Impact of wildland fire smoke: Concern for Clinicians Worldwide

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Millions of people each year are exposed to wildland fire smoke, often repeatedly within a fire season. The expansion of the wildland urban interface and influx of people into fire prone areas further increases risk. Wildfires are increasing in severity, causing a deterioration in air quality of region in Himalayas and south East Asia. Wildland fires have become a national public health issue given the increasing area burned by both unplanned wildfires and planned prescribed fires. Both wildfires and prescribed fires produce smoke and impair air quality, so both raise health concerns. However, large wildfires create particular challenges because they are less predictable and impact large areas for long periods. Unpredictable weather changes can create more smoke than anticipated, exposing nearby communities. Prescribed fires tend to burn at lower temperatures with more smolder than wildfires, likely producing a different smoke profile. However, smoke exposure assessment studies have used different sampling periods at different proximities to the fire, which complicates efforts to directly compare pollutant exposures from prescribed fires and wildfires[1]. The factors that predict differences in the quantity, composition, toxicity, and duration of smoke emissions are still emerging[2]. In recent years, wildfires have become a significant threat among natural disasters in a warming climate, causing significant economic and environmental impacts in Nepal and globally. In Nepal, dry weather and fuel availability that characterize the premonsoon season altogether cause increased wildfires[3]. Evidence based data regarding the adverse health effects of wildfire smoke is limited by the lack of control populations or long-term studies. In addition, some epidemiologic research combines respiratory diagnoses (for example, asthma, COPD, and bronchitis) and outcomes (such as emergency department visits and hospitalizations) for analysis, which may limit interpretation. Research into the health effects of wildfire smoke is also influenced by the methods used to estimate exposure[4], and there is no universally accepted standard for approximating exposure on a population level.

Various approaches are used to estimate wildfire smoke exposure, including area monitor PM measurements, modeled PM, satellite data, chemical transport models, and a combination of these techniques. Temporal comparisons are confounded by temperature and humidity, and area monitors can be imprecise due to spatial variation in smoke.[5] In one study used multiple datasets and trajectory analysis to examine hazardous air pollution levels in Nepal's Kathmandu valley was largely due to wildfire smoke from neighboring and transboundary areas, with a strong correlation between active fire counts and pollution levels.[6]

Wildfire smoke also contains at least 20 types of hazardous air pollutants (HAPs) recognised such as formaldehyde, benzene, and hydrogen cyanide[7]. Although carbon monoxide exposure is usually confined to areas directly affected by a fire, the particulate matter spreads much further[8]. The particulate matter from wildfires can be more toxic than ambient non-smoke pollution particulates due to greater exposure peaks, more intensive cumulative exposure, and differences in composition. Wildfires generate fine (under 2.5 microns) and ultrafine (under 1 micron) particulates, commonly known as $PM_{2.5}$, which disperse over a greater area and settle more slowly than larger particles, resulting in prolonged exposure time and sizable affected regions. Wildfire $PM_{2.5}$ can impact residents in a 10 to 15 times larger area than the actual area burned. Fine and ultrafine particulates are unique in their ability to not only penetrate deeply into the lungs causing local damage, but can also be absorbed into the bloodstream causing systemic harm. Wildfire smoke contains more oxidative components, such as polycyclic aromatic hydrocarbons and quinones, along with pro-inflammatory elements, such as aldehydes and oxides of nitrogen, rendering it more toxic than the non-smoke pollution particulates in urban areas. Moreover, the high temperatures, characteristic of wildfires, facilitate the oxidation of the smoke particles, giving rise to free radicals. This amplifies the risk of cellular damage inflicted on cells and tissues within the human body.[9,10] World Health Organization recommends daily $PM_{2.5}$ exposure not exceed 25 $\mu g/m^3$; however, in wildfire affected areas, the $PM_{2.5}$ concentration can far exceed these guidelines.

Wildfire smoke exposure is strongly associated with asthma symptoms, healthcare utilization, emergency department visits, and hospitalizations. The majority of studies looking at wildfire smoke exposure and asthma emergency department visits have shown a positive association. Likewise, data regarding asthma hospitalizations after wildfire exposure demonstrates a significant increase in hospitalizations. A 10 $\mu g/m^3$ increase in $PM_{2.5}$ is associated with an 11% increase in asthma-related emergency department visits.

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A systematic review confirmed a significant increase in all respiratory emergency department visits and asthma-related hospitalizations within the first 3 days of exposure to wildfire smoke.[11] Nearly three decades of epidemiological, clinical, and toxicological research have demonstrated cardiopulmonary health effects of exposure to ambient particulate matter (PM), especially fine PM ($PM_{2.5}$). Investigators have examined a wide range of health outcomes, from subclinical indicators of inflammation to cause-specific mortality. In general, the associations between wildland fire smoke and cardiopulmonary health effects are consistent with those found for exposures to ambient $PM_{2.5}$. A large body of evidence indicates that wildland fire smoke increases rates of respiratory medication use, ambulance calls, emergency department visits, hospital admissions, and all-cause mortality. There is also growing evidence of acute cardiovascular health effects of wildland fires, although cardiovascular studies to date have been less consistent than respiratory studies.[12] There is an established link between total ambient air pollution and lung cancer. There is a 9% increase in lung cancer incidence or mortality for every 10 μ/m^3 increase in $PM_{2.5}$ and among never smokers, ambient air pollution exposure is associated with lung cancer. Global Initiative for Chronic Obstructive Lung Disease (GOLD) statement 2024 on COPD and air pollution describes ambient and indoor air pollution as a risk factor for COPD development, accelerated decline in lung function in people with COPD, and impairment of lung development in children.

People who are most susceptible to health effects of air pollution are children, the elderly, and those with cardiopulmonary diseases (including asthma, COPD, ischemic heart disease) or socioeconomic disadvantage appear to be more susceptible to wildland fire smoke. Pregnant women and the developing fetus also appear to be at increased risk. Even healthy children have been found to experience upper respiratory symptoms and increased cough and wheeze during wildfires, and those with relatively smaller airways have a higher risk of respiratory symptoms. Recent meta-analyses suggest that women older adults, African Americans, and those living in poorer neighborhoods are especially likely to experience respiratory health effects from wildland fire smoke exposure.[13,14]

Wildfires are increasing in frequency and severity due to climate change and human activities. This is predicted to become an ever present phenomenon with widespread impact on health. Numerous interventions for wildfire smoke risk reduction are suggested by public health organizations, including limiting outdoor exposure during poor air quality days, using air quality alert systems to plan activities, wearing a facemask, and using air filtration systems. To tackle this mounting public health crisis with growing respiratory health risks of wildland fire smoke requires a coordinated and integrated approach among scientists, fire managers, regulators, public health practitioners, and the affected public. Actions that arise from multidisciplinary research, policy development, and communications that penetrate to all levels, from those directly managing and fighting the fires to the health practitioners managing health consequences of smoke and to an informed and empowered public.

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