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Bloomington Air Quality

AN ADVISORY REPORT

MATT CALDIE

BLOOMINGTON ENVIRONMENTAL COMMISSION

Acknowledgements

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Introduction

Air pollution, whether visible or invisible, causes harm to people's health and the environment. The absence of visible pollutants should not lead us to believe that our health and welfare aren't threatened, because some pollutants cause harm even at very low levels. Those most vulnerable to pollutants include children, the elderly, and people with pre-existing heart or lung conditions. There is also an environmental justice element to pollutant exposure, as risk is increased among people who live in low-income neighborhoods or communities located near industrial sources of pollution.

According to the Environmental Protection Agency (EPA), pollution levels in many areas of the United States exceed national air quality standards for at least one of six common pollutants.[1] The pollutants sulfur dioxide and nitrogen dioxide are byproducts of fossil fuel combustion and cause numerous harmful respiratory effects. Particle pollution, also known as particulate matter (PM), and ground-level ozone have more diverse sources and can travel long distances. Fine particles can be emitted directly from combustion or formed from chemical reactions of gaseous emissions including sulfur dioxide or nitrogen oxides. Ozone is created when emissions of nitrogen oxides and volatile organic compounds (VOC) react. Pollutants lead and carbon monoxide now meet national air quality standards virtually nationwide thanks to the Clean Air Act.[1] Currently, ambient air monitoring by the state of Indiana is the most reliable way to track the concentration of pollutants in our area.

This report aims to summarize the current national standards and health consequences of air pollution. We will also look at which pollutants are being measured in Bloomington, where the measurements are taking place, and what can we tell from the data gathered in recent years. Finally, we will look at the impact climate change will have on air quality and recommend actions that could be taken by the state of Indiana and/or the city of Bloomington.

[1] "Air Pollution: Current and Future Challenges." *US EPA*, 30 Mar. 2023, www.epa.gov/clean-air-act-overview/air-pollution-current-and-future-challenges.

Current Considerations

National Standards

The Environmental Protection Agency (EPA) is required by the Clean Air Act to set National Ambient Air Quality Standards (NAAQS) for six principal criteria air pollutants (though lead and carbon monoxide will not be discussed in this section as they meet national air quality standards virtually nationwide).[1] Units of measure used for the standards are parts per million (ppm) by volume, parts per billion (ppb) by volume, and micrograms per cubic meter of air (µg/m^3). If primary and secondary standards are designated separately for an air pollutant, we will be focusing on the primary standards because they provide public health protection and are the stricter measure. Meanwhile, secondary standards are designed to protect public welfare from adverse environmental effects, e.g., soils, water, crops, weather, property damage, and personal comfort and well-being.[2]

Particulate Matter (PM) pollution represents inhalable solid particles and liquid droplets. Particles under 10 micrometers in diameter are labeled as PM_{10}, while fine particles under 2.5 micrometers in diameter are identified as $PM_{2.5}$. The EPA standard for PM_{10} is 150 µg/m^3 in 24 hours, not to be exceeded more than once per year on average over 3 years. One standard for $PM_{2.5}$ is that the 98^{th} percentile averaged over 3 years does not exceed 35 µg/m^3 in 24 hours. 98^{th} percentile means no more than 7-8 exceedance days per year. Additionally, it is not to exceed 12 µg/m^3 annual mean averaged over 3 years.[2]

Ground-level ozone is an air pollutant created by chemical reactions between oxides of nitrogen (NO_x) and volatile organic compounds (VOC) in the presence of heat and sunlight. According to the EPA, ozone is not to exceed 0.07 ppm, averaged over an 8-hour period. This standard is met when the 3-year average of the annual fourth-highest daily maximum 8-hour average ozone concentration is less than or equal to 0.07 ppm.[2]

Nitrogen Dioxide (NO_2) is a highly reactive oxide of nitrogen, which primarily enters the air from the burning of fuel from automobiles or power plants. The standard states that the 98^{th} percentile of 1-hour daily maximum concentrations of NO_2 should not exceed 100 ppb, averaged over 3 years. Additionally, the average mean for any given year should not exceed 53 ppb.[2]

Sulfur Dioxide (SO_2) is the most abundant oxide of sulfur, and thus serves as an indicator for all gaseous sulfur oxides. The main source of SO_2 is from the burning of fossil fuels at power plants and industrial facilities. The primary standard states that the 99^{th} percentile of 1-hour daily maximum concentrations do not exceed 75 ppb, averaged over 3 years. 99^{th} percentile means no more than 3-4 exceedance days per year.[2]

[2] "NAAQS Table." *US EPA*, 5 Apr. 2022, www.epa.gov/criteria-air-pollutants/naaqs-table.

World Health Organization Recommended Changes

In 2021 the World Health Organization (WHO) released updated global air quality guidelines.[3] The WHO cites insights into sources of emissions and the contribution of air pollutants to disease, the importance of addressing health inequities, and significant advances in measuring levels and trends in ground-level air pollution as reasons to adopt stricter standards. Since their previous update in 2005, there has been a significant increase in scientific evidence that shows how air pollution affects different aspects of health. As a result, many of the air quality guideline levels are lower than they were in the previous WHO report and lower than the current EPA standards. The guidelines can be used as an evidence-informed reference to help decision-makers set standards and goals for air quality management.

Table 1. WHO Global Air Quality Guidelines 2021 versus 2005

Pollutant	Averaging time	2005 AQGs	2021 AQG level
$PM_{2.5}$, µg/m³	Annual	10	5
	24-hour[a]	25	15
PM_{10}, µg/m³	Annual	20	15
	24-hour[a]	50	45
O_3, µg/m³	Peak season[b]	–	60
	8-hour[a]	100	100
NO_2, µg/m³	Annual	40	10
	24-hour[a]	–	25
SO_2, µg/m³	24-hour[a]	20	40
CO, mg/m³	24-hour[a]	–	4

µg = microgram

[a] 99th percentile (i.e., 3–4 exceedance days per year).

[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

Health Consequences

PM and gaseous air pollutants negatively impact our public health even at very low levels. They are primarily formed from the burning of fossil fuels, entering the atmosphere from the exhaust of our motor vehicles and the units that heat our buildings. People in the United States are breathing some of the cleaner air in the world, but despite this fact air pollution still has a significant impact on our health outcomes.

[3] "New WHO Global Air Quality Guidelines Aim to Save Millions of Lives from Air Pollution." *WHO | World Health Organization*, 22 Sept. 2021, www.who.int/news/item/22-09-2021-new-who-global-air-quality-guidelines-aim-to-save-millions-of-lives-from-air-pollution.

An ever-growing body of scientific studies has demonstrated that long- and short-term exposure to fine particulate ($PM_{2.5}$) causes a considerable risk to cardiovascular and respiratory health, particularly among the elderly population of the United States. Studies linked even low levels of exposure to thousands of hospital visits a year for heart attack, stroke, cancer, and respiratory diseases.[4]

Ozone (O_3) has been shown to increase the frequency of asthma attacks, aggravate lung diseases, and even cause permanent damage to the lungs.[1] Unhealthy levels of sulfur dioxide and nitrogen dioxide (NO_2) have also been shown to cause adverse respiratory effects, driving up emergency hospital admissions for respiratory illness.[1]

A 2021 study published in Environmental Health focusing on $PM_{2.5}$, O_3, and NO_2 found that even when levels were at or below the current EPA standards, they were still associated with significant mortality in elders, therefore suggesting that current standards do not sufficiently protect public health.[5] Furthermore, the study estimates that lowering $PM_{2.5}$ by less than 1 $\mu g/m^3$, O_3 by less than 2 ppb, and NO_2 by 3 ppb would prevent over 65,000 early deaths per year among elders.

Looking beyond mortality, air pollution reduces quality of life and causes health complications for people of all ages. Air pollution has long been identified as a trigger of asthma attacks and has more recently been understood to be a cause of asthma as well.[6] Children and infants are particularly vulnerable to pollutants, so reducing childhood exposure would decrease cases and severity of many respiratory conditions.[6] Furthermore, fine particulate exposure is a recognized risk factor for preterm birth and low birth weight.[6] The research is clear – reducing air pollution would both improve people's lives and prevent many early deaths.

[4] Yazdi, Mahdieh Danesh, et al. "Long-Term Association of Air Pollution and Hospital Admissions Among Medicare Participants Using a Doubly Robust Additive Model." 22 Feb. 2021, www.ahajournals.org/doi/10.1161/CIRCULATIONAHA.120.050252.

[5] Wei, Yaguang, et al. "Emulating Causal Dose-response Relations Between Air Pollutants and Mortality in the Medicare Population." *BioMed Central*, 6 May 2021, ehjournal.biomedcentral.com/articles/10.1186/s12940-021-00742-x.

[6] Perera, Frederica, and Kari Nadeau. "Climate Change, Fossil-Fuel Pollution, and Children's Health | NEJM." *New England Journal of Medicine*, 15 June 2022, www.nejm.org/doi/full/10.1056/NEJMra2117706.

Monitoring Background

Local Specifics

The Indiana Department of Environmental Management (IDEM) regulates ambient air quality across the state of Indiana to determine compliance with the EPA's NAAQS. IDEM is required by federal regulations to review Indiana's air monitoring network and determine if changes are needed to meet monitoring goals across the state. They collect both intermittent and continuous air quality data, then produce annual reports detailing findings and network plans.

Bloomington currently has two State or Local air monitoring stations (SLAMS), both located at Binford Elementary school, 2300 E 2nd St, for fine particulate matter ($PM_{2.5}$) collection. One station collects intermittent data, and the other collects continuous air quality data. Such monitoring stations make up the ambient air quality sites that are needed for NAAQS comparison. Intermittent data are all considered eligible and used for calculation of the design value of a site. Interestingly, while continuous data are usually considered eligible as well, the Bloomington – Binford site is considered an exception. Reportedly it has regularly produced very poor comparison data.[7][8][9]

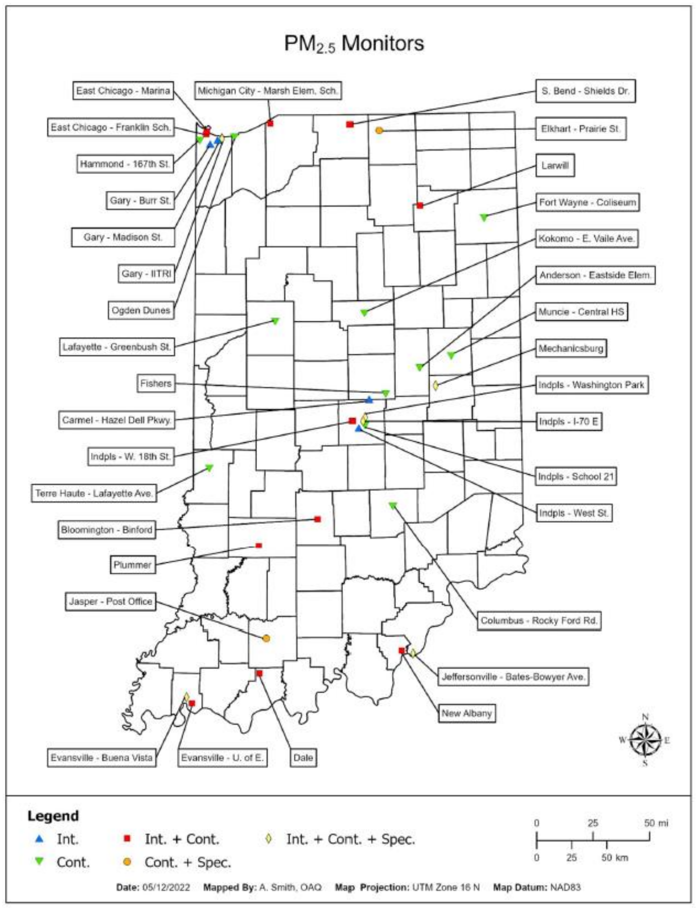

Figure 1. IDEM 2023 Annual Network Plan – Figure 10.
Adapted from: "Indiana's Ambient Air Monitoring Network."

Since Bloomington's metropolitan statistical area (MSA) has over 50,000 residents and the Ozone (O_3) isn't below 85% of the NAAQS design value, the city is required to have a monitor for O_3 as well. Historically this has been achieved by having a SLAM located at the Plummer location in neighboring

[7] "Indiana's Ambient Air Monitoring Network." *Air Monitoring*, 1 July 2015, www.in.gov/idem/airmonitoring/indianas-ambient-air-monitoring-network/.
[8] "Indiana's Ambient Air Monitoring Network." *Air Monitoring*, 1 July 2019, www.in.gov/idem/airmonitoring/indianas-ambient-air-monitoring-network/.
[9] "Indiana's Ambient Air Monitoring Network." *Air Monitoring*, 1 July 2022, www.in.gov/idem/airmonitoring/indianas-ambient-air-monitoring-network/.

Greene County. However, in 2013 Greene County was removed from the Bloomington MSA. For the 2020 network plan, a new O_3 site was selected in Helmsburg, which is to the northeast in Brown County. Helmsburg is technically part of the Indianapolis MSA rather than the Bloomington MSA, but consultations with EPA Region 5 decided it was acceptable as a downwind site to collect data for the Bloomington MSA. All sites for SLAM monitors are approved by the EPA.

Data from 2022

While it may be too early for finalized data on air quality for 2022, there is significant preliminary data available to study. The Environmental Protection Agency provides Air Quality System (AQS) data collected from thousands of monitors nationwide. They use AirNow data for recent days that are not yet available from AQS, then replace the AirNow data as AQS becomes available. AirNow reports on ambient air quality using the official U.S. Air Quality Index (AQI), but it is not fully verified and validated by the same procedures as AQS. Therefore, while useful to the public, AirNow data cannot be used to formulate any EPA position.

The Air Quality Index is essentially a scale from 0 to 500 – the higher the AQI value, the greater the level of air pollution and the greater the health concern. When values are below 50 the air quality is considered satisfactory, such that air pollution poses little risk. Values from 51 to 100 reflect that while air quality is acceptable, there may be risks to the public, specifically those who are particularly sensitive to air pollution. When values fall between 101 and 150, the air quality is considered unhealthy for sensitive groups. Under these circumstances the general public is less likely to experience negative health effects, but still may be affected.

Daily $PM_{2.5}$ AQI values measured for Bloomington in 2022 largely fell into the AQI category of Good, meaning 50 or below. Around 30 days out of the year were recorded in the Moderate AQI category, and about half a dozen days featured insufficient data. The average $PM_{2.5}$ AQI value for Bloomington in 2022 came in just a little over 30, which appears to be consistent with the average value from 2015-2019.

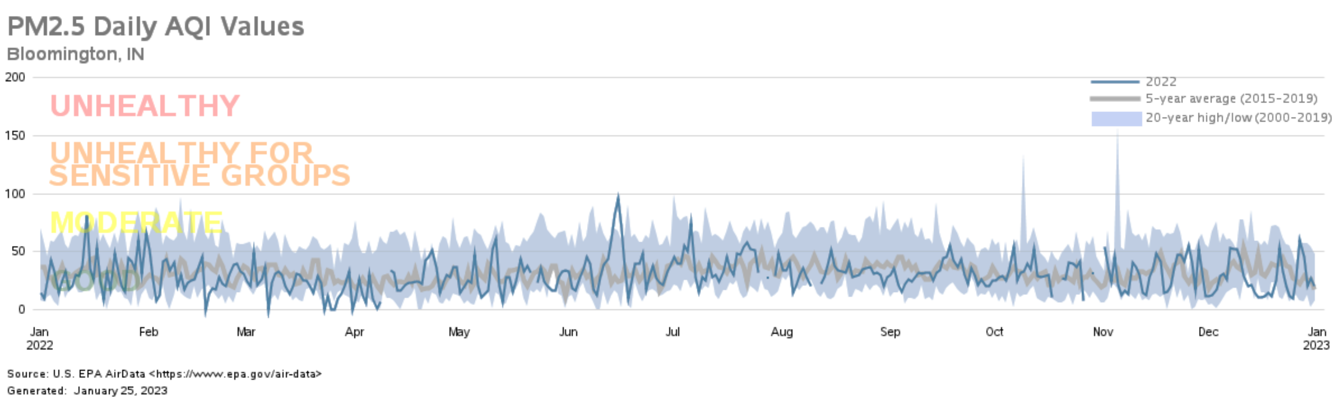

Figure 2. $PM_{2.5}$ Daily AQI values reported in AirNow for Bloomington, Indiana from January 2022 until January 2023.

Daily ground-level ozone AQI values measured in 2022 for Bloomington, via the Helmsburg site, also predominately fall under the AQI category of Good, meaning 50 or below. Around 20 days out of the year were recorded in the Moderate category, and once again a handful of days feature insufficient data. The average O_3 AQI value for Bloomington in 2022 was roughly 34, which again appears to be consistent with the average data value from 2015-2019.

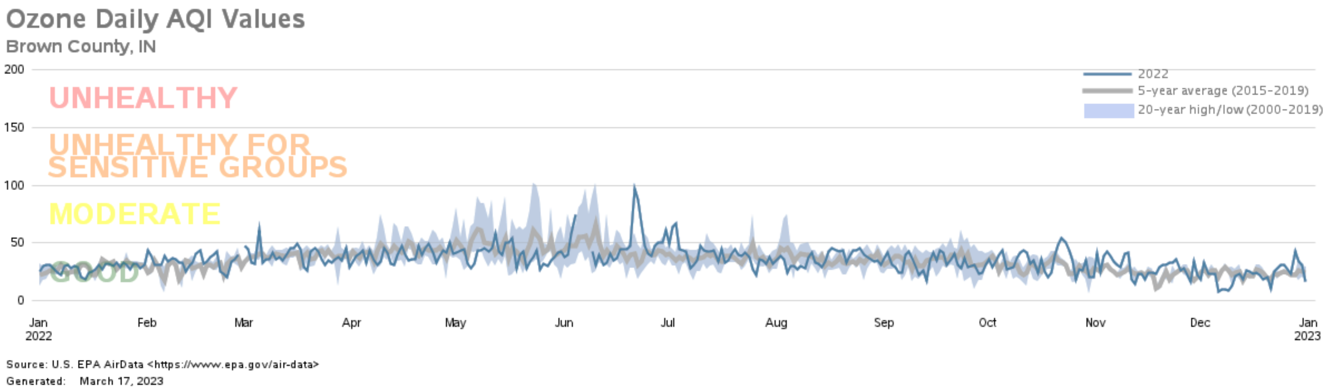

Figure 3. Ozone Daily AQI values reported in AirNow for Bloomington, Indiana from January 2022 until January 2023.

Comparisons and the Unknown

The $PM_{2.5}$ air quality data for Bloomington in 2022 is an improvement compared to long-term historical data, which is consistent with much of the country and indicative of the progress that has been made since the air quality legislation of the 1960s and 1970s. However, the short-term averages seem to show very little progress in the last decade. The AQI values provided by the EPA for 2022 are virtually identical to the averages from 2015 through 2020. The tile plot below reflects $PM_{2.5}$ data in micrograms per cubic meter of air (µg/m^3). Green represents less than or equal to 12 µg/m^3, yellow represents 12.1-35.4 µg/m^3, and orange through purple are not shown due to Bloomington's numbers not reaching sustained unhealthy levels of 35.5 µg/m^3 and beyond.

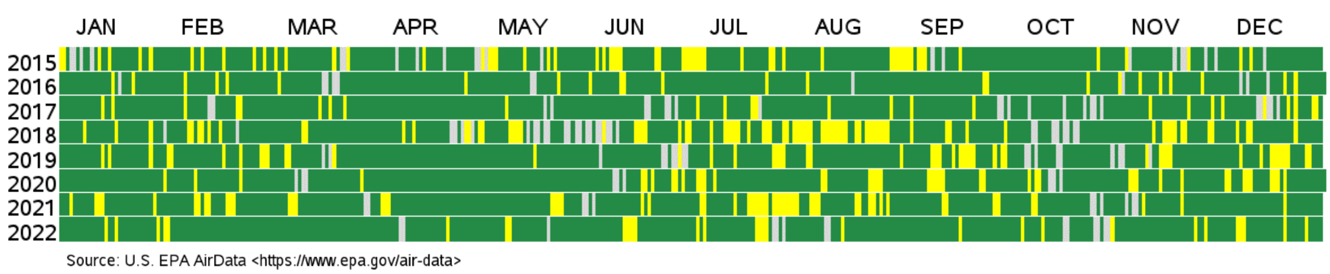

Figure 4. Tile plot for the years 2015-2022 showing the occurrences of $PM_{2.5}$ concentration values less than 12 ug/m^3 (green) and 12.1-35.4 ug/m^3 (yellow). Gray tiles correspond to no data.

The most recent Ambient Air Monitoring Network Plan (2022) released by IDEM also reports $PM_{2.5}$ site values gradually improving, and within the national standards.[9] Data in the report are from 2019-2021, and they show Bloomington's annual $PM_{2.5}$ value as 7.9 μg/m³, and the 24-hour value as 15 μg/m³. For reference, the EPA NAAQS standards are under 12 μg/m³ annually, and 35 μg/m³ within a 24-hour averaging time. The report data from 2019-2021 indicate the O_3 value as .061 parts per million (ppm), which meets the NAAQS 8-hour standard of .070 ppm.

There are many factors that may impact the air pollution levels for different time periods and probably deserve further analysis. How have $PM_{2.5}$ or O_3 levels in the air been affected by the last 8 years being the hottest in earth's history? This seems worth investigating, as rising temperatures seem likely to continue in the coming years. The spring of 2020 saw reduced local vehicle travel, as many residents' daily routines were impacted by the COVID-19 pandemic. Some people continue to work remotely or travel less to this day. It appears these events may have reduced $PM_{2.5}$ levels slightly, but even so, the effects may prove to be short-lived.

Perhaps the biggest unanswered question is this: what concentration of other air pollutants are we breathing in and around Bloomington? What have their average measures been, and how have they been trending in recent years? Are there any specific communities breathing more dangerous air as a result of activities at a neighboring business or residence? There is currently no good way to answer such questions, given the limited air quality monitoring equipment in our city. We can't account for what we aren't measuring.

The Future

Climate Impacts

Rising levels of carbon dioxide (CO_2) and higher temperatures impact air quality in various ways. For example, climate change has led to longer growing seasons and increased pollen production, which has resulted in an increase in allergy and asthma attacks, particularly among children.[6] This example, like so many others, does not affect all people equally. It should be noted that many climate impacts are experienced disproportionately by low- and middle-income populations, both globally and here in the United States.[10] While geography and socioeconomic status play a role in the two following climate impacts in the U.S. as well, they are still significant threats to human health nationwide.

One of the most obvious ways that climate change negatively impacts air quality is through wildfires pumping smoke into the air, primarily in the western United States. The specific contents of wildfire smoke can depend on factors like what is burning, how hot the fire is, and how far the smoke has traveled before being inhaled. Generally, wildfire smoke contains thousands of individual compounds, including VOC, nitrogen oxides (NO_x), hydrocarbons, and immense amounts of fine particulate matter ($PM_{2.5}$).[11] $PM_{2.5}$ pollution is so small that it not only harms respiratory health but can enter the bloodstream and hurt cardiovascular health as well. As a result of wildfires, some California counties experienced higher air pollution levels in 2020 than estimated levels in 1970.[12] Climate change has made wildfire seasons longer and more intense, and that trend is expected to continue in the coming years.

Extreme heat is another factor that contributes to a reduction in air quality. As days get hotter and stay hot for longer, increased use of air conditioning leads to a degradation in air quality. In fact, energy demand for air conditioning is so high on the hottest days that our dirtiest power plants must be utilized to meet those needs.[13] Old and inefficient plants emit several toxic heavy metals, SO_2, NO_x, VOCs, and PM. Since ground-level ozone is formed when NO_x and VOCs react in the presence of sunlight and heat, long hot days are usually the most dangerous for this principal air pollutant.

In addition to worsening air quality, extreme heat also makes any measure of ambient air pollutants more dangerous. Studies have found that while mortality risk increases with exposure to extreme heat

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[10] "New WHO Global Air Quality Guidelines Aim to Save Millions of Lives from Air Pollution." *WHO | World Health Organization*, 22 Sept. 2021, www.who.int/news/item/22-09-2021-new-who-global-air-quality-guidelines-aim-to-save-millions-of-lives-from-air-pollution.

[11] Montrose, Luke. "What's in Wildfire Smoke?" *Earth Island Journal*, 22 July 2021, www.earthisland.org/journal/index.php/articles/entry/whats-in-wildfire-smoke.

[12] Greenstone, Michael, et al. "Annual Update." *AQLI*, June 2022, aqli.epic.uchicago.edu/wp-content/uploads/2022/06/AQLI_2022_Report-Global.pdf.

[13] Limaye, Vijay. "A/C Cools Us in a Warmer World but Dirties Air, Harms Health." *NRDC*, 3 July 2018, www.nrdc.org/bio/vijay-limaye/ac-cools-us-warmer-world-dirties-air-harms-health.

or air pollution, the risks are even greater when the two combine. A California study analyzing data from 2014-2019 estimated a 36.2% increase in mortality risk by cardiovascular or respiratory issues for people over 75 when heat and air pollution are high.[14]

Climate change intensifies air quality issues, and not enough action has been taken globally to prevent significant warming. As a result, both climate adaptation policies and increased monitoring of air quality conditions will be of the utmost importance as we try to protect health outcomes in a warming world. Efforts enacted at federal, state, and local levels can all have a major impact.

What comes next?

IDEM, in accordance with the EPA, has reasonable guidelines in place for collecting data on criteria air pollutants within the state of Indiana. For example, metropolitan statistical areas (MSAs) with a population between 50,000 and 500,000 and $PM_{2.5}$ above 85% of NAAQS are required to test for $PM_{2.5}$ air pollution. The guidelines establish that Bloomington needs to be monitoring for $PM_{2.5}$ and O_3 pollutants, and that seems to be taking place. Unfortunately, the continuous $PM_{2.5}$ data at the Bloomington – Binford location has regularly been requested for exclusion from NAAQS comparison for the last decade. Unreliable data and siting issues led to a monitor change during 2018 from an older generation to a newer model. Exclusion continued to be requested until at least 24 months of data could be collected, but even once this mark was met, Bloomington – Binford data has shown poor data results. Due to this, the state is planning on another method change once funding is procured from the American Rescue Plan grant.

While PM and ozone must be monitored in the Bloomington MSA, it should also be noted that some compounds, such as VOC, have no requirements for monitoring listed. This seems to suggest that a monitor to sample and analyze VOCs in ambient air could potentially be installed anywhere within the state network at any time. However, the 2022 monitoring network report identified no plans to add a VOC monitor in Bloomington.

In addition to the American Rescue Plan funds referenced earlier, it has been widely reported that the Inflation Reduction Act (IRA) committed millions of dollars to state agencies to improve air quality monitoring. Though IDEM indicated in late 2022 that it is too early to determine what steps will be taken regarding IRA funding, it is possible such funds could be used to improve or expand monitoring in or around Bloomington.

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[14] Rahman, Md Mostafijur, et al. "The Effects of Coexposure to Extremes of Heat and Particulate Air Pollution on Mortality in California: Implications for Climate Change." *American Journal of Respiratory and Critical Care Medicine*, 5 Apr. 2022, www.atsjournals.org/doi/10.1164/rccm.202204-0657OC.

What can Bloomington do?

The logical first step is to accelerate our efforts to reduce reliance on fossil fuels. Increased utilization of renewable energy sources like solar energy, along with efforts to decarbonize transportation, would have a significant impact on both climate change and air quality. Since these issues are interconnected, policies that reduce dependence on fossil fuels can simultaneously combat climate change and enable people to live longer and healthier lives.[12]

Next, we should ask whether Bloomington is satisfied with the amount of ambient air quality monitoring by IDEM. They currently monitor $PM_{2.5}$ from Binford Elementary and downwind ground-level ozone from nearby Helmsberg. This monitoring data collection is required by regulation from the EPA and is collected to determine compliance with the EPA's NAAQS. However, $PM_{2.5}$ is only being monitored from one site, and ozone is only being measured from outside city limits. This allows for several intriguing possibilities for expanding air quality monitoring in Bloomington.

One policy worth considering would be placing a reference quality ozone monitor within the city limits. Having an ozone monitor in town could allow Bloomington to observe local ozone levels more closely and determine whether the monitor data from the surrounding counties is representative of ozone levels in Bloomington. If desired, the city could even opt to issue air quality warnings and guidance to protect citizens during periods of high ozone.

Another good option would be placing many low-cost $PM_{2.5}$ air sensors throughout Bloomington. Low-cost sensors have lower accuracy than EPA reference monitors and may be affected by some environmental conditions, but networks of these sensors can help increase our understanding of the spatial distribution of PM pollution and potentially identify air pollution hotspots in town. Furthermore, a network of sensors could provide data within less affluent neighborhoods and allow everyone to observe and react to more local air quality figures. One California study found that placing low-cost sensors at schools resulted in the most accurate and equitable distribution of air quality information.[15] Children's vulnerability to air pollution makes this potential strategy even more appealing.

Whether we're ready or not, a future shaped by climate change is looming. Improving air quality monitoring should give us a better baseline understanding of local air pollution, which will allow us to prepare more effectively for anticipated air quality challenges and protect citizens from the worst health outcomes. Furthermore, we have an opportunity to make policy decisions with environmental justice in mind. Taken in its entirety, this report advocates for increased air quality monitoring in Bloomington.

[15] Considine, Ellen M., et al. "Investigating Use of Low-Cost Sensors to Increase Accuracy and Equity of Real-Time Air Quality Information." ACS Publications, 9 Jan. 2023, pubs.acs.org/doi/10.1021/acs.est.2c06626.