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Health Impacts of Wildfire Smoke as a Consequence of Climate Change and Recommendations for Public Health Officials and the General Public in the Albuquerque Metropolitan Area

Jegason Diviant

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Part I

Climate change has direct implications for the entire state of New Mexico. Examples of impacts from climate change include decreased surface and groundwater reservoirs, alterations in infectious disease patterns resulting in increased morbidity and mortality, massive job losses due to crippled tourism and agricultural industries, reduced access to affordable and nutritious foods, and increasing warming trends in spring and summer temperatures. Individually, any of these impacts can make a profound difference on the quality of life for a large number of New Mexicans. Taken together, the projections forecast a grim reality and show us in no uncertain terms that this is an emergency that needs to be given a high priority and responded to simultaneously on multiple fronts. This paper will briefly discuss how climate change is associated with wildfire activity, discuss the health implications of wildfire smoke for vulnerable population groups in the Albuquerque Metropolitan Area, and suggest evidence based public health recommendations for addressing the identified problems.

New Mexico is the sixth-fastest-warming state in the United States. Each decade since 1970, the average annual temperature has increased by approximately 0.6°F. Since 1970, this represents an average annual temperature increase of more than 2.7°F. Models predict that the average annual temperatures for the state of New Mexico are going to increase between 3.5 to 8.5°F by the turn of the next century (Union of Concerned Scientists, 2016). During the summer of 2012, New Mexico experienced 85 days with temperatures greater than 90.0°F. In 2013, a temperature of 105.0°F was recorded at Albuquerque International Airport and 102.0°F at Santa Fe Municipal Airport (Tassy, 2013; Oswald, 2013). More recently in July of 2020, Roswell broke records as temperatures of at least 110.0°F for five consecutive days were recorded there. At the same time, Albuquerque had triple-digit temperatures for three consecutive days with a record high temperature of 103.0°F. In fact, during the months of July and August, Albuquerque experienced a total of 5 days with temperatures greater than 100.0°F as recorded at the Albuquerque International Airport (Meyer, 2020; U.S. Dept. of Commerce, 2020).

The average summer temperatures are increasing across the state and more cities are breaking records for the hottest single days, consecutive days, and average temperatures. As a consequence, we can expect to see worsening trends in factors that contribute towards more devastating wildfire seasons. These factors include an increase in periods of extreme drought, a reduction in the state's surface and groundwater resources, decreased snowpack, earlier snow melts, and drier soils. These factors have resulted in a substantially longer fire season, which over the past 40 years has increased from 5 months to 7 months across the state. Fires that are greater than 1,000 acres manifest twice as often and the

massive clouds of greenhouse gases and particulates that they form further trap heat, thereby exacerbating the threat of additional fires igniting (Union of Concerned Scientists, 2016).

Wildfires are becoming more devastating across the state. Two of the largest wildfires ever recorded in the state of New Mexico occurred within the past 10 years. During June of 2011, the Las Conchas Fire burned over 156,000 acres and became the largest wildfire in New Mexico's history as of that time (U.S. Dept. of the Interior, 2016). More than one million acres burned across New Mexico that year (NICC, 2011). The very next year, the historic Las Conchas Fire was dwarfed by the Whitewater Baldy Complex Fire. This fire burned more than 297,000 acres, nearly twice as many acres as the Las Conchas Fire (Union of Concerned Scientists, 2016). While writing this article, the Three Rivers Fire, which began on the morning of April 26th, has blazed across the Lincoln National Forest, scorching over 7,100 acres in less than a week. Warm temperatures, strong winds, and very low humidity are amplifying the fire's spread (NMFireInfo, 2021).

The multiyear megadrought is affecting a large swath of the southwest and is catching national attention as it is being described as among the worst in centuries. Major contributing factors include scarce monsoon rains during 2020 and greatly reduced snowfall over the winter. Wendy Mason, a New Mexico wildfire prevention official, describes the drought as, "quite possibly the worst since records have been kept." Tiffany Davila, an official with the Arizona Department of Forestry and Fire Management, forecasts the situation as, "widespread fire activity this year, and by widespread, I mean statewide." Arizona has already had 311 fires this year compared to 127 by this time last year, and more than ten times as many acres have burned across Arizona already compared to the previous year. Due to the pandemic, national parks are experiencing visitation records, which spark fears that this may result in an increase in accidental blazes in New Mexico and the surrounding states (Romero, 2021).

As mentioned previously, these trends in warmer temperatures and factors that contribute towards more devastating wildfire seasons are not limited to New Mexico. Our neighboring states have also experienced significant warming trends. These are the temperature changes for each of our neighboring states in °F per decade: Arizona 0.639, Utah 0.588, Texas 0.575, Colorado 0.483, and Oklahoma 0.413 (Tebaldi, 2012). Because of these warming trends, we should expect to see increasing wildfire activity across our neighboring states (Westerling, 2016). This has massive health implication for New Mexicans, especially in the Albuquerque Metropolitan Area. These health implications are directly associated to the frequency, duration, intensity, and location of wildfire smoke originating in and around New Mexico.

Part 2

Wildfires are capable of generating an enormous amount of gases, particulate matter, and toxic compounds that can affect the air quality for hundreds of miles. The fine particles in smoke can trigger a range of health effects from mild respiratory irritation to chronic heart and lung diseases. Depending on the level of exposure, air pollution that's generated from wildfires may even be linked to premature death. In fact, individuals with asthma, diabetes, heart disease, lung disease, pregnant women, elderly adults, children, and those that spend much of their days outside are especially at risk (EPA, 2021). Because there are so many vulnerable groups, whether due to underlying health conditions, age, employment conditions, socioeconomic status (SES), or lifestyle choices, I decided to focus specifically on the health implications for residents of the Albuquerque Metropolitan Area since it encompasses nearly half of the entire state's population.

The National Ambient Air Quality Standards (NAAQS) are established by the EPA as required by the Clean Air Act. Three principal pollutants for which there are standards, that are especially concerning in the event of a wildfire, are particulate matter, ground level ozone, and carbon monoxide. Particulate matter is regulated in two sizes as measured in microns across the diameter of the particle. These are PM_{10} and $PM_{2.5}$. Particles larger than 10 microns in diameter can be irritating, but generally do not reach the lungs. Particles between 2.5 and 10 microns in diameter can reach the lungs and impact the blood vessels, heart, and lungs. Particles smaller than 2.5 microns can reach deeply into the lungs and make their way into the bloodstream, which could potentially have multi-system consequences. Carbon monoxide can replace the oxygen in the red blood cells, thereby preventing oxygen from reaching cells, tissues, and organs. It is especially a concern for those that are within a few miles of the wildfires. Therefore, firefighters are often at increased risk of carbon monoxide poisoning when fighting these fires. Through complicated mechanisms, ground-level ozone could also be generated in the presence of wildfires, which could result in inflammation, chest pain, shortness of breath, reductions in lung function, and heart rate variability. All of these principal pollutants may lead to premature mortality (Airnow.gov, 2019). Other toxins that may be present in wildfire smoke include polyaromatic hydrocarbons (PAHs), oxides of nitrogen, benzene, formaldehyde, heavy metals, and flame retardants.

Abundant evidence has been mounting over the past few years that some microbes can survive on aerosolized particles that are generated from wildfires and travel hundreds, or possibly even thousands of miles away, thereby altering the microbial composition of the ecosystem. This is a new field of science called “pyroaerobiology.” There are many factors that could determine the viability of a microbe surviving a wildfire and traveling long distances while aerosolized. These factors include fluctuations in oxygen availability, temperature variability, entrainment of ambient air, the mixing of burned and unburned fuels, relative humidity, convective forcing, degree of mixing, ultraviolet radiation, and a variety of characteristics unique to each microbe. Some of these microbes may serve as endophytes or epiphytes of living plants. Some may be pathogenic to plants and animals. Some may be pathogenic to humans (Kobziar, 2018). For example, Valley fever, also known as coccidioidomycosis, is a condition cause by the *Coccidioides immitis* fungus. The inhalation of these fungal spores can cause muscle aches, joint pain, headaches, fever, coughing, fatigue, rashes, night sweats, and other symptoms. These symptoms may persist for weeks or months. Between 5-10% of individuals that develop Valley fever experience long-term complications which may affect a multitude of areas in the body, including the central nervous system (CNS). CNS effects could in rare cases result in an acute encephalitis or a chronic encephalopathy. The total number of cases had been on an increasing trend that peaked at 22,641 in 2011 and precipitously dropped down to 8,232 in 2014. However, the numbers of reported cases have been increasing each year since then and as of 2018 were at 15,611 reported cases. On average, about 200 people die each year of Valley fever. States that are disproportionately affected include Arizona, California, Nevada, New Mexico, and Utah (CDC.gov, 2020). It is clear that residents of the Albuquerque Metro Area will be experiencing increasing health consequences associated with pollutants and microbes derived from wildfire smoke generated both within and outside of New Mexico. Therefore, recommendations for public health officials and the general public are needed so that we can prepare for, mitigate, and respond to this evolving emergency.

Part 3

There are several primary prevention or mitigation strategies that are in place right now to reduce global greenhouse emissions with the goal of reducing warming trends over time, but these efforts will

take considerable time, resources, political will, partnerships, innovations, and multi-national agreements. There may be a powerful mitigation strategy that can be deployed as needed to increase precipitation. This strategy is known as cloud seeding. Cloud seeding is a weather modification technique in which small particles, often referred to as seeds or nuclei, are added to the atmosphere. Examples of chemicals that are used as nuclei include potassium iodide, silver iodide, sodium chloride, liquid propane, and dry ice. Water vapor condenses around these nuclei, providing a structure for raindrops and snowflakes to form around. The precipitation that has formed around these nuclei then falls back to the Earth's surface in the form of rain or snow (Desert Research Institute, 2019).

This is not a new concept, and it has been used in the past in New Mexico and surrounding states. There are currently nine active cloud seeding operational permits in the state of Colorado that are designed to increase their winter precipitation and improve snowpack, which enhances spring runoff, augments local stream flows and associated reservoir water storage, and also augments the flows in the regional Colorado River system (Hasenbeck, 2021). Colorado is not alone in pursuing an artificial means of generating increased precipitation. Additional states that are contributing to the research and efforts include Utah, Wyoming, Nevada, California, Arizona, and New Mexico. The operations are a combination of ground-based cloud seeding as well as aerial cloud seeding. Statistically, areas in which cloud seeding efforts are underway are experiencing 5-15% more snowfall each year, and the economic costs associated with this technology are approximately a few dollars per acre-foot of water. This makes the technology more affordable than other water-saving interventions, such as water conservation, desalination, or recycling, which can cost several hundreds of dollars per acre-foot (Harvey, 2021).

Secondary and tertiary prevention strategies, or adaptations, are efforts that public health officials can take to anticipate and prepare for the effects of climate change. These are some of the adaptations that can be made to anticipate and prepare for wildfires. Manual thinning of the forests can be done to increase the forests' resistance to environmental stressors, such as extreme temperatures and wildfires. Houses can be constructed that are tightly insulated from outside air. N95 masks and respirators can be stored and made available at no cost to emergency workers, outdoor workers, and members of the Albuquerque Metropolitan Area that are most vulnerable to the air pollution generated from wildfire smoke. Properties can be firescaped, which emphasizes landscaping and the use of plants and materials that are resistant to fires. Risk management strategies can be planned that identify materials and chemicals that could become toxic to nearby communities if burned in a fire and strategies can be put into place to quickly remove those materials and chemicals if a wildfire approaches the area. Members of the community should form partnerships and come together to create evacuation and shelter plans, especially in areas that are at high risk for being in close proximity to a wildfire or the smoke that it generates. Emergency food and water should be stored and shared with communities that might experience disruptions due to the wildfires. Emergency alert systems should be able to alert the public through multiple modes of communication, including radio, television, and cellular phones. Ongoing meteorological, ecological, and sociological surveillance or tracking systems should be actively monitored as the data can help to identify the risk of wildfires to various regions as well as populations that may be the most vulnerable and need special accommodations and assistance (Frumkin, 2008).

Perhaps the most important tool in terms of adapting to increasing temperatures, wildfires, and the resultant air pollution is education. Policymakers, industries, organizations, communities, families, and individuals all need to be given education that empowers them to make decisions that can prevent them from experiencing the onset of illnesses associated with breathing in wildfire smoke or at least reduce

the likeliness of an illness developing or worsening. The educational messages can be delivered through multiple methods. Examples include physician visits, schools, businesses, commercials, news reports, mailed advertisements, email, social media promotions, YouTube videos, websites, in-person community meetings, and more. Members of the community can be educated on how to research the location and size of fires, the air quality rating in their areas, whether they have unique risk factors that increase their vulnerability, whether or not they should be outside, methods for maintaining and improving indoor air quality, what kinds of air purifiers and filters they should consider, how to wear respirators and face masks properly, and additional precautions that individuals and families can take together.

Part 4

In conclusion, the direct implications of climate change on the state of New Mexico can already be seen and felt. As the models are forecasting, increasing temperatures will result in longer fire seasons, a greater number of annual fires, more intense fires, and more acres burned. The smoke that evolves from these wildfires can affect the health of all members of the Albuquerque Metropolitan Area, especially vulnerable groups that have pre-existing conditions, specific lifestyle choices, and types of employment that increases their level of risk. Wildfire smoke is able to impact the health of our community in ways that researchers are barely starting to appreciate, such as with the phenomena called "pyroaerobiology," in which microbes can be transported great distances while aerosolized, thereby altering the microbial composition of the ecosystem, and potentially causing disease in individuals that inhale the particles. Partnerships need to be formed between local, state, and federal governments, along with industries, organization, healthcare workers, and members of the community with a common goal of reducing the occurrence and impact of wildfire smoke on in the Albuquerque Metropolitan Area. Cloud seeding technologies may be a viable primary prevention or mitigation technique for increasing precipitation and snowpack, and as a result, increase groundwater and surface water reservoirs. Various adaptations can be made to anticipate and prepare for the effects of climate change. Most importantly, disseminating education through various campaigns is a vital tool for empowering members of our community and giving them options to work with.

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