Wisconsin Department of Natural Resources

2023 Wisconsin Air Quality Trends Report

Data From 2001-2022

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Disclaimer

Contents

Acronyms and Abbreviations

Table 1. Acronyms and abbreviations used in this report

Term	Definition
CAA	Clean Air Act
CO	Carbon monoxide
DNR	Wisconsin Department of Natural Resources
EQUATES	EPA's Air QUAlity TimE Series
EPA	U.S. Environmental Protection Agency
hr	Hour
mo	Month
NAAQS	National Ambient Air Quality Standards
NEI	National Emissions Inventory
NH_3	Ammonia
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides; NO + NO_2
O_3	Ozone
OMI	Ozone Monitoring Instrument
PM	Particulate matter
$PM_{2.5}$	Fine particles (particles 2.5 µm or smaller in diameter)
PM_{10}	Inhalable particles (particles 10 µm or smaller in diameter)
ppb	Parts per billion
ppm	Parts per million
SO_2	Sulfur dioxide
Story Map	Interactive map with data and context
TROPOMI	Tropospheric Monitoring Instrument
TSP	Total suspended particles
VOCs	Volatile organic compounds
yr	Year
$\mu g/m^3$	Microgram per cubic meter
µm	Micrometer (micron)

Report Summary

The Wisconsin Department of Natural Resources (DNR) monitors ambient concentrations of several air pollutants throughout the state including ground-level ozone (O_3), particle pollution, sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO). These pollutants are called criteria pollutants and are regulated by the U.S. Environmental Protection Agency (EPA) as part of the Clean Air Act (CAA). Monitored levels of criteria pollutants are compared against the National Ambient Air Quality Standards (NAAQS), set by EPA at levels protective of public health, to determine whether the standards are met. In addition to criteria pollutants, the DNR monitors air quality for numerous hazardous air pollutants.

First released in 2013, the Wisconsin Air Quality Trends Report is updated annually to incorporate the most current data. This year's trends report presents official state monitoring data through 2022 for criteria air pollutants and compares it to nearly 20 years of past ambient air monitoring data for contextual reference.

This report also includes the most up-to-date national emissions inventory (NEI) estimates from all source sectors in Wisconsin. Long-term trends in monitored air quality and air pollutant emissions, such as those presented in this report, guide decisions about the management of air quality issues at federal and state levels.

This report is organized into five sections:

1. An introduction to current air quality standards
2. An overview of each criteria pollutant including the regulatory history of the pollutant standards and historical attainment status in Wisconsin
3. Emissions data for criteria pollutants and their precursors (National Emissions Inventory data through 2020)
4. Trends in criteria monitoring data compared to the relevant NAAQS (through 2022)
5. Report appendices
    a. graphs of county-level pollutant trends
    b. tables showing percentage change in monitored pollutants over time
    c. table detailing the site name abbreviations used in this document

Notable Updates

Continuing on the long-term trend, concentrations of most criteria pollutants have decreased in all regions of the state since monitoring began.

Since the early 2000s, statewide concentrations of ozone have decreased 21% (Figure 1). Ozone forms via chemical reactions in the atmosphere between directly emitted pollutants known as ozone precursors such as nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. While the state has seen improvements along the Lake Michigan shoreline, an area historically impacted by elevated ozone concentrations, the Milwaukee area and parts of Kenosha and Sheboygan counties remain in nonattainment for the 2015 ozone standard. The most recent monitoring period shows decreases in ozone values across the state, including in the lakeshore region, which has seen a 17% average reduction in ozone concentrations from 2001-2003 to 2020-2022. Wisconsin has implemented many programs that have reduced emissions of ozone-causing pollutants from power plants, industry and transportation in the state. However, these emission reductions have not resulted in attainment of the 2015 ozone standard because most sources of ozone-causing emissions are outside of the state's control.

The DNR submitted a redesignation request to EPA for the last remaining Wisconsin nonattainment area for the 2008 ozone standard in December 2021. In spring 2022, the EPA concurred with the request and as a result, the entire state meets the federal 2008 ozone standard.

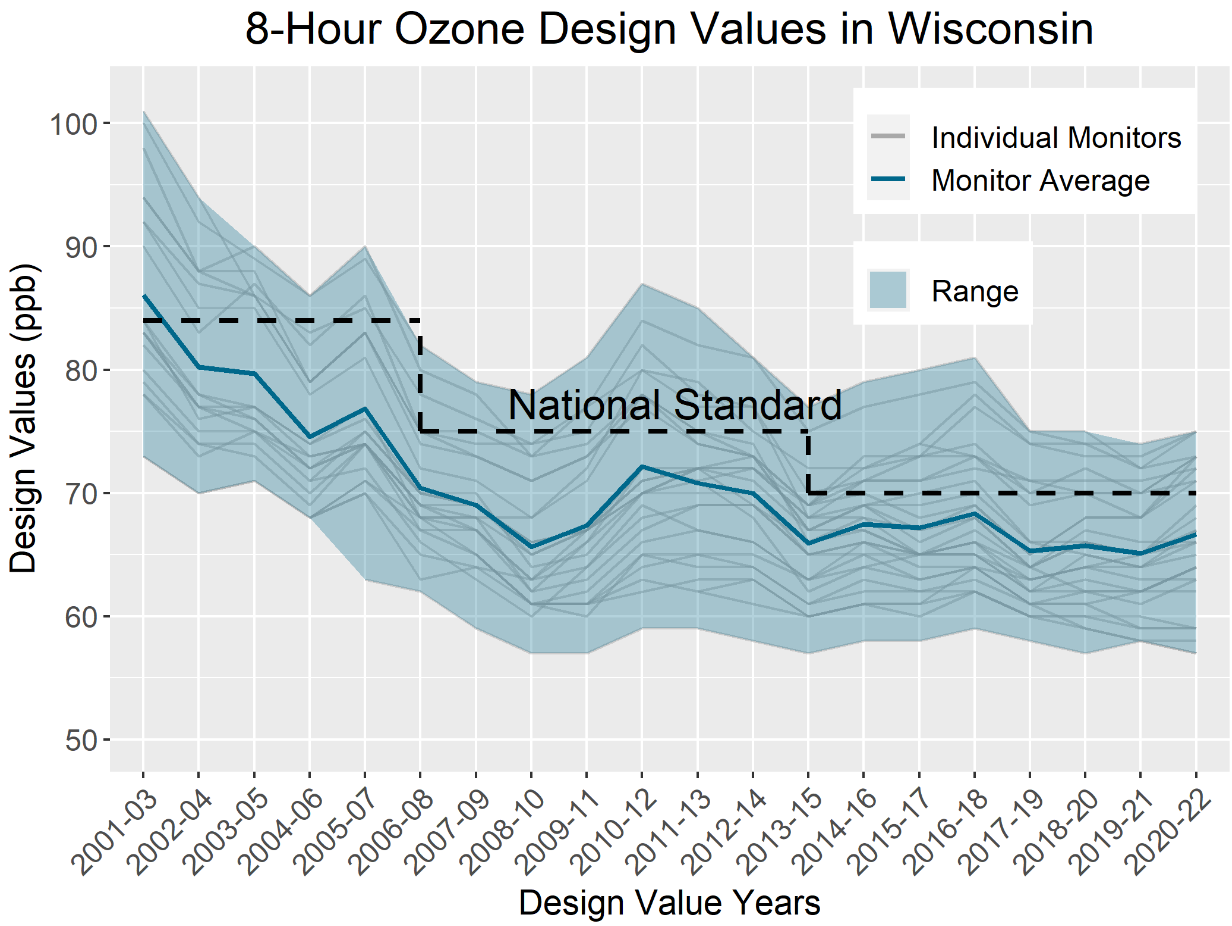

Figure 1. Trends in ozone[1]. The dark line shows the average design value, the light lines show trends for each monitor and the shaded area shows the range of values observed. The design value axis truncates at 50 ppb.

[1] Concentrations are reported as "design values," which are explained in the Background section of the main document.

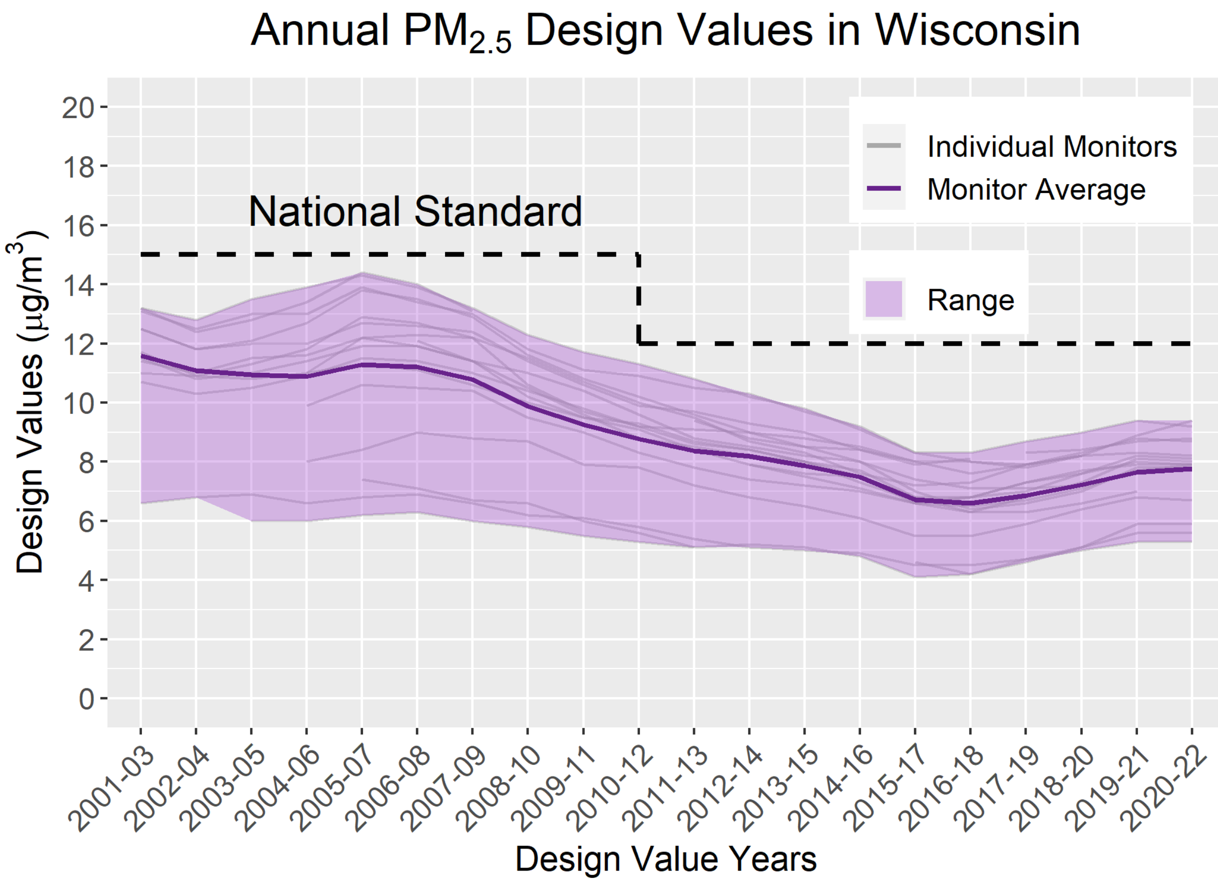

Figure 2. Trends in $PM_{2.5}$. The dark line shows the average design value, the light lines show trends for each monitor and the shaded area shows the range of values observed.

Reductions in $PM_{2.5}$ (particles 2.5 µm or smaller in diameter) concentrations have been observed across the state from 2003 to 2022. All $PM_{2.5}$ monitors in Wisconsin measured concentrations[2] well below the current federal air quality standards (Figure 2). As a result, EPA considers all of Wisconsin “in attainment” of federal $PM_{2.5}$ standards. Since the early 2000s, $PM_{2.5}$ concentrations have decreased by 26% (Figure 2). However, similar to ozone, after decades of decline in Wisconsin, downward trends have slowed in recent years. Upcoming changes to the federal standards are further discussed in the Overview of Pollutants (Particulate Matter) section.

Another success story is the reduction of SO_2 concentrations across the state. Starting in 2018-2020, all SO_2 monitors in Wisconsin measured concentrations[1] below the federal air quality standards (Figure 3). The DNR submitted a redesignation request in July 2021; EPA approved this request in January 2022. As a result, EPA considers all of Wisconsin “in attainment” for federal SO_2 standards. Since the early 2000s, SO_2 concentrations have decreased by 88% (Figure 3). EPA introduced the hourly standard in 2010; prior to 2010, a 24-hour standard was in place.

[2] Concentrations are reported as “design values,” which are explained in the Background section of the main document.

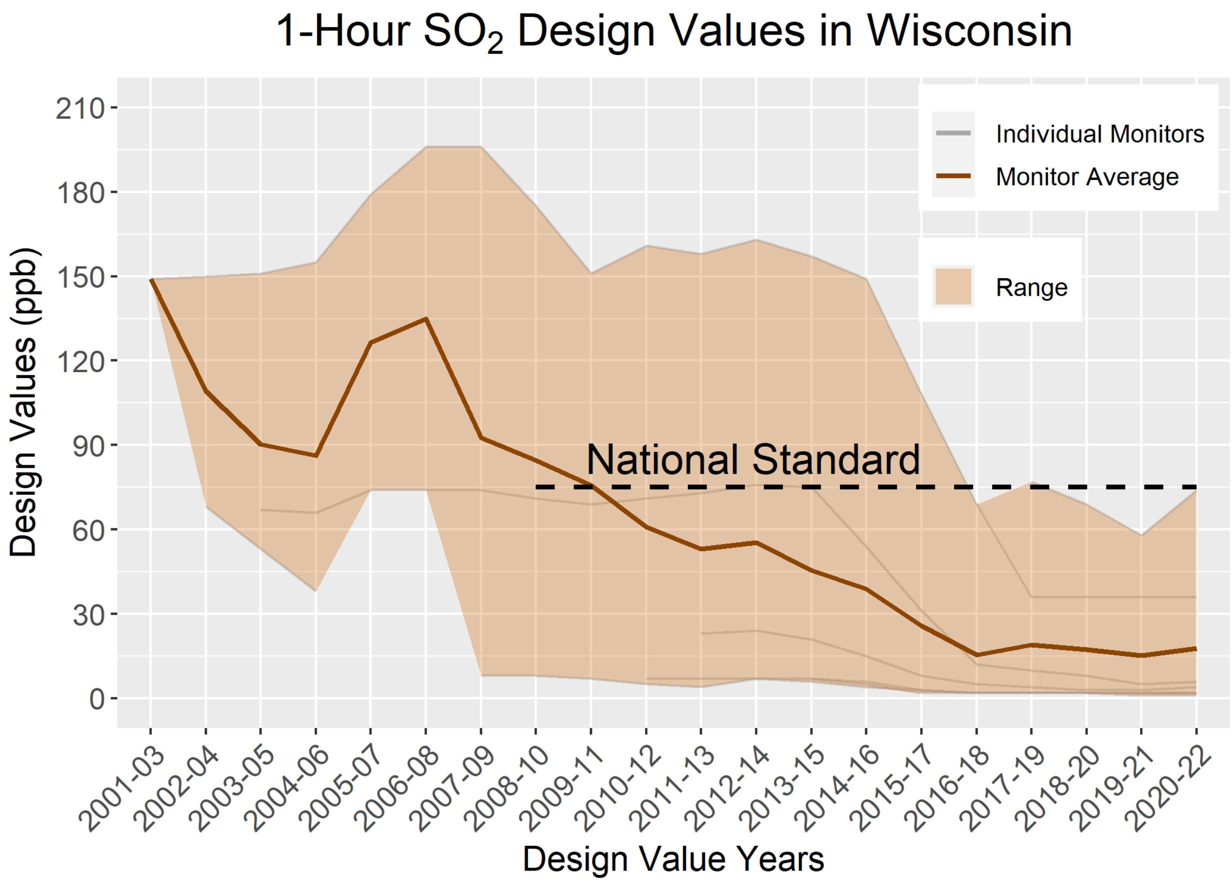

Figure 3. Trends in SO2[3]. The dark line shows the average design value, the light lines show trends for each monitor and the shaded area shows the range of values observed.

The observed decreases in several criteria pollutants are due to the implementation of a variety of federal and state control programs, which have led to significantly improved air quality across the state. This report shows that emissions of most directly emitted pollutants or their precursors have decreased substantially from 2002 to 2020. Some highlights include:

- A 72% decrease in reported emissions of nitrogen oxides (NOx) and a 28% decrease in volatile organic compounds (VOCs), compounds that form ground-level ozone.
- Emissions of sulfur dioxide (SO_2) decreased by 93%, with the largest reductions coming from the electric utility fuel combustion sector.
- Emissions of carbon monoxide (CO) decreased by 58%, with most of the reductions coming from highway vehicles and the off-highway sector.

[3] Concentrations are reported as "design values," which are explained in the Background section of the main document.

Background

National Ambient Air Quality Standards (NAAQS)

The Clean Air Act requires EPA to set NAAQS for pollutants considered harmful to public health and the environment. There are two types of standards, primary and secondary. Primary standards are set at a level to protect human health, especially for people with respiratory conditions or sensitivity to pollutant exposure. Secondary standards protect public welfare, including preventing impaired visibility, structural damage to buildings and vegetative/livestock injury. For some pollutants, there are multiple primary standards (e.g., $PM_{2.5}$ has 24-hour and annual standards). The different standards allow EPA to track both long-term and short-term exposure to these pollutants. This report compares Wisconsin air monitoring data with the primary standards.

The current NAAQS for the six criteria pollutants regulated by EPA are shown in Table 2. Note that both the 2015 ozone NAAQS of 0.070 ppm and the 2008 NAAQS of 0.075 ppm remain in effect.

Design Value Calculations

A design value is a statistic describing the air quality status of a given location relative to the NAAQS. The EPA sets standards and associated design values consistent with individual NAAQS and based on pollutant concentrations over long time periods, ensuring typical concentrations are represented, rather than isolated spikes or dips in concentrations. Each summer, EPA publishes design values based on data through the end of the previous year on its Air Quality Design Values webpage.

Design value calculations for criteria pollutants use methods specific for each standard, as shown in the *Averaging time* and *Definition* columns of Table 2. The paragraphs below explain design value calculations for ozone and $PM_{2.5}$.

Table 2. EPA criteria pollutants and National Ambient Air Quality Standards (NAAQS)*

Pollutant	Primary / Secondary	Averaging Time**	Level	Definition**
Carbon monoxide (CO)	primary	8 hour	9 ppm	not to be exceeded more than once per year
		1 hour	35 ppm	
Lead	primary and secondary	rolling 3 month	0.15 µg/m^3	not to be exceeded

Pollutant		Primary / Secondary	Averaging Time**	Level	Definition**
Nitrogen dioxide (NO_2)		primary	1 hour	100 ppb	annual 98th percentile value of daily maximum 1-hour concentrations, averaged over 3 years
Nitrogen dioxide (NO_2)		primary and secondary	annual	53 ppb	annual mean
Ozone (O_3)		primary and secondary	8 hour	0.070 ppm (2015 standard) 0.075 ppm (2008 standard)	annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particulate matter (PM)	$PM_{2.5}$	primary	annual	12.0 µg/m^3	annual mean, averaged over 3 years
Particulate matter (PM)	$PM_{2.5}$	secondary	annual	15.0 µg/m^3	annual mean, averaged over 3 years
Particulate matter (PM)	$PM_{2.5}$	primary and secondary	24 hour	35 µg/m^3	annual 98th percentile value, averaged over 3 years
Particulate matter (PM)	PM_{10}	primary and secondary	24 hour	150 µg/m^3	not to be exceeded more than once per year on average over 3 years
Sulfur dioxide (SO_2)		primary	1 hour	75 ppb	annual 99th percentile value of daily maximum 1-hour concentrations, averaged over 3 years
Sulfur dioxide (SO_2)		secondary	3 hour	0.5 ppm	not to be exceeded more than once per year

*** Based on https://www.epa.gov/criteria-air-pollutants/naaqs-table.**
**** 3-mo, 8-hour, and 3-hour averages are calculated as rolling averages; in contrast, annual averages are for the calendar year and 24-hour averages are for the calendar day (i.e., are not rolling)**

Ozone

The design value metric used to determine compliance with the ozone NAAQS is the annual fourth-highest daily maximum eight-hour (8-hour) concentration, averaged over a period of three years. Two ozone NAAQS are currently in effect, each with different methods of determining design values.

Design value calculations for the 2008 and 2015 standards are similar. Each standard uses a rolling 8-hour averaging procedure. The 2015 standard has 17, 8-hour rolling periods starting at 7 a.m. and with the last period starting at 11 p.m. For example, one period is 7 a.m. to 3 p.m., the next is 8 a.m. to 4 p.m.

and the last period of the day is 11 p.m. to 7 a.m. the following day. The 2008 standard has 24 8-hour rolling periods, one for each hour of the day. The change avoids counting the same early morning values over two separate days. Once the average ozone concentration is determined for each 8-hour period, the highest value represents the calendar day. Figure 4 shows the highest 8-hour average value from each day at a monitoring site during an example ozone season. To obtain the design value, EPA identifies the fourth-highest daily maximum 8-hour value for the year (circled value in Figure 4) and then averages the current-year's value with the fourth-highest values from the two previous consecutive years. For instance, a 2020-2022 ozone design value uses the fourth-highest 8-hour maximum value for 2022 with the fourth-highest values from 2021 and 2020.

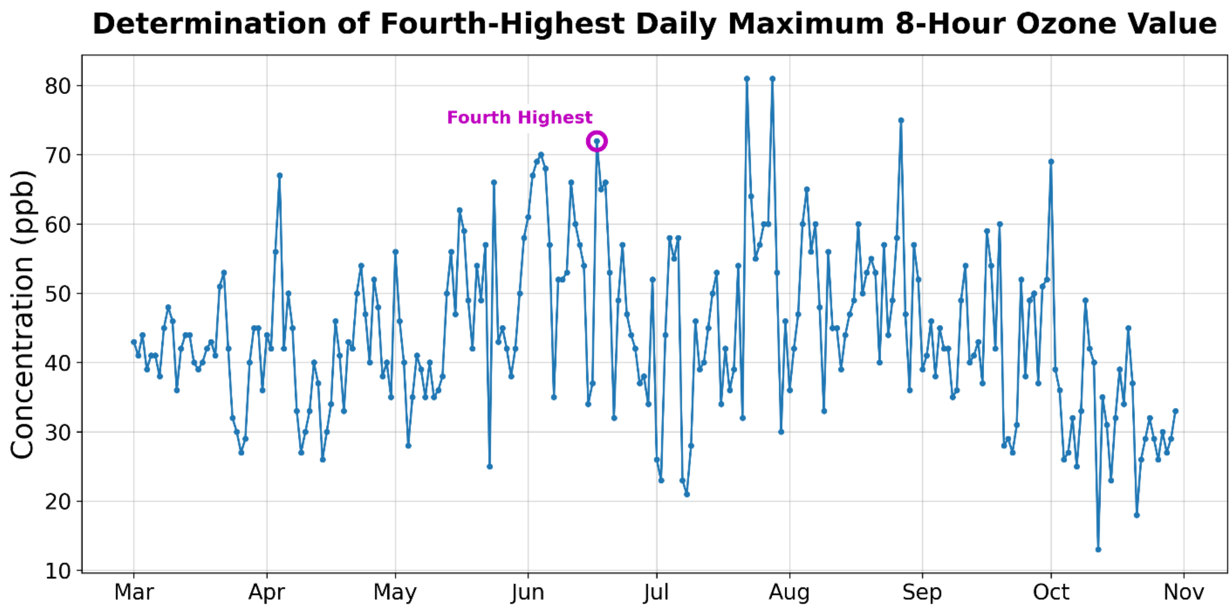

Figure 4. Example of a fourth-highest daily 8-hour maximum value identified for use in calculating an ozone design value.

Fine Particles ($PM_{2.5}$)

For $PM_{2.5}$, EPA compares design values to both the annual and 24-hour NAAQS. The design value for the annual $PM_{2.5}$ NAAQS is the average of the annual means from three consecutive years, where each annual mean is the average of the four quarterly mean concentrations. To obtain 24-hour NAAQS design values, EPA determines the observation representing the 98th percentile of 24-hour (calendar-day) average $PM_{2.5}$ concentrations for each year (e.g., Figure 5) and then averages that value over three consecutive years. The 98th percentile value is the observed concentration with 98% of the daily concentrations below the value and two percent of the daily concentrations above the value. To calculate a 2020-2022 24-hour $PM_{2.5}$ design value, EPA averages the 98th percentile value for 2022 with the 98th percentile values from 2020 and 2021. Then, compares the resulting design value to the 24-hour $PM_{2.5}$ NAAQS of 35 µg/m^3, determining compliance with the standard.

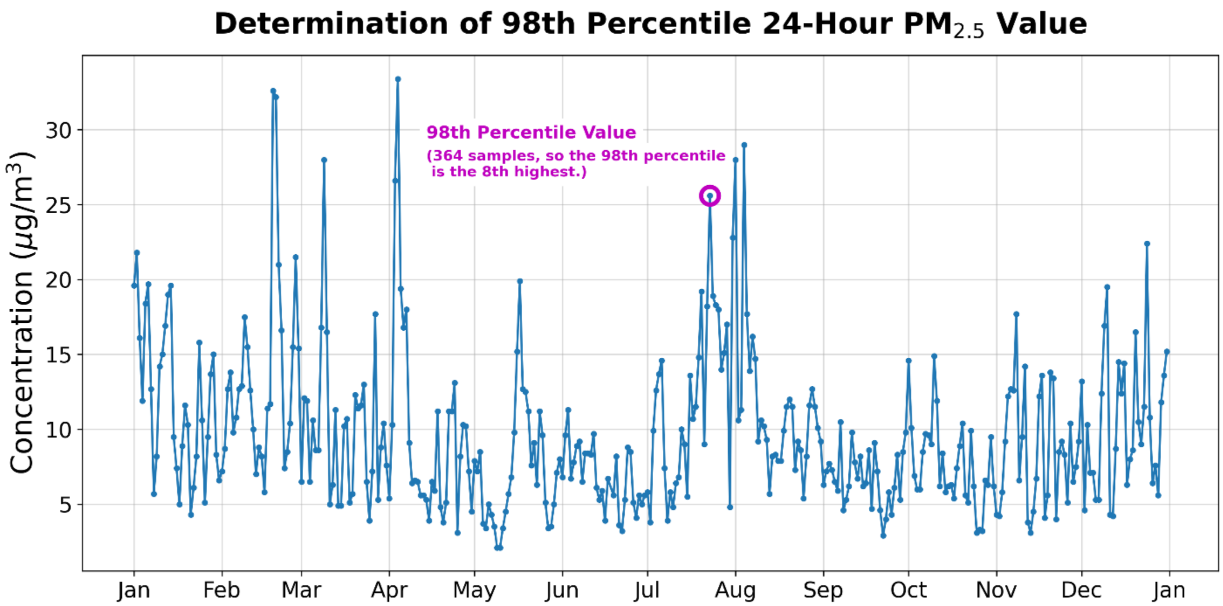

Figure 5. Example of a 98th percentile observation identified for use in calculating a 24-hour PM2.5 design value.

Overview of Pollutants

Ozone

Ozone (O_3) is a compound containing three oxygen atoms that occurs naturally in the atmosphere. Ozone is constantly produced and destroyed by chemical reactions in the atmosphere. Ozone is present in the Earth's upper atmosphere (stratosphere), as well as at ground level (troposphere). Ozone concentrations in the upper atmosphere filter out harmful ultraviolet rays from the sun. However, elevated concentrations of ozone at ground level can have an adverse impact on health. Monitored values of ozone in this report represent ground-level ozone.

Ground-level ozone is not directly emitted into the air; it is created by photochemical reactions (chemical reactions that occur in the presence of light) from ozone precursors and sunlight. Ozone is a regional pollutant because winds can transport ozone and ozone precursors long distances. The highest measured ozone concentrations typically occur downwind of urban areas on hot sunny days with light winds. To better represent this, the DNR created a video explaining ozone formation and transport to Wisconsin.

Ozone exposure can lead to or exacerbate many health issues, including chest pain, coughing, throat irritation and airway inflammation. It can reduce lung function and worsen bronchitis, emphysema and asthma. Children have an increased risk from ozone exposure because their lungs are still developing. In Wisconsin, a network of continuously operating monitors measure ozone and provide the basis for air quality forecasting, real-time health advisories and regulatory decision making.

Ozone concentrations in Wisconsin are higher during the warmer months. As a result, the state's ozone monitoring is seasonal. Most of Wisconsin's ozone monitors operate from April 1 to Oct. 15. The Kenosha County ozone monitors operate from March 1 to Oct. 31 due to their association with the three-state Chicago ozone nonattainment area, which has a longer monitoring season.

Regulatory History

In 1971, EPA issued a 1-hour standard of 0.08 ppm (effectively 84 ppb[4]) for total photochemical oxidants, which included ozone. In 1979, EPA replaced this standard with a 1-hour standard for ozone set at 0.12 ppm (effectively 124 ppb[5]). In July 1997, EPA replaced the 1-hour ozone standard with an 8-hour standard of 0.08 ppm (effectively 84 ppb[5]) to protect the public against longer-term exposure. In March 2008, EPA lowered the 8-hour standard to 0.075 ppm (75 ppb). EPA further decreased the 8-hour standard to 0.070 ppm (70 ppb) effective Dec. 28, 2015. The 2008 standard of 75 ppb remains in effect until EPA revokes it; therefore, both the 2008 and 2015 standards remain in effect.

Wisconsin's Attainment Status History

Wisconsin had 18 counties designated by EPA as nonattainment with the 1971 1-hour standard for total photochemical oxidants. In contrast, EPA designated only 12 Wisconsin counties nonattainment for the

[4] Because older standards were set at the 0.01 ppm level, while the parameter was measured to the 0.001 ppm level, rounding conventions associated with attainment determination result in effective standards that appear to be slightly higher than the official published values. The official and effective standards are equivalent.

1979 1-hour ozone standard. When EPA completed a second round of designations under the 1979 1-hour ozone standard in 1990, the number of counties designated nonattainment in Wisconsin decreased to 11. This trend continued in 2004 when only 10 Wisconsin counties were nonattainment for the 1997 8-hour ozone standard. Only Sheboygan County and the eastern part of Kenosha County were designated nonattainment for the 2008 ozone standard. EPA designated two counties and portions of seven lakeshore counties in Wisconsin as nonattainment for the more stringent 2015 ozone NAAQS.[5]

Because of improvements in air quality, many counties that EPA originally designated nonattainment for a given standard have been redesignated to attainment of that standard. For example, all 10 counties EPA designated nonattainment for the 1997 standard have attained the standard. Similarly, the two counties designated as nonattainment for the 2008 standard were redesignated to attainment in 2020 (Sheboygan) and 2022 (Kenosha). In 2022, two counties (Door and Manitowoc) were redesignated to attainment for the 2015 standard by EPA, resulting in seven counties remaining in nonattainment.

Particulate Matter ($PM_{2.5}$ and PM_{10})

Particulate matter, also known as PM, is made up of very small solid particles or liquid droplets in many shapes and sizes. These individual particles are so small they cannot be seen with the naked eye, but high concentrations of these particles can reduce visibility. The EPA classifies particle pollution based on particle diameter. There are two types of particles for which NAAQS have been set: $PM_{2.5}$ (fine particles 2.5 µm or smaller in diameter) and PM_{10} (inhalable particles 10 µm or smaller in diameter) (Table 2). The DNR has a video explaining sources, formation, transport and health effects of $PM_{2.5}$ and PM_{10}.

Transport and fate of particulate pollution varies based on size. Generally, $PM_{2.5}$ has a longer lifetime in the atmosphere (days to weeks), travels longer distances (hundreds to thousands of miles) and distributes more uniformly over regions. Contrastingly, PM_{10} forms from mechanical processes such as crushing and grinding, travels shorter distances (yards to a few miles) and remains closer to source-based operations.

While all particulate matter size fractions pose a health risk, $PM_{2.5}$ poses a greater risk because of its ability to penetrate deep into the respiratory tract or, for very fine particles, to enter the bloodstream. Studies have shown an association between fine particle exposure and premature death from heart or lung disease, as well as aggravated respiratory conditions, such as asthma and airway irritation. Individuals most sensitive to fine particle exposure include people with heart or lung disease, older adults and children.

Regulatory History

The original 1971 EPA standard for particle pollution set a limit for total suspended particles (TSP), which includes both $PM_{2.5}$ and PM_{10}, as well as coarser particles. In 1987, EPA discontinued the standard for TSP and replaced it with two standards for PM_{10}. Wisconsin, however, retained its own 24-hour TSP standard until 2011. In 1997, EPA added a $PM_{2.5}$ standard. On June 10, 2021, EPA announced that it will reconsider the previous administration's decision (Dec. 7, 2020) to retain the particulate matter NAAQS.

[5] Maps of these nonattainment areas can be found at https://dnr.wisconsin.gov/sites/default/files/topic/AirQuality/RevisedMaps2015.pdf.

In January 2023, EPA proposed a revision to the PM NAAQS. The EPA is expected to finalize the PM NAAQS later in 2023.

$PM_{2.5}$

In 1997, EPA established an annual $PM_{2.5}$ standard of 15.0 µg/m^3 as well as a 24-hour (calendar-day) $PM_{2.5}$ standard of 65 µg/m^3. In 2006, the 24-hour standard decreased to 35 µg/m^3 and in 2012, the annual standard decreased to 12.0 µg/m^3. In December 2020, EPA announced it would retain, without revision, the existing particulate matter standards. On Jan. 27, 2023, the EPA proposed to strengthen the NAAQS for $PM_{2.5}$ by revising the level of the primary annual standard. The proposed NAAQS took comment on a range of level of the standard from 8-12 µg/m^3 for the annual standard and down to 25 µg/m^3 for the 24-hour standard.

PM_{10}

In 1987, EPA established two PM_{10} standards: an annual standard of 50 µg/m^3 and a 24-hour (calendar-day) standard of 150 µg/m^3. In 2006, EPA revoked the 1987 annual PM_{10} standard. The 24-hour PM_{10} standard remains in effect today.

Wisconsin's Attainment Status History

$PM_{2.5}$

In 2009, EPA designated Milwaukee, Racine and Waukesha counties as nonattainment for the 2006 NAAQS for 24-hour $PM_{2.5}$ based on monitoring data from 2006 to 2008. In April 2014, EPA redesignated these counties to attainment based on monitoring data collected between 2008 and 2011. Consequently, all counties in Wisconsin are currently in attainment for both the annual and 24-hour $PM_{2.5}$ NAAQS.

PM_{10}

Design values for PM_{10} in Wisconsin have not exceeded PM_{10} standards. Consequently, there are no PM_{10} nonattainment areas in the state.

Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2), a product of combustion, is one of a group of highly reactive gases known as oxides of sulfur. The largest emission source of SO_2 is fossil fuel combustion at power plants and industrial facilities.

Studies have shown exposure to SO_2 may cause a range of adverse respiratory effects including bronchoconstriction and increased asthma symptoms. Further, emission sources that contribute to high concentrations of SO_2 also contribute to the formation of other oxides of sulfur. Some of these oxides react with other compounds in the atmosphere to form $PM_{2.5}$, which can penetrate deep into the lungs.

Regulatory History

In 1971, EPA first set two standards for SO_2: an annual standard of 30 ppb and a 24-hour standard of 140 ppb. In 1996, EPA reviewed the standards without revision. In 2010, EPA established a new 1-hour standard at 75 ppb and revoked the annual and 24-hour standards from 1971 because the 1-hour standard better protected public health.

Wisconsin's Attainment Status History

Portions of Brown, Dane, Marathon, Milwaukee and Oneida counties were designated nonattainment for the 1971 SO_2 NAAQS; all areas have since reached attainment. In 2013, EPA designated a portion of Oneida County as nonattainment for the 2010 SO_2 NAAQS. Subsequently, EPA designated the remainder of Wisconsin as attainment/unclassifiable. In April 2021, EPA made final designations for SO_2 and classified Outagamie County as being in attainment of the standard. In July of 2021, the DNR submitted a redesignation request for Oneida County which EPA approved and finalized in January 2022. This resulted in Wisconsin fully meeting the 2010 SO_2 NAAQS.

Nitrogen Dioxide (NO_2)

Nitrogen dioxide (NO_2) is a reactive byproduct of combustion, primarily from vehicles, resulting in concentrations that are highest immediately adjacent to roadways. Nitrogen dioxide and nitric oxide (NO), collectively referred to as NO_x, are important precursors of ozone. When NO_x reacts with VOCs in the presence of sunlight, it generates ozone.

Research indicates that direct exposure to NO_2 for short periods of time can result in respiratory issues such as airway inflammation and aggravated asthma. Longer-term exposure poses a risk of acute respiratory illness and inhibited lung development in children.

Regulatory History

In 1971, EPA set the original standard for NO_2 at 53 ppb based on an annual average. This standard is still in effect. In 2010, EPA established an additional 1-hour standard of 100 ppb and mandated the placement of NO_2 monitors near major roads in large urban areas, with installation in phases according to population. This required the DNR to add a near-road NO_2 monitor in Milwaukee in 2014. Due to low NO_2 concentrations found at monitors nationwide, EPA eliminated the requirement for near-road monitors in areas with populations between 500,000 and 1 million (e.g., Madison area).

Wisconsin's Attainment Status History

Design values in Wisconsin have not exceeded the NO_2 standards, therefore the entire state is in attainment.

Lead

Lead can be found in the atmosphere as well as in the water and soil. Before the introduction of unleaded gasoline in 1980, vehicle emissions were the primary source of airborne lead. Today, industrial metal processing sources and aviation fuel combustion emit most of the airborne lead.

Lead exposure can occur directly through contact with lead in the atmosphere. In addition, deposition of lead from the atmosphere into the soil or water bodies may cause this pollutant to accumulate in natural ecosystems and contaminate drinking water. The health effects of lead exposure in humans are numerous and well-documented. In general, neurological effects and developmental risks are the largest danger for children, whereas cardiovascular effects, such as heart disease and high blood pressure, commonly affect adults.

Regulatory History

In 1978 EPA set the original lead standard to 1.5 μg/m^3 based on a calendar quarter average. In 2008, EPA replaced this standard with a rolling three-month average and lowered the NAAQS to 0.15 μg/m^3. In 2016, EPA decided to retain the existing 2008 standard.

Wisconsin's Attainment Status History

Wisconsin used a collection technique that measured lead content as a subset of total suspended particle samples as required by federal rule. During the past two decades, no areas in Wisconsin have had lead levels that exceed the NAAQS, and the state has had no nonattainment areas. On March 22, 2019, EPA waived Wisconsin's lead monitoring requirements after the DNR demonstrated Wisconsin does not experience elevated lead values. Accordingly, the DNR no longer monitors for criteria lead.

Carbon Monoxide (CO)

Carbon monoxide (CO) is a toxic gas with known indoor dangers; however, it is also emitted into the ambient air, primarily by mobile sources[6]. Under certain conditions, CO can react to form ground-level ozone.

In the short term, CO exposure can reduce human respiratory efficiency. At extremely high concentrations, exposure can be fatal. People suffering from heart disease face increased risks from exposure to CO due to compromised respiratory efficiency.

Regulatory History

In 1971, EPA originally set two standards for CO: an 8-hour standard of 9 ppm and a 1-hour standard of 35 ppm. In 1994 and 2011, EPA reviewed these standards and left them unchanged.

Wisconsin's Attainment Status History

In the past, Wisconsin had nonattainment areas for CO in portions of Milwaukee and Winnebago counties. Both areas reached attainment. There are currently no CO nonattainment areas in the state.

[6] Mobile sources are primarily vehicles of all kinds (e.g., cars, trucks, boats, airplanes, trains, heavy equipment) but also include equipment with small engines such as lawn-care equipment and chain saws.

Wisconsin Emissions Data

Pollutants monitored by the DNR are either emitted directly from various sources or form in the atmosphere via chemical reactions (known as precursors). States and EPA work together to develop and release a comprehensive inventory of air emission sources every three years called the National Emissions Inventory (NEI). The NEI, coordinated by EPA, uses emission estimates and emission model inputs provided by federal, state, local and tribal air agencies. The most recent NEI data is available through 2020. Examining Wisconsin's emissions of pollutants and pollutant precursors can provide insight into the origin of the trends in monitored pollutants discussed later in this report, although emissions from outside Wisconsin can influence monitored pollutant concentrations.

Total Emissions

The graphs below show emissions from the last seven NEI inventories, beginning with 2002 and ending with 2020, the year of the most recently completed NEI. These graphs show the data aggregated into 13 major source categories, listed in Table 3 [7]. The data shown below reflect adjustments EPA made to NEI data to improve inventory consistency. The states and EPA continually improve the methodology used to estimate emissions, which leads to some variability in reported source category emissions between different NEI inventories. With the release of the 2020 NEI, EPA replaced all 2002 through 2019 data with values using a new approach based on EPA's Air QUAlity TimE Series (EQUATES[8]). Beginning in 2020, EPA employed additional changes to the methodology which were not applied retroactively. The 2020 NEI data represent the best, most up-to-date understanding of emissions, however, directly comparing 2020 NEI to previous NEIs (2017 and older) may not be appropriate because of the differences in methodology. For 2020 data, source categories significantly impacted by methodology changes have an asterisk (*) in the figures below. Data used in the graphs are from EPA's Air Pollutants Emissions Trends Data webpage.

Overall, emissions of most criteria pollutants and their precursors have decreased substantially since 2002. These reductions occurred due to implementation of a variety of federal and state pollution control programs.

[7] For each graph, only categories that contributed at least 2.5% of total emissions of that pollutant are graphed individually. Smaller source categories are combined into a category labeled "Other".

[8] EPA's Air QUAlity TimE Series. This methodology uses the 2017 NEI as the baseline year with the 2016v3 modeling platform. EQUATES reference: https://doi.org/10.1016/j.dib.2023.109022

Table 3. Emission source categories and their abbreviations. [9]

Emission Type	Emissions Source	Abbreviation
Stationary	Chemical and Allied Product Manufacturing	N/A*
	Fuel Combustion – Electric Utility	Fuel Comb. Elec. Util.
	Fuel Combustion – Industrial	Fuel Comb. Industrial
	Fuel Combustion – Other	Fuel Comb. Other
	Metals Processing	N/A*
	Miscellaneous	Miscellaneous
	Other Industrial Processes	Other Industrial Processes
	Petroleum and Related Industries	N/A*
	Solvent Utilization	Solvent Utilization
	Storage and Transport	Storage & Transport
	Waste Disposal and Recycling	Waste Disposal & Recycling
Mobile	Highway Vehicles	Highway Vehicles
	Off-Highway	Off-Highway

* N/A = not applicable; these categories emitted less than 2.5% of each pollutant's total emissions and have been grouped with other minor contributors into the "Other" category.

Gaseous Criteria Pollutants And Precursors

Gaseous criteria pollutants directly impact human health and may also be precursors to other criteria pollutants. Ammonia (NH_3) and VOCs play a similar role in the atmosphere, as both pollutants and important precursors. For example, NO_x, CO and VOCs react in the presence of sunlight to create atmospheric ozone, while most fine particles form from reactions between NO_x, SO_2, VOCs and NH_3.

Emission data for each of these gaseous pollutants are shown below for past NEI inventories (Figure 6 to Figure 10). Some highlights from 2002 to 2020 include:

- Total NO_x emissions decreased 72%, with the greatest reductions coming from fuel combustion at electric utilities and highway vehicles.
- Emissions of VOCs decreased 28%.
- Emissions of SO_2 decreased by 93%, with the largest reductions coming from the electric utility fuel combustion sector.
- Emissions of CO decreased by 58%, with most of the reductions coming from highway vehicles and the off-highway sector.

As previously noted, EPA's 2020 NEI methodology changed from previous years. The apparent increase in VOC emissions in 2020 (Figure 7) is due to significant changes in EPA's inventory methodology. Specifically, this notable increase is primarily due to the addition of Agricultural Silage, a new source category that was unaccounted for in previous versions of the NEI. In addition, methodology changes were made for Consumer and Commercial Solvents Use as well as Residential Wood Combustion.

[9] These source categories are one way that EPA reports NEI results. These classifications differ from the other commonly used NEI categories of point, area, onroad and nonroad.

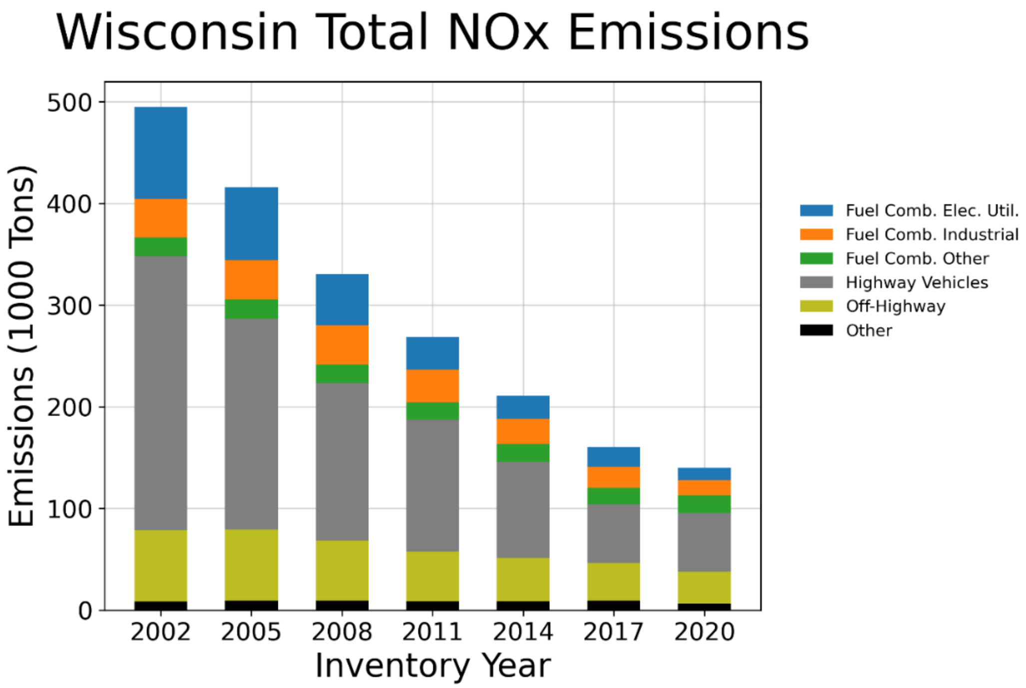

Figure 6. Emissions of NOx from all sources in Wisconsin. See Table 3 for source category abbreviations.

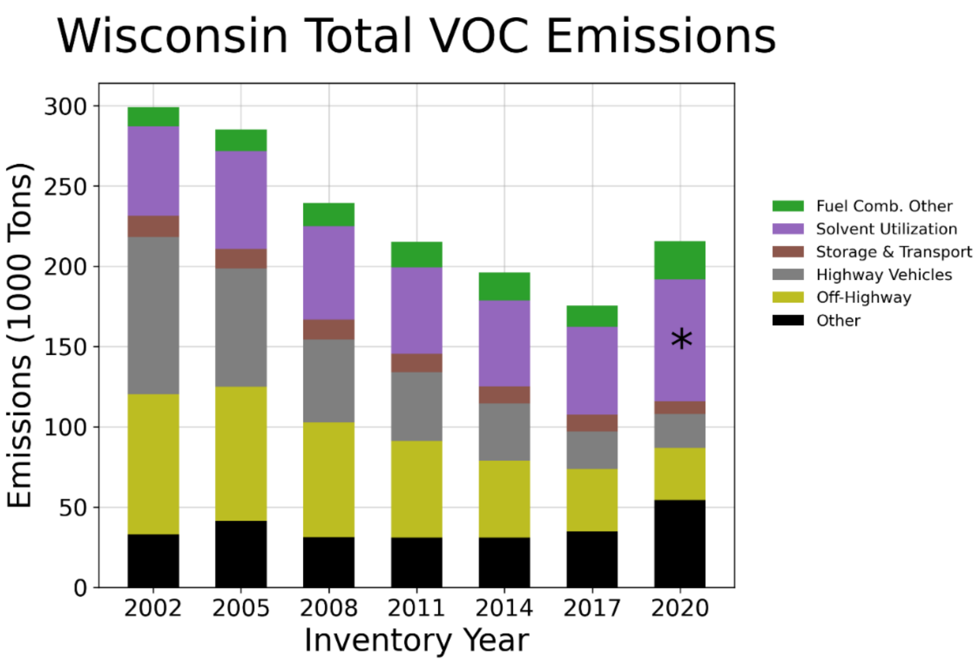

Figure 7. Emissions of VOCs from all sources in Wisconsin. The asterisks (*) mark sectors where EPA's inventory methodology differs from the previous year. The increase is primarily due to the addition of emissions from Agricultural Silage, followed by methodology changes for Consumer and Commercial Solvents Use and Residential Wood Combustion. See Table 3 for source category abbreviations.

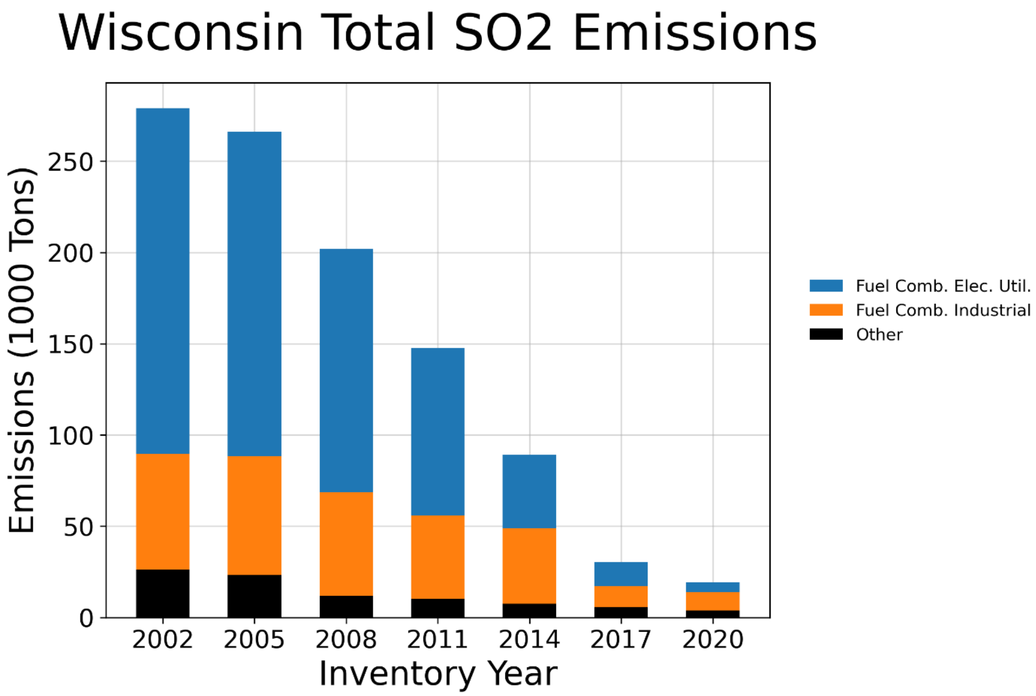

Figure 8. Emissions of SO2 from all sources in Wisconsin. See Table 3 for source category abbreviations.

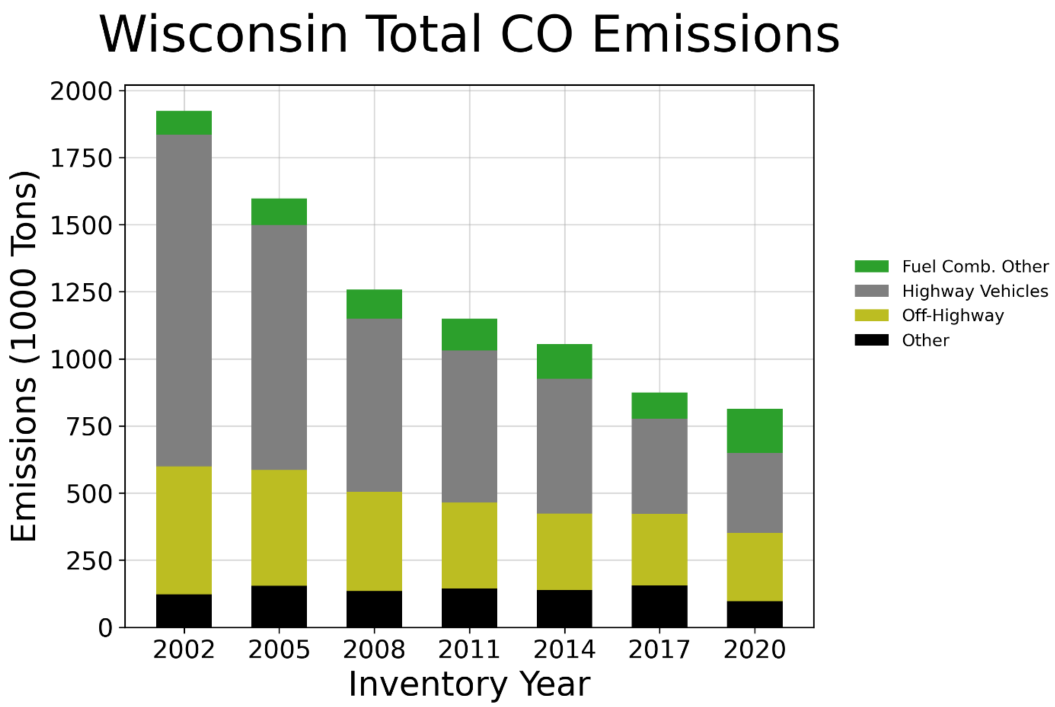

Figure 9. Emissions of CO from all sources in Wisconsin. See Table 3 for source category abbreviations.

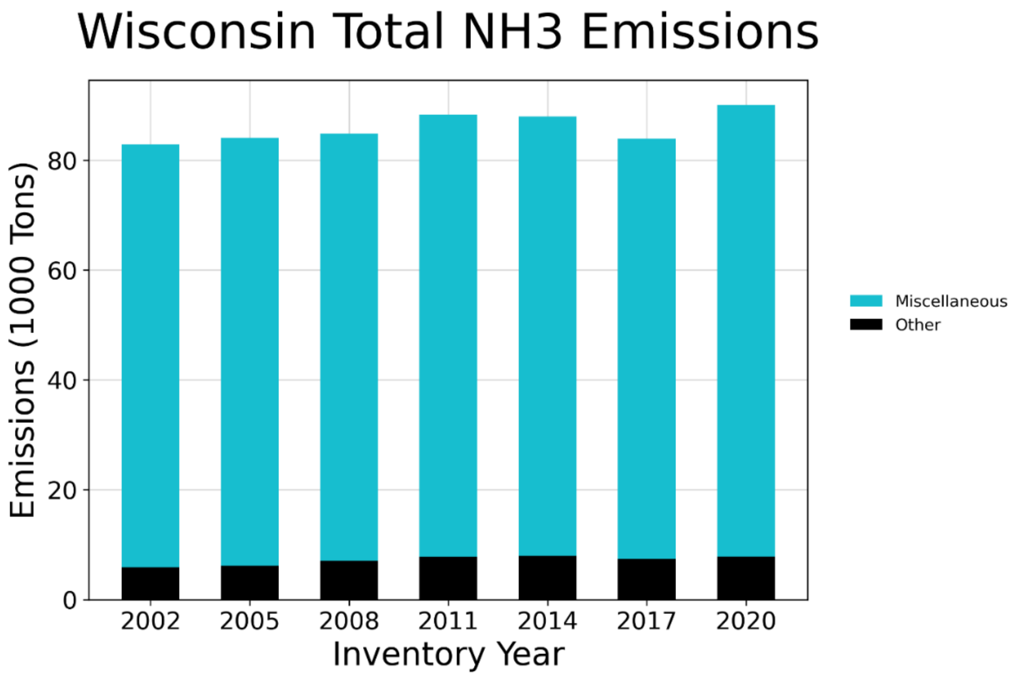

Figure 10. Emissions of NH3 from all sources in Wisconsin. See Table 3 for source category abbreviations.

Primary Particle Emissions

Chemical reactions produce the majority of $PM_{2.5}$ from precursor compounds in the atmosphere; however, a small portion of $PM_{2.5}$ is directly emitted into the atmosphere (i.e., are primary particles). Figure 11 shows the total directly emitted $PM_{2.5}$ emissions as reported by the NEI. The apparent increases for both $PM_{2.5}$ (Figure 11) and PM_{10} (Figure 12) in 2020 are due in large part, to methodology changes for Residential Wood Combustion, followed by methodology changes for Construction and Road Dust.

In contrast to $PM_{2.5}$, sources primarily emit PM_{10} directly into the atmosphere. Figure 12 shows the total directly emitted PM_{10} emissions data from the NEI.

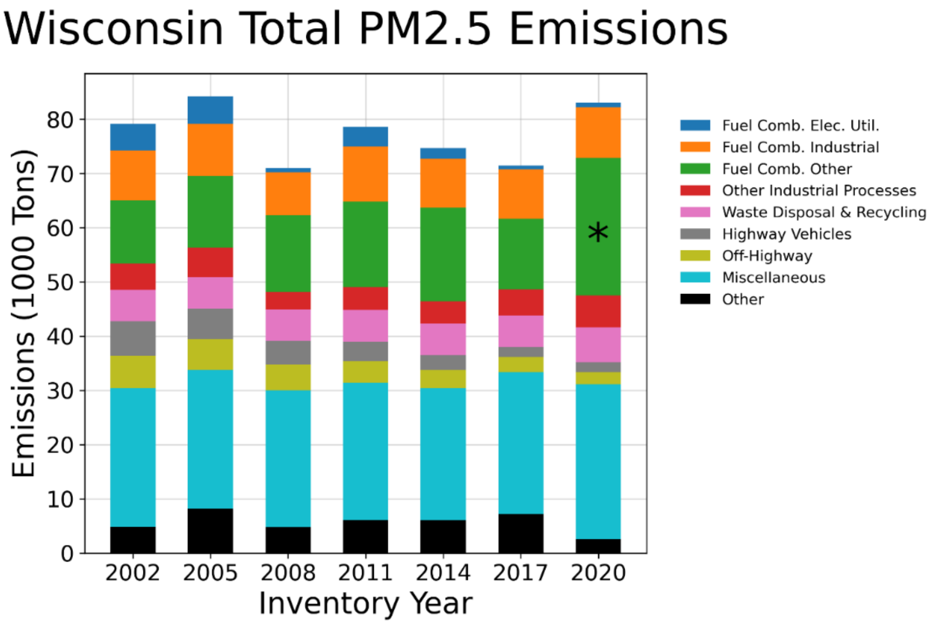

Figure 11. Emissions of PM2.5 from all sources in Wisconsin. The asterisks (*) mark sectors where EPA's inventory methodology differs from the previous year. This notable increase is primarily due to methodology changes for Residential Wood Combustion, followed by methodology changes for Construction and Road Dust. See Table 3 for source category abbreviations.

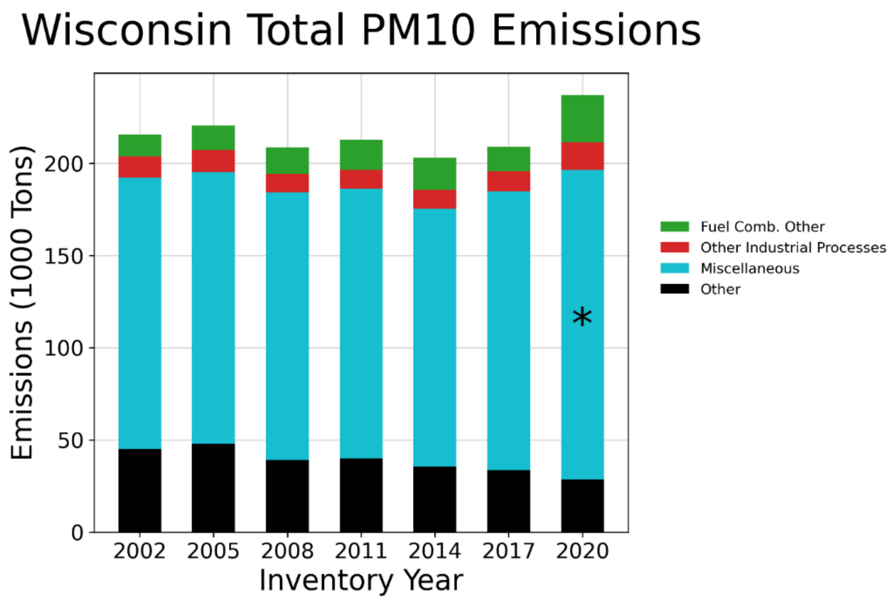

Figure 12. Emissions of PM10 from sources in Wisconsin. The asterisks (*) mark sectors where EPA's inventory methodology differs from the previous year. This notable increase is primarily due to methodology changes for Residential Wood Combustion, followed by methodology changes for Construction and Road Dust. See Table 3 for source category abbreviations.

Lead

Lead emissions are in either gaseous or particulate form. Emissions of lead decreased substantially and remain low with the use of unleaded gasoline. Because of the low emissions, comparison of lead emissions from year to year is difficult. Accordingly, this report does not show lead emissions data. Lead emissions from sources in Wisconsin are less than 20 tons in each of the NEI years examined (2002 to 2020). These emissions are more than 1000 times smaller than those of the other criteria pollutants and precursors.

Criteria Pollutant Trends

This section presents trends in Wisconsin monitoring data[10] for all six criteria pollutants since 2001 (as data are available). Each graph compares the design values for each monitoring site against the relevant NAAQS to show how the state's air quality has changed over time. The data highlights differences in the geographic distribution.

The data presented represent pollutants that are currently monitored at active ambient air monitoring sites operated by the DNR or tribal partners. Although the maps for each pollutant include all currently active monitoring sites in the state network, only sites with a valid design value for the most recent period (i.e., 2022 for 1-year design values or 2020-2022 for 3-year design values) have values shown after the site name. If data are not shown for a design value period, it is because the design value is invalid due to data-completeness issues.

Historically, EPA determined NAAQS attainment on a county-by-county basis. The DNR provides trend plots by county online and in Appendix A. Information on national air quality trends and how Wisconsin data compare to national averages is in EPA's trends report.

In 2022, Air Management developed an interactive Story Map which provides a visual representation of Wisconsin's air quality trends of each criteria pollutant over the last 20 years.

Ozone

Ozone in the lower atmosphere forms primarily as the result of reactions between NO_x and VOCs in the presence of sunlight. Chemical reactions that produce ozone have strong meteorological influences. For example, ozone formation is greatest on days with elevated temperatures and ample sunlight. Wind patterns also contribute to high ozone concentrations monitored in some areas of Wisconsin, like along the Lake Michigan shoreline.

The ozone precursors that affect Wisconsin may originate in other states, particularly those to the south. Wisconsin counties along Lake Michigan experience the highest ozone concentrations on days with southerly winds, which transport ozone precursors north to Wisconsin. These precursors can react over Lake Michigan to form high concentrations of ozone. When the land has warmed sufficiently, temperature gradients from the shoreline to the lake can create pressure differences, which cause an onshore flow of air, or lake breeze. The lake breeze, in combination with southerly winds, pushes ozone formed over the lake onshore, causing ozone concentrations in Wisconsin to closely correlate with the proximity to Lake Michigan. For this reason, the DNR has determined three distinct regions of ozone design values (as shown in Figure 13):

1) **Lakeshore** – counties bordering Lake Michigan extending from the Illinois border through Door County
2) **Inland** – counties in central and western Wisconsin

[10] Data presented are design values which were downloaded from EPA's Design Value webpage (https://www.epa.gov/air-trends/air-quality-design-values).

3) **Far North** – counties in the northern part of the state, including those near Lake Superior and the Upper Peninsula of Michigan

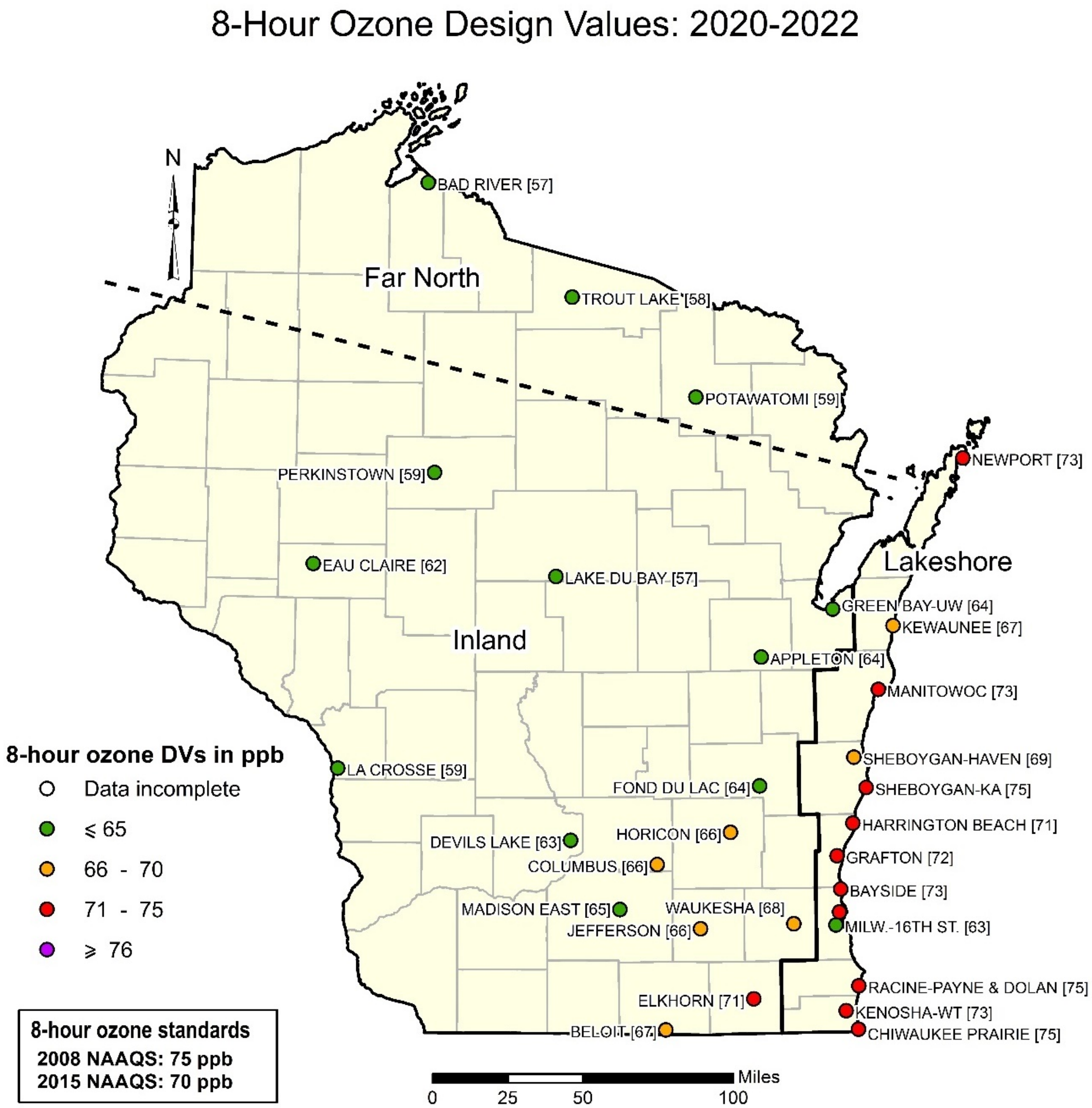

Figure 13. The 8-hour ozone design values for each monitoring site for 2020-2022. Note that the Far North region includes the three sites shown, but its boundaries are not clearly defined.

Figure 13 shows the most recently available ozone design values[11] for all ozone monitors in the state network. The 2020-2022 period shows overall decreases in ozone values, most noticeably in the Lakeshore region. Warmer, ozone-conducive summers combined with a lower 2015 standard resulted in 10 of 13 Lakeshore monitoring sites exceeding the 2015 NAAQS of 70 ppb for the 2020-2022 design

[11] The 2020-2022 ozone design values shown in Figure 12 were calculated using methods associated with the 2015 NAAQS.

value period. For the first time, one of 15 Inland sites exceeded the 2015 NAAQS. No sites in the Far North region had design values exceeding either ozone standard for the 2020-2022 design value period.

Lakeshore Region

Figure 14 shows trends in ozone design values for the Lakeshore region. The relationship between design values from different monitoring sites is generally consistent over time (e.g., the values from the Milwaukee-SER site are consistently greater than the values from the Milwaukee-16th St. site).

Figure 14 provides a visual representation of how ozone concentrations can be impacted by both chemistry and meteorology. For example, the 2008-2009 economic recession and associated reduction in ozone precursor emissions contributed to the relatively steep decrease in ozone design values through 2010. Meteorologically, the summer of 2009 was unseasonably cool, creating suboptimal conditions for ozone formation, thus reducing the ozone design values during this period. In contrast, the summers of 2012, 2016 and 2018 were unusually warm; therefore, any design value including these years is higher compared to other periods. Variations in meteorological conditions and ozone precursor concentrations highlight the sensitivity of design values to short-term changes and the importance of considering long-term trends to effectively manage air quality issues.

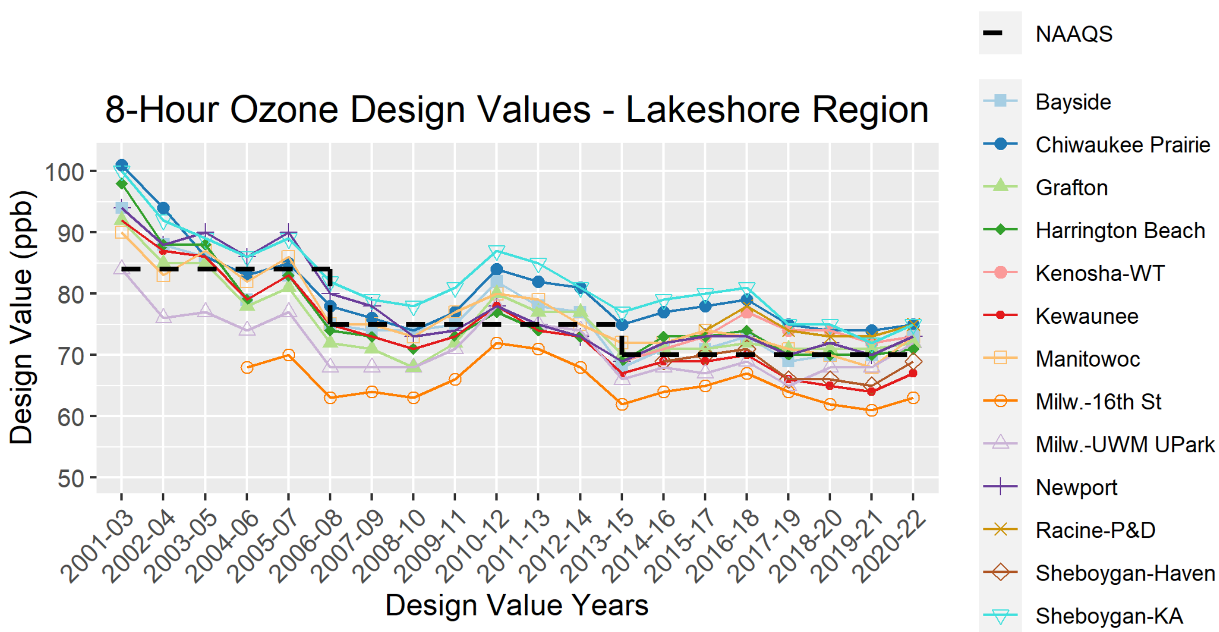

Figure 14. Trends in 8-hour ozone design values for the Lakeshore region. Note that the design value axis is truncated at 50 ppb to allow for a clearer view of the differences among sites.

Ozone concentrations at the Sheboygan-Kohler Andrae site have consistently been among the highest in the state (Figure 14). In 2014, the DNR established a special-purpose monitor at the Sheboygan-Haven site, approximately three miles inland from the lakeshore Sheboygan-Kohler Andrae site, to help determine the ozone gradient in Sheboygan County. The 2020-2022 design value at the Sheboygan-Haven site was 69 ppb, which is 6 ppb lower than the value at Sheboygan-Kohler Andrae for the same period. The Milwaukee 16th St. site records the lowest design values in the Lakeshore region and has ozone concentrations consistently below the NAAQS.

Collectively, the design values in the Lakeshore region demonstrated an overall downward trend over the length of the monitoring period shown in Figure 14. There was a 17% average reduction in design values in this region from 2001-2003 to 2020-2022 among sites with data available for the full period, including a 26% reduction in design values at the Chiwaukee Prairie site and 25% reduction at the Sheboygan-Kohler Andrea site (Appendix B, Table B1).

Inland Region

Figure 15 shows trends in ozone design values for the Inland region. The 2020-2022 data shows one design value exceeded the NAAQS at the Elkhorn site. The inland region has not previously exceeded the NAAQS. Design values for each of the monitoring sites in the Inland region generally decreased over time. There was a 20% average reduction in design values in this region from 2001-2003 to 2020-2022 among sites with data available for the full period (Appendix B, Table B1).

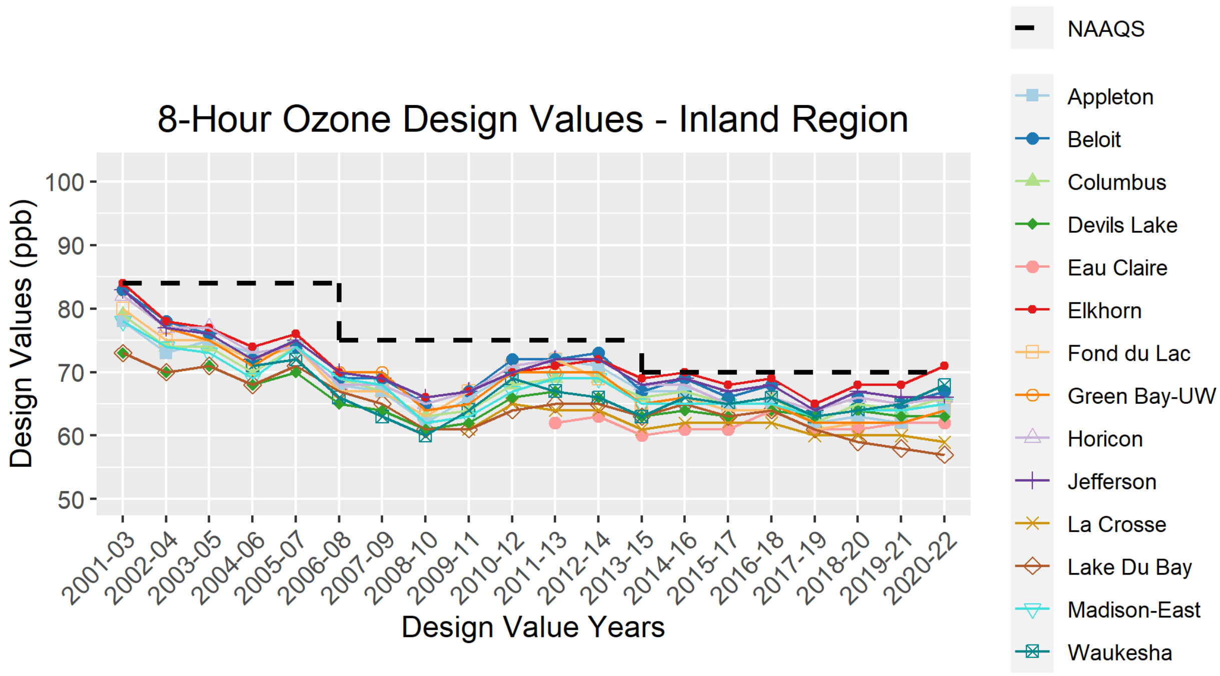

Figure 15. Trends in 8-hour ozone design values for the Inland region. Note that the design value axis is truncated at 50 ppb to allow for a clearer view of the differences among sites.

Overall, there is less variation in design values in the Inland region than those in the Lakeshore region. This suggests that while ozone concentrations are subject to variation at local scales in the Lakeshore region due to the impact of the lake breeze effect, Inland region concentrations are buffered from this effect because they are farther from the shoreline. Ozone concentrations at the Inland sites are generally lower than concentrations at the Lakeshore sites. In addition to having generally lower ozone concentrations, sites in the Inland region show a smaller average reduction in design value compared to the Lakeshore sites (19% vs 23%) for sites operating in 2001-2003 to 2020-2022 (Appendix B, Table B1).

Far North Region

Figure 16 shows trends in ozone design values for the Far North region. All sites are consistently below the NAAQS and have the lowest concentrations of ozone in the state. Overall, since the start of each site, the average ozone concentration has decreased by 11%.

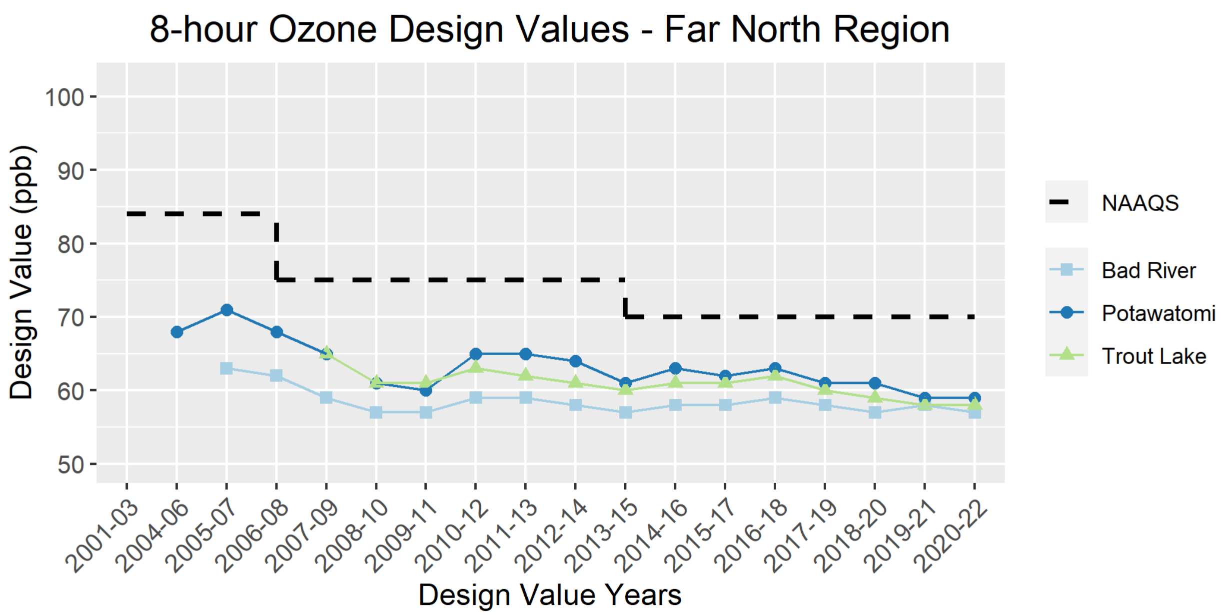

Figure 16. Trends in 8-hour ozone design values for Far North region. Note that the design value axis is truncated at 50 ppb to allow for a clearer view of the differences among sites.

$PM_{2.5}$

The DNR maintains a robust network of $PM_{2.5}$ monitoring sites throughout the state, consisting of primarily continuous monitors and a few federally required filter-based samplers. In 2018, the DNR made changes to modernize the network, incorporating continuous monitors using a measurement technique that captures more data; therefore, produces slightly higher $PM_{2.5}$ readings on average than historic monitors. The result is slightly increased $PM_{2.5}$ design values for recent years compared to 2016-2018 as more years incorporate the new measurement technique. This trend is recognized nationwide with the adoption of newer technology. The manufacturers of continuous monitors regularly work with EPA to update the technology to ensure data quality and consistency.

Due to the influence of long-distance transport, $PM_{2.5}$ is considered a regional pollutant. Weather and local topography strongly influence ambient concentrations of $PM_{2.5}$. Specifically, low-lying areas may exhibit elevated concentration levels during periods of localized air stagnation. Currently, the annual $PM_{2.5}$ standard is 12 µg/m^3 while the 24-hour standard is 35 µg/m^3.

To highlight geographic trends in $PM_{2.5}$ concentrations, design values are grouped by the following regions (as shown in Figure 17 and Figure 18):

1) Southeast
2) Inland

3) Far North

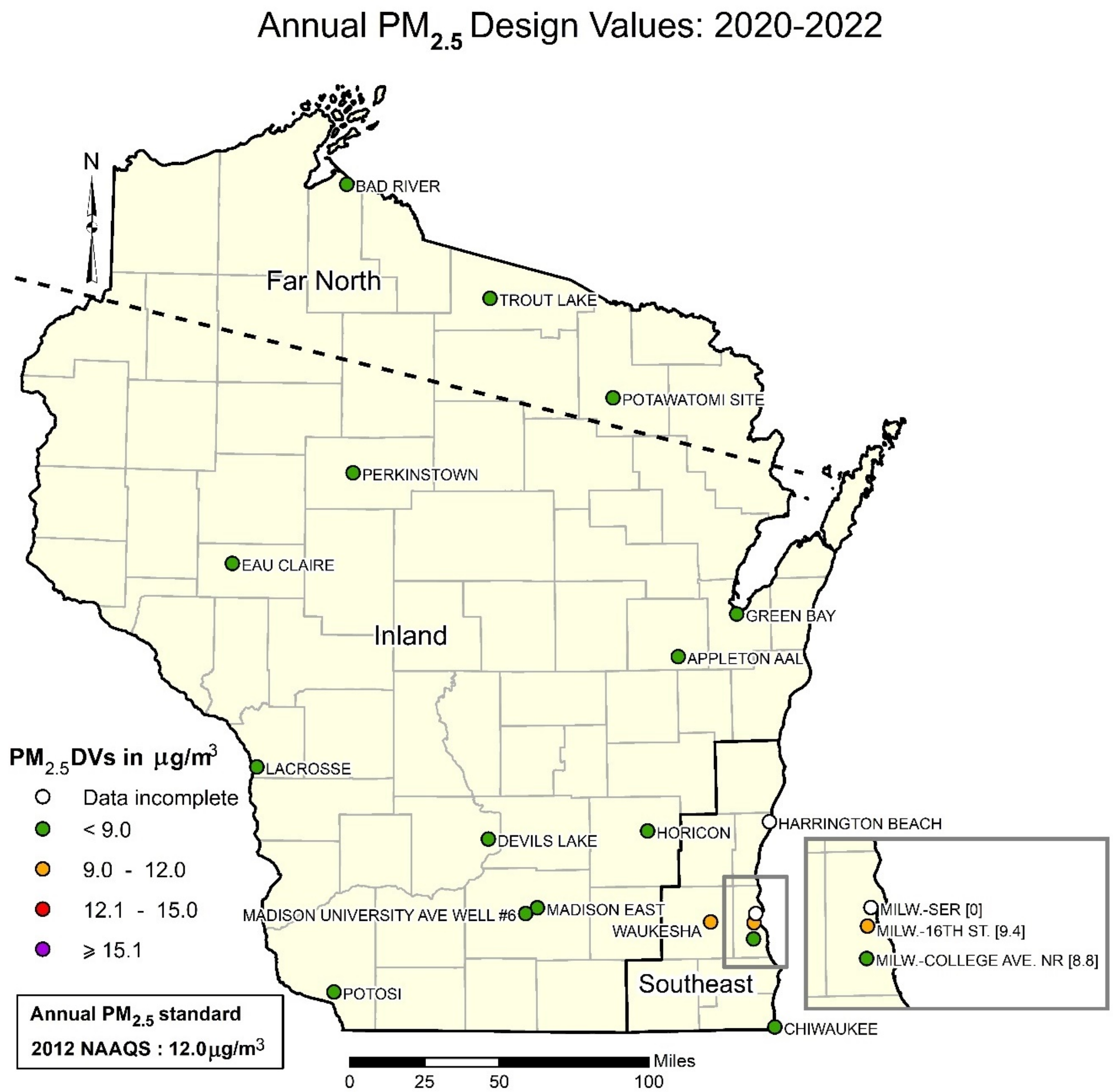

Figure 17. The annual PM2.5 design values for each monitoring site for 2020-2022. Note that the Far North region includes the three sites shown, but its boundaries are not clearly defined.

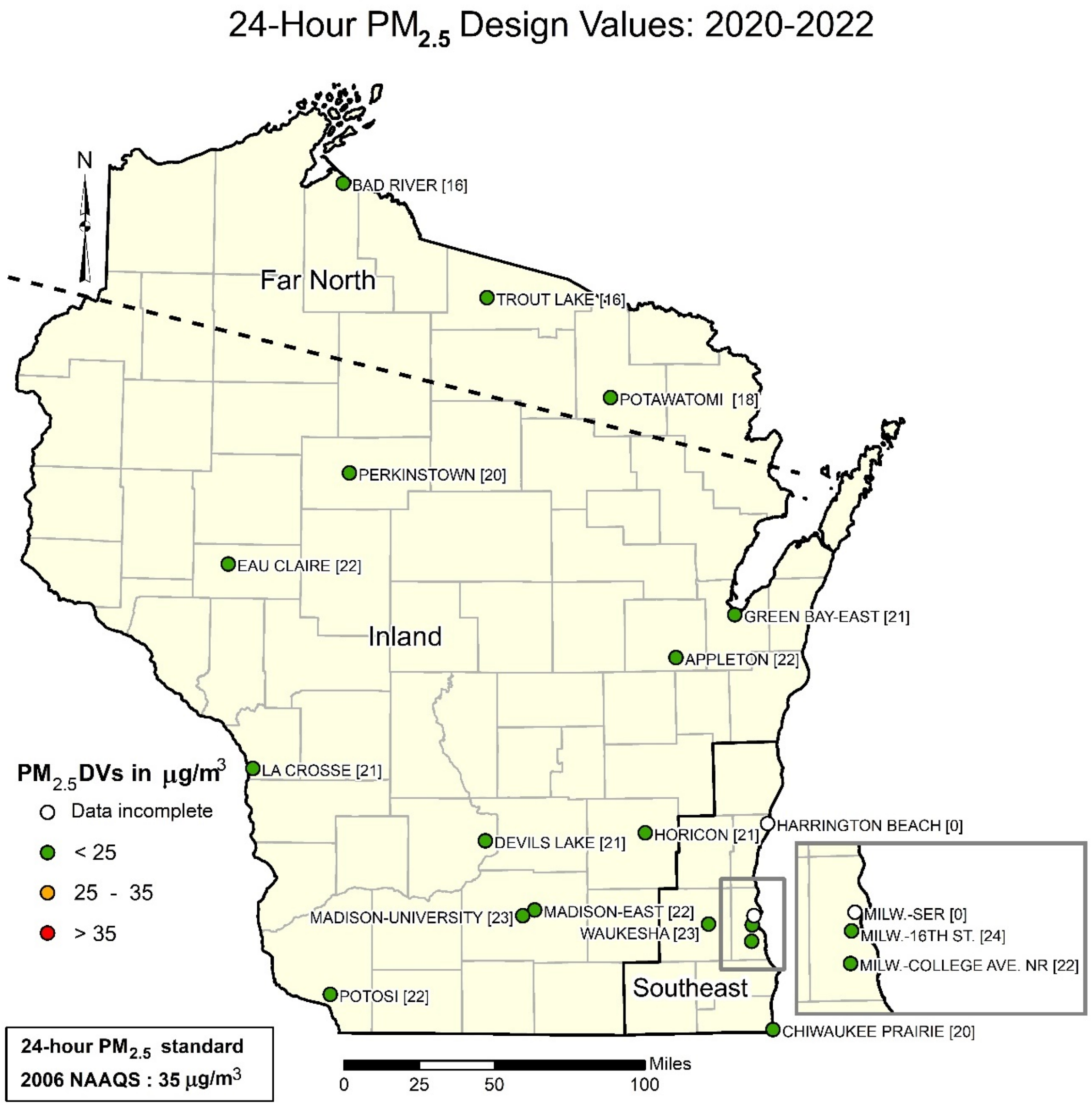

Figure 18. The 24-hour PM2.5 design values for each monitoring site for 2020-2022. Note that the Far North region includes the three sites shown, but its boundaries are not clearly defined.

Southeast Region

Figure 19 and Figure 20 show trends in annual and 24-hour $PM_{2.5}$ design values for the Southeast region. The relationships between design values at different sites are relatively consistent for both the annual and 24-hour design values. Design values for both metrics in recent years are well below the standards. The Milwaukee-SER site relocated in 2021; in the move, EPA approved $PM_{2.5}$ monitoring for discontinuation. The $PM_{2.5}$ requirements are met by other sites in the vicinity.

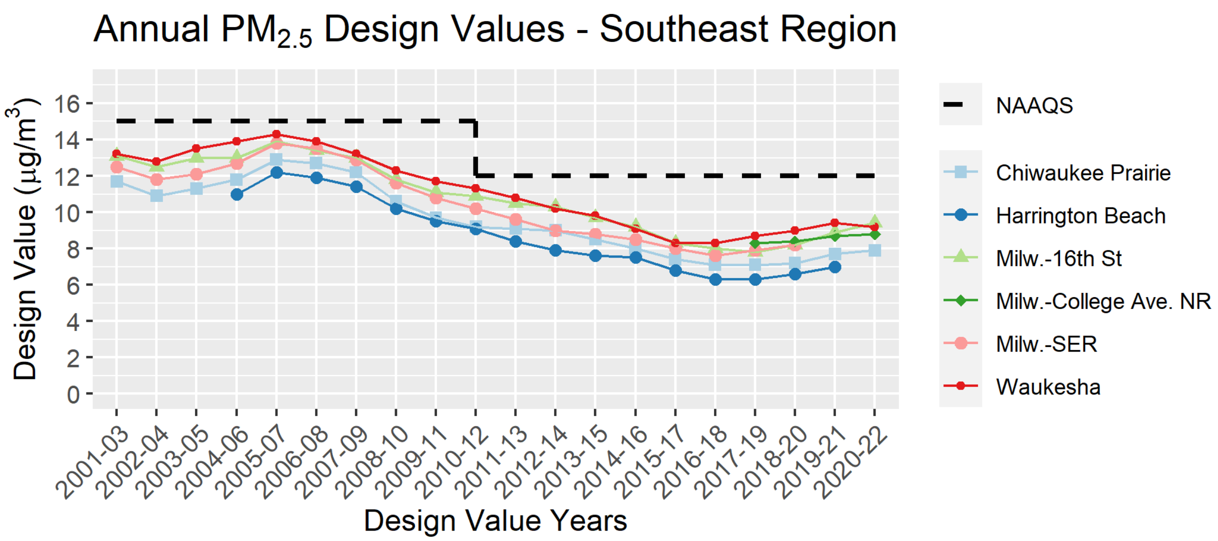

Figure 19. Trends in annual PM2.5 design values in the Southeast region.

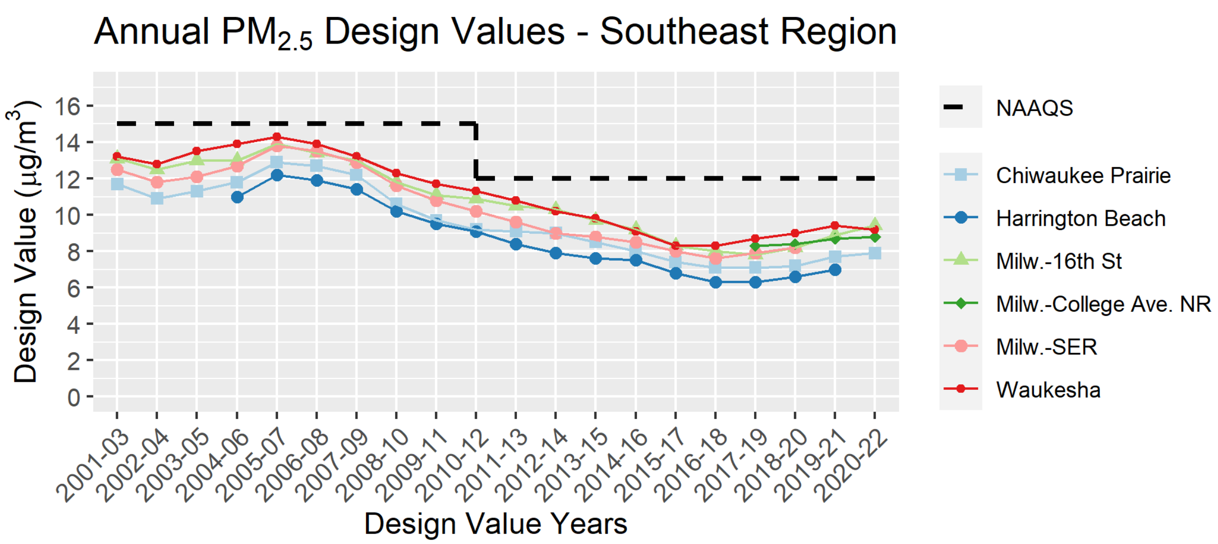

Figure 20. Trends in 24-hour PM2.5 design values in the Southeast region.

While none of the $PM_{2.5}$ monitoring sites in the Southeast region had an annual design value exceeding the relevant NAAQS, the decrease in the 24-hour standard from 65 to 35 µg/m^3 in 2006 resulted in design values at some sites exceeding the standard during subsequent years. Nonetheless, 24-hour design values for all sites in the region have been below the 2006 NAAQS since 2008-2010. The 24-hour $PM_{2.5}$ design values decreased 29% on average for the region between 2001-2003 and 2020-2022 among sites with data available for the full period (Appendix B, Tables B2-B3).

Inland Region

Figure 21 and Figure 22 show trends in annual and 24-hour $PM_{2.5}$ design values for the Inland region. Like the Southeast region, the relationship between annual design values at different sites in the Inland region are generally consistent over time. The annual design values decreased consistently at all sites after 2006-2008.

While none of the $PM_{2.5}$ monitoring sites in the Inland region had an annual design value exceeding the relevant NAAQS, the decrease in the 24-hour standard from 65 to 35 μg/m^3 in 2006 resulted in design values at some sites exceeding the standard during subsequent years. The 24-hour design values have generally decreased since 2008-2010. Inland region design values decreased 24% on average for the region between 2001-2003 or the earliest data available through 2020-2022 for the full period (Appendix B, Tables B2-B3).

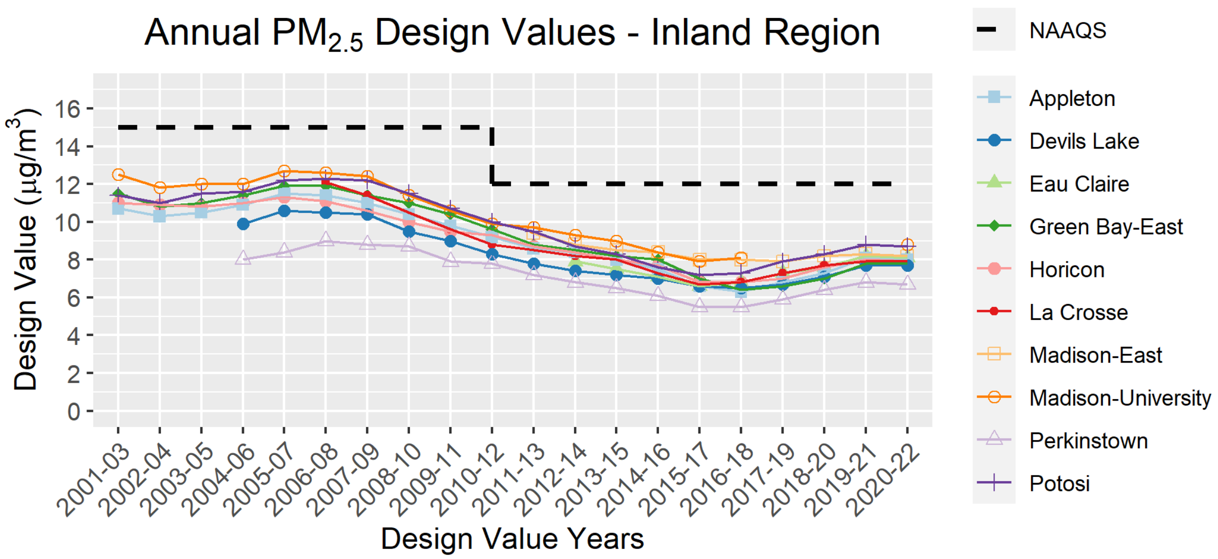

Figure 21. Trends in annual PM2.5 design values in the Inland region.

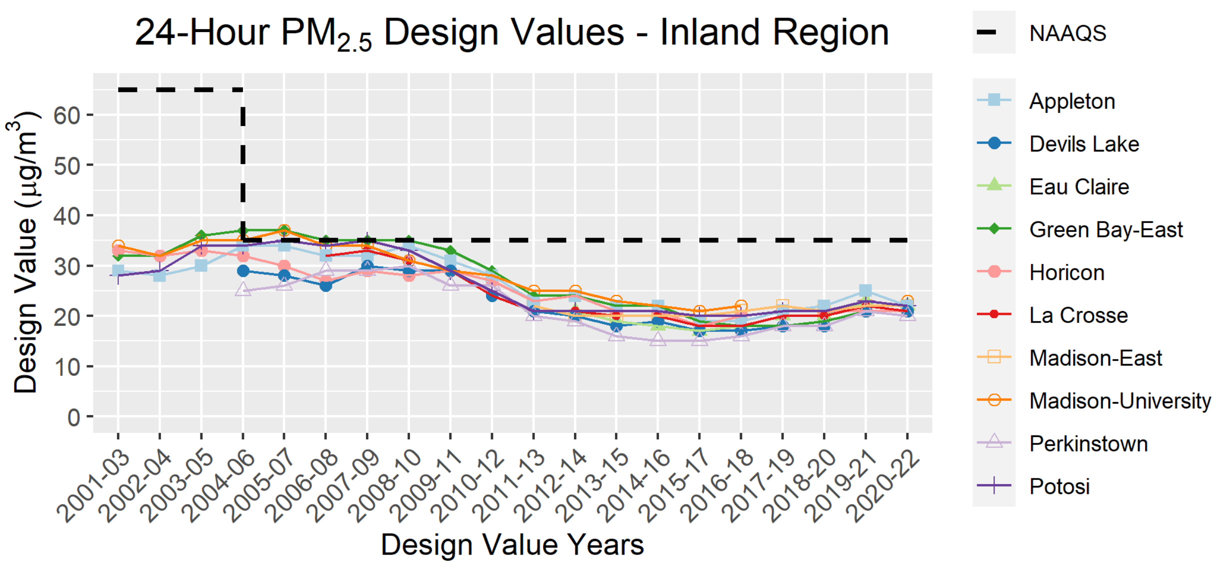

Figure 22. Trends in 24-hour PM2.5 design values in the Inland region.

Far North Region

Figure 23 and Figure 24 show trends in annual and 24-hour $PM_{2.5}$ design values for the Far North region. Sites in this region showed the lowest concentrations of fine particles in the state. The annual design values decreased consistently after 2006-2008. Values were more similar among sites for the annual design values than the 24-hour values. The Far North Region dealt with multi-day wildfire impacts during Summer 2021; design values remained well under the NAAQS even with smoke impacts.

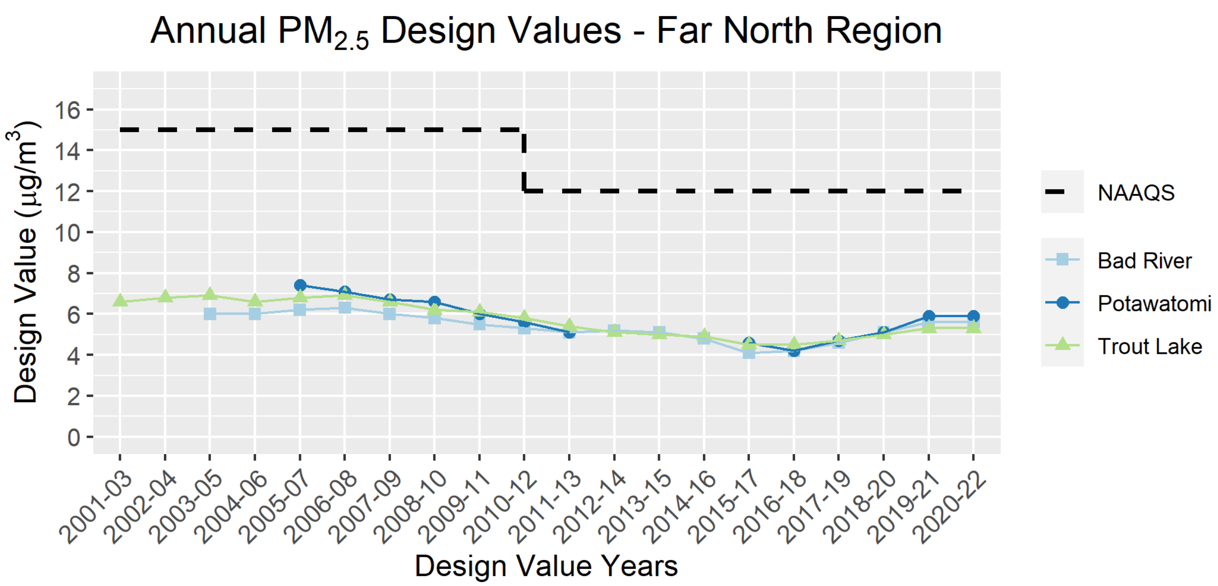

Figure 23. Trends in annual PM2.5 design values in the Far North region.

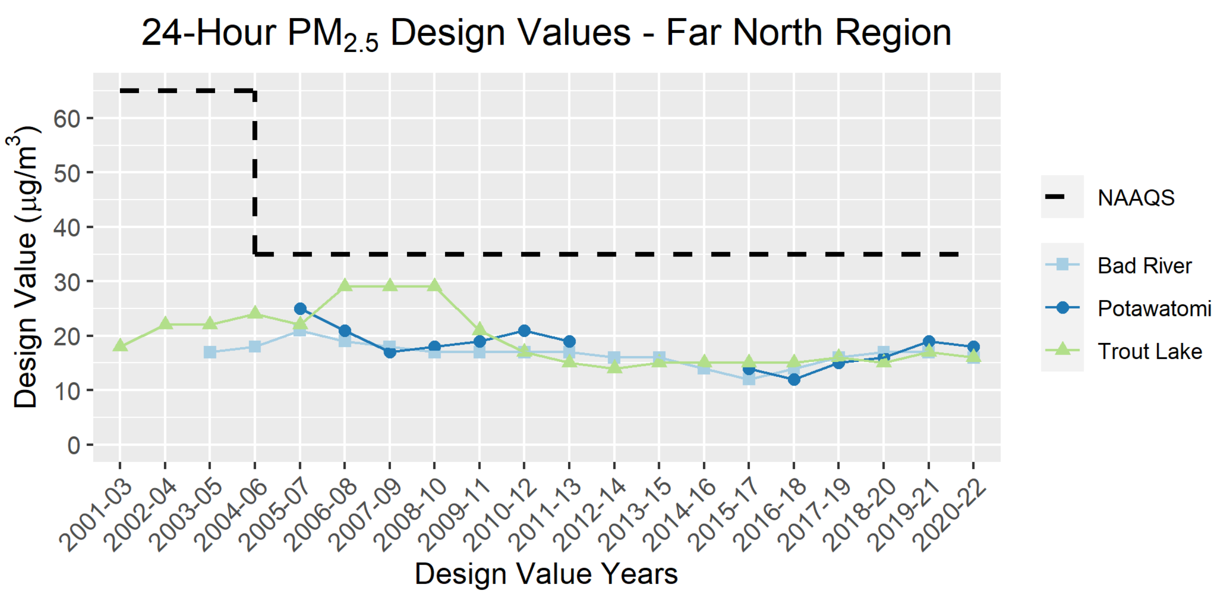

Figure 24. Trends in 24-hour PM2.5 design values in the Far North region.

PM_{10}

The PM_{10} monitoring network in Wisconsin consists of seven sites (Figure 25) primarily made up of continuous monitors. As with the $PM_{2.5}$ network, the DNR made changes to modernize the PM_{10} network in 2018, including increasing reliance on continuous measurement methods, rather than filter-based methods.

Values shown in the map below are the three-year maximum 24-hour (calendar-day) averages measured from 2020-2022. These averages contribute to the determination of the PM_{10} design value. Urban areas typically have the highest PM_{10} concentrations.

Some industrial sources in Wisconsin have a requirement in their air permits to monitor for PM_{10}. Most of these sources are industrial sand facilities. The DNR quality assures these data and posts them quarterly on a webpage for viewing.

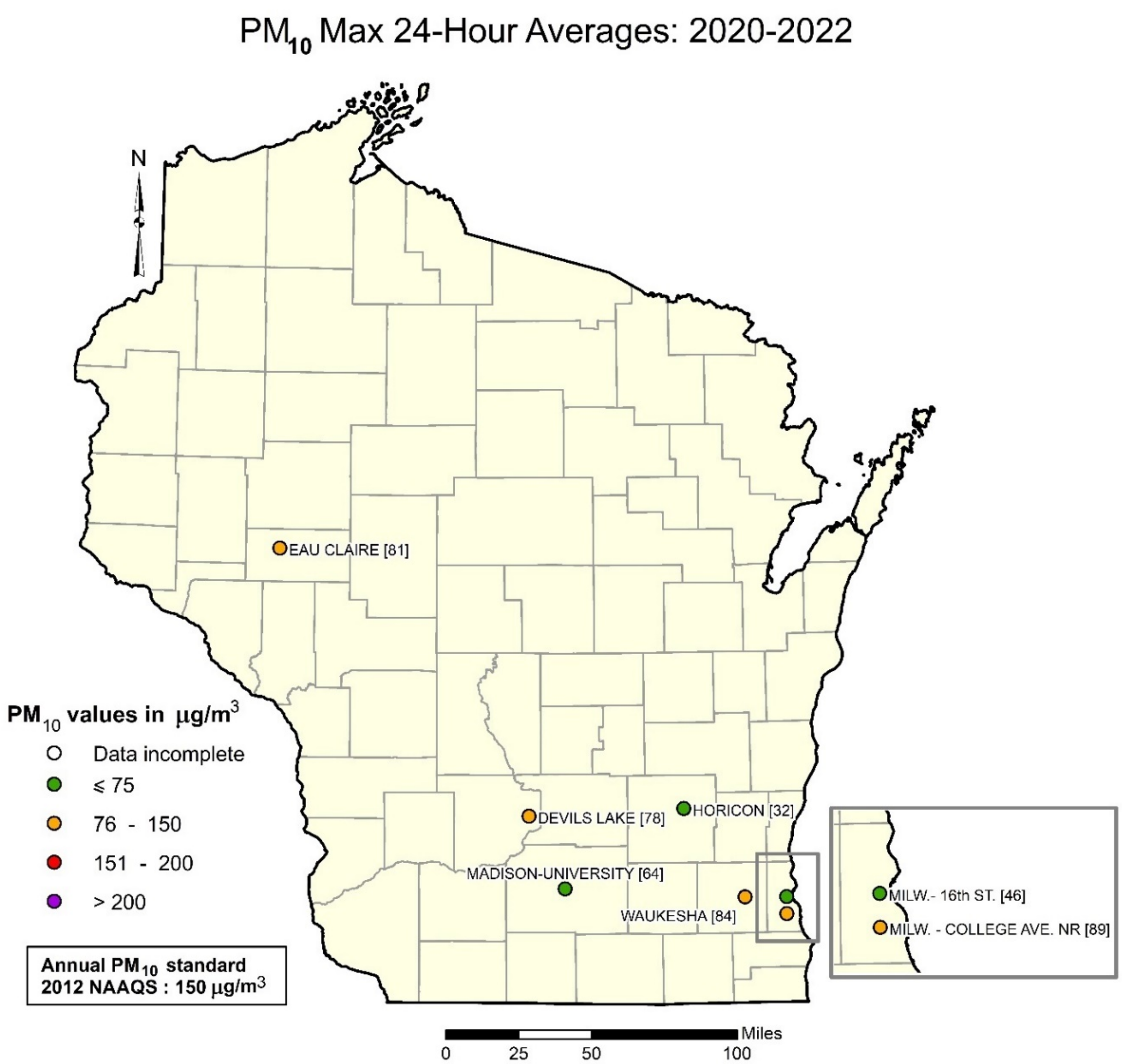

Figure 25. The maximum 24-hour averages of PM10 for 2020-2022.

The 3-year 24-hour maximum values for all sites are below the NAAQS. If the 24-hour average PM_{10} values exceed the standard (150 $\mu g/m^3$) more than once per year on average over three years, the site is in violation of the standard. In addition, concentrations of PM_{10} generally remain steady over time. Three-year 24-hour maximum values decreased by 48% at Horicon between the start of monitoring (2005-2007) and the most recent (2020-2022) values.

Sulfur Dioxide

Figure 26 shows SO_2 monitoring sites in the state network and the most recent one-hour design values. These data are compared against the 2010 1-hour NAAQS of 75 ppb.

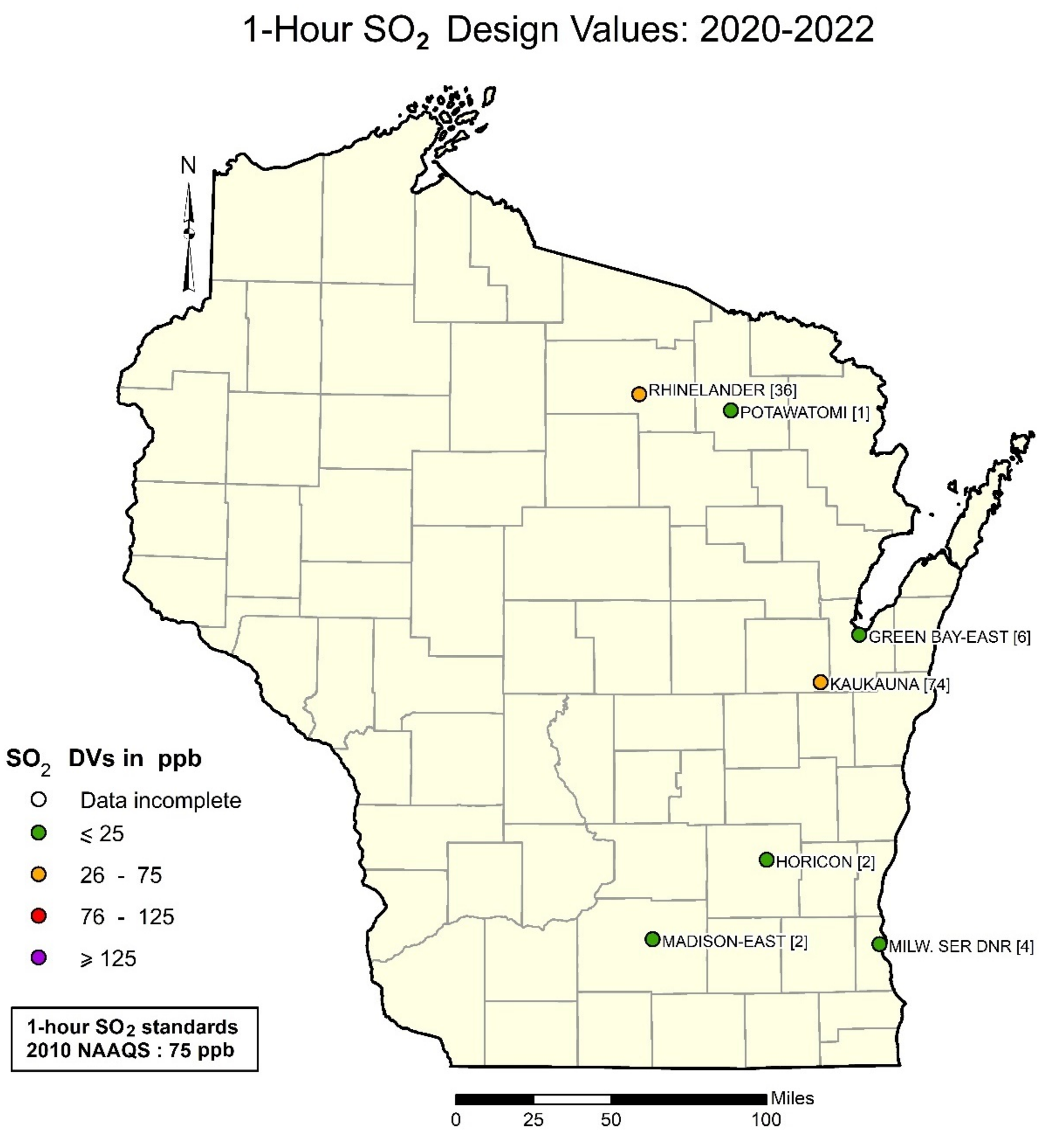

Figure 26. The 1-hour SO2 design values for each monitoring site for 2020-2022.

Figure 27 shows trends in 1-hour SO_2 design values. Note that the Milwaukee-SER site did not monitor SO_2 from 2007 through 2010, so no design values are available for 2005-2007 through 2010-2012. The

Kaukauna site began operating in January 2017 as a result of the SO_2 Data Requirements Rule; the first valid design value is 2017-2019.

The 1-hour standard replaced the annual and 24-hour SO_2 standards in 2010. To provide a clearer picture of trends in SO_2 concentrations over time, years prior to 2010 have 1-hour design values calculated for comparison.

The Horicon, Madison-East and Potawatomi sites monitor very low concentrations of SO_2. Milwaukee-SER observed low concentrations starting in 2011-2013. The Milwaukee-SER site relocated to Milwaukee – UWM UPark and has approval for data combination. Design values from the Green Bay-East site have decreased substantially since 2014-2016 and are now well below the NAAQS. Design values at the Rhinelander site have decreased substantially since 2015-2017 due to implementation of an attainment plan for that area and in 2018 dropped below the NAAQS for the first time since the site was established in 1981. The Kaukauna site is in attainment of the 2010 standard per EPA's final designation. Due to low monitored levels, the DNR requested shutdown of the Madison-East and Green Bay-East SO_2 sites which EPA approved in 2022.

Compared to design values from the start of SO_2 monitoring at each site, 2020-2022 design values are nearly 70% lower on average across all sites. The largest reduction in SO_2 occurred at the Milwaukee-SER site, where design values decreased 94% since monitoring at the site began. From the 2014-2016 to 2020-2022 period, the source-based Rhinelander site saw a 76% drop in design value (149 in 2016-2018 to 36 in 2020-2022 (Appendix B, Table B5).

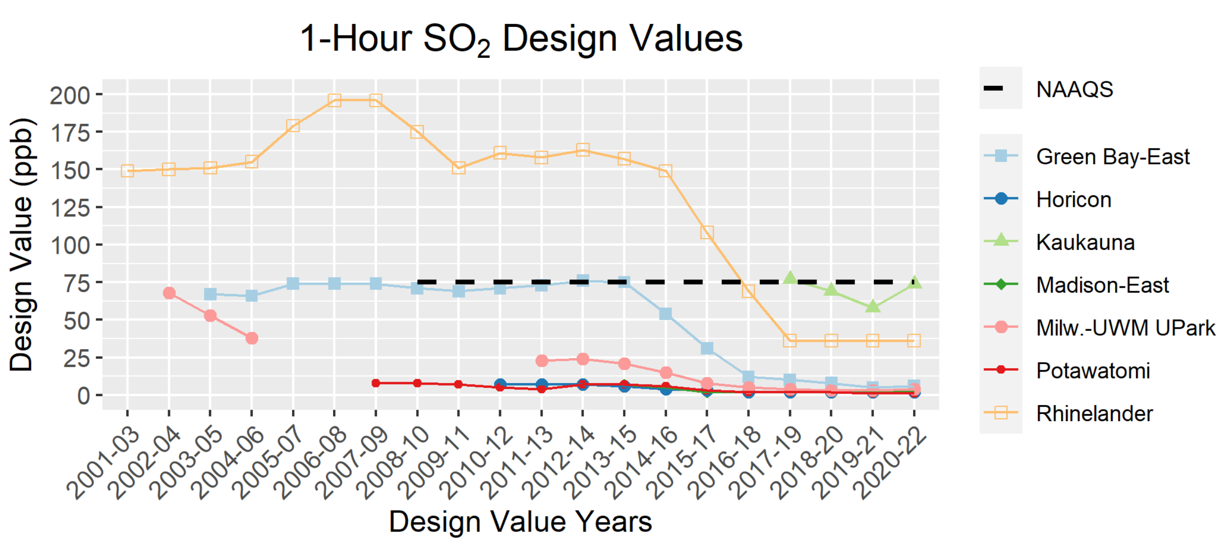

Figure 27. Trends in 1-hour SO2 design values. Note that the 75 ppb 1-hour NAAQS was established in 2010, replacing the annual and 24-hour standards.

Nitrogen Dioxide

Figure 28 and Figure 29 show annual and 1-hour design values for the two sites in the DNR network that measure NO_2 year-round.

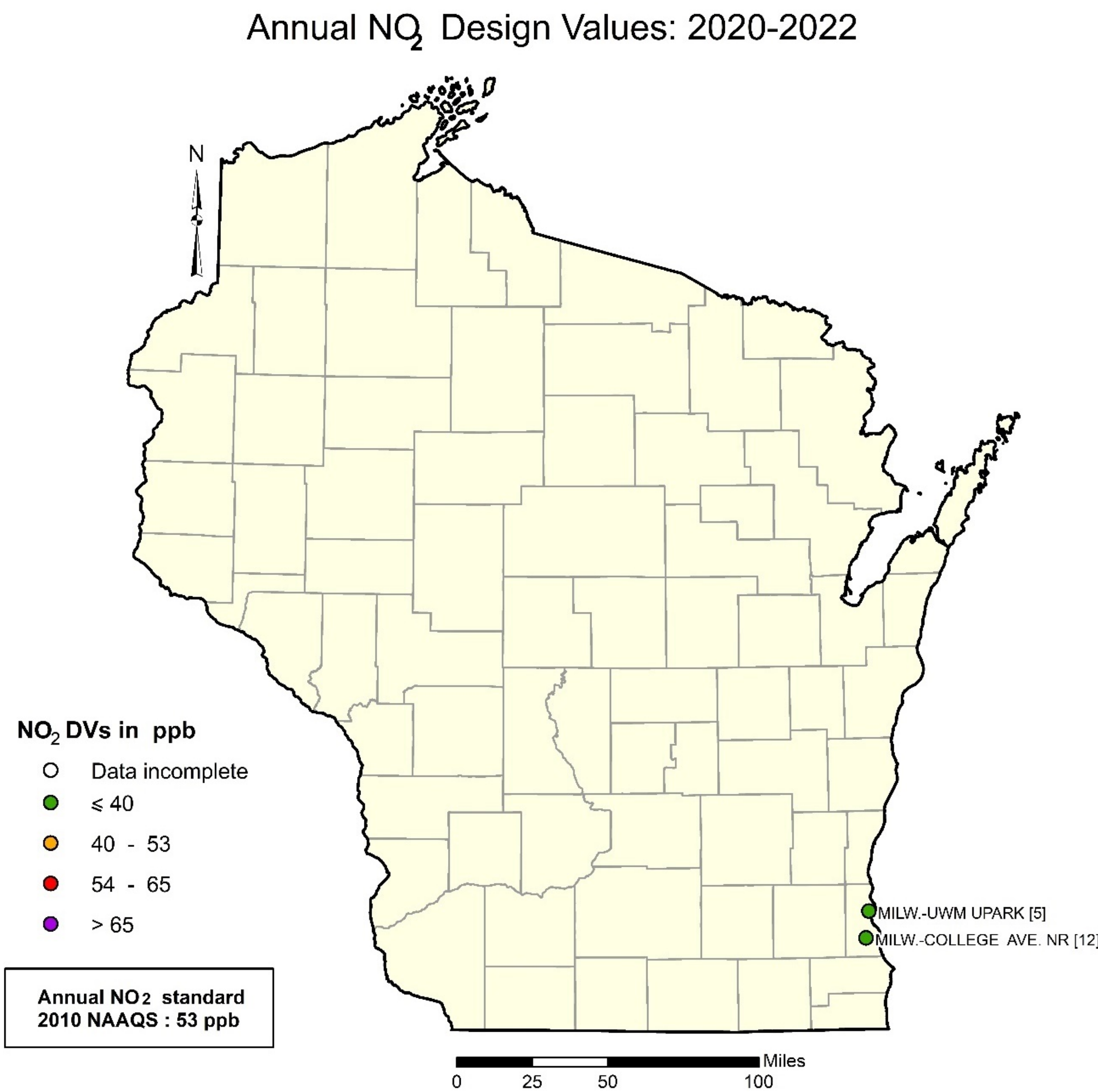

Figure 28. The annual NO2 design values for each monitoring site for 2022.

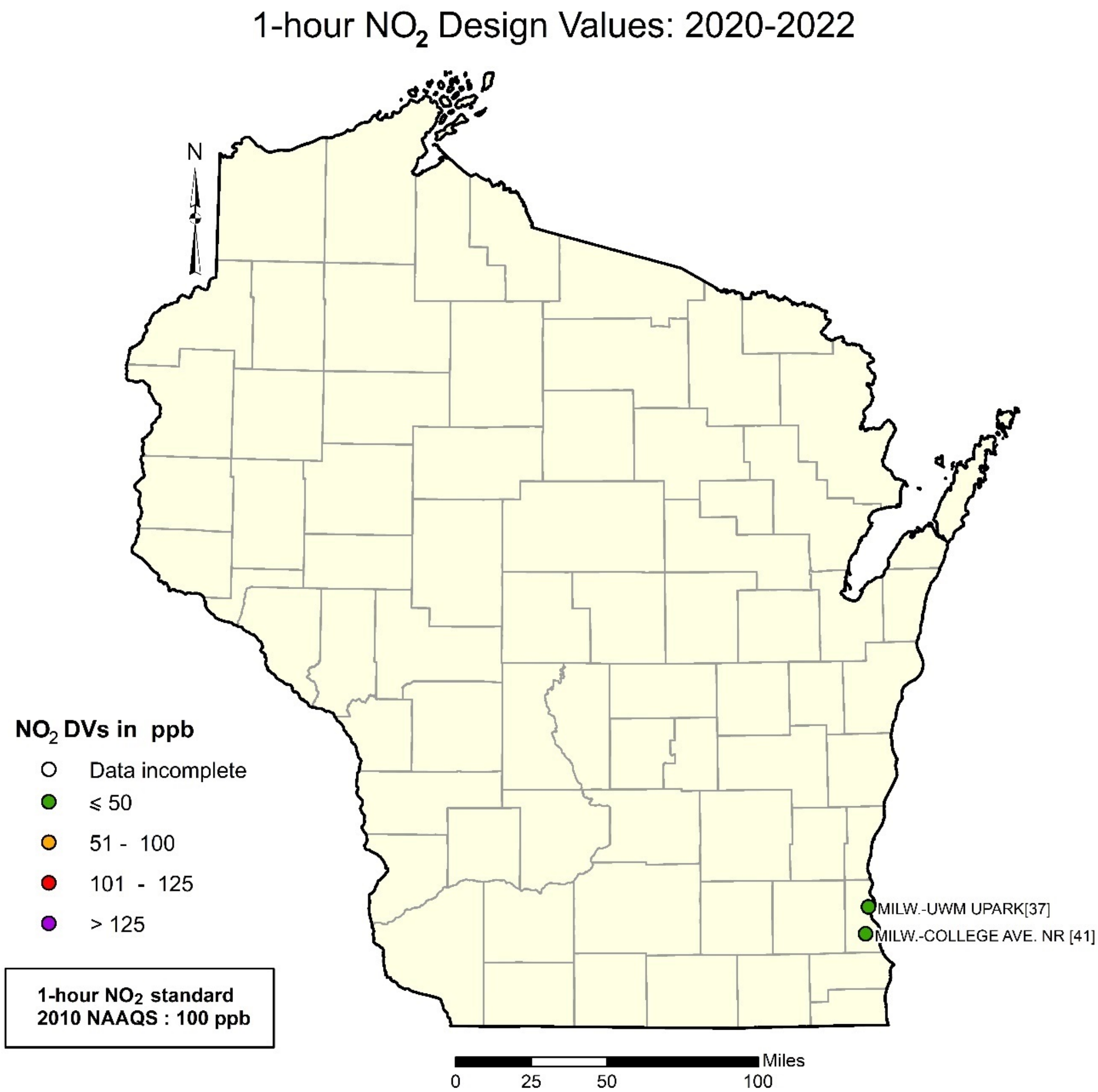

Figure 29. The 1-hour NO2 design values for each monitoring site for 2020-2022.

Figure 30 and Figure 31 show trends in annual and 1-hour NO_2 design values. Overall, monitored levels of NO_2 are very low and are decreasing at both locations.

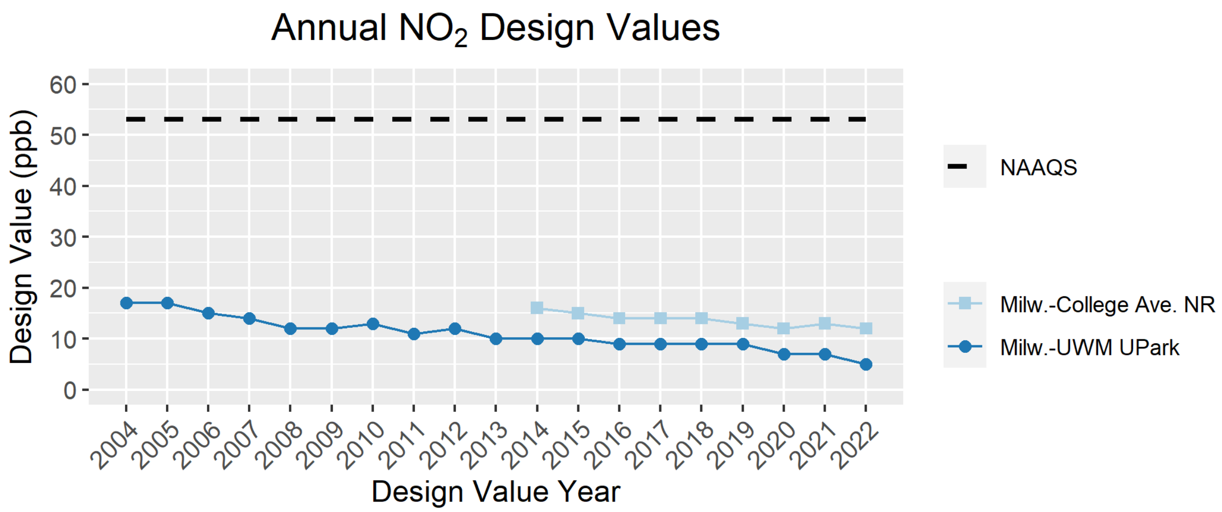

Figure 30. Trends in annual NO2 design values

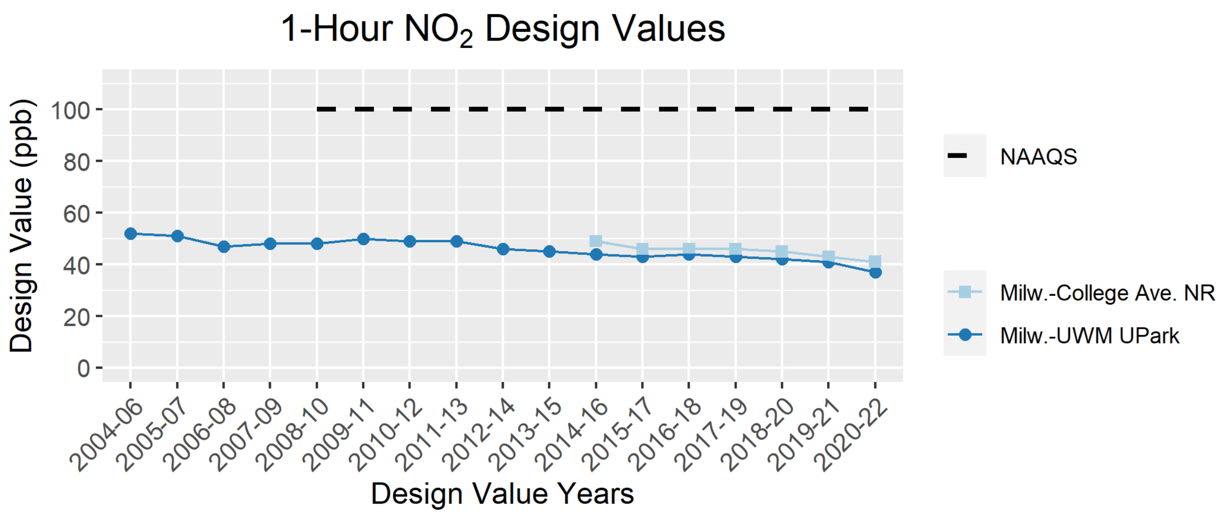

Figure 31. Trends in 1-hour NO2 design values.

Nitrogen Dioxide Satellite Observations

Satellites can estimate the total amount of NO_2 in the atmospheric column (i.e., the column of air between the satellite and the ground). While these estimates of NO_2 concentration are not directly comparable to the NAAQS, satellites can map NO_2 on the landscape between monitors, providing information about the spatial distribution of this pollutant in the atmosphere. Changes in the column density of NO_2 as mapped by satellites support the DNR's observations from ground-based monitors and further illustrate that NO_2 concentrations have decreased over time over a wide geographic area.

Satellite NO_2 Column Density Over Wisconsin

TRIPOMI Satellite Images

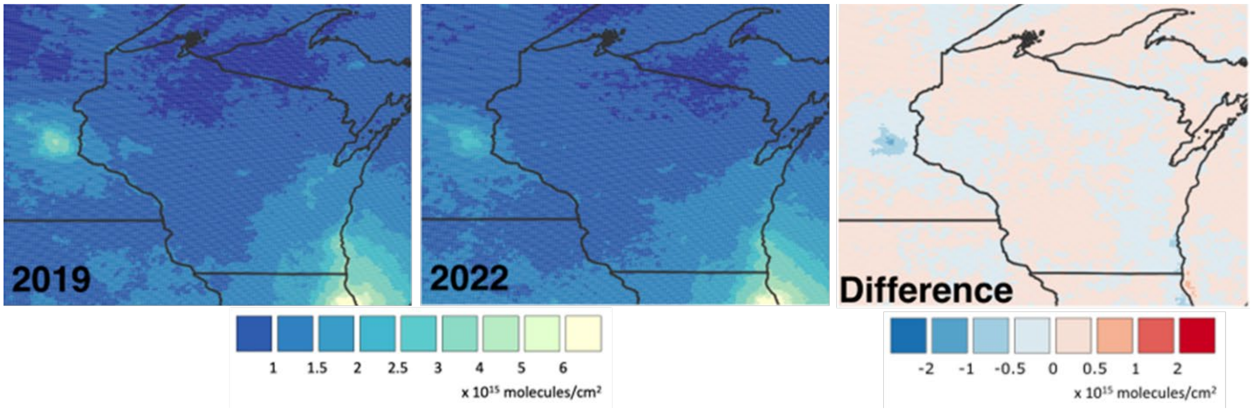

Figure 32. Maps of average annual NO2 column density from the Tropospheric Monitoring Instrument (TROPOMI) satellite. Difference in NO_2 column density between 2019 and 2022 is also provided. Maps courtesy of Dr. Monica Harkey, Dr. Tracey Holloway and Colleen Heck of the University of Wisconsin-Madison. Methodology available upon request.

Figure 32 shows estimated annual average NO_2 column densities[12] for Wisconsin and surrounding areas in 2019 and 2022 along with the difference between these two years, based on data from the Tropospheric Monitoring Instrument (TROPOMI)[13] on the Sentinel-5 Precursor satellite.

These maps show that the greatest NO_2 column densities occur in the Chicago area, and the lowest column densities occur in northern Wisconsin. Comparison of 2019 to 2022 shows the greatest reductions of NO_2 in the Milwaukee, Chicago and Minneapolis areas. These satellite data are consistent with the decreases in ground-based NO_2 monitoring sites which indicates widespread reductions of this ozone-forming pollutant.

[12] NO_2 column density maps were prepared by Drs. Monica Harkey and Tracey Holloway at the University of Wisconsin-Madison. Methodology available upon request. For more information about satellite NO_2 measurements, see https://airquality.gsfc.nasa.gov/no2.

[13] For more information about TROPOMI, see https://disc.gsfc.nasa.gov/datasets/S5P_L2__NO2____1/summary, https://disc.gsfc.nasa.gov/datasets/S5P_L2__NO2____HiR_1/summary and https://doi.org/10.5194/amt-15-2037-2022.

Carbon Monoxide

Two sites monitor for carbon monoxide in the DNR network. The data displayed compares design values against the 8-hour and 1-hour NAAQS (Figure 33 and Figure 34, respectively). Design value calculations use one year of data.

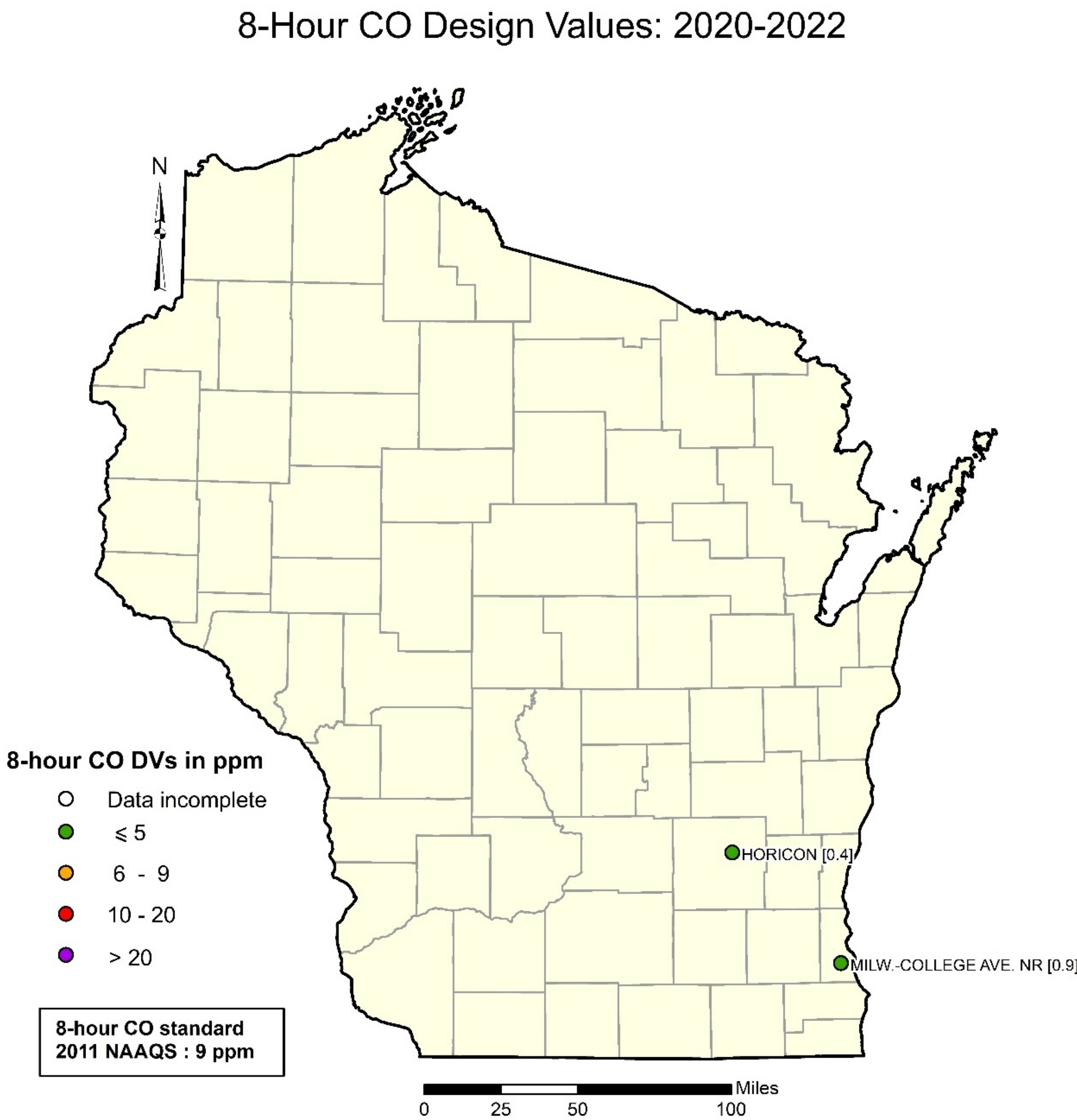

Figure 33. The 8-hour CO design values for each monitoring site for 2022.

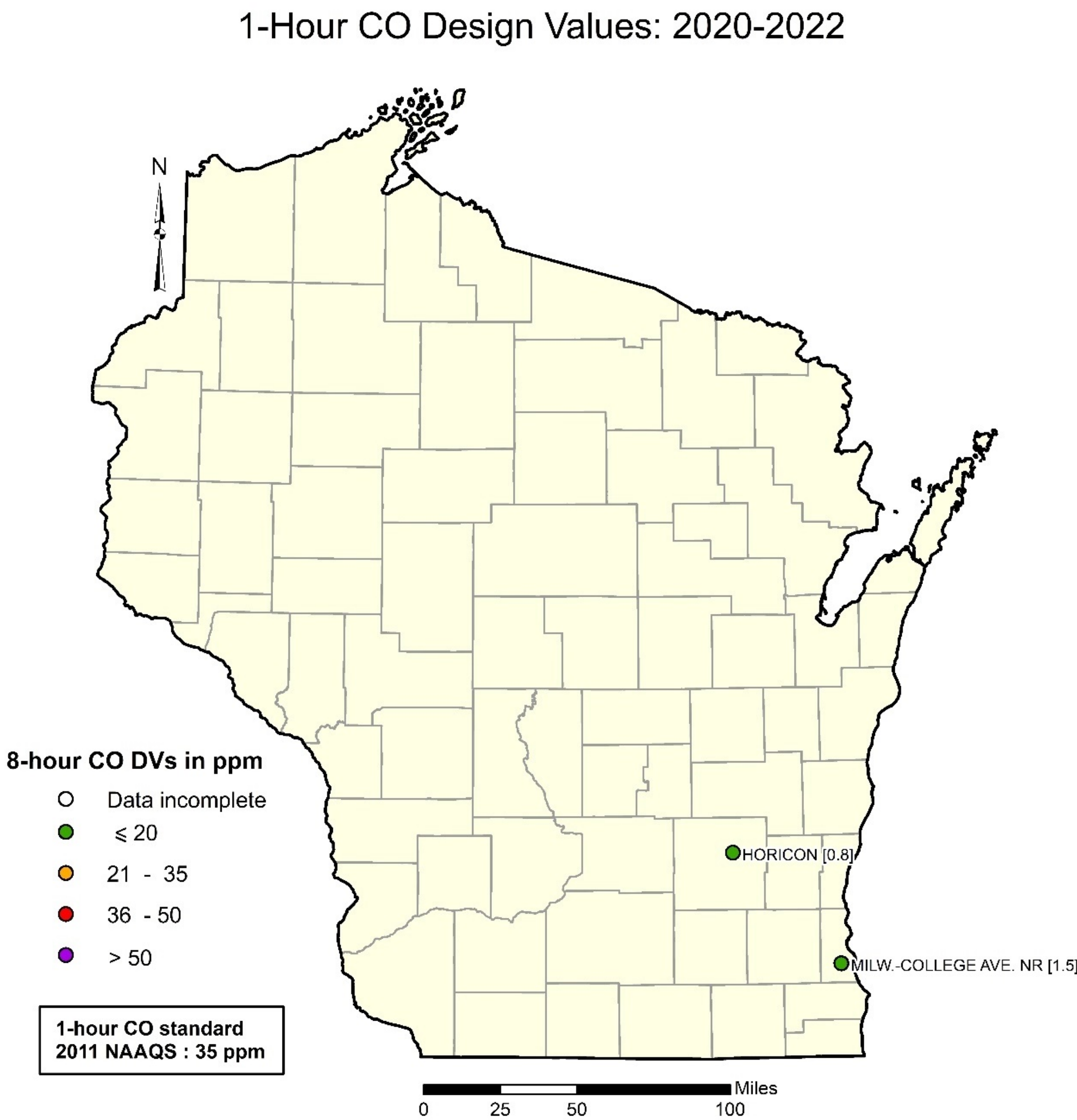

Figure 34. The 1-hour CO design values for each monitoring site for 2021.

Figure 35 and Figure 36 show trends in 8-hour and 1-hour CO design values, which are extremely low at both sites (Appendix B, Table B8).

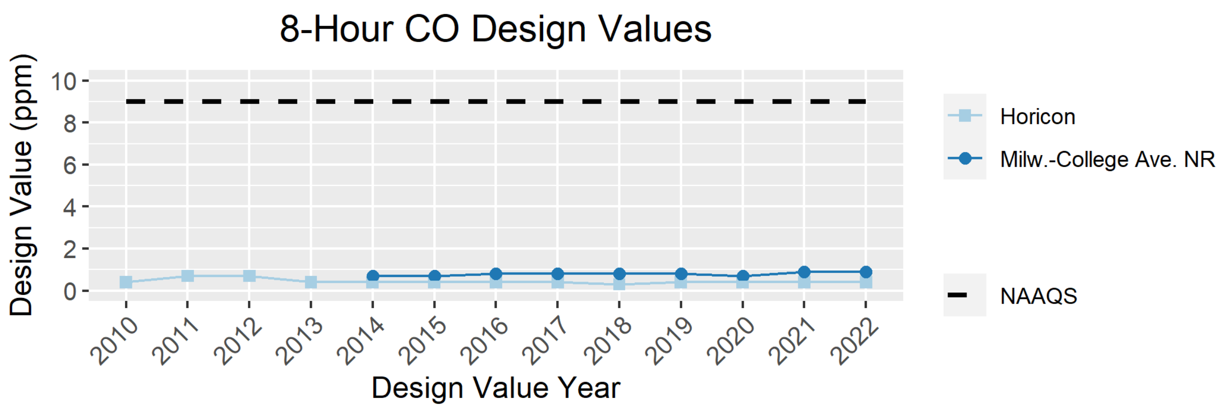

Figure 35. Trends in 8-hour CO design values.

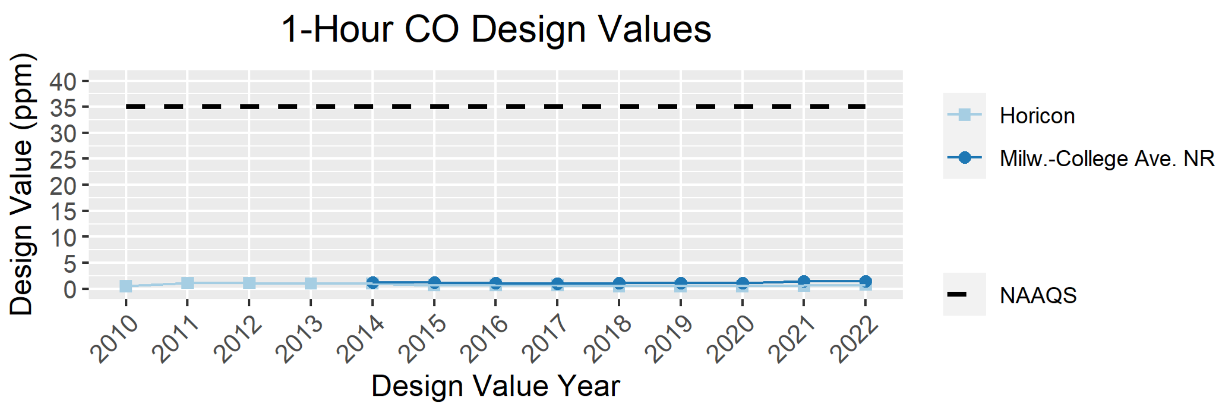

Figure 36. Trends in 1-hour CO design values.

Lead

Historically, lead monitoring for comparison to the NAAQS occurred at a site in the town of Kohler in Sheboygan County using filter-based samplers for TSP. The lead NAAQS requires a TSP size fraction for criteria analysis. The design value at the Kohler site never exceeded the lead NAAQS. Lead design values at the Kohler site decreased 55% from the first valid design value (2012-2014) to the last valid design value (2016-2018). On March 22, 2019, EPA granted the DNR a waiver to discontinue monitoring because the site met federal monitor shutdown requirements.

The DNR also monitors lead at the Horicon and Milwaukee-16th St. sites as part of the National Air Toxics Trends Stations network and Urban Air Toxics Monitoring program, respectively. The fraction of particles monitored for lead at these sites is PM_{10} instead of TSP. As a result, the lead monitoring data from the Horicon and Milwaukee-16th St. sites cannot be compared to the NAAQS and are omitted from this report.

Near Real-Time Air Quality Data

The air quality data presented in the figures above include data that have been through a rigorous quality assurance process. For readers interested in real-time air quality, the DNR maintains an interactive website containing the most recently available monitoring data. The *WisconsinAQM* mobile app is also available for both Apple® and Android™ mobile devices. The app includes an interactive map of near real-time data from the state's air monitoring network, individual monitoring station reports, weather information and more. Download in the Apple App Store® or the Google Play Store. It is important to note that these near real-time data have not been quality assured and have the potential to be corrected or excluded. The DNR's Air Quality Monitoring Data Information page provides important information about interpreting these data. In addition to the near real-time data, regularly updated air quality forecasts for Wisconsin are also available.

Appendix A. – Air Quality by County

County-level air quality maps can be found online. Please visit Wisconsin's Air Quality Trends and navigate to the link for Wisconsin Air Quality Trends by County to find information about station location and single-pollutant trends maps on a county-by-county basis.

Appendix B. – Design Value Changes

TABLE B1. Change in 8-hour design values for ozone between 2001-2003 and 2020-2022. The table includes only monitors with valid design values for both beginning and ending periods. Note that none of the Far North monitors operated in 2001-2003.

Site Name	County	Site ID	Region	First Years of Data	8-Hour Design Values^ (ppb)		Change (First Years to 2020-22)	
					First Years	2020-2022	ppb	%
Appleton	Outagamie	55-087-0009	Inland	2001-03	78	64	-14	-18%
Bad River	Ashland	55-003-0010	North	2005-07	63	57	-6	-10%
Bayside	Milwaukee	55-079-0085	Lake	2001-03	94	73	-21	-22%
Beloit*	Rock	55-105-0030	Inland	2001-03	83	67	-16	-19%
Chiwaukee Prairie	Kenosha	55-059-0019	Lake	2001-03	101	75	-26	-26%
Columbus	Columbia	55-021-0015	Inland	2001-03	79	66	-13	-16%
Devils Lake	Sauk	55-111-0007	Inland	2001-03	73	63	-10	-14%
Eau Claire	Eau Claire	55-035-0014	Inland	2011-13	62	62	0	0%
Elkhorn*	Walworth	5-5127-0006	Inland	2001-03	84	71	-13	-15%
Fond du Lac	Fond du Lac	55-039-0006	Inland	2001-03	80	64	-16	-20%
Grafton	Ozaukee	55-089-0008	Lake	2001-03	92	72	-20	-22%
Green Bay	Brown	55-009-0026	Inland	2001-03	83	64	-19	-23%
Harrington Beach	Ozaukee	55-089-0009	Lake	2001-03	98	71	-27	-28%
Horicon*	Dodge	55-027-0001	Inland	2001-03	82	66	-16	-20%
Jefferson*	Jefferson	55-055-0009	Inland	2001-03	83	66	-17	-20%
Kenosha-WT	Kenosha	55-059-0025	Lake	2013-15	69	73	4	6%
Kewaunee	Kewaunee	55-061-0002	Lake	2001-03	92	67	-25	-27%
La Crosse	La Crosse	55-063-0012	Inland	2008-10	61	59	-2	-3%
Lake Du Bay	Marathon	55-073-0012	Inland	2001-03	73	57	-16	-22%
Madison-East	Dane	55-025-0041	Inland	2001-03	78	65	-13	-17%
Manitowoc	Manitowoc	55-071-0007	Lake	2001-03	90	73	-17	-19%
Milw.-16th St.	Milwaukee	55-079-0010	Lake	2004-06	68	63	-5	-7%
Milw.-UWM UPark*	Milwaukee	55-079-0068	Lake	2001-03	84	72	-12	-14%
Newport	Door	55-029-0004	Lake	2001-03	94	73	-21	-22%
Perkinstown	Taylor	55-119-9991	Inland	2008-10	61	59	-2	-3%
Potawatomi	Forest	55-041-0007	North	2004-06	68	59	-9	-13%
Racine-P&D*	Racine	55-101-0020	Lake	2015-17	74	75	1	1%
Sheboygan-Haven	Sheboygan	55-117-0009	Lake	2014-16	69	69	0	0%
Sheboygan-KA	Sheboygan	55-117-0006	Lake	2001-03	100	75	-25	-25%
Trout Lake	Vilas	55-125-0001	North	2007-09	65	58	-7	-11%
Waukesha	Waukesha	55-133-0027	Inland	2004-06	71	68	-3	-4%
Lakeshore Region** Average					87	72	-15	-17%

Inland Region** Average	75	64	-11	-15%
North Region** Average	65	58	-7	-11%

^The 2001-2003 design values would be compared against the 1997 8-hour ozone NAAQS of 84 ppb; the 2020-2022 design values would be compared against both 8-hour ozone NAAQS in effect in 2018: 75 ppb for the 2008 standard and 70 ppb for the 2015 standard.

*See Appendix C for site combinations

**See Figure 13 and associated text for definition of these regions.

TABLE B2. Change in annual design values for $PM_{2.5}$ between 2001-2003 and 2020-2022. Only monitors with valid design values for both beginning and ending periods are included.

Site Name	County	Site ID	Region	First Years of Data	Annual Design Values^ (µg/m³)		Change (First Years to 2020-22)	
					First Years	2020-2022	µg/m³	%
Appleton	Outagamie	55-087-0009	Inland	2001-03	10.7	8	-2.7	-25%
Bad River	Ashland	55-003-0010	North	2003-05	6	5.6	-0.4	-7%
Chiwaukee Prairie	Kenosha	55-059-0019	Southeast	2001-03	11.7	7.9	-3.8	-32%
Devils Lake	Sauk	55-111-0007	Inland	2004-06	9.9	7.7	-2.2	-22%
Eau Claire	Eau Claire	55-035-0014	Inland	2012-14	7.9	8.1	0.2	3%
Green Bay-East	Brown	55-009-0005	Inland	2001-03	11.5	7.8	-3.7	-32%
Horicon*	Dodge	55-027-0001	Inland	2001-03	11	7.9	-3.1	-28%
La Crosse	La Crosse	55-063-0012	Inland	2006-08	12.1	7.9	-4.2	-35%
Madison-East	Dane	55-025-0041	Inland	2011-13	9.4	8.2	-1.2	-13%
Madison-University	Dane	55-025-0047	Inland	2001-03	12.5	8.8	-3.7	-30%
Milw.-16th St	Milwaukee	55-079-0010	Southeast	2001-03	13.1	9.4	-3.7	-28%
Milw.-College Ave. NR	Milwaukee	55-079-0056	Southeast	2017-19	8.3	8.8	0.5	6%
Perkinstown	Taylor	55-119-8001	Inland	2004-06	8	6.7	-1.3	-16%
Potawatomi	Forest	55-041-0007	North	2005-07	7.4	5.9	-1.5	-20%
Potosi	Grant	55-043-0009	Inland	2001-03	11.4	8.7	-2.7	-24%
Trout Lake**	Vilas	55-125-0001	North	2001-03	6.6	5.3	-1.3	-20%
Waukesha	Waukesha	55-133-0027	Southeast	2001-03	13.2	9.2	-4	-30%
Southeast Region† Average					12	9	-3	-25%
Inland Region† Average					10	8	-2	-20%
North Region† Average					7	6	-1	-14%

^The 2001-2003 design values would be compared against the 1997 annual $PM_{2.5}$ NAAQS of 15.0 µg/m³; the 2017-2019 design values would be compared against the 2012 annual $PM_{2.5}$ NAAQS of 12.0 µg/m³.

*See Appendix C for site combinations

†See Figure 17 and associated text for definition of these regions.

TABLE B3. Change in 24-hour design values for $PM_{2.5}$ between 2001-2003 and 2020-2022. Only monitors with valid design values for both beginning and ending periods are included.

Site Name	County	Site ID	Region	First Years of Data	24-Hour Design Values^ (µg/m³)		Change (First Years to 2020-22)	
					First Years	2020-2022	µg/m³	%
Appleton	Outagamie	55-087-0009	Inland	2001-03	29	22	-7	-24%
Bad River	Ashland	55-003-0010	North	2003-05	17	16	-1	-6%
Chiwaukee Prairie	Kenosha	55-059-0019	Southeast	2001-03	31	20	-11	-35%
Devils Lake	Sauk	55-111-0007	Inland	2004-06	29	21	-8	-28%
Eau Claire	Eau Claire	55-035-0014	Inland	2012-14	21	22	1	5%
Green Bay-East	Brown	55-009-0005	Inland	2001-03	32	21	-11	-34%
Horicon*	Dodge	55-027-0001	Inland	2001-03	33	21	-12	-36%
La Crosse	La Crosse	55-063-0012	Inland	2006-08	32	21	-11	-34%
Madison-East	Dane	55-025-0041	Inland	2011-13	22	22	0	0%
Madison-University	Dane	55-025-0047	Inland	2001-03	34	23	-11	-32%
Milw.-16th St	Milwaukee	55-079-0010	Southeast	2001-03	36	24	-12	-33%
Milw.-College Ave. NR	Milwaukee	55-079-0056	Southeast	2017-19	22	22	0	0%
Perkinstown	Taylor	55-119-8001	Inland	2004-06	25	20	-5	-20%
Potawatomi	Forest	55-041-0007	North	2005-07	25	18	-7	-28%
Potosi	Grant	55-043-0009	Inland	2001-03	28	22	-6	-21%
Trout Lake**	Vilas	55-125-0001	North	2001-03	18	16	-2	-11%
Waukesha	Waukesha	55-133-0027	Southeast	2001-03	34	23	-11	-32%
Southeast Region† Average					31	22	-9	-29%
Inland Region† Average					29	22	-7	-24%
North Region† Average					20	17	-3	-15%

^The 2001-2003 design values would be compared against the 1997 24-hour $PM_{2.5}$ NAAQS of 65 µg/m³; the 2019-2021 design values would be compared against the 2006 24-hour $PM_{2.5}$ NAAQS of 35 µg/m³.

*See Appendix C for site combinations

†See Figure 18 and associated text for definition of these regions.

TABLE B4. Change in 3-year maximum 24-hour averages for PM_{10} between the start of monitoring (date variable) and 2019-2021. Annual maximum values over three years contribute to the determination of the PM_{10} design value.

Site Name	County	Site ID	First Years of Data	3-Year Maximum 24-Hour Average^ (µg/m³)		Change (First Years to 2020-22)	
				First Years	2020-2022	µg/m³	%
Devils Lake	Sauk	55-111-0007	2011-13	41	78.4	37.4	91%
Eau Claire	Eau Claire	55-035-0014	2019-21	81	81.1	0.1	0%
Horicon*	Dodge	55-027-0001	2005-07	62	32	-30	-48%
Madison-University	Dane	55-025-0047	2008-10	63	64.2	1.2	2%
Milw.-16th St	Milwaukee	55-079-0010	2007-09	47	46	-1	-2%
Milw.-College Ave. NR	Milwaukee	55-079-0056	2018-20	96	89.1	-6.9	-7%
Waukesha	Waukesha	55-133-0027	2001-03	73	84.4	11.4	16%

^All design values would be compared against the 1987 24-hour PM_{10} NAAQS of 150 µg/m³, which is not to be exceeded more than once per year on average over 3 years.

*See Appendix C for site combinations

TABLE B5. Change in 1-hour design values for SO_2 between the start of monitoring (date variable) and 2020-2022. Only one monitor (Rhinelander) had valid design values for the entire 2001-2003 to 2020-2022 period.

Site Name	County	Site ID	First Years of Data	1-Hour Design Values^ (ppb)		Change (First Years to 2020-22)	
				First Years	2020-2022	ppb	%
Green Bay-East	Brown	55-009-0005	2003-05	67	6	-61	-91%
Horicon	Dodge	55-027-0001	2010-12	7	2	-5	-71%
Kaukauna	Outagamie	55-087-0015	2017-19	77	74	-3	-4%
Madison-East	Dane	55-025-0041	2013-15	7	2	-5	-71%
Milw.-UWM UPark*	Milwaukee	55-079-0026	2002-04	68	4	-64	-94%
Potawatomi	Forest	55-041-0007	2007-09	8	1	-7	-88%
Rhinelander	Oneida	55-085-0996	2001-03	149	36	-113	-76%

^Design values from 2010-2012 to 2019-2021 would be compared against the 2010 1-hour SO_2 NAAQS of 75 ppb. There was not a 1-hour standard in effect prior to 2010; rather there were annual and 24-hour standards of 30 ppb and 140 ppb, respectively.

*See Appendix C for site combinations

TABLE B6. Change in annual design values for NO_2 between the start of monitoring (date variable) and 2022.

Site Name	County	Site ID	First Year of Data	Annual Design Values^ (ppb)		Change (First Year to 2022)	
				First Year	2020-2022	ppb	%
Milw.-College Ave. NR	Milwaukee	55-079-0056	2014	16	12	-4	-25%
Milw.-UWM UPark*	Milwaukee	55-079-0068	2004	17	5	-12	-71%

^All design values would be compared against the annual NO_2 NAAQS of 53 ppb which EPA has retained since 1971.

*See Appendix C for site combinations

TABLE B7. Change in 1-hour design values for NO_2 between the start of monitoring (date variable) and 2020-2022.

Site Name	County	Site ID	First Years of Data	1-Hour Design Values^ (ppb)		Change (First Years to 2022)	
				First Years	2020-2022	ppb	%
Milw.-College Ave. NR	Milwaukee	55-079-0056	2014-16	49	41	-8	-16%
Milw.-UWM UPark*	Milwaukee	55-079-0068	2004-06	52	37	-15	-29%

^Design values from 2017-2019 would be compared against the 2010 1-hour NO_2 NAAQS of 100 ppb. There was not a 1-hour standard in effect prior to 2010; rather values would be compared to the 1971 annual standard of 53 ppb.

*See Appendix C for site combinations

TABLE B8. Change in 8-hour and 1-hour design values for CO between the start of monitoring (date variable) and 2022.

Site Name	County	Site ID	First Year of Data	8-Hour Design Values^ (ppm)		1-Hour Design Values^ (ppm)	
				First Year	2022	First Year	2022
Horicon	Dodge	55-027-0001	2010	0.4	0.4	0.5	0.6
Milw.-College Ave. NR	Milwaukee	55-079-0056	2014	0.7	0.9	1.2	2

^All 8-hour design values would be compared against the 1971 8-hour CO NAAQS of 9 ppm, and all 1-hour design values would be compared against the 1971 1-hour NAAQS of 35 ppm.

Appendix C. – Full Site Names

TABLE C1. Full site names corresponding to shorter names used in the text, tables, and figures.

Site Name	County	Site ID	Full site name
Appleton	Outagamie	55-087-0009	Appleton - AAL
Bad River	Ashland	55-003-0010	Bad River Tribal School - Odanah
Bayside	Milwaukee	55-079-0085	Bayside
Beloit*	Rock	55-105-0030	Beloit - Converse
Chiwaukee Prairie	Kenosha	55-059-0019	Chiwaukee Prairie Stateline
Columbus	Columbia	55-021-0015	Columbus
Devils Lake	Sauk	55-111-0007	Devils Lake Park
Eau Claire	Eau Claire	55-035-0014	Eau Claire - DOT Sign Shop
Elkhorn	Walworth	55-127-0006	Elkhorn
Fond du Lac	Fond du Lac	55-039-0006	Fond du Lac
Grafton	Ozaukee	55-089-0008	Grafton
Green Bay-East	Brown	55-009-0005	Green Bay - East High
Green Bay-UW	Brown	55-009-0026	Green Bay - UW
Harrington Beach	Ozaukee	55-089-0009	Harrington Beach Park
Horicon*	Dodge	55-027-0001	Horicon Wildlife Area
Jefferson*	Jefferson	55-055-0009	Jefferson - Laatsch
Kenosha-WT	Kenosha	55-059-0025	Kenosha-Water Tower
Kewaunee	Kewaunee	55-061-0002	Kewaunee
La Crosse	La Crosse	55-063-0012	Lacrosse - DOT Building
Lake Du Bay	Marathon	55-073-0012	Lake Du Bay
Madison-East	Dane	55-025-0041	Madison - East
Madison-University	Dane	55-025-0047	Madison – University Ave. Well #6
Manitowoc	Manitowoc	55-071-0007	Manitowoc - Wdlnd Dunes
Milw.-16th St.	Milwaukee	55-079-0010	Milwaukee - Sixteenth St. Health Center
Milw.-College Ave. NR	Milwaukee	55-079-0056	Milwaukee – College Ave. Near Road
Milw.-College Ave. P&R	Milwaukee	55-079-0058	Milwaukee – College Ave. Park & Ride
Milw.-SER	Milwaukee	55-079-0026	Milwaukee - SER DNR Hdqrs.
Milw.-UWM UPark*	Milwaukee	55-079-0068	Milwaukee – UWM UPark
Newport	Door	55-029-0004	Newport Park
Perkinstown	Taylor	55-119-8001	Perkinstown
Potawatomi	Forest	55-041-0007	Potawatomi
Potosi	Grant	55-043-0009	Potosi
Racine-Payne & Dolan	Racine	55-101-0020	Racine-Payne & Dolan
Rhinelander	Oneida	55-085-0996	Rhinelander Tower
Sheboygan-Haven	Sheboygan	55-117-0009	Sheboygan - Haven
Sheboygan - KA	Sheboygan	55-117-0006	Sheboygan - Kohler Andrae
Trout Lake	Vilas	55-125-0001	Trout Lake
Waukesha	Waukesha	55-133-0027	Waukesha - Cleveland Ave.

* The "Beloit" monitor combines records from the Beloit-Cunningham monitor (55-105-0024), which shut down in 2013, and the Beloit-Converse monitor, which replaced it. The "Horicon" monitor combines records from the Mayville monitor (55-027-0007), which shut down after 2009, and Horicon, which replaced it. The "Jefferson" monitor combines records from the Jefferson H.S. monitor (55-055-0002), which shut down after 2012, and the Jefferson-Laatsch monitor, which replaced it. The "Elkhorn" monitor combines records from the Lake Geneva. monitor (55-127-0005), which shut down after 2018, and the Elkhorn monitor, which replaced it. The “Milw-UWM UPark” monitor combines records from the Milw-SER (55-079-0026), which shut down in 2021 and the Milw UWM-UPark monitoring which replaced it.