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Wildland Fire Smoke Effects on Public Health What Does the Research Say?

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INTRODUCTION

Wildland fire smoke can impact public health and fire managers need to be aware of recent smoke science research findings to make informed decisions. In this fact sheet we seek to "clear the air" by summarizing the progress of scientific research investigating the effects of wildland fire smoke on public health and actions individuals can take to minimize their exposure to smoke. We draw primarily from literature reviews by Liu et al. (2015) and Reid et al. (2016) on related research over the last 20 years.

HOW WE KNOW WHAT WE KNOW

For most smoke impact studies, researchers obtain administrative health data, including mortality and hospitalization records, to look for changes in reported health problems during periods of known regional wildland fire smoke exposure. In earlier studies, smoke exposure estimates from wildland fire relied on ground-based air monitors to measure the extent of pollutants, but some recent studies have shifted to using satellite imagery and chemical transport models. This information is then typically used to compare health statistics either A) between periods of no fire and periods during or shortly after fire events or B) between regions with no wildland fire smoke and regions affected by wildland fire smoke. Some studies have used interviews, surveys, or direct measurement of smoke exposure on humans or other organisms. Smoke exposure duration examined in studies varied from a few days to over 12 years. The majority of scientific studies assessing the impacts of wildland fire smoke on public health have been in regions where such fires are most common, including: the Brazilian Amazon, southeastern Asia and Pacific islands, western North America and the Mediterranean region. While knowledge of the impacts of wildland fire smoke have increased, our overall understanding continues to be limited by several factors. These include the relatively small number of studies conducted globally, difficulties distinguishing between emissions from wildland fires and the many other sources of pollution (Leonard et al., 2007, Naeher et al., 2007), and the difficulty accounting for the differences among wildland conditions in terms of fuel, fire behavior, and weather (Naeher et al. 2007).

Prescribed fire in a Florida forest. Photo: David Godwin.

HARMFUL COMPONENTS OF WILDLAND FIRE SMOKE

Wildland fire smoke is known to contain unhealthy and carcinogenic compounds (see box). Negative health impacts can include: eye, nose, and throat irritation, headaches, loss of coordination, nausea, damage to liver, kidney or central nervous system, and possibly cancer. Particulate matter (PM), the most frequently studied air pollutant, can be several times normal levels as a result of wildland fires. PM is a mixture of microscopic solids and liquid droplets composed of many different organic chemicals, acids, metals, soil or dust particles, and allergens, which are suspended in the air during a fire. These particles are classified by size as fine ($PM_{2.5}$ = particles < 2.5 µm) or coarse (PM_{10} = particles < 10 µm). Particulate matter becomes increasingly harmful as it decreases in size, as smaller PM can penetrate deeper into the lungs (Franck et al., 2011). However, research is beginning to suggest ultrafine PM affects cardiac response while coarse PM causes lung inflammation, suggesting that both sizes are harmful (Kim et al., 2014).

Additionally, PM containing toxic chemicals, including bromine, arsenic, and chromium, can be even more harmful (Zanobetti et al., 2009). Particulate matter is produced mostly by incomplete combustion of fuels, especially from smoldering combustion, which can have an emission factor

Harmful Components of Wildland Fire Smoke

- Particulate Matter (PM)
- Polycyclic Aromatic Hydrocarbons (PAH)
- Volatile organic compounds (VOC)
- Carbon monoxide (CO)
- Nitrogen Dioxide (NO_2)
- Ozone

(production per unit biomass consumed) that is several times that of flaming combustion (Einfeld et al., 1991; Stone et al., 2018). Particle size and composition can also be influenced by fuel type, burn conditions, and dominant combustion phase (flaming versus smoldering; Leonard et al., 2007). For example, smoldering combustion was less efficient than flaming and had higher mutagenicity emission factors from burning ponderosa pine needles and lodgepole pine wood (Kim et al., 2018).

EFFECTS OF WILDLAND FIRE SMOKE ON PUBLIC HEALTH

Smoke can affect people in various ways from immediate impacts to cumulative effects over a long period of time. While risk varies between population groups, research broadly agrees that the greatest impacts are on people with existing conditions exacerbated by smoke, especially respiratory conditions like asthma, chronic obstructive lung/pulmonary disease (COPD) and probably heart disease.

Respiratory Conditions

The most well studied and best-established health outcomes related to wildland fire smoke are asthma and COPD. Multiple studies showed increased asthma admissions to medical facilities when exposed to wildland fire smoke, particularly PM. Evidence that exposure to wildland fire smoke exacerbates COPD is also mounting. With regard to respiratory infections, results are inconsistent but suggest an association between wildfire smoke exposure and acute bronchitis and pneumonia. Current research only establishes support for smoke worsening existing conditions or weakness, rather than causing new diagnoses of these respiratory conditions.

Cardiovascular Conditions

Links between wildland fire smoke exposure and cardiovascular illness are inconsistent, with only 43% of studies finding an association. In those studies, there is suggestive evidence of associations between wildland fire smoke and reduced blood supply to the heart, congestive heart failure, cardiac arrest, heart attack and stroke.

Other studies examined angina (pain from reduced blood supply to the heart), cardiac failure, irregular heart rhythm and hypertension, but found no association between these cardiovascular conditions and wildland fire smoke exposure. Overall, there is support for increased emergency department visits for cardiovascular and cerebrovascular problems when exposed to wildfire smoke, but the specific outcomes and mechanisms behind them are not fully understood.

Mortality

More and more research is supporting an association with wildland fire smoke and total (all causes) mortality, emphasizing the need for additional studies to assess which of these causes are most affected by wildland fire smoke. Studies suggest these premature deaths increase most under periods of high temperatures and with larger areas burned (>7,500 ac). While studies do not seem to support a link of all-cause mortality with age, specific causes of death may interact with age. For example, smoke from wildland fires in Greece influenced cardiovascular mortality more in individuals younger than 75 than in older individuals, while respiratory mortality was more greatly influenced in individuals over 75 than younger individuals (Analitis et al., 2012).

Other Possible Health Effects

Studies have also investigated effects of smoke on birth weight, bone marrow content, systematic inflammation, diarrhea, diabetes, injuries, physical strength and overall health. However, these studies are limited in number and have shown inconsistent results. Further research is needed to determine if or when wildland fire smoke may produce or contribute to these other health outcomes.

AT RISK POPULATION GROUPS

Studies that assess the public health risk of specific population groups to wildland fire smoke broadly agree that individuals with existing conditions or weaknesses are most likely to have negative health effects when exposed to wildland fire smoke. There is also growing evidence supporting a link between age and health risk from smoke. For example, middle-aged to older adults are at greater risk of increases in cardiorespiratory illness, while respiratory-related hospital visits are greatest among children under 5. One study suggests greater asthmatic exacerbations from smoke in obese children than those with lower body mass indices (Tse et al., 2015). Besides age, limited research suggests individuals in lower socio-economic status may be at greater risk of negative health outcomes from wildland fire smoke exposure, possibly due to a higher prevalence of existing chronic and under-treated medical conditions (Rappold et al., 2012). There is also research suggesting women and African-Americans have greater risk of respiratory admissions from wildfire smoke than men and Caucasian individuals (Liu et al., 2017).

WILDLAND FIRE SMOKE AND PUBLIC HEALTH IN THE SOUTHEASTERN UNITED STATES

Research addressing public health concerns from wildland fire smoke in the southeastern United States are limited to a few studies. Several of these are from North Carolina examining cardiorespiratory and cardiopulmonary outcomes from exposure to smoke from burning peat bogs (Rappold et al., 2011, 2012). Another study found overall exposure to wildland fire smoke was not dependent upon the social vulnerability of communities throughout the southeast (Gaither et al., 2015). Despite limited studies, online news reports frequently show that smoke from wildland fires is an important concern for individuals across the region. Most of these articles describe wildfires

ignited from lightning or arson, but they can include prescribed burns. In another study, exposure to wildfire smoke in temperate regions was shown to be typically episodic, suggesting that negative health outcomes from smoke exposure in the Southeast are likely to be acute and short lived as opposed to chronic (Reid et al., 2016). Although typically short lived, fires in the southeastern U.S. are historically more frequent than other parts of the country (Frost 1998). Frequent fire makes potential exposure to smoke more common but reduces emissions of $PM_{2.5}$ (Robertson et al., 2014) and other constituents of smoke per burn event. The tradeoff between frequent low-intensity fire and the potential for high-intensity wildfire with regard to air quality have not been well studied, but proximity to the fires is likely important, since smaller fires with weaker convection presumably have more limited smoke transport.

CONCLUSIONS

Smoke is known to contain several types of compounds that are harmful to human health at certain concentrations. While more research is needed to understand what health risks wildland fire smoke poses to the public, there does seem to be substantial evidence to support that wildland fire smoke exacerbates pre-existing respiratory and cardiovascular conditions or weaknesses including asthma and COPD (Reid et al., 2016). However, current research, which is limited in number of studies, does not yet have the capacity to determine long-term effects of wildland fire smoke or its relationship to other possible health outcomes including the development of new health problems.

Regardless of ongoing research, fire managers should seek to be proactive in minimizing the effects of wildland fire smoke on the public. This can be done by informing the public about anticipated smoke impacts, educating the public on ways to minimize exposure to smoke, and in the case of prescribed fire, prescribing burns in a manner that uses all available technology and appropriate practices to minimize potential impact on smoke sensitive areas in order to protect public health.

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Individual Actions to Reduce Smoke Exposure

Individuals can do several things to reduce their exposure to wildland fire smoke. First, they can monitor air quality using visibility or websites with data from nearby air monitoring stations and remote sensing (see below). Personal devices (e.g. FLOW URL: https://flow.plumelabs.com/) can be carried by individuals to monitor daily exposure to air pollutants. While such monitoring is not specific to wildland fire smoke, it gives the complete picture of air quality which will be more closely associated to adverse health conditions.

When poor air quality is present, individuals should reduce activity outdoors and close exterior windows and doors. Air conditioners should be set to recirculate and pleated medium- or high-efficiency particle filters can be used to filter some pollutants out of the air. Avoid doing things that further deteriorate interior air quality such as vacuuming, burning tobacco, candles or incense, and using gas or wood stoves. Air *cleaners* (e.g. high-efficiency particulate air (HEPA)) can also be used in appropriately sized rooms to reduce indoor air pollutants (Fisk and Chan 2017). While such steps should be enough for most people, individuals with existing conditions or weaknesses may want to discuss with their doctor additional measures such as the use of respirators designed to filter components of smoke (Wildfire Smoke, 2016). If these actions are not sufficient, then individuals should temporarily relocate to an area not impacted by smoke.

Tools to Monitor Air Quality

Air/Fire Tools	https://tools.airfire.org
EPA Outdoor Air Quality Data	https://www.epa.gov/outdoor-air-quality-data/interactive-map-air-quality-monitors
Worldwide Air Quality	http://aqicn.org
EPA AirNow Air Quality	https:///www.airnow.gov
EPA AirNow Fires	https://airnow.gov/index.cfm?action=topics.smoke_wildfires
NOAA Fire & Smoke Mapping	http://www.ospo.noaa.gov/products/land/hms.html
NASA Worldview	https://worldview.earthdata.nasa.gov

Prescribed Fire Smoke Management

Basic Smoke Management Practices for Prescribed Burning
http://southernfireexchange.org/SFE_Publications/factsheets/2014-1.pdf

Smoke Management App
http://smokeapp.serppas.org/

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For more information, visit www.southernfireexchange.org or email contactus@southernfireexchange.org

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