2020

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The effects of climate change on health are pronounced across a wide range of outcomes, from increased incidence of infectious disease to food insecurity to so many other worrisome scenarios. Here in New Mexico and the surrounding Southwest, one of the major ramifications of climate change is an increase in wildfires. The effects of an increasing number of wildfires across the state and the surrounding areas will likely lead to many negative health outcomes as well as economic losses as well as losses in biodiversity, to name a few. We will explore the predicted effects of climate change on wildfires in New Mexico and the surrounding Southwest in this paper.

Climate change creates an optimal environment for forest fires to start and violently spread across land at alarming rates. Climate change related factors that contributed to this include: warmer spring and summer temperatures with associated decrease in rainfall, reduced snowpack, melting of snow earlier in spring, and longer fire seasons during the summer (Westerling et al., 2008). These combined effects create an environment that is extremely prone to forest fires. Increases in forest fires not only require significant resources to control, but they also contribute to worsening health outcomes for people nearby. The smoke from forest fires expels particulates into the atmosphere that are then inhaled by people in nearby communities. This can lead to pulmonary diseases like asthma and COPD, which are chronic diseases that can also lead to heart disease.

New Mexico has an arid climate and receives light amounts of precipitation on a yearly basis. These factors alone make New Mexico a hospitable place for forest fires, but when you add on increasing temperatures which have led to more heat waves and earlier snow melt, it creates a recipe for an increase in number and intensity of future forest fires (US EPA, 2016). Since 1970, the total number of acres burned in New Mexico has grown exponentially, with a massive uptick since 2010 (New Mexico's Wildfire Threat, 2016). The threat of wildfires in New Mexico is projected to double from 2000 to 2030, and continually increase through 2050 (New Mexico's Wildfire Threat, 2016). Although the risk of future forest fires is hard to predict due to the complexity of factors that contribute to wildfires, based on the available data and models, it seems that we can confidently say that the risk of forest fires is increasing with time. Some experts predict that fire risk may increase in the short term due to climate change, but over longer periods the risk may actually fall due to a lack of fuel for fires (if forests burn completely and do not re-emerge like they normally do due to extreme heat and low precipitation) (Rocca et al., 2014). Based on these predictions, it seems that the area burned by wildfires will steadily elevate, with the risk increasing with each subsequent year, until fuel for these fires (forests) are burned out in the long term. It is not unreasonable to think that the amount of land area burned may rise at alarming rates due to positive feedback loops inspired by climate change. For example, if the land area burned increases, there is a proportional increase in the amount of carbon expelled into the atmosphere due to the burning of organic material, which may contribute to further heating of the climate. Furthermore, with a loss in the number of trees, there is less availability for carbon

sequestration, which may also lead to increased carbon dioxide in the atmosphere, furthering warming temperatures. These positive feedback loops (increased area burned → increased CO_2 released → further warming of temperatures → increased risk of wildfire frequency and intensity) may continue unchecked until there is no available fuel left for forest fires to burn.

Now that we have covered how climate change contributes to increased wildfire spread in New Mexico, lets transition to the health effects of the increased frequency and intensity of wildfires on a specific demographic in New Mexico. It is well documented that wildfires lead to negative health outcomes through a variety of pathways. Direct exposure to wildfire is the most obvious, leading to burn-related trauma. Firefighters also experience effects ranging from dehydration to full blown heat stroke. The mental health toll should also be stated, as people who become displaced and lose property due to forest fires are at increased risk for developing post-traumatic stress disorder (PTSD), insomnia, and depression (Belleville et al., 2019). Since wildfires also lead to increased particulate matter being expelled into the atmosphere, it would be logical to examine the effects of wildfires on people who have underlying pulmonary diseases, since the excess particulate matter may exacerbate these illnesses to the point of hospitalization or death.

Chronic pulmonary diseases like Chronic Obstructive Pulmonary Disease (COPD) and asthma are not uncommon in New Mexico. According to NM-IBIS, 6.3% of the adult population in New Mexico has been diagnosed with COPD (NM IBIS, 2018). Among children, 9.3% have been diagnosed with asthma, and among adults, 10.5% have been diagnosed with asthma (NM IBIS, 2018). This represents a large population of New Mexicans who are at-risk for pulmonary exacerbations due to wildfires. Wildfires emit a variety of air pollutants, but the ones that are most concerning with regard to human health are particulate matter, ozone, and carbon monoxide (Xu et al., 2020). While carbon monoxide usually only affects people in the immediate vicinity of the fire, ozone and particulate matter tend to disperse to more distant areas, where they can affect surrounding communities. Wildfire particulate also tends to be smaller (and therefore more toxic to the lungs due to increased penetration) when compared to urban background particulate matter (generated by fossil fuel combustion), which means that it may exert more toxic effects on humans (Dong et al., 2017). Studies have shown that exposure to particulate matter from wildfires are associated with impaired lung function, increases in medication used for asthma and COPD maintenance and exacerbations, and increases in respiratory infections (Dong et al., 2017). The clearest association that exists is between asthma exacerbations and wildfires, which may be due to a larger proportion of the population having asthma, making it less difficult to search for study participants with the disease. It has also been shown that people in the vicinity of wildfires are more likely to visit the emergency department compared to those not experiencing wildfires. A study conducted in Darwin, Australia found that the number of emergency department (ED) patients seen for asthma related concerns (most often asthma exacerbations) were 2.4 times higher on fire days compared to non-fire days (Johnston et al., 2002).

The economic burden of hospitalization and increased healthcare expenditure in the short term is difficult to quantify, but an estimate can be extrapolated based on available data. A report done by the Western Forestry Coalition analyzed the costs of 6 major forest fires in the Western U.S. between 2000-2003, ranging from Montana to New Mexico. They quantified what

percentage of costs for large fires are spent on suppression, direct costs, indirect costs, and additional costs. This data was then extrapolated to estimate the relative proportional costs of fighting the 9 largest fires in NM between 2009-2012. They found that the "additional" costs accrued from these 9 large fires amounted to $16.76 million dollars ("The Full Cost of NM Wildfires", 2013). By "additional" costs, they are referring to payments to family members for fallen firefighters (representing the cost of lost life) plus the estimated cost of health problems for those affected as well as mental health costs. While it is hard to find how much of this $16.76 million represents payments to families of fallen firefighters, we know that in NM a family receives $250,000 for the death of a firefighter (New Mexico Fallen Firefighter: Survivor Benefits, 2019). In 2011, 83 firefighters died in the U.S., and 19 died in a circumstance that made their family eligible to receive a payment (FEMA, 2012). Given this data, we may liberally estimate that the payouts given to NM firefighters may be about $2-3 million over the 4 years that these 9 fires occurred. Even accounting for other miscellaneous expenses categorized in this "additional" cost figure, we may conservatively estimate that the healthcare cost of these 9 fires in NM amounted to $10-12 million dollars. That is a pretty stunning healthcare cost due to forest fires – and this number likely doesn't capture a lot of the long-term burden of medication expenses, primary care services, and other related healthcare costs due to pulmonary diseases exacerbated or caused by forest fires.

Based on the data presented above, it seems clear that wildfires present a clear physical and financial burden to residents of New Mexico, but especially to those who have diagnosed pulmonary diseases. While the true healthcare-related financial cost of forest fires on those with pulmonary diseases is hard to accurately quantify, we can clearly see that the physical toll of wildfire particulate matter on those with pulmonary disease is profound, especially for those who suffer from asthma, which is the most common chronic pulmonary disease among residents of New Mexico.

One of the most important strategies to combat pulmonary disease exacerbations due to forest fires is to invest resources in controlling the forest fires in the first place. According to the Environmental Defense Fund (EDF), there are important policies that can be enacted to prevent wildfires. The EDF notes that investing more money towards wildfire *prevention* rather than wildfire *suppression* would be a more beneficial strategy to prevent the occurrence of future wildfires ("4 ways the right policies", 2020). They note that the Forest Service spent 55% of its budget to suppress wildfires in 2017, compared to just 16% of the budget being used to suppress wildfires in 1995 ("4 ways the right policies", 2020). Allocating a larger percentage of the budget for forest fire prevention could help to stop forest fires in the first place, and would likely lead to less money having to be used toward forest fire prevention. Forest fire prevention at this level is an "upstream" approach to preventing the resultant exacerbations of pulmonary disease that occur in affected communities.

In order to be prepared for potential pollution from wildfires, people with existing pulmonary disease should be educated about how to monitor air quality in their area. The New Mexico Environmental Public Health Tracking (EPHT) site has a very informative guide for gauging wildfire pollution risk based on visibility. This tool is called the "5-3-1 Visibility Method", and it provides an easy way to estimate air quality that anyone can use, even if they don't have access to technology (NM EPHT, 2020). The 5-3-1 numbers refer to the visible

distance, in miles, that a person can see. Based on these numbers, there are recommendations for actions for the healthy and for those who are more vulnerable to the effects of wildfire pollution (ie those with pre-existing pulmonary disease). For those who have access to the internet, knowing how to interpret Air Quality Index ratings is another way to be prepared. The website www.airnow.gov is an easily accessible tool that is managed by the EPA which tells people what the air quality is like in their area based on the U.S. Air Quality Index (AQI). The AQI is a color coded scale with corresponding numerical values ranging from 0-500 that make it easy to interpret what the air quality is like in an area (*AQI Basics,* 2020). For each color, there is a corresponding level of health concern descriptor, ranging from "good" to "hazardous". The AQI color orange corresponds to a level of concern descriptor entitled "Unhealthy for Sensitive Groups", which is an important level to be aware of for individuals who have existing pulmonary disease. The AQI number at this level is 101 to 150, which represents a pollution level at which those with pulmonary diseases may experience symptoms like cough, shortness of breath, or chest tightness (*AQI Basics,* 2020). For asthmatic individuals, another way of being prepared for increased air pollution due to wildfires is to have an asthma action plan handy. This is a fillable form that a patient creates with the guidance of their primary care provider that gives them a guide of what to do based on the symptoms they are experiencing (CDC Asthma Action Plan, 2020). If a person with asthma begins to realize that the air quality is worsening in their area due to a wildfire, they can utilize their asthma action plan to ready themselves in case they experience symptoms related to asthma exacerbation. For example, if they anticipate that they may become short of breath soon, they can refer to the "Asthma getting worse" section of their asthma action plan and they may pull out their quick-relief medicine (ie an albuterol inhaler) and keep it handy in case they need to use it.

In order to mitigate the effects of air pollution caused by a wildfire, community efforts like the creation of clean air shelters and disbursement of N95 respirators to vulnerable individuals are crucial. The creation of public clean air shelters is an important consideration since some people may not have good indoor air quality in their homes due to age of the home, lack of filtration, or lack of air conditioning ("Wildfire Smoke," 2019). Local governments can designate large buildings that are newer in age with central air conditioning as public clean air shelters ("Wildfire Smoke," 2019). These shelters may be used when air quality worsens during a wildfire, allowing for vulnerable individuals within the community (like those with pulmonary diseases) to have access to a safe place with good air quality. This can help prevent exacerbation of pulmonary illnesses in the community, which reduces the burden on healthcare facilities, since these institutions wouldn't have to deal with a sudden influx of patients needing stabilization due to pulmonary exacerbations brought on by air pollution from wildfires. Another community based strategy that can be employed to mitigate the risk of pulmonary exacerbations due to wildfire smoke is the distribution of N95 respirators to at-risk populations. N95 and P100 respirators are some of the only respirators that are effective in filtering out the small particles ($PM_{2.5}$) that are emitted from wildfires ("Wildfire Smoke," 2019). Community efforts to distribute these respirators to identified individuals with pulmonary diseases or other conditions that make them vulnerable to the effects of wildfire smoke can help to reduce the burden of disease as well as healthcare expenditures ("Wildfire Smoke," 2019). Special consideration must be made for those with pulmonary and cardiovascular disease, however, since N95 and P100 respirators can lead to a buildup of CO_2 and resultant hypercapnia, which can lead to unintended

negative health effects. People with these conditions should consult with a health professional to weigh the individual risks and benefits of using an N95 or P100 respirator.

Public Health officials usually have a response plan in case of a wildfire, which usually consists of clear communication between agencies, clear communication with the public, and mobilization of resources. State and local public health agencies usually have existing lines of communication with other agencies, which makes communication during a wildfire more clear due to those existing relationships. Public health officials will communicate with clean air agencies and land management agencies among others in order to determine what resources need to be allocated and what communications should be sent out to the public ("Wildfire Smoke," 2019). Local and state public health agencies will also communicate risks and protective actions with the public at large as well as organizations that serve at-risk individuals (ie assisted living facilities, hospitals) ("Wildfire Smoke," 2019). It is clear that interagency communication is the most important factor in determining how effective the community response to a wildfire will be.

Given the continued progression of climate change, we should expect that the number of wildfires in New Mexico will increase in the coming decades, as mentioned previously. With these increased wildfires, those with existing pulmonary disease will likely experience an increased amount of pulmonary related exacerbations. How might those with pulmonary diseases adapt to an increasing number of wildfires, though? In order to address this question, let's first take a step back and understand what makes a population vulnerable to climate related disasters.

According to a 2008 article by Keim, vulnerability to disaster can be broken down into two sub-components: susceptibility and resilience. Susceptibility refers to the extent which a community is exposed to the effects of a natural disaster (Keim, 2008). For example, the proximity of a community to a wildfire would determine how susceptible that community is to the health-related effects of a wildfire. Resilience refers to the capacity to deal with or recover from the effects of a natural disaster (Keim, 2008). For example, communities with a lower burden of disease will be more resilient in dealing with the fallout from a wildfire compared to communities with a higher burden of disease. Strategies to decrease susceptibility include prevention and mitigation, which are discussed earlier in this piece. We will now shift our focus to strategies that build resilience within a community. One of the most important strategies to build resilience within a community is to increase the overall health of the community, so that fewer people will be affected by the health-related effects of a disaster. While the main pulmonary diseases that we have focused on in this piece (asthma and COPD) are chronic conditions that are generally uncurable, we can however try to prevent the incidence of these diseases in a community so that future generations aren't affected as much. While genetics does determine the risk of developing COPD and asthma in certain populations, many modifiable environmental risk factors are known to contribute to the incidence of COPD and asthma. Some of these modifiable risk factors include smoking, air pollution, and respiratory tract infections (Postma et al., 2011). There are also protective factors like breastfeeding that decrease the likelihood that one might develop COPD or asthma (Postma et al., 2011). Smoking is the main modifiable risk factor for COPD, so continued public health campaigns to reduce the number of people who smoke will help in this regard. Reducing air pollution is another strategy, as air pollution contributes to both COPD and asthma incidence (Postma et al., 2011). There are many ways in which individual and community contributions can decrease levels of air pollution, such

as decreasing car travel, regulating emission levels by corporations, and reducing electricity use. Finally, infants who are breastfed experience fewer lower respiratory tract infections (LRTIs) during their upbringing compared to infants who weren't breastfed (Roth et al., 2008). By enacting public health campaigns to decrease smoking, decrease air pollution, and increase breastfeeding, communities will likely decrease the incidence of chronic pulmonary diseases like asthma and COPD. As mentioned previously, the healthier a community is, the more resilient it will be to the effects of a climate-related disaster. In other words, communities with fewer numbers of people who experience pulmonary disease will be better positioned to bounce-back from the effects of a wildfire because they won't have to expend as many resources to care for those who experience pulmonary exacerbations from wildfires.

There is an old adage that goes, "an ounce of prevention is worth a pound of cure." This rings true as the most effective strategy in building a community's resilience against the health-related impacts of climate-change induced wildfires. Essentially, doing everything possible to ensure that communities are healthier and have a lower burden of disease (especially pulmonary disease) will allow these communities to be able to withstand the impacts of wildfires and recover at a faster rate.

In order to recover from the damage that climate change-induced wildfires will bring in the future (should the prediction of more intense and more frequent wildfires come to fruition in NM), the knowledge that Indigenous communities in this state and across the world should be employed to help restore balance. Many Indigenous communities all throughout the state and across the globe believe that humans and nature are interconnected and should have a symbiotic relationship with one another. These beliefs are at the core of many Indigenous cultures and have been practiced for hundreds to thousands of years. Due to this historical connection to nature, many Indigenous communities hold a vast amount of knowledge about their environments, which is known as "traditional ecological knowledge," or TEK (Huntington, 2000). Many Indigenous communities across the world practiced intentional landscape burning in order to prevent large-scale wildfires and also to promote the growth of favorable crops (Trauernicht et al., 2015). They believed that small, controlled fires maintained balance in the ecosystem and also maintained biological diversity (Trauernicht et al., 2015). In the US, priority is placed on outright fire suppression, however, which makes it difficult for Indigenous people to utilize their TEK to create small, controlled fires that can actually counteract the intense, massive wildfires that we experience today and will likely experience more frequently in the future. In order to adapt to an increasing amount of wildfires brought on by climate change, policies should be enacted to encourage Indigenous populations to use their TEK to create small fires that will protect the forests from unmitigated blazes. In the United States, the Indigenous Peoples Burning Network (IPBN) was created to revitalize Indigenous fire practices and even includes participants from various pueblos in New Mexico (The Conservation Gateway, 2018). Increasing federal funding to the IPBN and creating more organizations like this can prove useful in adapting to wildfires using TEK and ensuring healthier ecosystems in the future.

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