UNDERSTANDING BARRIERS IN RESPIRATORY EQUIPMENT IMPLEMENTATION AMONG WILDLAND FIREFIGHTERS

By

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ABSTRACT

Background:

Over the past decade, awareness has grown among wildland firefighters about the health risks associated with smoke exposure and cancer. In June 2022 the International Agency for Research on Cancer (IARC) reclassified occupational exposure for firefighters as Group 1, carcinogenic to humans. However, limited data exist on respiratory protection practices, perceived barriers to adopting protective equipment, and chemical risk knowledge among firefighters. Understanding these gaps and barriers is essential for developing effective protection protocols and education programs.

Specific Aims:

This study aimed to evaluate firefighters' chemical risk knowledge of smoke produced in wildland/Wildland Urban Interface (WUI) fire incidents, identify knowledge and perception gaps between leadership and non-leadership levels, and explore attitudes, barriers and motivators to respiratory protection across leadership roles.

Methods:

A mixed-methods approach was employed using The Wildfire Conservancy Respiratory Protection Survey (n=766) and key informant interviews with non-leadership and leadership firefighters (n=27). In the quantitative analysis, data were analyzed using RStudio (version 2024.04.2+764) and the qualitative thematic analyses were conducted using Dedoose (version 9.2.012). The study applied Social Cognitive Theory to investigate cognitive, behavioral, and environmental factors influencing the use of respiratory protection among wildland firefighters.

Results:

The Wildfire Conservancy Survey revealed that 85.9% of firefighters do not use respiratory protection during wildland/WUI incidents, with cloth masks being the most commonly used form of respiratory protection (67.8). Significant knowledge gaps were found regarding hazardous chemical produced by smoke. No significant differences in chemical knowledge were observed between firefighters in leadership versus non-leadership (p-value=0.646). Impaired breathing (64.2%) emerged as a major barrier in respiratory protection. Leadership exhibited significantly more concern about the size of the respiratory equipment (p-value=0.004), whereas non-leadership firefighters placed greater importance on the appearance of the equipment (p-value=0.004). Cancer risk reduction (74.8%) was the strongest health motivator for respiratory protection use for both leadership and non-leadership. Key informant interviews highlighted leadership's influence on respiratory protection adoption, with non-leadership firefighters being less likely to adopt protection due to cultural norms and perceived feasibility.

Discussion:

Significant knowledge gaps regarding smoke exposure risks and respiratory protection exist among wildland firefighters. Targeted training across all ranks is needed to raise awareness, and leadership must model protective behavior to improve equipment adoption. Current respiratory

methods are inadequate, underscoring the need for effective, practical solutions. Addressing cultural norms that discourage safety measures and creating a national standard for respiratory protection are essential for fostering safer wildland firefighting practices.

Understanding Barriers in Respiratory Equipment Implementation Among Firefighters

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DEDICATION

To all the wildland firefighters who bravely stand between our communities and nature's fiercest forces, risking their own safety every day to protect the public. This work is a tribute to your courage, resilience, and sacrifice. May each step forward in health and safety be a testament to our gratitude and commitment to ensuring that those who safeguard us are safeguarded in return. Your strength, dedication, and unwavering spirit inspire all of us to work tirelessly toward making your protection as steadfast as the service you provide.

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CHAPTER 1: INTRODUCTION

It is predicted that wildfires will continue to become larger and more intense due to climate change, population expansion, and increases in the demand for housing (Flannigan et al., 2009; McCoy & Walsh, 2018); (Syphard et al., 2024). Over the past decade, the average number of acres burned in the United States jumped from 3.6 million acres in 2013 to 7.5 million acres in 2022. (Hoover & Hanson, 2018). These wildfires are dangerous and unpredictable, often creating a complex combination of airborne chemicals formed during the incineration of organic vegetation, housing materials, and other combustible sources (Stefanidou et al., 2008). Wildfire chemicals are highly dangerous and largely unstudied, with most research focusing only on controlled burn emissions (Selimovic et al., 2019). What has been confirmed, is the correlation between wildfire smoke exposure and respiratory morbidities, respiratory illness, potentially cardiovascular effects/illness, and cancer (Reid et al., 2016). On the front line of wildfire incidents are thousands of firefighters combating the flames and being exposed to these chemicals.

There are approximately 1,041,200 firefighters in the United States, with 35% being career firefighters (e.g. paid full-time, part-time, or seasonal) and 65% being volunteer firefighters (Fahy et al., 2022). Although the average number of on-duty firefighter fatalities has decreased over time, the percentage of firefighters diagnosed with cancer has steadily increased (Lee et al., 2023). Firefighters are also 14% more likely to die from cancer related deaths when compared to the general population (NFPA, 2017). Therefore, most states now recognize that cancer is associated with firefighting as an occupation and have codified that assumption through the enactment of presumptive laws for cancer. Occupational exposures that firefighters receive in

the line of duty are contributing to their cancer burden. Researchers have documented known and suspected carcinogens in blood, urine, and exhaled breath of firefighters' post fire. (Caux et al., 2002; Keir et al., 2017).

Inhalation is a primary route of the occupational exposures to wildland fire smoke among firefighters. Wildfires create a complex combination of harmful pollutants, including polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs) (Reisen et al., 2015). Wildfires often have a variety of mixed fuel sources including organic matter from natural vegetation and various synthetic housing or building materials leading to the production of a diversity of harmful chemicals. Wildfire smoke is an increasing public health and occupational health concern due to the exposure risk associated with these complex mixtures of chemicals and the distances these chemicals can travel and linger in the air (Black et al., 2017; Hurwitz; Whittaker et al., 2021).

It is well documented that the combustion of organic material causes the release of PAHs (Kim et al., 2013). PAHs are a suite of chemicals found as bi-products of incomplete combustion, typically composed of three or more fused benzene rings containing hydrogen and carbon. Differing sources and types of biomass fuels and structure fuels (e.g. homes, automobiles, commercial properties, utilities, etc.) can create varying types of PAHs. A primary exposure route of concern during fire suppression is inhalation due to the proximity and availability of airborne PAHs during fire suppression (Hwang et al., 2021). In many epidemiological studies, PAHs have been associated with a variety of morbidities, diseases, lung cancer, prostate cancer, and gastrointestinal cancer (Armstrong et al., 2004). PAHs have the ability to embed themselves in personal protective equipment (PPE) (e.g., pants, jacket, gloves, neck hood), increasing occupational dermal exposures over time and inhalation during PPE off

gassing(Fent et al., 2017; Wilkinson et al., 2023). In addition, PAH levels in PPE increase with each subsequent wildfire exposure causing further dermal exposure risk and concern (Fent et al., 2017).

Vegetation fueled wildfires produce significant amounts of VOCs. (Ciccioli et al., 2014). VOCs are organic compounds (e.g. carbon-based) that have a high vapor pressure at room temperature and low water solubility, which makes them volatile. These VOCs become easily trapped in firefighter PPE, increasing in concentration with increased duration of exposure (Fent et al., 2017). It has been documented that PPE continues to off-gas VOCs after fire suppression activities have ended, potentially posing a risk to firefighter who continue to wear their gear in confined spaces (such as vehicles, fire camp tents) or during extended shifts (Banks et al., 2021; Fent et al., 2015). One of the most concerning VOCs produced by a wildfire event is benzene. During active wildfire burning, benzene often exceeds standard exposure limit values of 1 part per million and has been recorded at several parts per million in dense smoke (Barboni et al., 2010). Benzene is a known carcinogen to humans according to the International Agency for Research (IARC) (Huff, 2007). The National Institute for Occupational Safety and Health (NIOSH) has established a Recommended Exposure Limit (REL) for benzene of 0.1 parts per million (ppm) over a 10-hour time-weighted average (TWA), with a short-term exposure limit (STEL) of 1 ppm for a 15-minute period (NIOSH, 2005). However, studies, such as those conducted by Burgess et al. (2001), as well as data from the Firefighter Cancer Cohort Study (FFCCS), indicate that benzene exposure during active fire suppression can far exceed these recommended limits. In some instances, firefighters have been recorded as experiencing benzene levels as high as 10 ppm or more during wildfire operations, particularly under conditions involving prolonged exposure or work in enclosed or poorly ventilated environments (Burgess et

al., 2001; FFCCS, 2020). Although studies have highlighted the daily chemical risks and toxic exposure faced by wildland firefighters, there has been little movement on implementation of respiratory equipment or smoke exposure reduction procedures. The National Fire Protection Agency (NFPA), which sets standards the majority of professional firefighting agencies adhere to, has created and implemented standards for a wildland respiratory protection device (NFPA, 2019). To date, no device has been manufactured that meets those standards. Therefore, in absence of a protective device that meets industry standards, the majority of wildland firefighters continue to work without any meaningful respiratory protection.

Purpose of the Study

While many structural firefighters use Self Contained Breathing Apparatus (SCBA) as a way to reduce respiratory exposures, there is no universally accepted standardized respiratory protection or procedure among wildland firefighters in the United States (Easterling & Prince, 2007). Currently, wildland firefighters fight fire without mandated respiratory protection or guidance from a respiratory protection standard (Garg et al., 2023). It is common for firefighters to use personal cloth bandanas to aid breathing during fire suppression; however, it has been documented that bandanas offer little to no protection against fine particulate matter, chemicals, and soot (Seale et al., 2023). There are many organizational and behavioral barriers that led to the slowed adoption and development of standard operating procedures (SOPs) related to respiratory equipment usage. Some barriers include the real and perceived feasibility of respiratory equipment in the field, lack of available funding for standardized equipment, personal beliefs surrounding respiratory equipment, lack of occupational exposure knowledge, as well as potential disengagement between leadership demands and firefighter personnel implementation (Harrison et al., 2018). Currently, fire departments and fire agencies have varying wildland

firefighter health and safety procedures due to their diverse operating environments, variations in resources, varying governing bodies, and established cultures (Page et al., 2019; Reimer & Eriksen, 2018). Wildland firefighters operate within a well-established culture of hierarchy, where strong deference to leadership is both ingrained and expected. This organizational structure mirrors one of the key characteristics of High Reliability Organizations (HROs), which emphasize clear chains of command and respect for authority to ensure operational safety (Weick & Sutcliffe, 2011). This strong deference to leadership is also why the fire service has adopted ranks similar to the military, with firefighters following a strict chain of command (Bullock et al., 2017). Following World War II, the fire service experienced a significant cultural shift, often referred to as the 'militarization of the fire service,' which further entrenched these hierarchical norms as a means of improving discipline and efficiency (Varone, 2007).

The reliance on observational learning in firefighting poses significant barriers to implementing health-promoting activities. Firefighters, especially those new to the field, often acquire essential skills by observing experienced colleagues, particularly in leadership roles. While effective for quickly transmitting operational strategies, this method can hinder the adoption of safety protocols. If leadership neglects health-promoting behaviors, such as proper use of respiratory protection or decontamination procedures, newer firefighters are likely to mimic these practices, perpetuating risky behaviors (Burgess et al., 2001; Rahn et al., 2023).

Leadership's role is critical in modeling and enforcing safety standards, directly influencing the adoption of health-promoting initiatives within teams (Weick & Sutcliffe, 2011). Additionally, cultural norms that emphasize toughness and endurance can reinforce resistance to new health measures, creating structural barriers to change (Varone, 2007). Therefore, leadership

must actively demonstrate and enforce adherence to safety protocols to ensure their successful implementation across all levels of the organization (Burgess et al., 2001; Rahn et al., 2023).

The implementation of respiratory protection among wildland firefighters presents unique challenges that remain underexplored. One of the key gaps in research is the limited understanding of how the leadership and firefighter personnel perceive respiratory protection. There is a lack of comprehensive studies investigating leadership attitudes toward enforcing such protective measures, as well as the willingness or reluctance of firefighters to adopt respiratory protection in practice. Issues such as practicality of wearing such equipment during physically demanding tasks, the discomfort associated with prolonged use, and the perceived barriers to implementing SOPs have not been thoroughly examined. Without addressing these factors, the development and adoption of effective respiratory protection protocols will remain limited, causing firefighters to continue being exposed to harmful smoke and chemicals The purpose of the study is to investigate knowledge gaps, perceptions, and barriers related to respiratory protection among wildland firefighters and leadership, with the goal of improving health and safety practices by elucidating challenges to the implementation of effective protection protocols.

Rationale

Wildland firefighter attitudes and awareness towards chemical risk have been slowly evolving, largely influenced by the emerging research of health risks associated with the occupation. Over the past decade, there is growing awareness among wildland firefighters regarding the health risks associated with smoke exposure and correlations with cancer. In June 2022, occupational exposure for structural and wildland firefighters was reclassified by the IARC as Group 1, identifying it as carcinogenic to humans based on sufficient evidence (Hwang

et al., 2023). This designation supported the general recognition that smoke exposure has long term impacts on firefighter health and safety.

Historically, the wildland firefighting culture has often emphasized toughness and hardiness at the expense of personal health and safety. However, over the past few decades, there has been a cultural shift toward prioritizing health and safety, driven by increasing awareness of the long-term health risks faced by firefighters. This shift began in the 1980s when structural firefighting agencies started implementing self-contained breathing apparatus (SCBA) to protect firefighters from toxic smoke and hazardous chemicals encountered during operations (Harrison, 2011). While SCBA was initially adopted for structural firefighting, wildland firefighters have been slower to adopt similar respiratory protection due to the different operational challenges in wildland environments. Nonetheless, following studies conducted in the aftermath of 9/11, which revealed alarming rates of cancer and respiratory illnesses among firefighters exposed to hazardous substances during the World Trade Center response (FDNY, 2016), there has been growing recognition of the need for better respiratory protection in wildland firefighting as well. This growing awareness underscores the importance of implementing respiratory protection standards for wildland firefighters to mitigate exposure to harmful chemicals and smoke. Increasingly, firefighters who have experienced health issues related to their own occupational exposure are sharing their stories with their peers. These personal connections in combination with the ever-emerging research connecting wildfire smoke to cancer have led to more serious attitudes toward adopting protective procedures and demands for change at the agency and national level (IAFF, 2019; NIOSH, 2024).

Despite growing awareness of health risks associated with smoke exposure, there remains a significant lack of data detailing the variability in the health and safety procedures related to

respiratory protection and smoke exposure among wildland firefighters across the United States. Moreover, there is scarce information that explores the specific barriers to the implementation of respiratory protection, the attitudes of firefighters towards such equipment, or the existing gaps in their knowledge of chemical risks. Understanding these factors is crucial for developing targeted and effective respiratory protection protocols, and designing educational programs that address chemical risk awareness and prevention. Without access to this essential knowledge, efforts to strengthen health and safety practices for wildland firefighters will be insufficient, leaving them at a heightened risk of preventable chemical exposures and associated health problems.

This project focused on addressing our understanding of wildland firefighting using a Social Cognitive Theoretical approach. The primary goal of this project was to illuminate these critical areas to enhance our understanding of existing health and safety procedures among wildland firefighters related to smoke exposure and respiratory protection, identify knowledge gaps regarding chemical risks of smoke exposure, and evaluate the obstacles to implementing respiratory protection.

Study Aims and Objectives

This study's goal was to gather insight into cognitive, behavioral, and environmental factors that may affect potential/perceived barriers among wildland firefighters regarding implementation of respiratory equipment. The specific aims were: Aim 1) To collect data on the chemical/health and safety knowledge of firefighters and leadership who are implementing standard operating procedures, Aim 2) To assess the gaps between firefighter knowledge and practices and leadership perceptions of firefighter knowledge and practices; and Aim 3) To

determine attitudes and barriers among firefighters towards respiratory equipment as well as health motivators

Objective 1

Using a wildfire survey dataset collected by The Wildfire Conservancy as well as key informant interview data, analyze and compare health and safety knowledge of firefighters and leadership who are implementing standard operating procedures. The data includes respondents who are wildland firefighters throughout the United States. Respondent data will help shed light on chemical health and safety knowledge. The Wildfire Conservancy survey includes information on demographic data chemical risk knowledge, respiratory related questions, and health motivators

Objective 2

The second objective was to assess the gaps between firefighter knowledge and practices and leadership perceptions of firefighter knowledge and practices using a wildfire survey dataset collected by The Wildfire Conservancy as well as key informant interview data. Wildland firefighting is a highly structured, paramilitary-style occupation that emphasizes hierarchy, discipline, and chain of command. The field heavily relies on the observational learning, where new and less experienced firefighters often learn critical skills, safety protocols, and operational strategies by observing and mimicking the actions of those in leadership positions. Assessing potential gaps in knowledge and practices between both groups can pinpoint critical areas where inconsistencies may exist.

Objective 3

The third objective was to gather data on firefighter attitudes and barriers towards respiratory equipment as well as health motivators using a wildfire survey dataset collected by The Wildfire Conservancy as well as key informant interview data. Understanding firefighter attitudes and barriers towards respiratory equipment along with health motivation is critical for developing and implementing effective respiratory protection procedures. By identifying specific attitudes such as concern, perceived discomfort, or doubts related to the necessity of respiratory protection, agencies can tailor educational initiatives that directly address these concerns.

Research Questions and Hypothesis

The dissertation research questions will be divided into two parts: A) Part 1- Quantitative research using a wildfire survey dataset collected by The Wildfire Conservancy and B) Part 2 – Qualitative research using original data collected from Key Informant interviews that were conducted with wildland firefighters. Part 1 and Part 2 will contain separate research questions and hypothesis.

Part 1- Quantitative research – The Wildfire Conservancy Respiratory Survey Data

When assessing The Wildfire Conservancy Survey Data, there were 6 primary research questions.

RQ 1 : How familiar are firefighters with common chemical compounds found in wildfire smoke?

RQ 2 : Is there a significant difference in chemical compound knowledge between wildland leadership firefighters and wildland non-leadership firefighters?

H_0 : There is no significant difference in chemical compound knowledge between wildland leadership firefighters and wildland non-leadership firefighters.

Ha : There is a significant difference in chemical compound knowledge between wildland leadership firefighters and wildland non-leadership firefighters.

RQ 3 : Do wildland firefighters use any respiratory protection when responding to a wildland/ Wildland Urban Interface **(**WUI) fire incident?

RQ 4 : What are the primary reasons or concerns wildland firefighters have for not wanting to wear respiratory protection or hesitation in using a respiratory protection device while responding to a wildland/WUI fire incident?

RQ 5 : Are the primary reasons or concerns for not wanting to wear respiratory protection different between wildland leadership firefighters and wildland non-leadership firefighters?

H_0 : The primary reasons or concerns for not wanting to wear respiratory protection are not significantly different between wildland leadership firefighters and wildland non-leadership firefighters.

Ha : The primary reasons or concerns for not wanting to wear respiratory protection are significantly different between wildland leadership firefighters and wildland non-leadership firefighters.

RQ 6 : What are the most common health motivators for wanting to wear a respiratory protection device on a wildland/WUI incident?

Part 2- Qualitative research – Key Informant Interview Data

When assessing the key informant interview data, there were three primary research questions. First, *were there gaps in chemical risk knowledge / health and safety knowledge between wildland leadership (who are implementing respiratory procedures) and wildland non-leadership firefighters (who are expected to implement them)?* The question aimed to provide valuable insight into what divergences may exist between those commanding health and safety protocols and those applying them in the field. Understanding these gaps is essential because any misalignment in knowledge and understanding could lead to ineffective implementation, reduced compliance, and increased health risks for firefighters. A series of open-ended interview questions will provide insight from wildland non-leadership firefighters and wildland firefighter leadership to better understand chemical risk knowledge, health and safety knowledge, and other factors.

Second, *are there gaps in perception of respiratory equipment feasibility between wildland leadership (who are implementing respiratory procedures) and wildland non-leadership firefighters (who are expected to implement them)?* This research question aimed to explore whether differences in perception exist between those designing and enforcing respiratory protection measures and those directly affected by these policies on the front line. Understanding these perception gaps is crucial, as leaders may view equipment as practical and necessary, while firefighters might see it as cumbersome, uncomfortable, or impractical in real-world conditions. Identifying these differences can provide valuable insights into the challenges faced by firefighters, allowing for the development of more realistic, acceptable, and effective respiratory protection strategies that align with both the operational demands and safety requirements of the job. A series of open-ended interview questions provided insight from

wildland non-leadership firefighters and wildland firefighter leadership to better understand respiratory equipment feasibility and attitudes.

Third, *what are the primary perceived barriers that may interfere with implementation of future standard respiratory equipment among firefighters?* This question aimed to identify key obstacles, both perceived and actual, that could hinder the successful adoption of new respiratory protection standards around wildland firefighters. By understanding these barriers from the perspective of firefighters, the research seeks to inform the development of more practical, acceptable, and effective respiratory protective solutions unique to the wildland firefighter working environment. A series of open-ended interview questions provided insight from wildland non-leadership firefighters and wildland firefighter leadership to better understand barriers that surround respiratory protection and firefighter culture.

Operational Definitions

Behavioral Capability: Defined as the individual's knowledge and skills required to perform a behavior which are acquired through both direct instruction and observation.

Chemical Risk Knowledge: Defined as the understanding of specific chemical hazards associated with smoke exposure, assessed through a knowledge test scoring system.

Expectations: Defined as the anticipated consequences of actions as significant motivators for behavior change, including both physical outcomes (health improvements) and social outcomes (peer approval).

Observational Learning: Defined as learning through observing the actions of others, particularly those in influential or leadership positions, and the consequences of those actions.

Perceived Barriers: Defined as the obstacles that firefighters believe hinder the use of respiratory protection, identified through survey responses to specific questions about comfort, accessibility, and impact on job performance.

Personal Protective Equipment (PPE): PPE for firefighters refers to the specialized gear and equipment designed to protect firefighters from various hazards encountered during firefighting. This includes protection against extreme heat and physical impacts. Key components of wildland firefighter PPE include: Nomex turnout gear, helmet, gloves, boots, goggles, fire shelter, face/neck shroud, and a light weight pack to carry essentials such as water.

Reciprocal Determinism: Defined as the continuous reciprocal interaction between individual cognitive factors (beliefs, expectations, attitudes), environmental factors (social norms, observational learning), and behavior.

Reinforcements: Defined as behavioral responses that are influenced by the presence of rewards or punishments.

Respiratory Protection Use: Operationally defined as the frequency with which firefighters wear respirators during wildland firefighting activities, measured using self-reported data.

Self-Efficacy: Defined as a core construct of SCT, self-efficacy refers to an individual's belief in their capacity to perform a specific behavior or task successfully.

Social Cognitive Theory (SCT): SCT is defined as a framework for understanding, predicting, and changing human behavior, which emphasizes the dynamic interaction between personal factors, environmental influences, and behavior. SCT postulates that behavior is learned through

observation, imitation, and modeling and that cognitive processes such as self-efficacy, outcome expectations, and goal-setting play critical roles in the adoption and maintenance of behavior. SCT has six key elements: reciprocal determinism, observational learning, self-efficacy, expectations, behavioral capability, and reinforcements.

Wildland Firefighter: A wildland firefighter is defined as a professional or volunteer individual who is actively engaged in the suppression, management, and control of wildland fires, including those occurring in forests, grasslands, or in wildland urban interfaces. This role specifically excludes urban firefighters who respond primarily to structural fires.

Wildland Firefighter Leadership: Defined as a wildland firefighter between the ages of 28 years and 65 years of age, who had a rank of captain or above for at least one year (or one season) and over 10 years of experience.

Wildland Non-Leadership Firefighter Defined as a wildland firefighter between the ages of 18 years and 65 years of age, who had been a wildland firefighter for at least one year (or one season) and held a rank lower than captain.

Wildland Urban Interface (WUI): The **WUI** is defined as the geographical area where human-built environments, such as homes, businesses, and other structures, directly intermingle with or are adjacent to wildland vegetation, including forests, grasslands, or other undeveloped natural landscapes.

CHAPTER 2: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Literature Review

Social Cognitive Theory (SCT) stresses upon the importance of the social environment and its connection to personal motivation for change, learning new behaviors/skills, and self-regulation and management of behaviors (Schunk & DiBenedetto, 2020). Motivation for changing behavior is an important aspect of SCT, as it emphasizes that motivational processes influence choices, personal efforts, determination, and success. These motivational processes include self-efficacy, social comparisons, personal beliefs, expected outcomes or rewards, and attributions (Schunk & DiBenedetto, 2020). These basic principles have been used to guide other popular models used in research on social cognitive influences of health behaviors as they are considered essential determinants of an individual's choices or actions (Maddux, 1993).

SCT is a particularly suitable for firefighters due to its focus on behavior learned through observation, imitation, and modeling. These are critical aspects involved in firefighter training, learning, and performance. Firefighters often learn important skills by observing experienced colleagues and leadership in the field (Brazil, 2019; Tracey, 2014). Experienced firefighters serve as role models for newer recruits. This allows rookie firefighters to observe veteran firefighters and learn their approach to various fire scenarios, use of equipment, and execution of safety protocols (Curral et al., 2023). For this reason, firefighters often mimic the actions of their superiors. Firefighting is an inherently team-oriented profession where social interactions are critical to safety and acquisition of knowledge. Key elements of firefighter learning include observational learning, modeling behavior, self-efficacy, and cognitive processes (Johnson, 2023; Sharifi et al., 2021) Thus, understanding firefighter health and safety knowledge,

firefighter leadership health and safety knowledge, current safety practices, and perceived barriers towards health and safety procedures are essential for anticipating challenges in adopting new safety measures.

When observing the relationship between SCT and firefighter health and safety, research indicated that there are several key factors that influence learning and behavior in this hazardous occupation. Firstly, the knowledge and expertise of leadership is paramount, as firefighters often rely on their superiors for critical guidance and education (Burke et al., 2006). The hierarchical transfer of knowledge ensures that safety protocols and practices are adopted from the top downward. Firefighters imitate the actions of their experienced colleagues in various aspects and influence perception, practice, and behavior (Wood & Bandura, 1989). This observational learning and modeled behavior ensure that proper techniques and appropriate responses are ingrained through real work practice. Consequently, this also plays a role in influencing risk-taking behaviors as well as health and safety if leadership is not well equipped with knowledge or unaware of safety protocols.

SCT has been used to assess many different aspects related to firefighter health and safety including mental health, various behavioral interventions, exercise regiments, high risk behaviors, and resilience (Schunk & DiBenedetto, 2020). Currently available SCT research in this field primarily addresses areas like stress management, physical health, safety behaviors, and implementation of behavioral safety protocols. Studies have explored how self-efficacy influences firefighters' ability to cope with occupational stress (Makara-Studzińska et al., 2019). It's a well-acknowledged fact that firefighters, like many other first responders, face significant mental health challenges due to the nature of their work (Sawhney et al., 2018). The occupational stress they experience can have profound effects on their mental well-being. The occupational

stress experienced by firefighters is influenced by many factors including traumatic experiences in the field, high-pressure, unpredictable work environments, fatigue from long shifts, physical demand of the job, and stigma surrounding mental health (Isaac & Buchanan, 2021). Much research has focused on firefighter stress and mental health in an attempt to assess various aspects of occupational stress, peer support, and attitudes toward mental health (Isaac & Buchanan, 2021). SCT has been used to design peer support and mentorship programs that emphasize observational learning and social support in an attempt to improve mental health outcomes among firefighter personnel (Cheskin et al., 2014).

SCT studies have identified that these stressors can change firefighter perception of health risk. Understanding perceived risk is indeed crucial in comprehending the barriers related to SCT among firefighters because it influences individual behaviors, outcome expectations, and observational learning. One novel study identified that firefighters understand risk perception via a lens of "delayed consequences", often considering risks that may arise in the long term (Martinez-Fiestas et al., 2020). Other aspects that were valuable in assessing risk were personal vulnerability and the catastrophic potential of the risk. These findings offer valuable insights into the complex nature of risk perception among firefighters and provides valuable insight as to what firefighters perceive as dangerous, creating opportunities to improve health and safety and risk communication. Additionally, the study revealed that salaried firefighters had greater risk perception than volunteer firefighters, implying that there may be professional experience or training disparities. This further characterizes the unique knowledge barriers among firefighters. In another novel, barriers in decontamination practices were analyzed using one-on-one key informant interviews (Stricker, 2023). Key barriers were determined to be modeled leadership behaviors, peer support, and firefighter culture. In this study, it was determined that an education

and training program with focused attention on leadership positions and peer-to-peer support should be implemented.

Studies have examined health promotion programs and exercise interventions in an attempt to improve physical health and fitness of firefighters. Research has applied SCT principles to develop health promotion programs aimed at improving firefighters' physical fitness and reducing injury risks. The PHLAME (Promoting Healthy Lifestyles: Alternative Models' Effects) Firefighter Study found that peer-based learning was significantly more effective than external expert-led interventions. Firefighters demonstrated higher engagement and success when learning from colleagues who had direct experience with the challenges they face on the job. This peer-led approach allows for more relatable, context-specific learning, enhancing the transfer of practical skills and knowledge compared to instruction from external experts who may lack direct firefighting experience (Elliot et al., 2007). These programs focused on setting realistic health goals, self-assessment, and social encouragement to enhance motivation and adherence to regimens (Poston et al., 2013). SCT-based interventions have been shown to improve exercise adherence among firefighters by enhancing self-efficacy, creating supportive environments, and providing role models (Long et al., 2014; Rengert, 2011).

SCT research has also been used to assess safety behaviors and implementation of safety protocols by focusing on training, education, behavioral interventions, organizational culture, and modeling. Training programs have been designed to improve firefighter safety behaviors by incorporating observational learning, feedback, and reinforcement; with the goal to increase self-efficacy and outcome expectancies related to safety practices (McLennan et al., 2017; Smith et al., 2016). SCT-based behavioral interventions targeting specific safety behaviors have been effective at promoting safer practices among firefighters (Smith et al., 2020). The research

highlights the importance of a supportive organizational culture in promoting safety in the workplace. SCT has been used to assess how environmental factors such as leadership and organizational policy, influence individual firefighter behavior and safety outcomes (Smith et al., 2016). Modeling and reinforcement, essential SCT principles, were observed to be crucial in the adoption and adherence of safety protocols (Freaney, 2011). Leaders and experienced firefighters serve as role models in the workplace and encourage compliance with protocols and safety measures (Freaney, 2011).

Existing research related to barriers in respiratory equipment implementation among wildland firefighter is limited. Most research has focused on immediate health risk and physiological impact of smoke inhalation rather than systemic barriers in implementation of respiratory protective equipment. Studies have documented the significant respiratory health risks experienced by firefighters exposed to wildfire smoke, such as decreased lung function, chronic respiratory conditions, and other respiratory symptoms (Held et al., 2024). Very few studies have focused on behavioral and cultural barriers related to respiratory protective equipment. Research available suggests that there is reluctance among firefighters to use respiratory equipment due to discomfort, interference with communication, and perception that the equipment impedes physical performance (Paulo et al., 2023; Ramos & Minghelli, 2022; Santos et al., 2022). Another barrier that has been considered are the operational challenges with the addition of new respiratory equipment. Some of the concerns that have been identified as perceived barriers include the additional weight of respiratory equipment, hindering mobility, and potential for increased strain during fire suppression (Barker et al., 2012; Wang et al., 2021). While there is foundational understanding of barriers to respiratory equipment among firefighters, the area of wildland firefighters remains largely unexplored. The research

specifically relating to western wildland firefighters is even less researched. There is a significant need for more targeted studies that explore these barriers to develop more practical solutions that will increase perception and adoption of respiratory protection in the field.

Failures in the adoption of respiratory protection among wildland firefighters are influenced by several unique challenges associated with the environmental conditions and physical demands of firefighting. Environmental and operational challenges have posed a significant barrier in the implementation of feasible respiratory protection strategies. Wildland firefighters often work in harsh, unpredictable terrain with high ambient temperatures and rugged landscapes for long work shifts. These conditions make using respiratory protections uncomfortable and difficult (Navarro, 2020). Respiratory protection can be bulky and restrict movement which provided concern due to the dynamic and physical demands of firefighting duties. The high physical demand of firefighting and high level of physical exertion caused by occupational tasks makes it difficult to use equipment that may increase breathing resistance and motivate firefighters to forgo usage (Beason et al., 1996; Reinhardt, 2000; Yost et al., 2022). It is also important to consider that there has been a lack of appropriate equipment designed to meet the specific needs of WUI firefighting. Currently, available gear may not be suitable for the variety of remote, environmental conditions firefighters endure (NIOSH, 2022). Available training and awareness of respiratory protection as a means of mitigation of health risks has also been seen as a barrier in respiratory procedure adoption. Firefighters may not receive adequate training on the importance of respiratory protection in reducing health risks (Grant, 2010). There seems to be a lack of awareness about the health risks associated with prolonged smoke inhalation and exposure that thus there may be a lack of clear policies mandating the use of respiratory protection or inadequate enforcement of existing policies (Koopmans et al., 2022).

Research highlights that many firefighters are not fully aware of the long-term health effects of smoke exposure, including risks of cancer (Adetona et al., 2016). These gaps in knowledge may be a significant barrier in consistent use of respiratory protection, thus increasing health risks among firefighters.

Current available research highlights several key areas that require further investigation to improve health and safety of firefighters from respiratory hazards. There are limited longitudinal studies available that examine health impact of smoke exposure (Navarro et al., 2019). This includes a lack of long-term studies that track the impact of smoke exposure over the course of a firefighter's career. There is also limited research that observes specificity of equipment that is suitable for wildland firefighting (Islam & Wu, 2020). There is a need for research to be conducted on efficacy and design of respiratory equipment that is specific for the unique task of wildland firefighting. Additionally, there is a significant gap in research concerning how firefighters perceive and utilize respiratory protection while on duty. This study aimed to fill a critical gap in current literature; thoroughly examining the cognitive, behavioral, environmental factors that influence use of respiratory protection among wildland firefighters. It intended to explore how these factors shape firefighters' attitudes, beliefs, and practices regarding respiratory PPE as well as their perceptions of health risks associated with exposure to wildfire smoke. By identifying and analyzing perceived barriers to the consistent implementation of respiratory PPE, such as discomfort, lack of awareness, or perceived feasibility, the study endeavored to uncover the underlying reasons why some firefighters may not fully adhere to safety protocols. Additionally, this research investigated how firefighters perceive health risks and overall well-being. The findings from this study are expected to provide valuable insights that could inform the development of more effective training programs, policy interventions, and

safety protocols designed to improve the health and safety of wildland firefighters in the face of increasing wildfire risks.

Theoretical Framework

Social Cognitive Theory (SCT) is the framework that was used to guide this research. Social Cognitive Theory was developed by Albert Bandura in 1960 (Bandura, 1999). SCT is a causative model of triadic reciprocal causation where personal factors such as knowledge, biological experiences, existing behavioral patterns, and environmental influences interact to affect the individual's choices (Bandura, 1999). This theory proposes that human behavior is determined by reciprocal actions between the behavioral factors, cognitive factors, and environmental factors. It posits that there are six primary constructs that determine human behavior: reciprocal determinism, behavioral capability, observational learning, reinforcements, expectations, and self-efficacy (**Figure 2.1**).

Reciprocal Determinism refers to the interaction between the person, the environment, and behavior. In the context of wildland firefighters, reciprocal determinism explains how these three elements interact to shape their behaviors, safety practices, and overall performance on the job. Behavioral capability refers to an individual's knowledge and skills necessary to perform a specific behavior. In the context of wildland firefighters, behavioral capability is crucial because it determines how well firefighters can perform their duties, including implementing safety protocol and using protective equipment like respiratory gear effectively. Observational learning is a key concept referring to learning behaviors by watching others, particularly those in influential roles, such as leaders or experienced peers. For wildland firefighters, observational learning is a critical way to acquire skills, understand protocols, and adapt behaviors in a dynamic work environment. Reinforcements are responses to behavior that influence whether or

not they will be repeated by the individual. Reinforcements take many forms in wildland firefighting (such as praise, criticism, or being mocked) and can play a significant role in shaping behavior through motivation and learning. Expectations refer to the anticipated outcomes of a behavior, influencing whether an individual is likely to engage in that behavior. Expectations can be based on past experiences, observation of others, or shared ideas. Expectations play a critical role in shaping wildland firefighter behaviors related to safety because they influence the potential benefits or draw backs of their actions. Self-efficacy refers to an individual's belief n their ability to successfully perform a specific task or behaviors. This concept directly impacts motivation, decision-making, and persistence in challenging situations. In the context of wildland firefighters, self-efficacy plays a role in influencing how firefighters approach their duties, manage risks, and adhere to safety protocols. Key informant interview questions in Part 2 were guided by the SCT framework and investigated these six core factors to provide greater insight into the cognitive, behavioral, and environmental constructs that surrounded respiratory protection and chemical smoke exposure risk among wildland firefighters. Exploring these key areas can help to enhance our understanding and help explain wildland firefighter behavior by identifying critical areas of SCT.

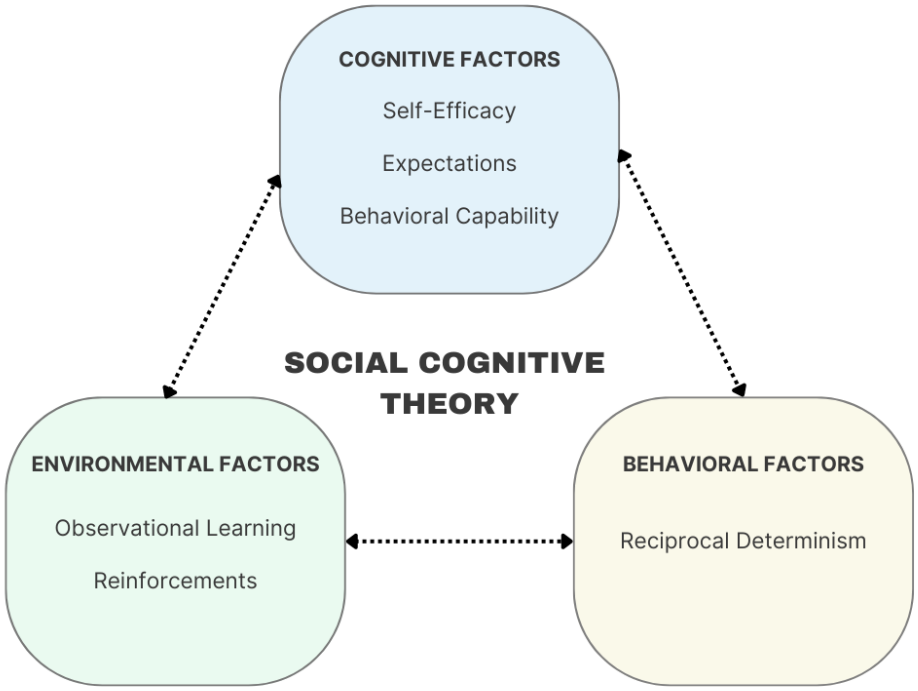

Figure 2.1. Social Cognitive Theory constructs.

Note. The Figure illustrates the framework of this study, modeled after Bandura's Social Cognitive Theory (Bandura, 1999).

CHAPTER 3: METHODS

Part 1- Quantitative Research Methods- The Wildfire Conservancy Respiratory Protection Survey Data

During the Part 1 of this research, a survey was conducted in consultation with the Wildfire Conservancy in 2023 to determine the types of respiratory protection being used by firefighters, required by agency/department, or recommended by agency/department (if any) in the field while on duty. As a part of my practicum as a doctoral student at ECU, I contributed to the development of this survey. The survey was also designed to gather demographic information such as rank, age, gender, years of experience, chemical health and safety knowledge and health motivators. The target population of this survey were wildland firefighters within the United States who had served at least one season and were between the ages of 18 and 65 years of age. Traditionally, the term 'fire season' in the United States has referred to the period when the risk of wildfires is at its peak, and firefighting resources are fully mobilized to manage and suppress fires. In many regions, this period typically spans from May to December. However, in California and other West Coast states, the concept of a 'fire season' is evolving due to the effects of climate change, which has led to hotter, drier conditions and an increase in the frequency and scale of wildfires throughout the year. As a result, wildfires are no longer confined to a specific season; instead, we are now experiencing a 'fire year,' where large-scale fires can occur at any time. Despite this shift, many seasonal job titles and firefighting roles have yet to adapt, reflecting an outdated perception of wildfire risks and management. The survey was created

using Survey Monkey, an online survey platform, and sent out through The Wildfire Conservancy partners via email to ensure maximum reach of our target population. We intended to obtain survey responses from 500 wildland firefighters. Participants were informed about the purpose of the survey and consent was obtained. Participation was voluntary and respondents could withdraw at any time. The survey was anonymous, ensuring individual responses could not be tracked back to participants. This study was conducted under the approval of the UMC Institutional Review Board (IRB) under protocol number UMC-IRB 23-001854. For further details on the IRB approval and related documents, please refer to Appendix A for the IRB approval letter and Appendix B for UMC-IRB Amendment Approval.

The survey consisted of thirty questions that included a mix of multiple choice, Likert scale, and open-ended questions to gather both qualitative and quantitative data (Appendix F). The questions were designed to be clear, concise, and unbiased to ensure validity and reliability of responses. These data were reviewed for completeness and consistency. Incomplete responses, outliers, and participants who did not meet our target population criteria were removed from the dataset.

Descriptive statistics were used to summarize the data. Data analysis was conducted using R-Studio software, a powerful statistical computing environment widely used for data manipulation, statistical analysis, and visualization (Posit, 2024). R was used to conduct descriptive statistics, Analysis of Variance (ANOVA), and multinomial logistic regression to analyze relationships between variables, such as familiarity with chemicals, and perceived concern levels. Post-hoc Tukey tests were conducted on interactions that showed significant differences. These analyses were performed to compare key differences between leadership

firefighters with 15 or more years of experience and non-leadership firefighters with less than five years of experience. The analysis involved data cleaning, model fitting, and evaluation of statistical significance (p-value < 0.05), leveraging R's extensive libraries and functions to ensure robust and accurate results.

Quantitative Measures and Data Analysis

In the following section, I have detailed the measures and analytical methods applied to my specific research questions.

RQ 1 : How familiar are firefighters with common chemical compounds found in wildfire smoke?

Context: The question connects to Reciprocal Determinism in SCT by examining the cognitive factor of chemical risk knowledge, which directly influences firefighter behavior and safety practices. A firefighter's familiarity with chemical compounds (cognitive factor) impacts their decision-making and use of protective equipment (behavioral factor), which then shapes their experiences and safety outcomes in the firefighting environment (environmental factor).

Measurement: Awareness of nine different chemical compounds commonly found in wildfire smoke was assessed using a Likert scale ranging from 0 (never heard of it) to 3 (know a fair amount about it).

Analysis: Descriptive analysis was conducted to summarize the survey responses by computing the frequencies and percentages of each variable.

RQ 2 : Is there a significant difference in chemical compound knowledge between wildland leadership firefighters and wildland non-leadership firefighters?

Context: The question connects to Reciprocal Determinism in SCT by examining knowledge (cognitive factor) varies between leadership and non-leadership roles and influences safety practices. This dynamic interaction highlights how cognitive differences between roles can influence overall team behavior (behavioral factor) and safety culture (environmental factor).

Measurement: Awareness of nine different chemical compounds commonly found in wildfire smoke was assessed using a Likert scale ranging from 0 (never heard of it) to 4 (know it very well). The survey responses were collected from two subpopulations: firefighter leadership and non-leadership firefighters.

Analysis: Familiarity variable was used as a response with chemical and leadership used as predictors in a multinomial regression. The multinomial regression was then fitted, and an ANOVA table was produced. In this study, p-values less than 0.05 were considered statistically significant.

RQ 3 : Do wildland firefighters use any respiratory protection when responding to a wildland/ Wildland Urban Interface **(**WUI) fire incident?

Context: This question connects to Behavioral Capability in SCT by exploring whether wildland firefighters have access to and the ability to use respiratory protective equipment. Lack of available equipment directly impacts use (behavioral factors).

Measurement: Respiratory protection usage was assessed through a survey question that asked firefighters whether they use respiratory protection during wildland/WUI fire incidents, with a binary response option (Yes/No).

Analysis: Descriptive statistics were used to analyze the responses, calculating frequencies and percentages to determine the proportion of firefighters, who reported using respiratory protection.

RQ 4 : What are the primary reasons or concerns wildland firefighters have for not wanting to wear respiratory protection or hesitation in using a respiratory protection device while responding to a wildland/WUI fire incident?

Context: This question connects to Self-Efficacy in SCT because it explores the internal beliefs that influence behavior. Understanding concerns or hesitations (cognitive factors) in using respiratory equipment can reveal barriers that may interfere with confidence needed to prioritize protective behaviors (behavioral factors).

Measurement: Nine common barriers and concerns identified from previous studies were listed, and firefighters were asked to rank these barriers using a Likert scale from 0 (not concerning at all) to 3 (most concerning).

Analysis: The responses were analyzed using descriptive statistics to determine the frequency and distribution of rankings for each barrier.

RQ 5 : Are the primary reasons or concerns for not wanting to wear respiratory protection different between wildland leadership firefighters and wildland non-leadership firefighters?

Context: The question connects to self-efficacy in SCT by examining how confidence and belief levels may differ between leadership and other roles in firefighting. Leaders' self-efficacy in using protective gear often sets behavioral standards, influencing others who rely on observational learning.

Measurement: Nine common barriers and concerns identified from previous studies were listed, and firefighters were asked to rank these barriers using a Likert scale from 0 (not concerning at all) to 3 (most concerning). Responses were analyzed by comparing leadership and non-leadership firefighter groups.

Analysis: A multinominal logistical regression was performed to test whether the reasons differ between leadership levels. The multinomial logistic regression was fitted, and an ANOVA table was produced. To test for differences in the overall distribution of responses between the different leadership levels, a post-hoc Tukey test was performed in RStudio.

RQ 6 : What are the most common health motivators for wanting to wear a respiratory protection device on a wildland/WUI incident?

Context: This question relates expectations and self-efficacy of SCT by examining what firefighters believe will be the health benefits of wearing respiratory protection (cognitive factors). Understanding these motivators highlights what drives their behavior, reenforcing positive safety practices (behavioral factors).

Measurement: Health motivators were evaluated using a survey question that provided multiple options allowing firefighters to rank their primary motivators. Respondents

ranked each motivator using a Likert scale ranging from 1 (most important) to 3 (least important). Frequency distribution was used to represent respondent answers.

Analysis: The responses were analyzed using descriptive statistics to determine the frequency and distribution of rankings for each motivator.

Part 2- Qualitative Research Methods- Key Informant Interview Data

In the qualitative portion of the study, key informant interviews were conducted to gain valuable insight on gaps in chemical risk knowledge, health and safety knowledge, and barriers regarding use of respiratory equipment. The case study tradition was chosen for this research as it provides a robust framework for examining the specific context of wildland firefighters and their understanding of occupational health risks. By focusing on both leadership and non-leadership firefighters, the case study approach allows for an in-depth exploration of knowledge gaps and perceived barriers within a real-world setting. This approach aligns well with SCT, which emphasizes the interaction between personal factors, behaviors, and the environmental influences. Through the case study tradition, the research is able to closely investigate these SCT components as they manifest in the wildland firefighting context. The detailed, contextual insights afforded by the case study method make it particularly effective for uncovering the complex, interrelated factors that influence health-related behaviors and perceptions among different firefighter groups. This tradition was selected to provide a comprehensive understanding of how leadership roles and environmental contexts shape wildland firefighters' responses to occupation health risks, ultimately contributing to the theoretical framework of SCT by illustrating how knowledge and perceived barriers are socially and contextually constructed.

Key informant interviews were conducted to capture insight from two firefighter populations: A) leadership firefighters and B) non-leadership firefighters. Self-selection sampling was employed to gather data from A) leadership firefighters and B) non-leadership firefighters. This method allowed individuals to self-select and volunteer to participate in the study by responding to an open invitation that was sent via email. Email invitations were distributed through Wildfire Conservancy partners, fire department networks, professional organization contacts, and by contacting fire departments directly. A clear and concise email invitation to participate was developed. The email invitation included information about the study's purpose, criteria for participation, the nature of participation, and assurances of confidentiality and anonymity. Participant criteria for leadership firefighters (A) were wildland firefighters between the ages of 18 years and 65 years of age, who had a rank of captain or above for at least one year (or one season) and over 10 years of experience. Participant criteria for non-leadership firefighters (B) were firefighters who were between the ages of 18 years and 65 years of age, who had been a wildland firefighter for at least one year (or one season) and held a rank lower than captain.

The invitation also provided a link to the online sign-up form. Volunteers were then screened to ensure they met criteria for participation and emailed to arrange the key informant interview. Interviews were conducted via zoom or via phone call. Interviews were then transcribed and de-identified. Separate interview guides were developed for A) leadership firefighters and B) non-leadership firefighters. Interview questions were developed using SCT components and data from Part 1 of the study. SCT components included: reciprocal determinism, behavioral capability, observational learning, reinforcements, expectations, and

self-efficacy. Definitions of these components and specific questions corresponding to each component can be found in **Table 3.1**.

Qualitative Measures and Data Analysis

A mixed-methods approach, combining quantitative and qualitative (qual/quant) analyses, was employed to explore key themes from the key informant interviews. First, thematic analysis was conducted to identify common themes related to barriers and perceptions of respiratory protection. These themes were then quantified by coding the frequency of responses, enabling comparisons between leadership and non-leadership firefighters. To further examine the relationships between leadership and non-leadership firefighters a modified Qualitative Comparative Analysis (QCA) was applied. This approach allowed for the identification of patterns and causal relationships among the key components between the two groups. Comparable questions were asked to both non-leadership firefighters and leadership firefighters as seen in **Table 3.1**.Themes were identified and coded based on the key components of SCT model, which guided the development of the key informant interview questions. A side-by-side comparison was conducted for each group by question to assess gaps and barriers. Interpretations of the findings were assessed using SCT framework. Key informant interview data were analyzed and coded using Dedoose software.

The use of qualitative and quantitative (qual/quant) analyses in mixed-methods research is well-established in fields that explore complex human behaviors and organizational dynamics, particularly in occupational health and safety. In the context of firefighter health and safety, this approach is particularly valuable because it allows for an in-depth understanding of individual perceptions (through qualitative analysis), while simultaneously providing measurable data on trends and differences across groups (through qualitative analysis). The tradition of using QCA

in health and safety research further justifies its application here. Originally developed by Charles Ragin (1987), QCA is particularly effective in identifying combinations of factors that contribute to specific outcomes, such as the adoption of respiratory protection or health risk perceptions among firefighters. QCA's ability to systematically compare multiple qualitative conditions makes it highly suitable for studies where variables such as leadership status, chemical knowledge, and perceived barriers interact to influence behavior and safety outcomes. This method has been successfully applied in public health research to examine how various combinations of factors impact workplace safety and has proven especially useful in studies with small-to-medium sample sizes (Ragin, 2014; Rihoux & Ragin, 2009).

Chapter 4: Results

Part 1- The Wildfire Conservancy Respiratory Protection Survey

A total of 766 participated in The Wildfire Conservancy Respiratory Protection Survey. The survey was distributed to approximately 25,000 prospective participants, resulting in a participation rate of approximately 3.1%. As shown in **Table 4.1,** a total of 408 participants reported being in non-leadership firefighter position (53.5%), while 228 participants reported being in middle leadership positions (16.6%), and 127 participants reported being in leadership positions (29.9%). Participants were predominantly male (93.7%) and between the ages of 25 and 54 (83.8%) (**Table 4.1)**. Most participants were from state agencies (76.2%) followed by the United States Forest Service (11.11%), and local/municipal agencies (7.1%) (**Table 4.2)**. As shown in **Table 4.3**, an analysis of participant occupational geographics revealed that the majority of survey participants were California firefighters (85.5%). Other locations, such as Arizona (2.94%), Colorado (1.34%), and Washington (1.07%), contributed smaller percentages, with many states and international regions represented by less than 1% of the total participants.

Table 4.1. Participant gender, position, and age distribution.

Table 4.2. Wildland firefighter agency distribution.

Table 4.3. Distribution of participants geographically.

Chemical Compounds Knowledge

The study assessed firefighters' familiarity with common chemical compounds found in wildfire smoke and results are summarized in **Table 4.4** and **Figure 4.1**. Varying levels of awareness and knowledge among firefighters regarding common chemical compounds found in

wildfire smoke were observed. The Likert scale used in this study categorizes responses as follows: 0 = "Never heard of it," 1 = "Heard of it," 2 = "Know a little about it," 3 = "Know a fair amount about it", and 4 = "Know it very well".

Carbon Monoxide (CO) was the most familiar compound with 77.7% of respondents indicating that they know it fairly well or very well (scores of "3" and "4"). Particulate Matter (PM) also showed a relatively high level of familiarity with 43.3% of respondents indicating that they know it fairly well or very well (scores of "3" and "4"). Hydrogen Cyanide (HCN) had a moderate level of familiarity among firefighters, with 36% reporting "3" or above and only 5.9% reporting "0" (never heard of them). Polycyclic Aromatic Hydrocarbons (PAHs) and Per- and polyfluoroalkyl Substances (PFAS/PFOA), were among the least familiar compounds, with 29.5% and 20.9% of respondents respectively, indicating they had never heard of them ("0"rating). Only a small percentage, 4.1% for PAHs and 7.9% for PFAS/PFOA, reported knowing these chemicals very well ("4" rating). Similarly, participants indicated low familiarity with Volatile Organic Compounds (VOCs), Sulfur Oxides (SOX), and Benzene, with most respondents reporting familiarity of "1" or lower (49.5%, 44.9%, and 46.8% respectively).

Table 4.4. Firefighters' familiarity with chemical compounds in wildfire smoke.

Figure 4.1. Firefighters' familiarity with chemical compounds

Chemical Compound Knowledge Comparison: Leadership vs Non-Leadership Firefighters

Whether the chemical compound knowledge differed between leadership and non-leadership firefighters was determined using type II ANOVA , which provided insights into whether the combined effect of chemical type and leadership status significantly impacts familiarity beyond their individual effects. The results are summarized in **Table 4.5**, which

indicated that there was no significant difference in chemical knowledge between the leadership levels ($p = 0.646$). The absence of a significant difference supports the retention of the null hypothesis, suggesting that chemical compound knowledge does not differ significantly between the leadership and non-leadership wildland firefighters.

Table 4.5. ANOVA Table assessing interaction between chemicals and leadership levels

Current Use of Respiratory Protection Among Wildland Firefighters

Table 4.6 presents the responses from wildland firefighters and their current use of respiratory protection during wildfire incidents. A large majority of respondents (85.9%) reported that they do not use any form of respiratory protection during a wildfire incident. Only 12.6% indicated that they currently use respiratory protection on incident, while 1.4% of respondents were unsure about their use. Firefighters were then asked to report what types of respiratory protection they were using in a "select all that apply" format from a set list of provided options (**Table 4.6**). The most commonly used type of respiratory protection were cloth masks (67.8%). N95 respirators were used by 15.8% of firefighters while 13.2% reported using self-contained breathing apparatus (SCBA). A small proportion of respondents (3%) used Air-Purifying Respiratory (APR) and only 0.3% reported using Powered Air-Purifying Respirators (PAPR), which are typically more advanced forms of respiratory protection. For the purpose of the study APRs were categorized separately from N95 respirators due to a key structural difference: N95 respirators lack a rubber face seal that ensures a tighter, more secure fit. Unlike APRs, which feature a rubber or silicone facepiece designed to form a seal around the user's nose and mouth, N95 respirators rely on a looser, more flexible fit, which may not provide the same level of protection against airborne particulates in wildfire smoke.

Table 4.6. Current usage and types of respiratory protective equipment among wildland firefighters

Common Concerns Preventing the Use of Respiratory Protection Among Wildland Firefighters

Table 4.7 and **Figure 4.2** summarize the primary concerns wildland firefighter have regarding the use of respiratory protection during wildland or WUI incidents. The concerns are categorized in four levels "0" being not concerning at all, "1" being least concerning, "2" being moderately concerning, and "3" being most concerning. Impaired breathing was identified as the most significant concern with 64.2% of respondents indicating it as the most concerning issue or level "3". Impaired communication was also a prominent concern, with 38.9% of respondents marking level "3" and 41.2% indicating it was a level "2" concern. Comfort and Fit were noted as high ranking with 39.2% reporting it as level "3" and 43.2% reporting it as level "2" concern. Impaired vision was reported as a level "3" concern by 29.3% of respondents and level "2" by 43.2% of respondents. Size and weight of equipment were reported as a level "3" concern for 25.1% or respondents and level "2" by 37.4% of respondents. Interference with existing gear was reported as a level "3" concern for 17.3% of respondents and level "2" for 37.2% of respondents. Simplicity of use was a level "3" concern for 13% of respondents and level "2" concern for 28.4% of respondents. Appearance and Personal Beliefs were the least concerning factors among respondents with a significant majority 66.9% and 67.4% respectively considering these a level "0" concern.

Table 4.7. Common Concerns Preventing the Use of Respiratory Protection Among Wildland Firefighters

Figure 4.2. Common Concerns Preventing the Use of Respiratory Protection Among Wildland Firefighters

Common Concern Comparison: Leadership vs Non-Leadership Firefighters

A comparison was conducted to see if concerns were different between leadership levels. A type II ANOVA table was produced (**Table 4.8**) and provided insight into whether the common concerns were affected by leadership status. The interaction between common concerns and leadership was statistically significant (p=0.002). Therefore, the null hypothesis was rejected, suggesting that there were differences in common concerns surrounding respiratory protection between leadership and non-leadership wildland firefighters. A post -hoc Tukey test was conducted to determine distribution of responses between the different leadership levels (**Table 4.9**) and assess differences. The t-ratio in this analysis represents the standardized difference between leadership and non-leadership groups mean responses across various concerns. A positive t-ratio indicated that leadership respondents rated the concern higher than the non-leadership respondents, while a negative t-ratio indicates that non-leadership respondents rated the concern higher.

Significant differences were found at several concern levels for Size and Weight. At concern level "0" (Not concerning at all), non-leadership showed significantly lower concern compared to leadership (t=-3.00, p=0.004). Significant differences were also observed at concern level "2" (moderately concerning)(t=2.83, p=0.007) and concern level 3 (most concerning) (t=2.63, p =0.0112) where leadership had higher levels of concern compared to non-leadership. However no significant difference was observed at concern level 1(least concerning) (p=0.120).

Significant differences for appearance were found at concern level “0” (t=2.69, p=0.010), concern level “1” (t=3.55, p=0.001), and concern level “3” (t=-2.97, p=0.004). However no significant difference was observed at concern level “2” (p=0.377).

When observing simplicity of use as a concern, a significant difference was found at concern level “0” between leadership and non-leadership groups (t=-2.64, p=0.011) Nonsignificant differences were observed at concern levels “1”,”2”, and “3” with p values of 0.706, 0.199, and 0.205, respectively. When observing comfort / fit, there was a significant difference between leadership and non-leadership groups (t=-2.03, p=0.047). No significant differences were found at concern levels “0”, “2”, and “3”, with p-values above 0.1. No significant differences were observed for concerns related to interference with gear, impaired vision, and personal beliefs.

Table 4.8. Common concern comparison between leadership levels ANOVA

Table 4.9. Common concern comparison between leadership levels Tukey Test

Health Motivators for Respiratory Protection Usage

Table 4.10 and **Figure 4.3** illustrate the distribution of responses for health motivators, categorized by levels of importance: “0” being not important, “1” being somewhat important, “2” being moderately important, and “3” being extremely important. Cancer risk reduction was the strongest motivating factor with 74.8% of respondents giving it an importance level of “3” and only 1.6% reported it as an importance level of “0”. Nearly 60% of participants reported that improving respiratory health was an importance level of “3” while only 4% reported an

importance level of “0”. Improved breathing was level “3” importance for 55.3% of respondents and 6.5% indicating it was an importance level of “0”.

Table 4.10. Health Motivators for Respiratory Protection Usage

Figure 4.3. Health Motivators for Respiratory Protection Usage

Part 2- Qualitative Key Informant Interviews

A total of 29 wildland firefighters were interviewed. Of the 29, two were excluded because they primarily focused on fire management in Australia, which differs significantly from Unites States fire agency policies and fire suppression methods. Interviewee demographic data was summarized in **Table 4.11**. Of the 27 participants, 5 were female (18.5%) and 22 of whom were male (81.5%). Of the participants, 20 self-identified as White (74.1%), 7 participants identified as Black Indigenous and People of Color (BIPOC) (25.9%). In this study, the term BIPOC is defined as referring to individuals who are black, indigenous, or belong to other communities of color, such as Latinos and Asians. This definition aligns with that used by the Department of Health and Human Services (HHS). The study involved interviews with two unique subpopulations; 11 participants were classified as holding "leadership firefighter" positions, and 16 participants were classified as being "non-leadership firefighters." Those in leadership positions had an average age of 52 years (with a median of 55) and an average of 25 years of experience (median 24 years). Non-leadership firefighters averaged 36 years of age (median 36) and 10 years of experience (median 9 years). The study included participants from various leadership and non-leadership fire service positions, including 10 Firefighters (37%), 4 Firefighter Paramedics (14.8%), 1 Assistant Captain (3.7%), 4 Captains (14.8%), 6 Battalion Chiefs (22.2%), and 2 Deputy Fire Chiefs (7.4%).

Among the firefighters interviewed, there were 11 individuals from federal agencies, including the USFS (37%) and the National Park Service (3.7%), 13 individuals from state and local agencies in California and Arizona, including San Bernardino County Fire (11.1%), Bonita Sunnyside Fire Protection (3.7%), the County of Los Angeles Fire Department (11.1%), Austin

Fire Department (3.7%), and Scottsdale Fire Department (11.7%). We had 1 participant from the Nature Conservancy (3.7%) a nonprofit organization, and 1 participant from Pala Fire (3.7%), a tribal fire department in California. In addition, we had 1 participant from British Columbia Wildfire Services (3.7%). While the participant was based outside of the United States, they were included in the study because British Columbia's wildfire conditions closely resemble those of the U.S. The West Coast of Canada shares similar challenges, firefighting, strategies, and firefighting cultural factors. British Columbia and the United States also frequently collaborate in wildfire management through the Northwest Compact, a mutual aid agreement involving U.S. states like Washington, Oregon, Idaho, Montana, and Alaska, along with Canadian provinces such as British Columbia and Alberta. This compact facilitates the efficient cross-border sharing of firefighting resources during wildfire emergencies.

The data was reviewed by two independent auditors with expertise in public health. One auditor specializes in firefighting research, particularly in the area of occupational health and safety, while the other brings a broader public health perspective. Both auditors independently assessed the data coding and thematic analysis, and their agreement on the coding and identified themes enhances the trustworthiness and credibility of the findings. This external validation provides added confidence in the accuracy and reliability of the data interpretations. Data and thematic quotes were summarized into **Table 4.12**.

Table 4.11. Key Informant Interviewee Demographics (n=27)

Figure 4.12. Key Informant Interview Results Summary and Thematic Quotes

Reciprocal Determinism Results

Reciprocal determinism is a concept from SCT, which suggests that a person's behavior is influenced by as well as influences three key factors: their personal factors (such as beliefs and attitudes), their environment (including social and physical surroundings), and the behavior itself. In the context of firefighting, this theory suggests that a firefighter's actions are molded by their experiences, training, and mindset, while their behavior can also impact their environment and how they perceived and respond to challenges. Both subpopulations, consisting of leadership and non-leadership firefighters, were interviewed using open-ended, semi-structured questions aimed at assessing their understanding of chemical risks and their perceptions of whether respiratory protection was prioritized by leadership.

Leadership Firefighters

All leadership participants agreed that there are chemical risks associated with firefighting (100%) and generally agree that smoke exposure can lead to illness. Leadership participants demonstrated minimal knowledge, when specifically questioned about PAH's (36.4%) and VOCs (27.2%). Approximately one-third of firefighter leadership believed respiratory protection for wildland fires was a priority for leadership (36.4%). Of those firefighters who believed respiratory protection was a priority, most commented on the "lack of available feasible equipment" for use in wildland operations and the "increases in cancer rates" among wildland firefighters.

Subject 5, a Battalion Chief, explained the department's prioritization of respiratory protection:

> Yes, it is. Again, even though we don't have anything yet for brush fires. But it's definitely been a priority for, on the other side, for our structure firefighting. It is a priority for the department. I just, I don't know how we're gonna wear a mask when we're out there fighting the brush fire. (Subject 5, Battalion Chief)

Another Battalion Chief, Subject 13, shared the personal impact of losing colleagues to cancer:

> I've been in for 17 and a half years and during that time, I buried 25 people on the job and a lot of them had to do with cancer. Yeah, I've worked in the camps with folks that had pancreatic cancer. A female that I came on with had contracted breast cancer and another one contracted, uterine cancer. So, it's absolutely incumbent, upon every department fire chief in the nation to take the life and safety of their firefighters as their number one priority. And if that means that they do everything they can to provide the appropriate airway protection then that's what's needed. (Subject 13, Battalion Chief)

Non-Leadership Firefighters

The majority of non-leadership participants agreed that there are chemical risks associated with firefighting (86.7%) and generally agree that smoke exposure can lead to illness and cancer. When specifically questioned about PAH's and VOCs, nearly all non-leadership participants reported being unfamiliar with these chemicals (100%; 93.3%). The majority of participants (76.9%) perceived that respiratory protection for wildland fires was not a priority for leadership. The most frequently cited reasons included the "lack of mandated respiratory procedures and respiratory equipment" and "lack of available, feasible equipment" for use among wildland firefighters.

Subject 22, a firefighter paramedic, expressed frustration with the lack of progress in this area:

> Because if it was, there would have been something done about it a long time ago. And I know it's been talked about for a while, but it would have been more streamlined like it is in the structure world. (Subject 22, Firefighter paramedic)

Another participant echoed concerns about the impracticality of current respiratory protection options:

> I think it feels unrealistic. You're already caring…like especially talking about anything resembling like an SCBA. We already carry so much on our backs. Why would we carry more? (Subject 12, Firefighter)

While most participants believed respiratory protection for wildland fires was not priority for leadership, more than half of participants (64.3%) agreed that their leadership educates them on best available health and safety practices.

Subject 22, a firefighter paramedic, stated:

> I believe so. With what their knowledge is. Yes. (Subject 22, Firefighter paramedic)

Similarly, Subject 8, a firefighter, shared:

> Yes, my captain, he had been with the organization, for a long time and he was. He was really into a lot of health and safety stuff, so he was always looking out for us. (Subject 8, Firefighter)

Behavioral Capability Results

Behavioral capability refers to a firefighter's knowledge and skills needed to perform specific behaviors effectively in various situations. This includes understanding the correct procedures and having the ability to execute tasks, such as using equipment, following safety protocols, and making critical decisions under pressure. Behavioral capability is essential for ensuring that firefighters can respond appropriately to emergencies, manage risks, and maintain safety in high-stress environments. Both subpopulations, consisting of leadership and non-leadership firefighters, were interviewed using open-ended, semi-structured questions aimed at assessing the scope of smoke exposure education/training/knowledge and personal smoke reduction practices.

Leadership Firefighters

Nearly all firefighter leadership (91.6%) reported not having any formal education or training related to wildland smoke exposure nor were they aware of any procedures or practices to reduced wildland smoke exposure mandated by their department or agency. Most leadership firefighters did not have any informal / personal ways to reduce smoke exposure and generally there was this theme of “staying out of direct smoke” for smoke exposure reduction.

Subject 1, a captain, explained:

> I mean, I just, I just kinda keep my guys out of smoke as much as possible but I mean, that’s my personal mitigation to it. (Subject 1, Captain)

Subject 11 also described their strategy for mitigating smoke exposure:

> So, rotating people out of heavy smoke. Rotating them out of heavy smoke or even putting people in places where there aren't or isn't as much smoke exposure even if it's short duration. (Subject 11, Captain)

Non-Leadership Firefighters

Most non-leadership firefighters (85.7%) reported not having any formal education or training related to wildland smoke exposure. Additionally, all non-leadership participants (100%) were unaware of any department or agency-mandated procedures or practices to reduced wildland smoke exposure. The primary informal strategy reported by these firefighters to reduce smoke exposure was “Keeping out of direct smoke”.

Subject 8, a firefighter, explained:

> No, really. We just try to, like I said, stay out of it. It’s the best you could do. (Subject 8, Firefighter)

Similarly, Subject 16 noted:

> Like, I said, trying to stay in clean air. If I have no opportunity to stay in clean air. I put my mouth in my shirt. I just try to find good air. (Subject 16, Firefighter)

All non-leadership participants (100%) reported that they would be willing to received training on smoke exposure reduction related to wildland/WUI and the most common recommended form of training was an “in person, annual refresher training”.

Observational Learning Results

Observational learning involves acquiring skills, knowledge, and behaviors by observing and imitating the actions of more experienced colleagues. This process is crucial during training exercises and real-life operations, where firefighters acquire new skills and behaviors by watching and imitating the actions of more experienced colleagues during training or in the field on wildland/WUI fire incidents. Both subpopulations, consisting of leadership and non-leadership firefighters, were interviewed using open-ended, semi-structured questions aimed at assessing influence of leadership, observed use and perceptions of respiratory protection in the field.

Leadership Firefighters

All participants (100%) agreed that leadership had significant influence over their crew members. Overall, leadership reports that they have a "positive" or "neutral" perception of respiratory protection with some stating their view of respiratory protection has improved since the pandemic.

Subject 24, a captain expressed:

> Good on him. You know, I think that, to me, it's an example of leading up. (Subject 24, Captain)

Subject 29 shared a similar sentiment:

> I would have no problem with that. We don't provide those, but I would have no problem with that whatsoever. (Subject 29, Deputy Fire Chief)

Subject 9, a battalion chief, reflected on the changes in attitude after the COVID-19 pandemic:

> I think after COVID I started realizing something because I listened to everybody [and] I had a lot of people who were very concerned about it. They don't wanna take it home with their wives and stuff. My new perception about somebody wearing a mask is people have the right to take care of themselves. And I will defend that right if I'm in a position to do so. (Subject 9, Battalion Chief)

Leadership did express general concerns about breathability in the context of wildland firefighting duties and cultural norms. Currently, leadership reports that seeing respiratory protection of any kind in the field is "rare" and limited to bandanas, Nomex shroud, cloth facial coverings, and N95 masks that provide lower-level coverage.

Subject 11 noted:

> I would say less than 10% [of wildland firefighters wear respiratory protection]. Almost nothing that would qualify formally as like a, a respirator or a mask that's intended to intentionally block any type of particulate matter. A lot of times what you're seeing are just like cloth or some type of elastic band with Nomex or some type of fire-resistant material that can be pulled up over the nose and mouth. (Subject 11, Captain)

Similarly, Subject 25 described:

> Very rare. Some sort of cloth barrier like a bandana that doesn't do much. (Subject 25, Captain)

Non-Leadership Firefighters

All participants (100%) agreed that captains, supervisors and managers enforce health and safety procedures among crew members. When asked about their perceptions of firefighters wearing respiratory protection in the field, responses varied. Approximately half of the participants expressed 'intrigue or neutral feelings' toward the use of respirators, while the other half reported having negative feelings.

Subject 8, A firefighter, expressed curiosity:

> I'm going to ask them about it… like how it works because my curiosity, maybe I'll try it out. You know, you know? (Subject 8, Firefighter)

Similarly, Subject 20 noted:

> I think it's cool, I appreciate it. At the same time, and that's a personal perception, at the same time, I've also heard a lot of people comment badly on it, and I've only ever seen it in the field, twice. I think, 7 years ago, fighting fire. (Subject 20, Firefighter)

Subject 10 provided a more neutral perspective:

> As long as they're doing their job, I really don't have any thoughts about it. I mean, if someone wants to wear a mask, I'm all about. I don't wear one. I'm not gonna say I'm not going to because it's not mandated to me to, but, if I see someone wearing one, I don't think twice about it as long as you know they're capable and competent in their position. (Subject 10, Firefighter)

Common negative feeling themes included “breathing concerns/impracticality of use” and associating masks with “individuals who are not a part of the agency/department”.

Subject 19, a firefighter, shared their perception of mask use:

> I've not seen a primary person wear a mask. So, if I see someone, I think, Oh, they're probably not primary. They're probably on the fire in a different capacity. And I guess the last time that I saw an individual in a mask, I thought, oh, that's nice for them that they get to do that. And also like, wow how impractical for our jobs. (Subject 19, Firefighter)

Similarly, Subject 15, an assistant captain, expressed:

> Yeah, I don't see anybody wearing masks. I only see people wearing handkerchiefs, and they're usually not agency people. Usually, if someone's wearing a handkerchief, you can tell like they haven't been in fire for very long. (Subject 15, Assistant Captain)

Currently, non-leadership participants report that seeing respiratory protection of any kind in the field is “rare” and limited to bandanas, Nomex shroud, cloth facial coverings, and N95 masks.

Reinforcements Results

Reinforcements refer to the rewards or consequences that follow a behavior, which can either strengthen or deter the likelihood of the firefighter repeating that behavior. Positive reinforcement such as recognition or praise encourage firefighters to continue following safety protocols or procedures. Negative reinforcements like adverse consequences or ridicule can discourage firefighters from innovation making them more likely to conform to group norms.

Stereotyping or preconceived opinions play a significant role in reinforcements, by causing conformation or behavior suppression. Both subpopulations, consisting of leadership and non-leadership firefighters, were interviewed using open-ended, semi-structured questions aimed at observing firefighter stereotyping and culture that influence reinforcements against respiratory protection.

Leadership-Firefighters

All of leadership (100%) agree that firefighter "knowledge and experience" symbolize a reliable and seasoned firefighter.

Subject 24, a captain, shared:

> I think someone who has been to a lot of different places, mainly in the West. You know they understand how to manage number one: risk. They understand how to manage people and priorities. They understand just how fire, works and a lot of different fuel types. I think, for me, too, having a good knowledge base is, is a really good foundation, too. So, you can understand, you know how fire behavior is gonna react in these types of conditions. (Subject 24, Captain)

Similarly, Subject 18, a battalion chief, emphasized the importance of experience:

> Reliable and experienced. Well, experience, really. Comes down to doing the job. Being on a number of different types of fire and having both the classes the trainings under their belt. Along with being out there in the environment and seeing these things, I think, you know, to me the experience piece of it. Reliable is the person who can understand the job. See the job through and get it done. (Subject 18, Battalion Chief)

Most leadership participants (81.8%) agree that they can point out a novice firefighter from experienced firefighters. Prominent themes in novice firefighter profiling included “behavior cues”, “age”, and “clean or brand-new gear”.

Subject 9 reflected on this ability:

> I think you can tell by how they, how they move. I think you can tell by how the how they act. I think you could tell by I know one big giveaway; huge giveaway is that old firefighters don't tell stories anymore. We don't walk around talking about some fire we fought last week. So, a lot of it is behaviors, I think, is the biggest giveaway just how they act. (Subject 9, Battalion Chief)

Similarly, Subject 5 noted:

> If he has like new equipment, right? His turnouts or his brush gear or his helmet or everything looks new. It's got brand new boots, shiny boots, and he's young. I would think, this guy's, you know, he's a rookie or he's new, right? (Subject 5, Battalion Chief)

Subject 26 added:

> Well, yeah, I think it would be easy to say that you can pick out a new firefighter because maybe their equipment is cleaner because it's brand new. But outside of that I don’t think you can tell besides age. (Subject 26, Captain)

When leadership participants were asked to describe the culture surrounding respiratory protection in the wildland firefighting community, key themes emerged, including a prevailing

“machismo attitudes” and the belief that “respiratory protection hasn’t been necessary” in wildland firefighting.

Subject 18 described the cultural norms:

> Yeah, the culture, kind of you know. I don't know if it's so much an accepted practice as much as it should be. I think there are some stigmas that come along with people who wear respiratory protection. If it were required by all agencies to do, and more agencies were adopting of that and enforcing of that. I think that's really, my opinion, the only way to curb the cultural norms. I think that's really the only way to kind of change the culture. (Subject 18, Battalion Chief)

Similarly, Subject 29 explained:

> It’s non-existent. We've got older folks that just, you know, yeah, they like, it's like, it's a macho thing, you know, with the smoke and all that stuff. You probably have heard that. But That's the way that culture is. The fire services, putting masks or anything on people might, in the world of vegetation fires, might be a difficult hurdle to get over. (Subject 29, Deputy Fire Chief)

Non-Leadership Firefighters

The majority of non-leadership participants agree that a reliable firefighter is symbolized by “fire knowledge and experience” with another emerging theme of “someone who advocates for crew and crew safety”.

Subject 16, a firefighter, described:

> A reliable and experienced firefighter is sets and reps. Knowing, like, being on fires, not just being trained into fires. The ability to make sound decisions and look out for their people. (Subject 16, Firefighter)

Similarly, Subject 27 noted:

> Yeah. Someone who is dependable, calm under situations, and someone who can problem solve quickly under pressure and that has your back…Someone who keeps you safe. (Subject 27, Firefighter)

Subject 15, an assistant firefighter, also emphasized the importance of crew safety:

> Someone who has a good work ethic but watches out for their people. Um, taking care of their people above everything else. (Subject 15, Assistant Firefighter)

Most non-leadership participants (85.7%) agree that they can point out novice firefighters from experienced firefighters. Prominent themes in novice firefighter profiling included "behavior cues" followed by "clean or brand-new gear".

Subject 22, a firefighter paramedic, explained:

> Just their behavior. Their body, language. How they, how they walk around. (Subject 22, Firefighter paramedic)

Similarly, Subject 15 observed:

> Yes. You can tell by just looking at them. It's hard because people are different, like so many people are different. Some people talk a lot more, than the more experienced

> people. But some people are a lot more quiet. I would say, in short either a very high or low amount of confidence that doesn't match their experience. If that makes sense. (Subject 15, Assistant Captain)

Other participants, such as Subject 12, noted:

> The dirtier you're yellow, it means like you're more seasoned, it means you, you know, you've seen more action, you know, what you're doing. Having those super clean super crisp Nomex. (Subject 12, Firefighter)

Subject 10 added:

> Subtle giveaways are. Just clean clothing. You know having the brand-new shirt the brand-new pants brand new boots generally with new firefighters you can kind of tell, like for our operations when they show up. (Subject 10, Firefighter)

When non-leadership participants where asked if they were familiar with the term "Smoke Eater" most firefighters (62.5%) had only ever heard the phrase "eating smoke". Among the participants who were familiar with the term "smoke eater", they associated it with negative connotations including "unsafe" and "outdated". In the past, the term "Smoke Eater" has had deep cultural connotations that included bravery, camaraderie, pride, and tradition, referring to experienced firefighters who directly stood in the face of smoke day in and day out.

Subject 23, a firefighter paramedic, explained:

> It's a corny thing that usually firefighters that don't really fight fire, say, because they think it's cool. But if you actually fight fire and fight fire consistently, then you already

> know that the phrase exists, but you don’t call yourself that. (Subject 23, Firefighter paramedic)

Similarly, Subject 8, a firefighter, noted:

> I believe that is someone who doesn't wear respiratory protection and is just inside the smoke all the time trying to be macho or something. (Subject 8, Firefighter)

Subject 19 added their perspective:

> I guess I've heard it more as in like eating smoke. Not smoke eater. So, when I've heard eating smoke, that just means that you have been inhaling a lot of smoke. It's been very dense. (Subject 19, Firefighter)

Subject 12 described the phrase “eating smoke” in detail:

> It just means that you're just standing in it. You're in, you’re sucked in. You're eating, you're literally eating smoke. I mean, like, open your mouth, open your nose, open your eyes. Like, it's just, it's going to, it's coming, you're in it, whether that means you're holding or you're like digging line. (Subject 12, Firefighter)

Expectations Results

Expectations refer to the belief’s firefighters hold about the likely outcomes of their actions in various situations. These expectations influence how firefighters approach tasks, make decisions, and engage in behaviors. Both subpopulations, consisting of leadership and non-leadership firefighters, were interviewed using open-ended, semi-structured questions aimed at

assessing influence of leadership, observed use and perceptions of respiratory protection in the field.

Leadership-Firefighters

All leadership participants (100%) agreed that smoke from wildfires plays a role in causing health effects or illnesses. Most participants also agree that primarily vegetation-fueled fire smoke was notably different than WUI fire smoke (80%) and carried greater risks for health (62.5%). Key themes in the reasoning included the perception that "vegetation combustion was natural" and contrasting the differences in "taste, smell or visual appearances" of WUI smoke vs vegetation smoke.

Subject 18, a battalion chief, described these differences:

> You see it in the color of the smoke. You see it in the density and the thickness of the smoke. And that is much more different than when you are burning a stand of timber, or you're burning off an acre of grass. It is very apparent whether it's visually, but it's most apparent to me in its density, and its thickness and the color of the smoke. That, you know that, this is a different type of smoke that you are either inhaling or ingesting this up. (Subject 18, Battalion Chief)

Similarly, Subject 3 ntoes:

> Yeah, so vegetation fires are mostly part of the combustion of natural materials. Like, oak trees, manzanita, sage, brush, grass. But when those vegetation fires start to impact wildland urban interface areas. The structures when they catch fire are now burning

products of combustion that are made by my petroleum products. (Subject 3, Deputy Fire Chief)

Most leadership participants (90.9%) have had personal experience with smoke exposure and related health effects, most commonly reporting “acute or chronic respiratory symptoms” or “flu like symptoms” due to wildland/WUI smoke exposure and “personally knowing firefighters who have died from cancer”.

Subject 3 shared a personal account:

> I was assigned to the Woolsey fire in 2018 for 20 to 24 days and after I was released from the fire back to my normal duties, I experienced a significant bronchitis. I went and was treated by a doctor; pulmonologist and it took 3 to 4 months to relieve the symptoms of bronchitis and he attributed to the exposure to the smoke on the Woolsey fire. (Subject 3, Deputy Fire Chief)

Subject 26, a captain, added:

> Oh, yeah, for sure. So, I’ve gotten some sort of sinus inflammation going on and the headaches for days. (Subject 26, Captain)

Subject 1 shared a story about a colleague:

> I have had a buddy who was in the forest service for about 18 years, he just recently passed away. He ended up getting, I think it was leukemia. And they deemed it that it was work related from smoke exposure. (Subject 1, Captain)

Non-Leadership Firefighters

All non-leadership participants (100%) unanimously agreed that smoke from wildfires plays a role in causing health effects or illnesses. All participants (100%) also unanimously agreed that vegetation fires were notably different than WUI smoke and carried greater risks for health. Key themes in the reasoning included the perception that "vegetation combustion was natural" and contrasting the differences in "taste, smell or visual appearances" followed by personal experiences with "WUI related illness".

Subject 16, a firefighter, explained:

> But I do feel that….if it's… purely organic material burning even though it's not good to breathe it but it's a lot better than plastics burning or any kind, any kind of petroleum product, that we have. That's why I mentioned earlier about being in the urban interfaces, it is more of a sketchy on the inhalation issues. (Subject 16, Firefighter)

Similarly, Subject 15 shared:

> When just so much of LA was burning down and it was wildland urban interface. There was grass and brush and trees burning, but there were also houses and railroad ties and telephone poles burning, and we woke up for a week, just feeling hungover…. like feeling sick. (Subject 15, Assistant Captain)

Subject 4 added their perspective:

> Woods smoke, I'm not saying that it's not bad for you, it definitely has long-term effects, but I've never gotten lightheaded and sick to my stomach from just wood smoke compared to burning plastics or treated wood that's burning. It does have a more immediate effect where you notice the bad things sooner because it's like, oh, this is affecting the way my brain is working right now in this moment. (Subject 4, Firefighter)

All non-leadership participants have had personal experience with smoke exposure and health outcomes, predominately “acute or chronic respiratory symptoms” or “flu-like symptoms” from wildland/WUI smoke exposure and “coughing black mucus”.

Subject 27 shared their experience:

> Yes. I think actually, recently, I've been told I have asthma, and I've never had asthma my whole entire life. And I didn't even know it was asthma until I went to the doctor. And now I have an inhaler and it's been helping. But, I mean, the only thing I can think of it is from the smoke that I've been over the years. It's been 7 years. (Subject 27, Firefighter)

Subject 12 recounted their experience with smoke exposure:

> Early October of 2020, last role of the season, we were fighting the Mullen fire in southern Wyoming that eventually blew into the in northern Colorado. You're just sitting there eating smoke all day every day and that was my 1st wildfire season where for the majority of the season or off season after that I had like chronic bronchitis undiagnosed but like I could not stop coughing. I had a persistent cough for about 4 or 5 months after that. Just that one fire alone. (Subject 12, Firefighter)

Subject 15 also mention a similar experience:

> And then, after I had that burn. After I was um helping with that burn, and I was coughing up black stuff. (Subject 15, Assistant captain)

Subject 12 added:

> Yeah, we were all kind of hacking up a lot of bad stuff for that off season. (Subject 12, Firefighter)

Self-Efficacy Results

Self-efficacy refers to the firefighter belief in their own capability to perform tasks or actions. This includes confidence in their skills, decision-making, and abilities. Factors such as training, experience, and mentorship, interact to shape a firefighter's self-efficacy. Both subpopulations, consisting of leadership and non-leadership firefighters, were interviewed using open-ended, semi-structured questions that aimed at assessing personal beliefs and explore barriers that surrounded respiratory protection implementation.

Leadership-Firefighters

Most Leadership firefighter participants (90.9%) largely agree on the necessity of respiratory protection for wildland firefighting, with the primary theme in reasoning being "protection from smoke exposure and cancer". All leadership participants (100%) unanimously agreed respiratory protection was a personal priority. Over half of participants (63.6%) believe respiratory protection is something that firefighters actively desire. Primary themes identified for the challenges in adopting respiratory protection in wildland firefighting included "lack of

feasible equipment", the "intense physical demands of wildland firefighting" and the prevailing "firefighter culture".

Subject 26, a captain, explained:

> Because of the culture, it's the culture, these guys, just like the old school structure firefighters that…A dirty helmet, a dirty coat like smoke, it shows that you did something. (Subject 26 , Captain)

Similarly, Subject 11 noted:

> I think it's just cultural and has a lot to do with the evolution of our programs. You know. Implementing change within federal land management, especially at the fire, within the fire program and especially at the field level is very, very slow and there are just so many cultural norms that exist around the way that we dress and operate in the field that implementing any new piece of equipment is met with a deep degree of skepticism and so you know it takes a long time to both sell any item and then and then adopt it. (Subject 11, Captain)

Subject 13, a battalion chief, highlighted the practical challenges

> Well, the first one is. Coming up with the design that's effective enough. That's lightweight enough. That won't encumber their ability to work. It's an environment you know you have to understand, it's typically warm. You know, we don't have brush fires in the winter when it's 60 degrees. We have brush fires when it's 90 degrees in California. So, it's 90 degrees out or it's 85 degrees out at 2 o'clock in the morning. You're pulling

> hose up an 8-degree slope 12-degree slope, in rocks, you're sweating. And so, you need some sort of protection that will absorb moisture. And clear the air and allow you to breathe effectively. And lightweight enough so that it's not so cumbersome. (Subject 13, Battalion Chief)

Key themes in essential criteria that respiratory protection would need to meet to be accepted by the wildland firefighting community were “breathability”, “lightweight”, and “comfortable” for long wear.

Subject 18, a battalion chief, described the need for practical respiratory protection:

> I think you know you need some kind of filtration system, that allows the individual to be climbing up a steep hill, or doing some of the most strenuous work that you can do, not only hiking up the steep hill, but working a steep hill. For sometimes miles. (Subject 18, Battalion Chief)

Similarly, Subject 7 emphasized breathability:

> It allows you to breathe and exchange oxygen as freely as possible and protect you at the same time. That was always the prohibitor of wearing something is because you couldn't because you couldn't breathe through the material. I mean, if you're just in no smoke and you're just wearing an APR, you know, especially everyone being living through COVID. I mean, you know, it could be difficult to breathe. But if they just had something that had something that was just a little bit better in exchanging, you know, air, oxygen, more freely, it would that would be something that'd be really, I think would be ideal for acceptance. Yeah. (Subject 7, Battalion Chief)

Subject 26 added:

> It's got to be something that's lightweight. That it's packable. (Subject 26, Captain)

Key recommendations for effectively implementing respiratory protection standards for wildland firefighters highlighted the importance of 'education and awareness of health risks' associated with wildland/WUI smoke exposure, as well as the need for a 'national standard' to ensure consistent enforcement.

Subject 24, a captain, suggested:

> Just like I said, agency-wide. Mandatory. Revamping Redbook standards. I think. (Subject 24, Captain)

Subject 9 echoed the need for national standardization:

> It would take a national standard. (Subject 9, Battalion Chief)

Subject 26 elaborated on the steps needed for implementation:

> It’s going to take a multi-step deployment. First, we've got to get some accurate information itself so its easily discernable out there in the field. Next from that, I think we got to focus on our leadership. From our leadership down almost like a sandwich. Take on, Top down, bottom up. And eventually we're gonna get some of hardheaded guys who don’t want to change. (Subject 26, Captain)

Subject 29 added:

> Well, kind of what we're doing right now, you know, if you can. If you can have some concrete data. That's helpful. I mean look at the fire service over the last 100 years we've made strides to where we are now. Is that what the next step is, is that something that we could do? We would need the data. Does the data have the support of it? It would have to come from the leadership. You know, the tone is gonna have to come from the top, you know. (Subject 29, Deputy Fire Chief)

Non-Leadership Firefighters

Most non-leadership firefighter participants (78.6%) agree on the necessity of respiratory protection for wildland firefighting, but expressed hesitation or concerns on the "breathability" and "feasibly" of respiratory protection.

Subject 19, a firefighter, explained:

> I do believe that we need something. But we are a workforce that is hired to hike…And to be like far extended from our vehicles. So, it's difficult right now to imagine what that looks like. (Subject 19, Firefighter)

Similarly, Subject 23 noted:

> I believe so, for the longevity of the firefighters. For all the stuff that we go through and have to breath in. (Subject 23, Firefighter paramedic)

Most participants agreed that respiratory protection was a personal priority primarily "to enjoy family, live a long life" and "improve health by reducing smoke exposure".

Subject 22, a firefighter paramedic, shared:

> I would like to live a very long life, and a very healthy life and be able to enjoy it. Grow old and go finish a career as well as watch my children grow up and have grandkids, watch my great grandkids and be able to enjoy that. (Subject 22, Firefighter paramedic)

Subject 6 added:

> My own health and safety and then I have a family that I want to be able to enjoy for as long as I can, so I think about that as well. (Subject 6, Firefighter)

Subject 25 further emphasized:

> Yes, absolutely. I've seen the dangers, seen the loss of members, team members that are still battling cancer because of it, and yeah, it's a no brainer. (Subject 25, Firefighter)

Key themes in essential criteria that respiratory protection would need to meet to be accepted by the wildland firefighting community were "breathability", "lightweight", "comfortable for long wear" and "cost effective".

Subject 20 noted:

> I think it would have to be like, lightweight, very comfortable and very easy to breath in. (Subject 20, Firefighter)

Subject 22 added:

> Something that doesn't hinder breathing or work that crews do on, Initial Attacks. Allows you to do your job for extended periods of time, without causing too much hindrance on your capabilities [than] without one. (Subject 22, Firefighter paramedic)

Subject 4 emphasized cost concerns:

> Cost. You know regular barriers that come with bureaucracy they're big agencies. (Subject 4, Firefighter)

Major emerging themes in recommendations for a successfully implementing respiratory protection standards for wildland firefighters included “education and awareness of adverse health outcomes” from wildland/WUI smoke exposure and “a change in firefighter culture”.

Subject 21 stated:

> Education. Prove that it will be better for them in the long run. Everyone has to understand why they're doing something. (Subject 21, Firefighter)

Subject 19 noted:

> And I think it would take some hard truths to be spoken. Like, we know the statistics, but we kind of just brush it off because we like love the job, and we love the work so much. And none of us think that it's going to be permanent. And, so to speak, like a lifelong career. Acknowledge that, yes, the work that we're asking you to do is so hazardous that it has these effects. It would be powerful for them to get behind it. (Subject 19, Firefighter)

Similarly, Subject 23 added:

> Most importantly, everything needs to be data driven. So, the science behind everything. But everyone that I have met, at least everyone that I've met from different departments.

> is receptive if the data is there and the proper information is there and it's conveyed properly then everyone is pretty understanding, and happily ready to receive it. But if it's something [is] askew or not conveyed properly, then firefighters are not apt to accept it. (Subject 23, Firefighter paramedic)

Subject 27 emphasized the importance of leadership and data:

> I think it would take just leadership kind of implementing it. Putting out the data out there, and like kind of seeing hard numbers. We're all pretty visual people. So, collecting data from like a lot of wild firefighters and seeing what their experiences are…the ones that are in smoke all the time. (Subject 27, Firefighter)

When non-leadership firefighters were asked how new respiratory procedures would impact their job duties, Major themes included "concerns about breathability", "issues with equipment weight", and the potential to reduce "operational efficiency".

Subject 15, an assistant captain, observed:

> It's hard to work out with a Covid mask on. And so, I think it would slow people down and take a while for them to get into the comfort of working hard with something covering their face. So, it would slow things down while we adapt. (Subject 15, Assistant Captain)

Subject 10 also commented:

> Hey, it depends on what the equipment is. I mean, if it's, you know, we gotta carry a tank, you know, 50-pound tank and masks or whatever. That's really gonna affect what we do. (Subject 10, Firefighter)

Subject 2 added:

> I guess it just depends on how the equipment is. Like if it makes it hard to do our day-to-day operations, it would be different if it's something simple. That's still easy to operate and normally it wouldn't be that big a deal, but I'm sure it would be something to get used to. (Subject 2, Firefighter paramedic)

CHAPTER 5: DISCUSSION, IMPLICATIONS, RECCOMENDATIONS, AND CONCLUSIONS

Discussion

The Wildfire Conservancy Respiratory Protection Survey Data

The findings from the Wildfire Respiratory Protection Survey reveal a concerning lack of chemical knowledge across all levels of leadership among wildland firefighters. A significant 85.9% of respondents reported not using any form of respiratory protection during firefighting activities, despite the known health risks of smoke exposure. This highlights a gap in standard practice for respiratory safety. Interestingly, factors such as appearance and personal beliefs were not major concerns, with 66.9% and 67.4% of respondents, respectively, rating these as unimportant. However, differences emerged in perceptions of equipment appearance: leadership showed less concern at lower levels ("0" and "1"), while non-leadership expressed more concern at level "3," suggesting that non-leadership firefighters are more sensitive to how respiratory equipment looks. Health-related motivators were key drivers for respiratory protection use, with cancer risk reduction being the most influential (74.8% rated it as extremely important). Additionally, nearly 60% of respondents recognized the immediate benefits of improved respiratory health, indicating strong awareness of the short-term and long-term health benefits of respiratory protection.

Chemical Compound Familiarity Among Firefighters

The study aimed to assess the familiarity of firefighters with common chemical compounds found in wildfire smoke. The results revealed significant variability in the levels of knowledge among firefighters regarding these compounds, highlighting critical gaps that may

influence the adoption and consistent use of respiratory protection. The data showed that firefighters were most familiar with CO and PM, which are well-known components of wildfire smoke. High familiarity with CO (77.7% knowing it, fairly well or very well) suggests that the educational efforts, potentially starting from fire academy training, have been effective in communicating the dangers of this compound.

However, the study identified substantial knowledge gaps concerning other hazardous compounds, such as PAHs, PFAS/PFOA, and Benzene, with 29.5%, 20.9%, and 11.4% of respondents respectively, indicating that they have never heard of these substances. The lack of familiarity is particularly concerning given the known carcinogenic and toxic properties of these compounds. Moreover, the lower levels of familiarity with other hazardous compounds, such as VOCs, further emphasize the need for comprehensive education in the fire service. Notably, a substantial body of research has highlighted PAHs and VOCs as significant hazards in wildland firefighting (Banks et al., 2021; Fent et al., 2015; Keir et al., 2017; Wilkinson et al., 2023); however, this crucial information appears to be inadequately disseminated to firefighters in the field. Consequently, many respondents reported little to no knowledge of these chemicals, which may result in underestimating the cumulative risks of smoke exposure and a lower prioritization of respiratory protection. Effective implementation of respiratory protection strategies relies not only on the equipment availability but also on a deep understanding of the risks posed by these toxic compounds to improve self-efficacy.

Knowledge Gaps Across Leadership Levels

The comparison between leadership and non-leadership firefighter showed no significant difference in chemical compound knowledge (p-value=0.646), indicating that knowledge deficits are consistent across different ranks. This finding suggests that leadership status does not

inherently confer additional chemical hazard awareness and therefore, the influence of leadership on respiratory protection behaviors may be limited by the same knowledge barriers. The absence of significant differences between leadership and non-leadership groups implies that both categories of firefighter are equally in need of targeted educational interventions. By enhancing chemical compound knowledge across all ranks, the likelihood of improved respiratory protection practiced may increase, as firefighters will be better equipped to recognize the necessity of using protective equipment.

Current Practices in Respiratory Protection Usage

The study aimed to assess if wildland firefighters were currently using any form of respiratory protection during wildfire incidents. A substantial majority of respondents (85.9%) reported not using any form of respiratory protection while engaged in firefighting activities. This underutilization of respiratory protective equipment indicates that, despite the well-documented health risks associated with smoke exposure, respiratory protection is not a standard practice in the field. This finding aligns with previous research on wildland firefighters (Navarro DuBose et al., 2024). Among the minority of firefighters who reported using respiratory protection (12.6%), cloth masks were the most commonly used for (67.8%). While cloth masks offer some level of protection, they are primarily designed to prevent the spread of bioaerosol droplets and do not provide adequate filtration against fine particulate matter, toxic gases, or other hazardous compounds present in wildfire smoke. The predominance of cloth mask use likely reflects a behavior influenced by the COVID-19 pandemic, during which cloth masks became widely adopted as a primary form of respiratory protection to reduce virus transmission. This trend suggests that some firefighters may have continued using cloth masks due to their

familiarity, ease of use, and misconception that they provide adequate protection in all hazardous environments.

The limited use of more effective respiratory protection, such as N95 respirators (15.8%), self-contained breathing apparatus (SCBA) (13.2%), and air-purifying respiratory (APR) (3%), highlights a significant gap in implementation of adequate respiratory protective measures as well as the variability in protocols. N95 masks, which offer superior filtration against PM compared to cloth masks, remain widely underutilized among wildland firefighters. This underuse may be attributed to barriers such as discomfort during extended firefighting operations, moisture retention in the mask due to sweating, and reduced breathability during strenuous hiking and physical exertion, which is typical in wildland firefighting.

The reported use of SCBA by respondents likely reflects responses from firefighters who are part of all-risk departments or crews that respond to both structural fires and wildland/WUI (Wildland-Urban Interface) fires, where SCBAs are standard equipment for structural firefighting. SCBAs are not used in wildland/WUI firefighting due to their weight, bulk, and limited air supply making them impractical for the extended durations and physically demanding conditions typical of wildland/WUI incidents (ISFFAOG, 2024). This suggests that the reported use of SCBA in the study is more of an artifact from structural firefighting practices and does not accurately reflect the typical equipment used in wildland/WUI firefighting environments, where SCBAs are not commonly assigned or accessible. Increased awareness of the dangers of wildland/WUI smoke has led some firefighters to personally purchase APRs, which may account for the reported use in this study, where only 21 individuals indicated using them. Additionally, 2 respondents reported using PAPRs, likely for HAZMAT situations during fire investigations. The minimal reported use of APRs highlights the need for better education and greater access to

effective and practical respiratory protective devices for wildland firefighting. Although APRs offer superior protection by filtering harmful particulates and gases, they are often impractical in wildland/WUI settings due to challenges with fit, maintenance, and their unsuitability for the rugged, physically demanding conditions of these environments. It is possible that those who reported using APRs were primarily engaged in hazardous material responses, where these devices are more appropriate, rather than typical wildland firefighting operations. Overall, these findings emphasize the critical need for enhanced education and access to appropriate protective equipment specifically designed for the unique conditions and demands of wildland firefighting.

Key Concerns Preventing Respiratory Protection Usage

The study identified several key concerns that act as potential barriers, preventing wildland firefighters from using respiratory protection during wildland/WUI incidents. The most significant concern was impaired breathing, with 64.2% of respondents rating it as the most concerning issue. This highlights that many firefighters perceive respiratory protection as a barrier to effective breathing during strenuous firefighter activities, which likely influences their reluctance. Impaired communication was another major concern, with 81.1% of respondents rating it as a level "2" concern or higher. Effective communication is essential in firefighting, especially with the frequent use of radios and the reliance on verbal commands. Any equipment that interferes with this can be seen as a barrier to both safety and coordination.

Comfort and fit were also notable concerns, with 39.2% of respondents reporting these issues as a highly concerning (level "3") and 43.2% as moderately concerning (level "2"). Respiratory protection that is uncomfortable or poorly fitting can be especially problematic during extended firefighting efforts in rugged environments. Impaired vision, size, and weight of equipment, and interference with existing gear were additional concerns that were reported at

moderate to high levels; indicating that practical operational challenges are significant barriers to adoption and thus reduces self-efficacy.

Interestingly, factors such as appearance and personal beliefs were the least concerning, with 66.9% and 67.4% of respondents, respectively, considering these factors as not concerning at all (level "0"). This suggests that aesthetic consideration and individual beliefs about respiratory protection are less influential compared to real or perceived operational barriers.

Comparison between Leadership and Non-Leadership Firefighter Concerns

The analysis revealed several important insights regarding how concerns differ between leadership and non-leadership groups. The interaction between common concerns and leadership status was statistically significant (p=0.002), indicating that leadership level does influence how certain concerns are perceived. This was further examined using a post-hoc Tukey test to compare the distribution of responses between leadership and non-leadership groups

For size and weight, significant differences were found at multiple levels. At concern level "0" (t=-300, p=0.004), non-leadership responses were greater than leadership responses, indicating that size and weight was more concerning for leadership compared to non-leadership. At concern level "2" and "3", leadership respondents expressed significantly higher concern than non-leadership, as indicated by the positive t rations (7=2.83, p=0.007 for level "2"; t=2.63, p=0.0011 for level "3"). This suggests that leadership places greater concern on the size and weight of respiratory equipment compared to non-leadership firefighters.

When examining appearance of respiratory equipment, significant differences emerge at concern levels "0", "1", and "3", with leadership expressing significantly higher responses at concern levels "0" and "1" (t=2.69, p=0.010 and t=3.55, p=0.001, respectively), and non-leadership showing more concern at level "3" (t=-297, p=0.004). This pattern indicates that the

appearance of respiratory equipment is more concerning for non-leadership firefighters when compared to leadership firefighters.

While there were significant values for simplicity of use at concern level "0" and comfort and fit at concern level "1" (t=-264, p=0.011 and t=-203, p=0.047 respectively), no significant differences were found at other levels. This indicates that leadership and non-leadership firefighters exhibited similar levels of concern across the remaining higher concern levels. No significant differences were found for interference with gear, impaired vision, and personal beliefs, indicating that both leadership and non-leadership groups share similar concerns across these factors, regardless of the concern level. Overall, these findings suggest that leadership and non-leadership groups differ in how they prioritize some concerns, particularly factors such as size/weight and appearance. However, for the remaining factors, leadership status does not appear to significantly impact the level of concern.

Health Motivators and Respiratory Protection

The study examined health-related motivators influencing the use of respiratory protection among wildland firefighters. Cancer risk reduction was the strongest motivator, with 74.8% of respondents rating it at extremely important. This reflects high awareness of the cancer risks associated with exposure to hazardous compounds in smoke, highlighting the need to link respiratory protection usage with cancer prevention to drive higher adoption rates. Nearly 60% of respondents rated improved respiratory health as extremely important, indicating recognition of the immediate benefits of protection. However, 4% did not see it as important, suggesting a small group may not fully grasp the short-term health risks. Additionally, 55.3% identified improved

breathing as a key factor, though 6.5% indicated that it was not important, potentially reflecting concerns about comfort or fit.

Public Health Implications

The knowledge gaps regarding hazardous compounds like PAHs, VOCs, Benzene, and PFAS/PFOA reflect low self-efficacy in identifying risks, a pattern observed consistently across all leadership levels. By providing targeted educational interventions, wildland firefighters can increase their confidence in understanding the dangers of smoke exposure, which will empower them to prioritize respiratory protection and reduce long-term health risks. The absence of significant knowledge differences between leadership and non-leadership roles indicated the uniform need for training across all ranks. Leveraging observational learning and role modeling can help spread awareness and reinforce protective behaviors, regardless of leadership status, fostering a consistent culture of safety.

Firefighters' reliance on ineffective methods like cloth masks, or the absence of any respiratory protection, highlights how behavior is influenced by environmental factors such as past experiences (e.g., COVID-19 habits) and operational changes. To shift these behaviors, fire agencies should promote the use of more effective respiratory protection while addressing barriers like discomfort, fit, and accessibility. By doing so, agencies can increase firefighters' perceived benefits (outcome expectations) of using proper respiratory equipment, ultimately leading to improved safety practices. The unsuitability of currently used structural equipment, like SCBAs, for wildland/WUI settings reduces firefighters' perceived ability (self-efficacy) to effectively use respiratory protection. Designing lightweight and practical alternatives that fit the specific demands of wildland firefighting will enhance firefighters' belief in their ability to use respiratory protection consistently. Practical concerns such as impaired breathing, discomfort,

and communication issues lower self-efficacy and hinder respiratory protection adoption. While there were differences in certain areas, such as appearance and size / weight, firefighters, regardless of leadership level, shared similar views on these practical concerns. By addressing these functional barriers through better equipment design and training, fire agencies can improve firefighters' confidence in using respiratory protection effectively in the field.

Health risks, particularly cancer, serve as powerful motivators (outcome expectations). Messaging that links respiratory protection to long-term health outcomes can increase self-efficacy and drive behavior change, reinforcing the importance of using protective gear. To address both cognitive and environmental barriers, agencies should create policies and campaigns that emphasize the health benefits of respiratory protection but also provide education on the true hazards of smoke exposure. Additionally, identifying practical solutions for respiratory protection tailored specifically for wildland/WUI use is essential for promoting long-term adoption.

Leadership and Non-Leadership Key Informant Interview Data

Reciprocal Determinism

Reciprocal determinism, a concept from SCT suggests that behavior is shaped by an ongoing interaction between personal factors, environmental influences, and the behavior itself (Bandura, 1999). In the context of wildland firefighting, this interplay is evident in how both leadership and non-leadership firefighters understand and approach chemical risks and respiratory protection. As reflected in the summary of **Table 4.12**, both leadership and non-leadership firefighters generally agree that there are chemical risks associated with firefighting and that wildfire smoke exposure can lead to illness. Leadership participants unanimously (100%) recognize these risks, while a slightly lower percentage (86.7%) on non-leadership firefighters held the same view. However, when it comes to specific knowledge about hazardous compounds like PAHs and VOCs, significant gaps exist in both groups. Leadership demonstrates minimal knowledge (36.4% and 27.2% for PAHs and VOCs, respectively), while non-leadership firefighters reported even less familiarity (100% and 93.3%, had no knowledge). This gap in chemical knowledge represents a shared cognitive barrier across both groups, which limits their ability to fully assess and mitigate health risks. Leaderships' limited understanding of these compounds is particularly concerning, as it suggests that they may not be effectively communicating these risks to their teams, influencing the work environment and how non-leadership firefighters perceive and respond to chemical hazards.

This lack of awareness among both groups undermines efforts to prioritize respiratory protection, as perceived risks are not fully understood. These findings illustrate personal factors within Social Cognitive Theory (SCT), as they highlight how individual knowledge, or lack thereof, affects the perception and assessment of chemical risks. Both leadership and non-

leadership firefighters recognize general health risks associated with smoke exposure, but significant gaps in specific chemical knowledge (such as PAHs and VOCs) create cognitive barriers that hinder their ability to accurately evaluate and respond to these hazards, impacting their personal risk assessment and protective behaviors.

Leadership and non-leadership diverge sharply in their perceptions of how respiratory protection is prioritized. Among leadership , only 36.4% believed respiratory protection was a priority largely citing the lack of practical respiratory equipment available for wildland/WUI operations. In contrast, the majority of non-leadership firefighters (76.9%) perceived that leadership did not prioritize respiratory protection at all, attributing this to the absence of mandated respiratory procedures and equipment. This difference highlights a mismatch between leaderships' understanding of environmental constraints (lack of feasible equipment) and non-leadership's perception of leadership's commitment to their safety. Leadership may feel constrained by the environment (availability of feasible equipment), while non-leadership firefighter interprets this as lack of concern, which influences their behavior and attitudes toward safety.

Leadership's behavior has a direct impact on the safety practices of non-leadership firefighters. While leadership acknowledges the importance of respiratory protection, their personal perception that current respiratory protection is not feasible in wildland/WUI settings limits their ability to effectively promote and enforce its use. Non-leadership firefighters, observing this lack of leadership emphasis on respiratory protection, are less likely to adopt these practices themselves. This dynamic illustrates how leadership behavior shapes the broader firefighting culture, reinforcing the underutilization of respiratory protection among non-leadership firefighters.

Even though more than half of non-leadership firefighters (64.3%) acknowledged that leadership educated them on general health and safety practices, the absence of strong emphasis on respiratory protection creates an environment where non-leadership firefighters do not feel empowered to prioritize it. As a result, both groups are caught in a cycle where the environmental constraints (lack of feasible equipment) and leadership behaviors (limited advocacy for respiratory protection) perpetuate a culture that deprioritizes respiratory safety.

These findings demonstrate the interplay of personal, environmental, and behavioral factors within Social Cognitive Theory (SCT). Personal factors are evident in the differing perceptions between leadership and non-leadership firefighters about the prioritization of respiratory protection. Leadership is aware of the importance of respiratory safety but cites environmental constraints, such as the lack of practical equipment, as a barrier. Non-leadership, however, perceives this as a lack of commitment to their safety, which influences their behavior and willingness to use protective equipment.

Environmental factors play a key role, as the perceived absence of feasible respiratory equipment creates a shared barrier. Leadership's acknowledgment of these constraints affects how they promote respiratory safety, and this perception is passed down, shaping the overall safety culture.

Behaviorally, the actions of leadership directly impact non-leadership firefighters. The limited advocacy and enforcement of respiratory protection by leadership lead non-leadership to deprioritize these practices, reinforcing a cycle where both groups adapt to environmental constraints rather than challenge them. This dynamic perpetuates a culture in which respiratory safety is not a priority, highlighting how environmental factors and leadership behavior collectively shape safety practices.

Behavioral Capability

Behavioral capability, a key component of SCT, refers to the knowledge and skills required to perform behaviors effectively (Bandura, 1999). For firefighters, this involved understanding safety protocols, managing risk, and making informed decisions, particularly in high stress environments like wildland firefighting. Both leadership and non-leadership firefighters demonstrated a lack of formal education or training specifically related to wildland/WUI smoke exposure. As reflected in the summary of **Table 4.12,** nearly all leadership firefighters (91.6%) and the majority of non-leadership firefighters (85.7%) reported having no formal education on the topic, nor were they aware of any departmental procedures to reduce smoke exposure. This shared deficit, highlights a critical gap in behavioral capability of both groups, as neither possesses the formal knowledge necessary to translate into skills to effectively mitigate the health risks associated with prolonged smoke exposure. Without structured training, their ability to effectively address these risks is restricted, leaving them reliant on informal, personal strategies that often prove insufficient.

The most common strategy reported by both leadership and non-leadership firefighters for reducing smoke exposure was to "stay out of direct smoke" when possible. However, this approach is impractical on wildland/WUI incidents, where smoke can travel long distances and permeate the entire environment. Even when not in direct contact with the smoke source, firefighters are still exposed to hazardous air conditions. While this strategy reflects some awareness of risk, it lacks the depth and effectiveness that could be achieved through formal training and use of department-mandated respiratory equipment. Leadership also mentioned rotating crew members out of heavy smoke, but this remains a reactive measure, insufficient in

an environment where smoke is constantly present, and exposure is unavoidable without proper respiratory protection.

While leadership firefighters were not asked directly about their interest in training, they frequently expressed a desire for training focused on smoke exposure and mitigation strategies to improve safety of their crew. Non-leadership firefighters (100%) expressed a clear interest in receiving formal education or training on smoke exposure reduction, particularly through annual, in-person refresher courses. This willingness demonstrates a higher potential for improving behavioral capability of non-leadership firefighters if such training programs were made available.

Observational Learning

Observational learning plays a crucial role in firefighting, as behaviors, skills, and safety practices are often learned observing more experienced colleagues or leadership (Bandura, 1999). As reflected in the summary of **Table 4.12,** Leadership firefighters universally agreed that they hold significant influence over the behaviors of their crew members. Their actions and attitudes serve as a guide for non-leadership firefighters, particularly regarding the use of safety equipment such as respiratory protection. Leadership generally expressed neutral to positive attitudes toward respiratory protection, with some acknowledging that their perceptions had evolved, particularly due to the COVID-19 pandemic. Despite this, leadership consistently noted that seeing respiratory protection in use during wildland/WUI operations is rare and largely limited to low level forms of protection like bandanas, Nomex shrouds, and N95 masks. Shrouds, while often included as part of firefighters' PPE, are not designed to function as respiratory protection. Their primary purpose is to shield the wearer from ambient radiant heat during wildland firefighting. However, there may be confusion among firefighters about the function of

shrouds, leading to a misconception that they offer some level of respiratory protection. Additionally, bandanas, which are not officially issued by departments, are frequently used by individuals as a more culturally accepted form of protection. This practice may stem from bandanas being modeled by leadership, reinforcing their use. Despite their popularity, bandanas are not respiratory devices and do not offer adequate protection against harmful chemicals and particulates present in smoke. Relying on these inadequate forms of protection highlights a need for better education about proper respiratory safety and the limitations of certain PPE. This is likely due to the lack of a national standard that would offer clear guidance and ensure the availability of standardized respiratory equipment across departments, leading firefighters to depend on varying levels of protection, which may not adequately mitigate the associated risks.

However, concerns about the feasibility of respiratory protection in the context of wildland firefighting persist among leadership. Many reported that the cultural norms and operational challenges (such as concerns about breathability and comfort) contribute to the limited adoption of higher-level protective equipment. Leaderships limited endorsement of respiratory protection coupled with their significant influence, likely reinforces the existing practices observed among non-leadership firefighters. Non-leadership firefighters echoed similar concerns about the rarity of respiratory protection use in the field. Their perceptions of respiratory protection were split, with some showing interest or curiosity in respiratory, while others expressed negative feelings or practical concerns. A notable theme among non-leadership firefighters was associating the use of masks with individuals outside their department or with firefighters who lacked experience, which further contributed to the reluctance to adopt respiratory protection. These mixed responses among non-leadership firefighters reveal that while they may be observing the actions of leadership and peers, their behavior toward

respiratory protection is influenced by the perceived cultural and operational feasibility of using such equipment. Additionally, the absence of consistent modeling of respiratory protection by leadership further diminishes its perceived importance among non-leadership.

This finding is significant because it underscores the role of observational learning in shaping safety behaviors within firefighting teams. The mixed responses among non-leadership firefighters suggest that their behavior toward respiratory protection is heavily influenced by what they observe in their work environment, particularly from leadership and peers. If non-leadership firefighters see that respiratory protection is not consistently used or emphasized by those in leadership positions, they are less likely to adopt these practices themselves, even if they understand the health risks associated with smoke exposure. This demonstrates that behavior change is not driven solely by knowledge but also by observing the actions and attitudes of others, especially those in positions of authority.

The absence of consistent modeling of respiratory protection by leadership is critical because, within the framework of observational learning, leaders act as role models. Their actions convey what is considered important and acceptable within the group. When leadership does not consistently use or advocate for respiratory protection, it sends a message to non-leadership firefighters that these practices are not a priority. This lack of visible commitment weakens efforts to promote respiratory safety, as behaviors are more effectively adopted when they are clearly modeled by those in leadership roles. Therefore, this finding highlights the need for leadership to actively demonstrate and model the consistent use of respiratory protection, reinforcing its importance and fostering a culture that prioritizes safety through observational learning.

Reinforcements

Reinforcements refer to the rewards or consequences that follow a behavior, influencing whether that behavior is repeated or altered (Bandura et al., 199(. For firefighters, these reinforcements are shaped by cultural norms, recognition from peers, and perceived expectations within their community. As reflected in the summary of **Table 4.12,** both leadership and non-leadership emphasized the value of knowledge and experience, highlighting these traits as markers of reliability and competency. This shared belief serves as a positive reinforcement, encouraging expertise in fire management and decision making. However, this reinforcement also perpetuates a culture that favors traditional practices, potentially hindering the adoption of new protective behaviors, such as the consistent use of respiratory equipment, which currently lacking.

Leadership firefighters described the culture of wildland firefighting as being influenced by negative reinforcements, particularly emphasizing a “machismo” attitude. A "machismo" attitude refers to a mindset that emphasizes traditional ideas of masculinity, such as being tough, strong, and not showing vulnerability. It often includes the belief that men should not express emotions, seek help, or show weakness, and may involve a tendency to take risks to prove their strength or courage. This attitude can influence behaviors, making it less likely for someone to prioritize safety measures, like using protective equipment, if they see it as a sign of weakness. These norms discourage the use of respiratory protection, as wearing such equipment is often seen as unnecessary or not feasible among wildland firefighters. This cultural mindset poses a challenge to change, as leadership’s hesitation to prioritize protection subtly reinforces its lack of adoption among their crews. Leaderships hesitation to shift from traditional practiced acts as a form of reinforcement that subtly discourages innovation in safety practices.

This is strongly related to observational learning results, highlighting that cultural attitudes and leadership behaviors are significant barriers to introducing new health and safety practices for respiratory protection. The prevailing "machismo" mindset, coupled with leadership's hesitation to prioritize respiratory protection, reinforces a cycle where the use of such equipment is seen as unnecessary or impractical. Leadership's reluctance to shift from traditional practices subtly signals to their crews that respiratory protection is not a priority, discouraging adoption and innovation in safety practices.

Furthermore, the mixed responses among non-leadership firefighters indicate that while they observe the actions of leadership and peers, their behavior is strongly influenced by the perceived cultural and operational feasibility of using respiratory equipment. Without consistent modeling from leadership, respiratory protection remains undervalued, further diminishing its perceived importance. This combination of cultural norms and leadership behaviors creates a substantial barrier to changing safety practices, as the lack of visible advocacy from leadership continues to discourage non-leadership from adopting new protective measures.

Non-leadership firefighters, while similarly influenced by these cultural norms, exhibited a greater openness to change. They emphasized the importance of advocating for crew safety and expressed a willingness to adopt new behaviors if they saw them modeled or reinforced by leadership. However, their behaviors are still constrained by the lack of reinforcement from leadership, as well as by group norms that prioritize immediate operational efficiency over long-term health protections. Negative reinforcement also plays a role here, as non-leadership firefighters may hesitate to adopt respiratory protection due to concerns about being perceived as inexperienced or non-conforming. Interestingly non-leadership participants were more critical of outdated practices such as "smoke eater" persona, which they viewed as a negative stereotype

associated with unsafe behavior. This signals a potential shift in attitudes among the newer or non-leadership ranks, but without strong reinforcement from leadership or systemic changes, these perspectives may remain underutilized in driving widespread behavior change.

Expectations

Expectations refer to firefighters' beliefs about the potential outcomes of their actions, particularly how their behaviors may influence safety, health, and operational success in the field (Bandura, 1999). As reflected in the summary of **Table 4.12,** In comparing the expectations of leadership and non-leadership firefighters, both groups strongly agree that wildfire smoke contributed to health effects or illnesses. Leadership firefighters emphasize the distinction between different types of smoke, particularly highlighting that smoke from vegetation fires are more "natural" and therefore less hazardous compared to complex, toxic components of WUI smoke. This perception shapes their expectations of the risks they encounter and may influence how they prioritize protective measures during firefighting operations. Leadership firefighters also tend to draw on personal experiences with smoke exposure and its associated health impacts, such as respiratory symptoms and illnesses, reinforcing their belief in the dangers of smoke but potentially underestimating the immediate risk from vegetation smoke alone.

Non-leadership firefighters, while similarly recognizing the health risks of smoke exposure, often expressed uncertainty about the long-term effects, particularly in relation to cancer. Many participants in this group were unsure if wildfire smoke was linked to cancer, indicating a gap in understanding regarding the severity of risks. However, their expectations are largely shaped by their firsthand experiences with both vegetation and WUI smoke, with many describing more immediate and acute health outcomes, such as persistent respiratory symptoms and other illnesses related to their exposure. This direct experience with health issues suggests

that while they share leaderships' general awareness of the risks, their uncertainty about cancer risks may affect how seriously they consider long-term protective measures.

Self-Efficacy

Self-efficacy refers to an individual's belief in their ability to successfully perform specific tasks or behaviors, particularly in challenging situations (Bandura et al., 1999(. Firefighter self-efficacy influences their confidence in carrying out critical tasks such as using protective equipment. As reflected in the summary of **Table 4.12,** when comparing leadership and non-leadership in terms of self-efficacy, both groups expressed strong beliefs in the necessity of respiratory protection in wildland firefighting. Leadership firefighters, however exhibited higher confidence in their ability to address these challenges, often pointing to cultural and practical barriers such as equipment design, breathability, and operational demands as significant hurdles. Despite these challenges, leadership expressed a clear sense of responsibility in finding feasible respiratory protection solutions and emphasized the need for a national standard and enhanced education to address the risks associated with smoke exposure. Their self-efficacy seemed rooted in their experience and understanding of the broader firefighting system, indicating that, although they see the need for change, they also recognize the complexities involved in implementation.

On the other hand, non-leadership firefighters also recognized the necessity of respiratory protection but were more focused on the immediate and personal benefits, such as protecting their health and living long lives. Many non-leadership participants expressed concerns similar to leadership regarding the practicality of respiratory protection, particularly around breathability and comfort. However, their sense of self-efficacy seemed slightly more tentative, as they also expressed a stronger desire for education and clearer understanding on the risks. This reflects a

gap in the confidence to implement protective measures effectively without further support from leadership. While they see the need for change, their concerns about how respiratory protection might impact their operational efficiency were more pronounced.

Implications

The research highlights several significant gaps in the understanding and application of safety practices within wildland firefighting, particularly around respiratory protection and chemical risk awareness. Both leadership and non-leadership firefighters demonstrated limited knowledge about hazardous compounds like PAHs and VOCs, which are known to be present in wildfire smoke. This lack of awareness undermines their ability to effectively assess and mitigate the risks associated with smoke exposure. Future research should focus on developing educational interventions that specifically target these knowledge gaps. Studies that investigate how to best deliver chemical safety training, and how this information can be integrated into existing firefighter education programs, are necessary to enhance the overall health and safety of firefighters. The lack of formal education related to wildland/WUI smoke exposure among leadership and non-leadership firefighters indicated a critical area for improvement. Since the current research shows that both groups are primarily reliant on informal strategies to mitigate smoke exposure, there is a need to explore the efficacy of structured training programs that could enhance behavioral capability.

Leadership plays a critical role in shaping the behaviors and safety practices of non-leadership firefighters. However, the findings suggest that leadership's perception of the infeasibility of respiratory protection in wildland/WUI settings may be inhibiting the broader adoption of such protective measures. Research should focus on the role of leadership in modeling effective safety practices, particularly how to overcome barriers related to cultural

norms and operational constraints. Studies that evaluate the impact of leadership training and interventions that focus on shifting attitudes toward safety equipment could lead to more widespread adoption of respiratory protection.

Cultural norms within wildland firefighting, particularly the “machismo” attitude that discourages the use of respiratory protection, are a significant barrier to improving firefighter safety. The research suggests that these cultural reinforcements, which prioritize operational efficiency and tradition over long-term health protections, must be addressed to drive change. Future research should explore how to shift these cultural norms, focusing on interventions to alter reinforcements surrounding safety practices. Recurring theme in the research was the lack of a national standard for respiratory protection in wildland firefighting. This absence not only leaves departments without clear guidance but also perpetuates inconsistent safety practices. Future research should focus on the development and testing of national policies that provide clear guidance on respiratory protection in wildland firefighting. Such policies should be informed by empirical studies that evaluate the feasibility, comfort, and effectiveness of different forms of respiratory protection in wildland/WUI conditions, with the goal of implementing consistent standards nationally. Future studies could focus on evaluating the effectiveness of training programs that specifically address practical concerns, such as the breathability and comfort of respiratory protection. By demonstrating that protective equipment can be integrated seamlessly into challenging environments without hindering performance, these programs can empower both leadership and non-leadership firefighters to adopt and advocate for safer practices. Emphasizing the reliability, practicality, and cultural acceptance of respiratory protection is essential for fostering greater self-efficacy and encouraging widespread adoption within the firefighting community.

Both leadership and non-leadership firefighters demonstrated a need for greater support to enhance their self-efficacy in implementing respiratory protection. To effectively address this, research should explore interventions that target self-efficacy by providing firefighters with the confidence that respiratory protection will not only reduce their health risks but also enable them to perform physically demanding tasks without compromising their exertion levels. It is important to address concerns that respiratory equipment might be seen as a sign of weakness or inexperience, and instead, reinforce its use as a standard of professionalism and safety.

Education and Training Recommendations for Wildland Firefighters

In light of the findings, several key recommendations for education and trainings are crucial to addressing the gaps identified in wildland firefighting practices, particularly regarding respiratory protection and chemical risk awareness. These recommendations emphasize the need for structured and comprehensive training programs to enhance wildland firefighter health and safety. To improve wildland firefighter safety, particularly in the area of respiratory protection and chemical risk awareness, a coordinated effort across multiple agencies is required. The following recommendations provide a framework for addressing key gaps in knowledge, training, and safety practices, involving relevant agencies and proposing brief implementation strategies.

Comprehensive Chemical Risk Training

The research highlights a significant lack of knowledge among wildland firefighters regarding hazardous compounds such as PAHs, VOCs, benzene, and other toxic substances present in wildfire smoke. To address this gap, state and federal fire agencies should collaborate with occupational safety organizations and academic institutions to develop structured chemical

safety training programs. Effective implementation of this training should involve three key components:

A) Develop standardized, accessible online educational modules: These modules should be specifically tailored to chemical risk awareness related to wildland/WUI smoke exposure. By making them easily accessible, agencies can ensure that foundational knowledge about chemical hazards is available to all firefighters, regardless of location, and can be revisited as needed. This online format provides flexibility and convenience, allowing for self-paced learning and reinforcing fundamental concepts.

B) Integrate hands-on workshops and scenario-based learning: In addition to online education, training academies should include practical, hands-on workshops that emphasize chemical hazards specific to wildland/WUI smoke. Scenario-based learning can be particularly effective, as it allows firefighters to engage in realistic situations where they must identify risks and practice using protective equipment. This approach not only enhances practical skills but also helps firefighters develop the confidence to respond appropriately in actual wildfire settings.

C) Mandate annual refresher courses: Continuous, tiered learning is essential as new information about chemical hazards and safety practices emerges. Mandating annual refresher courses ensures that both leadership and non-leadership ranks remain informed about the latest developments and reinforced on the importance of respiratory protection. These courses should build upon foundational knowledge, gradually introducing more advanced concepts and new research findings, fostering a culture of ongoing education and safety awareness.

By offering continuous, comprehensive learning opportunities through a combination of online modules, practical training, and mandatory refreshers, agencies can cultivate a broad and deep understanding of chemical hazards among firefighters. This approach empowers them to

effectively assess and mitigate the risks associated with smoke exposure, ensuring that safety practices evolve in step with new knowledge and technological advancements.

Structured Respiratory Protection Training

The reliance on informal strategies to mitigate smoke exposure, such as using cloth masks or rotating out of heavy smoke areas, underscores the urgent need for formal respiratory protection training in wildland firefighting. Currently, there is no feasible respiratory protection option specifically designed for wildland firefighting, which presents a critical gap in safety practices. To address this, federal agencies should collaborate with state and local fire departments to develop and implement a national respiratory protection curriculum, while also prioritizing the development and selection of practical, effective respiratory protection solutions tailored to the unique demands of wildland firefighting.

Implementation should include three key steps:

A) Identify and select feasible, lightweight, breathable respiratory protection: This should involve partnering with equipment manufacturers and research organizations to evaluate and test potential solutions that are specifically suited for wildland/WUI conditions. If suitable options are not currently available, efforts should be made to design new equipment that meets these operational demands. This step is essential for addressing the current gap, as no existing respiratory gear fully satisfies the needs of wildland firefighting, where mobility, breathability, and comfort are crucial.

B) Develop hands-on, equipment-specific training sessions: Once a feasible option is identified, comprehensive training programs should be developed to improve self-efficacy among wildland firefighters. These sessions should focus on the proper use of the selected respiratory protection, addressing practical concerns such as breathability, comfort, and the specific operational

challenges faced in wildland settings. Hands-on training will help firefighters gain confidence in using the equipment effectively, ensuring they are prepared to handle real-world conditions.

C) Incorporate respiratory protection training into pre-season preparation and certification: Mandating that respiratory protection training becomes a core component of pre-season wildland firefighter courses and certification requirements will ensure that all firefighters are adequately trained in both the use and maintenance of respiratory equipment. By integrating hands-on training with selected respiratory gear into the preparation and certification process, fire agencies can make sure that safety practices are standardized across all levels, enhancing the overall culture of health and safety.

By focusing on selecting or designing feasible respiratory protection solutions and integrating them into a structured, hands-on training approach, fire agencies can equip firefighters with the appropriate knowledge and tools to reduce their exposure risks effectively. This comprehensive strategy will foster a safer and healthier work environment, empowering firefighters to prioritize their respiratory health without compromising their operational capabilities.

Leadership Training to Model Safety Practices

Leadership within firefighting plays a critical role in shaping the safety practices of their crew, and this research identifies that leadership's perception of respiratory protection as impractical is a significant barrier to broader adoption. To address this, state fire associations should collaborate with leadership training organizations to design targeted programs that help overcome these cultural and operational challenges. Effective implementation strategies should include:

A) Train leadership to model consistent use of respiratory protection on wildland/WUI fire incidents: Leaders need to actively demonstrate the use of respiratory protection during operations, setting a clear example for their crews. This helps to normalize its use and communicate that safety practices are a priority at all levels.

B) Conduct leadership workshops to challenge cultural norms, such as “machismo” attitudes, surrounding the use of respiratory protection: These workshops should encourage leaders to address and shift the traditional mindsets that view respiratory protection as unnecessary or a sign of weakness. Emphasizing the importance of long-term health and operational safety can help leaders advocate for change and promote a culture where protective equipment is seen as essential, not optional.

C) Create leadership accountability through health and safety performance metrics and establish firefighter-led support groups: By incorporating health and safety priorities into performance evaluations, leaders are held accountable for promoting and maintaining safety practices. Additionally, creating support groups led by firefighters can encourage the sharing of best practices, fostering a collective effort to improve safety standards.

By equipping fire leaders with the knowledge, confidence, and accountability to model appropriate safety behaviors, agencies can create a top-down influence that promotes a safer culture. This approach ensures that leadership is not only endorsing but actively demonstrating and reinforcing the importance of respiratory protection, making it an integral part of wildland firefighting operations.

Addressing Cultural Norms Through Awareness Campaigns

Cultural norms, such as the “machismo” attitude that discourages the use of respiratory protection, are a significant barrier to improving wildland firefighter safety. To overcome these deeply ingrained attitudes, fire unions and health organizations should collaborate on launching national awareness campaigns aimed at shifting perceptions and promoting the importance of respiratory protection. Effective implementation of these campaigns should include:

A) Use data to create educational content linking respiratory protection to long-term health outcomes: Real-world data should be leveraged to highlight the health benefits of using respiratory equipment, emphasizing how it reduces the risks associated with smoke exposure and supports long-term well-being and career longevity. By demonstrating a direct link between respiratory protection and sustained health, these campaigns can help shift the narrative from short-term convenience to long-term safety.

B) Share anecdotal experiences and best practices through personal impact stories of firefighters affected by wildland/WUI smoke exposure: Developing case studies that feature real stories of firefighters who have experienced the adverse effects of smoke exposure can make the issue more relatable and compelling. Sharing success stories from departments that have successfully adopted respiratory protection practices can provide best practices and inspire others to follow suit. These personal experiences can serve as powerful testimonials that reinforce the importance of protective measures.

C) Broadly spread campaigns that encourage respiratory protection usage and chemical risk awareness via media and social platforms: To ensure widespread reach and engagement, campaigns should collaborate with media outlets and utilize social platforms to disseminate messages. By using platforms that firefighters are already familiar with, the campaigns can

effectively raise awareness and promote behavior change at all levels within the firefighting community. Messaging should focus on reframing respiratory protection as a symbol of strength, professionalism, and responsibility rather than a sign of weakness, thus fostering a healthier and safer work environment.

By implementing these strategies, awareness campaigns can help shift cultural norms within the firefighting community, emphasizing that respiratory protection is essential for both immediate safety and long-term health. Reframing protective equipment as an integral part of professional firefighting can lead to broader acceptance and consistent use, ultimately contributing to a safer and more health-conscious culture in wildland firefighting.

Establishing National Standards for Respiratory Protection

One of the major barriers to the widespread adoption of respiratory protection in wildland firefighting is the absence of a national standard. To address this, federal bodies such as OSHA, in collaboration with wildland fire organizations, should take the lead in developing enforceable national standards for respiratory protection tailored to wildland/WUI environments. Implementing these standards would involve three critical strategies:

A) Conduct additional research on the effectiveness of various respiratory protection options in wildland/WUI settings: This research should focus on testing and evaluating different devices to identify and select the most feasible solutions that meet the unique demands of wildland firefighting. By gathering empirical data, agencies can ensure that the selected equipment is both effective and practical for real-world use, addressing current gaps in protective gear.

B) Develop and implement national guidelines that provide clear outlines on when and how to use respiratory protection: Establishing uniform policies across all departments will help ensure consistent application of safety practices. These guidelines should include specific contexts and

scenarios where respiratory protection is essential, making it easier for firefighters to understand and follow safety protocols. A standardized approach will reduce disparities in safety practices across various firefighting organizations, promoting the consistent use of appropriate protective equipment.

C) Establish a dedicated task force to develop, oversee, and adapt national standards for wildland firefighting respiratory protection: This task force would be responsible for continuously reviewing and updating the standards to keep pace with new research, technology, and field conditions. By maintaining oversight, the task force ensures that standards remain relevant, effective, and adaptable, supporting a safer working environment for firefighters nationwide.

By implementing these strategies, federal and state agencies can ensure that respiratory protection in wildland firefighting becomes a consistent and standard practice. Creating national standards will not only reduce disparities in safety protocols but also promote the widespread adoption of effective protective equipment, ultimately leading to improved health and safety outcomes for all firefighters in wildland/WUI settings.

Limitations

Several limitations should be considered when interpreting the findings of this study. First the data relied heavily on self-reported information, which introduces the potential for bias. Firefighters may have inaccurately reported their knowledge or behaviors related to respiratory protection due to recall issues or social desirability bias. However, it is important to note that the data acquired aligns with previous research, suggesting that the findings remain consistent with broader trends in the field.

Additionally, the geographic distribution of participants may be seen as a limitation, with the majority coming from California. This regional overrepresentation may limit the

generalizability of the findings to other areas where fire conditions, practices, and firefighter culture may differ. Furthermore, the study's focus on state and U.S. Forest Service firefighters may not fully capture the experiences of local or municipal firefighters, narrowing the scope of applicability. However, it's worth noting that California firefighters are often regarded as elite due to the state's challenging terrain and constant threat of wildfires throughout the year. Many firefighters view California as setting the standard for protection strategies and tactics, which may lend credibility to the findings despite the geographic concentration of participants.

The study does not include direct measurements of health outcomes, such as lung function or respiratory illness rates, making it difficult to directly link the use of respiratory protection or the lack thereof to specific health consequences. Additionally, while perceived knowledge and chemical hazards were assessed, no objective measures of actual knowledge were included. This introduces the possibility that firefighters may overestimate their understanding of hazardous compounds, potentially influencing their behavior.

Lastly, the study focuses on respiratory protection in general without evaluating the effectiveness of specific devices in wildland firefighting conditions. Future research should explore the practical application and effectiveness of various respiratory protection devices in the field, under diverse environmental conditions. Despite these limitations, the study provides important insights into the knowledge gaps and barriers to respiratory protection use among wildland firefighters, highlighting the need for targeted interventions and improved safety protocols.

Conclusions

To summarize the aims of the study, the research focused on identifying gaps between firefighter knowledge and practices and leadership perceptions of these aspects specifically

regarding respiratory equipment, health and safety knowledge, as well as chemical risk awareness. The study also examined the gaps between leadership and non-leadership firefighters in their understanding of the feasibility of respiratory equipment, as well as perceived barriers to implementing standard respiratory protections in the future. The conclusion of this research highlights significant knowledge gaps regarding hazardous compounds and respiratory protection within the wildland firefighting community.

Both leadership and non-leadership firefighters exhibit limited awareness about the dangers of smoke exposure, particularly harmful chemicals such as PAHSs and VOCs, resulting in low self-efficacy in assessing these risks. Addressing this gap through targeted educational programs is critical for empowering firefighters to prioritize respiratory protection. The absence of formal training on chemical hazards and the uniform lack of knowledge across leadership and non-leadership roles underscores the need for training interventions that span all ranks. Leveraging observational learning and role modeling, particularly by leadership, can help reinforce the adoption of protective behaviors, fostering a consistent culture of safety within firefighting teams.

The research also emphasizes the inadequacy of current respiratory protection methods, such as cloth masks and bandanas, and highlights the need for more effective solutions. Operational challenges, discomfort, and unsuitability of certain equipment for wildland firefighting, lowers self-efficacy in using respiratory protection. Designing lightweight, comfortable, and practical alternatives that meet the specific needs of wildland firefighting will enhance firefighters' confidence and ability to use respiratory protection effectively. To overcome cognitive and environmental barriers, fire agencies should develop and promote policies that prioritize health outcomes through education on the risks of smoke exposure and the

benefits of respiratory protection. Agencies could also consider hosting seminars led by retired firefighters, who can provide firsthand accounts of the health problems they developed while on duty. These personal narratives, as conveyed by firefighters in the interviews, were often pivotal in raising awareness, making the risks of smoke exposure more tangible and relatable. Such accounts have been shown to generate interest, foster a deeper understanding of the hazards, and motivate a stronger commitment to adopting protective measures, underscoring the critical need for effective respiratory protection policies.

Addressing cultural norms, such as “machismo” attitude that discourages safety measures, will be key to promoting long-term behavior change. Additionally, the establishment of a national standard for respiratory protection in wildland firefighting is crucial for providing departments with clear guidance, ensuring consistent safety practices, and enhancing firefighter’ confidence in using proper protective equipment.

Future research should focus on developing and testing interventions that enhance self-efficacy, address concerns about respiratory equipment practicality, and evaluate the role of leadership in promoting respiratory protection. Studies exploring the development of national policies and training programs that align with specific demands of wildland firefighting will be essential in driving progress toward a safer firefighting culture.

TABLE 3.1 . Social cognitive theory factors, definitions and key informant interview questions for firefighter and non-firefighter leadership interviews.

Social Cognitive Theory components	Social Cognitive Theory Factor Definition	Firefighter Leadership Questions	Non-Leadership Firefighter Questions
Reciprocal Determinism	This refers to the dynamic and reciprocal interaction of a person (individual with a set of learned experiences), environment (external social context), and behavior (responses to stimuli to achieve goals).	A) Do you believe there is chemical risk associated with firefighting? B) Describe what you know about smoke exposure. C) Have you ever heard of Volatile Organic Compounds VOC's? D) Have you ever heard of Polyaromatic hydrocarbons PAH'S? E) In your opinion do you believe respiratory protection is a priority for leadership?	A) What are your thoughts on chemical risks associated with wildland firefighting? B) Describe what you know about smoke exposure. C) What do you know about Volatile Organic Compounds, which are also called "VOCs?" D) What do you know about Polyaromatic hydrocarbons PAH'S E) In your opinion do you believe respiratory protection is a priority for leadership? F) In your opinion, does your leadership educate you on the best available health and safety practices?
Behavioral Capability	This refers to a person's actual ability to perform a behavior through essential knowledge and skills. In order to successfully perform a behavior, a person must know what to do and how to do it.	A) Do you have any formal education or training on chemical risk associated with smoke exposure? B) Are you aware of any mandatory procedures or practices to reduce smoke exposure from your department? C) would you be willing to receive training on smoke exposure and ways to mitigate exposure in the WUI?	A) Have you ever received training on the health risks associated with smoke exposure, specifically? B) Are you aware of any mandatory procedures or practices to reduce smoke exposure from your department? C) would you be willing to receive training on smoke exposure and ways to mitigate exposure in the WUI?

Observational Learning	This asserts that people can witness and observe a behavior conducted by others, and then reproduce those actions. This is often exhibited through "modeling" of behaviors.	A) What influence do you perceive leadership to have over their crew? B) What is your perception of firefighters that were wearing masks in the field? C) Do you currently see respiratory protection while on wildland incident?	A) Who enforces health and safety procedures? B) What is your perception of firefighters that are wearing masks in the field? C) Do you currently see respiratory protection while on wildland incident?
Reinforcements	This refers to the internal or external responses to a person's behavior that affect the likelihood of continuing or discontinuing the behavior.	A) In your opinion, what symbolizes a reliable and experienced firefighter? B) Do you believe you can tell if a firefighter is new to the job or inexperienced just by looking at them? C) How would you define the culture around respiratory protection within the wildland firefighting community?	A) In your opinion, what symbolizes a reliable and experienced firefighter? B) Do you believe you can tell if a firefighter is new to the job or inexperienced just by looking at them? C) Have you heard of the term “Smoke-eater” before?
Expectations	This refers to the anticipated consequences of a person's behavior.	A) In your opinion, do you believe smoke from fires play a role in causing health effects or illnesses? B) In your opinion, is there a difference between vegetation smoke and smoke from a wildland urban interface fire?	A) In your opinion, do you believe smoke from fires plays a role in causing health effects or illnesses? B) In your opinion, is there a difference between vegetation smoke and smoke from a wildland urban interface fire?

Self-efficacy	This refers to a person's level of confidence in their ability to successfully perform a behavior.	A) Do you believe there is a need for respiratory protection while in the field? B) What would it take for successful role out of respiratory protection. C) Why do you believe respiratory protection has been hard to implement when it comes to wildland firefighting? D) What criteria would respiratory equipment have to meet to be accepted by wildland firefighters?	A) Do you believe there is a need for respiratory protection while in the field? B) What do you believe it would take to implement a successful respiratory standard role out among wildland firefighters. C) If your leadership implemented new respiratory protection equipment tomorrow, how would that affect you and your job duties? D) What criteria would respiratory equipment have to meet to be accepted by you?

Table 4.1. Participant Gender, Position, and Age Distribution.

Gender	**N**	**Percent**
F	55	7.3
M	701	92.7
Position	**N**	**Percent**
Firefighter	408	53.5
Leadership	127	16.6
Mid Leadership	228	29.9
Age	**N**	**Percent**
18 - 24 years	43	5.6
25 - 34 years	208	27.2
35 - 44 years	259	33.8
45 - 54 years	175	22.8
55 - 64 years	45	5.9
65 years or older	36	4.7

Table 4.2. Wildland Firefighter Agency Distribution.

Agency	N	Percent
BIA	1	0.13
BLM	5	0.65
Contractor/Private	4	0.52
FWS	2	0.26
Local/Municipal	54	7.06
NPS	3	0.39
Other	28	3.66
State	583	76.21
USFS	85	11.11

Table 4.3. Distribution of Participants Geographically.

State	N	Percent
Alaska	2	0.27
Alberta	2	0.27
Alberta, Canada	1	0.13
Arizona	22	2.94
Arkansas	1	0.13
Australia	1	0.13
Bc Canada	1	0.13
British Columbia	1	0.13
California	640	85.45
Canada	1	0.13
Colorado	10	1.34
District of Columbia (DC)	1	0.13
European Union	1	0.13
Florida	2	0.27
Georgia	1	0.13
Idaho	6	0.8
Italia	1	0.13
Kansas	1	0.13
Kentucky	3	0.4
Maryland	2	0.27
Michigan	1	0.13
Montana	4	0.53
Nebraska	2	0.27
Nevada	1	0.13
New Brunswick Canada	1	0.13
New Mexico	4	0.53
Nigeria	1	0.13
North Carolina	1	0.13
Ohio	3	0.4

Oklahoma	1	0.13
Oregon	6	0.8
Pennsylvania	1	0.13
South Carolina	1	0.13
South Dakota	2	0.27
Tennessee	1	0.13
Texas	2	0.27
Utah	3	0.4
Virginia	2	0.27
Washington	8	1.07
Wyoming	4	0.53

Table 4.4. Firefighters' Familiarity with Chemical Compounds in Wildfire Smoke.

Chemical	"0" Count	"0" Row pct	"1" Count	"1" Row pct	"2" Count	"2" Row pct	"3" Count	"3" Row pct	"4" Count	"4" Row pct
PM	50	6.50%	130	17.00%	254	33.20%	218	28.50%	113	14.80%
PAH	225	29.50%	206	27.00%	209	27.40%	92	12.10%	31	4.1%%
VOC	148	19.40%	230	30.10%	214	28.00%	117	15.30%	55	7.20%
BENZENE	87	11.40%	270	35.40%	211	27.70%	135	17.70%	60	7.90%
HCN	45	5.90%	170	22.30%	272	35.70%	192	25.20%	82	10.80%
NOX	44	5.80%	251	32.90%	263	34.50%	146	19.10%	59	7.70%
SOX	73	9.60%	268	35.30%	246	32.40%	122	16.10%	51	6.70%
PFAS/PFOA	159	20.90%	218	28.60%	202	26.50%	123	16.10%	60	7.90%
CO	1	0.10%	25	3.30%	145	19.00%	328	42.90%	266	34.80%
TOTAL	832		1768		2016		1473		777	

Note: The Likert scale used in this study categorizes responses as follows: 0 = "Never heard of it," 1 = "Heard of it," 2 = "Know a little about it," 3 = "Know a fair amount about it", and 4= "Know it very well".

Table 4.5. ANOVA Table Assessing Interaction Between Chemicals and Leadership Levels

Variable	LR Chisq	Df	Pr(>Chisq)
Chemicals	1455.16	32	<2e-16 ***
Leadership	120.47	4	<2e-16 ***
Chemicals * Leadership	28.47	32	0.646

Table 4.6. Current Usage and Types of Respiratory Protective Equipment Among Wildland Firefighters

Current Use	N	Percent
No	654	85.9
Unsure	11	1.4
Yes	96	12.6

Type Used	N	Percent
APR	21	3
CLOTH	473	67.8
N95	110	15.8
PAPR	2	0.3
SCBA	92	13.2

Note: Some of those who self-reported "No" in "Current Use" table later selected respiratory protection used in "Type Use". Many firefighters reported use of more than one type, so the total number of "Type used" responses is larger than the number of participants. The following acronyms are defined as follows: air-purifying respirator (APR), powered air-purifying respirator (PAPR), and self-contained breathing apparatus (SCBA).

Table 4.7. Common Concerns Preventing the Use of Respiratory Protection Among Wildland Firefighters

		Concern Level				
		"0"	**"1"**	**"2"**	**"3"**	Total
Size / Weight	Count	167	109	276	185	737
	Row pct	22.70%	14.80%	37.40%	25.10%	
Simplicity	Count	229	193	215	95	732
	Row pct	31.30%	26.40%	29.40%	13.00%	
Interference	Count	177	157	273	127	734
	Row pct	24.10%	21.40%	37.20%	17.30%	
impaired Vision	Count	94	108	318	216	736
	Row pct	12.80%	14.70%	43.20%	29.30%	
Impaired Communication	Count	64	83	304	287	738
	Row pct	8.70%	11.20%	41.20%	38.90%	
Impaired Breathing	Count	57	63	145	475	740
	Row pct	7.70%	8.50%	19.60%	64.20%	
Comfort / Fit	Count	69	100	287	276	732
	Row pct	9.40%	13.70%	39.20%	37.70%	
Appearance	Count	490	173	45	24	732
	Row pct	66.90%	23.60%	6.10%	3.30%	
Personal Beliefs	Count	485	148	51	36	720
	Row pct	67.40%	20.60%	7.10%	5.00%	
Total	Count	1,832	1,134	1,914	1,721	6,601

Note: The Likert scale used in this study categorizes responses as follows: 0 = "Not concerning at all" 1 = "Least concerning 2 = "Moderately Concerning," and "3 = "Most concerning".

Table 4.8. Common Concerns Comparison Between Leadership Levels ANOVA

Type II ANOVA

Variable	LR Chisq	Df	Pr(>Chisq)
Common Concerns	2590.25	24	< 2.2e-16 *
Leadership	11.46	3	0.009*
Common Concerns * Leadership	77.21	24	0.002*

Table 4.9. Common Concerns Comparison Between Leadership Levels Tukey Test

Concerns	Concern Level	SE	Df	T Ratio	P-Value
Size / Weight	**0**	0.14	54	-3	0.0041*
	1	0.161	54	-1.581	0.1198
	2	0.117	54	2.83	0.0065*
	3	0.132	54	2.626	0.0112*
Simplicity	**0**	0.124	54	-2.636	0.0109*
	1	0.129	54	-0.379	0.7058
	2	0.125	54	1.301	0.1989
	3	0.167	54	1.283	0.2051
Interference with Gear	**0**	0.132	54	0.212	0.833
	1	0.138	54	-0.978	0.3326
	2	0.115	54	0.944	0.3495
	3	0.149	54	-0.011	0.9912
Impaired Vision	**0**	0.168	54	0.293	0.7703
	1	0.16	54	0.258	0.7976
	2	0.115	54	-0.092	0.9271
	3	0.128	54	-0.625	0.5343
Comfort / Fit	**0**	0.194	54	0.246	0.8067
	1	0.174	54	-2.03	0.0472*
	2	0.123	54	1.629	0.1092
	3	0.124	54	0.843	0.4032
Appearance	**0**	0.215	54	2.691	0.0095*
	1	0.232	54	3.551	0.0008*
	2	0.3	54	0.891	0.3768
	3	0.561	54	-2.974	0.0044*
Personal Beliefs	**0**	0.137	54	0.474	0.6375
	1	0.168	54	1.583	0.1193
	2	0.235	54	-0.502	0.6177
	3	0.27	54	-0.79	0.4332

Note: The Likert scale used in this study categorizes responses as follows: 0 = "Not concerning at all" 1 = "Least concerning 2 = "Moderately Concerning," and “3 = "Most concerning". Significant differences are indicated by asterisks *.

Table 4.10. Health Motivators for Respiratory Protection Usage

		Importance Level				
		"0"	**"1"**	**"2"**	**"3"**	Total
Improved Respiratory Health	Count	30	84	184	446	744
	Row pct	4.00%	11.30%	24.70%	59.90%	
Cancer Risk Reduction	Count	12	52	123	555	742
	Row pct	1.60%	7.00%	16.60%	74.80%	
Improved Breathing	Count	48	100	184	411	743
	Row pct	6.50%	13.50%	24.80%	55.30%	

Table 4.11. Key Informant Interviewee Demographics (n=27)

Gender	
F	5
M	22
Leadership Positions	
Leadership	16
Non-Leadership	11
Race / Ethnicity	
White	20
BIPOC	7
Rank	
Captain	4
Assistant Captain	1
Firefighter	10
Firefighter Paramedic	4
Deputy Fire Chief	2
Battalion Chief	6
Agency	
USFS	10
Bonita Sunnyside Fire Protection District	1
The County of Los Angeles Fire Department	3
The Nature Conservancy	1
San Bernadino County Fire	3
National Park Service	1
Cal Fire	1
Austin Fire Department	1
Scottsdale Fire Department	3
British Columbia Wildfire Service.	1
Long beach fire department	1
Pala Fire Department	1

Figure 4.12. Key Informant Interview Results Summary and Thematic Quotes

Reciprocal Determinism	
Leadership Firefighters	**Non-Leadership Firefighters**
100% agreed chemical risks are associated with firefighting and can lead to illness.	86.7% agreed firefighting posed chemical risks and linked smoke exposure to illness and cancer.
63.6% of participants unfamiliar with PAHs, and 72.8% unfamiliar with VOCs.	100% of participants unfamiliar with PAHs, and 93.3% unfamiliar with VOCs.
63.6% believed respiratory protection was not a priority, citing lack of feasible equipment and increased cancer rates. Thematic Quotes: *Yes, it is. Again, even though we don't have anything yet for brush fires. But it's definitely been a priority for, on the other side, for our structure firefighting. It is a priority for the department. I just, I don't know how we're gonna wear a mask when we're out there fighting the brush fire.* (Subject 5, Battalion Chief)	76.9% believed respiratory protection was not a priority for leadership, citing lack of mandated procedures and equipment. Thematic Quotes: *Because if it was, there would have been something done about it a long time ago. And I know it's been talked about for a while, but it would have been more streamlined like it is in the structure world.* (Subject 22, Firefighter paramedic)
	64.3% of participants believed leadership educated them on best available practices Thematic Quotes: *Yes, my captain, he had been with the organization, for a long time and he was really into a lot of health and safety stuff, so he was always looking out for us*. (Subject 8, Firefighter)
Behavioral Capability	
Leadership Firefighters	**Non-Leadership Firefighters**
91.6% reported having no formal training on wildland/WUI smoke exposure.	85.7% reported having no formal training on wildland/WUI smoke exposure.
91.6% reported that they were unaware of agency-mandated smoke exposure reduction practices.	100% reported that they were unaware of agency-mandated smoke exposure reduction practices
The most commonly reported Informal strategy to reduce exposure was "Staying out of direct smoke".	The most commonly reported Informal strategy to reduce exposure was "Staying out of direct smoke".

Thematic Quotes: *I mean, I just, I just kinda keep my guys out of smoke as much as possible but I mean, that's my personal mitigation to it.* (Subject 1, Captain)	Thematic Quotes: *No, really. We just try to, like I said, stay out of it. It's the best you could do.* (Subject 8, Firefighter)
	100% of non-leadership firefighters express interest in formal training in the form of "in-person, annual refresher"
Observational Learning	
Leadership Firefighters	**Non-leadership Firefighters**
100% of participants acknowledged leadership had significant influence over crew members.	100% acknowledged captains, supervisors, and managers enforce health and safety procedures among crew members.
Perceptions of respiratory protection was viewed positively or neutrally Leadership did express general concerns about breathability in the context of wildland firefighting duties and cultural norms. Thematic Quotes: *Good on him. You know, I think that, to me, it's an example of leading up.* (Subject 24, Captain) *I would have no problem with that. We don't provide those, but I would have no problem with that whatsoever.* (Subject 29, Deputy Fire Chief)	Perceptions of respiratory protection were viewed with both intrigue and negative feelings. Common negative themes: concerns about breathability, impracticality of mask use, and the association of mask use with individuals not part of the agency/department. Thematic Quotes: *I'm going to ask them about it… like how it works because my curiosity, maybe I'll try it out. You know, you know?* (Subject 8, Firefighter) *I've not seen a primary person wear a mask. So, if I see someone, I think, Oh, they're probably not primary. They're probably on the fire in a different capacity. And I guess the last time that I saw an individual in a mask, I thought, oh, that's nice for them that they get to do that. And also like, wow how impractical for our jobs.* (Subject 19, Firefighter)
Respiratory protection use in the field was also rare, limited to bandanas, Nomex shroud and cloth / N95 masks. Thematic Quotes: *I would say less than 10% [of wildland firefighters wear respiratory protection]. Almost nothing that would qualify formally as like a, a respirator or a mask that's intended to intentionally block any type*	Respiratory protection use in the field was also rare, limited to bandanas, Nomex shroud and cloth / N95 masks. Thematic Quotes: *Yeah, I don't see anybody wearing masks. I only see people wearing handkerchiefs, and they're usually not agency people. Usually, if someone's wearing a*

of particulate matter. A lot of times what you're seeing are just like cloth or some type of elastic band with Nomex or some type of fire-resistant material that can be pulled up over the nose and mouth. (Subject 11, Captain)	*handkerchief, you can tell like they haven't been in fire for very long.* (Subject 15, Assistant Captain)
Reinforcements	
Leadership Firefighters	**Non-leadership Firefighters**
Leadership described experienced firefighters using the following characteristics: "knowledge and experience" Thematic Quotes: *Reliable and experienced. Well, experience, really. Comes down to doing the job. Being on a number of different types of fire and having both the classes the trainings under their belt. Along with being out there in the environment and seeing these things, I think, you know, to me the experience piece of it. Reliable is the person who can understand the job. See the job through and get it done.* (Subject 18, Battalion Chief)	Non-leadership described experienced firefighters using the following characteristics: "knowledge and experience" and "advocacy for crew and crew safety" Thematic Quotes: *A reliable and experienced firefighter is sets and reps. Knowing, like, being on fires, not just being trained into fires. The ability to make sound decisions and look out for their people. (Subject 16, Firefighter)* *Yeah. Someone who is dependable, calm under situations, and someone who can problem solve quickly under pressure and that has your back…Someone who keeps you safe.* (Subject 27, Firefighter)
81.8% of leadership agreed they can identify novice firefighters by appearance. Novice firefighters were identified based on: behavior cues, age, and clean or new gear. Thematic Quotes: *If he has like new equipment, right? His turnouts or his brush gear or his helmet or everything looks new. It's got brand new boots, shiny boots, and he's young. I would think, this guy's, you know, he's a rookie or he's new, right?* (Subject 5, Battalion Chief) *I think you can tell by how they, how they move. I think you can tell by how the how they act. I think you could tell by I know one big giveaway; huge giveaway is that old firefighters don't tell stories anymore.* (Subject 9, Battalion Chief)	85.7% of non-leadership agree they can identify novice firefighters by appearance. Novice firefighters were identified based on: behavior cues and clean or new gear. Thematic Quotes: *Just their behavior. Their body, language. How they, how they walk around.* (Subject 22, Firefighter paramedic) *The dirtier you're yellow, it means like you're more seasoned, it means you, you know, you've seen more action, you know, what you're doing. Having those super clean super crisp Nomex.* (Subject 12, Firefighter)

Leadership described the culture surround Respiratory protection as: "Resistant to respiratory protection" with "machismo" attitudes prevailing. Thematic Quotes: *Yeah, the culture, kind of you know. I don't know if it's so much an accepted practice as much as it should be. I think there are some stigmas that come along with people who wear respiratory protection. If it were required by all agencies to do, and more agencies were adopting of that and enforcing of that. I think that's really, my opinion, the only way to curb the cultural norms. I think that's really the only way to kind of change the culture.* (Subject 18, Battalion Chief) *It's non-existent. We've got older folks that just, you know, yeah, they like, it's like, it's a macho thing, you know, with the smoke and all that stuff. You probably have heard that. But That's the way that culture is. The fire services, putting masks or anything on people might, in the world of vegetation fires, might be a difficult hurdle to get over.* (Subject 29, Deputy Fire Chief)	The term "Smoke Eater" was associated with outdated, unsafe practices Only 62.5% had ever heard of the term "Smoke Eater". Thematic Quotes: *It's a corny thing that usually firefighters that don't really fight fire, say, because they think it's cool. But if you actually fight fire and fight fire consistently, then you already know that the phrase exists, but you don't call yourself that.* (Subject 23, Firefighter paramedic) *I guess I've heard it more as in like eating smoke. Not smoked eater. So, when I've heard eating smoke, that just means that you have been inhaling a lot of smoke. It's been very dense.* (Subject 19, Firefighter)
Expectations	
Leadership Firefighters	**Non-leadership Firefighters**
100% agreed smoke from wildfires causes health effects	100% agreed smoke from wildfires causes health effects
62.5% believed smoke produced from vegetation fires were viewed as less harmful than WUI smoke Reasoning: "vegetation combustion was natural" or "taste, smell or visual appearances " Thematic Quotes: *Yeah, so vegetation fires are mostly part of the combustion of natural materials. Like, oak trees, manzanita, sage, brush, grass. But when those vegetation fires start to impact wildland urban interface areas. The structures when they catch fire are now burning products of combustion that are made by my petroleum products.* (Subject 3, Deputy Fire Chief)	100% believed smoke produced from vegetation fires were viewed as less harmful than WUI smoke Reasoning: "taste, smell or visual appearances " or "WUI related illness" Thematic Quotes: *But I do feel that….if it's… purely organic material burning even though it's not good to breathe it but it's a lot better than plastics burning or any kind, any kind of petroleum product, that we have. That's why I mentioned earlier about being in the urban interfaces, it is more of a sketchy on the inhalation issues.* (Subject 16, Firefighter)
90.9% had personal experience with smoke exposure and poor health outcomes: Themes: "chronic / acute respiratory symptoms", "Flu-like symptoms" or "knowing a firefighter who has died from cancer"	100% had personal experience with smoke exposure and poor health outcomes: Themes: "chronic / acute respiratory symptoms", "Flu-like symptoms" or "coughing black mucus"

Thematic Quotes: *I was assigned to the Woolsey fire in 2018 for 20 to 24 days and after I was released from the fire back to my normal duties, I experienced a significant bronchitis. I went and was treated by a doctor; pulmonologist and it took 3 to 4 months to relieve the symptoms of bronchitis and he attributed to the exposure to the smoke on the Woolsey fire.* (Subject 3, Deputy Fire Chief) *I have had a buddy who was in the forest service for about 18 years, he just recently passed away. He ended up getting, I think it was leukemia. And they deemed it that it was work related from smoke exposure.* (Subject 1, Captain)	Thematic Quotes: *Early October of 2020, last role of the season, we were fighting the Mullen fire in southern Wyoming that eventually blew into the in northern Colorado. You're just sitting there eating smoke all day every day and that was my 1st wildfire season where for the majority of the season or off season after that I had like chronic bronchitis undiagnosed but like I could not stop coughing. I had a persistent cough for about 4 or 5 months after that. Just that one fire alone*. (Subject 12, Firefighter) *And then, after I had that burn. After I was um helping with that burn, and I was coughing up black stuff.* (Subject 15, Assistant captain)
Self-Efficacy	
Leadership Firefighters	**Non-leadership Firefighters**
90.9% believed respiratory protection was necessary for wildland/WUI firefighting, citing cancer prevention and smoke exposure reduction	78.9% believed respiratory protection was necessary for wildland/WUI firefighting, but expressed concerns about breathability and feasibility
Themes in respiratory protection implementation challenges described by leadership: lack of feasible equipment, intense physical demands of the job, and cultural norms Thematic Quotes: *Because of the culture, it's the culture, these guys, just like the old school structure firefighters that…A dirty helmet, a dirty coat like smoke, it shows that you did something.* (Subject 26 , Captain) *Well, the 1st one is. Coming up with the design that's effective enough. That's lightweight enough. That won't encumber their ability to work. It's an environment you know you have to understand, it's typically warm. You know, we don't have brush fires in the winter when it's 60 degrees. We have brush fires when it's 90 degrees in California. So, it's 90 degrees out or it's 85 degrees out at 2 o'clock in the morning. You're pulling hose up an 8-degree slope 12-degree slope, in rocks, you're sweating. And so, you need some sort of protection that will absorb moisture. And clear the air and allow you to breathe effectively. And lightweight enough so that*	Themes in respiratory protection implementation challenges described by non-leadership: concerns about breathability, issues with equipment weight, and the reduction on operational efficiency. Thematic Quotes: *It's hard to work out with a Covid mask on. And so, I think it would slow people down and take a while for them to get into the comfort of working hard with something covering their face. So, it would slow things down while we adapt.* (Subject 15, Assistant Captain) *Hey, it depends on what the equipment is. I mean, if it's, you know, we gotta carry a tank, you know, 50-pound tank and masks or whatever. That's really gonna affect what we do.* (Subject 10, Firefighter) *I guess it just depends on how the equipment is. Like if it makes it hard to do our day-to-day operations, it would be different if it's something simple. That's still easy to operate and normally it wouldn't be that big a deal, but I'm sure it would be*

it's not so cumbersome. (Subject 13, Battalion Chief)	*something to get used to.* (Subject 2, Firefighter paramedic)
Essential criteria for respiratory protection described by leadership: lightweight, breathable, and comfortable Thematic Quotes: *I think you know you need some kind of filtration system, that allows the individual to be climbing up a steep hill, or doing some of the most strenuous work that you can do, not only hiking up the steep hill, but working a steep hill. For sometimes miles.* (Subject 18, Battalion Chief) *It's got to be something that's lightweight. That it's packable.* (Subject 26, Captain)	Essential criteria for respiratory protection described by non-leadership: lightweight, breathable, comfortable, and cost effective Thematic Quotes: *I think it would have to be like, lightweight, very comfortable and very easy to breath in.* (Subject 20, Firefighter) *Something that doesn't hinder breathing or work that crews do on, Initial Attacks. Allows you to do your job for extended periods of time, without causing too much hindrance on your capabilities [then] without one.* (Subject 22, Firefighter paramedic)
Leadership recommendations for effective implementation of respiratory protection: "National standard" and "education on hazards" Thematic Quotes: *Just like I said, agency-wide. Mandatory. Revamping Redbook standards. I think.* (Subject 24, Captain) *Well, kind of what we're doing right now, you know, if you can. If you can have some concrete data. That's helpful. I mean look at the fire service over the last 100 years we've made strides to where we are now. Is that what the next step is, is that something that we could do? We would need the data. Does the data have the support of it? It would have to come from the leadership. You know, the tone is gonna have to come from the top, you know.* (Subject 29, Deputy Fire Chief)	Non-leadership recommendations for effective implementation or respiratory protection: "Education on hazards" and "cultural change" Thematic Quotes: *Education. Prove that it will be better for them in the long run. Everyone has to understand why they're doing something.* (Subject 21, Firefighter) *I think it would take just leadership kind of implementing it. Putting out the data out there, and like kind of seeing hard numbers. We're all pretty visual people. So, collecting data from like a lot of wild firefighters and seeing what they're experiences are…the ones that are in smoke all the time.* (Subject 27, Firefighter)
63.6% of leadership believe respiratory protection is something firefighters actively want	Themes is health motivators for use of respiratory protection among non-leadership firefighters: "Improving long term health" and "living long to enjoy family" Thematic Quotes:

	I would like to live a very long life, and a very healthy life and be able to enjoy it. Grow old and go finish a career as well as watch my children grow up and have grandkids, watch my great grandkids and be able to enjoy that. (Subject 22, Firefighter paramedic)

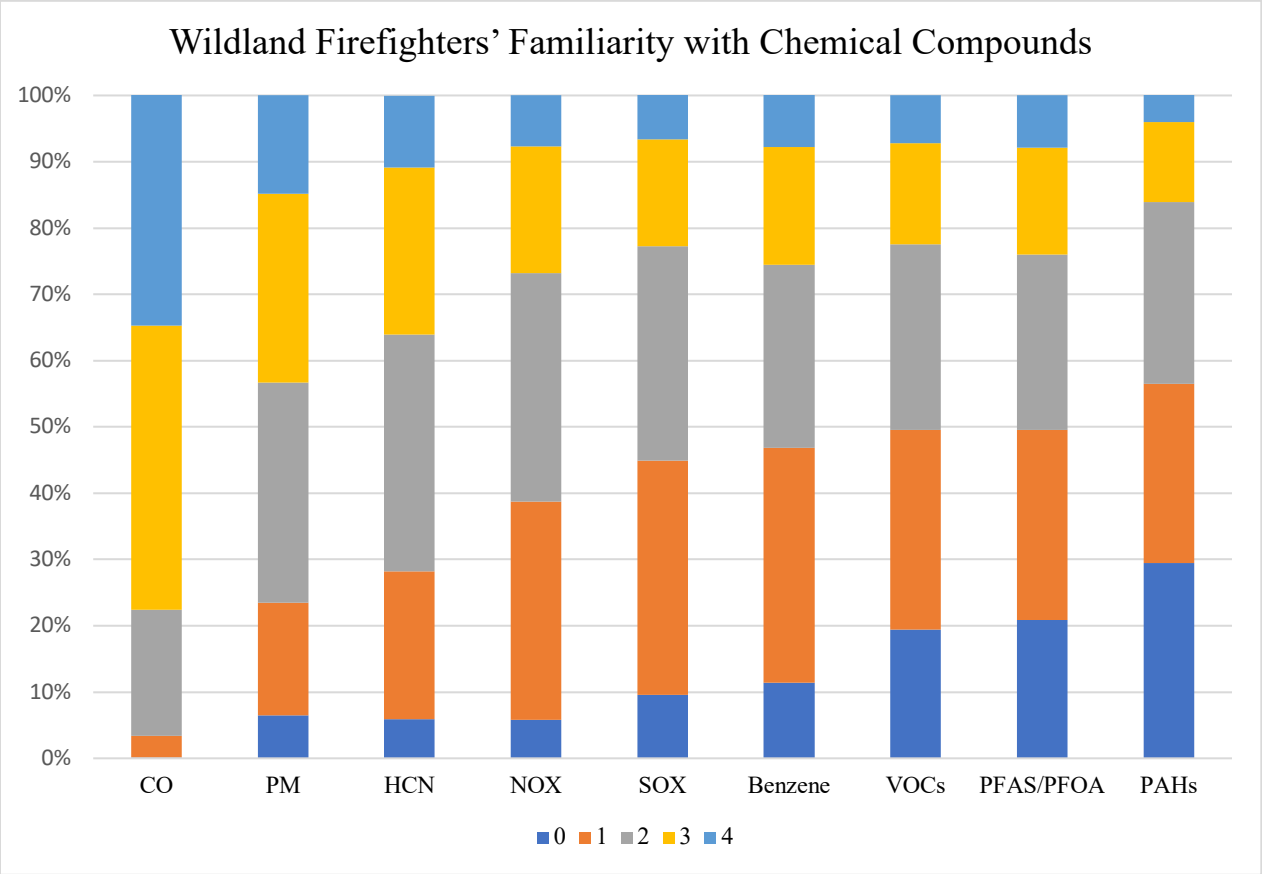

Figure 4.1. This stacked bar chart illustrates the levels of familiarity among firefighters with various chemical compounds commonly found in wildfire smoke. The data is categorized using a Likert scale: 0 = "Never heard of it," 1 = "Heard of it," 2 = "Know a little about it," and 3 = "Know a fair amount about it."

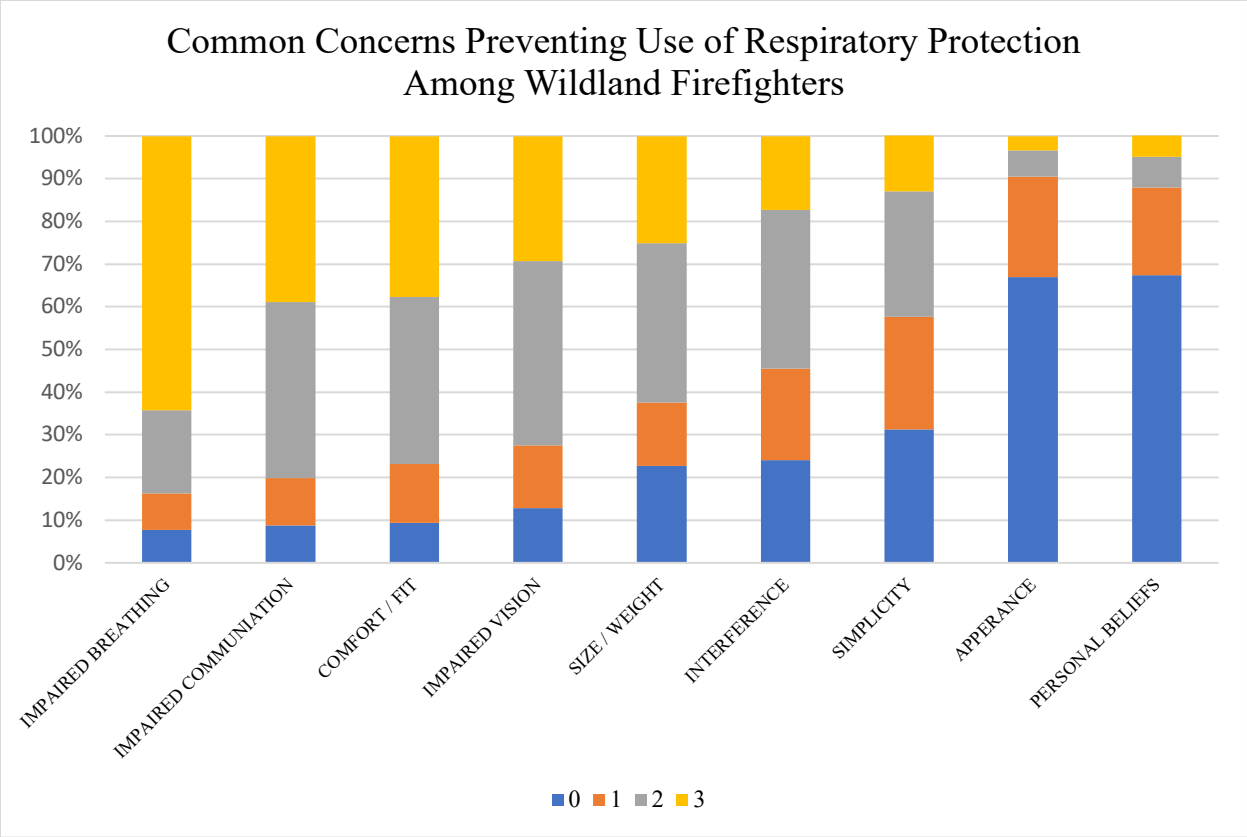

Figure 4.2. This stacked bar chart illustrates the common concerns preventing the use of respiratory protection among wildland firefighters. **Note:** The Likert scale used in this study categorizes responses as follows: 0 = "Not concerning at all" 1 = "Least concerning 2 = "Moderately Concerning," and “3 = "Most concerning".

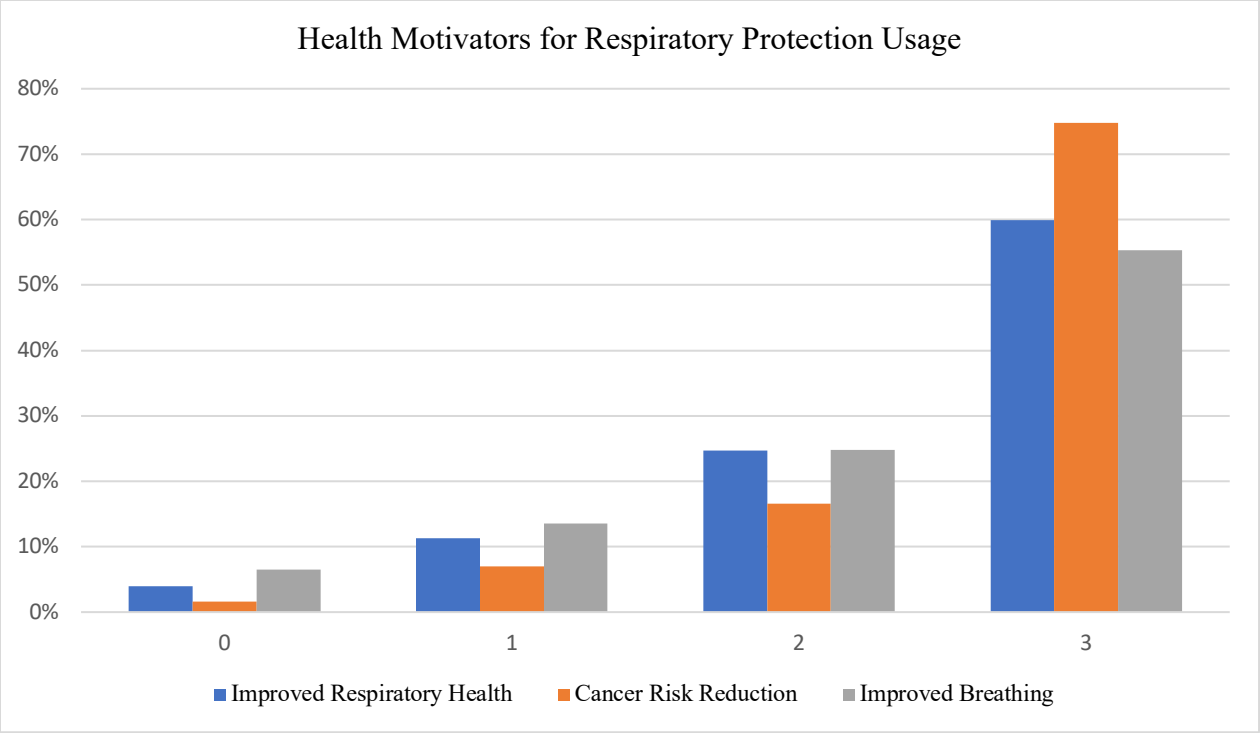

Figure 4.3. The bar chart illustrates the health motivators for using respiratory protection among wildland firefighters, categorized by levels of importance: "0" (Not Important), "1" (Somewhat Important), "2" (Moderately Important), and "3" (Extremely Important).

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Appendices

Appendix A: UMC-IRB Approval Letter

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board
Willis Building · Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** ·
rede.ecu.edu/umcirb/

Notification of Initial Approval: Expedited

From:	Social/Behavioral IRB
To:	AIDA RODRIGUEZ
CC:	Gregory Kearney
Date:	1/9/2024
Re:	UMCIRB 23-001854 Understanding barriers in respiratory equipment implementation among firefighters utilizing Social Cognitive Theory

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) occurred on 1/9/2024. The research study is eligible for review under expedited category # 4,6,7. The Chairperson (or designee) deemed this study no more than minimal risk.

As the Principal Investigator you are explicitly responsible for the conduct of all aspects of this study and must adhere to all reporting requirements for the study. Your responsibilities include but are not limited to:

1. Ensuring changes to the approved research (including the UMCIRB approved consent document) are initiated only after UMCIRB review and approval except when necessary to eliminate an apparent immediate hazard to the participant. All changes (e.g. a change in procedure, number of participants, personnel, study locations, new recruitment materials, study instruments, etc.) must be prospectively reviewed and approved by the UMCIRB before they are implemented;

2. Where informed consent has not been waived by the UMCIRB, ensuring that only valid versions of the UMCIRB approved, date-stamped informed consent document(s) are used for obtaining informed consent (consent documents with the IRB approval date stamp are found under the Documents tab in the ePIRATE study workspace);

3. Promptly reporting to the UMCIRB all unanticipated problems involving risks to participants and others;

4. Submission of a final report application to the UMICRB prior to the expected end date provided in the IRB application in order to document human research activity has ended and to provide a timepoint in which to base document retention; and

5. Submission of an amendment to extend the expected end date if the study is not expected to be completed by that date. The amendment should be submitted 30 days prior to the UMCIRB approved expected end date or as soon as the Investigator is aware that the study will not be completed by that date.

The approval includes the following items:

Name	Description
Aida Key Informant Interview Guide 11.12.23(1).docx	Interview/Focus Group Scripts/Questions
Aida Key Informant Interview Guide 11.13.23.docx	Recruitment Documents/Scripts
Dissertation Research Plan_updated_09.12.23.docx	Study Protocol or Grant Application
Focus Group Script	Recruitment Documents/Scripts
Key informant interview/focus group_Research Information Sheet and consent form.docx_09.12.23	Consent Forms
Respiratory Protection Focus Groups.docx_AIDA RODRIGUEZ_11.12.23 (1).docx	Interview/Focus Group Scripts/Questions
Respiratory Protection Focus Groups.docx_AIDA RODRIGUEZ_11.13.23.docx	Consent Forms
Rodriguez Recruitment Script_Email.docx_updated_11.20.23.docx	Recruitment Documents/Scripts

For research studies where a waiver or alteration of HIPAA Authorization has been approved, the IRB states that each of the waiver criteria in 45 CFR 164.512(i)(1)(i)(A) and (2)(i) through (v) have been met. Additionally, the elements of PHI to be collected as described in items 1 and 2 of the Application for Waiver of Authorization have been determined to be the minimal necessary for the specified research.

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

Appendix B: UMC-IRB Amendment Approval

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board
Willis Building · Mail Stop 682
Greenville, NC 27834
Office 252-744-2914 · Fax 252-744-2284 ·
rede.ecu.edu/umcirb/

Amendment Approved

ID: Ame1_UMCIRB 23-001854

Title: Amendment 1 for IRB Study #UMCIRB 23-001854

Understanding barriers in respiratory equipment implementation among firefighters utilizing Social Cognitive Theory

Description: Your amendment has been approved. To navigate to the project workspace, click on the above ID.

Appendix C: CEPH Competencies Addressed

This dissertation addressed foundational and concentration competencies outlined in the DrPH Environmental and Occupational Health (EOH) Handbook as required by the Council of Education for Public Health (CEPH). Of the DrPH foundational competencies, this dissertation addressed competency (2) design a qualitative, quantitative, mixed methods, policy analysis or evaluation protect to address a public health issue, (6) integrate knowledge, approaches, methods, values, and potential contributions from multiple professions and systems in addressing public health problems, and (18) assess an audience's knowledge. This research study utilized a mixed methods research design that involved analyzing data from The Wildfire Conservancy Respiratory Protection Survey and conducting key informant interviews between leadership and non-leadership firefighters. This research focused on evaluating knowledge gaps and current practices regarding respiratory protection, specifically in relation to smoke exposure, as well a perceived barrier of respiratory protective equipment, in order to identify challenges in implementation and improve strategies for reducing occupational health risks among firefighters. This study integrates public health and occupational health by addressing both chemical risks and behavioral health interventions. It draws from toxicological research and aligns it with practical occupational health challenges faced by firefighters in the wildland setting. The study identified significant gaps in firefighters' knowledge about hazardous chemicals in wildfire smoke. This assessment directly addresses how well firefighters understand the health risks posed by these compounds, thus guiding future educational interventions. The finding that both leadership and non-leadership firefighter exhibited knowledge deficits across all ranks reveals that there is a uniform need for education and training.

The DrPH EOH concentration competencies addressed were competency (7) interpret results of data analysis for public health research and policy and (8) synthesize and evaluate research on an environmental/occupational public health topic conducted by others. The research applies SCT to interpret the cognitive, behavioral and environmental factors influencing firefighters use of respiratory protection. The Wildfire Conservancy Respiratory Protection Survey data provided quantitative insights while key informant interviews offered qualitative context about knowledge gaps, barriers to equipment use, and leadership influence. The research involved analyzing survey data that evaluated firefighters' familiarity with chemical compounds, respiratory practices, and perceived barriers to its use. The analysis directly informed recommendations to improved safety protocols which is essential for public health research and policy development aimed at reducing occupational health risks for firefighters. The literature review provided an opportunity to evaluate data published by others and assess any limitations, helping to inform the research design prior to conducting the study. This dissertation involved a mixed methods approach requiring the use of various analytical techniques to interpret the results of the findings. There were both qualitative and quantitative results to interpret from analysis. Qualitative interviews were analyzed through coding, with key themes identified and supported by the direct quotes from the participants. This research required the interpretation of frequency tables, ANOVA and post-hoc Tukey test results to communicate the significance of survey responses as they related to the research questions.

Appendix D: Key Informant Interview Guide for Non-Leadership Firefighters

Interview Guide for Non-Leadership Firefighters

Obtain permission to begin recording and then read the following Introductory* statement

Introduction

My name is Aida, I'm a Public Health doctoral program student at the East Carolina University and graduate researcher with The Wildfire Conservancy. We are currently researching chemical/health and safety knowledge of firefighters. Your decision to participate in this interview is voluntary. You may decline to take part or choose to stop at any time. A decision to stop will not have a negative impact on you in any way. The interview conducted today will be recorded, transcribed (hard copy), and de-identified (anonymous); the information you provide will not be linked to you and will not be shared with your employer or anyone else. There is no direct benefit to being interviewed, however, your participation may assist in implementing health and safety practices that reduce occupational risk in wildland firefighters. I anticipate that this interview will take approximately 30 minutes to conduct. During the Zoom interview, you may choose to have your screen off for privacy reasons.

Would you like to proceed with the interview?

Do you have any questions?

I will begin and turn on transcription.

Screening Questions:

(NOTE: These will be sent in advance to potential interview candidates to reduce time during the in-person/zoom interview)

I will begin our interview by asking a few screening questions:

1.1 How old are you?
1.2 What is your gender/how to you identify?
1.3 What is your ethnicity?
1.4 How long have you been a firefighter?
1.5 What is your position/rank?
1.6 Are you full-time or seasonal?
1.7 What agency to do you work for?

Icebreaker Question

What do you like the most about your job?

Cognitive Factors (Evaluating knowledge):

These first few questions are going to ask you about your knowledge regarding chemical risk while firefighting as well as health and safety.

Note for actual interview: Some general questions and statements you can use to get more information on a topic without leading the subject and biasing the data include:

Say more about (topic or statement interview subject mentioned)

Why is that? Or Why do you say that?

2.1 What are your thoughts on chemical risks associated with wildland firefighting?

2.2. Describe what you know about smoke exposure.

2.3 What do you know about Volatile Organic Compounds, which are also called "VOCs?"

If "nothing" follow up question: "Have you heard of VOCs before?"

2.4 What do you know about Polyaromatic hydrocarbons PAH'S

If "nothing" follow up question: Have you ever heard of Polyaromatic hydrocarbons PAH'S

2.5 In your opinion, do you believe smoke from fires plays a role in causing health effects or illnesses?

Follow up question: What is your experience with smoke exposure and personal health?

2.6 In your opinion, is there a difference between vegetation smoke and smoke from a wildland urban interface fire? A wildland urban interface fire is one that includes both vegetation as well as structures, vehicles, and other materials.

Follow up question: In your opinion do you believe there is a difference in health risks that comes from being exposed vegetation smoke versus wildland urban interface smoke?

Behavioral Factors (self-efficacy):

These next few questions are related to chemical risk training and procedures.

3.1 Have you ever received training on the health risks associated with smoke exposure, specifically?

Follow-up: Describe the training you received. Was it in person? At Academy? Online? One-time? Annual?

3.2 Are you aware of any mandatory procedures or practices to reduce smoke exposure from your department?

Follow-up: Describe what you believe those procedures or practices are.

Who enforces those procedures?

3.3 Do you have any practices that you do personally to reduce smoke exposure?

Follow up question: Are these different from what your department or agency require?

Follow up question: Where did you learn those practices from? A captain/leadership, information you read, the news etc.

3.4 Would you be willing to receive training on smoke exposure risks and ways to reduce it while on duty?

If yes, ask what kind of training they think would be best or what they might prefer. A prompt could be "in person, online, at academy, or some other location." You can also ask how they prefer to learn new skills, "hands-on, reading, videos/multi-media, etc." The point is to have the interview subject tell you what they would most likely do.

Environmental Factors (Social Norms and Influence of leadership on behavior)

These next few questions are about your trust in leadership to keep you safe. When I mention leadership, I'm talking about anyone who you may report to in your organization—it doesn't necessarily have to be a Battalion Chief, Region Chief, or someone very high ranking.

4.1 What is your perception of firefighters that are wearing masks in the field?

4.2 In your opinion, does your leadership educate you on the best available health and safety practices?

4.3 In your opinion do you believe respiratory protection is a priority for leadership?

Follow up: Describe why you believe respiratory protection is/isn't a priority.

4.4 In your opinion, what symbolizes a reliable and experienced firefighter?

Follow up: Do you believe you can tell if a firefighter is new to the job or inexperienced just by looking at them? What would give it away?

4.5 Have you heard of the term "Smoke-eater" before?

Follow Up: if yes, Describe what you believe it means to be a smoke eater?

4.6 If your leadership implemented new respiratory protection equipment tomorrow, how would that affect you and your job duties?

4.7 Do you believe there is a need for respiratory protection while in the field?

What criteria would it have to meet to be accepted by you?

4.8 In your experience, does use of respiratory equipment and safety procedures on the job differ from what you are required to do in your job description?

4.9 Is respiratory protection a priority for you? Why or why not.

4.10 What do you believe it would take to implement a successful respiratory standard role out among wildland firefighters.

That concludes the interview questions. I will stop the recording now.

Appendix E: Key Informant Interview Guide for Leadership Firefighters

Interview Guide for Leadership Firefighters:

Obtain permission to begin recording and then read the following Introductory statement

Introduction

My name is Aida, I'm a Public Health doctoral program student at the East Carolina University and graduate researcher with The Wildfire Conservancy. We are currently researching chemical/health and safety knowledge of firefighters and firefighter leadership. Your decision to participate in this interview is voluntary. You may decline to take part or choose to stop at any time. A decision to stop will not have a negative impact on you in any way. The interview conducted today will be recorded, transcribed (hard copy), and de-identified (anonymous); the information you provide will not be linked to you and will not be shared with your employer or anyone else. There is no direct benefit to being interviewed, however, your participation may assist in implementing health and safety practices that reduce occupational risk in wildland firefighters. I anticipate that this interview will take approximately 30 minutes to conduct. During the Zoom interview, you may choose to have your screen off for privacy reasons.

Would you like to proceed with the interview?

Do you have any questions?

I will begin recording now and turn on transcription.

Screening Questions:

(NOTE: These will be sent in advance to potential interview candidates to reduce time during the in-person/zoom interview)

1.1 How old are you?
1.2 What is your gender?
1.3 What is your ethnicity?
1.4 How long have you been a firefighter?

1.5 What is your position/rank?
1.6 Are you full-time or seasonal?

1.7 What agency to do you work for?

Icebreaker Question

What do you like the most about your job?

Cognitive Factors (Evaluating knowledge):

These first few questions are going to ask you about your knowledge regarding chemical risk while firefighting as well as health and safety.

2.1 Do you believe there is chemical risk associated with firefighting?

2.2. Describe what you know about smoke exposure.

2.3 Have you ever heard of Volatile Organic Compounds VOC's? If so please describe what they are.

2.4 Have you ever heard of Polyaromatic hydrocarbons PAH'S? If so please describe what they are.

2.5 In your opinion, do you believe smoke from fires play a role in causing health effects or illnesses?

Follow up question: What is your experience with smoke exposure and personal health?

2.6 In your opinion, is there a difference between vegetation smoke and smoke from a wildland urban interface fire? A wildland urban interface fire is one that includes both vegetation as well as structures, vehicles, and other materials.

Follow up question: In your opinion do you believe there is a difference in health risks that comes from being exposed vegetation smoke versus wildland urban interface smoke?

2.7 Do you have any formal education or training on chemical risk associated with smoke exposure?

Follow-up: Describe the training you received. Was it in person? At Academy? Online? One-time? Annual?

2.8 Are you aware of any mandatory procedures or practices to reduce smoke exposure from your department?

Follow-up: Describe what you believe those procedures or practices are.

Who enforces those procedures?

Environmental Factors (Assessing perceived influence)

The next few questions will pertain to the influence of leadership in implementing new procedures. When I mention leadership, I'm talking about anyone who you may report to in your organization—it doesn't necessarily have to be a Battalion Chief, Region Chief, or someone very high ranking.

4.1 What influence do you perceive leadership to have over their crew?

4.2 What is your perception of firefighters that were wearing masks in the field?
Follow: what masks are available/do you see.

4.3 In your opinion do you believe respiratory protection is a priority for leadership?

Follow up: Describe why you believe respiratory protection is/isn't a priority.

Follow up: Is respiratory protection a priority for you? Why or why not.

4.4 In your opinion, what symbolizes a reliable and experienced firefighter?

Follow up: Do you believe you can tell if a firefighter is new just by looking at them? What would give it away?

4.5 Do you believe there is a need for respiratory protection while in the field? If so, what kind?

4.6 How would you define the culture around respiratory protection within the wildland firefighting community?

Follow up: Is respiratory protection something firefighters are actively wanting?

4.7 As a leader, what are your priorities regarding safety of your crew?

4.8 Why do you believe respiratory protection has been hard to implement when it comes to wildland firefighting?

4.9 What would it take for successful role out of respiratory protection.

Specs/qualities on respirators?

Other barriers?

That concludes the interview questions. I will stop the recording now.

Appendix F: The Wildfire Conservancy Respiratory Protection Survey Questions

THE WILDFIRE CONSERVANCY RESPIRATORY PROTECTION SURVEY

1. What is your age?

Open-Ended Response

2. What is your gender?

Open-Ended Response

3. How many years have you been in your current role?

Open-Ended Response

4. How many total years of experience do you have in the fire service?

Open-Ended Response

5. What is the Fireline job that you usually perform? Select all that apply.
   - Firefighter
   - Handcrew
   - Single Resource Boss
   - Strike Team / Task Force Leader
   - Division / Group Supervisor
   - Line Safety Officer
   - Aviation (ground support crew)
   - Aviation (pilot)
   - Heavy Equip Operator
   - Admin
   - Fire Investigation
   - IMT/overhead
   - Other (please specify)

6. To what type of crew are you usually attached? (Select all that apply)
   - Incident Management Team
   - Type I Crew
   - Type II Crew
   - Type II Crew IA Crew
   - Fire Engine
   - IHC
   - Helitack
   - Smokejumper
   - Dozer/Equipment
   - Aviation
   - Other (please specify)

7. What is the average weight of the fireline pack or equipment that you normally carry?
   - What Agency or Organization do you currently work for?
   - State
   - Local/Municipal
   - USFS
   - Other

8. What state do you work in? (if outside the United States, select other and specify).

Open-Ended Response

9. How familiar are you with the following hazardous compounds (0=never heard of it / 4=Know a lot about it):

PM (Particulates)	PAHs (Polycyclic Aromatic Hydrocarbons)	VOCs (Volatile Organic Compounds)	Benzene	Hydrogen Cyanide	Nitrogen Oxides (NOx)	Sulfur Oxides (SOx)	PFAS / PFOA (per-flourinated compounds)	Carbon Monoxide

10. Do you currently use any respiratory protection when responding to a wildland/WUI fire incident?
    - Yes
    - No
    - Unsure

11. Please describe any respiratory protection devices that you have ever used during wildland/WUI incidents only – please be as specific as possible regarding the model and details/manufacturer of the device

Open-Ended Response

12. If you currently use respiratory protection when responding to a wildfire/WUI incident, to the best of your ability provide the specific device type (manufacturer, make, model, etc. – please be as specific as you can).

Open-Ended Response

13. If you currently use respiratory protection when responding to a wildfire/WUI incident, how often do you use it?

Open-Ended Response

14. Please estimate to the best of your ability what percent of the time you use each respirator device (0% being none of the time and 100% all of the time) Please skip question if not applicable.

Open-Ended Response

15. Does your agency/department currently REQUIRE the use of any respiratory devices (required respiratory devices means any respiratory devices that are enforced while on duty or during specific activities performed)?
    - Yes
    - No
    - Unsure

16. If your department/agency REQUIRES a respiratory device, under what conditions are they required and which type of device? Please skip if not applicable

Open-Ended Response

17. Does your agency/department currently RECOMMEND the use of any respiratory devices?
    - No
    - Yes
    - Unsure

18. If your department/agency RECOMMENDS a respiratory device, under what conditions do they recommend it be used and which type of device? Please skip if not applicable

Open-Ended Response

THE WILDFIRE CONSERVANCY RESPIRATORY PROTECTION SURVEY

19. Please rank the following reasons or concerns for not wanting to wear respiratory protection or hesitation in using a respiratory protection device while responding to a wildland/WUI fire incident (0=never heard of it / 4=Know a lot about it):

Size and weight of device	Simplicity of use	Interfering with existing PPE	Impairing vision	Impairing communications/speech	Restricting breathing	Overall comfort/fit while performing duty	Appearance or "look" of the device	Personal beliefs	Other (please specify)

20. Of the following, please rank your personal reasons for wanting to wear a respiratory protection device on a wildland/WUI incident: (Least important, somewhat important, moderately important, extremely important)

Improved respiratory health and safety	Cancer risk reduction	Improved breathing while fighting fire

21. Based on your experience with firefighting, if you were working in a smoky environment, which of the following devices would you find most practical to use under various physical duties (e.g. direct suppression, hiking, cutting line, mop-up, etc.)

Open-Ended Response

22. Based on your experience with firefighting, if you were working in a smoky environment, which of the following devices would you find most practical to use under non-physical duties (e.g. safety/rest break, holding, patrolling, etc.)

Open-Ended Response

23. Based on your experience with firefighting, if you were working in a smoky environment (inversion), which of the following devices would you find most practical to use under non-physical duties while working at Base Camp/IC

Open-Ended Response

Appendix G: Interview Recruitment Email Script

Hello,

I hope this email finds you well.

My name is Aida Rodriguez, and I am a graduate researcher with The Wildfire Conservancy and a doctoral student at East Carolina University (ECU).

For our research, we are conducting a series of interviews with Firefighters and Firefighter Leadership to better understand chemical/health and safety knowledge regarding smoke exposure. For your reference, I have attached a brief project description to this e-mail ("Research Information Sheet.docx"). This is a research study. This work is being done in partnership with the Wildfire Conservancy and ECU.

To participate in this study you must be either:

1. A firefighter who is between the ages of 18 years and 65 years of age, who has been a wildland firefighter for at least one year (or one season)

or

2. A firefighter who is between the ages of 18 years and 65 years of age, who has been in a leadership position in the field of firefighting for at least one year (or one season)

The interviews will be one-on-one between the researcher and participant and will take place via zoom (web-based video conferencing) or phone (if internet access is a challenge). The interviews will last approximately 30 minutes and can be scheduled at a time that is most convenient for the participant's schedule. Participant responses will be decoded and anonymous.

Please note that participation in this project is voluntary and, furthermore, participants have the option to decline to answer any question or stop the interview at any time. Participant responses will be anonymous.

If you have firefighters who would like to participate they can either fill out the interest form at this web link: https://forms.gle/mVygHWCbhGg93gLcA

or they can reach out to me directly to express their interest at aidarodriguez@wildfireconservancy.org or (818) 445 5776

Please feel free to forward this email to anyone you feel would be interested!

I look forward to hearing from you and thank you for your help.

Please don't hesitate to contact me if you have any questions.

Sincerely,

Aida

Appendix H: Consent to Participate in Research

Consent to Participate in Study

Title of Study: Understanding barriers in respiratory equipment implementation among firefighters utilizing Social Cognitive Theory

Principal Investigator: Aida Rodriguez, DrPH(c)

Introduction:

You have been asked to participate in a research study conducted by East Carolina State University and sponsored by the Wildfire Conservancy. The purpose of the study is to try and determine firefighter health and safety knowledge as well as opinions on respiratory PPE. Your input will play a crucial role in shaping firefighter health and safety practices.

Study Procedure:

Key informant interview (leadership or firefighter)

If you agree to participate, you will partake in a one-on-one zoom interview that will take no longer than 30 mins. All questions asked will be related to health and safety knowledge as well as opinions on respiratory PPE and procedures.

Confidentiality:

Your privacy is of utmost importance. Any information you provide will be kept strictly confidential. Your responses will be anonymized, and your personal details will not be disclosed or linked to your data. The original recordings of this interview will be kept for the duration of the study, approximately 6 months. After they are analyzed and transcribed, the original video recordings will be destroyed. The de-identified transcriptions will be stored for three years after study completion.

Voluntary Participation:

Participation in this research study is entirely voluntary. You have the right to withdraw at any point without penalty or providing a reason. Your decision to participate or not will have no impact on any future opportunities or relationships with the research institution.

Risks and Benefits:

While we do not anticipate any significant risks associated with participation, some potential discomfort from questions asked. Benefits include contributing to the development of important research, gaining insights, and potentially influencing the design of future firefighter health and safety practices.

Data Usage and Consent:

By agreeing to participate, you are consenting to the use of the data you provide from the key informant interview. The data collected will be used solely for research and analysis purposes. Your participation and responses will remain confidential and will be used anonymously in research reports and publications.

Contact Information:

If you have any questions or concerns about this research study, you can contact Aida Rodriguez via email at rodriguezai20@students.ecu.edu or aidarodriguez@wildfireconservancy.org or by phone at (818) 445 5776.

Ethics Approval:

You may call the University and Medical Center Institutional Review Board (UMCIRB) at phone number 252-744-2914 (days, 8:00 am-5:00 pm) If you would like to report a complaint or concern about this research study, you may call the Director of Human Research Protections, at 252-744-2914

Acknowledgment of Informed Consent:

By participating in this research study, you acknowledge that you have read and understood the information provided in this sheet. Your participation is entirely voluntary, and you can withdraw at any time without any negative consequences.

If you agree to participate, please sign below.

Participant's Signature: _____

Participant's Printed Name:_____

Date: _____

Thank you for considering participating in our research study. Your input is invaluable in helping us enhance the quality and effectiveness of our research methods.

Appendix I: Research Information Sheet

East Carolina University

Research Information Sheet

IRB Study #: UMCIRB 23-001854

Principal Investigator: Aida Rodriguez, DrPH(c), M.S.

The purpose of this study is to research chemical/health and safety knowledge of firefighters. You are being asked to take part in a research study because you are a wildland firefighter who is at least 18 years old and under the age of 65 and has been working as a wildland firefighter for at least 6 months or one season.

Being in a research study is completely voluntary. You can choose not to be in this research study. You can also say yes now and change your mind later. You may refuse to take part or choose to stop at any time. A decision to stop will not have a negative impact on you in any way. If you choose to stop the interview before it is complete, you will have the option to have any of the interview information included or not included (destroyed) in the study.

If you agree to take part in this research, you will be asked to provide answers to questions about chemical/health and safety knowledge and respiratory protection. Your participation in this study will take about 30 minutes of time and may include up to 15 minutes of follow-up in the form of a phone call or email within a month of the initial interview. We expect that approximately 30 firefighters will take part in this research study.

The possible risks to you in taking part in this research are potential discomfort with some of the questions being asked or feeling uncomfortable with someone else finding out you have participated in a research study.

There is no direct benefit to being interviewed, however, your participation may assist in identifying PPE practices that reduce occupational risk in wildland firefighters.

The interview conducted today will be recorded, transcribed, and de-identified; the information you provide will not be linked to you and will not be shared with your employer. To protect your identity as a research subject the research data will not be stored with your name and the researcher(s) will not share your information with anyone. In any publication about this research, your name or other private information will not be used. The original recordings of this interview will be kept for the duration of the study, approximately 6 months. After they are analyzed, the original video recordings will be destroyed.

If you have any questions about this research, please contact the Investigator named at the top of this form by email at rodriguezai20@students.ecu.edu / aidarodriguez@wildfireconservancy.org or by phone at (818) 445 5776. If you have questions or concerns about your rights as a research subject, you may contact the University and Medical Center Institutional Review Board (UMCIRB) at phone number 252-744-2914 (days, 8:00 am-5:00 pm) If you would like to report a complaint or concern about this research study, you may call the Director of Human Research Protections, at 252-744-2914