MANDATORY SCBA USAGE DURING ALL FACETS OF SMOKE EXPOSURE ACTIVITIES

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ABSTRACT

The purpose of this paper is to show that wearing SCBA at all times under any type of smoke conditions is essential. This paper will also show the potential for toxins to be present in all types of smoke. Firefighters have grown accustomed to wearing their SCBA during intense interior firefighting operations. However, firefighters are failing to use their SCBA during training evolutions, overhaul, smoke investigations, dumpster fire extinguishments, car fire extinguishments, and exterior firefighting operations. The failure to use SCBA during these scenarios is causing acute and chronic illnesses including cancer, pulmonary edema, asthma, and even death. This paper will show that wearing SCBA is essential and will answer the question, “Why is wearing SCBA critical for firefighter survival and longevity on all runs involving any type of smoke situation.” The results of this paper indicate that toxins are found in all smoke. This writer concludes that SCBA has to be worn at all times until the air is proven to be safe by air monitoring equipment.

TABLE OF CONTENTS

INTRODUCTION

The intent of this paper is to educate those in the fire service the importance of SCBA usage on all runs where smoke or other inhalation hazards are present. Many of the inhalation hazards that are present can be easily overlooked. This paper is not meant to discuss SCBA usage during active structural firefighting or the hazards in this type of situation. Today's firefighters have made wearing SCBA's standard procedure during active structural firefighting. However, firefighters fall short when it comes to "routine" runs such as smoke investigations, fighting car or grass fires, extinguishing dumpster fires, or standing in the smoke outside of a structure fire. This paper will explain the inherent dangers of inhaling any type of smoke including long term and short-term effects on the body and the respiratory system.

Many questions were raised during this research such as: Is wearing SCBA necessary when fighting a car fire? Why does a fatigued firefighter need to wear SCBA during overhaul? What types of inhalation hazards is a firefighter being exposed to while performing exterior firefighting operations? This paper will answer these questions and explain why SCBA is a necessity under any smoke conditions. The final recommendations are to wear SCBA under all smoke conditions. My research has proven this by finding documented cases of firefighter fatalities caused by inhaling small quantities of toxic smoke.

Building materials have changed over the years and many new materials give off toxic byproducts when burned. Any amount of these toxic byproducts can cause negative health conditions to unsuspecting firefighters.

Today's firefighter has been highly trained in using their personal protective equipment (PPE) to guard them against injury and possible death. All parts of a firefighters PPE is essential but one piece that is sometimes left on the truck is the SCBA. Firefighters have become complacent in wearing their SCBA during seemingly "routine" fire runs. These runs include smoke investigations, car fire extinguishments, grass fire extinguishments, overhaul operations, dumpster fire extinguishments, exterior firefighting operations, and training evolutions by the trainers themselves. This lack of protection may be caused by several factors including the bulkiness of an SCBA, the time it takes to refill an SCBA tank, the lack of knowledge of the hazards that are present, and maybe even the traditional "smoke eater" mentality.

Firefighting is a unique job that presents many different situations with many different hazards. Fire fighting has evolved over the years to include the state of the art equipment that is currently in use today. Decades ago firefighters were able to extinguish fires by not wearing SCBA primarily because of the products that were being used to build the houses. Wood was a primary source for building materials. There was no carpeting except for an occasional rug. There was no polyvinyl chloride (PVC) for plumbing. There was no plastics or upholsteries, nor was there synthetic fibers. These materials have been shown to produce toxic gases during combustion. These toxins are produced and are present in smoke. Toxins do not differentiate between large fires or small fires; they are present in smoke regardless of the size of the fire.

The problem in the modern day firefighting atmosphere is that most firefighters have become very good at wearing their SCBA during active structural firefighting but they forget to wear their SCBA during many routine calls. Many firefighters have been injured or killed because of smoke or toxic gas inhalation at seemingly harmless and routine fire runs. There is still somewhat of a “traditional” attitude when it comes to wearing SCBA at these types of incidents. One of the problems is that today’s plastics and other building materials give off toxic smoke that can be inhaled even if the firefighter is outside in the open. Another problem is that firefighters tend not to wear SCBA during overhaul operations. This paper will point out the extreme hazards of inhaling this type of smoke.

The purpose of this research is to show the correlation between smoke inhalation and firefighter injuries, fatalities, and cancer. This paper will also prove that many routine fire calls can be deadly if SCBA is not worn. There are many different “routine” calls that firefighters respond to and my research will point out the inhalation hazards associated with these types of runs. Smoke inhalation is a recognized term that most firefighters tend to think of as something that occurs only during large fires and interior attacks. This paper will show that all fires no matter how big or small can and will generate toxic smoke that can cause acute or chronic health problems such as asthma, pulmonary edema, or even death. This paper will educate the firefighters on the hazards of inhaling any quantity of smoke. Firefighters have been killed during “routine” smoke investigations because they were not wearing their SCBA.

Fire departments have progressed over the years to include specialized training such as hazardous materials and confined space rescues. When a firefighter is faced with a hazardous materials incident they are trained to recognize the hazard before exposure to the chemical takes place. Generally, firefighters secure the area and call in a hazardous materials team. The hazardous materials team arrives with sophisticated equipment that allows them to monitor the air for specific toxins and their encapsulated suits protect them from the material. Confined rescue teams have also evolved into highly specialized technicians that are equipped to monitor the air before they even enter the space. What do these two things have in common? There is no fire and the air is monitored before one breath takes place. Every fire that a firefighter extinguishes has toxic byproducts in the smoke that is generated. The only difference between fire fighting and hazardous materials incidents or confined rescues is that firefighters fail to monitor the air for toxins. Firefighters do not seem to be trained in the toxins that can be produced at any fire scene. Smoke does not come in an OSHA approved package with warning labels. Many firefighters in training have witnessed the video where the firefighter walks up to a leaking rail tank car and physically touches the product that is leaking and smells it to determine what the substance is. Today's firefighters have been trained to keep their distance and always avoid contact. Ironically, many fires that are responded to today are handled much the same way as the rail car in regards to wearing SCBA. We smell the air and breath in the smoke until it is determined if there are toxins in the air, by then it's too late. Firefighters need to wear their masks anytime there is smoke to avoid inhalation injuries.

This paper will answer many questions such as: Why would a firefighter need to wear an SCBA during a car fire extinguishments? What type of materials gives off toxic smoke? What potential hazards exist while investigating a smoke scare without wearing an SCBA? This paper is not meant to discuss SCBA usage during aggressive interior attacks. It has become second nature for a firefighter to wear SCBA during this type of situation. However, the intent of this paper is to hopefully make SCBA usage second nature when working in any environment that has smoke.

BACKGROUND AND SIGNIFICANCE

The fire service has evolved over hundred of years of service. With this service have come many traditions that the modern day firefighter must overcome to ensure safe scene mitigation and to live a long and healthy life. Early firefighters were able to survive firefighting using such techniques as breathing through a wet beard. As the fire service grew it modernized and with this modernization came SCBA's. Tradition is hard to break in the fire service and having to use SCBA's at "minor" incidents is no different. We've all heard tales of the smoke eaters and how macho it is to get back to the station after working a fire and blowing your nose and seeing black mucous on the tissue. That black mucous contains soot that carries with it many toxins that is not only in the nose but the lungs themselves. These toxins then pass from the lungs into the bloodstream.

Wearing an SCBA while fighting a car or dumpster fire was and still is not done by some departments throughout the country partly because of the inconveniance of having to fill an air cylinder and a lack of knowledge of possible hazards. Currently, wearing an SCBA while actively fighting a structure fire is second nature for most modern day departments. The problem is, after the fire is out the mask comes off. The firefighters become fatigued and the first thing that comes off is the mask. The misconception is that the hazard is over and a mask is not needed. Investigating a fire scene is no different. No investigator, including myself, wants to wear a bulky SCBA for hours in a hot environment. There is also the inconvenience of not being able to see through a camera lens, obscured vision, and the fact that SCBA's are cumbersome.

Firefighters routinely extinguish fires on a daily basis. Many times these firefighters get to go back to the station without incident. Occasionally firefighters experience tragic consequences because a poison has entered into their body via their respiratory tract. This exposure can be tragically caused by small quantities of smoke during an ordinary call that has been handled many times before without incident. Car fires, overhaul, training fires, car fires, dumpster fires, and exterior firefighting operations pose serious health threats that need to be recognized by every firefighter.

Car Fires

Car fires are not taken seriously enough by many firefighters across the nation. These car fires are routinely extinguished by firefighters who are not using SCBA. Car fires pose many hazards that can go unrecognized or contain hazards that are not taken into consideration.

The transportation of goods occurs daily on our highways and freeways. These transported items can be hazardous and some are required to be labeled by law. These vehicles may not be labeled due to various circumstances. Commercial vehicles can contain a wide array of hazardous materials. The smoke generated by this type of fire has the potential for the creation of many types of toxic gases. If an SCBA is not initially worn toxins may be inhaled before the hazard is recognized.

A routine car fire can have equally devastating results. Many people transport gasoline, propane, hazardous materials, and fireworks. Cars are also made of large quantities of plastic. This plastic generates poisonous gases when undergoing combustion. PPE can protect the firefighter from dermal exposure but not respiratory exposure if SCBA is not worn. There have been instances where firefighters have been killed when gas tanks have ruptured and the firefighters were engulfed in the ensuing flames. Compressed natural gas vehicles carry large quantities of natural gas and if involved in a fire could pose potentially disastrous results when the pressure relief valve activates.

Dumpster Fires

Dumpster fires are always taken lightly as if there are no hazards present. Unfortunately none of us know exactly what is inside of that dumpster. Many industrial dumpsters contain a host of hazardous materials. We conduct building surveys to make ourselves aware of the hazards inside of the building, but unfortunately those very same hazards have probably found their way out to the dumpster.

Dumpsters can be the dumping grounds for illegal trash removal and can be in such places as a grocery store, party store, or an apartment building just to name a few. There could be anything in that dumpster ranging from propane tanks to poison. In addition there could be mercury, discarded PVC piping, aerosol cans, carcinogens, ammunition, gas cans, explosives, or other significant hazards.

LITERATURE REVIEW

Research has shown that toxic byproducts are created by the combustion of modern day materials. When not fully prepared or properly protected firefighters over the years have been unnecessarily exposed to these toxins. Scientific studies reveal that the toxins, if inhaled, can create long-term health effects or even death. The compiled data concludes that at every fire there is a toxic component to the smoke. There are documented cases that show that even the smallest quantity of smoke that contains a toxin can be deadly or lead to long-term disabilities. The review of the literature will answer several questions including: (1) What types of toxins are out there? (2) What types of materials create toxic smoke? (3) What are the quantities that need to be inhaled before injury or death occur? (4) How many firefighters have been affected by toxic inhalation? (5) What types of situations would a firefighter expect to encounter toxic smoke?

Firefighter Fatalities/Injuries

The documentation of firefighter fatalities shows that toxic smoke is present at every fire scene no matter how big or small the fire is. Fahy and Leblanc (2001) show us through their statistics that in the year 2000, three career firefighters died as a result of asphyxiation (p.68). Karter and Badger's (2001) report indicates that in the year 2000, 2,870 firefighters were injured on the fireground as a result of smoke or gas inhalation. Another 855 were injured as a result of "other" respiratory distress (p.51). According to the smoke inhalation and smoke exposure deaths 1978-1987 (1988):

> "Of the twenty five firefighters that died as a result of exposure to smoke, twelve were not using SCBA (five were fighting fires in their own homes, four were members of a fire brigade and three were fighting grass or brush fires), seven ran out of air, two had removed their SCBA, one had a broken face piece and no information was available for the other three" (p.45).

This report also reveals a startling correlation between heart attacks and smoke exposure. Heart attacks were directly related to smoke exposure in the autopsy reports (p.43).

These figures reveal the significance of protecting the respiratory system under all smoke conditions. Some of the provided data is not specific in regards to how the injuries occurred, i.e. SCBA malfunction etc. However, there is a direct relation between smoke inhalation and injuries or death. Cunninghame (2001) notes that an Ontario study reports that, "Eighty percent of firefighter injuries can be attributed to smoke inhalation or oxygen deficiency and that fifty percent of line of duty deaths are due to smoke exposure" (p. 18).

Smoke Toxicity

The smoke that a firefighter encounters is a dangerous brew. Not only are toxins present in the smoke; they combine to create highly poisonous mixtures. O'Brien's (1997) studies contend: The poisons that a firefighter encounters in smoke include carbon monoxide, benzene, formaldehyde, acrolein, acetaldehyde, nitrogen dioxide, hydrogen cyanide, hydrogen chloride, sulfur dioxide, sulphuric acid, and polycyclic hydrocarbons. Carbon monoxide is a frequently encountered gas during most fires. Carbon monoxide is created by incomplete combustion. It is odorless and colorless and can be fatal at concentrations of 1,500 ppm (Wallace, 1995, p.25). Carbon monoxide combines with red blood cells. These are the cells that carry oxygen throughout our bodies. If the red blood cell is loaded with carbon monoxide it will be unable to transport oxygen to the cells. Therefore, hypoxia will result. Carbon monoxide also has cumulative affects. Inadequate respiratory protection leads to inhalation of this gas and repeated exposures cause a loading effect. A firefighter may feel fine leaving the scene of a large fire only to suffer ill affects when inhaling CO at a minor fire or vice versa.

Albinson (1996) points out that floor coverings and paint can emit heavy metals when subject to combustion. These heavy metals in the smoke can travel in the air. This smoke can be confined to the building or escape and travel out of doors (p.33). According to Winney (1990), after a fire was put out twenty-one hazardous chemicals were suspended in the atmosphere. Nineteen of these chemicals are toxic, and seven of the chemicals are suspected to be carcinogens (1990, p.68).

The DHHS (NIOSH) (1977) report points out one prime example of a toxic chemical, acrylonitrile: This chemical is used in the manufacture of carpeting, blankets, draperies, and upholsteries, and some apparel. Synthetic furs and wigs are also manufactured using this chemical. ABS plastic, styrene-acrylonitrile resins, and nitrile are also included in the use of acrylonitrile. This chemical has been banned for use in the manufacture of soft drink bottles by the U.S.F.D.A. The Manufacturing Chemists Association conducted these studies in April 1977. The report concluded that twenty-six of the rats that inhaled the chemicals were killed after one year of exposure (1977, pp.1-3).

Cunninghame (2001) lists several materials that when burned give off toxic chemicals: Wool, silk, and hair produce hydrogen cyanide (HCN), nitrogen dioxide, and carbon monoxide. Hydrogen cyanide reduces the ability of the human nose to sense this chemical. “Polyurethane rubbers, urethane foams, PVC’s, and vulcanized rubbers produce hydrogen chloride, sulfur dioxide, hydrogen sulfide formaldehyde, acrolein, and carbonyl sulfide (p.18)”.

The list of toxic chemicals that can be generated at a fire as listed by Cuninghame (2001) include:Acrolein, benzene, formaldehyde, hydrogen cyanide, nitrogen dioxide, and phosgene. Wood, cotton, carpeting, and upholstery create acrolein when burned.

Acrolein has been classified a carcinogen by the EPA. Benzene is a common chemical found in smoke and is used in the manufacture of certain chemicals, varnishes, dyes, and lacquers. Benzene is also a carcinogen. Formaldehyde, a carcinogen, is found in resins, fungicides, plastics, glues, wood products, insulation, paints, and rubber. Hydrogen cyanide which blocks oxygen from getting to the cells, is found when materials such as wool, silk, polyurethanes, nylons, and fumigants burn. It is estimated that HCN is present at fifty percent of all fires. Nitrogen Dioxide is an irritant and can cause pulmonary edema and is a suspected carcinogen.   This chemical is present when grains and pyroxylin plastics burn. Phosgene is present in the smoke created when refrigerants are impinged upon by flame. If phosgene is inhaled hydrochloric acid forms in the lungs (p.18,20). *Inhaled Toxins* (1995) adds two more chemicals to the list, Ammonia, and methyl chloride. Ammonia is common in many household products and can cause eye and respiratory irritation as well as seizures. Methyl chloride is also a common chemical and if inhaled can cause nausea, and nervous system alteration and seizures (p.13).

Upshur (2001) reported on a fire that occurred on July 9, 1997 in Hamilton, Ontario involving PVC's: The fire burned for almost eight days until it was extinguished. During the fire a smoke plume enveloped the surrounding area, which affected the health of the residents in the area. The citizens were surveyed and the residents reported numerous health problems including throat irritation, headaches, breathing difficulties, and other ailments. The burning PVC's produce at least seventy toxic chemicals including hydrogen chloride, which forms hydrochloric acid when exposed to water (p.1-12). Markowitz, Gutterman, Schwartz, Link, & Gorman researched a PVC fire that occurred in Plainfield, N.J. on March 20, 1985:They describe the breakdown of PVC's due to thermal degradation include not only hydrogen chloride but benzene and tolulene as well. The firefighters at the scene were uninformed of any chemicals that were burning which resulted in a time lapse where SCBA was not used. Their study strongly enforces the fact that exposure to the smoke generated at this fire caused short-term health effects to the firefighters at the scene (p.1023-1031).

Gabler (1999) explains that dioxins, furans, and polycyclic aromatic hydrocarbons can be present in many modern day firefighting operations. Seventy-five of the dioxins and 135 furanes have highly toxic properties. These chemicals are deemed super poisons and cannot be detected by the human olfactory system. Some of the scenarios that could emit these toxic gases include: burning transformers, flame proof products that undergo direct flame impingement, certain drugs, insecticides, wood preservatives, certain types of paint and varnishes, and certain plastics (p. 30).

Case Studies

David Peterson (2001) describes several scenarios that caused injury and or premature deaths to firefighters:

The first incident occurred in Florida when the fire department responded to an apartment complex to investigate the odor of smoke. Upon arrival they were brought to a back room where the smoke originated. The door was not hot and the crew opened the door only to be immediately overcome with smoke. Further investigation revealed several chemicals in the room including sodium hydroxide. The firefighters were tested for blood chemicals and PCB's as well as chloroforms were found in their blood. The three firefighters involved in the fire experienced disabilities from the incident.

The second incident occurred in New York City February 27, 1975. The firefighters were engaged in fighting a fire at a telephone company. 239 firefighters were treated for injuries after being exposed to toxic chemicals created by burning plastics and wire insulation. Many of the firefighters experienced cancers and early deaths due to their exposure to the chemicals.

The third incident occurred in Fort Lauderdale Florida in 1969 at a fertilizer factory. Firefighters during that era did not routinely wear SCBA's. Many of the firefighters suffered from cancer as a result of their exposure to the chemicals that were in the smoke.

The fourth incident describes a fire at an industrial site. Metal zinc had been burning and two firefighters did not use their SCBA. These firefighters experienced metal fume sickness as a result of their inhalation exposure to the fumes. Ironically, the third firefighter wore his SCBA and did not experience any ill effects (p.2-3).

Naylis (1996) reports an incident in June 1994 that occurred in Bergenfield, N.J. Firefighters responded to a report of something burning in an oven. Upon arrival there was smoke showing and firefighters entered the structure wearing full PPE and SCBA. The area was ventilated and the cause of the smoke was found. A subsequent investigation revealed that the home had recently changed owners. When the new owners turned on the oven, rodent poison in the oven began to thermally degrade and generated toxic smoke. Because the firefighters were wearing SCBA none of the firefighters suffered injuries (p.1).

Guglielmo (1996) describes an incident in October 1995 in Elk Grove, IL when firefighters were responding to an oven fire that was reportedly out. Upon arrival there was no smoke showing and firefighters investigated the cause of the alarm. Because there was no smoke in the area, SCBA was not worn. The electric oven was unplugged to deenergize the heating element and the oven door was opened. Immediately firefighters were overcome with fumes. Their eyes and throats burned and the oven door was immediately closed. The firefighters were unaware that the homeowner had used a chlorinated halon extinguisher before their arrival. Halon produces phosgene gas when it comes in contact with hot metal, the heating element (p.1).

Fire fighter fatality investigation report #99F-34 (2000) outlines the scenario when three firefighters were burned, and one later died due to full thickness burns. The firefighters had responded to a recreational vehicle fire on August 8, 1999 in Arkansas. The firefighters were attempting to extinguish this fire without using any PPE. The gas tank ruptured and the three firefighters were engulfed in flames (p.2). Even if the firefighters had been wearing full PPE minus SCBA there is a high probability that the firefighters would have suffered from inhalation injuries and possibly inhaled toxic gases causing severe thermal upper respiratory burns.

A New Jersey FACE report (1997) describes what happened to a deputy fire chief and two other firefighters on August 14, 1996 in the New Jersey area. The fire department responded to a working restaurant fire. The fire had spread through the ventilation duct and to the roof. Upon reaching the roof it was sucked into an air conditioning unit. The coils of the unit ruptured and spewed freon into the atmosphere. The freon generated phosgene gas when it was exposed to the heat of the fire. The phosgene gas mixed with the smoke and entered the structure. When crews began to ventilate, the deputy fire chief and two others were exposed to the toxic smoke that had exited the structure. The chief who was not wearing an SCBA became ill and was treated and released at a local hospital. Ten days later the deputy chief collapsed in his home due to “marked tracheobronchial inflammation, alveolar hemorrhage, and pulmonary edema due to smoke inhalation containing phosgene”. One of the firefighters was wearing their SCBA but not their mask. The other firefighter, the department chief, was not wearing an SCBA when the smoke descended on him (p.3).

Firefighter injury project investigation #1 (1997) describes an incident where sixteen firefighters and two EMS workers were exposed to toxic smoke and were treated at a local hospital for their inhalation injuries. One firefighter experienced respiratory arrest and subsequent cardiac arrest. The incident occurred in November of 1996 in the New Jersey area. The firefighters responded to a report of smoke showing from an abandoned industrial building. Upon arrival the firefighters forced entry and encountered a light gray smoke. The firefighters were wearing their SCBA’s but not their masks. While investigating the area they went up to the next level of the building. At that point they began to experience heavier smoke conditions and they began to put on their masks. However, the initial inhalation had already occurred. At this point three of the firefighters began to experience medical symptoms and exited the building. The one firefighter collapsed after exiting the building. The cause of the fire was smoldering insulation on copper wire in a steel drum. The insulation was made of PVC’s. PVC’s generate hydrogen chloride when burned. The hydrogen chloride forms hydrochloric acid in the moist membranes of the respiratory system. Inhalation of hydrogen chloride causes acute bronchitis, pulmonary edema, and death (p.1-5).

<u>Overhaul/Fire Investigations/Training Fires</u>

During overhaul operations firefighters typically remove their masks and SCBA backpacks. Since overhaul occurs after the fire is extinguished, firefighters are exhausted and hot. The last thing a firefighter wants to do is breath from an air cylinder and wear a heavy SCBA tank while engaged in further strenuous activities. The problem is that overhaul outside of suppression poses extreme inhalation hazards. Bolstad-Johnson, Burgess, Crutchfield, and Clifton (2000) show that toxic gases remain in the atmosphere after a fire is extinguished. Organic vapors and halogenated compounds attach to already airborne particulate matter that provides and excellent transportation modem that easily enters the firefighters lungs. In addition they express the possibility of asbestos being in the air. During their studies they monitored hydrogen cyanide gas at levels 10 times higher than anticipated. During their study of the overhaul of twenty-six fires several of the fires had gases that exceed ceiling values. These gasses included CO, acrolein, and, glutaraldehyde. The following gases were above short-term exposure limits: benzene, nitrogen dioxide, and sulpher dioxide. Coal tar pitch volatiles (PNA's) exceeded permissible exposure limits. These hazards may remain in the air for long periods of time. One unusual finding was that the gas powered PPV fans generate CO (p.636-641).

Gabler (1999, May) points out that the ultra poisons break down at approximately 300 degrees C. After breaking down they are easily absorbed into the smoke, soot, ash, and dust. Therefore, when any of these are inhaled, toxic chemicals are transported into the lungs. These toxins remain toxic even after they are cool (p.30). Cunninghame (2001) expresses that, "The greatest danger to staff lies when the fire is out and overhaul or an investigation is being conducted". He goes on to say that the hazard increases when the dust and soot is kicked up into the air which is then inhaled (p.18). Wallace (1995) asks the question, "When do most of our firefighters usually get overcome by smoke and toxic gases?" His answer is, "During the overhaul stage of firefighting"(p.24). Bolstad-Johson et al. (2000) reinforce this by adding that, "It is during this phase of fire [overhaul], when there is little or no smoke in the environment, that a firefighter is most likely to remove his or her respirator face piece and work in this environment without respiratory protection" (p.636).

Trainers in a training fire scenario may not wear SCBA while monitoring the trainees as was in the research submitted by Feunekes, Jongeneelen, and Laan (1997) who report that inhalation hazards are present in this scenario just as they are in any working fire. These trainers are exposed to smoke and soot on a frequent basis. Polycyclic aromatic hydrocarbons (PAH) are present in soot and are inhaled if not wearing an SCBA. The trainers were monitored by analyzing their urine and measuring urinary-1 hydroxypyrene. Measuring urinary-1 hydroxypyrene enables the researchers to detect exposure to PAH. The results show that the trainers had concentrations of several carcinogens as well as PAH. Coke oven workers display a similar exposure level to PAH (p.25).

<u>Wildland/Car Fires</u>

Most firefighters assume that when they are fighting a grass fire or other wild land fire, their chance for toxic gas inhalation is minimal. Health hazards of wildfire smoke under study (1992) shows that wild fire smoke contains, carbon monoxide, lead, sulfur, aldehydes, black carbon, ozone, and organic acids. The article goes on to describe a report conducted in 1990 by the California Department of Health Services

(CDHS)/National Wildfire Coordinating Group (NWCG). The report was conducted to evaluate wild land firefighters exposure to smoke and found, "Remarkable health hazards to firefighters" (31-32).

Gustin (1996) states that cars contain hydrocarbon-based synthetic materials. When these plastics burn heavy smoke is produced. Cancers among firefighters have been caused by the inhalation of this type of smoke (p.1). Gustin (1996) also explains that many new cars are manufactured with plastic fuel tanks. These fuel tanks are easily ruptured during fire conditions. Many different items may be in the trunk of an auto mobile such as propane, or gas tanks (p.2)

Inhalation Injuries

The effects of toxic smoke inhalation can produce acute, chronic, or fatal injuries. The effects of these toxins affect the body in various ways. Matera (1996) explains that certain chemicals combine with water to create other toxic chemicals. These chemicals have the ability to travel to the alveoli and can cause bronchospasms, edema, tissue death, and can injure normal ciliary function. The cilia are responsible for clearing out unwanted materials from the lungs (p.61). He goes on to explain that one minute of carbon monoxide exposure at a 2 percent concentration could create carboxyhemoglobin levels to rise over thirty percent. At this level hospitalization is mandatory. Symptoms of toxic inhalation can cause pulmonary edema and pneumonia. These medical conditions may not be initially present (p.62).

Campbell (2000) reports that if nitriles are inhaled they can metabolize to form cyanides. "Cyanides inhibit cellular respiration by binding with enzymes containing ferric ions, in particular cytochrome oxidase. The clinical manifestations of this are those of tissue hypoxia. Inhalation of hydrogen cyanide gas can be rapidly fatal and deaths have been reported in minutes". Hydrogen sulphide inhalation can cause cerebral and cellular hypoxia. This chemical may also cause thermal burns to the upper respiratory tract (p.1-6).

Eighty percent of burn victims die each year due to the inhalation of toxic by-products that are given off in a fire (Weibelhaus, 2001, p.1). Weibelhaus (2001) advises that any firefighter that inhales smoke, dust, fumes, steam, aerosols, or toxic gases while fighting a fire can suffer from asphyxiation, direct tissue damage, systemic effects, or injuries caused by the body's defense mechanisms. Cyanide gas inhalation can cause cardiac arrest, and other neurological symptoms such as seizures. Direct contact with the chemical causes redness, swelling, and tissue ulceration of the airways. Systemic destruction occurs when the chemical enters the blood stream and damages internal organs. Inhaled mercury and mustard gas initiate this type of response (p.1-2).

Armstrong's (1995) research indicates that there are four phases of inhalation injury. The first phase occurs begins at first inhalation and continues for 36 hours. The second phase occurs on days 2-6. The third phase causes inflammation and can last up to one year (p.25-26). Armstrong (1995) reinforces previous research and states, "Gases released by thermo genesis can result in severe chemical burns to the upper and lower respiratory tree. Carbon monoxide, hydrogen cyanide, nitrogen dioxide, carbon dioxide, hydrochloric acid, ammonia, benzene, and aldehydes are commonly involved and present a variety of clinical pictures" (p.26). Armstrong (1995) also describes how these chemicals attach to the smoke particles and travel into the lungs. Injuries to the lungs includes, tracheobronchitis, bronchoconsrtiction, soft tissue swelling, impaired mucosal ciliary clearance, mucosal sloughing, atelectasis, and pulmonary edema (p.26). Armsrtong (1995) goes on to explain that mucous membranes found in the respiratory tract are easily damaged by compounds in smoke that are water-soluble. Ammonia, sulfur dioxide, and hydrochloric acid are highly destructive to the mucous membranes. The chemical itself causes direct tissue damage to the site. Then inflammation sets in followed by sloughing of the membranes. The human body reacts with its own defense mechanisms causing further inflammation. The insult leads to brochospasms, airway obstruction, and pulmonary edema (p.29-30).

According to Feunekes et al. (1997), short-term health effects of smoke exposure include reduced pulmonary function and possibly pulmonary edema. Carbon monoxide exposure can cause death, and long-term exposure to soot causes lung cancer. If poly aromatic hydrocarbons PAH are added to the soot the results "may be very significant" (p.23).

Bolstad-Johnson et al (2000) emphasize that formaldehyde is classified as a possible carcinogen. Gluteraldehyde is a sensory irritant and can cross-link or fix proteins (p.638). Bostad-Johnson, et.al. (2000) explain that:

> In addition to the studied contaminants evaluated in this study, fire scenes include a diverse mix of chemicals that are not easily characterized. Published health effects often are not available on the combined effects of multiple low-level exposures. Adverse health effects may occur from exposure to a mixture of products of combustion, even if individual components do not exceed occupational exposure limits (p.639).

O'Brien (1997) expresses that many of the discussed compounds are:

> Known or suspected carcinogens, severe respiratory irritants, chemical asphyxiants, etc. Some have immediate acute adverse health effects, others long term chronic health effects, others both. Their individual toxicities have been well characterized; their ability to act upon the body synergistically to cause adverse effects have not been well studied (p.40).

The toxic action of polychloro-dibenzo dioxins (PCDD) and polychloro-dibenzofuranes (PCDF) according to Gabler (1999) include absorption into fat cells and long decomposition. Half lifes exceed 2000 days therefore, tissue damage may occur over a long period of time. Small quantities of these chemicals are carcinogenic. The immune system also becomes damaged by the actions of theses chemicals (p.30). Cunninghame (2001) states “There have been reports of cancers developing that can be traced back to inhalation of these products by firefighters who have been active for 20-30 years” (p.18). Firefighters have experienced bladder, colon, brain, and lymphatic cancers due to exposure to toxic inhalation (Cunninghame, 2001, p.18).

Wildand firefighters experience decreased lung capacity due to smoke exposure. Further research is required to determine if the lungs heal and return to normal capacity (Health hazards of wildfire smoke under study, 1992, p.30).

O’Brien (1997) cites an NFPA report released in 1996 that reports:

> Thirty percent of severe firefighter injuries area result of exposure to smoke, toxic fire products, chemicals, fumes, or gases. About fifty percent of these severe injuries occurred under circumstances perceived by firefighters as not requiring SCBA usage (e.g. outdoors at ground level, inside structures on floors other than where fire is burning, during overhaul, during ventilation activities, etc.) (p.41).

Professional Recommendations

According to Bolstad-Johnson et al. (2000), firefighters are “overexposed” to many different types of toxins including carcinogens. Their recommendations include wearing SCBA during overhaul activities. The air should be monitored and if CO is found assume that there are other toxins present in unsafe levels. Air purifying respirators can be worn if CO levels are below 150 ppm (p.639). Cunninghame (2001) emphasizes that firefighters must always protect themselves while engaged in any type of firefighting activity including overhaul and investigations (p.18). All of the injuries that Peterson (2001) has discussed were all preventable. Avoiding inhalation injuries is simple and “prevention is the key” (p.3).

Gabler (July 1999) outlines several precautions to take to avoid injury: Always wear SCBA, position unnecessary and unequipped firefighters out of the smoke zone, be sure areas are ventilated properly before entering if not using SCBA, and investigations should always be conducted using SCBA (p.25). Wallace (1995) suggests that air monitoring and sampling equipment is always used (p.25). While fighting car fires Gustin (1996) reminds us that SCBA must be worn. Trying to avoid the smoke without a mask is not sufficient for optimal protection (p.1).

OSHA standard 1910.120, hazardous waste operations standard, paragraph q (iv) states:

> Employees engaged in emergency response and exposed to hazardous substances presenting an inhalation hazard or potential inhalation hazard shall wear positive pressure SCBA while engaged in emergency response, until such time that the individual in charge of the ICS determines through the use of air monitoring that a

> decreased level of respiratory protection will not result in hazardous exposures to employees (Wallace, 1995, p.24).

Inhaled toxins (1995) reinforces that prevention is the key to avoid inhalation injuries. Today's firefighter can be equipped with sophisticated air monitoring equipment that should be used any time smoke or questionable atmospheres are present (p.12).

NFPA 1404 (1996) 3-1.2 specifically states:

> Respiratory protection shall be used by all members who are exposed to respiratory hazards or who might be exposed to such hazards without warning. Members who are operating in areas that might be subject to these hazards where there is sufficient warning to don respiratory protection equipment shall have respiratory protection equipment readily available fore use (p.7).

Appendix A-3.1.2 of NFPA 1404 clarifies this paragraph by stating, "[Respiratory hazards] include overhaul situations, unless it can be determined that the area has been adequately ventilated to eliminate respiratory hazards" (p.14). The definition of respiratory hazard as defined by NFPA 1404 is, "Any exposure to products of combustion, superheated atmospheres, toxic gases, vapors, or dust, or potentially explosive or oxygen deficient atmospheres, or any condition that creates a hazard to the respiratory system" (p.5).

PROCEDURE

The research was conducted using professional web sites, Internet sources, journals, and on-line databases. The references cited were of three types: Firefighter specific, medical/scientific, and statistical data. Many of the references were based on actual scenarios that had been experienced by firefighters. The firefighter references include those from professional journals such as the NFPA Journal, Fire Engineering, Minnesota Fire Chief, Firefighting in Canada, Firehouse, Fire international, and Industrial Fire World. These are just a few of the sources that were included in the research. These magazines/journals are read throughout the world and firefighter professionals have read their articles throughout the years. Highly trained individuals wrote the medical/scientific sources. The majority of the articles were written by doctors, RN's, firefighters, fire officers, fire chiefs, and the like. These sources contained a host of professional citations themselves. Several of the articles were documented cases where several firefighters had been seriously injured.

Some of the statistics were taken from U.S. governmental agencies such as the U.S. Fire Academy. The NIOSH investigations revealed data that was found at the scene where the incidents took place and the circumstances involved. The reports also contained autopsy reports that provided irrefutable evidence of how the firefighter died.

I began my research by searching for information on smoke inhalation and toxic inhalations. This information formed the base for my research paper. The data showed the types of toxins that are encountered as well as the concentrations that are typically found at many fire scenes. I also found articles that answered such questions as, "What materials found in the average fire give of toxins?" I then found information that told me the types of toxins that can be generated in fires. I also wanted to know what phase of firefighting is more probable to cause an inhalation injury than others.

The second step was to discuss several firefighting scenarios as firefighters may experience many different fires in a days work. In these scenarios I pointed out the possible dangers that could be experienced. This writer included the documented cases where firefighters were injured as a result of inhalations injuries experienced during “routine” calls.

The third step was to find documentation of firefighter inhalation injuries so as to bring a sense of reality to the material. Many firefighters may have experienced similar situations where they may or may not have experienced an injury. I wanted the reader to have the information “hit home”. Therefore, a firefighter would think twice before entering any type of smoke environment without his or her mask.

The fourth step was to find articles pertaining to the effects of the toxins on the human body. These toxins were listed previously and I wanted to associate symptoms and the damage that occurs with each toxin. The medical information is real and proves these toxins can be devastating and potentially fatal. Firefighters can associate firefighting with cancer. Many of these toxins have shown to be or are suspected of being carcinogenic.

RESULTS

Firefighters should wear their SCBA during any environment that has not been deemed safe by air monitoring equipment. The data provided in this paper provides proof that toxins can be present in any smoke. This includes smoke generated from dumpsters, car fires, grass fires, and any other type of fire that creates smoke. This paper has provided documentation of fires that appeared to be routine from the outset but in reality a toxic environment existed.

Firefighters should wear their SCBA even after the fire is extinguished including overhaul operations. Not only is SCBA a requirement by NFPA 1404, it is an OSHA requirement. These code professionals have recognized the hazards of the overhaul environment. The data contained in this paper back their findings and prove that toxins exist during overhaul evolutions.

Firefighters need to wear their SCBA while fighting car fires. Documentation has been provided that concludes the materials that a car is manufactured of generate toxins when they are burned. The premise that if a firefighter keeps his or her face out of the smoke they will be safe is false. The toxins attach to smoke particles and when any amount of smoke is inhaled, the toxins are transported deep into the lungs.

DISCUSSION

This writer has found that all of the information provided in this paper corresponds to the same conclusion. Fire smoke toxins are present any time smoke is generated. These toxins can produce symptoms ranging from mild discomfort to respiratory arrest. Toxins can be found at any type of fire ranging from a small dumpster fire to a large industrial fire. Firefighters generally wear their SCBA at working fires but frequently they do not wear them during fires that are perceived to be free from toxins. Today's society produces large quantities of synthetic materials that when burned produce toxic gases. These synthetic materials can be found at any type of fire including dumpsters, car fires, and wild land fires. Unless a firefighter is absolutely guaranteed that toxins are not present, SCBA should be worn. Unfortunately, this is not that easy because there are a large number of natural products that also generate toxins when burned. Therefore, all smoke is toxic and it should not be inhaled.

Often times firefighters on the outside of a burning structure are close enough to the structure that inhalation of toxic smoke is likely. These firefighters are either in rehab, command officers, or pump operators. A “hot” zone needs to be established around a structure where inhalation of smoke will be likely.

With today’s technology and state of the art equipment there should never be inhalation injuries due to toxic smoke. According to Peterson (2002):

> Many departments stress the dangers of smoke and hazardous atmospheres and the use of protective equipment and even have standard operating guidelines or procedures in place to prevent responders from becoming victims yet these exposures continue to happen. As an industry, we have to change our approach to these situations. Prevention is the key! (p.3).

Unexpected situations do arise and firefighting is an extremely hazardous occupation. However, with proper training firefighters will be aware of the potential hazards of smoke under any condition.

This writer also has concluded that the atmosphere after a fire, especially during overhaul, is extremely hazardous. The overhaul environment contains dust, smoke, fumes, and soot. Toxins attach to this “smoke dirt” which provides a transportation medium for the toxins. Most firefighter inhalation injuries occur during overhaul (Wallace, 1995, p.24).

This writer interprets these results as valid and proves that SCBA has to be worn at any situation until such time that air monitoring equipment shows that the air is safe. This air monitoring equipment should be kept on all firefighting equipment and readily accessible. The monitor should be easy to use and provide an accurate picture of the atmosphere.

The implications of this research for fire department organizations run deep. Firefighters are in a hazardous occupation already and firefighter injuries need to be reduced. Too many firefighters are disabled on a yearly basis due to a wide range of injuries suffered while on the job. Cancers are prevalent among firefighters and the quickest way for toxins to enter our body is through the lungs. Fire departments can reduce these injuries and cancer occurrences by adhering to strict SCBA usage. The purified air that a firefighter breathes is an inexpensive way to prevent injuries. The cost of air purification and filling capabilities far outweighs the disadvantages of a fatal or long-term disability due to an inhalation injury.

RECOMMENDATIONS

Fire departments around the country need to reevaluate their SOP's on SCBA usage. In one of the case studies involving the rodent poison in the oven, no firefighter was injured because that departments SOP required that SCBA be worn until the air is proven to be free of toxins. Firefighters need to be educated on the numerous toxins that are present in any smoke. Firefighters need to be reminded that just because there may be no flames, there are still toxins in the air. This will not be able to take place overnight. These changes need to take place from the top down.

Air monitoring equipment needs to be placed on all firefighting units. These units need to be used anytime the atmosphere is in question. However, the air needs to be assumed toxic even on “routine” runs. Therefore, SCBA has to be worn until the environment is safe.

After a fire, SCBA needs to be worn until such time that the structure has been well ventilated and air monitors are able to give the “all clear”. There will always be drawbacks to this procedure. First of all, previous documentation has shown that gas powered ventilation equipment generates CO. Secondly, the “smoke dirt” previously described will still exist. Because of these factors the structure should be well ventilated and when CO levels permit entry without a positive pressure SCBA, the appropriate air-filtering mask should be worn. The overhaul team and the investigators should also adhere to these guidelines.

In conclusion, it is imperative that every firefighter facing a possible situation involving smoke or toxins in the air wear an SCBA until they are 100 percent guaranteed that there are no inhalation hazards present. With this attitude, firefighter injuries and fatalities will be reduced. I have displayed the extreme hazard of inhalation injuries and have answered the question over and over, “Why is wearing SCBA critical for firefighter survival and longevity on all runs involving any type of smoke situation?

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