Particulate Matter Emissions from Prescribed Burns in the Chicagoland Area

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Acknowledgements
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Particulate Matter Emissions from Prescribed Burns in the Chicagoland Area

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ABSTRACT Prescribed burns are a land management tool currently used to aid in fire mitigation and promotion of plant growth of desired species and reduction of undesired species, which are often invasive species. Currently there is public stigma surrounding prescribed burns which limits their use in certain parts of the US. There are also particular challenges of conducting prescribed burns in urban and suburban areas. A better understanding of prescribed burns and their impact on atmospheric chemistry and air quality can allow for better communication with the public about their positive impacts and also acknowledge and quantify any potential drawbacks. This study looks at the particulate matter emissions of prescribed fires being conducted in the greater Chicago area. We employed low-cost sensors to measure particulate matter emissions at several sites in the Chicagoland area in the spring and fall of 2022. With the ever-expanding wildland-urban interface, understanding particulate matter emissions of prescribed fires set in populated areas can help provide more data regarding prescribed fire emissions and air quality impacts. These impacts should be weighed against the benefits of prescribed burns and also potential air quality impacts from uncontrolled burns from ecosystems that are not treated with prescribed burns. Measuring air quality impacts can also inform fire management practices with the goal of reducing future emissions. With the very present effects of climate change, understanding baselines regarding prescribed fire can better equip future research and fire professionals in fighting fire with fire.

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INTRODUCTION

Wildland fires have always had a strong presence in the U.S. Historically, wildland fires were a tool used in land management. Some of the earliest uses include hunting, plant food source regeneration, clearing ground for human living spaces, killing vermin, and facilitations of travel (Pausas and Keeley, 2009). Over the years public perception of benefits and potential threats changed, resulting in total prevention, especially during the second half of the 20th Century. While this strategy worked for decades, fires have been increasing over the last 20 years. Between 1999 and 2018 wildland fires burned an average of 2.8 million ha per year (Jaffe et al. 2020). With the increase in large wildland fires, there is a growing need for land management practices that mitigate out of control fires (Rutherford and Schultz, 2019). Prescribed fires are currently the predominant practice for this mitigation. Prescribed fires are more akin with the fires experienced historically.

Prescribed fires are smaller, controlled fires that burn with intention. These intentions are both the way in which the fire is lit as well as the goal of the fire. With how volatile fire is, fire professionals have developed strategies to control most variables. After accounting for weather and land type, burn managers prepare the area to generate fire breaks or strips of land with no fuel for the fire to burn. These can be generated mechanically or by using a backburn where the fire is lit against the wind and creeps toward the desired edge of the burn area. Once a strong perimeter has been established the burn crew will use the wind to push the fire forward toward the breaks. These are known as head fires and can vary from very small to several feet in flame height depending on fuel type and topography. Intent also refers to the goals of the burn. These goals could be anything from reducing leaf litter, to promoting growth, to preventing certain species from establishing (Dudley and Lajtha, 1993). Given the general public’s current relationship with fire, the current worries surrounding size and type of fire are understandable.

While prescribed burns are an important tool for land management, there are many aspects of these burns that need to be better understood before land managers push for large scale implementation (Pearce et al. 2012). One such aspect is what emissions prescribed burns are putting into atmosphere and how these could affect air quality. It is known that fires emit a wide range of chemicals and particulate matter (Sparks and Wagner, 2021). One of the largest and most common emissions with potential negative health impacts is particulate matter with a diameter of 2.5 μm or PM2.5 (Johnson and Fernando, 2022). PM2.5 pollution can lead to low visibility and negative health effects, often associated with wildland fires found on the west coast. However, as the southeast is also a very fire prone area due to its topography, weather patterns, and the longer standing fire regimes established there, this region also sees annual PM2.5 concentrations due to fire. (Gaither et al., 2011). Other important emissions from fires include CO, NOx, and many other volatile chemicals. These are important due to their interactions and effects on other chemicals present in the atmosphere (Alshuler et al. 2020). According to the 2020 Chicago Air Quality and health report, Chicago’s PM2.5 concentrations are some of the highest in the nation while still meeting federal standards (City of Chicago). In the U.S., the Environmental Protection Agency (EPA) discusses these emissions not as absolute data but in the relative units of Air Quality Index (AQI). Using this scale, air quality is split into six categories ranging from good to hazardous to allow for more immediate correlations between measured values and human health concerns. (AQI Basics). As these additional emissions interact with the urban emissions, the impacts on ozone chemistry only increase.

With the increase in wildfires, there has been more data tracking sites like AirNow becoming available for the public to understand how air quality is affected by fire. While many of these sites use existing atmospheric measuring stations, increasingly the EPA has been utilizing low-cost sensors such as Purple Air sensors to provide
additional measurements to federal air quality maps (Johnson et al., 2020). As Purple Air sensors increase in use, more studies are finding that even with the low cost of the Purple Air sensors, research-grade quality can be found using calibrations correlating to the higher quality and cost sensors for smoke mapping. Even with the increase in data being measured, there is still little field research on how prescribed fires affect atmospheric conditions (Barkjohn et al., 2022).

While often the Midwest is not the first location associated with wildland fire, that makes it no less important to the area. The historic tall grass prairies found through the Midwest are historically well adapted to natural disturbances such as fire. The human-driven removal of these natural disturbances has led to shrinking native prairies as well as species decline within the existing native patches (Dupont-Morozoff et al., 2022). Modern day land management practices in Illinois and throughout the Midwest include more fire (Prescribed Fire) generating an increased need in data for prescribed fire emissions, especially with parks throughout the city of Chicago being restored to native prairie.

Using purple air low-cost sensors, we collected data on prescribed fire atmospheric emissions in the Chicagoland area. The goal of the study was to obtain measurements of particulate matter emissions proximate to urban and suburban prescribed fires. These measurements provide information about personal exposure of the burn crew and could be used for larger spatial scale air quality impacts.

METHODS

Across four different burns, a pair of upwind and downwind Purple Air sensors were used to measure PM$_{2.5}$ emissions generated by prescribed fires. These burns occurred mostly in the spring of 2022 with one in the fall of 2022. The burns were conducted at a variety of sites within the Chicago Park District and McHenry County Conservation Districts’ purview. Locations, dates, coordinates, and plot size (acres) can be found in table 1. Permits for these sites were attained from their governing body before attending burns. Given the weather dependency of prescribed fire, burns were attended on a variety of days in spring and fall of 2022 according to our availability and the districts’ burn schedules. At each site, the district-provided burn plan was collected either by handout or by photograph of the plan. These were used to generate the Google My Maps burn area maps. These maps included final sensor placement and were used to generate an estimate of burn plot size in acres.

Emissions data were collected both upwind and downwind of the fires being measured. To collect the upwind emissions data, a Purple Air (Draper, Utah) sensor for PM$_{2.5}$ was adhered to a tripod placed in an area that the person in charge of the burn, the burn boss, identified to be upwind of the plot being burned. To collect the downwind data, a second identical tripod with a Purple Air was set up near the initial point of ignition, often the most downwind spot on the plot. Tripod setup can be seen in figure 1. Before beginning the burn, all sensors were placed upwind to calibrate together. The duration of the calibration varied based on availability of burn staff; however, it was found that the purple air sensors were essentially calibrated and measuring as expected after receiving power. Upon receiving the go from the Burn boss the downwind sensor(s) were relocated to their downwind spot with ignitions starting shortly after. The final locations were negotiated with the Burn boss to insure safe distances but also significant smoke. Following the burn, the sensors were left to run for a short period of time before being unplugged. In addition to particulate matter, the Purple Air also measured relative humidity and temperature.

Following the burns, daily wind data were collected from the cli-MATE: MRCC Application Tools Environment. The Chicago Midway Regional station was used for the McHenry County burns and the Chicago Midway station was used for the burn in Chicago. These data were used to plot wind vectors for the duration of each measurement period.
Table 1. Burn date, county where burn was conducted, burn location, and approximate burn plot acres.

<table>
<thead>
<tr>
<th>Date</th>
<th>County</th>
<th>Park Name</th>
<th>Lat</th>
<th>Long</th>
<th>Acres (approx.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.12</td>
<td>McHenry</td>
<td>Glacial Park</td>
<td>42°25’34” N</td>
<td>88°18’38” W</td>
<td>182</td>
</tr>
<tr>
<td>4.26</td>
<td>McHenry</td>
<td>High Point Conservation Area</td>
<td>42°28’26” N</td>
<td>88°33’23” W</td>
<td>40</td>
</tr>
<tr>
<td>4.27</td>
<td>McHenry</td>
<td>North Branch Conservation Area</td>
<td>42°29’30” N</td>
<td>88°19’18” W</td>
<td>22</td>
</tr>
<tr>
<td>12.1</td>
<td>Cook</td>
<td>Montrose Bird Sanctuary</td>
<td>41°57’46” N</td>
<td>87°37’59” W</td>
<td>4</td>
</tr>
</tbody>
</table>

RESULTS

Figures 2 through 5 show the burn area for each day with the sensor placement marked. It should be noted that Montrose Bird Sanctuary has two downwind sensors marked as the sensor was moved between burning the two areas. The largest area burned was Glacial Park at about 182 acres and the smallest area was the Montrose Bird Sanctuary at about 3.5 acres.
Figures 6 through 9 show the Relative Humidity (RH), Air Quality Index (AQI), Temperature, and wind vectors for each of the four burns. As expected, at each burn an inverse relationship between RH and the temperature can been seen. This relationship is most clearly shown with the downwind sensor but can also be seen in the upwind sensors data. Looking at the data, the 26th and 27th of April most clearly show his relationship.

Another trend is in the AQI data. Looking at the downwind sensors, each burn experienced an initial large spike in AQI that then dropped off quickly. AQI then spikes at least once more but not as high as the initial spike.

Looking at the wind plots, each day appears to have similar magnitude with direction being the only change. The maximum wind speed was 16 mph on April 27th and the minimum was 7 mph on April 26th and December 1st. The average wind speed was around 12 mph.
Figure 6. Relative Humidity, AQI, Temperature, and wind vectors for the 4.12 Glacial Park Burn.
Figure 7. Relative Humidity, AQI, Temperature, and wind vectors for the 4.26 High Point Conservation Area Burn.
Figure 8. Relative Humidity, AQI, Temperature, and wind vectors for the 4.27 North Branch Conservation Area Burn.
Figure 9. Relative Humidity, AQI, Temperature, and wind vectors for the 12.1 Montrose Bird Sanctuary Burn

DISCUSSION

One observation of particular interest is the spikes seen in the AQI data. These could be attributed to the active fire line moving further away from the downwind sensor as the burn continued. The spikes would then be smoke blowing back toward the sensor from elsewhere in the burned plot. Purple Air lists AQI over 100 as potentially dangerous to sensitive groups and anything over 200 to be considered a risk to the general public with continuous exposure. The North Branch burn showed the highest AQI with values well over 750; however, within an hour and a half, the values dropped back down to 0. This indicated that, while the burns do generate a significant amount of air pollution, they do not linger too far beyond the duration of the burn.
This could signify that, despite the large volume of particulate matter put off during a burn, there are few lingering particles following a burn. Sensor placement is also important to consider when looking at these numbers. Due to the access of the author (KP) and cooperation of the burn staff, the downwind sensor was consistently located closer to the fireline than someone from the public could safely be. This means that the AQI levels experienced by the sensors was likely equivalent to that experienced by the burn crew but not the public and surrounding areas. Without a setup with multiple downwind sensors moving away from the burn area, it is hard to quantify how the smoke dissipated as it traveled away from the burn area. Measurements such as local windspeed and specific atmospheric conditions would be needed to better estimate dispersion and boundary layer behavior. However, looking at the fluctuations in the sensors during the burn, it is likely that the concentrations of PM$_{2.5}$ dissipated with time and space. The burn crew experienced high levels of PM$_{2.5}$. California Occupational Safety and Health Administration (OSHA) standards require respirators to be given to workers to be outside at air quality levels greater than 500 (Barkjohn et al., 2022). Looking at the AQI recorded, this concentration was experienced at least once on every burn. Using the California OSHA standards, some type of respirator for people on the Fireline would not be ill advised, even if these levels are only experienced for short periods of time.

As discussed in the introduction, there has been more research conducted on the accuracy and precision of the purple air sensors. Much of this area of research has found that, overall, the Purple Airs are comparable to high quality AQI monitoring stations with accurate trend measurement and values accurate with correlations used. This signifies that, while the trends displayed in the graphs above are true, a smoke-based correlation factor should be used for more accurate data reporting. This study recognized the relevance of these factors but chose to use the Purple Airs as rough indicators with the knowledge that some values may be slightly over reported.

In terms of burn strategy, all of the burns that were attended were backburns around the perimeter with lines of head fire burning at no more than a few feet at a time until the full plot had been burned out. This means that they were smaller and therefore cooler than if the head fire had been allowed to grow. Future research is needed to better understand how burn strategy can affect air pollutants. A hotter larger fire often causes more lift clearing smoke faster. However, there are certain safety concerns that must be considered before large fires are able to burn freely. Finding the line between burning in a controlled manner and best mitigating smoke will be critical for urban uses of prescribed fire where space is often smaller. This becomes increasingly more important when considering the larger atmospheric picture and how climate change and wildland fires will continue to influence each other in the coming years.

ACKNOWLEDGEMENTS

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REFERENCES


