Indicators and Data

An environmental public health indicator provides information about a population's health status with respect to environmental factors. Tracking Indicators were developed in collaboration with national, state, and local environmental health partners. Here you can access detailed information about each indicator available on the Tracking Network.

Content Area:

View Data Explorer

Air Quality

Indicator:

Current and Historical Air Quality

Type of Indicator	Hazard
Measure(s)	• $PM_{2.5}$: Highest Annual Average Concentration [µg/m^3] (Monitor Data) • $PM_{2.5}$: Highest Annual Average Concentration [µg/m^3] (Monitor + Modeled Data) • $PM_{2.5}$: Daily Air Quality • O_3: Daily Air Quality • CO: Daily Air Quality • SO_2: Daily Air Quality • $PM_{2.5}$: Daily Concentration by Particle Type • $PM_{2.5}$: Daily Percent by Particle Type • $PM_{2.5}$: Hourly Air Quality • O_3: Hourly Air Quality

Derivation of Measure(s)

Derivation of "$PM_{2.5}$: Annual Average Concentration [µg/m^3] (Monitor Data)" Measure

$PM_{2.5}$ concentration data derived from reference-grade air quality monitors were acquired from the U.S. Environmental Protection Agency (EPA) Air Quality System (AQS).

Processing raw data

Daily average $PM_{2.5}$ concentrations (µg/m^3; parameter code "88101") and supplemental data fields (e.g., latitude, longitude, and elevation) for all the monitoring sites across the U.S. are acquired from EPA's AQS Data Mart. The data are obtained only from monitors that are designated as Federal Reference Methods or equivalent. The data include any flagged values associated with exceptional events (high winds, fires, construction, etc.) regardless of concurrence by the EPA Regional Office. EPA retains data from monitors that meet the minimum data completeness criteria set forth in the national ambient air quality standard for $PM_{2.5}$ (40 CFR Part 50, Appendix N). Only the maximum daily concentration is retained at each monitoring site where multiple monitors are located; the pollutant occurrence code (POC) distinguishes monitors at a monitoring site. Annual average concentrations of $PM_{2.5}$ are then calculated using the site-level daily monitoring data. Only monitors that have at least 11 observations for each of the four calendar quarters are considered complete. The annual averages are computed only for monitors that satisfy the completeness criteria.

Derivation of "PM 2.5 Annual Average Concentration [µg/m^3] (Monitor + Modeled Data)" Measure

Many U.S. counties and census tracts do not have sufficient air quality monitoring to derive $PM_{2.5}$ concentration estimates from monitor data alone. To fill these gaps, the monitor data are supplemented with modeled estimates of $PM_{2.5}$ concentrations derived from the Downscaler (DS) model, which is a statistical fusion of monitoring data and Community Multiscale Air Quality modeled outputs.[1] DS modeled estimates are available at census tract centroid-the geographic center of the census tract. Daily county-level modeled estimates are obtained by selecting the maximum value among all the census tracts within each county, and daily census tract-level modeled estimates are obtained by selecting the maximum concentration for each census tract. The "$PM_{2.5}$: Annual Average Concentration (Monitor + Modeled Data)" measure includes monitor data in counties with sufficient monitor observations and DS modeled estimates for locations lacking monitor data. All census tract-level data are modeled data only.

Derivation of "$PM_{2.5}$: Daily Air Quality," " O3: Daily Air Quality," "CO: Daily Air Quality," "SO_2: Daily Air Quality," "$PM_{2.5}$: Daily Concentration by Particle Type," and "PM 2.5 Daily Percent by Particle Type" Measures

The pollutants included have all been designated by the EPA Clean Air Act as "criteria air pollutants," widespread pollutants considered harmful to public health and the environment.[2] EPA has defined six levels of health concern or AQI categories for exposure to these pollutants. The AQI categories include the following:

- Hazardous
- Very Unhealthy
- Unhealthy
- Unhealthy for Sensitive Groups
- Moderate
- Good

These daily measures display the AQI category and the daily concentration from which the level of health concern for each pollutant is derived (e.g., 24-hour mean and 8-hour rolling mean). CDC's Environmental Public Health Tracking Program collaborated with the National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center and EPA to develop these measures.

Two separate datasets underlie these measures. The first is EPA AirNow contour data, which is the default data source for the "$PM_{2.5}$: Daily Air Quality" and "O3: Daily Air Quality" measures. The included AirNow contours contain daily gridded air quality index (AQI) values for the contiguous 48 U.S. states (all states except AK and HI). Contours are derived using inverse distance weighted interpolation, which leverages discrete AQI estimates at EPA AirNow air quality monitors to generate continuous estimates across locations with and without monitors. The gridded AQI estimates are generated at a 0.045o resolution (~5 km continental United States).[3] Average AQI estimates were calculated within each county and census tract by intersecting grid cells with county/tract boundaries and weighting grid cell values based on their proportional overlap with counties/tracts. The AQI category associated with each daily AQI was determined as specified in the EPA technical documentation.[4] Finally, $PM_{2.5}$ and ozone concentrations were calculated from the AQI value using a derivation of the EPA AQI equation that solves for concentration rather than AQI. In areas with few monitor observations, the uncertainty in the interpolated AQI estimates can be very high and, as a result, are not provided by EPA. In cases where more than 25% of a county or census tract does not contain data, no AQI value is reported.

The second dataset, Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2), is an atmospheric reanalysis model spanning 1980 through present-day, that incorporates satellite and in situ observations. All the daily air quality measures incorporate MERRA-2 except "O3: Daily Air Quality." MERRA-2 $PM_{2.5}$ is calculated using the Goddard Earth Observing System, Version 5 model coupled to the Goddard Chemistry, Aerosol, Radiation, and Transport (GOCART). MERRA-2 includes $PM_{2.5}$ constituent species consisting of organic carbon (OC), black carbon (BC), sea salt (SS), dust, and particulate sulfate (SO_4). Surface $PM_{2.5}$ is derived for this analysis as $PM_{2.5} = [DUST_{2.5}] + [SS_{2.5}] + [BC] + [OC] + 1.375 \times [SO_4]$.[5] Surface SO_2 and CO concentrations are calculated using emission inventories and modeled meteorology in GOCART.[5-7]

The MERRA-2 output is publicly released at an hourly resolution on a 0.5° latitude × 0.625° longitude grid (approximately 50 km × 50 km).[8] Using values describing surface level conditions, average hourly values for $PM_{2.5}$ (and constituents), CO, and SO_2 were calculated within each county by intersecting grid cells with county boundaries and weighting values weighted based on their proportional overlap with the county. Coordinated

	Universal Times were converted to the local time of each county centroid, then daily statistics (24-hour mean [$PM_{2.5}$, SO_2], 24-hour maximum [SO_2, NO2], and maximum 8-hour rolling mean [CO]) were calculated from hourly values for each county. The Air Quality Index (AQI) and AQI category associated with each daily MERRA-2 concentration was determined as specified in the EPA technical documentation.[4] Concentrations higher than the AQI scale ("Beyond the AQI") are classified as if they were in the highest AQI category. ***Derivation of "$PM_{2.5}$: Hourly Air Quality" and "O_3: Hourly Air Quality" Measures*** AQI categories, as described above, and concentration values are derived for each county and census tract in the United States using gridded data located within the county or census tract border for each measure. AQI data is from federal reference-grade or equivalent air quality monitors as reported to the U.S. Environmental Protection Agency (EPA). Data is made available through the AirNow website and processed internally through an Azure Data Factory pipeline. Concentration values are calculated from AQI values given by AirNow. Air monitors represent the contiguous United States as well as Alaska and Hawaii. The areas between the monitors use the AirNow Contour interpolations described above to depict those values where there are no monitors. Similar to the Daily Air Quality data, in areas with few monitor observations, the uncertainty in the interpolated AQI estimates can be very high and, as a result, are not provided by EPA. In cases where more than 25% of a county or census tract does not contain data, no AQI value is reported.
Unit	Microgram per cubic meter [µg/m³] ($PM_{2.5}$) Parts per million [ppm] (CO and O_3) Parts per billion [ppb] (SO_2) Air Quality Index [AQI] (O_3 and $PM_{2.5}$)
Geographic Scope	Contiguous United States
Geographic Scale	Census tract, County

Time Period	*$PM_{2.5}$: Annual Average Concentration [µg/m^3] (Monitor Data) and $PM_{2.5}$: Annual Average Concentration [µg/m^3] (Monitor + Modeled Data)* 2001–most recent year of available data *$PM_{2.5}$ Daily Air Quality, O_3: Daily Air Quality:* Previous two months (not including current) and all days in the current month (e.g., January, February, March 1–18) *Note: The MERRA-2 data for the previous month is released around the 20th of the following month (e.g., January data released on February 20th), so MERRA-2 data will be missing for the most recent days in this period.* *CO: Daily Air Quality, SO_2: Daily Air Quality, $PM_{2.5}$: Daily Concentration by Particle Type, $PM_{2.5}$: Daily Percent by Particle Type* Previous two months (not including current month) *Note: The MERRA-2 data for the previous month is released around the 20th of the following month (e.g., January data released on February 20), so data may be missing during the third month of this period.* *$PM_{2.5}$ Hourly Air Quality and O_3: Hourly Air Quality*: Start date will be when data are released in 2024. End date has not been established yet as more testing is needed to see how much space historical hourly data will occupy. *(Will be updated once it is determined how much data will be stored)*
Time Scale	*Daily*: $PM_{2.5}$: Daily Air Quality, O_3: Daily Air Quality, CO: Daily Air Quality, SO_2: Daily Air Quality, $PM_{2.5}$: Daily Concentration by Particle Type, and $PM_{2.5}$: Daily Percent by Particle Type *Calendar year*: $PM_{2.5}$: Highest Annual Average Concentration [µg/m^3] (Monitor Data) and $PM_{2.5}$: Highest Annual Average Concentration [µg/m^3] (Monitor + Modeled Data) *Hourly*: $PM_{2.5}$: Hourly Air Quality and O_3: Hourly Air Quality

Rationale	Air pollution is associated with increased rates of hospitalization for respiratory and cardiovascular conditions, adverse birth outcomes, and lung cancer.[9-11] Research also suggests that air pollution is associated with 100,000 to 200,000 excess deaths annually in the United States and Canada.[12] Human-caused emissions have been linked with 100,000 excess deaths in the United States alone.[13] Additionally, long-term exposure to $PM^{2.5}$ is correlated with a number of adverse health effects.[14,15] Each 10 $\mu g/m^3$ elevation in $PM^{2.5}$ is associated with an 8% increase in lung cancer deaths, a 6% increase in cardiopulmonary deaths, and a 4% increase in death from general causes. The annual average of $PM^{2.5}$ provides an indication of the long-term trends in overall burden, relevant to the long-term health effects.[15] More acute events have also been shown to have wide-reaching effects. As seen with the Canadian wildfires of 2023 where “most areas in the northern hemisphere” had severe $PM_{2.5}$ pollution in the northern United States, hazardous air quality events can affect areas far beyond the local region of the event.[22] In addition to understanding the year-to-year impact of air pollution, being able to track changes in air quality hour by hour can be useful in event planning, emergency response, and assessing the impact of hazardous events. Seeing how air quality is changing in real time is important to understand the best ways to protect those at risk from poor air quality and inform policies and decision making that do so.
Use of the Measure(s)	This indicator can help public health practitioners, policymakers, and the public assess potential exposures to criteria air pollutants across space and over time. Annual average values may shed light on chronic exposures that are associated with cancer, cardiopulmonary diseases, and other negative health outcomes. Daily estimates can be used to track short-term exposures that could result in acute health problems and associated outcomes like emergency department visits and hospitalizations. Hourly estimates can be used for day-to-day planning of outdoor activities and helping at-risk individuals understand when they should avoid going outdoors, if possible. They can also be used in emergency response tracking hazardous air quality events like wildfires or industrial incidents.

Limitations of the Measure(s)	The included measures provide a general indication of the overall patterns and trends in air pollutant concentrations. They do not directly reflect individual exposure. The relationship between outdoor ambient concentrations, indoor air pollution, and individual exposures are topics of ongoing research, and likely vary depending upon pollutants, behavioral patterns, and microenvironments. MERRA-2 data are provided at a coarse geographic resolution (i.e., ~50km x 50km); thus, point sources, plumes, strong gradients, and microenvironments of pollution will not be fully resolved. Studies that have compared MERRA-2 $PM^{2.5}$ with ground-based satellite and aircraft observations have shown that while MERRA-2 $PM^{2.5}$ compares generally well to observations, the agreement is usually better in rural areas because the local emission hotspots in urban/suburban areas are not fully captured by the model.[5,16] Nitrate, which can be an important constituent of $PM^{2.5}$ during winter, is not included in GOCART and thus not included in MERRA-2 estimates. Winter $PM^{2.5}$ concentrations and AQI estimates derived from MERRA-2 data may be underestimated as a result. AirNow observational data are not fully verified or validated. These data are subject to change and should be considered preliminary.[17] Areas farther from monitor points contain data that is interpolated and may not be as accurate for the air quality of the specific location. As mentioned above, in cases where more than 25% of a county or census tract does not contain data, no AQI value is reported. MERRA-2 is a research product and is not intended to support operational activities. This indicator should not be used to assess National Ambient Air Quality Standards compliance.
Data Source(s)	EPA Air Quality System Monitoring Data, State Air Monitoring Data: https://aqs.epa.gov/aqsweb/documents/data_mart_welcome.html EPA Downscaler modeled data: https://www.epa.gov/hesc/rsig-related-downloadable-data-files#faqsd EPA AirNow Contours: https://gispub.epa.gov/airnow/?showgreencontours=true EPA AirNow Air Quality Index (AQI): https://docs.airnowapi.org/ MERRA-2 $PM_{2.5}$ and SO_2 data: https://disc.gsfc.nasa.gov/datasets/M2T1NXAER_5.12.4/summary MERRA-2 CO data: https://disc.gsfc.nasa.gov/datasets/M2T1NXCHM_5.12.4/summary?keywords=tavg1_2d_chm_Nx

Limitations of Data Source(s)

Both the monitor and model-derived data incorporated in this indicator have significant limitations. As a result of these limitations, it is important to consider multiple sources of air pollution data, which, when combined, can provide a more comprehensive and accurate representation of air quality.

Monitored Data

Because monitors are typically situated in fixed locations, they cannot capture the variability in air quality that occurs across entire counties and census tracts. This issue may lead to an overestimation or underestimation of the true air quality depending on where the monitor is located.

Model-derived Data

While modeled data usually contains spatially continuous air quality estimates (unlike monitor data), modeled estimates also have important limitations. Some of the limitations include overly simplistic assumptions that are built into the model (e.g., inverse distance weighting of monitor readings), incomplete and/or static emissions inventories that do not account for the dynamic and varied sources of pollutant emissions, and spatially coarse model outputs that do not capture local variability in pollution levels.

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Page last reviewed: December 10, 2024