety data sheets. As of December 1, 2013, the HCS required that all workers be trained on the new labels elements of safety data sheets format to facilitate recognition and understanding (Hazard Communication, n.d., p. 1).

On the osha.gov's page on Permissible Exposure Limits - Annotated Tables (n.d.), the following information was given in relation to PELs:

OSHA recognizes that many of its permissible exposure limits (PELs) are outdated and inadequate for ensuring protection of worker health. Most of OSHA's PELs were issued shortly after adoption of the Occupational Safety and Health (OSH) Act in 1970, and have not been updated since that time. Section 6(a) of the OSH Act granted the Agency the authority to adopt existing Federal standards or national consensus standards as enforceable OSHA standards. Most of the PELs contained in the Z-Tables of 29 CFR 1910.1000 were adopted from the Walsh-Healy Public Contracts Act as existing Federal standards for general industry. These in turn had been adopted from the 1968 Threshold Limit Values (TLVs®) of the American Conference of Governmental Industrial Hygienists (ACGIH®). Some consensus standards from the American Standards

Association were also adopted at that time, following the 6(a) procedures. Comparable PELs were adopted for shipyards (29 CFR 1915.1000) and construction. (29 CFR 1926.55). (Permissible Exposure Limits - Annotated Tables, n.d., para. 1)

The American Conference of Governmental Industrial Hygienists (ACGIH) has established acceptable workplace environmental exposure levels (WEELs), that are known as threshold limit values (TLVs) (Stefan, n.d., para. 2). When exploring the difference between a permissible exposure limit (PEL) and threshold limit value (TLV), Bako (2012, para. 2, 3) provides the definitions for understanding:

Permissible exposure limits are set by OSHA to protect workers against the adverse effects of exposure to chemical substances. In the world of gas detection, PELs limit the amount or concentration of a substance in the air and generally are based on an 8-hour time-weighted average exposure. A threshold limit value, set by the American Conference of Governmental Industrial Hygienists, is the limit of exposure to a chemical substance that a worker can be exposed to, day after day, without adverse health effects. TLVs are estimates based on the known toxicity of a chemical substance in humans or animals given the currently available analytical and technological resources. To determine TLVs, ACGIH uses committees to review various published literature in disciplines such as industrial hygiene, toxicology and occupational medicine. TLVs are then developed as recommendations or guidelines and are intended to be interpreted and used by a person trained in the discipline of industrial hygiene. (Bako, 2012, para. 2, 3)

Bako (2012, para. 4, 5) continues to explain that they sound very similar, yet TLVs are not legal limits, while PEL's are legally enforceable by OSHA in the United States. TLVs are more stringent, derived solely on health factors, and do not account for economic or technical

feasibility (Bako, 2012, para. 4, 5). Additional literature review on the enforceability of PELs discovered that “OSHA sets permissible exposure limits (PELs) to protect workers against the health effects of exposure to hazardous substances. PELs are regulatory limits on the amount or concentration of a substance in the air. They may also contain a skin designation. PELs are enforceable. OSHA PELs are based on an 8-hour time weighted average (TWA) exposure” (“1988 OSHA PEL Project Documentation,” 2016, para. 1).

To further reveal what a Time Weighted Average (TWA) is, the literature revealed that hazardous substances such as: (a) chemicals, (b) dusts, (c) fumes, (d) mists, (e) gases, (f) vapors, and (g) agents such as: occupational noise are averaged to an 8-hour work day, with an accounting of the average levels of the substance or agent and time spent in the area, calculated with a TWA to determine possible PELs (“Water and Wastewater Terms Beginning T.,” n.d., para. 1). Llanes (2016, para. 4), provided the formula used for calculating a TWA as follows:

- Common formula

$$\text{TWA} = \frac{t_1c_1 + t_2c_2 + \dots + t_nc_n}{t_1 + t_2 + \dots + t_n}$$

Llanes (2016), explains the formula as: “A TWA is equal to the sum of the portion of each time period multiplied by the levels of the substance or agent during the time period divided by the hours in the workday.

- TWA indicates time-weighted average,
- “t” indicates duration,
- “c” indicates concentration. (para. 4)

The literature review also discovered that there are Recommended Exposure Limit (REL) values associated with exposures. An article, Recommended Exposure Limit (REL) (n.d., para.

1), provided the definition; a REL is a numeric value defining the maximum concentration or level of exposure to a hazardous substance or chemical condition that is permitted in a workplace. NIOSH establishes recommended exposure limits for the workplace on hazards such as: (a) excessive noise, (b) chemical fumes, (c) airborne particulates, and (d) biological agents (“Recommended Exposure Limit (REL),” n.d., para. 1, 2). NIOSH believes these limits would be protective of worker safety and health over a working lifetime if used in combination with engineering and work practice controls and are recommended to OSHA. RELs are expressed in Parts per million (ppm) or milligrams per cubic meter (mg/m³), are used as guides in some industry and advocacy organizations, yet no REL has ever been adopted by OSHA (“Recommended Exposure Limit,” n.d., para. 1).

The literature discovered on Occupational Exposure Limits (OELs), revealed that OELs are the limit of a particular material or class of materials and the acceptable concentrations of a hazardous substance in the workplace air. For over 60 years, multiple regulatory and authoritative organizations have established OELs for airborne workplace chemicals. With increasing change and a growing global view on industrial hygiene issues, it is important for the Occupational Hygiene profession to maintain viability of OEL’s in professional practice (“AIHA Protecting Worker Health,” n.d. para. 1-2). The pioneering effort for OELs began in the 1940s when the American Conference of Governmental Industrial Hygienists (ACGIH) created a list of 132 specific chemicals (“Occupational Exposure Limits - State of the Science,” 2016, para. 1). Exposure limits, with the exception of legally enforceable PELs, are guidelines and useful when taking a risk based approach, keeping in mind that the lack of published exposure limits does not mean that the hazard does not exist (*The Chemical Safety Mechanism*, 2012, para. 2, 3, 4, 5).

An article from Lenntech, *Health effects: Terminology of the health effects of elements and compounds* (n.d.), gives the definition of Short Term Exposure Limits (STELs) as defined by the ACGIH (American Conference of Governmental Industrial Hygienists) the STEL is the concentration to which workers can be exposed continuously for a short period of time without suffering from:

- Irritation
- Chronic or irreversible tissue damage
- Narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency. (p. 1)

They are generally only used when toxic effects have been reported from high acute exposures in humans or animals (“Health effects: Terminology of the health effects of elements and compounds,” n.d., para. 8, 9).

Immediately dangerous to life and health (IDLH) values were developed by NIOSH in the 1970’s (“Immediately Dangerous to Life or Health (IDLH) Values,” n.d., para. 1). As a component of respirator selection criteria, the IDLH values are established for the following reasons:

- (1) to ensure the worker can escape from contaminated environment in the event of the failure of the respiratory equipment.
- (2) to indicate a maximum level above which only a highly reliable breathing apparatus, providing maximum worker protection, is permitted. (“Immediately Dangerous to Life or Health (IDLH) Values Overview,” n.d., para. 2).

Having explored what cancer is and the different exposures, the literature review was directed at cancer and exposures in relation to firefighters. In relation to cancer’s danger to firefighters, it

was discovered that cancer is an epidemic among firefighters and many now believe they are more likely to die from cancer than all other hazards combined (Hayes, 2017). The International Association of Firefighters (IAFF) (n.d.a), reveals that firefighters face serious risks of heat, flames, physical and mental stress, high levels of carbon monoxide (CO), and other toxic risks around fires. In the section detailing cancer, the information says that firefighters come in contact with cancer causing materials when they fight fire, with an increased risk of getting (a) colon, (b) brain, (c) bladder, (d) kidney, and (e) Hodgkins lymphoma cancer (“International Association of Firefighters,” n.d.a).

Further alarming statistics are given by Sendelbach (2015), stating that cancer diagnoses in Boston firefighters is 20 per year and over the past three years, 27 firefighters have died from cancer in Chicago, and 32 percent of Miami firefighters have been diagnosed with some form of cancer between 2008 and 2010. Tutterow (2015) gives a comparison from an IAFF study of the growing concern by first giving information of firefighter cancer deaths from 1993 to 2003 at 31 members before the age of 60. For the period of 2003 to 2013, the number of firefighter deaths before age 60 rose to 298. Furthermore, for 2014, 62 percent of all IAFF firefighter deaths were from cancer (Tutterow, 2015, para. 4).

Wallace and DeHaan (2000), explained that overhaul discovers and extinguishes any hidden fires or hotspots that have the potential to cause a rekindle fire, which could result in the total destruction of what is left of the structure. Some of the dangers that firefighters can face while performing overhaul are: (a) falls, (b) inhalation of toxic combustion products, (c) strains, and (d) sprains (Wallace and DeHaan, 2000, p. 1). A report published in 2011 by the Tualatin Fire & Rescue and Oregon Office of State Fire Marshal addressing a study on chemicals found in

the overhaul phase of structure fires provides the following information relative to firefighters in the overhaul stage:

During the overhaul phase of structure fires, firefighters commonly doff their self-contained breathing apparatus SCBA protection for easier working conditions and traditionally rely upon carbon monoxide (CO) detection as the determinate for this action. A CO level of below 35 ppm has traditionally been the acceptable limit for firefighters to wear this lesser level of respiratory protection. Removal of respiratory protection during fire overhaul activities or in the general area can expose firefighters and fire investigators to an unknown variety of toxic chemicals and particulates. Typical structure fires involve high temperature destruction of many types of plastics, foams, various species of wood, fabrics and other materials. (*A Study on chemical*, 2011, p. 2)

Additionally, in the report, information was given that an SCBA should be worn continuously during the overhaul phase unless detection equipment concludes a safe environment. There have been a growing number of studies informing that there are many known carcinogens produced from a structure fire that should be monitored for after the fire has been knocked down (*A Study on chemical*, 2011).

Another article on overhaul and salvage explains how firefighters fail to recognize dangers associated with salvage and overhaul, and let their guard down and unfortunately there are many carcinogens present in smoke that can be inhaled and absorbed through the skin (“Important Considerations for Overhaul and Salvage,” 2009). The article gives recommendations that firefighters always wear an SCBA and PPE during overhaul. Additionally, the article recommended the use of PPV fans because they introduce fresh air and remove

carcinogens produced by hot debris although smoke is not visible (“Important Considerations for Overhaul and Salvage,” 2009).

The International Association of Firefighters’ (IAFF) (n.d.a) article on firefighter toxic substance exposures has information that firefighters may be exposed to chemicals during a fire through inhalation or skin contact. The information revealed that synthetic chemicals are released from the combustion of materials in a fire. The common classes of synthetic chemicals firefighters are may be exposed to are:

- Perfluorinated compounds (PFCs), ingredients in some types of firefighting foams, and
- Polychlorinated and polybrominated dioxins and furans are combustion byproducts of halogenated flame retardants used in residential furniture (“Firefighter Toxic Substance Exposures,” n.d., para. 1).

PFC’s are used to make products resistant to stains, grease and water, and are commonly used on a variety of materials including some firefighting foams (“Perfluorinated Chemicals,” n.d., para. 2). PFCs are extremely stable and can build up in the environment and the human body, where they may concentrate in the blood and the liver (“Firefighting and Your Health, Perfluorinated Chemicals (PFCs),” n.d., para. 1, 3). When relating PFC’s occupational exposure among firefighters, the article provides that very little research has been done. It does reveal that firefighter occupational exposures to these chemicals can cause several health problems: (a) elevated thyroid hormone levels, higher rates of prostate cancer, (b) higher levels of bad cholesterol, (c) greater numbers of abnormal sperm in men, (d) low birth weight in newborns, (e) difficulty conceiving a child, and (f) early menopause (“Firefighting and Your Health, Perfluorinated Chemicals (PFCs),” n.d., para. 6-9).

The National Institute of Environmental Health Sciences released an article, *Perfluorinated Chemicals (PFCs)* (2016), that provided information on PFCs explaining that they break down very slowly in the environment with widespread wildlife and human exposure to several PFCs including perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS). PFOS is no longer manufactured in the United States and PFOA production has been reduced and will soon be eliminated (para. 3). The PFCs are not stored in body fat but have a long half-life, taking 50% of the chemical to leave the human body several years. Due to this slow elimination, it is difficult to determine how lifestyle and other changes influence blood levels (“*Perfluorinated Chemicals (PFCs)*,” 2016, para. 4).

A factsheet from the CDC (2016) National Biomonitoring Program page on perfluorochemicals details that PFCs are used to make fluoropolymer coatings that resist heat, oil stains grease, and water. The coatings are used in the following products: (a) clothing, (b) furniture, (c) adhesives, (d) food packaging, (e) heat resistant non-stick cooking surfaces, and (f) the insulation of electrical wire (para. 1). The health effects listed found that PFCs may affect growth and development, reproduction, and injure the liver. CDC scientists performed tests, indicating widespread exposure of PFCs to the U.S. population, due to the following four PFCs in nearly all of the people tested: (a) perfluorooctanoic acid (PFOA), (b) perfluorooctane sulfonate (PFOS), (c) perfluorohexane sulfonic acid (PFHxS), and (d) perfluorononanoic acid (PFNA) (“*CDC*,” 2016, para. 3,5).

An article from the International Association of Firefighters (IAFF) (n.d.b), explains that dioxins and furans are a closely related group of chemicals, often referred to as “dioxin (para. 1).” They are made up of carbon rings formed during incomplete combustion. Chlorine or bromine are attached to the outside of the rings and the final structure is dependent on the

material burned, resulting in long lived dioxins with toxic buildup in the body over time (“International Association of Firefighters (IAFF),” n.d.b, para. 2). In relation to firefighter exposures, the article informs that dioxins and furans appear to be produced by almost all combustion. Structure fires are known to be a source of dioxins and furans, in turn exposing firefighters in smoke and soot during calls; a recent example was the detection of elevated levels of dioxins in the blood and urine of firefighters who responded to the World Trade Center disaster (“International Association of Firefighters (IAFF),” n.d.b, para. 2, 3). Additionally, the article states that the chemicals pose an unnecessary threat to firefighters and references that “according to the EPA, dioxins and furans are likely to cause cancer” (“International Association of Firefighters (IAFF),” n.d.b, para. 4, 5).

Another article, *Dioxins & Furans: The Most Toxic Chemical Known to Science* (n.d.), begins explaining dioxins with the following reference: “A draft report released for public comment in September 1994 by the US Environmental Protection Agency clearly describes dioxin as a serious public health threat. The public health impact of dioxin may rival the impact that DDT had on public health in the 1960's (para. 1).” Furthermore, the article confirms that dioxin is a cancer hazard to people, and is considered a Group 1 Carcinogen (“Dioxins & Furans: The Most Toxic Chemicals Known to Science,” n.d., para. 4). The International Agency for Research on Cancer (IARC), Standard IARC classification (n.d.) page defines group 1 carcinogens as; “Carcinogenic to humans. There is enough evidence to conclude that it can cause cancer in humans.” A 2003 re-analysis from dioxin provided that there is no known “safe dose” or threshold below which dioxin will not cause cancer (“Dioxins & Furans: The Most Toxic Chemicals Known to Science,” n.d., para. 5).

The company RAE Systems (2012), explains the dangers of smoldering fumes from a recently doused fire that threaten the life and health of firefighters involved in the fire overhaul operations. Potentially toxic chemicals and compounds frequently found during overhaul operations are carbon monoxide (CO), sulfur dioxide (SO₂), hydrogen cyanide (HCN), nitrogen oxides (NO and NO₂), formaldehyde, benzene and phosgene. The report identifies CO and HCN as the “toxic twins” of fire overhaul, having devastating short term and long term effects if inhaled and inform that they can only be detected by metering and monitoring (“RAE Systems,” 2012). The literature review directed efforts into understanding exposure and health effects the potentially toxic chemicals and compounds found in overhaul operations relative to the RAE Systems report. Sideras (2008, para 13, 17) explained that:

- Firefighters are at risk of CO exposure and it is recommended that they should be evaluated in rehab in firefighting operations using Pulse CO-oximetry, treating CO poisoning with high concentrations of oxygen. CO poisoning has adverse effects on all systems of the body, displacing oxygen, affecting the cardiovascular system, with significant impact to the central nervous system. The symptoms of CO poisoning may vary depending upon the level of CO and the time of exposure which can include; flu-like illness, fatigue, chest pain, lethargy, depression, nausea, vomiting, headaches, abdominal pain, drowsiness, and coma. (Sideras, 2008, para. 5, 6, 7, 8)
- Evans (2016) recommended that fire agency’s address the exposure of CO and follow OSHA’s permissible exposure limit of 50 parts per million over an 8-hour time frame. (para 2)
- Information related to the health effects of SO₂ (Sulfur Dioxide), explains that short term exposure can harm the human respiratory system, making breathing difficult.

Additionally, the SO₂ can react with different compounds forming small particles that may penetrate deeply into sensitive parts of the lungs (“Sulfur Dioxide Basics,” 2016, para. 5, 6). The short term exposure levels of SO₂ can be immediately dangerous to life and health at 100 parts per million. Exposures occur by breathing it in and absorbing it through your nose and lungs, entering your bloodstream, which eventually breaks down into sulfate and leaves through urine. Symptoms of exposure include burning in the nose and throat, breathing difficulties, and severe airway obstructions (“Toxic Substances Portal - Sulfur Dioxide,” 2015, para. 14). The OSHA PEL for Sulfur Dioxide is 5 parts per million (“NIOSH Pocket Guide to Chemical Hazards - Sulfur dioxide,” 2016).

- With a possible odor of a bitter almond smell, and released when materials such as plastic burn, hydrogen cyanide is known as a fast acting potentially deadly chemical that prevents the cells of the body from using oxygen properly (“Hydrogen Cyanide - Fact Sheet,” 2012, para. 1 & 2). The health effects of hydrogen cyanide are highly toxic with rapid onset of symptoms which may occur seconds following inhalation or minutes following ingestion or dermal contact. The tissues with a high metabolic demand such as the central nervous system (CNS). A list of early and late symptoms includes: (a) non-specific CNS symptoms, (b) muscular and neurological effects, (c) tachypnea, (d) tachycardia, (e) seizures, (f) rapid loss of consciousness, (g) cardiorespiratory depression and collapse, (h) pulmonary edema and death (*Hydrogen Cyanide Toxicological Overview, 2016, p. 2*). The OSHA PEL for Hydrogen Cyanide is 10 PPM (“NIOSH Pocket Guide to Chemical Hazards - Hydrogen cyanide,” 2016).
- Nitric Oxide (NO) is a colorless and odorless gas while Nitrogen Dioxide (NO₂) is a red-brown gas with a pungent smell that is soluble in water. Typical man made releases come

from the burning of fossil fuels, biomass burning and some production processes (“Nitrogen oxides, NO, NO₂ as NO₂,” n.d., para. 2 & 4). Breathing air with NO₂ can irritate the respiratory system, producing symptoms such as coughing, wheezing, or difficulty breathing, with longer exposures leading to development of asthma and susceptibility of respiratory infection (“Basic Information about NO₂,” 2016, para. 3). The OSHA PEL for Nitric Oxide (NO) is 25 PPM (“NIOSH Pocket Guide to Chemical Hazards - Nitric oxide,” 2016). The OSHA PEL for Nitrogen dioxide is 5 PPM (“NIOSH Pocket Guide to Chemical Hazards - Nitrogen dioxide,” 2016).

- An article on Formaldehyde (2014a) from cancer.org indicated that formaldehyde is a colorless strong-smelling gas that is used in making many building materials and household products. A list of products includes pressed wood products such as: (a) particle board, (b) plywood and fiberboard, (c) glues and adhesives, (d) permanent-press fabrics, (e) paper product coatings, (f) certain insulation materials and other chemicals. Quickly broken down in the air and dissolving easily in water, exposure can occur by inhaling it or through absorbing it through the skin. Symptoms of exposure include watery eyes, burning sensation in the eyes, nose and throat, coughing, wheezing, nausea, and skin irritation. Exposure to formaldehyde has been shown to cause cancer in laboratory animals and some types of cancer in humans (“Formaldehyde,” 2014b). The OSHA PEL for Formaldehyde is 0.75 PPM (“NIOSH Pocket Guide to Chemical Hazards - Formaldehyde,” 2016). As defined by the OSHA carcinogen policy [29 CFR 1990], NIOSH considers formaldehyde to be an occupational carcinogen (“Formaldehyde,” December, 2014b).

- The United States Department of Labor (n.d.) page on Benzene, reveals the following information on benzene; found in gasoline and other fuels, benzene is an element of coal and petroleum products. Used in the manufacturing of (a) plastics, (b) detergents, (c) pesticides and (d) other chemicals, individuals with exposures to benzene from less than five years to more than 30 years have developed and died from leukemia. Long term exposures can result in affecting bone marrow and blood production while short term exposures can cause drowsiness, dizziness, unconsciousness, and death (“United States Department of Labor,” n.d.) Benzene is among the 20 most widely used chemicals in the United States and is known to cause cancer, based on evidence from studies in both people and lab animals (“Benzene and Cancer Risk,” n.d., para., 2, 11). The OSHA PEL for Benzene is 1 PPM (“NIOSH Pocket Guide to Chemical Hazards - Benzene,” 2016).
- Phosgene is essential in the manufacturing of everyday life products including: (a) polycarbonate plastics, (b) pharmaceuticals, (c) agricultural chemicals, (d) specialty chemical intermediates, (e) flex foam, (f) rigid foam, (g) thermoplastic polyurethane, (h) coatings, (i) adhesives, (j) sealants, (k) elastomers, and (l) used on floors and automotive interiors. Phosgene is a raw material used primarily in the production of methylene diphenyl diisocyanate (MDI) and toluene diisocyanate (TDI) (“Products and Technology Phosgene,” n.d., para. 1, 2). EPA has classified phosgene as not classifiable to human carcinogenicity, yet phosgene is extremely toxic by acute inhalation exposure causing ocular irritation and dermal burns as well as severe respiratory effects that include pulmonary edema, pulmonary emphysema, and death in humans. Chronic exposure has shown some result in tolerance to acute effects but may cause irreversible pulmonary changes of emphysema and fibrosis (“Phosgene 75-44-5,” 1992, para. 1). The

OSHA PEL for phosgene is 0.1 PPM (“NIOSH Pocket Guide to Chemical Hazards - Phosgene,” 2016).

The literature on toxic exposures to firefighters during overhaul revealed continuing education material from Fire Engineering University by Herbert (n.d., p. 4), who discussed the results of the Burgess Study, measuring serum pneumoproteins from firefighters which indicated exposures to carboxyhemoglobin, acetaldehyde, formaldehyde, sulfur dioxide, respirable dust, and sulfuric acid. “The study determined that cartridge respirators should not be worn as respiratory protection against overhaul hazards. These studies indicated that overhaul presents serious risk to firefighters who choose not to wear SCBS and that the occupational hazard of overhaul requires further study. Herbert (2009) recommended that due to hazardous gases that exist during overhaul that are undetectable to the senses, gives the need for more research to be conducted to further evaluate what firefighters are exposed to and how the exposures may affect firefighter health (p. 6). The literature review directed efforts into understanding exposure and health effects of the potentially toxic chemicals and compounds found in Herbert’s information that had not been explored previously. Carboxyhemoglobin is not explored due to it being the result of carbon monoxide being inhaled. A reference to explain carboxyhemoglobin provides information that it is a stable complex of carbon monoxide that forms in red blood cells when carbon monoxide is inhaled (“Carboxyhemoglobin,” 2017).

- A publication from the Delaware Health and Social Services provided some information through frequently asked questions in a report titled *Acetaldehyde* (2015). This revealed that acetaldehyde is a clear liquid that burns easily with a strong, fruity, odor with the possibility of making breathing difficult. It is also known as ethanol forms naturally in the body and in plants. Information was provided that exposure can occur through

inhalation when burning wood in a fireplace or wood burning stoves, also revealing that fumes can be present near gas pumps (“Acetaldehyde,” 2015). Acetaldehyde is a known potential occupational carcinogen. The symptoms of exposure include: (a) irritation of the eyes, nose, throat, eyes, and skin burns (b) dermatitis, (c) conjunctivitis, (d) cough, (e) central nervous system depression; delayed pulmonary edema. The OSHA PEL for acetaldehyde is 200 ppm (“NIOSH Pocket Guide to Chemical Hazards - Acetaldehyde,” 2016).

- Respirable dust is dust of less than 10 microns which is capable of penetrating deep into the alveoli (“Meaning of respirable dust,” 2014). A micron is one millionth of a meter (“Micron,” n.d.). Health effects can range in respiratory and cardiovascular illnesses including the following: Irritation of the airways, coughing, difficulty breathing, decreasing lung function, aggravation of asthma, development of chronic bronchitis, adverse effects on the cardiovascular system and premature death in people with heart or lung disease (“Health effects of Air Pollutants - Respirable and Fine Suspended Particles,” n.d.). The OSHA PEL for respirable particulates is 5 mg/m³ (“NIOSH Pocket Guide to Chemical Hazards - Particulates not otherwise regulated,” 2016).
- Sulfur trioxide is formed from sulfur dioxide, which forms sulfuric acid when it comes in contact with water. (“Toxic Substances Portal - Sulfur Trioxide & Sulfuric Acid,” n.d.). Sulfuric acid is a colorless oily liquid with exposure resulting in adverse health effects from exposure (“Sulfuric Acid,” n.d.). Exposure routes include: (a) inhalation, (b) ingestion, and (c) skin/ or eye contact with the following symptoms resulting from exposure: (a) irritation to the eyes, (b) skin, nose, (c) throat, (d) pulmonary edema, (e) bronchitis emphysema, (f) conjunctivitis, (g) stomatis (h) dental erosion (i) eye, (j) skin

burns, (k) dermatitis. The OSHA PEL is 1 mg/m³ (“NIOSH Pocket Guide to Chemical Hazards - Sulfuric acid,” 2016). The International Agency for Research on Cancer (IARC) determined that exposure to strong inorganic acid mists containing sulfuric acid is carcinogenic to humans (“Toxic Substances Portal - Sulfur Trioxide & Sulfuric Acid,” n.d.).

A comprehensive air monitoring study by Bolstad-Johnson et al. (2017) characterizing the City of Phoenix firefighter’s exposures during the overhaul phase of 25 structure fires. The study resulted in the following data:

Personal samples were collected for aldehydes; benzene; toluene; ethyl benzene; xylene; hydrochloric acid; polynuclear aromatic hydrocarbons (PNA); respirable dust; and hydrogen cyanide (HCN). Gas analyzers were employed to continuously monitor carbon monoxide (CO), HCN, nitrogen dioxide (NO₂), and sulfur dioxide (SO₂). Area samples were collected for asbestos, metals (Cd, Cr, Pb), and total dust. During overhaul the following exceeded published ceiling values: acrolein (American Conference of Governmental Industrial Hygienists [ACGIH] 0.1 ppm) at 1 fire; CO (National Institute for Occupational Safety and Health [NIOSH] 200 ppm) at 5 fires; formaldehyde (NIOSH 0.1 ppm) at 22 fires; and glutaraldehyde (ACGIH 0.05 ppm) at 5 fires. In addition, the following exceeded published short-term exposure limit values: benzene (NIOSH 1 ppm) at two fires, NO₂ (NIOSH 1 ppm) at two fires, and SO₂ (ACGIH 5 ppm) at five fires. On an additive effects basis, PNA concentrations exceeded the NIOSH recommended exposure limits (0.1 mg/M³) for coal tar pitch volatiles at two fires. Maximum concentrations of other sampled substances were below their respective permissible exposure limits. Initial 10-min average CO concentrations did not predict concentrations

of other products of combustion. The results indicated that firefighters should use respiratory protection during overhaul. In addition, these findings suggest that CO should not be used as an indicator gas for other contaminants found in this atmosphere. (Bolstad-Johnson et al., 2017, para. 1).

In the study by Bolstad-Johnson et al. (2017) the potentially toxic chemicals and compounds were identified as:

- Glutaraldehyde is a colorless, oily liquid with a sharp, pungent odor. Used in industrial, laboratory, agricultural, medical and some household purposes, exposure can result from inhalation and skin contact. The health effects are irritation to the skin and eyes, mouth, esophagus, and stomach, being classified as non-carcinogenic to humans (“Toxic substance portal - Glutaraldehyde,” n.d.). There is no established OSHA PEL for glutaraldehyde (“NIOSH Pocket Guide to Chemical Hazards - Glutaraldehyde,” 2016).
- Toluene is a clear, colorless liquid with a distinctive smell (“Toxic substances portal - Toluene,” n.d.). Toluene is a solvent used to make: (a) aviation gasoline, (b) spray and wall paints, (c) paint thinner, (d) medicine, (e) dyes, (f) explosives, (g) detergent, (h) fingernail polish, (i) spot removers, (j) lacquers, (k) adhesives, (l) rubber, and (m) antifreeze. Exposures can occur through inhalation and skin contact, with health effects of: (a) light headedness, (b) dizziness, (c) headache, (d) fatigue, (e) weakness, (f) memory loss, (g) nausea, (h) appetite loss, (i) coughing, (j) wheezing, (k) hearing and color vision loss, (l) permanent brain damage, (m) depression, and (n) death (“Toluene,” n.d.). The OSHA PEL of toluene is 200 PPM (“NIOSH Pocket Guide to Chemical Hazards - Toluene,” 2016). Toluene is not classifiable as to its carcinogenicity in humans (“Toxic substances portal - Toluene,” n.d.).

- Ethyl benzene is mainly used in the manufacture of styrene. Health effects from exposure include respiratory effects such as throat irritation and chest constriction, irritation of the eyes, and neurological effects such as dizziness. Not classifiable a carcinogenic to humans, animal studies have incidence of increased kidney and testicular tumors in rats and lung and liver tumors in mice (“Ethylbenzene,” n.d.). The OSHA PEL for ethylbenzene is 100 ppm (“NIOSH Pocket Guide to Chemical Hazards – Ethyl benzene,” 2016).
- Xylene, an aromatic hydrocarbon, is a colorless, sweet smelling liquid or gas occurring naturally in petroleum, coal and wood tar. There is inadequate evidence for carcinogenicity of xylene in humans. Exposure can occur via inhalation, ingestion, eye or skin contact with symptoms including headache, dizziness, nausea and vomiting (Kandyala, Raghavendra, & Rajasekharan, 2010). The OSHA PEL for xylene is 100 ppm (“NIOSH Pocket Guide to Chemical Hazards - o-Xylene,” 2016).
- The Dangers of Hydrochloric Acid Exposure (2011), informs that hydrochloric acid is formed when hydrogen chloride dissolves in water, and is used in the process of making tin, cleaning metal products, electroplating, cleaning out boilers, as a catalyst in some chemical processes, to make fertilizer and dye, in photography, textile and rubber manufacturing. Very corrosive on contact, skin exposure can cause severe burns to the skin or digestive system, or even blindness. Vapor exposures can cause coughing, shortness of breath, larynx spasms, respiratory tract sores, and fluid buildup in the lungs (“Dangers of Hydrochloric Acid Exposure,” 2011). THE OSHA PEL is 5 ppm (“NIOSH Pocket Guide to Chemical Hazards - Hydrogen Chloride,” 2016).

- Helmenstein (2017, para. 1, 2, 3), informs that polynuclear aromatic hydrocarbons (PNA's), also known as PAH, polycyclic aromatic hydrocarbons, and polyaromatic hydrocarbon, are molecules made from fusing two or more benzene rings, only containing carbon and hydrogen atoms. Natural PNA's form from forest fires, volcanic eruptions, coal and petroleum. Man contributes PAH's by burning wood and incomplete combustion of fossil fuels, cooking food at a high temperature, grilled or smoked, and chemicals are released from cigarette smoke and burning waste (Helmenstein, 2017, para. 6, 7, 8, & 9). Exposure can result from contaminated air, eating foods that have the compounds or from skin contact. The health effects are associated with genetic damage and diseases, often mutagenic, carcinogenic, and teratogenic. There are seven PAH's the EPA has identified as carcinogens: (a) benz[a]anthracene, (b) benzo[a]pyrene, (c) benzo[b]flouranthene, (d) benzo[k]flouranthene, (e) chrysene, (f) dibenz[a, h]anthracene, (g) indeno(1,2,3-cd)pyrene (Helmenstein, 2017, para. 10 & 11). Benz[a]anthracene, benzo[b]flouranthene, chrysene, benzo[a]pyrene are all coal tar pitch volatiles with an OSHA PEL of 0.2 mg/m³ ("Coal Tar Pitch Volatiles (benzene soluble fraction)," n.d.). benzo[k]flouranthene should be evaluated in terms of the TLV-TWA for coal tar pitch volatile as benzene soluble 0.2 mg/m³ ("Benzo(k)flouranthene," 2014). Dibenz[a,h]anthracene has no TLV established ("Dibenzo(a,h)anthracene," 2014). Indeno(1,2,3-cd)pyrene has been recommended by the ACGIH to be evaluated in the terms of the TLV-TWA for coal tar pitch volatile, as benzene soluble 0.2 mg/m³ ("Indeno(1,2,3-cd)pyrene," 2014).
- Asbestos has six naturally occurring types; chrysotile, tremolite, crocidolite, amosite, anthophyllite, and actinolite, all highly toxic and the primary cause of mesothelioma

cancer (“Asbestos: An Overview of What it is & exposure Risks,” 2017). The article *What is Asbestos* (n.d.), indicated that asbestos is now strictly regulated and it once was the material of choice for several products including, but not limited to, roof shingles, floor tiles, ceiling materials, cement compounds, textile products, and automotive parts. The fibers are microscopic in nature and are extremely durable and resistant to fire and most chemical reactions and breakdowns. Once inhaled, fibers cling to the respiratory system, including the lining of the lungs and inner cavity tissue, not easily expelled or broken down by the body. Exposures present three major lung conditions; lung cancer, mesothelioma, and asbestosis, with the associated symptoms of coughing, chest pain, and difficulty breathing (“What is Asbestos,” n.d.). The OSHA PEL for asbestos is 0.1 fiber per cubic centimeter of air (0.1 fiber/cm³) (“Appendix C - Supplementary Exposure Limits,” 2016).

- Commonly used in batteries, alloys, coatings, solar cells, plastic stabilizers, and pigments, cadmium is a soft malleable bluish white metal found in zinc ores and in cadmium mineral greenockite (“Cadmium,” n.d.). Exposures occur from inhalation, ingestion, and absorption, with inhalation being the major route of occupational exposure through manufacture of products containing cadmium such as paint and operations such as plating, soldering, and welding (“Cadmium Toxicity - How are People Exposed to Cadmium?,” 2008). The OSHA PEL for cadmium compounds is 0.005 mg/m³ (“NIOSH Pocket Guide to Chemical Hazards - Cadmium,” 2016). Cadmium is considered to be carcinogenic to humans (“Toxic Substances Portal - Cadmium,” 2011).
- The *Toxic Substances Portal - Chromium* (2013) page details that chromium is a naturally occurring element found in rocks, animals, plants, and soil, existing in several

different forms such as liquid, solid, or gas. Exposure occurs from ingestion or inhalation, with inhalation damaging the nose and causing cancer and ingestion resulting in anemia or damage to the stomach or intestines (“Toxic Substances portal - Chromium,” 2013). Symptoms of exposure to different chromium compounds include shortness of breath, coughing, wheezing, perforations and ulcerations of the septum, bronchitis, decreased pulmonary function, pneumonia, and other respiratory effects. Human studies have shown that inhaled chromium (VI) is a human carcinogen (“Chromium Compounds Hazard Report,” n.d.). The OSHA PEL for chromium metal is 1 mg/m³ (“NIOSH Pocket Guide to Chemical Hazards - Chromium metal,” 2016).

- The EPA article on lead, *Learn about Lead* (2017) explains that toxic to humans and animals, lead can be found in all parts of our environment including the air, soil, water, and even inside our homes. Many lead compounds in our homes are in the form of paint, ceramics, pipes and plumbing materials, solders, gasoline, batteries, ammunition, and cosmetics. The effects of lead exposure include the following; behavior and learning problems, lower IQ and hyperactivity, slowed growth, hearing problems, anemia, reduced growth of the fetus, premature birth, cardiovascular effects, increased blood pressure and incidence of hypertension, decreased kidney function and reproductive problems (“Learn about Lead,” 2017). The OSHA PEL for lead is 0.050 mg/m³ (“NIOSH Pocket Guide to Chemical Hazards - Lead,” 2016).
- The article *What is the difference between respirable and total dust sampling?* (n.d.), explains that the ACGIH has been examining three dust size fractions;
 - Inhalable dust particles are those materials that are hazardous when deposited in the respiratory tract including the nose and mouth.

- Thoracic dust particles are those materials that are hazardous when deposited within the lung airways and the gas-exchange region.
- Respirable dust particles are those materials that are hazardous when deposited in the gas-exchange region.

Dust particles can be natural or manmade and can vary in size from visible to invisible, with health effects from exposure causing irritation of the eyes, coughing, sneezing, hay fever, and asthma attacks (“Health effects of dust,” n.d.). The OSHA PEL for total dust is 15 mg/m³ (“Particulates Not Otherwise Regulated (Total Dust),” n.d.).

- The *Toxic Substances Portal - Acrolein* (n.d.) page informs that acrolein is a colorless or yellow liquid with a disagreeable odor used in pesticides and in making of other chemicals. Dissolving in water easily and changing to vapor when heated, exposure can occur from smoking tobacco, breathing in air containing tobacco smoke or automobile exhaust, working or living near industries where acrolein is used, or inhaling vapors from overheated cooking oil or grease. Exposure from inhalation can cause irritation to the nasal cavity, lowered breathing rate, damage to the lining of the lungs, while animals that have ingested it have shown stomach irritation, vomiting, stomach ulcers and bleeding (“Toxic Substance Portal - Acrolein,” n.d.). The OSHA PEL for acrolein is 0.1 ppm (“NIOSH Pocket Guide to Chemical Hazards - Acrolein,” 2016).

The findings discovered during the literature review for this applied research project directed the author by laying a foundation of credibility for the need to continue to identify the toxic chemical exposure hazards that firefighters may be exposed to during overhaul operations along with the effects of positive pressure ventilation to the overhaul environment. Literature on the chemicals present in the overhaul environment indicate unpredictable toxic exposure hazards

to firefighters. The inherent risk of being in the overhaul environment can have lasting effects on anyone that enters without personal protective equipment. Firefighting operations in the overhaul stage present many challenges in ensuring the safety of all personnel on scene and require that further research direct standard operating procedures to protect responder vulnerabilities.

Procedures

The purpose of this research was to identify what toxic chemical exposures the Casper Fire EMS firefighters may be exposed to during real fire overhaul operations with positive pressure ventilation. Descriptive methodology was used to direct an air sampling data collection and analysis, and an email survey to other fire service organizations.

An air sampling plan, CFEMS Overhaul Operations Air Sampling Plan (Appendix A), was developed to gather information on the toxic chemicals in real fire overhaul operations that the CFEMS responded to and operated within. The framework for the air sampling plan included: (a) an analytical timeline, (b) analytical compounds, (c) sampling protocol, (d) sample collection, (e) shipment and re-ordering, (f) analytical results, and (g) financial.

The analytical timeline was determined to be a four-month time frame in which samples were to be collected on structure fires that required overhaul operations. This time frame was set to be from May 2017 through August 2017, with plans to request an extension for research through the National Fire Academy Executive Fire officer program in the event that more time was needed to do an analysis on more samples.

In determining the analytical compounds, an interview was scheduled with C.S.P. Steven Dacus (personal communication, March 13, 2017) with CS Consulting of Casper, WY for direction. ESIS Environmental Health Laboratory was contacted for services. Lab analysis would

cost up to \$6,000 and Dacus (personal communication, March 13, 2017) pledged financial support for half of the lab fees.

The research was presented to Division Chief Daniel Griswold (personal communication, March 15, 2017), to establish that the sampling guidelines for safe operations, with no personnel being exposed to toxic environments, ensuring that the sample collection during the overhaul operations maintained positive pressure ventilation in an effort to protect firefighters from non-visible toxins as much as possible during operations and the study.

In determining the structure of the sampling protocol, ESIS Environmental, James Kenny (personal communication, March 21, 2017) was contacted to discuss the purposes of the research. In order to identify non-visible toxic chemical compounds, it was recommended that a Gas Chromatography/Mass Spectrometry (GC/MS) scan to include total hydrocarbons quantitated as toluene plus the ten largest peaks identified by the GC/MS software, as well as an aldehyde (Carbonyl) scan, all with a detection range from 0.5 ppb to the percent range.

Sample collection, shipment, and re-ordering was also assisted through ESIS Environmental (J. Kenney, personal communication, March 21, 2013). Information was obtained that the canisters and sampling equipment to be used would be accompanied by instructions for use (Appendix B). The sampling would require multiple responsible personnel for the sample collection, due to the department having three separate shifts and the possibility of a fire on any of the three shifts.

An interview with Division Chief of Operations, Daniel Griswold (personal communication, March 15, 2017), determined that the battalion chiefs of each of the three shifts would be informed and able to assist with the sampling procedures and also recruit interested personnel from each shift to assist if needed. The sample collection was to be executed by those

trained in the procedures, with notification to the author to maintain a chain of custody with documentation and proper shipment to the laboratory, followed by the re-ordering of replacement canisters to be ready for the next samples. The final draft of the sampling plan was submitted to Chief Griswold on May 9, 2017 (personal communication, May 9, 2017). On May 22, 2017, the Division Chief of Operations, D. Griswold, relayed the sampling plan to the battalion chiefs through departmental email (Appendix A). Multiple shifts and stations were communicated with, recruiting individuals to assist in the sample collection. The training for the sample collection included the CFEMS Overhaul Operations Air Sampling Plan (Appendix A), a short list of reference instructions (Appendix C), and air monitoring logs (Appendix D).

The analysis desired was determined through dialog with Kenny (personal communication, March 21, 2017) based off of ESIS Environmental laboratory standards. Results were to be analyzed through sample collection with Entech canisters and analyzed by GC/MS and include total hydrocarbons quantitated as toluene plus the ten largest peaks in the chromatogram as identified by the GC/MS library search software. Detection range extends from 0.5 ppb to the percent range. After the first 1-3 initial GC/MS analytical scans, the scan could then be reduced to a more focused range of chemicals if needed. This was based off of similarities in results and laboratory recommendations. Each sample analysis report was reported to be available within 5-7 business days of the laboratory receiving the samples. The final report for the study was anticipated for completion by September 17th, 2017, unless an extension request was needed for the gathering of additional data.

After receiving the results, further interpretation was required to relate the compounds discovered to exposure risks. Each report was to contain three separate reports within four pages of results, and one interpretation page; GC/MS Whole air canisters; TO-15 scan (one page);

Carbonyl Scan (one page); and GC/MS Spectral Library Match Summation Report (two pages). Each report required interpretation for research purposes (Appendix E). The financial responsibilities were obtained through sponsorship through any available funds from the Casper Fire-EMS department and matched funding from CS Consulting LLC. Price estimates from Kenny (personal communication, March 21, 2017), deduced an estimated total research cost of around \$6,000, based off of 10 separate overhaul sample collections. The research responsibility was conducted by the author. Lab analysis was conducted through ESIS Environmental Health Laboratory.

An email survey (Appendix F) was developed to assess what other fire service organizations monitored for toxic exposure hazards and identify hazards that other agencies monitor for or had identified. CFEMS equipment used to monitor in the overhaul environment (Austin Burgess, email communication, March 9, 2017) and the possible toxic exposures identified in the literature review (Bolstad-Johnson et al, 2017) generated the chemical exposure details in the email survey (Appendix F). Google forms was the data collection instrument used in developing and distributing the survey. Google forms allows the user to create a customized, web-based data collection media. When the user has created the form, a link can be obtained and distributed to the survey group via email or text. The recipient within the desired survey group opens the link on their mobile device or personal computer, answers the questions, and submits the survey by clicking “submit” at the end of the survey. Once the respondent submits their information, the data is then collected into the Google form database specific to that form. The information is recorded and automatically calculates the percentages respective to each individual question. To determine the survey questions data gathering through literature review was used to determine elements that previous research had identified within the overhaul

environment. The selected survey group was identified as any fire service organization that had researched toxic exposures in the overhaul stage of structure fires. To maintain focus on this survey group, previous experience dictated that a large email network through the National Fire Academy Executive Fire Officer program could be used as a data gathering platform for the fire service. This email network was a selected resource due to the vast amount of information available from other fire-rescue organizations. EFO Section Liaison, Spencer Cheatham (personal communication, September 30, 2017) (Appendix G), confirmed an email distribution list of about 1,250 EFO section members. Angela Krantz (personal communication, September 15, 2016) (Appendix H) with the National Fire Academy advised that to distribute information to the email group, send the following information to efo@iafc.org:

- Name of the project
- Name, rank and department
- Brief Description of the project that explains why members should take the survey
- Survey deadline
- Link to survey

The email with the information was sent on August 13, 2017. For additional organizations that had conducted research of the toxic exposures in overhaul environments, the Google search engine was used to search for the following word set; fire-rescue agencies overhaul operations exposure, fire department overhaul exposures, fire overhaul exposure to firefighters, and fire overhaul research. This search method was able to produce a limited list of departments that have researched firefighter exposures in the overhaul environment. Each department identified through the internet was contacted through email (Appendix I) and sent a link to the survey (Appendix F); 32 responses were received.

There were limitations identified that may have influenced the study. The first limitation identified through the air sampling, was that every structure fire will be different, containing different structural components and contents present in every situation. This presents the caveat that no two fires will be the same, and only representing the toxins in each specific environment. The second limitation identified was on how few organizations had data and research they had conducted respective to air sampling for a broad spectrum of non-visible toxins in the overhaul environment. Another limitation identified was the lack of data available on the toxic exposure hazard comparison between the non-ventilated overhaul environment and the overhaul environment with positive pressure ventilation; there was no studies or information found comparing the two. The limitation of time impacted the study by restricting the amount of structure fires the CFEMS responded to and the amount of samples that were able to be collected. The dynamics of emergency operations on the fire ground was also a limitation in the ability to obtain comparative samples on the single fire that the CFEMS did obtain samples on.

Results

Descriptive methodology was used to guide the data collection to answer the research questions. The first question was answered through air sample collection and analysis. The second question was answered with air sample collection and analysis. The third research question was answered with literature review and a survey.

The first question asked: What are the toxic chemical exposures to firefighters during real structure fire overhaul operations without positive pressure ventilation? Although literature was discovered on exposures during real fire overhaul operations, there was only one article (“Important Considerations for Overhaul and Salvage,” 2009) found recommending the use of positive pressure ventilation, but there was not specific information relative to the differences of

before and after positive pressure ventilation. Air sampling was not able to analyze the results of before and after positive pressure ventilation due to limitation on the fire ground operations.

Pre-Ventilation Samples, Structure Fire #1 - July 9, 2017: The first structure fire that was significant enough for sampling occurred on July 9, 2017. The sampling procedures were not followed as directed due to circumstances with the structure fire. Samples were still obtained, with one from a room that was pre-overhaul, post ventilation in a downstairs room (#1 Sample canister number 3217), and one sample that was pre-overhaul, post ventilation in an upstairs room (#2 Sample canister number 3216). The lab analysis for the structure fire on July 9, 2017 provided information from three separate reports; GC/MS Whole air canisters; TO-15 scan (Appendix J); Carbonyl Scan (Appendix K); and GC/MS Spectral Library Match Summation Report (Appendix L). These reports resulted in four separate pages of information from the lab, along with an interpretational page for the library match report. For the purposes of the research, the first fire did not provide pre-overhaul, pre-ventilation results, yet pre-overhaul post ventilation samples were obtained, which assisted in answering the second research question.

Pre-Ventilation Samples, Structure Fire #2 – September 3, 2017: The second structure fire that was significant enough for sampling occurred on September 3, 2017. The sampling procedures were followed, yet equipment use for the collection of the samples failed due to incomplete connections of the air restrictors on the air canisters. No samples were obtained.

Research question one Summary: The first research question was focused on determining what the toxic chemical exposures are to firefighters during real structure fire overhaul operations prior to positive pressure ventilation. The samples collected and analysis performed were unable to capture the pre-ventilation environment. The lack of this sample results in the inability to effectively determine whether positive pressure ventilation helps or harms the toxic

exposures in the overhaul environment. The literature review did not provide any data on the overhaul environment, and the question still remains on the effects of positive pressure ventilation on exposure hazards.

The second research question asked: What are the toxic chemical exposures to firefighters during real structure fire overhaul operations with positive pressure ventilation? Although literature was discovered on exposures during real fire overhaul operations, there was only one article (“Important Considerations for Overhaul and Salvage,” 2009) discovered relative to recommending the use of positive pressure ventilation during real structure fire overhaul operations, but there was no supporting information on the specific benefits of using the ventilation. However, air sampling and data analysis performed in CFEMS overhaul operations provided data to answer the question.

Post Ventilation Samples, Structure Fire #1 - July 9, 2017: The first report, the GC/MS whole air canister TO-15 scan, analyzes 81 different chemicals and total hydrocarbons (Appendix J). In the post ventilation sample #1, Canister # 3217, of the 81 different compounds analyzed, 26 provided detectable levels in micrograms per cubic meter (ug/m³) and parts per billion (ppb). Calculations to parts per million (ppm) from parts per billion (ppb) were performed and compared the levels to known OSHA PEL’s and Immediately Dangerous to Life or Health (IDLH) values. Values with a “N.D.” indicate that an IDLH has not been determined (“NIOSH Pocket Guide to Chemical Hazards,” n.d.). The values are provided in Table 1. Values identified near or exceeding OSHA PELs, STELs, or compounds suspected to be carcinogenic have been highlighted.

Table 1: Structure Fire #1, TO-15 Scan, Sample #1

#1 Canister 3217					
TO-15 Scan					
Compound	PPB	PPM	PEL PPM	STEL PPM	IDLH PPM
Acetone (“NIOSH Pocket guide to Chemical hazards - Acetone,” 2016)	19	0.019	1000	None	2500
Acetonitrile (“NIOSH Pocket guide to Chemical hazards - Acetonitrile,” 2016)	4.0	0.004	40	None	500
Acrylonitrile (“NIOSH Pocket guide to Chemical hazards - Acrylonitrile,” 2016)	1.8	0.0018	2	None	85
Benzene (“NIOSH Pocket guide to Chemical hazards - Benzene,” 2016)	77	0.077	1	5	500
Benzyl Chloride (“NIOSH Pocket guide to Chemical hazards - Benzyl chloride,” 2016)	0.66	0.00066	1	None	10
1, 3 Butadiene (“NIOSH Pocket guide to Chemical hazards - 1, 3 Butadiene,” 2016)	12	0.012	1	5	2000
Chloromethane (“NIOSH Pocket guide to Chemical hazards - Methyl chloride,” 2016)	16	0.016	100	None	2000
Ethanol (“NIOSH Pocket guide to Chemical hazards - Ethyl alcohol,” 2016)	330	0.33	1000	None	3300
Ethyl Acetate (“NIOSH Pocket guide to Chemical hazards - Ethyl acetate,” 2016)	1.3	0.0013	400	None	2000

Ethyl Benzene (“NIOSH Pocket guide to Chemical hazards - Ethyl benzene,” 2016)	1.9	0.0019	100	None	800
Heptane (“NIOSH Pocket guide to Chemical hazards - n-Heptane,” 2016)	0.67	0.00067	500	None	750
Hexane (“NIOSH Pocket guide to Chemical hazards - n-Hexane,” 2016)	0.85	0.00085	500	None	1100
4-Isopropyltoluene (“p-Cymene,” 2014)	0.72	0.00072	None	None	N.D.
Methanol (“NIOSH Pocket guide to Chemical hazards - Methyl alcohol,” 2016)	430	0.43	200	None	6000
Methyl Ethyl Ketone (“NIOSH Pocket guide to Chemical hazards - 2-Butanone,” 2016a)	4.8	0.0048	200	None	3000
Methyl Methacrylate (“NIOSH Pocket guide to Chemical hazards - Methyl methacrylate,” 2016)	7.7	0.0077	100	None	1000
Naphthalene (“NIOSH Pocket guide to Chemical hazards - Naphthalene,” 2016)	18	0.018	10	None	250
2-Propanol (“NIOSH Pocket guide to Chemical hazards - Isopropyl alcohol,” 2016)	1.9	0.0019	400	None	2000
Propene (“Propylene,” 2014).	51	0.051	None	None	N.D.
Styrene (“NIOSH Pocket guide to Chemical hazards - Styrene,” 2016)	13	0.013	100	None	700
Tetrahydrofuran (“NIOSH Pocket guide to Chemical hazards - Tetrahydrofuran,” 2016)	0.70	0.0007	200	None	2000

Toluene (“NIOSH Pocket guide to Chemical hazards - Toluene,” 2016)	15	0.015	200	None	500
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In the post ventilation sample #2, Canister # 3216, of the 81 different compounds analyzed, 27 provided detectable levels in micrograms per cubic meter (ug/m³) and parts per billion (ppb). Calculations to parts per million (ppm) from parts per billion (ppb) were performed and compared the levels to known OSHA PEL’s and Immediately Dangerous to Life or Health (IDLH) values. Values with a “N.D.” indicate that an IDLH has not been determined (“NIOSH Pocket Guide to Chemical Hazards,” n.d.). The values are provided in Table 2. Values identified near or exceeding OSHA PELs, STELs, or compounds suspected to be carcinogenic have been highlighted.

Table 2: Structure Fire #1, TO-15 Scan, Sample #2

#2 Canister 3216					
TO-15 Scan					
Compound	PPB	PPM	PEL PPM	STEL PPM	IDLH PPM
Acetone (“NIOSH Pocket guide to Chemical hazards - Acetone,” 2016)	19	0.019	1000	None	2500
Acetonitrile (“NIOSH Pocket guide to Chemical hazards - Acetonitrile,” 2016)	4.2	0.0042	40	None	500
Acrylonitrile (“NIOSH Pocket guide to Chemical hazards - Acrylonitrile,” 2016)	1.8	0.0018	2	None	85

Benzene (“NIOSH Pocket guide to Chemical hazards - Benzene,” 2016)	58	0.058	1	5	500
Benzyl Chloride (“NIOSH Pocket guide to Chemical hazards - Benzyl chloride,” 2016)	0.69	0.00069	1	None	10
1, 3 Butadiene (“NIOSH Pocket guide to Chemical hazards - 1, 3 Butadiene,” 2016)	12	0.012	1	5	2000
Chloromethane (“NIOSH Pocket guide to Chemical hazards - Methyl chloride,” 2016)	17	0.017	100	None	2000
Dichlorodifluoromethane (“NIOSH Pocket guide to Chemical hazards - Dichlorodifluoromethane,” 2016)	.53	.00053	1000	None	15000
Ethanol (“NIOSH Pocket guide to Chemical hazards - Ethyl alcohol,” 2016)	340	0.34	1000	None	3300
Ethyl Acetate (“NIOSH Pocket guide to Chemical hazards - Ethyl acetate,” 2016)	1.3	0.0013	400	None	2000
Ethyl Benzene (“NIOSH Pocket guide to Chemical hazards - Ethyl benzene,” 2016)	2.0	0.002	100	None	800
Heptane (“NIOSH Pocket guide to Chemical hazards - n-Heptane,” 2016)	0.97	0.00097	500	None	750
Hexane (“NIOSH Pocket guide to Chemical hazards - n-Hexane,” 2016)	1.1	0.0011	500	None	1100
4-Isopropyltoluene (“p-Cymene,” 2014)	0.70	0.00070	None	None	N.D.

Methanol (“NIOSH Pocket guide to Chemical hazards - Methyl alcohol,” 2016)	490	0.49	200	None	6000
Methyl Ethyl Ketone (“NIOSH Pocket guide to Chemical hazards - 2-Butanone,” 2016a)	4.3	0.0043	200	None	3000
Methyl Methacrylate (“NIOSH Pocket guide to Chemical hazards - Methyl methacrylate,” 2016)	7.4	0.0074	100	None	1000
Naphthalene (“NIOSH Pocket guide to Chemical hazards - Naphthalene,” 2016)	18	0.018	10	None	250
2-Propanol (“NIOSH Pocket guide to Chemical hazards - Isopropyl alcohol,” 2016)	3.3	0.0033	400	None	2000
Propene (“Propylene,” 2014).	51	0.051	None	None	N.D.
Styrene (“NIOSH Pocket guide to Chemical hazards - Styrene,” 2016)	13	0.013	100	None	700
Tetrahydrofuran (“NIOSH Pocket guide to Chemical hazards - Tetrahydrofuran,” 2016)	0.73	0.00073	200	None	2000
Toluene (“NIOSH Pocket guide to Chemical hazards - Toluene,” 2016)	15	0.015	200	None	500

The notes for the TO-15 scan indicated that a 22-minute sample time was collected using a 12-minute restrictor. Sampling beyond the recommended time may cause a loss of compounds through reverse migration, resulting in underestimated concentrations. Additionally, Polynuclear

Aromatic Hydrocarbons (PNA's) and other high boiling point compounds were observed in both samples.

The second report, the GC/MS whole air canister Carbonyl Scan (Appendix K), analyzes 18 different compounds relative to aldehydes. In the post ventilation sample #1, Canister # 3217, of the 18 different compounds analyzed, 17 provided detectable levels in micrograms per cubic meter (ug/m³) and parts per billion (ppb). In the post ventilation sample #2, Canister # 3216, of the 18 different compounds analyzed, 13 provided detectable levels in micrograms per cubic meter (ug/m³) and parts per billion (ppb). The author calculated conversions into parts per million (ppm) from parts per billion (ppb) and compared the levels to known OSHA PEL's, OSHA STELs, and Immediately Dangerous to Life or Health (IDLH) values. The values are provided below. Values identified near or exceeding OSHA PELs, OSHA STELs, or compounds suspected to be carcinogenic have been highlighted in Table 3.

Table 3: Structure Fire #1, Carbonyl Scan, Sample #1

#1 Canister 3217					
Carbonyl Scan					
Compound	PPB	PPM	PEL PPM	STEL PPM	IDLH PPM
Acetaldehyde (“NIOSH Pocket guide to Chemical hazards - Acetaldehyde,” 2016)	130	0.13	200	None	2000
Acrolein (“NIOSH Pocket guide to Chemical hazards - Acrolein,” 2016)	28	0.028	0.1	None	2
Benzaldehyde (“Benzaldehyde,” 2014)	4.9	0.0049	None	None	N.D.
Butyraldehyde (“Butyraldehyde,” 2014)	8.4	0.0084	None	None	N.D.

Crotonaldehyde (“NIOSH Pocket guide to Chemical hazards - Crotonaldehyde,” 2016)	12	0.012	2	None	50
2, 5-Dimethylbenzaldehyde	2.6	0.0026	None	None	N.D.
Formaldehyde (“NIOSH Pocket guide to Chemical hazards - Formaldehyde,” 2016)	230	0.23	0.75	2	20
Furfural (“NIOSH Pocket guide to Chemical hazards - Furfural,” 2016)	240	0.24	5	None	100
Heptanal (“Heptanal,” n.d.)	0.52	0.00052	None	None	N.D.
Hexanal (“Hexanal,” n.d.)	3.5	0.0035	None	None	N.D.
Nonanal (“Nonanal,” n.d.)	6.9	0.0069	None	None	N.D.
Octanal (“Octanal,” n.d.)	1.2	0.0012	None	None	N.D.
Propanal (“NIOSH Pocket guide to Chemical hazards - n-Propyl alcohol,” 2016)	16	0.016	200	None	800
o-Tolualdehyde (“o-Tolualdehyde,” n.d.)	1.1	0.0011	None	None	N.D.
m-Tolualdehyde	1.2	0.0012	None	None	N.D.
p-Tolualdehyde (“p-Tolualdehyde,” n.d.)	1.7	0.0017	None	None	N.D.
Valeraldehyde (“NIOSH Pocket guide to Chemical hazards - n-Valeraldehyde,” 2016)	1.2	0.0012	None	None	N.D.
Total Volatile Organic Compounds (TVOC) 1,900 ug/m ³					

In the post ventilation sample #2, Canister # 3216, of the 18 different compounds analyzed, 13 provided detectable levels in micrograms per cubic meter (ug/m³) and parts per billion (ppb). The author calculated conversions into parts per million (ppm) from parts per

billion (ppb) and compared the levels to known OSHA PEL's, OSHA STELs, and Immediately Dangerous to Life or Health (IDLH) values. The values are provided below. Values identified near or exceeding OSHA PELs, OSHA STELs, or compounds suspected to be carcinogenic have been highlighted in Table 4.

Table 4: Structure Fire #1, Carbonyl Scan, Sample #2

#2 Canister 3216					
Carbonyl Scan					
Compound	PPB	PPM	PEL PPM	STEL PPM	IDLH PPM
Acetaldehyde (“NIOSH Pocket guide to Chemical hazards - Acetaldehyde,” 2016)	120	0.12	200	None	2000
Acrolein (“NIOSH Pocket guide to Chemical hazards - Acrolein,” 2016)	26	0.026	0.1	None	2
Benzaldehyde (“Benzaldehyde,” 2014)	4.3	0.0043	None	None	N.D.
Butyraldehyde (“Butyraldehyde,” 2014)	9.2	0.0092	None	None	N.D.
Crotonaldehyde (“NIOSH Pocket guide to Chemical hazards - Crotonaldehyde,” 2016)	12	0.012	2	None	50
Formaldehyde (“NIOSH Pocket guide to Chemical hazards - Formaldehyde,” 2014b)	240	0.24	0.75	2	20
Furfural (“NIOSH Pocket guide to Chemical hazards - Furfural,” 2016)	240	0.24	5	None	100
Heptanal (“Heptanal,” n.d.)	0.53	0.00053	None	None	N.D.
Hexanal (“Hexanal,” n.d.)	3.3	0.0033	None	None	N.D.

Nonanal (“Nonanal,” n.d.)	6.2	0.0062	None	None	N.D.
Octanal (“Octanal,” n.d.)	1.0	0.001	None	None	N.D.
Propanal (“NIOSH Pocket guide to Chemical hazards - n-Propyl alcohol,” 2016)	15	0.015	200	None	800
Valeraldehyde (“NIOSH Pocket guide to Chemical hazards - n-Valeraldehyde,” 2016)	1.1	0.0011	None	None	N.D.
Total Volatile Organic Compounds (TVOC) 1,800 ug/m ³					

The third report, the Tentatively Identified Compounds (TIC’s) report (Appendix L), provides the top peaks identified within the scans. There were twelve peak compounds identified, of which the top ten were identified within the EPA TO-15 and Carbonyl Scans. This reinforces that values for the compounds possessing the highest peaks were identified and evaluated for exposure risks. Those twelve peak compounds comparative to the scan identified are illustrated in Table 5 and Table 6.

Table 5: Structure Fire #1, Top 10 peaks, Sample #1

#1 Canister 3217	
Sorted by Top 10 Peak Area Amounts of 109 Total Peaks	
Best Matching Spectrum Compounds	
Compound	Scan
Methyl Alcohol	TO-15
Acetaldehyde	Carbonyl
Ethanol	TO-15

Acetone	TO-15
Benzene	TO-15
2, 3-Butanedione	Not Detected in Scans
2-Butanone	Not Detected in Scans
Toluene	TO-15
Styrene	TO-15
Furfural	Carbonyl
Nonanal	Carbonyl
Naphthalene	TO-15

Table 6: Structure Fire #1, Top 10 peaks, Sample #2

#2 Canister 3216	
Sorted by Top 10 Peak Area Amounts of 114 Total Peaks	
Best Matching Spectrum Compounds	
Compound	Scan
Methyl Alcohol	TO-15
Acetaldehyde	Carbonyl
Ethanol	TO-15
Acetone	TO-15
Benzene	TO-15
2, 3-Butanedione	Not Detected in Scans
2-Butanone	Not Detected in Scans

Toluene	TO-15
Styrene	TO-15
Furfural	Carbonyl
Nonanal	Carbonyl
Naphthalene	TO-15

The two compounds that were not detected, 2, 3-Butanedione and 2-Butanone, were researched for OSHA PEL, STEL, and IDLH values. Values identified near or exceeding OSHA PELs, STELs, or compounds suspected to be carcinogenic have been highlighted in Table 7 and Table 8.

Table 7: Structure Fire #1, Compounds not detected in TO-15 or Carbonyl Scan, Sample #1

#1 Canister 3217							
Sorted by Top 10 Peak Area Amounts of 109 Total Peaks							
Best Matching Spectrum Compounds							
Compound	ug/m3	mg/m3	Molecular Weight	PPM	PEL PPM	STEL PPM	IDLH PPM
2, 3-Butanedione (“2, 3 - Butanedione,” n.d.)	25	0.025	86.09	0.0071	None	None	N.D.
2-Butanone (“NIOSH Pocket guide to Chemical hazards - 2-Butanone,” 2016a)	25	0.025	72.1	0.00848	200	None	3000

Table 8: Structure Fire #1, Compounds not detected in TO-15 or Carbonyl Scan, Sample #2

#2 Canister 3216							
Sorted by Top 10 Peak Area Amounts of 114 Total Peaks							
Best Matching Spectrum Compounds							
Compound	ug/m3	mg/m3	Molecular Weight	PPM	PEL PPM	STEL PPM	IDLH PPM
2, 3-Butanedione (“2, 3 - Butanedione,” n.d.)	26	0.026	86.09	0.00738	None	None	N.D.
2-Butanone (“NIOSH Pocket guide to Chemical hazards - 2-Butanone,” 2016a)	26	0.026	72.1	0.00882	200	None	3000

Additionally, for the compounds and values, the author provided the exposure routes and symptoms to exposure to all of the compounds, and if the compound is noted as a known carcinogen to humans (Appendix M). The list of possible exposure routes of the chemicals identified included: (a) inhalation, (b) ingestion, (c) skin and/or eye contact, (d) and skin absorption. The chemical exposure effects (Appendix N), along with being potential carcinogens, provide an overview of the known effects the chemicals detected.

Post-Ventilation Samples, Structure Fire #2 – September 3, 2017: The second structure fire that was significant enough for sampling occurred on September 3, 2017. The sampling procedures were followed, yet equipment use for the collection of the samples failed due to incomplete connections of the air restrictors on the air canisters. No samples were obtained.

The second research question was focused on determining what the toxic chemical exposures are to firefighters during real structure fire overhaul operations with positive pressure ventilation. The samples collected and analysis performed showed that there were 44 compounds that were identified as exposure risks in the one fire that samples were obtained. Of those 44 compounds, 6 were known carcinogens. The list of all toxic chemical exposures detected in the overhaul environment after ventilation (Appendix M), was further confirmation of the dangerous exposures to firefighters in the overhaul environment with positive pressure ventilation in progress.

The third research question asked: What exposures have been discovered by other agencies on toxic chemical exposures to firefighters during real structure fire overhaul operations? The literature review provided a baseline of information on studies that have been performed to identify toxic chemical exposures to firefighters. The exposure hazards found by other agencies in literature review included: CO (*A Study*, 2011); perfluorinated compounds (PFCs), Polychlorinated and polybrominated dioxins and furans (“Firefighter Toxic Substance Exposures,” n.d., para. 1); sulfur dioxide (SO₂), hydrogen cyanide (HCN), nitrogen oxides (NO and NO₂), formaldehyde, benzene and phosgene (*Fire Overhaul Safety*, 2012); carboxyhemoglobin, acetaldehyde, formaldehyde, sulfur dioxide, respirable dust, and sulfuric acid (Herbert, 2009, p. 4); and from Bolstad-Johnson et al. (2017), aldehydes; benzene; toluene; ethyl benzene; xylene; hydrochloric acid; polynuclear aromatic hydrocarbons (PNA); respirable dust; and HCN; CO, NO₂, and SO₂.

The survey that was distributed gathered 32 responses (Appendix P) from other fire rescue organizations on the specific toxic exposure hazards that the responding agencies have identified and monitor for. The survey responses to the question (Does your organization perform overhaul operations on structure fires?) indicated that all 32 organizations (100%)

confirmed that perform overhaul operations. The second survey question (Does your organization perform positive pressure ventilation during overhaul operations on structure fires?) indicated a *yes* by 29 organizations (90.6%), with three (9.4%) not performing positive pressure ventilation during overhaul operations on structure fires. The third survey question (What does your organization monitor for in the overhaul environment?) allowed the ability to select yes or no on carbon monoxide (CO), hydrogen cyanide (HCN), lower explosive limit (LEL), and oxygen (O₂). The responses to survey question three were: carbon monoxide (CO) is monitored by 28 (87.5%), with 4 (12.5%) not monitoring for CO; hydrogen cyanide (HCN) is monitored by 20 (62.5%), with 12 (37.5%) not monitoring for HCN; lower explosive limit (LEL) is monitored by 25 (78.1%), with 7 (21.9%) not monitoring for LEL; oxygen (O₂) is monitored by 25 (78.1%), with 7 (21.9%) not monitoring for LEL; additional toxic chemicals are monitored by 8 (25%), with 24 (75%) not monitoring for additional toxic chemicals.

There were 21 additional toxic chemicals (Appendix O) included in the survey with an option to write in additional chemicals. Of the additional chemicals, eight agencies indicated that they monitor for additional chemicals, one of the eight (12.5%) monitors for nitric oxide (NO₂), and two of the eight (25%) monitor for sulfur dioxide (SO₂), with one additional write in (12.5%) stating that they monitor for H₂S with their four-gas meter.

Additional comments were an option prior to submittal at the end of the survey. Information relative to the overhaul environment indicated that one organization had policies on equipment for monitoring and it rarely gets done, with the additional statement that they still have a hard time getting firefighters to wear an SCBA during overhaul. Another organization reported that they require their firefighters to exit the structure for 45-60 minutes after the knockdown before overhaul begins. Another agency reported that they have an instrument

(chempro) that has been an overhaul library and that it resides on their hazmat unit and rarely gets used in overhaul operations. An additional notation was made that their organization performs overhaul with SCBAs at all times.

The third research question was focused on determining what other agencies had discovered on toxic chemical exposures to firefighters during real structure fire overhaul operations. The results of the surveys showed that out of 32 (100%) responding agencies, all agencies perform overhaul operations and 29 (90.6%) perform positive pressure ventilation during overhaul operations. When ranking the chemicals that agencies monitor, the order was: CO, LEL & O₂, HCN, SO₂, NO & H₂S. With a list of seven out of 25 listed exposure hazards, there was evidence that many toxic chemical exposures are not addressed. The exposures monitored that were confirmed through agencies (Appendix P), was supportive of the research that identified toxic chemical exposures to firefighters in the overhaul environment.

Discussion

This applied research project has been very beneficial in regards to the providing information to the CFEMS on the toxic exposure hazards present in the overhaul stage of fire operations. The air samples obtained and analyzed provide confirmation that firefighters are being exposed to toxins that have the ability to physically harm and kill personnel. Data on the differences in the overhaul environment pre-and post-ventilation, can reinforce or discredit the importance of positive pressure ventilation and the effects of toxins in the environment when used. As noted there are still detectable levels in the overhaul environment post-ventilation, identifying that there is still an exposure hazard. The survey results (Appendix P) showed that there is a baseline caution used with monitoring for basic elements in the environment (CO, HCN, LEL, O₂), yet many of the unknown non-visible toxins that require deeper analysis do not

fit within day to day firefighter safety. “Whether in a residence or chemical plant, firefighters have to deal with unknown exposures in every fire (“Firefighting and Your Health, Exposure to Toxic Chemicals on the Job,” n.d.).” The literature identified the recommendation that personnel involved in overhaul operations use an SCBA, full PPE, and positive pressure ventilation (“Important Considerations for Overhaul and Salvage,” 2009). The combination of positive pressure ventilation during overhaul operations and full PPE requirements will support the USFA’s third key initiative; promote a culture of health, wellness and behavior that enhances emergency responder safety and survival (United States Fire Administration, 2014, p. 1, 9, &12). Analysis of the air samples (Appendix J, K, L) and the effects of the identified compounds (Appendix M, N) confirmed that personnel involved in overhaul operations should use an SCBA, full PPE, and positive pressure ventilation. The effects of positive pressure ventilation were not confirmed in the research analysis, but supported that there were still chemicals present with its use (Appendix J, K, L). Research and information are still in the beginning stages of truly identifying what toxic chemical exposures firefighters are exposed to and the aftermath of such exposures.

Chemical exposures and cancer date back thousands of years (Brautbar, n.d.). Compounds discovered in the overhaul (Table 1, 2, 3, 4) environment post-ventilation, detected six known carcinogens in the overhaul environment: (a) acrylonitrile, benzene, (a) 1, 3 butadiene, (b) chloromethane, (c) acetaldehyde, and (d) formaldehyde. Additionally, ethyl benzene was detected, which is not classifiable as carcinogenic to humans, but animal studies have increased incidence of kidney and testicular tumors in rats and lung and liver tumors in mice (“Ethylbenzene,” n.d.). PNA’s were also detected, with health effects associated with genetic damage and diseases, often mutagenic, carcinogenic, and teratogenic (Helmenstein,

2017, para. 10, 11). The literature review and the CFEMS samples identified the following chemicals as exposure hazards: (a) acetaldehyde, (b) acrolein, (c) benzene, (d) ethyl benzene, (e) formaldehyde, (f) toluene, and (g) PNA's. Compounds identified by the CFEMS that were not found in research included: (a) Acrylonitrile, (b) 1,3-butadiene, and (c) chloromethane. All of these compounds are known carcinogens.

Of the identified chemical compounds, none of them exceeded any of the OSHA PELs or STELs. OSHA PELs were referenced because they are legally enforceable by OSHA in the United States (Bako, 2012, para. 4, 5). There were two compounds that were identified with levels that were of concern. Acrolein has a PEL of 0.1 ("NIOSH Pocket Guide to Chemical Hazards – Acrolein," 2016). Sample levels post ventilation were 0.028 and 0.026 ppm, being 28% and 26% of the 8-hour exposure limit values. Formaldehyde has a PEL of 0.75 ("NIOSH Pocket Guide to Chemical Hazards – Formaldehyde," 2016) Sample levels post ventilation were 0.23 and 0.24 ppm, being 30.66% and 32% of the 8-hour exposure limit values.

Although none of the chemical compounds identified were above OSHA PELs, the presence of these detected compounds support information revealing that firefighters come in contact with cancer causing materials when they fight fire, with an increased risk of getting colon, brain, bladder, kidney, and Hodgkins lymphoma cancer ("Campaign for a Smoke Free Union," n.d.). Identification of these chemicals in a fire that CFEMS personnel were exposed to is alarming enough to question what the exposures are in every overhaul operation and what do those exposures do over a career of fighting fire, even if they are not levels that are above OSHA PELs.

Researching what toxic chemical exposures other fire-rescue organizations have identified and or monitor for was a challenge in the aspect that consistency through every

organization is not alike and it is unknown if every agency responding has been thoroughly informed of the hazards associated with the overhaul phase of firefighting and what non-visible toxic exposures may be present. To contrast the level of concern in different organizations, both ends of the spectrum can be viewed: the Bolstad-Johnson et al. (2017) characterizing City of Phoenix firefighter exposures during the overhaul phase of 25 structure fires thoroughly looked at the toxic chemical exposures and produced results of exposure hazards, whereas the survey results (Appendix P), identified four organizations that do not monitor for exposures at all in the overhaul environment. Disparities such as this point out that research and communication throughout the fire service is either not consistent or organizations do not heed warning. Positive gains from the survey were identified showing the number of organizations that do monitor for some type of exposure hazard in their overhaul environments, which provides baseline data that there is some concern across the majority of organizations. All organization that did report that they monitor for exposures reported that CO was monitored. This can be looked at as a baseline exposure hazard, relative to traditional practices of if and when firefighters can doff their SCBA for easier working conditions in the overhaul phase of structure fires (*A Study*, 2011). This practice relates to how firefighters fail to recognize dangers associated with salvage and overhaul, and let their guard down and unfortunately there are many carcinogens present in smoke that can be inhaled and absorbed through the skin (“Important Considerations for Overhaul and Salvage,” 2009). Further research of exposures during the overhaul stage and the effects of positive pressure ventilation in it will enable the CFEMS to obtain a comprehensive view hazards. If research determines solid evidence that overhaul atmospheres repetitively contain toxic chemical exposures and positive pressure ventilation helps or hinders it, it will be a step in the right direction of creating a foundation of safety.

Recommendations

The recommendations were based on the result of the study. The first recommendation was to ensure that all precautions be utilized in the overhaul stages of the operations to reduce or eliminate toxic chemical exposures to firefighters. The second recommendation was that further research be conducted by the CFEMS to identify concrete data on the effects of positive pressure ventilation in overhaul operations on toxic chemical exposures. The third recommendation was to partner with stakeholders in the community that would financially support further research. It was also recommended that all members of the CFEMS are informed on the final results of the research project and the dangers they have been exposing themselves to in overhaul operations. Additional consideration should be given to the modification of sample collection to ensure all variables are accounted for and documented. It is recommended for future readers to standardize department wide training for sampling techniques to ensure that all sampling techniques are properly executed. Additionally it is recommended that future readers extend the sampling period to maximize the chances of obtaining sufficient data from structure fires.

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Appendix A

CFEMS Overhaul Operations Air Sampling Plan

2017 SAMPLING PLAN FOR OVERHAUL OPERATIONS

Casper Fire – EMS (CF-EMS) CANCER EXPOSURE RESEARCH

CAPTAIN JACOB BLACK

EFO APPLIED RESEARCH PROJECT



Industrial Hygiene Sampling and Analysis

Overhaul Operations on Structure Fires

Casper, Wyoming 2017

Introduction

The overall goal of the proposed sampling and research is to identify hazardous exposures to employees within the work environment of overhaul operations after a structure fire. The specific hazardous exposures of this research are to focus on non-visible compound exposures. This will be foundational research for the Casper Fire-EMS (CF-EMS) to identify hazardous exposures with an anticipated direction for increased awareness, protective measures, and a research platform to follow in the future for all members of the CF-EMS.

This information will be collected and utilized for the National Fire Academy Executive Fire Officer Program, fourth year applied research project for Captain Jacob Black.

Analytical Timeline

The analysis is to be conducted within the time period of May, 2017 through August, 2017. If no samples are collected, Captain Black will request an extension through the National Fire Academy Executive Fire Officer Program for the time frame determined through their discretion. To fiscally regulate the research, no more than ten samples will be collected through the analytical timeline.

Analytical Compounds

Equipment to be utilized for Sample Collection (per fire overhaul):

Non-visible compounds

- Entech canister (2)
- Entech Regulator set for 10 minutes from ESIS Environmental Health Laboratory (2)

END INTRODUCTION

Sampling Protocol

Sampling Protocol Non-Visible Compounds

Samples will be collected for a minimum 10-minute period during the overhaul operations of CF-EMS structure fires. There will be two (2) samples obtained per overhaul operation.

- The first sample will be taken before overhaul operations begin without positive pressure ventilation.
- The second sample will be taken during overhaul operations while positive pressure ventilation is being utilized.

During each exposure analysis, the sample will be collected within the room of the structure that received the highest amount of damage from the fire. The collection of each sample will require:

- One (1) Entech canister
- One (1) Entech regulator (set for 10 minutes)
- The canister will be placed so that the inlet of the regulator will be placed in position that the inlet is between 60 inches and 72 inches off the floor.
 - This will be accomplished by using the Combination A-Frame ladder off of Truck 1, placing a board on the top steps when in the unfolded position.

The minimum sampling time shall not be less than ten minutes to ensure that adequate sampling data has been collected. Conditions inside the building during air sampling will be as close to standard overhaul operations as possible.

Structure fires to be sampled on will be any structure fires that produced significant interior or structural damage requiring overhaul operations by CF-EMS personnel.

END SAMPLING PROTOCOL

Sample Collection, Shipment, Reordering

If Captain Black is not on scene or available, the Battalion Chief on duty will be responsible for the deployment, collection, and chain of custody to Captain Black for shipment to the laboratory for analysis. Captain Black will train the Battalion Chiefs and additionally recruited personnel from each shift in proper sampling procedures. Deployment requires knowledge of Entech Canisters and proper documentation of their use. Captain Black will ensure that this is a seamless operation with proper resources and training to execute tasks. All canisters and regulators come with instructions on deployment and documentation.

With the collection, shipment, and analysis of every sample, replacements of sampling media will be ordered for the next collection. Each additional sample for Non-Visible Compounds will require:

- Two (2) Entech canisters
- Two (2) Entech regulator (set for ten minutes)
- Ordered from the laboratory for delivery to Captain Black, who will deliver to the Battalion Chiefs.

This will ensure additional samples can continue to be collected until a total of ten (10) overhaul samples have been collected or the 4-month research time frame has elapsed. Captain Black will take care of the ordering of all additional samples.

Sampling Plan Changes:

In the event any changes to the sampling plan are required, changes will be communicated and documented for effective implementation.

END SAMPLE COLLECTION, SHIPMENT, REORDERING

Analytical results

Non-Visible Compounds (Entech Canisters)

- All analyses from the Entech Canisters are performed by Gas Chromatography/Mass Spectrometry (GC/MS) and include total hydrocarbons quantitated as toluene, an aldehyde (carbonyl) scan, plus the ten largest peaks in the chromatogram as identified by the GC/MS library search software. Detection range extends from 0.5 ppb to the percent range.
- After 1-3 initial GC/MS analytical scans, the scan can be reduced to a more focused range of chemicals. This will be based off of similarities in results and laboratory recommendations.
- Results will be available within 5-7 business days of the laboratory receiving the samples.
- Final report will be available by September 17th, 2017.
 - Report with applicable calculations and results will be created for delivery to all stakeholders involved with the testing and funding of the testing.

END ANALYTICAL RESULTS

Financial

Cost

The initial cost estimate is set to a total estimate of **\$6,000**. The most comprehensive GCMS analysis for ten (10) samples, rental fees, and shipment of samples is estimated at \$600/sample. If initial results produce similarities, the laboratory will be consulted to narrow the focus of the GCMS scan, reducing the cost to \$250-\$350 cost/sample.

Cost Sharing:

It is proposed that the fees associated with the laboratory analysis for this research be paid for by:

- | | |
|---|--|
| <ul style="list-style-type: none"> • Casper Fire-EMS
200 N. David
Casper, WY 82601 | Unknown Amount of Funds, if any |
| <ul style="list-style-type: none"> • CS Consulting LLC
4151 Ten Mile Road
Casper, WY 82604 | \$3,000 |

Research Responsibility:

All research and results will be conducted and analyzed by Captain Jacob Black. Lab analysis will be conducted through the following two laboratories:

Entech Canisters GCMS Analysis

ESIS Environmental Health Laboratory
100 Sebethe Drive,
Suite A5
Cromwell, CT 06416
866.635.6475

END FINANCIAL

END SAMPLE PLAN

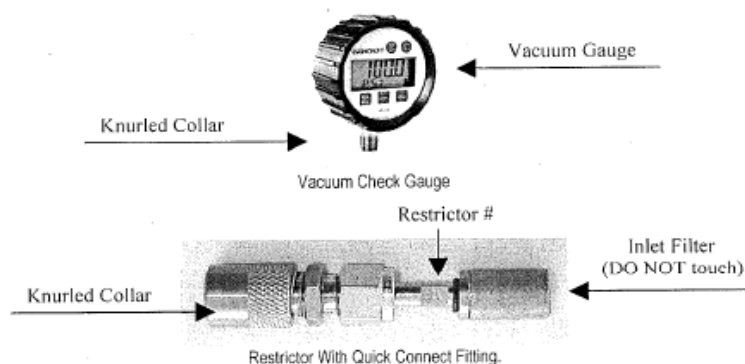
Appendix B

ESIS Environmental Entech Canister Instructions

AIR CANISTER SAMPLING AND HANDLING PROCEDURES

ESIS Environmental Health Laboratory

1. These sampling canisters/equipment are designed for analyzing VOC's in the ppt range and can be contaminated by incorrect storage and handling. Unless sampling, avoid exposing open canisters or restrictors to the environment. **Do not store near any chemicals. While handling, make sure hands are contamination free. Do not touch the tip of the canister inlet, the flow restrictor inlet filter or the flow restrictor connector inlet with your fingers.** For example, if you have pumped gasoline or applied perfume within the last few hours you should not handle this equipment.



2. Choose the sample flow restrictor appropriate for the desired application.

Restrictor #	Sampling Time
0 (Grab)	30 seconds
1	1 – 2 minutes
2	5 – 10 minutes
5	30 – 60 minutes
6	60 – 120 minutes

3. Remove the protective end cap from the canister by loosening ½ turn and pulling the entire cap assembly off. Holding the vacuum check gauge in one hand, slide back the knurled collar with thumb and index finger. Holding the canister in the other hand, insert the canister tip into the vacuum check gauge and release the knurled collar. The silver (uncoated) tip of the male canister fitting should not be visible.

NOTE: Simple vacuum gauge instructions can be found on the back side of each gauge, full feature instructions are located on the inside lid of its storage box. The gauge *does not* automatically vent to atmosphere, simply use from one sample to the next. The minimal internal volume will not affect readings or cross contaminate samples.

NOTE: Initial vacuum gauge readings for each canister should read near -30 inches of Hg (1 in. Hg less per 1,000 ft altitude rise above sea level). If significantly lower, a leak may have formed. Please contact the lab for guidance.

4. Record the canister ID ("SN:" on red label), and vacuum start reading on the enclosed Request for Analytical Services form. Holding the vacuum check gauge in one hand, slide back the knurled collar with thumb and index finger to disconnect the vacuum gauge from the canister.

(continued on other side)

ESIS Environmental Health Laboratory

100 Sebethe Drive, Suite A5
Cromwell, CT 06416
www.esis.com/rcs/ehlab

Phone (Local): (860) 635-6475
Phone (Toll-Free): (800) 243-4903
Fax: (860) 635-6750

AIR CANISTER SAMPLING AND HANDLING PROCEDURES

ESIS Environmental Health Laboratory

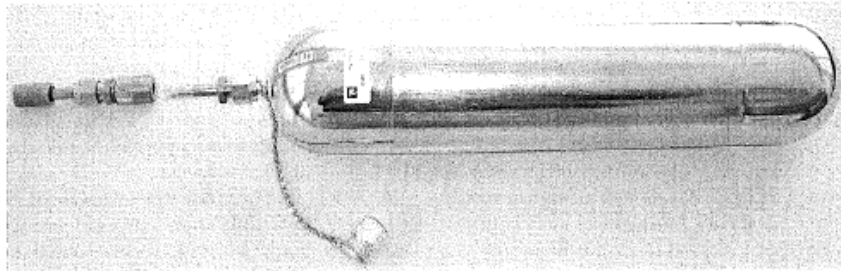
(continued from other side)

5. Insert the canister tip into the restrictor and release the knurled collar. The silver (uncoated) tip of the male canister fitting should not be visible.

NOTE: Sampling begins immediately. Bear in mind that this is a whole air sampling technique. If, for example, the person performing the sampling or the person being sampled should be wearing perfume or cologne, volatile components of these will also be sampled.

NOTE: Restrictors will not stop before reaching ambient pressure. Use the chart in step 2 to estimate the approximate time of sample collection. When this estimated time has elapsed, check the canister using the vacuum gauge to verify that the appropriate amount of sample has been collected. Canisters must be filled to greater than half full (-15 to 0 in Hg) to achieve normal detection limits. Best results are obtained when canisters have a final vacuum of -2 to -5 in Hg (RUSH analysis must have a final vacuum less than -5 in Hg.).

6. Record the sample start time and restrictor # for the appropriate canister ID ("SN:" on red label) on the enclosed Request for Analytical Services form along with any pertinent sample information (location, humidity, etc.).



7. When sampling is complete, reverse above steps to disengage the canister from the restrictor by sliding back the knurled collar with thumb and index finger to separate the canister from the restrictor. Attach the vacuum check gauge and record the ending vacuum reading and the sample end time for the appropriate canister ID ("SN:" on red label) and/or flow restrictor # on the enclosed Request for Analytical Services form.
8. Remove the vacuum check gauge and replace the protective end cap on each canister (finger tight). Place the flow restrictor and vacuum check gauge back into its Ziploc bag and seal for return shipment to ESIS EHL.
9. Store trapped samples in a cool place away from direct sunlight. Ship the samples, equipment and Request for Analytical Services form immediately to ESIS EHL using overnight delivery if possible (not on weekends). Analytical results normally are available within 6-9 business days. Please arrange any RUSH analyses or special requests with ESIS EHL prior to ordering equipment.

Each canister is conditioned, analyzed and specially packaged for shipment. Due to the associated costs in providing canisters having a low background, ESIS EHL asks clients to only order equipment expected to be used immediately. Storage of canisters for periods greater than one month is not recommended.

ESIS EHL will charge clients a \$50 reconditioning fee for each returned canisters/flow controller that will not be analyzed. A charge of up to \$1250 will apply for each canister/restrictor broken, damaged, or not returned.

ESIS Environmental Health Laboratory

100 Sebethe Drive, Suite A5
Cromwell, CT 06416
www.esis.com/rcs/ehlab

Phone (Local): (860) 635-6475
Phone (Toll-Free): (800) 243-4903
Fax: (860) 635-6750

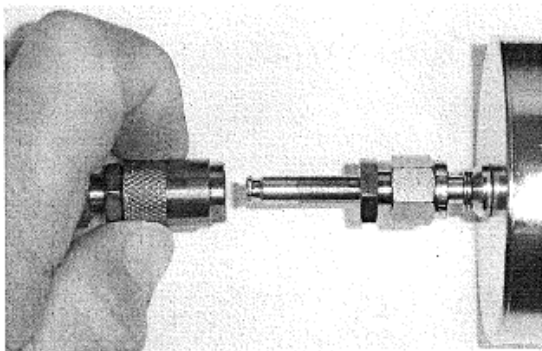
AIR CANISTER QUICK CONNECT HANDLING PROCEDURES

ESIS Environmental Health Laboratory

Miniature Quick-Connects

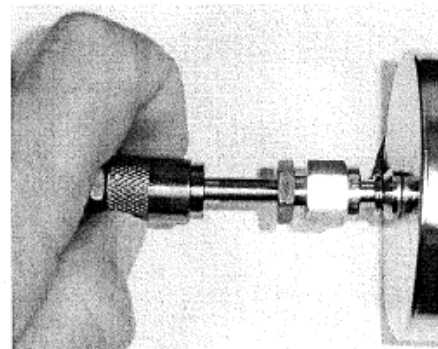
To Couple:

Align stem (male) with body (female).
 Pull body sleeve back.
 Firmly insert stem into body until it bottoms out.
 The silver tip of the male fitting should not be visible.
 Release body sleeve.
 Make sure that the sleeve returns to its original position.

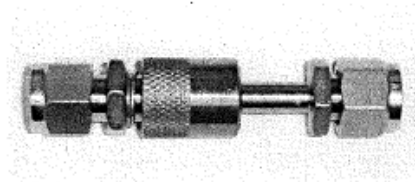


To Uncouple:

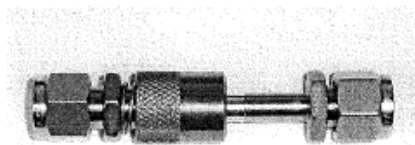
Pull body sleeve back.
 Remove stem from body.
 Release body sleeve.
 Replace canister stem cap assembly.



Correct Connection:



Incorrect Connection:



Good Practices When Operating Quick-Connects

- Align bodies and stems when coupling or uncoupling.
- Use body and stem protectors or dust caps on uncoupled bodies and stems.
- Use filters ahead of quick-connects.
- Support hanging hoses or other equipment to prevent side load.

Caution

- Do not rotate while coupled.
- Do not insert foreign objects into uncoupled bodies or stems.

ESIS Environmental Health Laboratory

100 Sebethe Drive, Suite A5
 Cromwell, CT 06416
 www.esis.com/rcs/ehlab

Phone (Local): (860) 635-6475
 Phone (Toll-Free): (800) 243-4903
 Fax: (860) 635-6750

Appendix C

CFEMS Air Sampling Guideline Instructions

Sampling Instructions*Two (2) samples per fire. One (1) without ventilation after knock down, and one (1) during overhaul with ventilation. We want an analysis of the results to identify the ventilation affects to the toxic exposure environment.

Step 1 – Set up A frame ladder off of truck 1 in the room with the most damage from the fire. Place the plank that is with the sampling equipment on top of the frame ladder. This will be the platform for the canister to sit on.

Step 2 – Take the monitoring logs, canisters, pressure gauge and regulators out of the box.

Step 3 – Document appropriate information on Pre-ventilation log.

Step 4 – Turn on the pressure gauge.

Step 5 - Take the cap off canister.

Step 6 – Place pressure gauge on canister. Look at reading, record on log.

Step 7 – Take gauge off, turn off and replace in box.

Step 8 – Place canister on plank in structure on ladder. Connect regulator to canister. Do not touch regulator inlet.

Step 9 – Record times on log – Collect air for 10 minutes.

Step 10 – Break down equipment, place in boxes, record 2nd pressure gauge and information.

Step 11 - Repeat steps for Overhaul with ventilation sample.

***Immediately notify Captain Black with any questions and when samples are obtained.**

Appendix D Air Monitoring Logs



CASPER FIRE-EMS AIR MONITORING LOG 2017

Date:	CFEMS SAMPLE TECHNICIAN
Address:	
Location in structure:	

Canister Number	Flow Regulator Number	Work Activities	Vacuum Start (in. Hg)	Vacuum End (in. Hg)	Start Time	Stop Time	Analysis Type
		Pre-Overhaul Operations with no Ventilation					GCMS
Notes:							

Overhaul Operations – With Ventilation



CASPER FIRE-EMS AIR MONITORING LOG | 2017

Date: _____ **CFEMS SAMPLE TECHNICIAN**

Address: _____

Location in structure: _____

Canister Number	Flow Regulator Number	Work Activities	Vacuum Start (in. Hg)	Vacuum End (in. Hg)	Start Time	Stop Time	Analysis Type
		Overhaul Operations with Ventilation					GCMS
Notes:							
Overhaul Operations – With Ventilation							

Appendix E

Pre-and Post-ventilation Interpretation Report 1, 2, & 3 for every sample collected

Interpretation Report 1

GC/MS Whole air canisters; TO-15 scan: Each analysis report was to provide the following information relative to exposure hazards for each specific sample obtained: the chemical compound name and the Chemical Abstracts Service registry number (CAS #) of the material (“CAS Number – Chemical Abstracts Service Registry Number,” n.d.), the detected levels of the compound in micrograms per cubic meter of air (ug/m³), and detected levels of the compound in parts per billion (ppb). To relate the compound and detected levels to exposure risks, efforts were required to identify and provide the parts per million (PPM) concentration, and relate that to the OSHA permissible exposure limit (PEL) values, OSHA short term exposure limit (STEL) values, and immediately dangerous to life or health (IDLH) values. Additionally, information was searched on the exposure routes, symptoms, and if the compound was a possible carcinogen. To do this, a table was created with all of the relative fields required along with an inclusive list for all reports in the appendices of each compound with respective exposure routes, symptoms, and possible carcinogenic effects. Values were then converted from PPB to PPM. This was done by taking the PPB value and dividing it by 1,000. There are 1,000 PPB in 1 PPM (“Ppm to ppb conversion,” n.d.). Next, using google, an internet search of the compound name or the compound number was performed. This revealed all of the needed information for applicable OSHA PELs, OSHA STELs, IDLH, exposure routes, symptoms, and if the compound was a possible carcinogen. Values were then entered into the table to compare and identify exposure vulnerabilities. All compound values that met or exceeded OSHA PELs, OSHA STELs and were noted as potential carcinogens were highlighted.

Interpretation Report 2

GC/MS Whole air canisters; Carbonyl scan: Each analysis report was to provide the following information relative to exposure hazards for each specific sample obtained: the chemical compound name and the Chemical Abstracts Service registry number (CAS #) of the material (“CAS Number – Chemical Abstracts Service Registry Number,” n.d.), the detected levels of the compound in micrograms per cubic meter of air (ug/m³), and the detected levels of the compound in parts per billion (ppb). To relate the compound and detected levels to exposure risks, efforts were required to identify and provide the parts per million (PPM) concentration, and relate that to the OSHA permissible exposure limit (PEL) values, OSHA short term exposure limit (STEL) values, and immediately dangerous to life or health (IDLH) values. Additionally, information was searched on the exposure routes, symptoms, and if the compound was a possible carcinogen. To do this, a table was created with all of the relative fields required along with an inclusive list for all reports in the appendices of each compound with respective exposure routes, symptoms, and possible carcinogenic effects. Values were then converted from PPB to PPM. This was done by taking the PPB value and dividing it by 1,000. There are 1,000 PPB in 1 PPM (“Ppm to ppb conversion,” n.d.). Next, using google, an internet search of the compound name or the compound number was performed. This revealed all of the needed information for applicable OSHA PELs, OSHA STELs, IDLH, exposure routes, symptoms, and if the compound was a possible carcinogen. Values were then entered into the table to compare and identify exposure vulnerabilities. All compound values that met or exceeded OSHA PELs, OSHA STELs and were noted as potential carcinogens were highlighted.

Interpretation Report 3

GC/MS Spectral Library Match Summation Report: The results from the analysis provide the following information relative to the comprehensive analysis: the top 10, in this case they provided 12, chemical compound names identified at the peak levels within the GC/MS analysis of the TO-15 and Carbonyl scans. Each peak identified provides three tentatively identified compounds with best matching spectrums compared to known chemicals, the Chemical Abstracts Service registry number (CAS #) of the material ("CAS Number – Chemical Abstracts Service Registry Number," n.d.), the peak number supplied by the chromatogram, the retention time of the gas chromatogram peak, the percentage of the chemical in the total organic compound (TVOC) value, the detected levels of the compound in micrograms per cubic meter of air (ug/m³), and the quality factor of the unknown peak to the known spectrum with a factor above 70 being a good match for the specific compound identified. To relate the compounds identified as the top peaks identified, the highest quality factor compounds were compared with the compounds identified in the TO-15 and Carbonyl scans. A table was created of the peak compounds and cross referenced them with what was identified in the scans, documenting which scan detected which peak compound in the table. This was a way to validate that high peak compounds were found in the scans. If peak compounds were identified that were not listed in the scans, the author was required to identify exposure risks and provide the parts per million (PPM) concentration, and relate that to the OSHA permissible exposure limit (PEL) values, OSHA short term exposure limit (STEL) values, and immediately dangerous to life or health (IDLH) values. Additionally, information was searched on the exposure routes, symptoms, and if the compound was a possible carcinogen. A table was created with all of the relative fields required along with an inclusive list for all reports in the appendices of each compound with

respective exposure routes, symptoms, and possible carcinogenic effects. Next, using google, an internet search of the compound name or the compound number was performed. This revealed all of the needed information for applicable molecular weight, OSHA PELs, OSHA STELs, IDLH, exposure routes, symptoms, and if the compound was a possible carcinogen. The author was required to convert micrograms per cubic meter of air ($\mu\text{g}/\text{m}^3$) to milligrams per cubic meter of air (mg/m^3) and identify the molecular weight to calculate the ppm. Values were then converted from $\mu\text{g}/\text{m}^3$ to mg/m^3 with the ratio of 1,000 milligrams to 1 microgram. The CDC's "Safety Checklist Program for Schools (2014)," provides the calculation used to complete the conversion to parts per millions is as follows:

$$X_{\text{ppm}} = (Y \text{ mg}/\text{m}^3)(24.45)/(\text{molecular weight})$$

The equation identified the ppm values which were then entered into the table to compare and identify exposure vulnerabilities. All compound values that met or exceeded OSHA PELs, OSHA STELs and were noted as potential carcinogens were highlighted.

Appendix F

Email Survey (Created by Jacob Black using Google Forms)

Toxic Chemical Exposures to firefighters during real structure fire overhaul operations

Casper Fire - EMS data gathering assessment for toxic exposures in the overhaul environment of REAL (NOT SIMULATED) STRUCTURE FIRES

* Required

Name of your organization *

Your answer

City, State of your organization *

Your answer

Does your organization perform overhaul operations on structure fires? *

Yes

No

NEXT

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Toxic Chemical Exposures to firefighters during real structure fire overhaul operations

* Required

Ventilation conditions during overhaul?

Does your organization perform positive pressure ventilation during overhaul operations on structure fires? *

Yes

No

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Toxic Chemical Exposures to firefighters during real structure fire overhaul operations

* Required

What does your organization monitor for in the overhaul environment?

Carbon monoxide (CO) *

Yes

No

Hydrogen cyanide (HCN) *

Yes

No

Lower explosive limit (LEL) *

Yes

No

Oxygen (O₂) *

Yes

No



Additional toxic chemical? *

Yes

No

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Toxic Chemical Exposures to firefighters during real structure fire overhaul operations

Has your organization previously or does your organization currently monitor for additional chemical toxins in the overhaul environment?

Acetaldehyde

- Yes
- No

Acrolein

- Yes
- No

Asbestos

- Yes
- No

Benzene

- Yes
- No



Cadmium

Yes

No

Chromium

Yes

No

Ethyl Benzene

Yes

No

Formaldehyde

Yes

No

Glutaraldehyde

Yes

No

Hydrochloric acid

Yes

No

Lead

Yes

No

Nitric dioxide (NO₂)

- Yes
- No

Nitric oxide (NO)

- Yes
- No

Polynuclear aromatic hydrocarbons (PNA's) Polyaromatic hydrocarbon (PAH's)

- Yes
- No

Phosgene

- Yes
- No

Respirable dust

- Yes
- No

Sulfur Dioxide (SO₂)

- Yes
- No

Sulfur Trioxide / Sulfuric Acid

- Yes
- No

Toluene

Yes

No

Total dust

Yes

No

Xylene

Yes

No

If not listed above, and your organization has or does perform additional monitoring in the overhaul environment, please list additional chemicals identified:

Your answer

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Toxic Chemical Exposures to firefighters during real structure fire overhaul operations

Additional information if necessary

Additional comments:

Your answer

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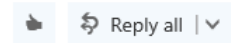
Appendix G

Email (Spencer Cheatham, September 30th, 2017)

RE: EFO section members - How many in the email list



EFO <EFO@iafc.org>
Today, 5:02 PM
Jacob Black ✓



The emails go out to about 1250 EFO members.

From: Jacob Black [mailto:jblack@casperwy.gov]
Sent: Friday, September 29, 2017 4:50 PM
To: EFO <EFO@iafc.org>
Subject: EFO section members - How many in the email list

Spencer,

How many people receive emails on this list? Please let me know.

Thanks,

Jake

All City of Casper e-mails and attachments are public records under the Wyoming Public Records Act, W.S. § 16-4-201 *et seq.*, and are subject to public disclosure pursuant to this Act.

Appendix H**Email (Angela Krantz, September 15th, 2016)**

EFOP - Jacob Black

Page 1 of 1

EFOP

Krantz, Angela (CTR) <Angela.Krantz@associates.fema.dhs.gov>

Thu 9/15/2016 6:58 AM

To: Jacob Black <jblack@casperwy.gov>;

Jake,

I looked and I am not showing receipt of a survey from you. However, I have not been able to send out student surveys for many years.

I send anyone who asks to email out a survey to the Executive Fire Officer Section of the International Association of Fire Chiefs. In order to have them post your survey, you need to send an email to EFO@iafc.org along with the following:

- Name of the project
- Your name, rank and department
- Brief description of the project that explains why members should take the survey
- Survey deadline
- Link to the survey

Take care,
Angie

Angie Krantz (CTR)
GTI Federal/ZAI, Contractor
FEMA/USFA/NFA
16825 South Seton Ave., Room H-026
Emmitsburg, MD 21727
Phone 301-447-1176
Fax: 301-447-1601
angela.krantz@associates.fema.dhs.gov

Appendix I

Fire Departments Determined through Internet Research

Phoenix Fire Department - August 18th, 2017 (“City Hall at Your Service,” n.d.)

Sara Jahnke Sponsored by Fire-Dex - August 18th, 2017 (Jahnke, 2015).

Tualatin Valley Fire Rescue - August 18th, 2017 (“Tualatin Valley Fire Rescue Form Center,”
n.d.)

Appendix J

Structure Fire 1: GC/MS Whole Air Canister - TO-15 SCAN

LABORATORY ANALYSIS REPORT

ERIS ENVIRONMENTAL HEALTH LAB
100 Sobotta Drive, Ste A-5
Crownell, Connecticut 06410
(800)43-4003/(860)635-6475

TO: Jake Black
CS Consulting
4151 Ten Mile Road
Casper, WY 82604

Report #: C1755164
P.O. No.:

Casper, WY

Analysis: TO-15 Scan
Analytical Method: GC/MS Whole Air Canisters; EPA TO-15

Date Received: 07/14/17 Date Analyzed: 07/19/17
Date Prepped: 07/17/17 Date Reported: 07/21/17

Sample Number	3217	3217	3216	3216		
Air Volume Liters	0.250	0.250	0.250	0.250		
Compounds	ug/m3	ppb	ug/m3	ppb		CAS #
Acetone	44	19	46	19		67-64-1
Acetonitrile	6.7	4.0	7.0	4.2		75-05-8
Acrylonitrile	3.9	1.8	3.9	1.8		107-13-1
Allyl Chloride	<1.6	<0.50	<1.6	<0.50		107-05-1
Benzene	250	77	180	58		71-43-2
Benzyl Chloride	3.3	0.66	3.5	0.69		100-44-7
Bromodichloromethane	<3.3	<0.50	<3.3	<0.50		75-27-4
Bromoethane	<2.2	<0.50	<2.2	<0.50		74-96-4
Bromoethane	<2.2	<0.50	<2.2	<0.50		593-60-2
Bromoform	<5.2	<0.50	<5.2	<0.50		75-25-2
Bromomethane	<1.9	<0.50	<1.9	<0.50		74-83-9
1,3-Butadiene	26	12	27	12		106-99-0
Butylbenzene	<2.7	<0.50	<2.7	<0.50		104-51-8
sec-Butylbenzene	<2.7	<0.50	<2.7	<0.50		135-98-8
Carbon Disulfide	<1.6	<0.50	<1.6	<0.50		75-15-0
Carbon Tetrachloride	<3.1	<0.50	<3.1	<0.50		56-23-5
Chlorobenzene	<2.3	<0.50	<2.3	<0.50		108-90-7
Chloroethane	<1.3	<0.50	<1.3	<0.50		75-00-3
Chloroform	<2.1	<0.50	<2.1	<0.50		67-66-3
Chloromethane	33	16	34	17		74-87-3
Cumene	<2.5	<0.50	<2.5	<0.50		98-82-8
Cyclohexane	<1.7	<0.50	<1.7	<0.50		110-82-7
Dibromochloromethane	<4.2	<0.50	<4.2	<0.50		124-48-1
1,2-Dibromo-3-chloropropane	<4.8	<0.50	<4.8	<0.50		96-12-8
m-Dichlorobenzene	<3.0	<0.50	<3.0	<0.50		541-73-1
p-Dichlorobenzene	<3.0	<0.50	<3.0	<0.50		106-46-7
o-Dichlorobenzene	<3.0	<0.50	<3.0	<0.50		95-50-1
Dichlorodifluoromethane	<2.0	<0.50	2.1	0.53		75-71-8
1,1-Dichloroethane	<2.0	<0.50	<2.0	<0.50		75-34-3
1,2-Dichloroethane	<2.0	<0.50	<2.0	<0.50		107-06-2
1,1-Dichloroethylene	<2.0	<0.50	<2.0	<0.50		75-35-4
cis-1,2-Dichloroethylene	<2.0	<0.50	<2.0	<0.50		156-59-2
trans-1,2-Dichloroethylene	<2.0	<0.50	<2.0	<0.50		156-60-5
1,2-Dichloropropane	<2.3	<0.50	<2.3	<0.50		78-87-5
1,3-Dichloropropane	<2.3	<0.50	<2.3	<0.50		142-28-9
cis-1,3-Dichloropropene	<2.3	<0.50	<2.3	<0.50		10061-01-5
trans-1,3-Dichloropropene	<2.3	<0.50	<2.3	<0.50		10061-02-6
Dichlorotetrafluoroethane	<3.5	<0.50	<3.5	<0.50		76-14-2
1,4-Dioxane	<1.8	<0.50	<1.8	<0.50		123-91-1
Epichlorohydrin	<1.9	<0.50	<1.9	<0.50		106-89-8
Ethanol	620	330	640	340		64-17-5

LABORATORY ANALYSIS REPORT

ESIS ENVIRONMENTAL HEALTH LAB
100 Seabrook Drive, Ste A-5
Cromwell, Connecticut 06416
(800)243-4903/(860)535-6475

Analysis: TO-15 Scan

Analytical Method: GC/MS Whole Air Canisters; EPA TO-15

Report Number **C1755164**

Sample Number	3217	3217	3216	3216		
Air Volume Liters	0.250	0.250	0.250	0.250		
Compounds (cont.)	ug/m3	ppb	ug/m3	ppb		CAS #
Ethyl Acetate	4.7	1.3	4.6	1.3		141-78-6
Ethyl Acrylate	<2.0	<0.50	<2.0	<0.50		140-88-5
Ethyl Benzene	8.5	1.9	8.8	2.0		100-41-4
Ethylene Dibromide	<3.8	<0.50	<3.8	<0.50		106-93-4
4-Ethyltoluene	<2.5	<0.50	<2.5	<0.50		622-96-8
Heptane	2.7	0.67	4.0	0.97		142-82-5
Hexachlorobutadiene	<5.3	<0.50	<5.3	<0.50		87-68-3
Hexane	3.0	0.85	3.7	1.1		110-54-3
Isooctane	<2.3	<0.50	<2.3	<0.50		540-84-1
4-Isopropyltoluene	3.9	0.72	3.9	0.70		99-87-6
Methanol	600	430	640	490		67-56-1
Methyl tert-Butyl Ether	<1.8	<0.50	<1.8	<0.50		1634-04-4
Methyl Butyl Ketone	<2.0	<0.50	<2.0	<0.50		591-78-6
Methyl Ethyl Ketone	14	4.8	13	4.3		78-93-3
Methyl Iodide	<2.9	<0.50	<2.9	<0.50		74-88-4
Methyl Isobutyl Ketone	<2.0	<0.50	<2.0	<0.50		108-10-1
Methyl Methacrylate	32	7.7	30	7.4		80-62-6
Methylene Chloride	<1.7	<0.50	<1.7	<0.50		75-09-2
Naphthalene	97	18	97	18		91-20-3
4-Phenylcyclohexene	<1.3	<0.20	<1.3	<0.20		4994-16-5
2-Propanol	4.7	1.9	8.0	3.3		67-63-0
Propene	88	51	88	51		115-07-1
Styrene	55	13	53	13		100-42-5
1,1,1,2-Tetrachloroethane	<3.4	<0.50	<3.4	<0.50		630-20-6
1,1,2,2-Tetrachloroethane	<3.4	<0.50	<3.4	<0.50		79-34-5
Tetrachloroethylene	<3.4	<0.50	<3.4	<0.50		127-18-4
1,1,1,2-Tetrafluoroethane	<2.1	<0.50	<2.1	<0.50		811-97-2
Tetrahydrofuran	2.1	0.70	2.1	0.73		109-99-9
Toluene	57	15	55	15		108-88-3
1,2,4-Trichlorobenzene	<3.7	<0.50	<3.7	<0.50		120-82-1
1,1,1-Trichloroethane	<2.7	<0.50	<2.7	<0.50		71-55-6
1,1,2-Trichloroethane	<2.7	<0.50	<2.7	<0.50		79-00-5
Trichloroethylene	<2.7	<0.50	<2.7	<0.50		79-01-6
Trichlorofluoromethane	<2.8	<0.50	<2.8	<0.50		75-69-4
1,1,2-Trichloro-1,2,2-trifluoroethane	<3.8	<0.50	<3.8	<0.50		76-13-1
1,2,4-Trimethylbenzene	2.7	0.55	2.7	0.56		95-63-6
1,3,5-Trimethylbenzene	<2.5	<0.50	<2.5	<0.50		108-67-8
Vinyl Acetate	<1.8	<0.50	<1.8	<0.50		108-05-4
Vinyl Chloride	2.1	0.81	2.0	0.77		75-01-4
m,p-Xylene	14	3.3	15	3.4		1330-20-7
o-Xylene	6.9	1.6	7.0	1.6		95-47-6
	ug/m3		ug/m3			
**Total Volatile Organic Compounds (TVOC)	1,900		1,800			---

Unless noted, the condition of samples on receipt was acceptable. Results relate only to items tested in the condition received.

The stated collection time on the Chain of Custody (COC) form indicates that a 22 minute sample was collected using a 12 minute restrictor. Sampling by the recommended time may cause loss of compounds through reverse migration, resulting in underestimated concentrations.

Polynuclear Aromatic Hydrocarbons (PNA's) and other high boiling point compounds were observed in both samples. These compounds are beyond the nominal range of this analytical method (C3-C12) and other sampling techniques should be employed, if warranted.

**This value is a summation of all peak areas present in the sample (quantitated as toluene).

Appendix K

Structure Fire 1: GC/MS Whole Air Canister - Carbonyl Scan

LABORATORY ANALYSIS REPORT

ESIS ENVIRONMENTAL HEALTH LAB
100 Sabathe Drive, Ste A-5
Cromwell, Connecticut 06416
(800)243-4603/(860)935-6475

TO: Jake Black
CS Consulting
4151 Ten Mile Road
Casper, WY 82604

Report #: C1755164

P.O. No.:

Casper, WY

Analysis: Carbonyl Scan
Analytical Method: GC/MS Whole Air Canisters; EPA TO-15

Date Received: 07/14/17

Date Analyzed: 07/19/17

Date Prepped: 07/17/17

Date Reported: 07/21/17

Sample Number	3217	3217	3216	3216			CAS #
Air Volume Liters	0.250	0.250	0.250	0.250			
Compounds	ug/m3	ppb	ug/m3	ppb			
Acetaldehyde	230	130	220	120			75-07-0
Acrolein	63	28	60	26			107-02-8
Benzaldehyde	21	4.9	19	4.3			100-52-7
Butyraldehyde	25	8.4	27	9.2			123-72-8
Crotonaldehyde	34	12	34	12			4170-30-3
Decanal	<3.2	<0.50	<3.2	<0.50			112-31-2
2,5-Dimethylbenzaldehyde	14	2.6	<2.7	<0.50			5779-94-2
Formaldehyde	280	230	290	240			50-00-0
Furfural	940	240	960	240			98-01-1
Heptanal	2.4	0.52	2.5	0.53			111-71-7
Hexanal	14	3.5	14	3.3			66-25-1
Nonanal	40	6.9	36	6.2			124-19-6
Octanal	6.4	1.2	5.5	1.0			124-13-0
Propanal	39	16	37	15			123-38-6
o-Tolualdehyde	3.7	1.1	<1.8	<0.50			529-20-4
m-Tolualdehyde	4.2	1.2	<1.8	<0.50			620-23-5
p-Tolualdehyde	6.0	1.7	<1.8	<0.50			104-87-0
Valeraldehyde	4.1	1.2	3.8	1.1			110-62-3
	ug/m3		ug/m3				
**Total Volatile Organic Compounds (TVOC)	1,900		1,800				---

Unless noted, the condition of samples on receipt was acceptable. Results relate only to items tested in the condition received.

**This value is a summation of all peak areas present in the sample (quantitated as toluene).

Appendix L

Structure Fire 1: TIC - GC/MS Spectral Library Match Summation Report

GC/MS Spectral Library Match Summation Report
Sorted by Top 10 Peak Area Amounts of 109 Total Peaks

Sample Name : 3217, C1755164, Can 3217, MC6420 TVOC (ug/m3)*: **1,900**
 Date Acquired : 07/20/2017 0:15
 * This value is an estimated concentration present in the sample (quantitated as toluene).

Peak #	R.T.	Area %	ug/m3*	Library ID and Top 3 Matches by Quality Fit	CAS #	Qual
9	6.261	10.0	189	C:\Database\NIST11.L Methyl Alcohol Hydrazine Formaldehyde	000067-56-1 000302-01-2 000050-00-0	86 4 1
14	8.565	4.2	80	C:\Database\NIST11.L Acetaldehyde Dimethyl ether Acetic acid, hydroxy-, ethyl ester	000075-07-0 000115-10-6 000623-50-7	86 35 9
14	8.565	6.3	120	C:\Database\NIST11.L Ethanol Dimethyl ether Acetic acid, hydroxy-, ethyl ester	000064-17-5 000115-10-6 000623-50-7	90 35 9
24	14.08	2.2	42	C:\Database\NIST11.L Acetone 2-Methyl-3-oxobutyronitrile Ethene, methoxy-	000067-64-1 004468-47-7 000107-25-5	86 9 4
29	15.609	6.8	129	C:\Database\NIST11.L Benzene 2,4-Hexadiyne Fumaronitrile	000071-43-2 002809-69-0 000764-42-1	95 90 86
35	17.608	1.3	25	C:\Database\NIST11.L 2,3-Butanedione 2-Butanone 2-Pentanone	000431-03-8 000078-93-3 000107-87-9	87 83 72
35	17.608	1.3	25	C:\Database\NIST11.L 2-Butanone 2,3-Butanedione 2-Pentanone	000078-93-3 000431-03-8 000107-87-9	86 83 64
39	19.485	3.6	69	C:\Database\NIST11.L Toluene 1,3,5-Cycloheptatriene 2,5-Norbornadiene	000108-88-3 000644-25-2 000121-46-0	95 87 64
53	23.169	2.9	55	C:\Database\NIST11.L Styrene Bicyclo[4.2.0]octa-1,3,5-triene 1,3,5,7-Cyclooctatetraene	000100-42-5 000694-87-1 000629-20-9	97 96 96
61	24.618	11	200	C:\Database\NIST11.L Furfural 3-Furaldehyde 2(1H)-Pyridinone	000098-01-1 000498-60-2 000142-08-5	95 91 50
92	27.5	2.3	44	C:\Database\NIST11.L Nonanal 5-Methyl-2-hexene,c&t Piperidin-4-ol, 2,3-dimethyl-, cis	000124-19-6 003404-62-4 305383-19-1	91 35 35
99	28.271	6.3	120	C:\Database\NIST11.L Naphthalene Azulene 4a,8a-(Methaniminomethano)naphthalene-9,11-dione, 10-phenyl-	000091-20-3 000275-51-4 069915-10-2	95 91 78

GC/MS Spectral Library Match Summation Report
Sorted by Top 10 Peak Area Amounts of 114 Total Peaks

Sample Name : 3216, C1755164, Can 3216, MC6419

TVOC (ug/m3)*: **1,800**

Date Acquired : 07/20/2017 1:49

* This value is an estimated concentration present in the sample (quantitated as toluene).

Peak #	R.T.	Area %	ug/m3*	Library ID and Top 3 Matches by Quality Fit	CAS #	Qual
12	6.246	10	181	C:\Database\NIST11.L		
				Methyl Alcohol	000067-56-1	86
				Hydrazine	000302-01-2	4
				Formaldehyde	000050-00-0	1
16	8.554	4.1	73	C:\Database\NIST11.L		
				Acetaldehyde	000075-07-0	86
				Dimethyl ether	000115-10-6	25
				Acetic acid, hydroxy-, ethyl ester	000623-50-7	9
16	8.554	6.1	110	C:\Database\NIST11.L		
				Ethanol	000064-17-5	90
				Dimethyl ether	000115-10-6	25
				Acetic acid, hydroxy-, ethyl ester	000623-50-7	9
26	14.076	2.2	39	C:\Database\NIST11.L		
				Acetone	000067-64-1	86
				2-Methyl-3-oxobutyronitrile	004468-47-7	9
				Diazane, dimethyl-	000503-28-6	4
32	15.607	6.4	115	C:\Database\NIST11.L		
				Benzene	000071-43-2	95
				2,4-Hexadiyne	002809-69-0	91
				Fumaronitrile	000764-42-1	86
38	17.608	1.4	26	C:\Database\NIST11.L		
				2,3-Butanedione	000431-03-8	87
				2-Butanone	000078-93-3	80
				2-Pentanone	000107-87-9	72
38	17.608	1.4	26	C:\Database\NIST11.L		
				2-Butanone	000078-93-3	86
				2,3-Butanedione	000431-03-8	83
				2-Pentanone	000107-87-9	64
43	19.485	3.7	66	C:\Database\NIST11.L		
				Toluene	000108-88-3	94
				1,3,5-Cycloheptatriene	000544-25-2	81
				Tetracyclo[3.2.0.0(2,7).0(4,6)]heptane	000278-06-8	59
58	23.168	2.9	53	C:\Database\NIST11.L		
				Styrene	000100-42-5	97
				Bicyclo[4.2.0]octa-1,3,5-triene	000694-87-1	96
				1,3,5,7-Cyclooctatetraene	000629-20-9	96
65	24.618	11	192	C:\Database\NIST11.L		
				Furfural	000098-01-1	95
				3-Furaldehyde	000498-60-2	91
				2(1H)-Pyridinone	000142-08-5	50
96	27.5	2.2	40	C:\Database\NIST11.L		
				Nonanal	000124-19-6	87
				2-Nonen-1-ol, (E)-	031502-14-4	43
				Butane, 1-isocyanato-	000111-36-4	30
103	28.27	6.7	121	C:\Database\NIST11.L		
				Naphthalene	000091-20-3	95
				Azulene	000275-51-4	91
				4a,8a-(Methaniminomethano)naphthalene-9,11-dione, 10-phenyl-	069915-10-2	78

Interpretation of Library Match Report

GC/MS Spectral Library Match Summation Report
Sorted by Top 5 Peak Area Amounts

Your sample name/number

Total Volatile Organic Compound (TVOC) value (based on toluene response).

Sample Name : Worker #1, EHL 030, tube 2065
Date Acquired : 17 March 2000 9:12

TVOC (ug/m3)*: **1,600**

* This value is an estimated concentration present in the sample (quantitated as toluene).

Peak #	R.T.	Area %	ug/m3*	Library ID and Top 3 Matches by Quality Fit	CAS #	Qual
3	1.952	3.9	62	C:\Database\NIST05.L Ethane, 1,2-dichloro- Ethene, chloro- Thiophene, 3,4-dichlorotetrahydro-	000107-06-2 000075-01-4 003001-57-8	83 36 9
7	3.66	2.1	34	C:\Database\NIST05.L 1-Propene, 1,1-dichloro- 1-Propene, 1,2-dichloro- 1-Propene, 1,3-dichloro-, (Z)-	000563-58-6 000563-54-2 010061-01-5	91 90 64
8	6.382	64	1030	C:\Database\NIST05.L Ethane, 1,1,2-trichloro- Ethane, 1,1,1-trichloro- Propane, 1,2,2-trichloro-	000079-00-5 000071-55-6 003175-23-3	94 32 23
11	7.09	5.1	81	C:\Database\NIST05.L Benzene, ethyl- Benzene, 1,3-dimethyl- Benzene, 1,4-dimethyl-	000100-41-4 000108-38-3 000106-42-3	91 53 50
12	7.468	9.8	156	C:\Database\NIST05.L Benzene, (1-methylethyl)- Benzene, 1-ethyl-2-methyl- Benzene, 1,2,3-trimethyl-	000098-82-8 000611-14-3 000526-73-8	91 80 64

Peak number supplied

Retention time of gas chromatograph peak

Chemical Abstract number of tentatively identified compound

Peak magnitude. The percentage of this particular chemical in the total volatile organic compound (TVOC) value.

Estimated peak concentration. Multiply area % by the total volatile organic compound (TVOC) value to get the approximate concentration (based on toluene response)

Tentatively identified compounds with best matching spectrums compared to known chemicals

Quality factor of unknown peak to known spectrum. A factor greater than 70 means good match. Low factors can be due to low concentration levels or the presence of coeluting peaks, however chemical family classification can be estimated (i.e. silane, ketone, aromatic, etc.).

Appendix M

Compound Exposure/Symptom/Carcinogen information for all fires and scans

- Acetaldehyde exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation of the eyes, nose, throat; eye, skin burns; dermatitis; conjunctivitis; cough; central nervous system depression; delayed pulmonary edema; In Animals: kidney, reproductive, teratogenic effects; [potential occupational carcinogen] (“NIOSH Pocket guide to Chemical hazards - Acetaldehyde,” 2016)
- Acetone exposure routes are inhalation, ingestion, skin and or eye contact, creating the following symptoms; irritation of the eyes, nose, throat; headache, dizziness, central nervous system depression; dermatitis (“NIOSH Pocket guide to Chemical hazards - Acetone,” 2016).
- Acetonitrile exposure routes are inhalation, skin absorption, ingestion, skin and/or eye contact creating the following symptoms; irritation nose, throat; asphyxia; nausea, vomiting; chest pain; lassitude (weakness, exhaustion); stupor, convulsions; In Animals: liver, kidney damage (“NIOSH Pocket guide to Chemical hazards - Acetonitrile,” 2016).
- Acrolein exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation of the eyes, skin, mucous membrane; decreased pulmonary function; delayed pulmonary edema; and chronic resp disease (“NIOSH Pocket guide to Chemical hazards - Acrolein,” 2016).
- Acrylonitrile exposure routes are inhalation, skin absorption, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, skin; asphyxia; headache; sneezing; nausea, vomiting; lassitude (weakness, exhaustion), dizziness; skin

vesiculation; scaling dermatitis; [potential occupational carcinogen] (“NIOSH Pocket guide to Chemical hazards - Acrylonitrile,” 2016).

- Benzaldehyde exposure routes are through skin absorption, inhalation, and ingestion creating the following symptoms: cough and sore throat; redness of the skin; redness and pain in the eyes (“Benzaldehyde,” 2014).
- Benzene exposure routes are inhalation, skin absorption, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, skin, nose, respiratory system; dizziness; headache, nausea, staggered gait; anorexia, lassitude (weakness, exhaustion); dermatitis; bone marrow depression; [potential occupational carcinogen] (“NIOSH Pocket guide to Chemical hazards - Benzene,” 2016).
- Benzyl Chloride exposure routes are inhalation, skin and/or eye contact (liquid) creating the following symptoms; irritation eyes, skin, nose; lassitude (weakness, exhaustion); irritability; headache; skin eruption; pulmonary edema (“NIOSH Pocket guide to Chemical hazards - 1, 3 Butadine,” 2016).
- 2, 3-Butanedione exposure routes are inhalation, skin absorption and/or eye contact, and ingestion creating the following symptoms; irritation of the skin and eyes, dizziness or suffocation (“2, 3-Butanedione,” n.d.).
- 1, 3 Butadiene exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, nose, throat; drowsiness, dizziness; liquid: frostbite; teratogenic, reproductive effects; [potential occupational carcinogen] (“NIOSH Pocket guide to Chemical hazards - 1, 3 Butadiene,” 2016).

- 2-Butanone exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, skin, nose; headache; dizziness; vomiting; dermatitis (“NIOSH Pocket guide to Chemical hazards - 2-Butanone,” 2016b).
- Butyraldehyde exposure routes are through skin absorption, inhalation, and ingestion creating the following symptoms; a cough and sore throat; redness of the skin; redness and pain in the eyes; and a burning sensation internally if ingested (“Butyraldehyde,” 2014).
- 2, 5-Dimethylbenzaldehyde exposure, symptoms, and carcinogenic information was not found.
- Chloromethane exposure routes are inhalation, skin and/or eye contact (liquid) creating the following symptoms; dizziness, nausea, vomiting; visual disturbance, stagger, slurred speech, convulsions, coma; liver, kidney damage; liquid: frostbite; reproductive, teratogenic effects; [potential occupational carcinogen] (“NIOSH Pocket guide to Chemical hazards - Methyl chloride,” 2016).
- Crotonaldehyde exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation of the eyes, respiratory system; and in animals: dyspnea (difficulty breathing), pulmonary edema, and irritation of the skin (“NIOSH Pocket guide to Chemical hazards - Crotonaldehyde,” 2016).
- Dichlorodifluoromethane exposure routes are inhalation, skin and/or eye contact (liquid) creating the following symptoms; dizziness, tremor, asphyxia, unconsciousness; cardiac arrhythmias, cardiac arrest; liquid: frostbite (“NIOSH Pocket guide to Chemical hazards - Dichlorodifluoromethane,” 2016).
- Ethanol exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, skin, nose; headache, drowsiness, lassitude

(weakness, exhaustion), narcosis; cough; liver damage; anemia; reproductive, teratogenic effects (“NIOSH Pocket guide to Chemical hazards - Ethyl alcohol,” 2016).

- Ethyl Acetate exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, skin, nose, throat; narcosis; dermatitis (“NIOSH Pocket guide to Chemical hazards - Ethyl acetate,” 2016).
- Ethyl Benzene exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, skin, mucous membrane; headache; dermatitis; narcosis, coma (“NIOSH Pocket guide to Chemical hazards - Ethyl benzene,” 2016).
- Formaldehyde exposure routes are inhalation, skin and/or eye contact creating the following symptoms; irritation eyes, nose, throat, respiratory system; lacrimation (discharge of tears); cough; wheezing; [potential occupational carcinogen] (“NIOSH Pocket guide to Chemical hazards - Formaldehyde,” 2016).
- Furfural exposure routes are inhalation, skin absorption, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, skin, upper respiratory system; headache; dermatitis (“NIOSH Pocket guide to Chemical hazards - Furfural,” 2016).
- Heptanal exposure routes are inhalation and absorption creating the following symptoms; eye, skin, and respiratory tract irritation (“Heptanal,” n.d.).
- Hexanal exposure routes are inhalation and absorption creating the following symptoms; eye, skin, and respiratory tract irritation (“Hexanal,” n.d.).
- Heptane exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; dizziness, stupor, incoordination; loss of appetite, nausea; dermatitis; chemical pneumonitis (aspiration liquid); unconsciousness (“NIOSH Pocket guide to Chemical hazards - n-Heptane,” 2016).

- Hexane exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, nose; nausea, headache; peripheral neuropathy: numb extremities, muscle weak; dermatitis; dizziness; chemical pneumonitis (aspiration liquid) (“NIOSH Pocket guide to Chemical hazards - n-Hexane,” 2016).
- 4-Isopropyltoluene exposure routes are by inhalation of its vapour and by ingestion creating the following symptoms; irritation of the eyes and skin, defects the skin, and may cause aspiration into the lungs with risk of chemical pneumonitis (“p-Cymene,” 2014).
- Methanol exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, skin, upper respiratory system; headache, drowsiness, dizziness, nausea, vomiting; visual disturbance, optic nerve damage (blindness); dermatitis (“NIOSH Pocket guide to Chemical hazards - Methyl alcohol,” 2016).
- Methyl Ethyl Ketone exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, skin, nose; headache; dizziness; vomiting; dermatitis (“NIOSH Pocket guide to Chemical hazards - 2-Butanone,” 2016b).
- Methyl Methacrylate exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, skin, nose, throat; dermatitis (“NIOSH Pocket guide to Chemical hazards - Methyl methacrylate,” 2016).
- m-Tolualdehyde: No exposure routes or symptom information was found for m-Tolualdehyde.
- Naphthalene exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes; headache, confusion, excitement, malaise (vague feeling of discomfort); nausea, vomiting, abdominal pain; irritation bladder; profuse sweating; jaundice; hematuria (blood in the urine), renal shutdown; dermatitis, optical

neuritis, corneal damage (“NIOSH Pocket guide to Chemical hazards - Naphthalene,” 2016).

- Nonanal exposure routes are ingestion, skin and/or eye contact creating the following symptoms; irritation to the skin, eyes, lungs, and stomach if ingested (“Nonanal,” n.d.).
- n-Propyl alcohol (Propanal) exposure routes are inhalation, skin absorption, ingestion, skin and/or eye contact creating the following symptoms; eyes, skin, respiratory system, gastrointestinal tract, central nervous system (“NIOSH Pocket guide to Chemical hazards - n-Propyl alcohol,” 2016).
- Valeraldehyde exposure routes are through inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, skin, nose, throat (“NIOSH Pocket guide to Chemical hazards - n-Valeraldehyde,” 2016).
- Octanal exposure routes are through absorption creating the following symptoms; eye and skin irritation (“Octanal,” n.d.).
- o-Tolualdehyde exposure routes are through inhalation, ingestion, or skin absorption creating the following symptoms; irritation (“o-Tolualdehyde,” n.d.).
- p-Tolualdehyde exposure routes are through inhalation, ingestion, or skin absorption creating the following symptoms; skin and eye irritation, respiratory tract irritation, and may cause drowsiness or dizziness (“p-Tolualdehyde,” n.d.).
- 2-Propanol exposure routes are inhalation, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, nose, throat; drowsiness, dizziness, headache; dry cracking skin; In Animals: narcosis (“NIOSH Pocket guide to Chemical hazards - Isopropyl alcohol,” 2016).

- Propene exposure routes are by inhalation creating the following symptoms; suffocation, frostbite, effects to the central nervous system, and lowering of consciousness (“Propylene,” 2014).
- Styrene exposure routes are inhalation, skin absorption, ingestion, skin and/or eye contact creating the following symptoms; irritation eyes, nose, respiratory system; headache, lassitude (weakness, exhaustion), dizziness, confusion, malaise (vague feeling of discomfort), drowsiness, unsteady gait; narcosis; defatting dermatitis; possible liver injury; reproductive effects (“NIOSH Pocket guide to Chemical hazards - Styrene,” 2016).
- Tetrahydrofuran exposure routes are inhalation, skin and/or eye contact, and ingestion creating the following symptoms; irritation eyes, upper respiratory system; nausea, dizziness, headache, and central nervous system depression (“NIOSH Pocket guide to Chemical hazards - Tetrahydrofuran,” 2016).
- Toluene inhalation, skin absorption, ingestion, and skin and/or eye contact creating the following symptoms; irritation eyes, nose; lassitude (weakness, exhaustion), confusion, euphoria, dizziness, headache; dilated pupils, lacrimation (discharge of tears); anxiety, muscle fatigue, insomnia; paresthesia; dermatitis; liver, and kidney damage (“NIOSH Pocket guide to Chemical hazards - Toluene,” 2016).

Appendix N

Chemical Exposure Effects

(a) abdominal pain, anemia, anorexia asphyxia, (e) aspiration into the lungs, (f) bone marrow depression, (g) burning sensation internally if ingested, (h) cardiac arrest, (i) cardiac arrhythmias, (j) central nervous system depression, (k) chemical pneumonitis (aspiration liquid), (l) chest pain, (m) chronic resp disease, (n) confusion, (o) convulsions, (p) conjunctivitis; coma; corneal damage; cough; decreased pulmonary function; defatting dermatitis; defeats the skin; delayed pulmonary edema; dermatitis; dizziness; dilated pupils; euphoria; excitement; frostbite; headache; hematuria (blood in the urine); incoordination; irritability; irritation of the skin, eyes, nose, throat, bladder, stomach if ingested, mucous membrane, respiratory system, upper respiratory system and respiratory tract; insomnia; kidney damage; jaundice; lacrimation (discharge of tears); lassitude (weakness, exhaustion); liver damage; loss of appetite; lowering of consciousness; malaise (vague feeling of discomfort); muscle weakness; narcosis; nausea; numb extremities; optic nerve damage (blindness); optical neuritis; paresthesia; peripheral neuropathy; profuse sweating; pulmonary edema; redness and pain in the eyes; redness of the skin; renal shutdown; reproductive effects; scaling dermatitis: skin burns; skin eruption; skin vesiculation; sneezing; sore throat; staggered gait; stagger; slurred speech; stupor; suffocation; teratogenic; tremor; unconsciousness; visual disturbance; and vomiting. Symptoms identified in animals include; liver, kidney damage; reproductive; teratogenic effects; dyspnea (difficulty breathing), pulmonary edema, and irritation of the skin.

Appendix O**Survey Selection of Additional Toxic Chemicals**

(a) acetaldehyde, (b) acrolein, (c) asbestos, (d) benzene, (e) cadmium, (f) chromium, (g) ethyl benzene, (h) formaldehyde, (i) glutaraldehyde, (j) hydrochloric acid, (k) lead, (l) nitric dioxide (NO₂), (m) nitric oxide (NO), (n) polynuclear aromatic hydrocarbons (PNA's), (o) polyaromatic hydrocarbons (PAH's), (p) phosgene, (q) respirable dust, (r) sulfur dioxide (SO₂), (s) sulfur trioxide/sulfuric acid, (t) toluene, (u) total dust, and (v) xylene, with an option (w) to write in additional chemicals.

Appendix P

Survey Results

Toxic Chemical Exposures to firefighters during real structure fire overhaul operations

32 responses

Name of your organization

32 responses

- Elkhart Fire Department
- Bernalillo County Fire Department
- Tulsa Fire Dept
- Grand Island Fire Department
- Buckley FES
- Goshen Fire and EMS
- Winterville Fire-Rescue-EMS
- Annapolis Fire Department
- Bourne Fire/Rescue
- Derry Fire Department
- City of Peoria Fire Medical Department
- Moultonborough Fire Rescue
- York Area United Fire and Rescue
- Longview FD
- Berthoud FPD
- Sheboygan Fire Department
- Rogers Fire Department
- London Fire Department
- Germantown Fire Department
- Nikiski FD
- Superstition Fire and Medical District
- Gwinnett County Department of Fire & Emergency Services

- Nebraska City Fire Rescue
- Dixon FD
- Washington Township/Avon Fire Department
- Gallatin Fire Department
- NORTH COUNTY FIRE
- Copley Fire Department
- Campbell County Fire Department
- Essa Fire Department
- Smithfield Fire Department
- South Kitsap Fire and Rescue

City, State of your organization

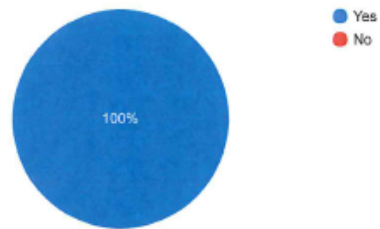
32 responses

- Elkhart, In
- Albuquerque, NM
- Tulsa, Oklahoma
- Grand Island, NE
- Aurora, Co
- Goshen, Ohio
- Winterville, NC
- Annapolis, Maryland
- Bourne, Massachusetts
- Derry, NH
- Peoria, Arizona
- Moultonborough, NH
- York, Pa.
- Texas
- Berthoud, CO
- Sheboygan, Wisconsin
- Rogers, AR
- London, Ontario, Canada
- Germantown, Wisconsin
- Alaska
- Apache Junction Az
- Lawrenceville, GA

- Nebraska
- Dixon, CA
- Avon, Indiana
- Gallatin, Tennessee
- San Diego, CA
- Copley, OH
- Gillette, Wyoming
- Utopia, Ontario
- Smithfield, RI
- Port Orchard, WA

Does your organization perform overhaul operations on structure fires?

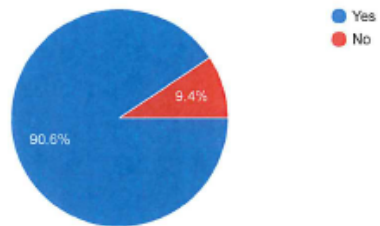
32 responses



Ventilation conditions during overhaul?

Does your organization perform positive pressure ventilation during overhaul operations on structure fires?

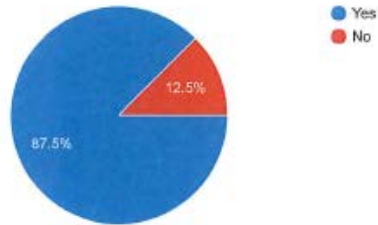
32 responses



What does your organization monitor for in the overhaul environment?

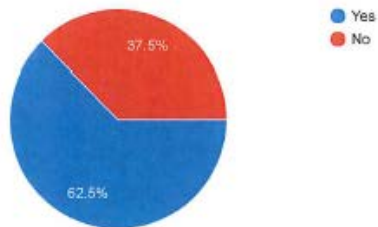
Carbon monoxide (CO)

32 responses



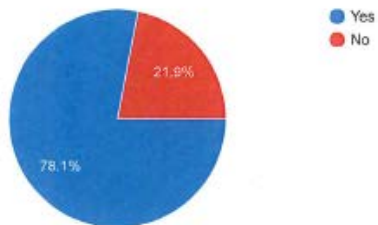
Hydrogen cyanide (HCN)

32 responses



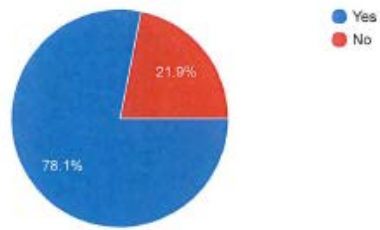
Lower explosive limit (LEL)

32 responses



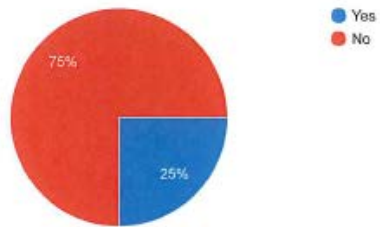
Oxygen (O2)

32 responses



Additional toxic chemical?

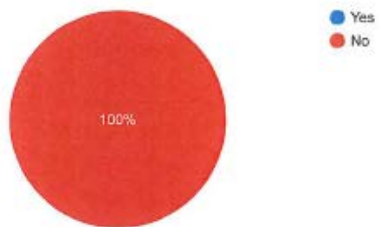
32 responses



Has your organization previously or does your organization currently monitor for additional chemical toxins in the overhaul environment?

Acetaldehyde

8 responses



Acrolein

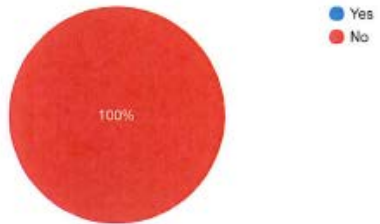
8 responses



Asbestos
8 responses



Benzene
8 responses



Cadmium
8 responses



Chromium

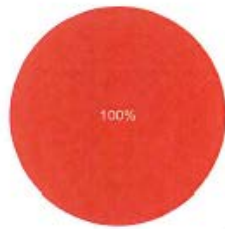
8 responses



● Yes
● No

Ethyl Benzene

8 responses



● Yes
● No

Formaldehyde

7 responses



● Yes
● No

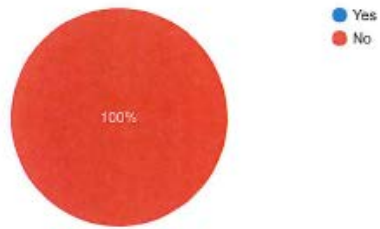
Glutaraldehyde

8 responses



Hydrochloric acid

8 responses



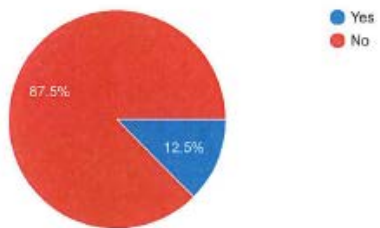
Lead

8 responses



Nitric dioxide (NO2)

8 responses



Nitric oxide (NO)

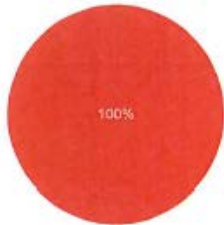
8 responses



● Yes
● No

Polynuclear aromatic hydrocarbons (PNA's) Polyaromatic hydrocarbon (PAH's)

8 responses



● Yes
● No

Phosgene

8 responses



● Yes
● No

Respirable dust

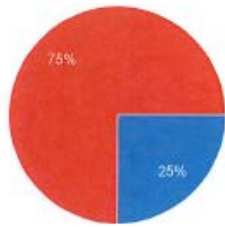
7 responses



● Yes
● No

Sulfur Dioxide (SO₂)

8 responses



● Yes
● No

Sulfur Trioxide / Sulfuric Acid

8 responses



● Yes
● No

Toluene

8 responses



● Yes
● No

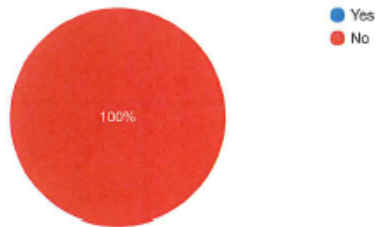
Total dust

8 responses



Xylene

7 responses



If not listed above, and your organization has or does perform additional monitoring in the overhaul environment, please list additional chemicals identified:

1 response

H2S as part of 4-gas meter

Additional information if necessary

Additional comments:

5 responses

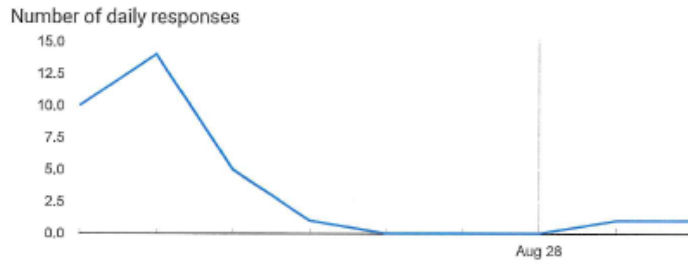
We have policies on and some equipment for monitoring but it rarely gets done. We still have a hard time getting firefighters to wear SCBA during overhaul

Good luck Jake!

Our policy requires that firefighters exit the structure for 45-60 minutes after knockdown before overhaul begins.

We have an instrument (chemPro) that has an overhaul library however it resides on our hazmat unit and we rarely use in on overhaul ops.

Overhaul is performed with SCBAs at all times.



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