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Attitudes of fire service personnel toward respiratory protection in wildland firefighting

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Abstract

Wildland and wildland–urban interface (W/WUI) fires are increasing in frequency and intensity, increasing concerns about firefighters' exposure to hazardous smoke and the need for respiratory protection. This qualitative study explored the perspectives of California fire service personnel on the use of respiratory protective devices (RPDs), particularly powered air-purifying respirators, and a potential Cal/OSHA regulation mandating their use in W/WUI firefighting. Participants were experienced in W/WUI firefighting and had some role in their fire department related to respiratory protection or other aspect of firefighter safety. While all participants recognized the health risks associated with smoke exposure, including cancer and acute respiratory symptoms, and that RPDs would reduce their exposures, participants had concerns that RPDs would negatively affect fatigue, comfort, communication, mobility, and situational awareness. Some concerns specifically relate to the design of the RPDs. Most participants supported using RPDs in specific scenarios such as mop-up and prescribed burns, but fewer supported RPD use during high-exertion tasks like cutting line. Participants preferred flexibility or guidance rather than prescriptive regulation and advocated for engagement of firefighters in the development of any potential regulation to ensure practicality and feasibility. Some participants acknowledged resistance to change in the industry as a barrier for RPD adoption, but felt that evidence of RPD effectiveness and usability, including opportunities for training with devices and changes to device design, could assist with adoption. A programmatic regulation, coupled with education and engagement, can facilitate the incorporation of RPDs in W/WUI firefighting.

Keywords: fire departments; occupational health; powered air-purifying respirator; qualitative research; regulation.

What's Important About This Paper?

Occupational exposures of firefighting are recognized as carcinogenic, but firefighters responding to wildland fires do not wear respiratory protection. In this study, firefighters identified that respirators would be feasible for some activities with lower physical exertion, but expressed concerns about the devices increasing fatigue and impacting situational awareness. Firefighters want to be engaged in the development of improved respiratory protective technology and potential regulations about its use in wildland firefighting.

Introduction

The frequency and intensity of wildland fires and fires at the wildland–urban interface (W/WUI fires) are increasing in California, the United States, and many other regions of the world owing to climate change and changes in land use patterns (Westerling 2018). As a result, increased W/WUI firefighting is anticipated in response to unplanned fires, as well as for prescribed burns used as a land management strategy.

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Occupational exposures among firefighters include inhalation and dermal exposure to a complex mixture of combustion products, and have been recognized as carcinogenic to humans (Group 1) by the International Agency for Research on Cancer (IARC 2023). While less is known about the exposures and health outcomes associated with W/WUI firefighting than structural firefighting, it is clear that W/WUI firefighters are exposed to particulate matter, toxic gases, metals, polycyclic aromatic hydrocarbons, and volatile organic compounds, among other materials (West et al. 2024). Beyond cancer risks, studies among W/WUI firefighters have documented declines in respiratory function across shifts and across fire seasons (Miranda et al. 2012; Gaughan et al. 2014), as well as symptoms of eye, nose, and throat irritation like cough and watery eyes (De Vos et al. 2009; Cherry et al. 2022). Concerns about exposures and adverse health effects have led to consideration for the use of respiratory protective devices (RPDs) in W/WUI firefighting.

In California, wildland firefighting activities are a multi-agency endeavor, with the California Department of Foresty and Fire Protection (CAL FIRE) typically serving as the lead agency, with the exception of areas under federal jurisdiction. CAL FIRE, which has more than 12,000 full-time and seasonal personnel, is responsible for preventing fires in the State Responsibility Area and managing the State Forest system, but also serves as an "all risk" fire department and provides services through contracts with local governments. In the event of a large wildfire or W/WUI fire incident on state lands in California, CAL FIRE leads the unified command structure, and coordinates resources. From within the state, these resources include personnel and equipment from: CAL FIRE, the California Conservation Corps (which operates firefighting hand crews), the Bureau of Land Management (which operates Interagency Hotshot Crews), and local and county fire departments (which often have specific crews and equipment trained for W/WUI firefighting), among others. CAL FIRE also coordinates with federal agencies, including the US Forest Service, Bureau of Indian Affairs, and National Park Service, depending upon the location of the incident. Unlike in some countries, few volunteers responds to W/WUI fire incidents in California.

There are several types of RPDs that could be used in W/WUI firefighting. The self-contained breathing apparatus (SCBA) delivers fresh air from a canister worn on the back and is widely used in structural firefighting. SCBAs, however, are considered to have limited practically for W/WUI firefighting owing to their weight and the logistical challenge of providing fresh air canisters to firefighters every 30 to 60 minutes in remote locations (Hwang et al. 2023). Air-purifying respirators (APRs) use facepieces made of filter material (filtering facepiece respirators, FFRs) or filters and cartridges affixed to elastomeric half-mask or full-facepieces to remove contaminants from air as it is being inhaled. Structural firefighters utilize APRs in some activities, as nearly all fire departments in the United States use SCBAs with facepieces that can be connected to filters and cartridges when the environment has been determined to not be immediately dangerous to life and health (IDLH). Discretionary use of APRs in W/WUI firefighting has been explored in a few studies in Canada, and use has been reported in Australia bush firefighting (De Vos et al. 2009; Cherry et al. 2022; Zadunayski et al. 2024). Powered air-purifying respirators (PAPRs) use a battery powered fan to draw air through a filter and/or cartridge before delivering air to the facepiece. PAPRs are thought to be a good option for W/WUI firefighting because the delivery of filtered air to the facepiece means firefighters do not need to exert force to draw air through filters. It is common for W/WUI firefighters to wear bandanas or heat shields over their nose and mouth. Hot shields are fabric face and neck coverings designed to protect firefighters from heat and some contain particle-filtering materials, but they are not regulated RPDs.

The California Division of Occupational Safety and Health (Cal/OSHA) has initiated rulemaking for reducing harmful inhalation exposures for W/WUI firefighting operations. In 2022, Cal/OSHA drafted regulatory text describing a multi-pronged approach that included engineering controls, administrative controls, and personal protective equipment as methods to decrease inhalation exposures (Cal/OSHA 2022). The draft regulation would require that employers develop, implement, and maintain a respiratory protection program that uses full-face Class 3 PAPRs certified by the National Institute for Occupational Safety and Health (NIOSH) and fitting the requirements of the National Fire Protection Association (NFPA) 1984, Standard on Respirators for Wildland Fire-Fighting and Wildland Urban Interface Operations (2022 update). There are no APRs or PAPRs available in the commercial market certified by NIOSH and compliant with NFPA 1984, but at least one PAPR—the Wildland Firefighter Respirator Device—is in development (National Urban Security Technology Laboratory 2022a, 2022b).

Barriers to PAPR development and certification for W/WUI firefighting are numerous and are both technical and cultural. Technical issues include: energy-efficient delivery of sufficient air supply for wearers engaged in intense physical activity; ensuring the form factor does not impede the physical motions of work activities, communication or life-safety actions; ensuring materials are heat resistant; and selection of respirator filters and cartridges that offer effective protection in an environment with myriad, dynamic airborne contaminants. The fire

Table 1. Interview questions.

1. Can you tell me what your job is in the fire service? Describe. (a) Do you have any responsibilities related to occupational health and safety? Describe. (b) How long have you had these responsibilities?
2. Firefighters are exposed to smoke and other hazardous chemicals. Do you think that respiratory hazards and smoke inhalation are a problem for firefighters? Please describe.
3. About your department… (a) How large is your department? (b) How large is the population that your serve? (c) How large is the area you serve? [sq miles] (d) How many people in your department are trained to respond to W/WUI fires? (3) What types of activities does your department do when responding to W/WUI fires? [crew types, task types,…]
4. What is your experience with powered air-purifying respirators "PAPRs" or air-purifying respirators "APRs" in the fire service?
   (a) What do you think are the benefits of using a PAPR or APR for Wildland/WUI firefighting activities where respirators aren't currently required?
   (b) What do you think are the challenges of using these respirators?
   (c) Do you think the added benefits of wearing these respirators outweigh the challenges?
   Why?
5. What you think about firefighters wearing a PAPR or APR while performing the activity: (a) cutting line, (b) running hose, (c) mop-up, (d) structure defense, (e) controlled burns, (f) at base camp.
6. How would the required increased use of respirators for W/WUI firefighting impact you or your organization?
7. What policies and procedures do your organization currently have about the use of respirators and what do they require? (including SCBAs, PAPRs, APRs)?
   (a) How are those policies and procedures established? For example, do you have a committee that writes policies and procedures to comply with specific regulations or other external demands?
   (b) Would these policies and procedures need to be changed for the increased use of PAPRs or air purifying respirators in W/WUI firefighting?
   (c) Does your organization have any challenges with complying with the current Cal/OSHA regulations related to respiratory protection?
   (d) After we are finished, can I get a copy of your current respiratory protection policies and procedures? We're particularly interested those related to respirator selection and evaluation.
8. What do you think about Cal/OSHA and Cal/OSHA regulations?
9. If Cal/OSHA passes a regulation requiring the use of PAPRs or APRs for some W/WUI firefighting activities…
   (a) Are there any elements or aspects to a potential regulation that are important to you or your organization? And why is that important?
   (b) How useful to your organization would it be if Cal/OSHA provided guidance for the selection of respirators and respirator cartridges?
   (c) How useful to your organization would it be if Cal/OSHA required specific types of respirators and respirator cartridges for specific tasks?
   (d) How do you feel now about the use of respiratory protection for W/WUI firefighting, and has this changed over time?
10. Is there anything else you would like to share with me today?

service is a resilient institution with a culture built upon tradition and shared experiences, which can serve as a barrier to change (Blume 2024). Adoption of RPDs in W/WUI firefighting will be a significant change for the fire service, requiring effective management of change to ensure the acceptability of RPDs among fire service personnel.

The objective of this study is to describe attitudes of California fire service personnel toward the use of RPDs, particularly PAPRs, in W/WUI firefighting in general, and about a potential Cal/OSHA regulation more specifically. California fire service personnel with W/WUI firefighting and a role in respiratory protection programs or other aspect of firefighter safety were recruited and interviewed about their personal opinions and attitudes towards a number of topics related to the potential value and use of RPDs and an RPD regulation for W/WUI firefighting. Findings from the research are intended to assist Cal/OSHA and fire service organizations to develop guidance, recommendations, or regulations regarding RPDs that meet the needs and address concerns of W/WUI firefighters, thereby improving their effectiveness.

Methods

A qualitative research methodology was employed using semi-structured interviews to obtain narratives

from fire service personnel related to RPD use and regulation in W/WUI firefighting (Creswell and Poth 2018). The interview guide, shown in Table 1, was developed by the research team, which had expertise in occupational medicine, industrial hygiene, and occupational health, and was reviewed by subject matter experts to ensure questions were relevant and appropriate for the audience. Individuals were eligible to participate in the interviews if they were English-speaking adults, employed in a California fire service organization that was engaged in W/WUI firefighting, and had a role with respiratory protection within the organization (eg occupational health and safety, training, or decision-making). The study was reviewed and approved by the Institutional Review Board of the University of California, Los Angeles, protocol IRB-23-1146.

The primary sampling strategy was random selection from a publicly available list of California fire departments ($n = 741$) maintained by CAL FIRE, but some participants were recruited based on referral. One member of the research team (S.V.) made a telephone call to each fire department and asked to speak to a person who has knowledge of their department's respiratory protection program. Depending upon whether the research team member was transferred to that person directly, or given a name and contact information, up to three phone calls or e-mails were made to identify a potential participant, screen for eligibility, and schedule an interview. After screening for eligibility, a written summary of the study was provided to participants via email, and an interview was scheduled. The initial target sample size was 20, but was expected to vary based on the similarity of interview contents. Recruitment materials are available in the Supplementary Materials.

Interviews were conducted via video conferencing (Zoom Communication, San Jose, CA). Participants provided verbal informed consent. Interviews were conducted by one researcher (L.S.), and a second researcher (S.V.) was present to assist with any technical issues. The interviews were audio-recorded, and a preliminary transcript was generated by Zoom. During the interview, participants were asked to share any written policies from their fire department about respiratory protection, and the investigator who scheduled the interview followed up via e-mail to obtain the documents after the interview.

The Zoom-generated preliminary transcripts were reviewed for accuracy by members of the research team (E.D. and S.N.), and some editing for clarity was performed. During this review, identifying information (eg names of individuals, fire departments, towns, counties, and some fires) was removed from the transcripts, and each participant was assigned a unique identification number (eg P01, P02). The audio recording and transcripts were stored in a secure file, and audio recordings were destroyed upon completion of the transcript coding and analysis. Deidentified transcripts were retained.

A codebook was developed that reflected content analysis on topics anticipated by the interview instrument, and emergent themes. The initial draft of the codebook was applied by four investigators (E.D., S.N., S.V., and R.M.J.) to four interview transcripts, but some codes were found to be difficult to apply. The second draft of the codebook was developed and applied by the same four investigators to four interview transcripts (two were the same and two were new). The final round of coding was developed by two of the investigators (E.D. and S.N.), who applied up to five codes/subcodes to each participant response in all 17 interview transcripts. Upon completion, the two other investigators (S.V. and R.M.J.) reviewed and resolved any differences in the final coding. The final round of coding had a Cohen's kappa of 0.57, indicating moderate agreement before differences were resolved.

While many of the interview questions were posed specifically about PAPRs, participants often mentioned other types of APRs, and sometimes the type of respirator being referred to was not clear. Ultimately, most of the comments could apply to PAPRs and other APRs, so the specific type of respirator is not mentioned in the results and discussion of the results unless the respirator type was important to the answer.

Participants were specifically asked about their opinions on the use of respirators during some specific firefighting tasks (Table 1). Cutting line is the process of creating a fire break 1 to 3 m wide by removing fuel to the bare soil with hand tools. Running hose is the process of carrying and extending a series of charged fire hoses away from a fire engine to an active fire site. Mop-up involves using hand tools and/or water to identify and extinguish "hot spots" of residual fire, like smoldering or burning roots or stumps, after the fire line has passed. Structure defense is focused on protecting structures, such as clearing vegetation, wetting with water, or actively defending the structure with water. Controlled burns, also known as prescribed burns, involve the planned application of fire to a specific area and are used for forest management (Teie 2018).

Results

Participant characteristics

A total of 97 fire departments were contacted, and direct contact with individuals who were screened for eligibility was made in 38 fire departments. A total of 17 participants completed interviews. The most common reasons contacted individuals did not participate were not responding to follow-up and lack of time, which included being called to a fire. Recruitment and

interviews were completed between August and December 2024, when there were several significant W/WUI fires in California.

Participants were affiliated with 17 unique fire departments from Northern California ($n = 9$) and Southern California ($n = 8$). Though the fire departments of 14 participants were in cities or towns ("urban"), some of these departments also served rural areas ($n = 3$), heavily forested or mountainous areas with seasonal tourism ($n = 4$), and a desert community ($n = 1$). The fire departments also varied in size. While five departments served communities of > 100,000 people and some had >100 personnel, 14 departments had 12 to 60 personnel. Participants held a variety of leadership roles, including Battalion Chief ($n = 5$), Captain ($n = 6$), Division Chief ($n = 2$), Engineer ($n = 2$), Lieutenant ($n = 1$), and Operations Chief ($n = 1$). All participants stated that all department personnel were trained to respond to W/WUI fires. All participants were male, but further demographic information was not obtained.

All participants ($n = 17$) had experience wearing SCBAs in structural firefighting to enter environments that were considered IDLH. Most participants also had experience wearing APRs, typically by affixing a cartridge to the full-facepiece worn with their SCBA during overhaul operations on structure fires. A few participants had prior experience with PAPRs, mostly reported by participants who responded to medical calls during the COVID-19 pandemic. All participants reported there were no written policies for wearing respiratory protection during W/WUI firefighting in their fire department. Some participants described wearing bandanas or hot shields.

Health effects

All participants recognized that smoke was a health and safety hazard, and all identified cancer as a health outcome of concern, among other health impacts. One participant stated "…for firefighters, when we retire, we have a couple of years, and we die of lung cancer" (P09). Another participant stated, "I have two of my friends who had thyroid cancer… and they hadn't even been in the fire service for maybe about 10 years" (P10). Participants also described acute health effects of smoke exposure. A participant described a typical firefighting scene, stating "You have snot running down their noses because they're breathing in all this stuff and their eyes are watering unless they're wearing goggles, and even still, sometimes they're watering" (P14). Another participant described the toll of wildland fires, stating, "It's like they've got pneumonia at the end of it. They've lost their voices. They've got bronchitis. They're coughing. And it takes a while for your body to heal" (P02).

Some participants described how the understanding of the toxicity of smoke from wildland fires has changed over time because of research and education. One participant noted that in the past, "the verbiage was that wildland smoke was benign; it was like sitting around a campfire," but that many "products of combustion that we didn't recognize years ago now have been identified" through research by the fire service and universities (P01). This was echoed by another participant who stated, "[w]hen I was a brand new firefighter going out on wildland fires, I didn't think a whole lot. It's just smoke. It's like being at a barbeque. […] It's not bad for you. And then, obviously over time and with education you find out that, hey, any type of smoke is not good for you" (P14). Many participants mentioned that W/WUI fires burned materials other than wood, such as petroleum-based and plastic-based materials, lithium batteries, furniture synthetics, glues, etc., which can generate hazardous chemicals. Specific chemicals mentioned in smoke were carbon monoxide and volatile organic compounds like benzene and xylene.

Attitudes about the exposures and health risks varied among participants, reflecting some dependence on fire service role and generation. A few participants discussed these risks as being part of their job, while other participants who were in more senior/supervisory roles spoke to their desire to protect the firefighters they supervise from this risk. One participant stated, "… but it's a hazard inherent with the job. I mean, you can't have fire without smoke" (P04). In contrast, other participants stated, "[N]ow, being in my position where I'm trying to keep everybody healthy and safe and without getting cancer, and I've got a little bit more experience, I do think [respirators] would be beneficial" (P14), and "…as my career kind of grew, it's like, 'God, how can we protect ourselves?' […] I've always kind of had that in back of my mind, like […] what can we do to actually protect our firefighters?" (P17). In addition, one participant acknowledged a generational change in attitudes about health risk, stating "the new generation of firefighters being more health conscious and us recognizing those concerns, I think they're going to be more adapted to using [respirators] first than guys that have been around for a long time" (P01).

Potential impacts of wearing respirators

Many participants supported the use of some type of RPD for W/WUI firefighting to reduce exposures to smoke and prevent adverse health effects. One participant stated, "The benefits are definitely, you know, we're going to stop inhaling […] hazardous smoke. That is a huge plus. I think that's great" (P11). This participant drew parallels to the health benefits achieved since the introduction of SCBAs. Participants, however,

Table 2. Concerns about respirator use in W/WUI firefighting, and their implications for respirator design.

Concern	Rationale	Design implications
Comfort	Issues of comfort were related to facepiece fit, duration of use owing to the long work shifts, sweat and heat, and skin irritation. On participant described it as a "distraction" (P01).	Comfortable facepiece fit
Communication	Firefighters need to speak to one another in person and through a radio. "How well are they designed that I can talk to people next to me and be on the radio and do multiple communication tasks at the same time?" (P01).	Facepiece fitted with microphone and radio communication or other technology to facilitate communication.
Fatigue	Concerns about fatigue included both the work of drawing air through the respirator or whether there is insufficient air supply from the PAPR, and the weight of the equipment. One participant stated, "If it can't supply enough air that you need, you end up drawing on your mask, and that fatigues your lungs, which would cause quicker, rapid fatigue" (P04). Another participant stated, "we're already carrying a bunch of weight going up and down these hills" (P06).	PAPR must provide adequate air supply and APRs minimal breathing resistance to prevent fatigue
Heat	Heat stress is already a health concern that may be exacerbated by wearing a respirator. One participant stated, "so [a respirator] that increases our safety, but it also isn't going to just change the risk where, […] now I can breathe, but now I'm going to more likely to go into rhabdomyosis and then my liver or my kidney and all my organs are going to shut down because now I'm overheated" (P06). Heat may damage respirator materials, affecting performance or leading to off gassing of chemicals. "There are situations that I've been in where I've been exposed to extreme heat, and it would have to be able to stand up to that heat" (P03).	PAPR must provide adequate air supply and APRs minimal breathing resistance to enable thermal regulation Respirator materials must be resistant to heat
Mobility	The respirator is a piece of additional equipment that could hinder firefighters' ability to escape in difficult situations. One participant discussed a specific fatality in which crew were overrun by fire and stated "…to potentially add more equipment that will inhibit their ability to safely escape to their safety zones or temporary refuge area would be very concerning to me" (P08). Another participant discussed that the delay in donning or doffing could impact safety. One participant stated, "You are taught to eliminate your gear off your back before getting in the shelter…donning and doffing the respirator every time would be difficult" (P03). The size and weight of PAPRs may interfere with other equipment or firefighting activities. One participant stated "If [the respirator] is getting in my way, I'm going to get rid of it… At what point do you defeat the purpose if I can't function" (P01).	Form must be compact and lightweight Respirator must easy to don and doff PAPR hoses must be secured out of the way
Vision	Wearing a mask may impair vision. Most participants noted that masks can narrow the field of view, limiting peripheral vision. One participant stated "then the claustrophobic feeling of wearing a mask, which could fog up on you" (P05).	Facepiece should limit fogging and have good field of view
Air filtration	Respirator cartridges need to filter out the important health hazards, and last for extended periods of exposure.	Cartridges should filter particles, gases and vapors for at least 12 h of exposure.

identified a variety of concerns associated with the use of respirators for W/WUI firefighting—comfort, communication, fatigue, heat, mobility, and vision—and framed many of these concerns as increasing the potential for adverse health and safety outcomes among firefighters (Table 2).

Many participants expressed concern about being "restricted" or "constricted" by the respirator. These terms were typically used in reference to increased breathing effort and/or increased physical exertion induced by the respirator because of increased breathing resistance from APRs or insufficient air supply from PAPRs. One participant, for example, explained that though they have some respiratory protection in W/WUI firefighting "people don't use them unless it is really bad, and that is because, again, it restricts how much air you're getting in" (P14). Another participant specified that the PAPR needs to prove that it "doesn't have the feel of trying to just like pull air into your lungs" (P17). Less frequently, the terms were used to reflect physical constraints on movement.

Situational awareness is the ability to identify and process elements of an incident in real time in order to make informed decision. Only a few participants used the phrase "situational awareness" but many talked about elements of situational awareness as being negatively impacted by RPDs. For example, one participant stated, "you want to be able to hear and see everything so that you can make the correct decision" (P13), highlighting the importance of vision and communication for situational awareness. Participants reported vision-reduction (or impairment) while wearing SCBAs with full-facepieces, but one participant thought the potential impact of a reduced field of vision to be more significant in W/WUI firefighting because the weather and environmental changes make these fires less predictable than structural fires. Another participant expressed that RPDs put "people more at danger when you're in the middle of the forest at nighttime, can't see already, can't hear already" affecting the firefighter's ability to escape, but also their ability to deploy and get inside a fire shelter. Communication concerns were mentioned in the context of working in a crew and needing to use the radio.

Use scenarios

Participants were asked about whether the use of RPDs was appropriate in specific W/WUI firefighting tasks. Most participants were supportive of using RPDs for mop-up, prescribed/controlled burns, and structure defense activities. Participants were about evenly split in their support of respirator use during progressive hose laying (running hose). Most participants did not support respirator use during cutting line or in base camp.

Support for respirator use in most activities was associated with participants perception of the physical exertion of the task. Mop-up, prescribed burns, and structure defense activities were generally considered by participants to involve less exertion than cutting line and running hose. For example, one participant stated "I could see possibly where [mop-up is] a slower pace. […] There is a lot of still a lot of smoke in the air, so I could see it be beneficial there", but stated with respect to wearing a respirator when cutting line "…absolutely not. That's one of the hardest physical activities you can do as a firefighter" (P16). Participants who were supportive of wearing RPDs during progressive hose laying emphasized that this task typically involves heavy smoke exposure, while those opposed emphasized the physical activity. For example, one participant stated, "[Progressive hose laying] is where we are breathing the most smoke, because we're trying to put the fire out as fast as possible, and this would be the most benefit [for respiratory protection]" (P12), while another stated, "We were moving quickly, trying to catch a fire and most of the time [progressive hose laying] is highly physical. A lot of weight. A lot of stuff already on our back and restricting your ability to breathe during this time [by wearing a respirator] is not a good idea" (P08).

Participants also supported the use of RPDs during prescribed burns because it was a planned activity, so there was lower risk of fire danger, and some felt a heightened need to protect firefighters from smoke exposures arising from fires started by the fire service. One participant described that using respiratory protection would err "on the side of extra safety" and "we could plan for it ahead of time. Try not to put ourselves in bad situations, make sure that we have everyone with the right equipment. […] So I think that might be a good implementation" (P02). Another participant stated, "this is an intentional fire so we shouldn't be putting our firefighters in danger at controlled burns and giving them potential to get cancer and other diseases because we are actually lighting these fires" (P14). Participants who were not supportive of respiratory protection for controlled burns explained that there is not smoke exposure if the burn is properly planned.

With respect to basecamp, while some participants recognized that basecamp can be smoky, most felt that it was impractical to wear respirators at this location because firefighters were eating, recuperating, and cooling down. One participant explained, "that's your downtime […]. But at the same time, I can't tell you how many times I've been at a base camp and had the thing […] absolutely socked in with smoke, and your eyes are burning" (P04).

Potential Cal/OSHA regulation

Nearly all participants had a positive attitude toward Cal/OSHA: participants valued the organization's role

in worker health and safety and intended to comply with regulations. However, many participants expressed concern about the relevance and practicality of Cal/OSHA regulations in general, and specifically for respiratory protection in W/WUI firefighting. A few participants, for example, identified challenges implementing regulations in the fire service that had been written to be generalized across industries (eg regulations related to COVID-19 and ladders), or considered some regulations to be impractical or duplicative (eg requiring wearing high-visibility vests over yellow turnout gear with reflective tape). One participant stated, "At times when it comes down to 'boots on the ground' and application across all of our industries, I think they miss the target" (P01). Participants emphasized that before a regulation for respiratory protection is issued it's important that equipment be "well-vetted […] with tangible evidence about how much it's protecting somebody" (P02) and that policymakers engage firefighters and/or "that they put on packs, and […] see it, smell it, feel it, live it before making any recommendations" (P10). One participant stated, "I think if there was an awareness, and maybe they worked with the firefighters, we […] try to come up with a prototype that works with us rather than just forcing something down our throats would probably be the most beneficial" (P16).

Most participants expressed preference for flexibility in the regulation, such as Cal/OSHA providing guidelines or general performance criteria rather than prescribing specific respirator types and respirator cartridges. There were different reasons provided for this preference including: the change of equipment over time, financial constraints, and perceptions of overreach that might increase resistance among firefighters. A few participants compared the NFPA guidelines favorably relative to OSHA or Cal/OSHA regulations because the NFPA guidelines are recognized as the industry standard, but also because "NFPA makes recommendations based on the best interest of firefighters, and they're purely recommendations" (P07).

Impact on fire departments

Most participants identified that the required use of RPDs for W/WUI firefighting would be a financial burden for departments, but the concern about that cost varied. Some participants, mostly from smaller departments or departments that serve under-resourced communities, stated that securing finances to purchase and maintain essential equipment was a challenge. Many participants expected that federal/state grants or other resources would be made available to purchase required respirators. Some participants discussed the burden of equipment maintenance and replacement, in addition to the cost of initial acquisition; requirements to periodically replace turnout gear and SCBA bottles were given as an example by one participant. A couple of participants noted concerns associated with price inflation for equipment used in firefighting and contracting.

All participants stated that they did not currently have department policies regarding the use of respiratory protection for W/WUI firefighting. All participants, however, described that they have processes in place to develop policies that involved both firefighters and management. No participant expressed concern about the process for developing respiratory protection policies in W/WUI firefighting within their fire department.

Though process barriers were not identified by participants, cultural barriers were identified. One participant explained that RPDs are new to the culture of W/WUI firefighting and "what we hate is change" (P01), though the participant provided examples of change and suggestions for how to make the change happen. Other participants also provided indications that change was possible. For example, several participants ascribed positive benefits to adoption of SCBAs in structural firefighting and described recent changes in respirator use during mop-up operations in structural firefighting. Education about hazards was described as a key motivator for respirator compliance and culture change, as well as losses of personnel. A participant stated, "I think we're going to have a lot of push back on [requiring respirators]. But again, if we educate people and we come out and say why we're doing it and we potentially, at the same time, change our policies in order to allow other or more crews to come in so we can get more breaks, things like that, then that would be helpful" (P14).

Written policies

Six participants provided written policies that addressed: training or procedures for SCBAs ($n = 3$), training plans for respiratory protection in general ($n = 1$), respiratory protection programs ($n = 2$), and documents not specific to respiratory protection ($n = 2$). The respiratory protection programs were nearly identical and copyrighted by Lexipol, LLC, a company that provides site-specific policy development and other services to public safety and local government agencies. Owing to the small number of documents provided by participants, they were not thoroughly reviewed against relevant standards but appeared to be consistent with regulations and expectations for training materials.

Discussion

This study sought to understand the perspectives of California fire service personnel regarding the use of

respirators in W/WUI firefighting and potential regulation by Cal/OSHA. Participants with experience in W/WUI firefighting and role in respiratory protection or other aspect of firefighter safety were recruited from across the State. The study revealed that California fire service personnel are aware of the health risks associated with W/WUI firefighting and generally supportive of RPD use in certain firefighting activities, though they have substantial concerns about functionality of the RPDs, operational practicality, and the implementation of a potential regulation. While quotes have been included throughtout the Results section, additional quotes are available in the Supplementary Materials. While our study was focused on the California context, the findings are broadly relevant because respiratory protection is not a standard of practice among W/WUI firefighting across the United States or globally.

The target sample size was 20 participants, but participant responses were found to be similar after 17 interviews were completed so recruitment was discontinued. Attainment of saturation, indicated by lack of new information provided by the last few participants, was a strength of the study, particularly in light of the diversity of fire departments represented by participants. The study may have been subject to selection bias, with participants who are supportive or opposed to respirators or regulations being more likely to participate. This risk of bias, however, was unlikely to affect the results of this study because while participants had shared knowledge about the hazards of W/WUI smoke exposures, the participants expressed a range of opinions about respiratory protection. Participants indicated that concerns about occupational health are broadly shared in the fire service.

Participants were aware of acute and chronic health risks, particularly cancers, affecting W/WUI firefighters because of smoke exposures, and many referenced their personal experiences, the experiences of colleagues and/or research findings. The 2023 classification of occupational exposure as a firefighter as a known carcinogen by IARC (IARC 2023) received a lot of attention in the fire service and was preceded by several major research initiatives that engaged fire service organizations and personnel involved in W/WUI firefighting. In the United States, these include the Fire Fighter Cancer Cohort Study, a collection of studies that has focused on biomarkers of exposure and early health effects (Goodrich et al. 2025), and the Wildland Firefighter Exposure and Health Effects Study (Navarro et al. 2022).

Participants expressed concern about the effort required to inhale air through a RPD and insufficient air supply. Breathing resistance is a recognized characteristic of APRs that varies among respirator models and is influenced by the type of filter or cartridge used and level of exertion (Caretti et al. 2001). In a prior study of wildland firefighters wearing full-face APRs, participants reported reduced ability to perform arduous physical activities like progressive hose laying at the current work rates (Beason et al. 1996). This means that changes to work organization may need to be made to accommodate the use of APRs in W/WUI firefighting, just as were made to accommodate the use of SCBAs in structural firefighting. In theory, PAPRs that deliver a flow of filtered air in excess of the wearer's breathing rate should not increase breathing resistance, but experimental simulation studies have found that the airflow provided by PAPR fans can be lower than the air supply required by the wearer during moderate or high exertion (Sinkule et al. 2016). Depending upon the facepiece, this can lead to increased breathing resistance and/or the inhalation of contaminated air into the facepiece (Johnson et al. 2011; Sinkule et al. 2016). Many PAPRs sold today are intended for use by workers with low to moderate levels of physical exertion, such as welders, so it is not surprising that the airflow rate produced by the blowers will need to be increased for use by workers during physically strenuous tasks like W/WUI firefighting.

Participants expressed a related concern that RPD use would increase fatigue owing to the increased breathing resistance and weight of the PAPR. SCBAs are likely to have a greater impact on physiological response and biomechanical performance than APRs and PAPRs, and have been effectively incorporated into structural firefighting though the duration of exertion in structural firefighting is much shorter than in W/WUI firefighting. Research into this topic is ongoing. However, W/WUI firefighters often describe feeling ill after smoke exposure, with respiratory symptoms, headache, fatigue, nausea, and mental fog (De Vos et al. 2009; Cherry et al. 2022). By reducing smoke exposures, RPDs may alleviate these symptoms (Filiberti et al. 2025). Reduced smoke exposures as a result of full-facepiece APRs were reported by wildland firefighters to enable better decision making: the smoke exposure did not "take their breath away" and force them to run for fresh air (Beason et al. 1996). Further research, however, is necessary to understand the benefits of reduced smoke exposure with respect to fatigue and situational awareness, and the challenge posed by increased weight or breathing effort and limitations on field-of-view and communications from RPD use in W/WUI firefighting.

Participants expressed a strong preference for a guidance approach from Cal/OSHA rather than a prescriptive approach toward RPD use in W/WUI firefighting. It was unclear what motivated this preference. Some participants may have wanted to avoid regulation on principle. Others may have been influenced by organizational culture or concerns about practicality. Some expressed a preference for having options to achieve

regulatory compliance. Such options could include flexibility for firefighters or fire service organizations to decide which situations require need RPDs, as well as flexibility in response to financial constraints or local preferences. Further, the lack of detail about what a regulation would entail may have influenced participants' preference for guidance and flexibility.

Cal/OSHA has taken at least two different approaches to RPD regulations, which have varied flexibility. The Cal/OSHA Respiratory Protection standard (Title 8 §5144) uses a programmatic approach in which employers are required to develop and implement a program that leads the employer to identify the type of NIOSH-certified respiratory protection required for specific work tasks, and then select the specific respirator models that achieve the necessary level of protection. In contrast, recent amendments to the Occupational Exposures to Respirable Crystalline Silica standard (Title 8 §5204) require specific RPDs during "high-exposure tasks," as defined in the regulation. While any regulation developed by Cal/OSHA for W/WUI firefighting will most likely leed to the use of RPDs that are NIOSH-certified and compliant with NFPA 1984, a programmatic approach that requires fire service organizations to provide RPDs and training, but provides some flexibility for departments to identify the specific tasks or exposure scenarios when specific RPD models (and filters or cartridges) must be used, may be a path forward.

Participants were most supportive of using RPDs for mop-up, controlled burns, and structure defense activities. Though personal exposures of W/WUI firefighters have been found to exhibit variability over time along multiple dimensions, exposures during mop-up and controlled burns have been found to have high exposures to respirable particulates, carbon monoxide, PAHs, formaldehyde, and benzene relative to other tasks (Reinhardt and Ottmar 2004; Reisen et al. 2011; Semmens et al. 2021; Zadunayski et al. 2024; Gili et al. 2025). This means that use of RPDs during only these activities could meaningfully reduce exposures to smoke constituents, with the likely exception of carbon monoxide, depending upon the type of filter or cartridge utilized.

While participants in this study have intentions to comply with Cal/OSHA regulations, RPD use in W/WUI firefighting will be a major shift in work practice, and consistent use of RPDs may take time to develop. In a study of discretionary use of half-mask elastomeric APRs and two other types of masks, Broznitsky et al. (Broznitsky et al. 2024) found that 20% of participants did not wear the APRs at all, and those that wore the devices did not wear them for 5.5 h per day, on average. In a study of wildland firefighters randomly allocated to wear N95 FFRs, Zadunayski et al. found that while firefighters' subjective ratings of smoke density were strongly correlated with objective measures of exposure in this study, perceived smoke density was not associated with FFR use (Zadunayski et al. 2024). The fire service has demonstrated the ability to incorporate new RPDs into their work practices with the adoption of SCBAs for structural firefighting, which are now viewed as indispensable tools.

A challenge with the use of RPDs in W/WUI firefighting is that knowledge about exposures is incomplete, and health effects may arise from the mixture of exposures when exposures to individual agents to not exceed occupational exposure limits (West et al. 2024). Traditionally, respirator selection is based on identification of the individual agents and exposure levels. Each respirator model has an assigned protection factor that describes the magnitude of exposure reduction expected owing to facepiece design (Occupational Safety and Health Administration 2009). The filter and/or cartridge is selected for the specific agent to which the firefighter is exposed, while the magnitude and duration of the exposure influence the change-out schedule for the filter or cartridge. Together, these choices seek to ensure that the contaminant concentration inside the respirator facepiece is below the Permissible Exposure Limit. Research is ongoing to better characterize exposures in W/WUI firefighting that can inform the selection of RPDs, but the occupational health regulatory framework has limited ability to assess exposures and select RPDs in the context of complex mixtures. This is an area in need of further research.

Incorporation of RPDs into W/WUI firefighting requires the development and dissemination of evidence about RPD effectiveness, training opportunities for firefighters, and modifications to the design and performance of existing APRs and PAPRs to meet user requirements for this application (Table 2). It is reasonable to expect that the design and performance of APRs and PAPRs can be modified to meet requirements for W/WUI firefighting and address concerns expressed by participants in this study and in prior research (Beason et al. 1996), given the interest in reducing smoke exposures expressed by study participants. There are well-established methods for user-centered design and evaluation of technology using principles of human factors and prevention-through-design that can be applied to RPDs (Chen et al. 2015). Virtual reality may facilitate innovation in design (Beam et al. 2023), while also providing opportunities for firefighters to gain familiarity with RPDs in W/WUI fire use scenarios.

Conclusions

Based on the evidence to date, and the findings in this study, it is clear that APRs or PAPRs can become part

of the standard kit of W/WUI fire fighters. A Cal/OSHA regulation would certainly motivate this transition among a fire service that has expressed heightened concern about the health and safety of their personnel. Findings in this study indicate that any initiative to increase RPD adoption in W/WUI firefighting will be well-served by furthering efforts to incorporate firefighters into the rulemaking process, such as by: providing opportunities for fire fighters to use candidate RPDs in training or prescribed burn settings; sharing evidence about the effectiveness of RPDs in reducing exposures and their impact on breathing resistance and fatigue; and exploring the logistics of implementing a potential regulation in the fire service. Information priorities include developing further evidence about the impact—positive and negative—of RPDs on fatigue and situational awareness W/WUI firefighting, employing user-centered testing to develop and evaluate RPD design changes, and educating firefighters on the anticipated risk reduction associated with different RPD options and use scenarios.

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Supplementary material

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Conflict of interest

The authors declare no conflicts of interest relating to the material presented in this article. Its contents, including any opinions and conclusions expressed, are solely those of the authors.

Data availability

Deidentified transcripts, transcript excerpts classified by code and meta-data are available from the investigators upon reasonable request.

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