NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

PREVENTING FIREFIGHTER EXPOSURE HAZARDS

by

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September 2017

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No.0704-0188*

1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** September 2017	**3. REPORT TYPE AND DATES COVERED** Master's thesis

4. TITLE AND SUBTITLE PREVENTING FIREFIGHTER EXPOSURE HAZARDS	**5. FUNDING NUMBERS**
6. AUTHOR(S) Paul F. Burke	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A	**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB number ____N/A____.

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.	**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200words)

This thesis examines detrimental health exposures for firefighters and recommends fire service policy and equipment upgrades designed to slow or eliminate these harmful exposures. Because firefighters are exposed to numerous environmental dangers during their careers, this thesis focuses on eliminating three occupational exposures contributing to health issues: chemical flame retardants, diesel exhaust, and toxins in synthetic furniture. Existing studies written by scholars, consumer advocacy groups, and government agencies identify several exposure hazards and recommend preventive measures to address them. In addition to examining these studies, this thesis reviews a well-intentioned California state law—which allowed chemical flame retardants in home furniture and electronic products—that has caused an exposure hazard for both firefighters and the general public. The thesis also exposes necessary upgrades for firefighters' portable air-supply units to reduce respiratory exposures. Finally, because diesel exhaust emissions have adverse health effects and are abundant in fire stations, the thesis recommends making changes to fire stations to better contain the diesel by-products of the fire trucks, including the possibility of purchasing electric-powered fire trucks to eliminate the diesel engine. Rather than providing a clinical study, this thesis offers an examination of occupational health hazards and recommends mitigative equipment and policy upgrades.

14. SUBJECT TERMS firefighter exposure hazards	**15. NUMBER OF PAGES** 73
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UU

NSN7540-01-280-5500 Standard Form 298 (Rev.2-89)
Prescribed by ANSI Std.239-18

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PREVENTING FIREFIGHTER EXPOSURE HAZARDS

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Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF ARTS IN SECURITY STUDIES
(HOMELAND SECURITY AND DEFENSE)**

from the

**NAVAL POSTGRADUATE SCHOOL
September 2017**

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LIST OF ACRONYMS AND ABBREVIATIONS

EPA	Environmental Protection Agency
IAFF	International Association of Firefighters
IARC	International Agency for Research on Cancer
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PBB	polybrominated biphenyl
PPM	parts per million
SCBA	self-contained breathing apparatus

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EXECUTIVE SUMMARY

As an integral segment of the nation's homeland security first responder community, firefighters are often the first to arrive on the scene of a multitude of emergency situations, including building fires and explosions, transportation accidents, hazardous material accidents, natural disasters, and terrorist attacks. Because firefighters often work in confined spaces with limited oxygen supply—inside buildings, below-ground subway tunnels, and motor vehicle tunnels—they must perform their duties using supplemental portable air supplies carried on their backs. This portable air supply lasts for only thirty minutes, designed to give the firefighter time to reach a clean atmosphere; however, the urgency surrounding victim rescue at emergency incidents does not always allow firefighters to exit the hazardous area after their thirty-minute air supply is exhausted. To evacuate victims—who do not have the benefit of portable air-supply units—firefighters must inhale unseen toxins. These harmful substances are contributing to the rise in a multitude of illnesses among the nation's firefighters.

The National Institute for Occupational Safety and Health (NIOSH) is a government agency within the U.S. Centers for Disease Control and Prevention (CDC), with a "mandate to assure every man and woman in the Nation safe and healthful working conditions and to preserve our human resources."[1] A NIOSH-supported study regarding firefighters in the United States found strengthened "evidence of a relation between firefighters' occupational exposure and cancer."[2] This research and several ongoing studies linking firefighter health issues to occupational exposure is proof that better equipment and policy changes are required to prevent these exposures and provide a safe and healthy working environment for all firefighters.

Large fire departments have begun to implement new preventative equipment and procedural steps to address these exposures, including purchasing new portable air-

[1] "About NIOSH," Centers for Disease Control and Prevention, last updated June 15, 2016, http://www.cdc.gov/niosh/about/default.html.

[2] Robert D. Daniels et al., "Mortality and Cancer Incidence in a Pooled Cohort of US Firefighters from San Francisco, Chicago and Philadelphia (1950–2009)," *Occupational & Environmental Medicine* 71, no. 6 (June 2014): 388, doi: 10.1136/oemed-2013-101662.

supply units that provide more breathable air. The new self-contained breathing units provide air for forty-five minutes for use in oxygen-deficient environments—a fifteen-minute improvement over previous models. New cloth hoods that surround exposed skin on the firefighter's head have also been issued to limit direct-skin absorption of toxins into the firefighter's body. To remove toxins from outer gear, some fire departments, such as the Boston Fire Department, now require firefighters to have their outer uniform laundered after every suspected exposure. The Boston Fire Department also conducts air quality monitoring at the scene of fires after the flames are extinguished to test for hazardous atmospheres. In some states, firefighter advocacy groups have joined with environmental groups and politicians to pass legislation to remove or regulate cancer-causing chemicals from home furniture products. These actions are moving in the right direction to prevent hazardous exposures to firefighters, but more must be done by the fire departments and municipalities that employ the nation's firefighters.

A cancer registry for firefighters has been proposed by the nation's firefighter union. Biomonitoring, which measures toxins in the human body, must be conducted prior to employment as a firefighter and should continue at regular intervals throughout firefighters' careers in an attempt to locate exposure points and begin treating firefighters prior to the onset of medical symptoms.[3] Fire departments must encourage continued research into creating better-protecting, lighter-weight equipment that completely, not partially, prevents the entry of hazardous substances into the body. Diesel exhaust from fire trucks is a known carcinogen, and it is the only carcinogen over which fire departments have absolute control.[4] Fire chiefs need to find more ways to prevent firefighter exposure to diesel exhaust in the fire stations and at the scene of incidents by designing new stations that do not contain diesel exhaust and by purchasing electric-powered fire trucks that produce no diesel exhaust.

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[3] "National Biomonitoring Program," Centers for Disease Control and Prevention, September 5, 2014, https://www.cdc.gov/biomonitoring/about.html.

[4] "IARC: Diesel Engine Exhaust Carcinogenic," International Agency for Research on Cancer, press release no. 213, June 12, 2012, https://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf.

The policy and equipment changes outlined in this thesis are not new to leadership both within fire departments and firefighter labor unions. It is a matter urgency that obligates these industry and union leaders to step up and require municipalities, through legislation if necessary, to implement these workplace changes to protect those who provide one of the first lines of defense in an increasingly dangerous homeland security environment.

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ACKNOWLEDGMENTS

I would like to thank my wife, Julie, whose acceptance of the time requirements for the completion of this academic program and thesis was gracious and abundant. I would like to thank my three children, Lauren, Annie, and Ryan, for their patience and understanding of the rigors of an academic pursuit and for their occasional technical assistance with the computer software that allowed for the completion of this thesis.

I would like to thank Fire Commissioner/Chief of the Boston Fire Department Joseph E. Finn for recommending me for the Naval Postgraduate School master's degree program; his leadership has set an admirable example for all members of the Boston Fire Department. I am convinced that Commissioner Finn's policy initiatives to create a safer and healthier work environment for the members of the Boston Fire Department will someday be adopted by every fire department in this country.

Most importantly, I dedicate this thesis to several co-workers I had the honor to work with at the Boston Fire Department prior to their early deaths from occupational exposures—this is only a small portion of a long list due to space constraints. The service and safety they provided to the residents of Boston can never be forgotten. They are: Captain John Kenney, Lieutenant Neal Mullane, Firefighter Francis O'Connor, Firefighter Richard Bessie, Firefighter John Fascaldo, Firefighter Mark Matthews, Firefighter Francis Flynn, and Firefighter Thomas McKernan, along with all the other Boston firefighters who have died from occupational exposure and the families they left behind.

Finally, I would like to thank Rodrigo Nieto-Gomez and Christopher Bellavita, my thesis advisors, for their patient assistance, advice, and support during the preparation of this thesis.

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I. INTRODUCTION

This thesis identifies the occupational exposure hazards firefighters face in the line of duty, and new firefighting equipment and operational changes that should be implemented to reduce the effects of these hazardous exposures.

A. PROBLEM STATEMENT

After the collapse of the World Trade Center on September 11, 2001, multiple studies surfaced about the negative health effects, including cancer and respiratory ailments, suffered by a large number of New York City firefighters who worked in and around the World Trade Center. These studies focused attention on the occupational exposure hazards experienced by all firefighters not only during major incidents, but also during their routine duties.[1] This heightened awareness of firefighters' occupational exposure hazards and accompanying health issues has led fire service leaders to examine new equipment and firefighting methods that may address or mitigate health problems; several studies have examined firefighters' numerous exposure hazards in an effort to identify equipment and or procedural deficiencies.[2]

One of the first steps in identifying the health hazards associated with the fire service is to identify the types of illnesses that are most prevalent among firefighters. The next step is to identify deficiencies in the personal protective equipment worn by firefighters, and then examine the procedural methods that control the amount of time firefighters are exposed to a given hazard. Once these are identified, the next step is to research known health effects associated with these avenues of exposure, such as respiratory disorders or certain types of cancer. If it can be determined how firefighters are becoming ill, the information may serve as a further impetus for fire departments to

[1] Jenna Flannigan, "15 Years Later, Nearly 40,000 People Have Health Conditions Related to 9/11,"Healthline, September 6, 2016, http://www.healthline.com/health-news/nearly-40000-have-health-conditions-related-to-9-11.

[2] Robert D. Daniels et al., "Mortality and Cancer Incidence in a Pooled Cohort of US Firefighters from San Francisco, Chicago and Philadelphia (1950–2009)," *Occupational & Environmental Medicine* 71, no. 6 (June 2014): 388–397, doi: 10.1136/oemed-2013-101662; "NIOSH: Firefighters at Higher Risk for Several Types of Cancer," *Safety + Health*, May 12, 2015, http://www.safetyandhealthmagazine.com/articles/12284-niosh-firefighters-at-higher-risk-for-several-types-of-cancer.

purchase new personal protective equipment and revise or update tactical procedures. This thesis examines three possible contributors to firefighters' illnesses: chemical flame retardants, diesel exhaust, and toxins in synthetic furniture

Several industry studies have pointed to the use of chemical flame retardants as a possible carcinogenic exposure hazard for firefighters. Because fire safety codes in states such as California require certain products to be flame retardant, furniture and other home product manufacturers in such states have used chemical flame retardants in their merchandise. Though these ingredients have been proven harmful to humans when they are in chemical form, it is difficult to measure their harmfulness when the chemicals are transformed into smoke during a fire; the smoke is dispersed into the atmosphere before it can be examined.[3]

Additionally, with the World Health Organization's 2012 classification upgrade of diesel exhaust from "probably carcinogenic" to "carcinogenic," fire departments must seek to reduce the level of diesel exhaust to which firefighters are exposed.[4] Another possible cause of harmful exposure may be the carcinogens present in the smoke firefighters are exposed to whenever they remove their self-contained breathing equipment at the scene of a fire. If the high percentage of synthetic materials used in modern consumer products is the cause of firefighters' higher cancer rates and other health issues ,how can firefighters limit their exposure time when extinguishing these materials during a fire? If the carcinogens in the plastics or building material components that are used in modern construction create the hazardous, cancer-causing exposure, is there a way to prevent it permanently?

Hazardous chemicals, including carcinogens, are entering firefighters' bodies through some undetermined pathway. If the personal protective equipment that is worn by firefighters is not protecting them sufficiently or not being used properly, it must be upgraded.

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[3] Arlene Blum, "Tackling Toxics," *Science* 351, no. 6278 (March 2016): 1117, doi: 10.1126/science.aaf5468.

[4] "IARC: Diesel Engine Exhaust Carcinogenic," International Agency for Research on Cancer, press release no. 213, June 12, 2012, https://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf.

To summarize, this thesis can be broken down into three key questions, or areas of study: First, if—as academic studies and government reports have suggested—occupational exposure hazards are inherent in firefighting, what equipment or operational changes must be instituted to reduce these hazards? Second, organizations such as the International Association of Fire Fighters (IAFF), the union representing the majority of firefighters in the United States and Canada, also believe their members are experiencing occupational exposures that lead to higher levels of cancer and have started a firefighter cancer registry to examine possible links; has that registry produced any results? Third, are equipment upgrades in some fire departments—such as increased portable air supply and mandatory uniform cleaning—reducing the rate of exposure-related health issues among firefighters?

Because preventative measures to limit firefighters' exposure to dangerous substances have only recently been put into place, the full impact cannot necessarily be measured with any degree of accuracy. While more research is needed to identify the numerous exposure hazards firefighters are subjected to, the fire service cannot wait until that research is performed to implement new mitigation policies. This thesis examines some of the exposures inherent in firefighting and recommends the acquisition of new fire service equipment and policy changes with the goal of reducing industry-specific negative health effects.

B. LITERATURE REVIEW

Many studies have sought to identify the connection between firefighting and health issues such as respiratory ailments and cancer. These studies pertain to a specific fire department or a specific activity, such as training simulations using real smoke. Still yet to be identified, however, is the specific link(s)—whether in training, equipment, tactics, or some unknown factor—that truly connects the fire service to higher-than-normal rates of certain chronic health issues.

This literature review examines research conducted by the Green Science Policy Institute, an environmental organization located in Berkeley, California, that has been instrumental in gaining knowledge about chemical hazards affecting the American

consumer. This institute's research has been used to identify specific harmful chemicals that may be causing the rising health issues among firefighters. This review also examines a chemical accident documented in the book *The Poisoning of Michigan*, wherein chemicals used in chemical flame retardants in 1973 were mistakenly mixed into cattle feed, resulting in tragic physical effects on livestock and the people who consumed the affected livestock.[5] The Michigan chemical accident provides a link to the chemicals used in chemical flame retardants and the accompanying multitude of negative health effects. This may be the only documented case of this category of chemicals and their effects on humans, and the event was further examined by a Emory University study called "Tracing the Toxic Legacy of PBB Contamination."[6]

The cause of most cancers in the population as a whole is a topic that has been examined repeatedly over time. Identifying the environmental factors that cause negative health issues among humans is a source of constant debate within the fields of science and medicine. That being said, several points of agreement have been reached regarding the possible origins of some cancers in humans. Along with genetic factors, the environment plays a role in whether an individual will develop cancer; for instance, pollutants in the atmosphere, such as industrial smoke emissions, have been found to cause cancer in humans.[7] Cigarette smoking has been linked to lung cancer, as has exposure to polychlorinated biphenyls (PCBs).[8] Yet, in these examples, the one known factor pertaining to the likelihood of contracting cancer—making it difficult to identify the external carcinogenic material—is that each person's body reacts to the carcinogenic exposure differently. Two people who have been subjected to the same carcinogen over the same time frame may react differently, or may not react at all. The fields of science and medicine are difficult for a non-scientific researcher to examine with the objective of

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[5] Joyce Egginton, *The Poisoning of Michigan* (New York: Norton, 1980).

[6] Michelle Marcus, "Tracing the Toxic Legacy of PBB Contamination," *Emory News Center Public Health Magazine*, May 22, 2015, http://publichealthmagazine.emory.edu/issues/2015/spring/briefs/tracing-the-toxic-legacy/.

[7] "Coal Power: Air Pollution," Union of Concerned Scientists, accessed September 5, 2015, http://www.ucsusa.org/clean-energy/coal-and-other-fossil-fuels/coal-air-pollution#.WPZFAZgrJE4.

[8] "Harms of Cigarette Smoking and Health Benefits of Quitting," National Cancer Institute, last reviewed December 3, 2014, https://www.cancer.gov/about-cancer/causes-prevention/risk/tobacco/cessation-fact-sheet.

finding a link between a given profession and cancer. Because identifying the chemical cause of the exposure is extremely difficult, this thesis instead investigates the various ways in which firefighters are becoming exposed, through inadequate equipment or improper firefighting procedures, and recommends procedural and equipment upgrades that will eliminate such exposures. Because these occupational hazards are specific to the fire service, the objective of this thesis is to identify the possible environmental exposures exclusive to the firefighting profession, and to examine results provided in the available written material on the subject.

In general, the activities of firefighters, whether fighting fires or responding to other types of emergency calls—such as hazardous material incidents or medical calls—vary greatly based on the physical location of the fire department. East Coast fire departments are typically exposed to older buildings with dangerous architectural components such as asbestos and wood finishing materials like cresol, both known carcinogens.[9] West Coast fire departments encounter structures with artificial exterior surfaces, such as stucco, along with newer, better-insulated buildings. These better-insulated structures allow for greater heat buildup, resulting in rapid combustion of newer synthetic flame-retardant furnishings, which releases toxic smoke. Because of the many variable occupational exposures to dangerous environments from region to region, these studies have attempted to find the most common exposures.

This literature review identifies areas of focus that are common to all firefighters, regardless of the physical location of the fire department for which they work. All firefighters are exposed to smoke from building materials and furniture; they are also all exposed to the exhaust fumes from their trucks, whether in their fire stations or at the site of an emergency. Because these are the common denominators throughout the literature, this thesis focuses on three related exposure hazards: chemical flame retardants, diesel exhaust, and toxins in smoke.

[9] "Asbestos Exposure and Cancer Risk," National Cancer Institute, last reviewed December 3, 2014, https://www.cancer.gov/about-cancer/causes-prevention/risk/substances/asbestos/asbestos-fact-sheet.

1. Types of Cancer in Firefighters

Studies have identified several types of cancers found in higher rates in firefighters than in the general public. The most comprehensive study, completed by the National Institute of Science and Health, listed the cancer rates in firefighters compared to the general public (see Table 1).[10] As identified by this list, firefighters are over two times likely to be diagnosed with testicular cancer than the average American.[11]

Table 1. Increased Cancer Risk for Firefighters[12]

Type of Cancer	Increased Risk for Firefighters
Leukemia	1.14 times
Colon	1.21 times
Prostate	1.28 times
Brain	1.31 times
Malignant Melanoma	1.31 times
Skin	1.39 times
Non-Hodgkin's Lymphoma	1.51 times
Multiple Myeloma	1.53 times
Testicular	2.02 times

[10] "NIOSH," *Safety + Health.*

[11] LeMasters et al., "Cancer Risk among Firefighters: A Review and Meta-analysis of 32 Studies," *Journal of Occupational and Environmental Medicine* 48, no. 11 (2006):1189–202, doi: 10.1097/01.jom.0000246229.68697.90.

[12] Adapted from LeMasters et al., "Cancer Risk among Firefighters."

Exposure can also occur from within fire stations. Several studies, including one that used cohorts from San Francisco, Chicago, and Philadelphia—all cities with older buildings and fire stations—have found that firefighters have an excess of malignant mesothelioma attributed to exposure to asbestos.[13] It is possible that the exposure to asbestos takes place not only at the scene of a fire, but also back at the fire stations where firefighters spend a large portion of their workday.

2. Flame Retardants and Firefighter Cancer

Over the years, many architectural innovations have been developed in an attempt to prevent or limit death and injury resulting from building fires. Among these innovations are smoke detectors, fire sprinkler systems, non-combustible building components, and flame retardants that slow flame spread over certain building components and furnishings. Of these innovations, flame retardants are the most controversial, due to their chemical makeup. The toxicity of the chemicals found in chemical flame retardants may be contributing to harmful exposure hazards for the very people they are ultimately intended to protect: firefighters. Chemical flame retardants are used as additives in consumer products such as furniture, electronics, insulating foams, and carpet padding to slow the spread of flames across the material, granting people in fire emergencies more time to exit the room or building on fire. California has the most stringent regulations in the country allowing the use of flame retardants, and the regulations have been subjected to scrutiny from environmental groups. The flame retardant industry is a profitable industry and favors the California regulations because of the economic benefits. The advantages of flame retardants in consumer products when compared to the health hazards continues to be a controversial topic between scientists, the flame retardant industry, and firefighters. A chemist and science advocate named Arlene Blum has conducted extensive research on the health effects of exposure to flame retardants in clothing and household furnishings. Her findings were instrumental in removing flame retardants from children's sleepwear in the 1970s.[14] She believes that

[13] Daniels et al.," Mortality and Cancer Incidence."

[14] Arlene Blum, "Flame Retardants and Flammability Standards" (speech, TEDxGreatPacific GarbagePatch, November 6, 2010), http://greensciencepolicy.org/topics/flame-retardants/.

flame retardants in furniture are causing cancer in humans through dust, and are furthermore ineffective for their intended fire safety purposes, such as slowing down the flame spread rate across items treated with the retardants.

A California environmental group headed by Professor Blum, the Green Science Policy Institute, continues to research and speak out about the negative health issues related to chemical flame retardants. The group is in agreement with firefighters, who contend chemical flame retardants do not provide as much of a benefit as they do a hazard. This group points to the decrease in national fire deaths, which it argues can be attributed to behavioral changes—such as reduced cigarette usage, smoke detectors, educational campaigns, and fire sprinkler systems—rather than the increased use of flame retardants in consumer products. This research concludes that a flame retardant's added three-second delay between the onset of a fire and a product's combustion—which the group contends has never been proven—cannot be considered a safety benefit when compared to the increased toxicity of the smoke created by the chemicals in flame retardants.[15]

The connection between harmful occupational exposures and firefighting is not always related to fighting fires. Several studies have mentioned diesel exhaust exposure as a workplace hazard.[16] Fire trucks are located in the same building where firefighters work and live. When the trucks are started, as they are many times in a given shift, the fumes migrate to the upper living spaces. Studies have detected high levels of diesel particles throughout fire stations.[17] In 2012, the International Agency for Research on Cancer (IARC), part of the World Health Organization, upgraded diesel engine exhaust from "probably carcinogenic to humans" to "carcinogenic to humans" due to "sufficient evidence that exposure is associated with an increased risk of lung cancer."[18]

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[15] Dashka Slater, "How Dangerous Is Your Couch?" *New York Times*, September 6, 2012, http://www.nytimes.com/2012/09/09/magazine/arlene-blums-crusade-against-household-toxins.html.

[16] John R. Froines et al., "Exposure of Firefighters to Diesel Emissions in Fire Stations," *American Industrial Hygiene Association Journal* 48, no. 3 (March 1987): 202–207,doi: 10.1080/15298668791384634.

[17] Ibid.

[18] "IARC: Diesel Engine Exhaust Carcinogenic," International Agency for Research on Cancer.

3. Firefighters' Personal Protective Equipment and Harmful Exposure

The personal protective equipment used by firefighters nationwide has several layers of protection designed to shield the user from any number of hazardous exposures. But because the clothing is porous and absorbs some of the toxins in the hazardous environments, if this clothing is not laundered after every hazardous incident and the firefighters continue to wear the same uniform repeatedly, they are re-exposing their bodies to the same chemicals each time they respond to an emergency call. One of the most important pieces of personal protective equipment used by firefighters is the self-contained breathing apparatus (SCBA), which provides the wearer with a limited supply of breathable air as he or she works in oxygen-deficient or chemically harmful environments. The personal protective clothing and equipment worn by firefighters is a key determining factor in the amount of time firefighters can be subjected to a given hazard. The uniform material's durability and the amount of air provided by the portable air units are the two major components that can either allow or eliminate occupational exposures to firefighters in the performance of their duties.

The SCBA could be updated to allow more protection for firefighters in dangerous environments. The benefits of SCBAs are well known in the fire service. In environments that are classified by the National Institute for Occupational Safety and Health(NIOSH) as immediately dangerous to life or health, this vital piece of protective equipment allows firefighters to enter into, and remain in, environments devoid of oxygen or environments that are saturated with chemicals that could cause severe injury or death. The benefits of wearing the SCBA are only as strong as the amount of clean air in the portable cylinder. The apparatus is a heavy, cumbersome piece of equipment which a majority of firefighters remove and place on the ground after the initial fire is extinguished due to discomfort, even though the atmospheric hazards are still present in the form of harmful gases. Depending on the level of ventilation at a given fire, hazardous material incident, or terrorist attack, the gases present in high levels after the fire is extinguished are varied, dangerous, and beyond governmentally permissible amounts. Air monitoring after fire extinguishment has found high levels of carbon

monoxide, hydrogen cyanide, and other cancer-causing carcinogens such as benzene and hydrochloric acid.

C. RESEARCH DESIGN

For this thesis, I examined the available body of research regarding the types of cancer found among firefighters. I compared the data to that of the general public with the goal of identifying causes connected to the cancers with the highest recidivism rates. I examined occupational environmental factors that may contribute to this dangerous upward trend. The data sources are several studies conducted by research professionals, fire departments, and medical journals that not only identify the hazardous exposures but also recommend equipment and procedural remedies and discuss the costs associated with these changes.

My research focused on three potential causes of firefighters' hazardous exposures: chemical flame retardants, diesel exhaust, and synthetic contents in modern furniture. The research into those topics included a review of identified exposures in other industries such as mining, as well as research conducted regarding chemical exposure in furniture sold in California. I also reviewed a Michigan chemical accident in which flame-retardant chemicals were accidentally added to cattle feed, resulting in tragic health repercussions for the animals and humans.

The search phase of my research included, in addition to the main studies listed, recent legislation that acknowledges a possible link between chemical exposure and occupational health hazards. I looked at the Lautenberg Chemical Safety for the 21st Century Act, passed by Congress and signed into law on June 22, 2016.[19] This new law requires the Environmental Protection Agency (EPA) to evaluate the "risks of harmful exposures to chemical substances and mixtures" on the American public. The law prioritizes chemicals that are known human carcinogens and requires protection of firefighters where possible.

[19] Frank R. Lautenberg Chemical Safety for the 21st Century Act, H.R. 2576,114th Cong. (2016), https://www.congress.gov/bill/114th-congress/house-bill/2576.

I concluded by reviewing current and possible future exposure prevention measures that fire departments can utilize to limit exposure time to workplace carcinogens, such as biomonitoring—a method of measuring toxic chemicals in the body.[20] I looked at the potential of this method to identify dangerous toxic substances in firefighters. It is possible this information could help in early cancer detection among firefighters. I also researched the feasibility of using advances in medical technology, such as biomonitoring, and weighed the pros and cons of that technology. I also examined new training or equipment methods to evaluate the benefits of those procedures, such as a new, emerging self-contained breathing apparatus that provides a longer air supply for firefighters while they work in oxygen-deficient environments.

My interpretation of the research could help firefighter unions eliminate or at least slow this increasing deadly trend. My hope is that this thesis will add to the general awareness surrounding the issue of higher-than-normal cancer rates among the nation's firefighters and provide strategies to mitigate these industry-specific exposure risks. Firefighters provide the public with a first line of defense when their safety is jeopardized by life-threatening situations such as fires, medical emergencies, natural disasters, hazardous material incidents, and terrorist attacks. If the general public is informed that their public safety officials are dying from workplace cancer at a higher rate than the general public, then it is hoped that they will contribute to the efforts of finding the cause and the cure.

1. Limits

My study is not concerned with finding the cause or a cure for cancer. My boundaries address the possible sources of occupational exposure among firefighters without delving into medical diagnoses. There are several identified exposure sources common to firefighters that could explain the rise in health issues, including the higher rates of cancer, such as carcinogens used in flame retardants applied to building components and incorporated in furniture and other consumer products. Another possible

[20] "National Biomonitoring Program," Centers for Disease Control and Prevention, May 26, 2016, https://www.cdc.gov/biomonitoring/.

method of exposure to carcinogens for firefighters is diesel exhaust within fire stations, along with the high rate of toxins in smoke generated by the combustion of modern synthetic home furniture.

2. Output

My thesis identifies deficiencies in equipment and tactical procedures that are the cause of hazardous occupational exposures to firefighters and recommends the purchase of new personal protective equipment and tactical updates that may decrease or eliminate these hazards. This thesis will contribute to the existing body of work to help firefighter unions, municipal governments, and the fire service industry define an emerging phenomenon with life-or-death ramifications for their membership, adding to the urgency for more in-depth scientific studies with the final goal of eliminating these harmful occupational exposure hazards. Finally, my hope is that this thesis can be added to the general awareness surrounding the issue of the many health hazards encountered by the nation's firefighters during the performance of their duties.

II. FLAME RETARDANTS

> Cancer is now the leading cause of death for firefighters nationwide. Sixty (60) percent of the names added to the IAFF Fallen Firefighter Memorial Walls in Colorado Springs since 2002 are IAFF members who have died from occupational cancers.
>
> —International Association of Fire Fighters[21]

In 2006, the *Journal of Occupational and Environmental Medicine* published a meta-analysis of thirty-two studies regarding the frequency of cancer in the firefighting profession. The article listed the most common cancer types found in firefighters and compared those to cancer rates among the general public. The authors found that firefighters are over two times more likely to develop testicular cancer, over one and half times more likely to have multiple myeloma and non-Hodgkin's lymphoma, and 1.39 times more likely to contract skin cancer.[22] One suspected cause of these higher rates is chemical flame retardants.

Chemical flame retardants are chemical components that are infused into home and commercial furnishings such as mattresses, carpet padding, electronic equipment, plastics, building materials, and automobile and airplane interiors; the intended goal of flame retardant additives is to slow the flame spread over a given surface to allow more time for occupants to exit a building that is on fire.[23] Because the chemicals in flame retardants are carcinogenic and present in so many home furnishings, firefighters are repeatedly exposed to the toxic smoke the chemicals create, and are slowly dying from several types of cancer.

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[21] International Association of Fire Fighters (IAFF), "GPS Cancer: Breakthrough Testing for Cancer Treatment Strategies," *Fire Fighter Quarterly* (Winter 2007): 10–11, http://www.iaff.org/mag/2017/01/html5/.

[22] LeMasters et al., "Cancer Risk among Firefighters."

[23] Alissa Cordner et al., "Firefighters and Flame Retardant Activism," *New Solutions* 24, no. 4 (February 2015): 511–534, doi:10.2190/NS.24.4.f.

In an effort to determine how and why firefighters are dying from the chemical ingredients in flame retardants, this chapter examines the chemicals in flame retardants and examines one documented case of human exposure to these chemicals.

A. THE CHEMICALS

Chemical flame retardants are called halogenated flame retardants. There are two classes within the halogenated category: PBDEs and TDCPP/TCPP. The two most common chemical flame retardant categories within these classes are brominated and chlorinated, both of which are mutagens that have damaging genetic health effects on humans.[24] Why, the fire service asks, are these chemicals in flame retardants responsible for the increased rate of cancer among firefighters? Unfortunately, there is no easy answer; with approximately one hundred seventy-five chemical combinations forming the base of flame retardants, it is difficult to find the root cause.

Because of the uncertainty surrounding the dangers associated with chemical flame retardant, a group of over two hundred signatories with expertise in health, science, environment, and fire safety have written a scientific paper called the "San Antonio Statement," which calls for "comprehensive regulation of brominated and chlorinated flame retardant chemicals."[25] Along with revealing the health risks associated with these chemicals—including birth defects, infertility, neurodevelopment delays, and cancer—the authors revealed that "brominated and chlorinated flame retardants can increase fire toxicity, but their overall benefit in improving fire safety has not been proven."[26] The signatories dispute the chemical industry's claim that flame retardants slow flame spread across a given surface. If these dangerous carcinogenic chemicals are marketed as fire safety products but in reality do not provide the level of fire prevention the manufacturers claim, the state and local regulations allowing the continued use of these products should be rescinded.

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[24] Blum, "Flame Retardants."

[25] Joseph D. Gangi et al., "San Antonio Statement on Brominated and Chlorinated Flame Retardants," *National Institutes of Health*118, no. 12: A516–A518, doi:10.1289/EHP.1003089.

[26] Ibid.

B. CALIFORNIA LAW

Technical Bulletin 117 (TB117) is a California flammability standard enacted in 1975 by current Governor Jerry Brown during his first term as governor of California. TB117 requires furniture sold in the state of California meet "a small flame ignition standard which requires polyurethane foam in juvenile products and upholstered furniture to withstand exposure to a small open flame for twelve seconds."[27] According to product researcher Irina Webb, "The law does not require the use of flame retardants" to achieve the flammability standard; "it merely requires certain materials—mostly couch cushions—to be able to withstand a small open flame for twelve-seconds without bursting into flame."[28] TB117 also requires that furniture be labeled to inform the consumer that the flammability standard has been achieved for the products in question.[29] In California, the method used to meet the flammability standard is to infuse chemical flame retardants into consumer products with the goal of making the products burn at higher temperatures, in theory slowing the flame-spread rate of the entire product.

When enacted into law, "TB 117 was a compromise response between the tobacco industry and the chemical manufacturers to relieve legislative pressure on the tobacco industry to produce a self-extinguishing cigarette."[30] The reason for this compromise was that cigarettes, at the time this law was proposed, were the leading cause of fire and fire-related deaths in this country. This compromise between the cigarette manufacturers and the chemical flame retardant manufacturers saved money for the cigarette manufacturers by eliminating the need for research and development that would be required to create a self-extinguishing cigarette, at the same time benefiting the chemical companies by creating an increased demand for their flame retardant products—a lucrative deal for both industries. California's new flame-spread requirement

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[27] Vytenis Babrauskas et al., "Flame Retardants in Furniture Foam: Benefits and Risks," *Proceedings of the Tenth International Symposium on Fire Safety Science* (2011): 266, doi: 10.3801/IAFSS.FSS.10-265.

[28] Irina Webb, "Key Flame Retardant Law Is about to Change," *I Read Labels for You* (blog), November 6, 2013, https://ireadlabelsforyou.com/flame-retardant-law-is-about-to-change/.

[29] Ibid.

[30] Dina Fine Maron,"Cancer-Linked Flame Retardants Eased out of Furniture in 2014," *Scientific American*, December 31, 2013, https://www.scientificamerican.com/article/cancer-linked-flame/.

was achieved by injecting cushion foam with brominated flame retardant chemicals, a known carcinogen as defined by the Environment Protection Agency.

Since its inception in 1975, TB117 has been opposed by environmental-conscious scientists and firefighter organizations. Related groups has been working to repeal the standard on the grounds that the dust produced by this category of flame retardants is harmful to humans and animals. Firefighters also contend that chemical flame retardants, when they burn, create a toxic smoke that is responsible for the higher cancer rates in firefighters. To reduce production costs that would be incurred if consumer products were made to meet the California standard, the largest consumer market in the United States, the furniture industry, decided to produce all furniture with the flame retardants infused in the foam, resulting in a nationwide exposure hazard.

The battle to repeal TB117 has seen legislative lobbying from both advocates and adversaries of the legislation. The pro-repeal groups, as mentioned previously, consist of firefighters, scientists, consumer advocates, and sympathetic politicians. The opponents are largely the three chemical companies that manufacture the majority of chemical flame retardants sold worldwide. They stand to lose financially if the law is repealed, which has caused them to use less-than-ethical tactics to fight the repeal legislation. These three companies set up a fake consumer advocacy group called Citizens for Fire Safety, which, according to group's own literature, was composed of firefighters, fire marshals, and concerned citizens, all with the common goal of saving lives by opposing the repeal of TB117. The group used public service announcement–type advertisements showing pictures of small children standing in front of a fire station and "describes itself as a group of people with altruistic intentions: "a coalition of fire professionals, educators, community activists, burn centers, doctors, fire departments and industry leaders, united to ensure that our country is protected by the highest standards of fire safety.'"[31] They also used the testimony of a burn doctor who, while acting as a paid expert witness, testified to the tragic harm that could happen to the state's residents if the law were repealed. His testimony in front of the California legislature included specific examples

[31] Patricia Callahan and Sam Roe, "Fear Fans Flames for Chemical Makers," *Chicago Tribune*, April 21, 2017, http://www.chicagotribune.com/news/watchdog/ct-met-flame-retardants-20120506-story.html.

of children burned in fires, with graphic details of their deaths. The doctor's testimony was later proven not to be true; death records for the children he spoke of could not be found. Reporters from the *Chicago Tribune* also uncovered the fact that the advocacy group promoting the continued use of chemical flame retardants in California was not a consumer advocacy group at all; a public relations firm had funded the creation of the consumer group at the request of one of the chemical manufacturers. The group was disbanded when the *Chicago Tribune* series exposed its fraudulent origins.[32]

One of the most vocal advocates for the removal of chemical flame retardants from home furnishings in California is scientist Arlene Blum. Blum began her activism during the 1970s while a professor at the University of California, Berkeley. Her first environmental concerns were regarding chemical called chlorinated tris that the United States government required to be infused in all children's pajamas beginning in 1973. The induction of the chemical flame retardant in the pajamas was meant to protect children from being burned. Professor Blum, however, did not trust the chemical makeup of the flame retardants and began a scientifically driven campaign to understand the effects of chlorinated tris on humans. What she found convinced her that chemical flame retardants could cause cancer, and are not worth the questionable fire safety benefits promoted by their chemical manufacturers. Professor Blum is not an uninformed consumer advocate; she is a scientist who studied the chemical contents of the flame retardants by compiling laboratory toxicology reports from children wearing the flame retardant–laced pajamas. Professor Blum's research on brominated tris proved, through urine tests, that children wearing the pajamas containing brominated tris were more likely than non-users of this sleepwear to have learning defects. After seeing the elevated levels of chlorinated tris in the children's laboratory reports, she concluded that, as a safety measure, adding the flame retardants to clothing was counterproductive and dangerous. Because of her research, the United States Consumer Protection Safety Commission banned brominated tris from use in children's sleepwear on April 7, 1977.[33]

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[32] Michael Hawthorne, Katie Nieland, and David Eads, "Tribune Watchdog: Playing with Fire," *Chicago Tribune*, May 10, 2012, http://media.apps.chicagotribune.com/flames/index.html.

[33] "CPSC Bans TRIS-Treated Children's Garments," U.S. Consumer Product Safety Commission, August 22, 2016, https://www.cpsc.gov/content/cpsc-bans-tris-treated-childrens-garments.

According to Professor Blum, the only chemicals requiring EPA approval are those that are used in food, drugs, or pesticides. The chemicals in flame retardants that were infused into home furnishings were not approved by the EPA before they were put on the market.[34] The Environmental Protection Agency was established in 1972 by President Nixon for the safety of the American consumer. The EPA uses the Toxic Chemical Act of 1976 as the template for enforcement guidelines for their employees. The Act was broad in scope with limited provisions for the enforcement of the suspected chemical dangers. What it did include were several measures that gave the chemical companies protection from potential litigation. One provision allowed the chemical companies to withhold the ingredients of their products from the public, which put citizens and environmentalists at a great disadvantage when inquiring about the chemical components of a suspected dangerous chemical on the market. From the beginning, this legislation was deficient due to corporate protections allowing the chemical makeup of dangerous chemicals to be withheld from the public.[35]

C. MICHIGAN'S AGRICULTURE ACCIDENT

> As the cattle were dying, the cats and dogs were dying too. A fully grown cat would live only six weeks. Our three dogs went crazy. Our neighbors had bees that were dead in the hives. The frogs were dead in the streams.
>
> —Michigan farmer[36]

Because of the health risks associated with the chemicals in flame retardants, human experiments are not possible; however, one documented accidental exposure did take place with Michigan livestock in 1973, indirectly involving humans. The Michigan accident occurred during a paper shortage that caused the mislabeling of a toxic chemical used in flame retardants with a similarly named nutritional cattle feed supplement; both were produced at the Michigan Chemical Corporation factory in St. Louis, Michigan. The chemical compound was called Firemaster and contained the chemical polybrominated

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[34] Blum, "Flame Retardants."

[35] IAFF, "Congress Passes Chemical Safety for the 21st Century Act," *Fire Fighter Quarterly* (Summer 2016): 38–40, http://www.iaff.org/mag/2016/03/html5/.

[36] Egginton, *Poisoning of Michigan*, 13.

biphenyl (PBB) used as a flame retardant to prevent flame spread in consumer products such as home and office furniture and plastics in electronics. The other product, Nutrimaster, contained magnesium oxide, a nutritional supplement used in food and given to cattle.

A shipment of PBB-containing Firemaster, labeled incorrectly as Nutrimaster, was mistakenly delivered to the Michigan Farm Bureau and mixed into the cattle feed, and subsequently delivered to farms throughout the state. As a result of the mixed-up delivery, "tens of thousands of farm animals became deathly ill, milk production fell, calves died in their barns, cows aborted, lambs were born with gross deformities and chickens developed strange tremors."[37] Even though this accident took place in 1973, the effects of the accident are still being felt and studied forty years later. Not only were 35,000 cattle killed, but PBB was introduced into the Michigan food supply, causing tragic long-term health effects.[38] The documented physical effects began in the people who consumed the tainted products, but still persist today. According to an Emory University study of the accident, the rate of breast cancer among women exposed to PBB is higher than the national average, as is the rate of miscarriages. It is believed that PBBs live in human tissue throughout a person's entire life, through a process known as bioaccumulation, and are passed on to descendants.[39]

The St. Louis chemical plant responsible for Michigan chemical accident, owned by Velsicol Chemical, closed in 1978, but the fifty-two-acre campus is now one of the nation's largest and most expensive superfund sites.[40] The accident and the resultant detrimental health effects of these chemicals, combined with their unproven and/or limited ability to reduce flame spreading, proves that flame retardants should not be used as a fire prevention tool.

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[37] Egginton, *Poisoning of Michigan*.

[38] Ibid.

[39] Marcus, "PBB Contamination."

[40] Andy Szal,"Michigan Still Dealing with Effects of Decades-Old Chemical Accident," ChemInfo, May 10, 2016, http://www.chem.info/news/2016/05/michigan-still-dealing-effects-decades-old-chemical-accident.

D. CORPORATE DISHONESTY

One reason these harmful chemicals are still being used to satisfy the flammability standard is that they are financially beneficial for the companies that produce them—extensive lobbying efforts by the producers of the flame retardants are one indicator of their profitability. With the previously discussed circumstances of the dishonest lobbying efforts surrounding the repeal of the California's TB117, corporate profits played a major role in the continued use of flame retardants. The dishonest actions of the chemical companies during the repeal efforts are an example of corporations putting profits ahead of the health and well-being of the American consumer.

Along with the *Chicago Tribune* series that exposed the fraudulent activities of the chemical manufacturers in opposing the repeal of TB117, several other events have transpired over the years with the objective of educating the public regarding the dangers of chemical flame retardants. "Give Toxics the Boot" was the name given to a day, March 27, 2014, for firefighters to remember their fallen coworkers who died from occupational exposures related to undetermined toxins in their work environments. In Massachusetts, firefighters placed boots on the State House steps in honor of their fallen fellows. The event was sponsored by the filmmakers of *Toxic Hot Seat*, an HBO film about the fire retardant industry, along with the International Association of Fire Fighters.

Progress is being made in the right direction on several fronts, including the determined efforts of scientists, firefighter organizations, and consumer advocacy groups to identify, reduce, and ban not only dangerous, cancer-causing chemical flame retardants, but also other dangerous chemicals produced and sold in the United States. In 2013, after many years of hard work by opponents of California's flammability standard, a partial victory was achieved: though TB117 was not repealed, it was modified to replace the twelve-second flammability test with a less stringent smolder-resistant requirement test, which can be achieved without the use of chemical flame retardants. The new law, titled TB117–2013, also requires new furniture sold in California to have a label informing the consumers if chemical flame retardants are contained in the product. Although the law does not ban the use of chemical flame retardants in furniture sold in California, it does reduce the previous requirements for TB117 to meet both the

flammability test and smolder-resistant test, effectively eliminating the need for the inclusion of chemical flame retardants in the furniture.[41]

With the political activism of consumer groups, segments of the science community, fire departments, and firefighter unions, the message about the toxicity of chemical flame retardants is reaching more state legislatures, up to and including Congress. One of the most promising developments in the fight to reduce the use of harmful chemicals is recently passed federal legislation that updates the EPA's duties and enforcement regulations regarding dangerous chemicals manufactured and sold in this country. On June 28, 2016, Congress passed, and President Obama signed, legislation called the Frank R. Lautenberg Chemical Safety for the 21st Century Act. The new law is an update to the forty-year-old Toxic Substances Control Act. It gives the EPA more authority to keep track of chemicals that can be harmful to humans. The new law also addresses the environmental concerns surrounding the chemical industry and the products that are introduced into the U.S. marketplace. Several of these provisions in the new legislation are beneficial to the fire service industry. Chemicals are now examined in groups, not just individually. Because flame retardants have so many different chemicals mixed together, this provision will help determine the harmfulness of a multitude of different chemical groups. The law also updates the chemical list used to identify harmful chemicals, replacing the list created in the early 1970s.

As the California children's sleepwear incident, the Michigan feed accident, and the dishonest corporate activity surrounding the repeal of TB117 have shown, evidence does exist that the chemicals in flame retardants are dangerous to humans and the environment. These tragic examples have indicated the dangers of flame retardants in their original chemical state. But firefighters are unfortunately exposed to these chemicals when they burn and become toxic smoke, and the harmfulness of this toxic smoke has yet to be been examined; more scientific research is needed to examine the toxins in the smoke produced when chemical flame retardants are consumed by fire. Although current

[41] Brett Israel, "California to Unveil New Flammability Standard to Avoid Chemicals in Furniture," *Scientific American*, February 8, 2013, https://www.scientificamerican.com/article/california-to-unveil-new-flammability-standard-to-avoid-chemicals-in-furniture/.

regulations are trending in the direction of banning or restricting the use of these chemicals, it is important to remember that even if all chemical flame retardants were removed from the marketplace, the existing products containing the flame retardants will remain in households for generations to come. Because toxic smoke is inhaled by firefighters, it is imperative that the protective equipment used and worn by firefighters, such as the portable breathing equipment, be improved to allow firefighters to breath clean air for longer periods, and, in so doing, reduce their exposure levels and the possible bioaccumulation of these toxins in their bodies that are causing long-term health issues.

III. DIESEL EXHAUST

Ongoing research efforts are attempting to determine the reason(s) for the disproportionately high cancer rate among members of the fire service, including a study being conducted by the National Institute for Occupational Safety and Health.[42] Several research efforts are focusing specifically on the diesel exhaust exposure levels encountered during the routine duties of the nation's firefighters.

In every community in this nation, workplace exposure to diesel exhaust is killing and disabling firefighters. According to the Occupational Safety and Health Administration (OSHA), "Prolonged diesel exhaust/diesel particulate matter (DPM) exposure can increase the risk of cardiovascular, cardiopulmonary and respiratory disease and lung cancer."[43] The International Agency for Research on Cancer (IARC) has reclassified diesel engine exhaust from "probably carcinogenic" to full classification as "a carcinogen—a substance that causes cancer."[44] The chemicals contained in diesel exhaust include arsenic, benzene, formaldehyde, and nickel, which bind to diesel soot and migrate into fire stations and the lungs of firefighters working in those stations.

Exposure to diesel exhaust is also affecting workers in other occupations; miners, for instance, also work in confined-space environments with diesel exhaust contaminating their breathable air. What does the government do about this occupational exposure hazard? Very little. As corporations increase their profit margin at the expense of human capital, those assigned the task of protecting them sit idly by as these corporations continue to control the regulatory process through congressional lobbying.

The hazardous exposures firefighters come into contact with daily are limitless. Because of the inconsistency in the content of smoke generated at a given fire, it is

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[42] "Study of Cancer among U.S. Fire Fighters," Centers for Disease Control, last reviewed July 18, 2016, http://www.cdc.gov/niosh/firefighters/ffCancerStudy.html.

[43] "Hazard Alert Diesel Exhaust/Diesel Particulate Matter," Occupational Safety and Health Administration, accessed March 26, 2017, https://www.osha.gov/dts/hazardalerts/diesel_exhaust_hazard_alert.html.

[44] IARC is a component of the World Health Organization. "IARC: Diesel Engine Exhaust Carcinogenic," International Agency for Research on Cancer.

difficult to determine the source of the harmful chemicals present at the scene of any emergency incident. The one source of carcinogenic exposure fire departments worldwide do have control over, however, are their trucks. Fire trucks are powered by diesel engines that produce diesel exhaust, including the diesel particles that cause cancer.

In general, fire department apparatus are composed of two primary types of trucks. One is called the engine, sometimes referred to as a pumper, which delivers a constant supply of water for extinguishing purposes. The other vehicle is the ladder truck, formerly referred to as the hook and ladder, which has an aerial ladder built onto the truck chassis and is used for rescue and ventilation purposes. Although there are many different fire apparatus manufacturers, the one common component of each vehicle is the diesel engine. These engines are used not only to move the vehicles but also to power the built-in equipment at a fire or other emergency incident. The water pump on the engine, which supplies the water to the fire hoses, and the mechanisms used to raise the aerial ladder on the ladder trucks are both powered by the vehicle's diesel engine. The high levels of exposure to diesel exhaust experienced by firefighters has come under increased scrutiny within the fire service since, as previously mentioned, the World Health Organization's 2012 upgrade of diesel exhaust exposure from "probably carcinogenic" to "carcinogenic."

While the EPA did require a reduction in dangerous chemicals, such as sulfur, in diesel fuels manufactured, imported, and consumed in this country starting in 2000, more must be done to limit institutional exposure to diesel exhaust for the members of the fire service.[45] For instance, the EPA could mandate that all fire stations in the United States be equipped with diesel exhaust ventilation systems, which must be maintained and functioning at all times. If for any reason the diesel exhaust ventilation system is not working, firefighters should not be allowed to inhabit the firehouse until the system is again functioning properly. If the EPA required such a mandate, along with federal subsidies to pay for the installation of the diesel exhaust ventilation systems, it would

[45] "Gasoline Sulfur," Environmental Protection Agency (EPA), last updated December 5, 2016, https://www.epa.gov/gasoline-standards/gasoline-sulfur.

encourage municipalities with limited funds to complete the installation immediately. According to IARC, however, even with the exhaust ventilation systems installed, firefighters may be exposed to diesel engine exhaust when vehicles exit and return to the fire station, when vehicles are in operation, and when vehicles remain running at the fire scene or during routine training exercises. Also according to IARC, short-term exposure to diesel exhaust can irritate the eyes, throat, and bronchi, and can cause light-headedness, nausea, and respiratory symptoms such as coughing.[46]

On a normal workday for a firefighter in the United States, the day starts with arrival at the fire station. Before reporting for duty in the living area of the fire station, the arriving members remove their work gear from their open-air lockers, which are located in the garage section of the fire station, where the trucks are housed. The gear consists of a helmet, overcoat, pants, boots, and personal facemask that the firefighters will attach to their self-contained breathing apparatus, which allows them to operate in smoke-filled or oxygen-starved environments. The lockers are referred to as "open-air" because they are made with metal similar to a chain-link fence, which allows the firefighter's wet clothing to dry when not in use. Sadly, this design has a negative exposure hazard; each time the fire trucks are started in the building for equipment checks or to respond to a call, the diesel exhaust particles adhere to the clothing, saturating the material and re-exposing the firefighters time and again. When the off-duty firefighters return to work, they remove the contaminated gear from their lockers and place it on the fire trucks to expedite their reaction time when an alarm response is dispatched, in effect re-exposing themselves to the chemicals saturated in their clothing each time they put the clothing on for an emergency response.

In the United States, the OSHA is the primary governmental organization supervising workplace safety. The National Institutes of Occupational Safety and Health (NIOSH), an agency within the Centers for Disease Control (CDC), is responsible for investigating firefighter health issues, including fatalities. OSHA regulates diesel exhaust levels in the U.S. mining industry but does not have a standard or regulation mandating

[46] "The Report on Diesel Exhaust," California Environmental Protection Agency Air Resources Board, July 21, 2015, https://www.arb.ca.gov/toxics/dieseltac/de-fnds.htm.

the removal of diesel exhaust from fire stations in the United States. Currently, there is no federal regulation for the levels of diesel exhaust or diesel particulate matter in buildings. OSHA regulates "workplace levels of carbon dioxide, carbon monoxide, nitrogen dioxide, and sulfur dioxide; however, OSHA has not adopted standards for 'whole' diesel exhaust."[47] The EPA does provide a reference concentration that recommends a "maximum long-term exposure to diesel particulates at 0.05mg/m3. This is not a regulation and cannot be enforced, but it does provide a baseline level that could present a hazard to individuals experiencing chronic exposure."[48] NIOSH claims that the diesel particulate matter levels in a fire station "ranges from 0.1 to 0.48," clearly in excess of the EPA's recommended maximum for long-term exposure of 0.05.[49]

In the United States, the EPA enforces the motor vehicle fuels provisions of Title II of the Clean Air Act:

> These provisions include certain requirements and prohibitions regarding the quality of motor vehicle fuels, and are designed to greatly reduce harmful emissions from all motor vehicles, including passenger cars, light trucks and heavy duty trucks.
>
> The gasoline and diesel fuel requirements and prohibitions apply to all parties in the distribution system, including refiners, renewable fuel producers, importers, distributors, carriers, oxygenate blenders, retailers and wholesale purchaser-consumers (fleet operators having their own fueling facilities). EPA enforces these provisions with environmental audits and inspections (including testing of fuels), and through various recordkeeping and reporting requirements. EPA may seek civil penalties or injunctive relief (including remediation of the violations and projects to offset illegal emissions) for violations of the Act or regulations, and may bring cases in federal district court or through an administrative process.[50]

These EPA standards regulate the amount of toxic chemicals American workers can be exposed to over an eight-hour period. The problem with the diesel exposure regulation is

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[47] "Diesel Exhaust: Standards," Occupational Safety and Health Administration, accessed August 29, 2017, http://www.osha.gov/SLTC/dieselexhaust/standards.html.

[48] "The Dangers of Diesel Exhaust in the Fire Station," MFRI, accessed August 12, 2017, https://www.mfri.org/dom/drill_0907.html.

[49] Ibid.

[50] "Clean Air Act Fuels Settlement Information," EPA, November 4, 2016, https://www.epa.gov/enforcement/clean-air-act-fuels-settlement-information.

that it is not based on the "whole" mixture of the noxious chemicals present in diesel exhaust; it is based on each chemical individually.

Some fire departments have begun enacting measures to reduce firefighter exposure. Because the effects of diesel exhaust exposure are well known, the design of new fire stations now includes encapsulating the garage area that houses the fire trucks in an effort to prevent the migration of diesel exhaust into the living space. Diesel exhaust capture systems are being installed in some fire stations to expel the diesel exhaust to the exterior of the building. Also, the newest generation of fire trucks are equipped with a built-in diesel exhaust regeneration system. This regeneration system captures the diesel particles in the vehicle exhaust system before they escape into the atmosphere, and then uses high heat to burn the particles before they are vented into the atmosphere. These efforts to reduce diesel exhaust exposure—with the intended goal of no exposure—are a step toward reducing firefighter health issues. Still, more research must be done to enhance prevention methods.

The current EPA approach to reduce exposure to diesel exhaust is a two-pronged assault. First, the Agency regulates the content of the diesel fuel produced, sold, and imported into the United States. The goal of the fuel regulation is to require diesel engines to burn a diesel fuel with less sulfur content. According to the EPA, the United States and Canada were required to reduce sulfur levels from 500 parts per million (ppm)in 2006 to 15 ppm in 2008. By 2010, diesel fuel sulfur levels were required to be reduced to 10–15 ppm in the United States, Europe, and Japan. European Union standards were reduced from 350 ppm in 2004 to 10 ppm in 2010, including an intermediate 50 ppm level required in 2006.[51]

The second method the EPA uses to reduce diesel emissions is requiring vehicles manufactured after 2007 to meet EPA-established air pollution emission standards. This applies to any class of new motor vehicle engine that causes or contributes to air pollution which may reasonably be anticipated to endanger public health or welfare. The EPA sets the standards regulating the emissions of hydrocarbons, carbon monoxide, and

[51] "Clean Air Act Fuels Settlement Information," EPA.

particulate matter from heavy-duty trucks produced after 2007. For heavy-duty vehicle manufacturers to meet EPA particulate matter standards, they rely on a diesel particulate filter after-treatment system that filters the diesel vehicle's exhaust fumes, significantly reducing emissions. These filters trap particulate matter and remove it from the exhaust fumes. There are two types of particulate matter that accumulate as a result of diesel engine combustion, combustible and noncombustible, which require two different types of cleaning methods: regeneration and ash cleaning.[52] Regeneration is designed to complete the combustion of the trapped combustible particulate matter components that flow from the exhaust pipe. The non-combustible particulate matter, such as metallic ash, cannot be destroyed and will remain inside the diesel particulate filter.[53]

To limit indoor exposure to diesel emissions, fire trucks use a system that attaches a hose to the exhaust pipe of the truck while it is parked inside the firehouse. This hose captures exhaust emissions and moves them to the outside of the building. According to manufacturers of emission exhaust systems, the systems recapture one hundred percent of the exhaust fumes produced inside of a structure. That is not, however, the case in practice. For instance, the hose must be manually connected by a firefighter as the truck backs into the station. Any movement of the vehicle is sensed by the hose, which rapidly, and automatically, detaches the hose to prevent it from being ripped off of the pipe connecting it to the mechanical unit. Additionally, before the hose is connected and after it is automatically disconnected, the exhaust emissions are still being absorbed by the building and its occupants. Although the capture system is an improvement from no system at all, it must be further improved to trap more exhaust.

While the EPA requires a reduction in dangerous chemicals such as sulfur in diesel fuels manufactured, imported, and consumed in this country, more must be done to eliminate or reduce occupational exposure by members of the fire service. The absence of any federal mandate or standard requiring diesel exhaust ventilation systems at fire stations, as recommended in the National Fire Protection Standard 1500,is troubling. The

[52] EPA, "Diesel Particulate Filter General Information," (EPA-420-F-10-029, May 2010), https://www.epa.gov/sites/production/files/2016-03/documents/420f10029.pdf.

[53] Control of Air Pollution From Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards, 79 FR 23413 (2014).

separation or segregation of different parts of fire stations is one solution some fire departments, such as the Boston Fire Department, are considering. The firefighters' living space should be separated by distance and structural barriers from the apparatus area. In this type of building design, called encapsulation, barriers—such as stronger walls—that do not allow diesel particles to migrate into the living space are installed in all fire stations. With the health issues surrounding exposure to diesel exhaust in other occupations such as mining, it is difficult to argue that diesel exhaust is not a contributing factor to the high cancer rates among firefighters.

Because they offer several advantages, particularly eliminating the exposure hazard of diesel engines, electric-powered fire trucks should be considered as an alternative to diesel-powered fire trucks. The London, Fire Brigade is currently using a fire truck that is partially powered by electricity. In these trucks, electricity is used to power the pump that supplies water to the hoses used by the firefighters; the engines that power the vehicle, however, remain diesel powered.[54] To replace diesel-powered fire trucks with either completely or partially electric-powered fire trucks would not only eliminate the health risks associated with diesel exhaust, it would also reduce the cost associated with building new fire stations that require more space and encapsulated areas to prevent the dangerous diesel exhaust particles from migrating into living quarters.

[54] "Brigade Introduces Brand New Fire Engines on London's Streets," London Fire Brigade, January 23, 2017, http://www.london-fire.gov.uk/news/LatestNewsReleases_London-Fire-Brigade-introduces-brand-new-fire-engines-on-London%E2%80%99s-streets.asp#.WXtdL4TyvIU.

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IV. RESPIRATORY EQUIPMENT

When any piece of matter—regardless of its physical contents—combusts, two byproducts are produced: carbon monoxide and hydrogen cyanide. When they enter the human body, these byproducts are deadly. They close oxygen pathways to the lungs, reduce brain function, and, in high-dose exposure, can cause immediate death.[55] The smoke generated when a room or a building is engulfed in fire is full of toxins that seep into firefighters' bodies and lead to multiple exposure hazards, including cancer and premature death. It is difficult to identify the chemical content of smoke, but smoke produced in a building fire can be assumed to have several known carcinogens. Those carcinogens are entering the bodies of the nation's firefighters through inhalation, absorption, and ingestion, causing irreversible physical harm.

In July 1988, five firefighters died in a Hackensack, New Jersey, auto dealership fire. Two minutes after the command ordered all firefighters out of the building, the roof collapsed, tragically killing three of the firefighters and trapping the remaining two inside. The two trapped firefighters were later found dead after exhausting the clean air from their self-contained portable breathing apparatus.[56]

In February 1991, three firefighters died at the Meridian high-rise fire in Philadelphia, Pennsylvania. These three firefighters, along with a search and rescue team sent to locate them, became lost in the thick smoke generated by the fire. The eight-member search team exhausted the air in their self-contained breathing apparatus and was rescued by a second search team, which deployed via helicopter on the roof of the fire building. None of the search teams sent into the building were able to rescue the three trapped firefighters. The after-action fire investigation determined that the three

[55] James Augustine and Donald W. Walsh, "Smoke Associated Cyanide Exposure: The Importance of Prompt Recognition and Protocols for Prehospital Treatment," *Fire Engineering* 159, no. 8 (August 2006): 15.

[56] Fire Rescue Magazine, "Hackensack Tragedy: A Failure in Command," My Firefighter Nation, July 1, 2010, http://my.firefighternation.com/profiles/blogs/hackensack-tradegy-a-failure.

firefighters died after "they had exhausted all of their air supply and could not escape to reach fresh air."[57]

In February 2015, in Hartford, Connecticut, a firefighter died in a house fire. The medical examiner ruled that the firefighter's death was caused by lack of "breathing gas." The self-contained portable breathing apparatus worn by firefighters hold a minimum of thirty minutes of breathable air, yet this firefighter had been inside of the house for less than twenty-one minutes.

Firefighters are constantly exposed to smoke during firefighting operations, yet the only method of limiting the inhalation of smoke is to provide clean air in the form of a portable, self-contained breathing apparatus (SCBA) worn on their backs. There are two reasons behind the use of SCBAs: to provide breathable oxygenated air in an oxygen-deficient environment and to prevent toxic substances from entering the lungs of the firefighters. The SCBAs come in two categories, open circuit and closed circuit. The open-circuit SCBAs used in the fire service have a cylinder with compressed air that is reduced as it is delivered to the user. This system does not use any atmospheric air and relies solely on the cylinder for air. The second type of SCBA, a closed-circuit system, uses the wearer's exhaled breath, after the carbon dioxide has been effectively removed, to re-oxygenate the air concentration to suitable levels.

This method to prevent smoke inhalation has been in existence for over a hundred years. The current apparatus in use in the fire service has a thirty-minute supply of clean air, with some larger units providing forty-five minutes. This time limit is a problem when operating in a high-rise building or other large structure, where more time is needed to locate the source of the fire, extinguish it, and then exit safely. If entry is made and the SCBA must be immediately activated due to poor air quality, then the air supply may be consumed prior to reaching the fire. In reality, if half of the total air supply is consumed prior to reaching the fire, firefighters must turn around to exit the area because they will consume the remaining half of the air supply while exiting safely, leaving no time to

[57] J. Gordon Routley, Charles Jennings, and Mark Chubb, *Highrise Office Building Fire, One Meridian Plaza, Philadelphia, Pennsylvania* (USFA-TR-049) (Washington, DC: FEMA, 1991), https://www.usfa.fema.gov/downloads/pdf/publications/tr-049.pdf.

rescue occupants or extinguish the fire. Additionally, a variety of factors contribute to the longevity of a firefighter's air tank, such as the firefighter's physical size and amount of air needed during physical exertion, which can cause a portable breathing apparatus to fall short of its thirty-minute promise.[58]

The SCBA must be reexamined with an emphasis on extending the available air supply. Advances in this technology have included many safety features, but the amount of breathable air provided to the user has increased only minimally since its original design in the mid-1800s. Two other industries that use SCBAs, however—mining and space exploration—have made advances in the amount of air provided to the user. If the fire service is going to reduce inhalation exposure hazards, it must find a way to produce an SCBA that provides an unlimited supply of clean, breathable air for firefighters so as to prevent exposure to toxic smoke encountered at fires.

As the tragic anecdotes provided at the beginning of the chapter show, too many firefighters have died of smoke inhalation at fires and other emergencies because their portable air supply in their SCBAs was exhausted before they could safely exit a hazardous area. They are either trapped or unable to reach an oxygen-rich location, or they are in a location that does not allow them the opportunity to replace the cylinder that holds the air they breathe. According to the National Fire Protection Association (a nonprofit fire industry source), in 2014, 14 percent of all firefighter deaths at fires were caused by asphyxiation/smoke inhalation.[59] These deaths could have been prevented if the portable air supply in the firefighters' SCBAs had a longer or infinite air supply. The hazards of firefighting are many, but an unlimited portable air supply for trapped firefighters or civilians would provide more time for the rescue personnel to reach them, particularly if the victims are not in direct contact with fire or extreme heat, but rather are asphyxiating on toxic smoke.

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[58] Steven Goode, "Hartford Fire Department Task Force Issues Recommendations," *Hartford Courant*, June 19, 2015, http://www.courant.com/news/connecticut/hc-hartford-fire-department-task-force-recommendations-0620-20150619-story.html.

[59] Rita F. Fahey, Paul R. Leblanc, and Joseph L. Molis, *Firefighter Fatalities in the United States* (NFPA No. FFD10) (Quincy, MA: National Fire Protection Association,2015), http://www.nfpa.org/research/reports-and-statistics/the-fire-service/fatalities-and-injuries/firefighter-fatalities-in-the-united-states.

As previously mentioned, the air cylinders used with fire service SCBAs provide, or are rated as providing, thirty or forty-five minutes of air, with the national standard being the thirty-minute cylinder.[60] As is also previously mentioned, however, those time ratings are not accurate. In the article "Breathe in the Change: Firefighter Safety Health," Ray Reed explains that "with the increased physiological demands placed on the body during active firefighting, a firefighter could expend a NIOSH-rated 30-minute cylinder in as little as 12–15 minutes under extreme workloads."[61] This short time allotment provided by the cylinder capacity has a direct impact on escape time; a SCBA user may only have two to three minutes of air left when the low-air alarm signals.[62]

The mining, space exploration, and fire service industries, have spent many years and a great deal of resources researching, designing, developing, and improving SCBAs. One of the main objectives of this research has been to extend the amount of time the wearer can stay in oxygen-deprived environments by increasing the air supply necessary to complete the task at hand.

A. MINING INDUSTRY

There are economic reasons for miners to work for longer periods underground using self-contained breathing units. The miners can retrieve more of the product for the mine owners, thereby increasing profits. The mining industry now uses an electrically powered ventilation system with large fans to pull fresh air into the mines, while also removing harmful emissions. The fans are connected to computers that monitor the movement of the miners, allowing an automatic increase or decrease in airflow based on demand.[63] Prior to the current use of ventilation fans, the mining industry used SCBAs. The individual self-contained breathing apparatus is now used only during rescue

[60] Karen Abeyasekere, "Breathe Easy: Firefighters Train on SCBA to Ensure Own, Others Lives Kept Safe," Royal Air Force Mildenhall, May 1, 2014, http://www.usafe.af.mil/news/story.asp?id=123409234.

[61] Ray Reed, "Breathe in the Change," *FireRescue Magazine*, March 20, 2009, http://www.firefighternation.com/article/firefighter-safety-health/breathe-change.

[62] "Self-Contained Breathing Apparatus (SCBA)," Burston Innovation, June 28, 2015, http://burstoninnovation.com/SCBA.htm.

[63] Steve Fiscor,"Engineering Improvements that Eliminate Risk," *Engineering and Mining Journal*, April 8, 2015, http://www.e-mj.com/features/5119-engineering-improvements-that-eliminate-risk.html#.WPbP4pgrJE4.

attempts of trapped miners. These units use a closed circuit that acts as a filtering system, which allows the user a longer period during which to work.[64]

Because the mining industry system uses fans to circulate the air, the system would not work as-is at a fire scene; the added oxygen from the fans would accelerate the fire—not to mention the system would take too long to set up.

B. SPACE EXPLORATION

At the beginning of the NASA space program, the astronauts were encapsulated in bulky space suits that provided them with fresh air, but now they roam freely in space stations that use a process called water electrolysis, which converts moisture in the space station into breathable air.[65] The process of electrolysis includes the water reclamation and the oxygen generation system. The water reclamation system recycles the water within the space station, such as wastewater and humidity condensation on the walls and windows.[66] All this fluid is then purified to be reused. Electrolysis is used to split the water into atoms of hydrogen and oxygen. This involves passing an electric current, provided by solar panels, through the water, which separates the atoms and recombines them as hydrogen gas and oxygen. This process is "similar to the process of photosynthesis, where plants break down water into hydrogen and oxygen."[67]

C. FIRE SERVICE

The one thing that mining industry and NASA breathing equipment have in common is that both units provide a longer supply of clean, breathable air to their workers, in contrast to the limited supply of air provided to firefighters.

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[64] Greg Fenrick, "Self-Contained Breathing Apparatus (SCBA)," TechnoMine, February 1, 2008, http://technology.infomine.com/articles/1/2477/health.safety.breathing/self-contained.breathing.apparatus.aspx.

[65] Michelle Starr, "Breathe Deep: How the ISS Keeps Astronauts Alive," CNET, March 19, 2015, http://www.cnet.com/news/breathe-deep-how-the-iss-keeps-astronauts-alive/.

[66] Ibid.

[67] Ibid.

1. Then and Now

Self-contained breathing apparatus use in the fire service dates back several hundred years. The first firefighters grew long beards that they dipped into a pail of water before entering a burning building—once their beards were saturated with water, they placed the beards in their mouths and used them as air filters, breathing exclusively through their mouths.[68] There is no record of the additional time gained in the smoke-filled atmosphere using the wet beards, yet this is an example of the inventive initiative currently absent from the mindset of today's SCBA manufacturers.

With the threat of a terrorist attack in a large, populated American city using weapons of mass destruction (WMDs), it is especially important that a new self-contained breathing apparatus is created to provide unlimited fresh air for potential, long-duration WMD incidents. As with any chemical attack or accident, the first hour is the most important. Whether it is shutting a valve to stop the flow of a dangerous chemical at a chemical plant or evacuating the wounded, it makes no sense to limit the time that first responders can help victims to thirty minutes or less. After thirty minutes, if the rescuer does not exit the immediate hazard area to replace his or her air cylinder, the rescuer will become a victim as well. When rescuers are reluctant to leave the contaminated area, they play a dangerous game of Russian roulette with their own lives and the lives of those they are there to help, all because of the limited air supply.

Today's firefighters face hazards at the onset of an emergency, during firefighting and evacuation, and even after the incident, during overhaul operations. In relation to homeland security, terrorists are aware of our first responders' capabilities; they have even used secondary devices timed to target first responders' arrival time.[69] If they prevent the rescue of the initial victims and instead create new victims of the rescuers, they will be causing the greatest possible amount of disaster and destruction against civilians and government officials. Additionally, as discussed previously, current SCBAs

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[68] "Major Firefighting Milestones and Engineering," *Company 23 FVFD Blog*, July 6, 2014, https://bobdi23.wordpress.com/fvfd-history/history-of-major-firefighting-milestones-and-engineering/.

[69] National Counterterrorism Center, *Worldwide: IED Targeting of First Response Personnel* (Washington, DC: Department of Homeland Security, 2012), https://publicintelligence.net/nctc-first-responder-ieds/.

have limited effectiveness in high-rise buildings; not only do firefighters need more air supply to locate the fire and retrieve victims, they also need lighter-weight equipment to negotiate flights of stairs when elevators are rendered useless for traversing and evacuating the building. Then, depending on the success of the ventilation at a given fire, the toxin levels remain high during overhaul operations. Because of the extra weight and the prohibited mobility of the SCBAs, the overhaul activities, including checking for unseen fire extension by opening up walls and removing burnt furniture, are regularly performed after shutting down and removing the portable self-contained breathing apparatus. Fire departments must begin purchasing less cumbersome SCBAs with a greater air capacity to allow firefighters to perform all of their duties while breathing clean air.

There is currently a nationwide initiative within the fire service that would require firefighters to continue using their SCBAs during overhaul operations, limiting their exposure to carcinogens in the atmosphere after the flames are extinguished.[70] If that requirement were officially instituted, it would become even more imperative to design a self-contained breathing apparatus with an unlimited air supply. It is well known throughout the fire service that the toxins in and around fires cause cancer.[71] One way for firefighters to safely perform their jobs in hazardous environments and reduce personal exposure is to have the equipment that would allow them to breathe clean air using a less cumbersome unit with an unlimited breathable air supply.

There have been several advancements to SCBAs used in the fire service, but no advancements in the amount of breathable air available to the user. Some of the new equipment incorporated into today's SCBAs include a Personal Alert Safety System (PASS) that makes a loud noise if the wearer is motionless for more than twenty seconds. The SCBAs also have what is called a vibra-alert notification system that sends vibrations through the facemask when the air supply goes below 33 percent of the cylinder's capacity. The two leading SCBA suppliers in the United States, Scott Aviation

[70] "SCBA Use During Overhaul," Fire Engineering, September 1, 2007, www.fireengineering.com/articles/print/volume-160/issue-9/departments/roundtable/scba-use-during-overhaul.html.

[71] Josh Cable, "NIOSH Study Finds Higher Cancer Rates among Firefighters," *EHS Today*, October 21, 2013, http://ehstoday.com/health/niosh-study-finds-higher-cancer-rates-among-firefighters.

and Mine Safety Appliances, are currently developing a self-contained breathing apparatus with built-in thermal image cameras, which would allow firefighters to see through smoke. All of these improvements are helpful to complete the task of rescue and fire extinguishment, but if the breathable air provided is inadequate for the job at hand, these other improvements are of no use.

In the fire service, technological advances have continued at a rapid pace for firefighters' clothing, fire trucks, tools and equipment, and extinguishing agents such as foams. Yet no advancement has occurred in the amount of breathable air provided by the self-contained breathing apparatus. The expense of research and development aimed at this problem appears to be the reason for not resolving this industry-specific health hazard. Because this product is used in a small market, namely the fire service, it would be a costly endeavor within the research and development divisions of the SBCA manufacturing companies. Could it be that the profitability and complacency of these two corporations is the reason for this lack of innovative initiative?

2. The Way Forward

How can the municipalities responsible for the safety of first responders and citizens alike influence the SCBA manufacturing industry to conduct more research and development? Should private industry, with its profit-driven culture, continue to be the only avenue for a solution to this problem? Perhaps a more feasible solution would be to encourage academia to team up with private industry and the fire service in a collaborative effort to solve this life safety issue.

Both the mining and space exploration industries overcame an equipment deficiency that was an obstacle to achieving their objectives. It is time for the fire service industry to the same. Current SCBA manufacturers do develop new features for their units, but most of their research and development, as described in the previous section, focus on improvements such as low air alarm systems, improved face shield heat resistance, and technology to locate a disabled firefighter. While these features are helpful, they are useless if the wearer's air supply runs out.

Research and development must focus, instead, on a hybrid self-contained breathing unit that uses NASA's water electrolysis technology. This new hybrid unit could use the existing air cylinder as the primary source of air. When the cylinder air decreases to a certain level, a smaller version of the NASA electrolysis system built into the harness would activate. With the moisture in the surrounding air—or, if there is none, using the moisture produced by the firefighter's exhalation and captured in his or her facemask—the electrolysis process could be combined with the remaining air in the cylinder to extend the amount of breathable air. Another possibility is to enhance the SCBA using the mining industry's closed-circuit system that filters atmospheric air. If used as a last resort or combined with—or in place of—NASA's electrolysis system, it could add valuable time for the SCBA wearer. The safety deficiency of this equipment has been neglected long enough, and there exists the capacity and the knowledge to correct this vulnerability in our emergency response capabilities, especially during this time of uncertain potential terrorist threats.

The production of this new breathing apparatus could be possible with the combined effort of the fire service, current SCBA manufacturers, and institutions of higher learning such as the Massachusetts Institute of Technology (MIT). The creation of a new portable breathing apparatus with an unlimited supply of clean air would provide multiple benefits to not only the firefighters, but also to the people they serve; with an unlimited supply of clean air, firefighters can rescue more victims and limit their inhalation exposure hazards while seeking safety.

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V. TOXIC SMOKE

Modern buildings and furnishings contain many different products—some are simply made out of wood, while others are component items with multiple materials incorporated into them, such as cloth-covered furniture or plastic-covered electronic products like televisions and computers. These household items create toxic smoke when consumed by fire. Each type of material is uniquely dangerous when it burns. Plain wood furniture is covered in a stain to preserve the wood; plastics are petroleum based, and padded furniture is allowed to have chemical flame retardants infused in the foam padding to slow the spread of fire. These materials create a toxic smoke mix containing particles that can enter the human body via the respiratory tract. The inhalation of this "toxic soup" of smoke is believed to play a large role in the high cancer rates among firefighters.

In an Underwriters Laboratories experiment, researchers tested the flammability of modern furniture by conducting a controlled fire test, igniting two rooms of furniture and measuring the time it took to have full fire involvement in each room.[72] One room had modern furniture made from synthetic materials, while the second room had furniture from thirty years ago made from common cloth and wood. The results were amazing; the room with the modern furniture was fully engulfed in flames in two to four minutes while the second, identical, room with older furniture took twenty-eight minutes to become fully engulfed in flames. When considering these results along with the limited portable air supply carried by firefighters, the obvious conclusion is that fire burns faster because of the synthetic makeup of modern furniture, and flame retardants have little effect on escape time provided to the building occupants.

Because the contents of smoke make it difficult to identify a specific carcinogen in a fire, exposure is also difficult to pinpoint. As science is an imperfect discipline, and smoke dissipates into the atmosphere quickly, the scientific facts necessary to definitively

[72] "Comparison of Modern and Legacy Home Furnishings," UL FSRI Fire Safety Research Institute, May 22, 2013, http://ulfirefightersafety.org/projects_blog/comparison-of-modern-and-legacy-home-furnishings/.

identify the exact source or exposure of cancer-causing substances with any degree of accuracy is limited. Because of this inability to pinpoint the exact carcinogens to which firefighters are exposed, many states in this country have passed laws that provide health and pension benefits for firefighters and their beneficiaries based on the presumption that cancer is caused by occupational exposure. The passage of these "presumptive cancer laws" is governmental recognition that firefighters do, in fact, face carcinogenic substances in performance of their duties. Though these laws are necessary, they are reactionary. The issue of firefighter cancer has to be addressed prior to exposure to possible carcinogenic toxins. If cancer entry routes into the human body can be determined, then protection of these entry routes must be taken, regardless of the cost.

If cancer is entering the bodies of firefighters, then how do we stop exposure? A longer air supply in the self-contained breathing apparatus as well as cloth hoods worn around any unprotected skin surrounding the face mask of the wearer would reduce exposure to the respiratory tract and skin absorption. These hoods surround the face shield that supplies the clean air. Some fire departments are handing out baby wipes at the scene of a fire when the incident de-escalates. The baby wipes are used to remove the soot that adheres to the skin after the protective clothing is removed and limit the contact of physical particulate to the skin.

Several other protection measures for denying carcinogens entry into the body are being used by many fire departments. "Bunker gear" is the term used to describe the outerwear firefighters wear when responding to a fire. The safety design and material components that are used in the construction of the bunker gear has evolved over time. The first firefighters wore very little in the way of protective clothing. But, as in any evolving industry, the need for better clothing to protect the firefighter became apparent with each tragic accident. After World War II, firefighters wore rubber rain coats that went down to their knees. To accompany the rubber coats, they wore rubber boots that folded up above the knee under the long-hanging rubber coats. This design came about to protect the firefighters from their main instrument of extinguishment—water. Up until the mid-1990s, rubber coats were still being used. At that time, bunker gear was introduced. The bunker gear had a waist-level coat made from flame-retardant material, accompanied

by full-length pants of the same material, held up by suspenders. The cloth lining of the new bunker gear absorbed water, adding weight to the clothing and speeding the physical onset of fatigue. Another added hazard of the bunker gear was that the water retained in its cloth material became hot from a combination of the firefighter's body heat and the ever-present atmospheric heat of all building fires. Several firefighters received burns from the bunker gear itself due to its heat retention. Frustration with this new gear was evident in the fire service, which forced an industry-wide reevaluation of the equipment. The gear was replaced with two more generations of the same style bunker gear with a double lining that prevents the thermal buildup of heat.

With the increased protection afforded by the new bunker gear, the focus has turned to the hazardous chemicals contained in consumer products and chemical flame retardants. As long as it took to upgrade the bunker gear, it was still an industry-specific problem that the fire service had autonomy over. Carcinogenic chemicals in consumer products, however, have wide-ranging governmental (federal, state, and local) and private-sector interests with which to contend. The federal government must take the lead in removing chemical flame retardants from consumer products. California's new TB117-2013 is a step in the right direction, as the law requires a level of fire safety; but this new level can be obtained without the use of dangerous chemicals. The city of Boston has also moved in the right direction by amending the Boston Fire Prevention Code by, "allowing hospitals, schools, colleges, and other public buildings with sprinkler systems to use furniture free of toxic flame retardant chemicals."[73] The EPA must follow these local governments' examples by putting the safety of its citizens before corporate interest and setting a national fire safety standard that prohibits the use of chemicals to meet fire safety requirements in consumer products and building code requirements.

[73] "Boston Changes Fire Code to Allow Furniture Free of Flame Retardants in Public Spaces," Silent Spring Institute, March 23, 2016, http://silentspring.org/press-releases/boston-changes-fire-code-allow-furniture-free-flame-retardants-public-spaces.

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VI. CONCLUSION

> The definition of insanity is doing the same thing over and over again, but expecting different results.
>
> —Rita Mae Brown[74]

The occupational exposures that firefighters encounter in the performance of their duties—such as toxic smoke, hazardous chemicals, oxygen-deficient environments, and byproducts from diesel exhaust—are well known; what should be done, and at what cost, to provide better personal protective equipment and improved tactical firefighting strategies is what must be decided. The discourse now taking place in the fire service industry is heading in the right direction. Several fire departments have explored procedural and equipment changes in an attempt to protect their members from these life-threatening hazards. It is beneficial to conduct more research into the causes of occupational exposures in the fire service, but, as in other industries such as mining and space exploration, the implementation of new policies and equipment should be instituted immediately.

Chemical flame retardants must be banned from all consumer products to eliminate the off-gassing that occurs when flame retardants produce a hazardous dust from infused consumer products, as determined by Professor Blum's experiments.[75] The total elimination of chemical flame retardants would also decrease exposure to firefighters who inhale the toxic smoke generated by these chemicals' ignition. These two reasons alone should be enough for government intervention to prevent these chemicals from ever reaching the American consumer. The argument supporting total ban of chemical flame retardants can be justified after reviewing the Emory University study of the Michigan chemical plant accident that directly poisoned animals and indirectly poisoned the residents of Michigan.[76]Blum's research findings through the Green Policy

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[74] Rita Mae Brown, *Sudden Death* (New York: Bantam Books, 1983).

[75] Blum, "Tackling Toxins."

[76] Marcus," Tracing the Toxic Legacy."

Institute regarding the hazards of chemical flame retardants in children's sleepwear (now banned by the U.S. government) and the harmful effects of chemical flame retardants in home furnishings, along with the scientific evidence presented in the "San Antonio Statement" disputing the overall effectiveness of the flame retardants, make a strong case for a total ban of all chemical flame retardants.[77] More research into the hazards of chemical flame retardants can, and should, be conducted by public and private-sector entities, but the existing evidence documenting the health risks of these products is more than enough to stop production and distribution of these dangerous chemicals. It is time for the EPA to step up enforcement of the recently passed Toxic Chemical legislation and prohibit these chemicals from being produced and distributed in this country.

Additionally, fire departments and firefighter unions must demand the passage of the cancer registry—which would document the locations where firefighters are being stricken with the most cancer cases, and the types of cancer associated with those locations—in an effort to identify similarities and preventive actions. To quickly identify and treat dangerous exposures, biomonitoring of all firefighters must begin immediately.

Most importantly, the one tool that could prevent the high rates of respiratory exposures among firefighters is a new self-controlled breathing apparatus with an unlimited supply of clean air. With today's advances in computers and science, to have a profession as important to public safety as firefighting using SCBAs with the same amount of air as was available when the units were invented in the mid-1800s is regressive and irresponsible. If the manufacturers of the current SCBAs do not want to spend the money on research and development to create a new version of these "iron lungs," the government, in conjunction with the academic community, must get involved. The question is not will there be another terrorist attack on American soil, but rather when. With the threat of terrorism ever present, it is in the best interest of every American to give our first responders the equipment necessary to respond to an attack. If first responders are not properly equipped, their deaths will be accompanied by increased civilian deaths.

[77] Blum, "Flame Retardants"; Gangi et al., "San Antonio Statement."

There is saying in the fire service regarding the lack of progress in firefighting since the inception of the profession: “200 years of tradition unimpeded by progress.” All firefighters know this saying is steeped in truth, but it is time we put this institutional mindset to rest so that firefighters can enjoy their families and look forward to a long and healthy retirement.

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