Sulfur Dioxide Concentrations

Sulfur dioxide (SO_2) is one of the multiple gaseous oxidized sulfur species and is formed during the combustion of fuels containing sulfur, primarily coal and oil. The largest anthropogenic source of SO_2 emissions in the U.S. is fossil fuel combustion at electric utilities and other industrial facilities. SO_2 is also emitted from certain manufacturing processes and mobile sources, including locomotives, large ships, and construction equipment (see SO_2 Emissions indicator). The highest concentrations of SO_2 are typically recorded in the vicinity of large emissions sources.

Short-term exposure to ambient SO_2 has been associated with various adverse health effects (U.S. EPA, 1994; ATSDR, 1998). Multiple human clinical studies, epidemiological studies, and toxicological studies support a causal relationship between short-term exposure to ambient SO_2 and respiratory morbidity. The observed health effects include decreased lung function, respiratory symptoms, and increased emergency department visits and hospitalizations for all respiratory causes. These studies further suggest that people with asthma are potentially susceptible or vulnerable to these health effects (U.S. EPA, 2017). In addition, SO_2 reacts with other air pollutants to form sulfate particles, which are constituents of fine particulate matter ($PM_{2.5}$). Inhalation exposure to $PM_{2.5}$ has been associated with various cardiovascular and respiratory health effects (see PM Concentrations indicator).

Ambient SO_2 also causes or contributes to numerous environmental impacts. For instance, ambient SO_2 along with ambient nitrogen oxides contribute to acidic deposition, and this deposition can harm susceptible aquatic and terrestrial ecosystems, including injury to forests and changes in the composition of fish and other aquatic species (see Acid Deposition indicator). In some watersheds, sulfate deposition increases mercury methylation rates, which leads to formation of methylmercury—the chemical form of mercury that accumulates in the aquatic food chain (U.S. EPA, 2020). In addition, SO_2 contributes to the formation of fine airborne particles that can impair visibility—an issue of particular concern in National Parks and Wilderness Areas (see Regional Haze indicator).

This indicator presents ambient SO_2 concentrations in parts per billion (ppb) from 1990 to 2021 using 1-hour averaging times to be consistent with the current primary National Ambient Air Quality Standard (NAAQS). Trend data are based on measurements from the State and Local Air Monitoring Stations network and from other special purpose monitors. From 1990 through 2021, 92 monitoring sites in 81 counties nationwide have sufficient data to characterize 1-hour trends. Trends are displayed for the entire nation and for each EPA Region. Refer to the technical documentation for the selection criteria that were applied to identify the sites with sufficient data to characterize air quality trends.

Trends in 1-hour SO_2 concentrations are presented for the annual 99^{th} percentile of daily maximum 1-hour values. This averaging time and statistic are consistent with the primary NAAQS, which was derived to protect public health, including the health of sensitive populations such as people with asthma. All exhibits in this indicator present the SO_2 NAAQS as a point of reference. The exhibits showing trends in 1-hour concentrations display the current NAAQS. The fact that the national or regional concentrations fall below the standards does not mean that all monitoring sites nationally or in any EPA Region also are below the standards. The indicator also displays the number of trend

sites nationwide at which SO_2 concentrations exceeded the level of the standards, but these statistics are not displayed for each EPA Region.

What the Data Show

Annual 99th percentile of daily maximum 1-hour SO_2 concentrations decreased by 91 percent between 1990 and 2021, and the 2020 and 2021 levels are the lowest in the 32-year period of record (Exhibit 1). Among the 92 sites with sufficient data, the number reporting 1-hour SO_2 concentrations above the level of the NAAQS decreased from 61 in 1990 to zero in 2020 (Exhibit 2). This downward trend in SO_2 concentrations parallels the downward trend in SO_2 emissions, which has been attributed largely to decreased emissions from electric utilities (the SO_2 Emissions indicator). Decreased emissions from mobile sources due to use of low sulfur fuels has also contributed to the ambient concentration trend.

Consistent with the nationwide trend, the 99th percentile of daily maximum 1-hour SO_2 concentrations decreased between 1990 and 2021 in every EPA Region with trend sites (Exhibit 3). The greatest reduction in 1-hour SO_2 concentrations occurred in Region 1 (98 percent reduction).

Also shown in Exhibit 1 are the 90th and 10th percentiles based on the annual measurements at the monitoring sites. This provides additional graphical representation of the variability of measured concentrations across the monitoring sites for a given year. The area between those lines in this exhibit displays the concentration range where 80 percent of measured values occurred for that year.

Limitations

- While many SO_2 monitoring sites are located near dense population centers, other sites are located near emissions sources and the trends might not accurately reflect conditions outside the immediate monitoring areas.
- Because of the relatively small number of trend sites in some EPA Regions, the regional trends are subject to greater uncertainty than the national trends. Some EPA Regions with low average concentrations may include areas with high local concentrations, and vice versa. In addition, the trend sites in this indicator are not dispersed uniformly across all states in the EPA Regions. The 92 sites for the 1990-2021 trends are located in 29 states. In the remaining 21 states, there currently are insufficient long-term data from the existing monitoring sites to include in this indicator.
- To ensure that long-term trends are based on a consistent set of monitoring sites, selection criteria were applied to identify the subset of SO_2 monitoring sites with sufficient data to assess trends since 1990. Monitoring sites without sufficient data are not included in the trend analysis. Some excluded monitoring sites reported SO_2 concentrations above the level of the NAAQS over the time frame covered by this indicator. In 2021, for example, 12 sites in the U.S. measured SO_2 concentrations above the level of the 1-hour NAAQS, but none of these was a trend site for this indicator.

Data Sources

Summary data in this indicator were downloaded from EPA's National Air Quality: Status and Trends of Key Air Pollutants website (U.S. EPA, 2022a) (https://www.epa.gov/air-trends). The trends data are based on SO_2 ambient air monitoring data in EPA's Air Quality System. National and regional trends in this indicator are based on the subset of SO_2 monitoring stations that have

sufficient data to assess trends since 1990.

References

ATSDR (Agency for Toxic Substances and Disease Registry). 1998. Toxicological profile for sulfur dioxide. Atlanta, GA. https://www.atsdr.cdc.gov/ToxProfiles/tp116.pdf (PDF) (223 pp, 3.5MB).

U.S. EPA (United States Environmental Protection Agency). 2022a. Data from the National Air Quality: Status and Trends of Key Air Pollutants website. Accessed 2022. https://www.epa.gov/air-trends.

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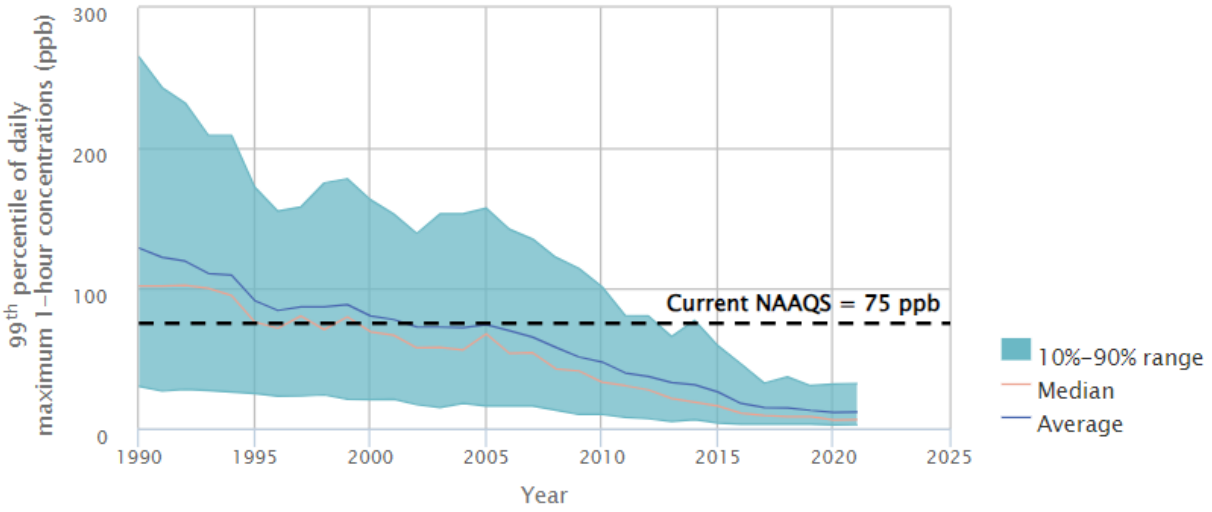
U.S. EPA. 2020. Integrated science assessment for oxides of nitrogen, oxides of sulfur and particulate matter – ecological criteria. EPA/600/R-20/278. Research Triangle Park, NC. https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=349473.

U.S. EPA. 2017. Integrated science assessment for sulfur oxides – health criteria. EPA/600/R-17/451. Research Triangle Park, NC. https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=338596.

U.S. EPA. 1994. Supplement to the second addendum (1986) to air quality criteria for particulate matter and sulfur oxides (1982): Assessment of new findings on sulfur dioxide and acute exposure health effects in asthmatic individuals. EPA/600/FP-93/002. Research Triangle Park, NC. https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=96580.

Exhibit 1. Ambient 1-hour SO_2 concentrations in the U.S., 1990–2021



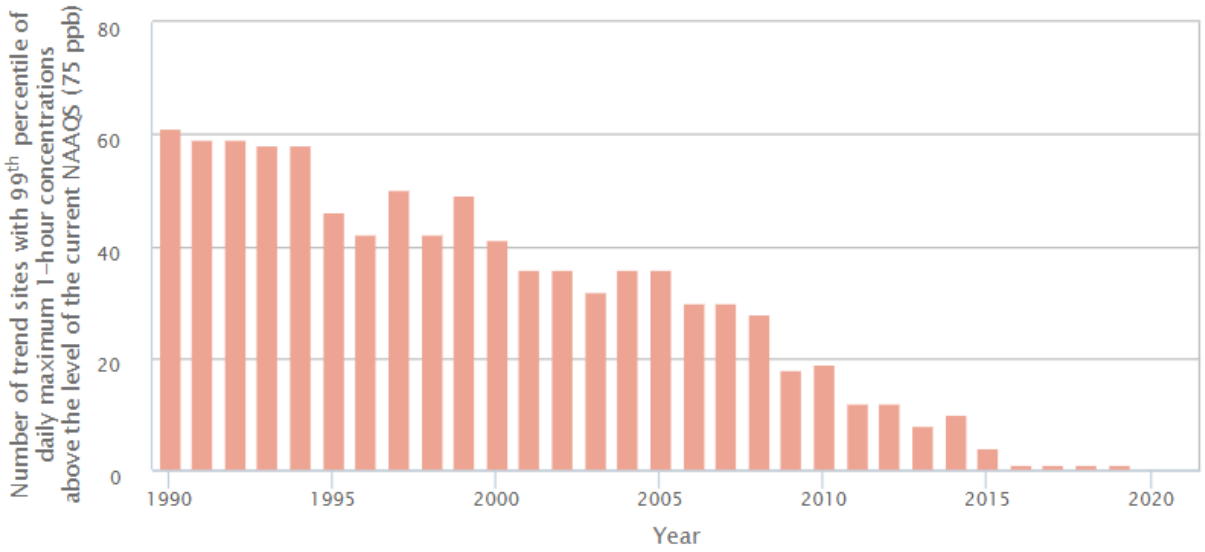
The current 1-hour SO_2 NAAQS was established in 2010 and is shown to provide context for the magnitude of pollutant concentrations. No 1-hour SO_2 NAAQS existed prior to 2010 (U.S. EPA, 2022b).

Coverage: 92 monitoring sites in 81 counties nationwide (out of a total of 368 sites measuring SO_2 in 2021) that have sufficient data to assess SO_2 trends since 1990.

Analysis shows that these trends are statistically significant. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2022a

Exhibit 2. Ambient 1-hour SO_2 concentrations above the level of the current NAAQS in the U.S., 1990–2021



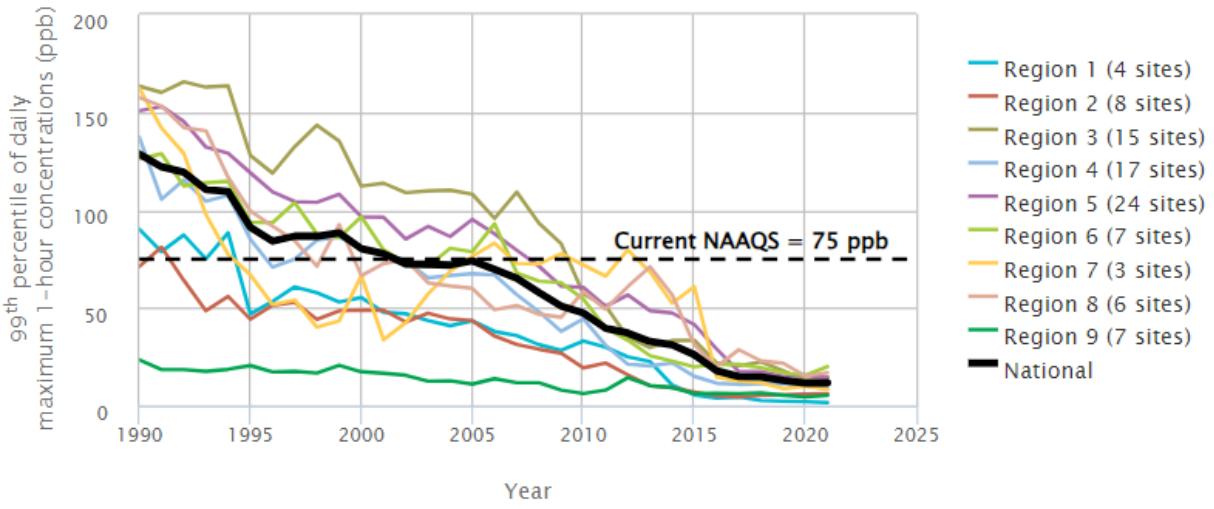
The current 1-hour SO_2 NAAQS was established in 2010 and is shown to provide context for the magnitude of pollutant concentrations. No 1-hour SO_2 NAAQS existed prior to 2010 (U.S. EPA, 2022b).

Coverage: 92 monitoring sites in 81 counties nationwide (out of a total of 368 sites measuring SO_2 in 2021) that have sufficient data to assess SO_2 trends since 1990.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2022a

Exhibit 3. Ambient 1-hour SO_2 concentrations in the contiguous U.S. by EPA Region, 1990–2021



The current 1-hour SO_2 NAAQS was established in 2010 and is shown to provide context for the magnitude of pollutant concentrations. No 1-hour SO_2 NAAQS existed prior to 2010 (U.S. EPA, 2022b).

Coverage: 91 monitoring sites in 80 counties nationwide(out of a total of 368 sites nationwide measuring SO_2 in 2021) that have sufficient data to assess SO_2 trends in the contiguous U.S. since 1990.

States in Region 10 have removed SO_2 monitors in recent years because of low concentrations, and consequently none of this Region's monitoring sites has a complete record dating back to 1990. Thus, no trend line for Region 10 is shown.

Information on the statistical significance of the trends in this exhibit is not currently available. For more information about uncertainty, variability, and statistical analysis, view the technical documentation for this indicator.

Data source: U.S. EPA, 2022a