Introduction
Wildland firefighters often work under hazardous situations involving extreme fire behavior, topography and power tools and potentially health-compromising situations are commonplace. Because of the physical injuries such as cuts, burns and broken bones, the potentially debilitating effects of smoke inhalation are often viewed as just a job inconvenience. Studies show that exposure to the chemical components of wildland smoke can lead to negative health effects and other symptoms which may compromise worker performance. Most health problems are not long term, and can be managed using proper preventative techniques such as crew rotation through heavy smoke conditions and proper personal protective equipment. However, a solid understanding of the chemical components of wildfire smoke and its effects on the human body assists both workers and supervisors in making educated decisions in emergency situations that can protect employees from dangerous exposure to smoke.

Alberta Sustainable Resource Development asked FERIC to review both print and web-based literature and to summarize this information.

Results

Composition of Wildfire Smoke
The cause of many firefighters’ physical discomfort is the dangerous cocktail of chemicals mixed into wildfire smoke. Researchers have discovered the presence of respirable particulate, carbon monoxide, formaldehyde, acrolein, benzene, sulphur dioxide, formic acid, polyaromatic hydrocarbons, and lead in burning vegetation (Sharkey 1997; USDA Forest Service 2001; Harrison et al. 1995). They have also detected levels of herbicides, pesticides, fire retardant and lead that have become airborne after treated areas have burned (Harrison et al. 1995). Naturally occurring silica and asbestos found in dust can also become a hazard in dry work conditions (Harrison et al. 1995).

Smoke Constituents and Health Concerns
Most chemicals exist in small, tolerable amounts, but health concerns surround the intake of especially respirable particulates, carbon monoxide, and sulfur dioxide. Respirable particles consist of airborne soot that is small enough to be inhaled directly into the lungs; there it irritates and burdens airways, and introduces carcinogenic compounds to surrounding tissue (Sharkey...
Carbon monoxide is an odorless, colorless product of incomplete combustion that inhibits the blood’s ability to carry oxygen (Sharkey 1997). Aldehydes like formaldehyde and acrolein sting and burn eyes and irritate airways (Sharkey 1997).

Acute or day-to-day exposure to these gases and chemicals can lead to detrimental physical conditions. Symptoms have been linked to excessive inhalation by these components including eye irritation, coughing, wheezing, headaches, irritability, nausea, dizziness, decreased work capacity, loss of time awareness, difficulty with decision making and difficulty performing complex tasks (Sharkey 1997; Harrison et al. 1995; USDA Forest Service 2001; Davis and Mutch 1995; Langley 1997; Reinhardt et al. 1999). Research has also shown an increase in the number of cases of neurotoxic injury and upper and lower respiratory airway irritation (Harrison et al. 1995). One study shows that 30 to 50% of visits to medical tents in fire camps were due to coughs, colds and sore throats (USDA Forest Service 2001). As carbon monoxide converts healthy bloodstreams into carboxyhemoglobin-laden oxygen-deficient tramways, the central nervous system is affected causing headache, impaired judgment, progressive lethargy and a decrease in sharpness of vision (Davis and Mutch 1995). These symptoms are a debilitating combination that could affect a firefighter’s ability to escape a dangerous situation.

Chronic exposure to components of smoke can increase the risk of heart disease, chronic lung disease and cancer, and can compromise the effectiveness of the immune system (Sharkey 1997). Harrison et al (1995) measured FVC (forced vital capacity), and found that wildland firefighters may suffer from airway damage by acute decrements in pulmonary function leading to a decrease in airflow rates across the field season. More research is required to fully understand long-term effects. The creation of a database containing information on exposure, past medical history, smoking and work history (Harrison et al. 1995) would be beneficial to those involved in wildland firefighting operations, but would be difficult to implement due to today’s privacy and confidentiality issues.

Although studies suggest small but statistically significant decreases in lung function after either a day or a season of firefighting, most respiratory problems appear to return to normal after
exposure to clean air (USDA Forest Service 2001). In fact, wildland firefighters do not experience extreme acute exposures to carbon monoxide that structural firefighters face, and may be exposed to levels exceeding occupational safety and health standards on average only five percent of the time (Letcher 2004; Sharkey 1997; Harrison et al. 1995; Materna et al. 1992). A study by the Rural Industries Research and Development Corporation (1994) showed that firefighters absorbed more carbon monoxide from their cigarettes than from bushfire smoke. Rather than isolated extreme acute exposures, the more significant health concern for wildland firefighters relates to periods of continuous smoke exposure while performing fire related activities. Workers often operate in heavy visible smoke for up to 16 hours a day for several days or weeks, where they are at risk of exceeding regulatory and/or recommended full shift occupational exposure limits for carbon monoxide, respirable particulates and aldehydes (Harrison et al. 1992). During these extended work shifts, they made uptake a larger dose of contaminants and less time is available between exposures for the body to eliminate substances stored in the body (Materna et al. 1992). Prolonged exposure to carbon monoxide can be hazardous as carboxyhemoglobin accumulates in the blood over time, decreasing the blood’s ability to transport oxygen to brain and muscle tissues (Sharkey 1997). Carbon monoxide readings taken in base camps have also shown levels exceeding occupational standards, meaning workers are still being exposed to potentially harmful chemicals even when not directly attacking fire (Materna et al. 1992). Exposure time and intensity will vary among tasks, and so will the combination of active chemicals. For example, a worker running a pump or chainsaw will experience higher concentrations of carbon monoxide and benzene, while an individual working at a mop-up site will be exposed to higher concentrations of respirable particulates (Materna et al. 1992).

Because of the large variance in smoke environments across fire activities, it is difficult to fully understand the influence of smoke on firefighter health. Most wildfires are emergency situations and workers cannot be easily monitored as they are relocated frequently. Working conditions such as high altitude, high temperature and rapid breathing rates may affect the degree of chemical uptake, but have not yet been fully investigated by researchers (USDA Forest Service 2001; Materna et al. 1992). There is also a documented difference between smoke exposures in initial attack scenarios compared to project work. Although initial attack crews may work at a faster pace, on average they spend less time in smoky situations as they are moved about the emergency scene and wait for fires to occur (Reinhardt and Ottmar 2004). Prescribed fire workers spend longer periods of time maintaining fire within designated boundaries and directly attacking spot fires, often spending whole shifts in heavy smoke (Reinhardt and Ottmar 2004).

**Management Practices to Reduce Firefighter Exposure**

Management practices can protect firefighters from unnecessary exposure to smoke. Crews should be rotated through areas of heavy smoke and allowed to rest and recover in a smoke-free environment after every 7 to 9 days on the fireline (Reinhardt et al. 2000). Changing shift patterns can put average carbon monoxide intake levels above or below the regulated limits (Reinhardt and Ottmar 2000). Decision makers and incident commanders need to provide a smoke-free environment for brainstorming activities to prevent confusion and irritability associated with smoke exposure (Reinhardt et al. 2000).

Fire operations can also be managed to reduce smoke exposure. All planning and briefing sessions should include discussion of smoke hazards and address techniques to control crew
exposure. These techniques can include using flank rather than head attack on fires where appropriate, minimizing mop-up activities and relying on burn-up rather than water to extinguish fires, avoiding inversion conditions, watering heliports and road to control dust, locating camps, staging areas, helibases and command posts in low smoke areas, using equipment rather than people in holding areas, designing burn plans with maximum allowable perimeters and more complete combustion, as well as providing masks and goggles as personal protection from the effects of smoke (Letcher 2004; Reinhardt et al. 2000). Firefighters can also be equipped with personal dosimeters\(^1\) to detect levels of carbon monoxide in the air and alarm in dangerous conditions (Walter 2001; Hall and Adams 1998; Harrison et al. 1995).

**Personal Protective Equipment**

Respirators and filtering masks have been investigated for use in wildfire situations. Providing effective protection is a difficult task, as firefighters are exposed to both toxic gases and dangerous particulates, and few technologies can protect against both. Air purifying filter masks cannot protect against carbon monoxide exposure (USDA Forest Service 2001; Harrison et al. 1995) and large self-contained breathing apparatuses (SCBA) such as those used in structural fires are too bulky and heavy for wildland situations (USDA Forest Service 2001; Hall and Adams 1998; Budd et al. 1996). Although SCBA can protect against inhalation of carbon monoxide and other gases, they are not feasible in wildland scenarios as they generally are only effective for short periods of time, restrict breathing and vision, decrease the ability to communicate, increase pulmonary load and are difficult to use in remote locations and over long distances (Hall and Adams 1998; Budd et al. 1996). Firefighters have been known to use bandanas for protection in smoky areas, but they cannot defend against noxious gases. Bandanas do not create a seal between face and mask, protection is minimal (Reh and Deitchman 1992), and the material is often not fire resistant.

Disposable single use masks, such as the 3M™ 9211 respirator and Bandit® particle mask, have been suggested for use on the fireline to protect against respirable particulates (Hartley 2002; Reh and Deitchman 1992). There are many particle masks available on the market, but those used should meet NIOSH (National Institute for Occupational Safety and Health) standards (Hartley 2002; Reh and Deitchman 1992). The respirator should be comfortable for extended use in hot conditions, have minimal negative effect on air intake, and be portable and convenient to use. The Bandit® is a bandana style protection mask with a sewn in replaceable carbon filter that claims to protect from gasoline and diesel fumes, acid gases, lead oxide and irritant dusts (although it does not meet any NIOSH standards). The 3M™ 9211 respirator meets NIOSH standards and protects from smoke size particle inhalation. When properly fitted, it provides a seal from outside air and a specially designed valve allows for easy dispersal of hot and moist air.

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\(^1\) This instrument identifies the full-shift exposure that a person has received to a physical hazard.
Disposable masks are rarely fire resistant. It is important for a firefighter’s attire to be completely fire resistant in order to avoid burns. Some air filter masks on the market are intended for use in wildland firefighting. Whiffs Brush-Pro® Mask is made of Advance Nomex® and has a heat rating to 1050°F. A specially-designed liner material wicks moisture away from the face and prevents the transfer of radiant heat to the skin. The Brush-Pro® meets the NFPA (National Fire Protection Association) 1977 Protective Clothing Standard; even the elastic and cloth of the filter have been fire rated (Reese 2005). Whiffs® also design a product similar to the Bandit® but composed of a fire resistant material. Respro® has designed the FB-1 mask, with a hepa-type filter that adheres to the EN149 (European Standard for filtering pieces as directed by the Care of Substances Hazardous to Health group) and protects against respirable submicron particulates. The mask is made of a flame resistant neoprene material and is fitted with two valves designed to release carbon dioxide, heat and water vapor.
Understanding the potential health effects of smoke inhalation can encourage firefighters to make decisions in the workplace to reduce exposure and allow their respiratory systems opportunity to recover. Further research into more suitable respiratory protection, adjustment of standards to comply with long work schedules, exposure limits in high temperatures and heavy work rates, and potential risk from exposure to multiple contaminants will help managers keep crews safer in heavy smoke conditions (Harrison et al. 1995). In wildland fire situations, harmful health effects of smoke can be mitigated with educated management techniques, and knowledge and respect for chemicals involved.

References


