Criteria Air Pollutants

Air pollution contributes to a wide variety of adverse health effects. EPA has established national ambient air quality standards (NAAQS) for six of the most common air pollutants—carbon monoxide, lead, ground-level ozone, particulate matter, nitrogen dioxide, and sulfur dioxide—known as "criteria" air pollutants (or simply "criteria pollutants"). The presence of these pollutants in ambient air is generally due to numerous diverse and widespread sources of emissions. The primary NAAQS are set to protect public health. EPA also sets secondary NAAQS to protect public welfare from adverse effects of criteria pollutants, including protection against visibility impairment, or damage to animals, crops, vegetation, or buildings.

As required by the Clean Air Act,[1] EPA periodically conducts comprehensive reviews of the scientific literature on health and welfare effects associated with exposure to the criteria air pollutants.[2-7] The resulting assessments serve as the basis for making regulatory decisions about whether to retain or revise the NAAQS that specify the allowable concentrations of each of these pollutants in the ambient air.[8]

The primary standards are set at a level intended to protect public health, including the health of at-risk populations, with an adequate margin of safety. In selecting a margin of safety, EPA considers such factors as the strengths and limitations of the evidence and related uncertainties, the nature and severity of the health effects, the size of the at-risk populations, and whether discernible thresholds have been identified below which health effects do not occur. In general, for the criteria air pollutants, there is no evidence of discernible thresholds.[2-7]

The Clean Air Act does not require EPA to establish primary NAAQS at a zero-risk level, but rather at a level that reduces risk sufficiently so as to protect public health with an adequate margin of safety. In all NAAQS reviews, EPA gives particular attention to exposures and associated health risks for at-risk populations. Standards include consideration of providing protection for a representative sample of persons comprising at-risk populations rather than to the most susceptible single person in such groups. Even in areas that meet the current standards, individual members of at-risk populations may at times experience health effects related to air pollution.[9-13]

Childhood is often identified as a susceptible lifestage in the NAAQS reviews, because children's lungs and other organ systems are still developing, because they may have a preexisting disease (e.g., asthma), and because they may experience higher exposures due to their activities, including outdoor play.[14-17] Evaluating the effects of criteria air pollutants in children has been a central focus in several recent NAAQS reviews, including revisions of the lead,[18] ozone,[19] and particulate matter[20] standards to strengthen public health protection.

Some of the air quality standards are designed to protect the public from adverse health effects that can occur after being exposed for a short time, such as hours to days. Other standards are designed to protect people from adverse health effects that are associated with long-term exposures (months to years). For example, the standard for ozone is based on pollutant concentrations measured over a short-term period of eight hours. By contrast, the standard for lead considers average concentrations measured over a rolling three-month period. For fine particulate matter ($PM_{2.5}$), annual and 24-hour standards work together to provide protection against effects associated with long- and short-term exposures.

Health effects that have been associated with each of the criteria pollutants are summarized below. This information is drawn primarily from EPA's assessments of the scientific literature for the criteria pollutants.

Ozone

Ground-level ozone forms through the reaction of pollutants emitted by industrial facilities, electric utilities, and motor vehicles; chemicals that are precursors to ozone formation can also be emitted by natural sources, particularly trees and other plants.[2] Ground-level ozone can pose risks to human health, in contrast to the stratospheric ozone layer that protects the earth from harmful wavelengths of solar ultraviolet radiation. Short-term exposure to ground-level ozone can cause a variety of respiratory health effects, including inflammation of the lining of the lungs, reduced lung function, and respiratory symptoms such as cough, wheezing, chest pain, burning in the chest, and shortness of breath.[2,13,21] Ozone exposure can decrease the capacity to perform exercise.[2] Exposure to ozone can also increase susceptibility to respiratory infection. Exposure to ambient concentrations of ozone has been associated with the aggravation of respiratory illnesses such as asthma, emphysema, and bronchitis, leading to increased use of medication, absences from school, doctor and emergency department visits, and hospital admissions. Short-term exposure to ozone is associated with premature mortality.[2] Studies have also found that long-term ozone exposure may contribute to the development of asthma, especially among children with certain genetic susceptibilities and children who frequently exercise outdoors.[22-24] Long-term exposure to ozone can permanently damage lung tissue.

Particulate Matter

Particulate matter (PM) is a generic term for a broad class of chemically and physically diverse substances that exist as discrete particles (liquid droplets or solids) over a wide range of sizes. Particles originate from a variety of man-made stationary and mobile sources, as well as from natural sources such as forest fires. Particles may be emitted directly, or may be formed in the atmosphere by transformations of gaseous emissions such as oxides of sulfur (SO_x), oxides of nitrogen (NO_x), and volatile organic compounds (VOCs). The chemical and physical properties of PM vary greatly with time, region, meteorology, and the source of emissions. For regulatory purposes, EPA distinguishes between categories of particles based on size, and has established standards for fine and coarse particles. PM_{10}, in general terms, is an abbreviation for particles with an aerodynamic diameter less than or equal to 10 micrometers (µm), and represents inhalable particles small enough to penetrate deeply into the lungs (i.e., thoracic particles).[i]

[i] For comparison, the diameter of PM_{10} particles is 1/7 the diameter of an average human hair or less.

PM_{10} is composed of a coarse fraction referred to as $PM_{10\text{-}2.5}$ or as thoracic coarse particles (i.e., particles with an aerodynamic diameter less than or equal to 10 µm and greater than 2.5 µm) and a fine fraction referred to as $PM_{2.5}$ or fine particles (i.e., particles with an aerodynamic diameter less than or equal to 2.5 µm). Thoracic coarse particles are emitted largely as a result of mechanical processes and uncontrolled burning. Important sources include resuspended dust (e.g., resuspended by cars, wind, etc.), industrial processes, construction and demolition operations, residential burning, and wildfires. Fine particles are formed chiefly by combustion processes (e.g., from power plants, gas and diesel engines, wood combustion, and many industrial processes) and by atmospheric reactions of gaseous pollutants.

Although scientific evidence links harmful human health effects with exposures to both fine particles and thoracic coarse particles, the evidence is much stronger for fine particles than for thoracic coarse particles. Effects associated with exposures to both $PM_{2.5}$ and $PM_{10\text{-}2.5}$ include premature mortality, aggravation of respiratory and cardiovascular disease (as indicated by increased hospital and emergency department visits), and changes in sub-clinical indicators of respiratory and cardiac function. Such health effects have been associated with short- and/or long-term exposure to PM.[ii] Exposures to $PM_{2.5}$ are also associated with decreased lung function growth, exacerbation of allergic symptoms, and increased respiratory symptoms.[6] Children, older adults, individuals with preexisting heart and lung disease (including asthma), and persons with lower socioeconomic status are considered to be among the groups most at risk for effects associated with PM exposures.[6] Information is accumulating and currently provides suggestive evidence for associations between long-term $PM_{2.5}$ exposure and developmental effects such as low birth weight and infant mortality due to respiratory causes.[6]

Sulfur Dioxide

Fossil fuel combustion by electrical utilities and industry is the primary source of sulfur dioxide in the United States.[5] People with asthma are especially susceptible to the effects of sulfur dioxide.[5] Short-term exposures of asthmatic individuals to elevated levels of sulfur dioxide while exercising at a moderate level may result in breathing difficulties, accompanied by symptoms such as wheezing, chest tightness, or shortness of breath. Studies also provide consistent evidence of an association between short-term sulfur dioxide exposures and increased respiratory symptoms in children, especially those with asthma or chronic respiratory symptoms. Short-term exposures to sulfur dioxide have also been associated with respiratory-related emergency department visits and hospital admissions, particularly for children and older adults.[5]

Nitrogen Dioxide

Nitric oxide (NO) and nitrogen dioxide (NO_2) are emitted by cars, trucks, buses, power plants, and non-road engines and equipment. Emitted NO is rapidly oxidized into NO_2 in the

[ii] For $PM_{10\text{-}2.5}$, the evidence linking health effects to short-term (e.g., 24-hour) exposures is stronger than the evidence for effects of long-term exposures.

atmosphere.[4] Exposure to nitrogen dioxide has been associated with a variety of health effects, including respiratory symptoms, especially among asthmatic children, and respiratory-related emergency department visits and hospital admissions, particularly for children and older adults.[4]

Lead

Historically, the major source of lead emissions to the air was combustion of leaded gasoline in motor vehicles (such as cars and trucks). Following the elimination of leaded gasoline in the United States by the mid-1990s, the remaining sources of lead air emissions have been industrial sources, including lead smelting and battery recycling operations, and piston-engine small aircraft that use leaded aviation gasoline.[3] Lead accumulates in bones, blood, and soft tissues of the body. Exposure to lead can affect development of the central nervous system in young children, resulting in neurodevelopmental effects such as lowered IQ and behavioral problems.[3]

Carbon Monoxide

Gasoline-fueled vehicles and other on-road and non-road mobile sources are the primary sources of carbon monoxide (CO) in the United States.[7] Exposure to carbon monoxide reduces the capacity of the blood to carry oxygen, thereby decreasing the supply of oxygen to tissues and organs such as the heart. People with several types of heart disease already have a reduced capacity for pumping oxygenated blood to the heart, which can cause them to experience myocardial ischemia (reduced oxygen to the heart), often accompanied by chest pain (angina), when exercising or under increased stress. For these people, short-term CO exposure further affects their body's already compromised ability to respond to the increased oxygen demands of exercise or exertion. Thus people with angina or heart disease are identified as at greatest risk from ambient CO. Other potentially at-risk populations include those with chronic obstructive pulmonary disease, anemia, diabetes, and those in prenatal or elderly lifestages.[7]

The period of fetal development may be one of particular vulnerability for adverse health effects resulting from maternal exposure to some criteria air pollutants. This may occur if maternal exposure to air pollutants is transferred to the fetus during pregnancy; for example, lead and PM have both been shown to cross the placenta and accumulate in fetal tissue during gestation.[3,6] In addition to the findings noted above regarding associations of prenatal PM exposure and adverse birth outcomes (such as low birth weight), limited studies of prenatal exposure to criteria air pollutants have reported that exposure to PM and oxides of nitrogen and sulfur may increase the risk of developing asthma as well as worsen respiratory outcomes among those children that do develop asthma.[25-27] However, it is often difficult to distinguish the effects of prenatal and early childhood exposure because exposure to air pollutants is often very similar during both time periods.

Additional research indicates that exposure to pollution from traffic-related sources, a mix of criteria air pollutants and hazardous air pollutants, may pose particular threats to a child's respiratory system. Many studies have reported a correlation between proximity to traffic (or to traffic-related pollutants) and occurrence of new asthma cases or exacerbation of existing asthma and other respiratory symptoms, including reduced growth of lung function during childhood.[25,28-35] A report by the Health Effects Institute concluded that living close to busy roads appears to be an independent risk factor for the onset of childhood asthma.[36] The same report also concluded that the evidence was "sufficient" to infer a causal association between exposure to traffic-related pollution and exacerbations of asthma in children.[36] Some studies have suggested that traffic-related pollutants may contribute to the development of allergic disease, either by affecting the immune response directly or by increasing the concentration or biological activity of the allergens themselves.[37-39]

Many of the effects of criteria air pollutants on children can be reduced by limiting outdoor activities on high pollution days.[40] Such avoidance measures can have their own adverse impacts on children's health when they reduce opportunities for play and exercise.

The following three indicators provide different perspectives on children's exposures to criteria air pollutants. Indicator E1 summarizes the percentages of children over time living in counties where measured pollutant concentrations were above the levels of the short- and/or long-term standards for each of the criteria air pollutants.[iii] Indicator E2 provides additional detail on the frequency with which pollutant concentrations were above the levels of the ozone and 24-hour $PM_{2.5}$ standards in one year (2017). Indicator E3 focuses on the frequency with which children were exposed to good, moderate, or unhealthy daily air quality, based on EPA's Air Quality Index. All three indicators have been revised since the publication of *America's Children and the Environment, Third Edition* (January 2013) to incorporate updates to air quality and census data from 1999 to 2009 and to add new air quality and census data from 2010 to 2017.

[iii] For standards with averaging times less than or equal to 24 hours, Indicator E1 includes counties where concentrations were above the level of the standards at least one day per year.

Indicator E1: Percentage of children ages 0 to 17 years living in counties with pollutant concentrations above the levels of the current air quality standards, 1999–2017

Indicator E2: Percentage of children ages 0 to 17 years living in counties with 8-hour ozone and 24-hour PM2.5 concentrations above the levels of air quality standards, by frequency of occurrence, 2017

About the Indicators: Indicators E1 and E2 present the percentage of children living in counties where measured ambient concentrations of criteria pollutants were greater than the levels of the Clean Air Act health-based standards at any time during a year. Indicator E1 presents results for each criteria pollutant for each year. Indicator E2 presents more detailed information on the frequency with which measured ambient ozone and fine particle ($PM_{2.5}$) concentrations were greater than the levels of the short-term standards for ozone and $PM_{2.5}$ in 2016. The air quality data used in these indicators are from an EPA database that compiles measurements of pollutants in ambient air from around the country each year.

Air Quality System

State and local environmental agencies that monitor air quality submit their data to EPA. EPA compiles the monitoring data in the national EPA Air Quality System (AQS) database.[iv] AQS contains some monitoring data from the late 1950s and early 1960s, but there is not an appreciable amount of data for lead until 1970, sulfur dioxide until 1971, nitrogen dioxide until 1974, carbon monoxide and ozone until 1975, and PM_{10} until 1987. AQS also contains monitoring data for $PM_{2.5}$ beginning in 1999; $PM_{2.5}$ was measured only infrequently prior to 1999. Indicators E1 and E2 are derived from analysis of air pollution data in AQS.

Air Quality Standards and Concentrations Above the Levels of the Standards

Under the Clean Air Act, EPA has established National Ambient Air Quality Standards (NAAQS) for carbon monoxide, lead, ground-level ozone, particulate matter, nitrogen dioxide, and sulfur dioxide. There are four basic elements of NAAQS that together serve to define each standard: the definition of the pollutant,[v] the averaging time (e.g., annual average or 24-hour average), the level, and the form of the standard (which defines the air quality statistic compared to the level of the standard in determining whether an area attains the standard—for example, the 24-hour $PM_{2.5}$ standard uses 98th percentile concentrations, averaged over three years). These

[iv] Information on the AQS database is available at http://www.epa.gov/airdata/.

[v] In the development of NAAQS, the term "indicator" defines the chemical species or mixture that is to be measured in determining whether an area attains the standard. To avoid confusion with the way in which "indicator" is used throughout *America's Children and the Environment*, the term is not used in the following paragraphs, except to refer to the ACE criteria pollutant indicators E1, E2, and E3.

elements must be considered collectively in evaluating the health and welfare protection afforded by the NAAQS.

Indicators E1 and E2 consider the first three elements of a NAAQS: the definition of the pollutant, the averaging time, and the level of the standard. The indicators present percentages of children living in areas with pollutant concentrations above the level of the current standards, using the appropriate averaging time. The indicators do not consider the form of the standard, which often includes considerations for multiple years of air quality data (e.g., 3 years), adjustments for missing data and less-than daily monitoring, and consideration for the frequency and magnitude with which a standard level is exceeded. In considering the form of the NAAQS, these standards are defined to allow some days to be above the level of the standard while limiting the extent to which they are above the level of the standard. Furthermore, determinations of attainment with the NAAQS are generally based on air quality averaged over multiple years. Therefore, air quality in any one-year period, as presented in Indicators E1 and E2, cannot be used to characterize whether air quality does or does not meet the NAAQS. The analyses for Indicators E1 and E2 therefore differ from the analyses used by EPA for the designation of "nonattainment areas" (locations that have not attained the standard) for regulatory compliance purposes.[41] Nonetheless, looking at air quality within a given year, or across many individual years, provides important public health information.

For each of the years 1999–2017, Indicator E1 reflects comparisons of the monitoring data with the levels of the current NAAQS. The indicator for all years therefore incorporates the 2006 revision of the level of the 24-hour $PM_{2.5}$ standard[20] from 65 µg/m^3 to 35 µg/m^3; the 2008 revision of the level of the eight-hour ozone standard[19] from 0.08 ppm to 0.075 ppm, followed by the 2015 revision of the level of the eight-hour ozone standard from 0.075 ppm to 0.070 ppm;[vi] the 2008 revision of the level of the three-month standard[18] for lead from 1.5 µg/m^3 to 0.15 µg/m^3; the establishment of a new one-hour standard[42] for nitrogen dioxide with a level of 100 ppb, issued in 2010; the establishment of a new one-hour standard[43] for sulfur dioxide with a level of 75 ppb, issued in 2010; and the 2012 revision of the level of the annual $PM_{2.5}$ standard from 15 µg/m^3 to 12 µg/m^3.[vii] Table 1 in the Methods documentation shows the criteria pollutant levels used for the purpose of this indicator to determine whether concentrations were above the standard level for each pollutant.[viii]

[vi] See https://www.epa.gov/ozone-pollution/2015-national-ambient-air-quality-standards-naaqs-ozone for more information.

[vii] See http://www.gpo.gov/fdsys/pkg/FR-2013-01-15/pdf/2012-30946.pdf.

[viii] All criteria pollutants are included in Indicator E1, but for some pollutants with multiple primary standards (reflecting different averaging times), only a single standard is included. For CO only the 8-hour standard is included, because the 1-hour standard is rarely exceeded. For NO_2 only the 1-hour standard is included, because the annual standard is rarely exceeded.

NAAQS are intended to provide public health protection, including providing protection for at-risk populations, with an adequate margin of safety.[ix] EPA's selection of the current standards for ozone, nitrogen dioxide, and sulfur dioxide were intended to protect against respiratory effects in at-risk populations, including children. EPA's selection of the current standards for particulate matter was based primarily on concerns for mortality and cardiovascular effects, as well as respiratory effects. EPA's selection of the current standard for lead was intended to reduce risks of neurodevelopmental effects in children. The standard for carbon monoxide is intended primarily to protect against potential effects in people with heart disease. The Clean Air Act does not require the EPA Administrator to establish a primary NAAQS at a zero-risk level or at background concentration levels, but rather at a level that reduces risk sufficiently so as to protect health with an adequate margin of safety. However, pollutant concentrations that are lower than the levels of the standards are not necessarily without risk for all individuals. No risk-free level of exposure has been determined for any of the criteria pollutants.

Data Presented in the Indicators

Indicator E1 presents the percentage of children living in counties with measured pollutant concentrations above the level of a NAAQS for any of the criteria pollutants, for each year from 1999–2017.[x] The indicator begins with data for 1999 because, as noted above, this was the first year of widespread monitoring for $PM_{2.5}$. In addition to presenting data for each of the criteria pollutants separately, the indicator also presents the percentage of children living in counties with measured concentrations above the level of a NAAQS for any criteria air pollutant (i.e., exceedance of standard levels for one or more criteria air pollutants).

Indicator E1 does not differentiate between counties in which concentrations were above standard levels frequently or by a large margin, and areas in which concentrations were above standard levels only rarely or by a small margin. It also assumes that air pollutant concentrations are consistent throughout a county. Some pollutants, such as ozone and $PM_{2.5}$, tend to be well dispersed and generally have limited spatial variation within a county, whereas other pollutants such as lead might have higher concentrations within relatively smaller areas. The indicator is based on concentrations of individual pollutants compared with individual standard levels, and does not reflect any combined effect of exposure to multiple criteria pollutants.

All children living in all counties are considered in the indicator; however, many counties do not have air pollution monitors. Monitoring networks are typically designed to focus on areas that are expected to have higher concentrations or that have larger populations. If any of the

[ix] The legislative history of section 109 of the Clean Air Act indicates that a primary standard is to be set at "the maximum permissible ambient air level… which will protect the health of an [sensitive] group of the population," and that for this purpose, "reference should be made to a representative sample of persons comprising the sensitive group rather than to a single person in such a group" S. Rep. No. 91-1196, 91st Cong., 2d Sess. 10 (1970).
[x] For standards with averaging times less than or equal to 24 hours, Indicator E1 includes counties where concentrations were above the level of the standards at least one day per year.

unmonitored counties have concentrations above the levels of the NAAQS, Indicator E1 will understate the percentage of children living in counties with concentrations above standard levels. The indicator thus represents the percentage of all children who lived in counties with confirmed pollutant concentrations above the levels of the standards each year, where confirmation is provided by a valid monitor value in that year. The percentages of children in unmonitored counties in 2017 range from about 30% for ozone and $PM_{2.5}$ to about 50% for PM_{10}, carbon monoxide, sulfur dioxide and nitrogen dioxide, and about 90% for lead.[xi] These percentages have been fairly stable or shown small increasing or decreasing trends from 1999–2017. For lead, the percentage was about 80% from 1999 to 2009, dropped to about 75% from 2010 to 2014 due to increased monitoring requirements, and then increased to 85% and above from 2015 to 2017. Those limited changes in monitoring mean that there are some small changes in data available for calculation of the indicator over time.

The supplemental data tables E1a and E1b show the percentage of children living in counties with concentrations above the levels of the air quality standards in 2017 by race/ethnicity (Table E1a) and family income (Table E1b).

Ambient concentrations were more frequently above the levels of the 8-hour ozone and the 24-hour $PM_{2.5}$ standards than the levels of the standards for other criteria pollutants. Indicator E2 provides information on the frequency with which concentrations were above the levels of these two standards in 2017. Counties were classified by the number of days during 2017 that measured pollutant concentrations were above the levels of the 8-hour ozone and 24-hour $PM_{2.5}$ standards. This indicator, therefore, shows the percentage of children living in counties in which concentrations were measured above the levels of these two short-term standards a few times, as well as the percentage in counties with more frequent measurements above the levels of the standards. The percentage of children in counties without monitors for these two pollutants in 2017 is also shown in Indicator E2. The data table for this indicator (Table E2) also provides the same information for each year 1999–2017, using the current level of the standards for each year's calculation.

Values in this indicator may be understated due to the fact that most monitors do not operate every day. Ozone monitors operate daily during the ozone season, which lasts from 6 to 7 months in most locations but can be between 5 and 12 months (based on ranges of dates when high temperatures associated with high ozone concentrations may occur). $PM_{2.5}$ monitors operate year round, but may collect measurements daily or every third or every sixth day. EPA requires areas that measure concentrations within 5% of the 24-hour $PM_{2.5}$ standard to monitor daily. Monitors for other criteria pollutants operate year round.

Statistical Testing

Statistical analysis has been applied to Indicator E1 to evaluate trends over time in the percentage of children living in counties with concentrations above the standard levels each

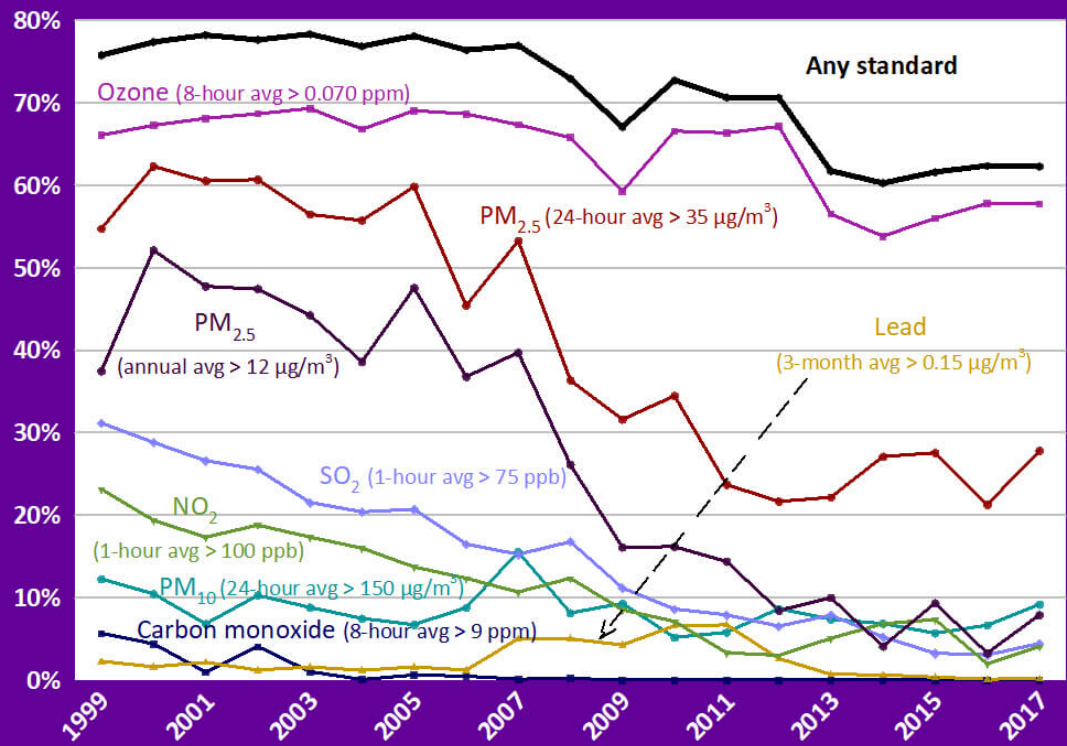
[xi] EPA issued increased requirements for lead monitoring in December 2010.[44]

year. These analyses use a 5% significance level, meaning that a conclusion of statistical significance is made only when there is no more than a 5% probability that the observed trend occurred by chance ($p \leq 0.05$). The statistical analysis of trends over time is dependent on how the annual values vary as well as on the number of annual values. For example, the statistical test is more likely to detect a trend when data have been obtained over a longer period. It should be noted that conducting statistical testing for multiple air quality standards increases the probability that some trends identified as statistically significant may actually have occurred by chance.

A finding of statistical significance is useful for determining that an observed trend was unlikely to have occurred by chance. However, a determination of statistical significance by itself does not convey information about the magnitude of the increase or decrease in indicator values. Furthermore, a lack of statistical significance means only that occurrence by chance cannot be ruled out. Thus, a conclusion about statistical significance is only part of the information that should be considered when determining the public health implications of trends.

Indicator E1

Percentage of children ages 0 to 17 years living in counties with pollutant concentrations above the levels of the current air quality standards, 1999-2017



Data: U.S. Environmental Protection Agency, Office of Air and Radiation, Air Quality System

Note: Values shown represent measured pollutant concentrations above the levels of air quality standards at least once during a calendar year. Measuring concentrations above the level of a standard is not equivalent to violating the standard. The level of a standard may be exceeded on multiple days before the exceedance is considered a violation of the standard.

America's Children and the Environment, Third Edition, Updated August 2019

Data characterization

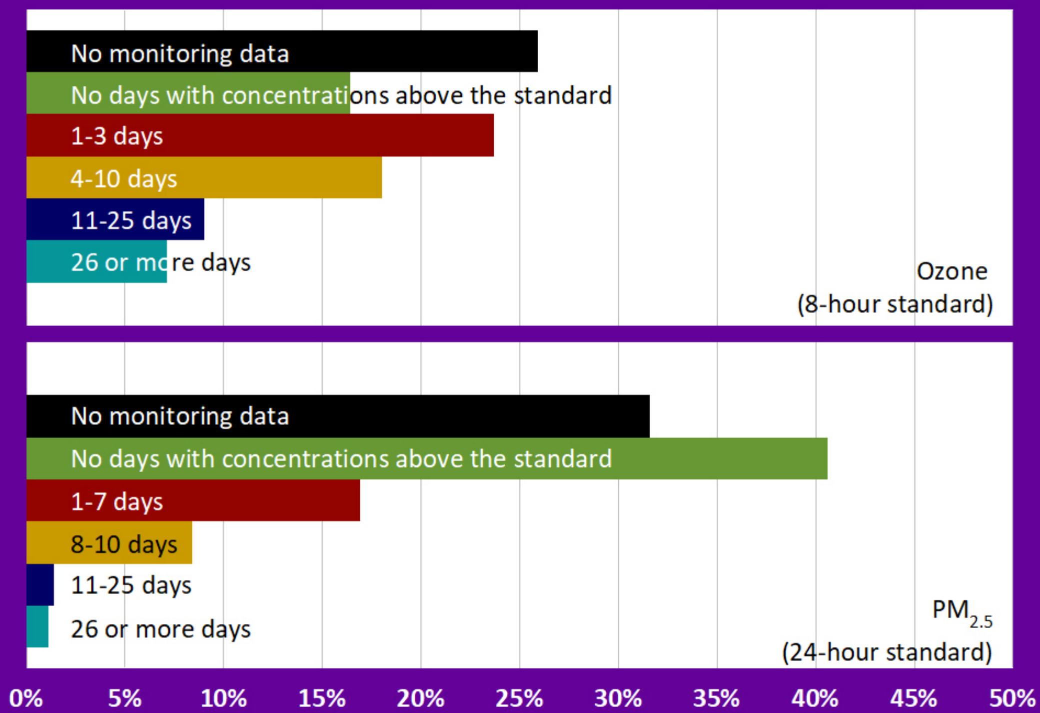
- Data for this indicator are obtained from EPA's database of air quality monitoring measurements.
- Air pollution monitors are placed in locations throughout the country, with an emphasis on areas expected to have higher pollutant concentrations or that have larger populations. Not all counties in the United States have air pollution monitors, and the number of counties with monitors has changed over time.
- Monitors generally tend to stay in the same location over many years, but there may be some limited changes in the number or location of monitors providing data from year to year.

- From 1999 to 2017, the proportion of children living in counties with measured pollutant concentrations above the levels of one or more national ambient air quality standards decreased from 76% to 62%. This includes both concentrations above the level of any current short-term standard at least once during the year as well as average concentrations above the level of any current long-term standards.

- The decreasing trend over the years 1999–2017 was statistically significant.
- From 1999–2017, the percentage of children living in counties with measured ozone concentrations above the level of the current 8-hour ozone standard at least one day during the year decreased from 66% to 58%.
- The decreasing trend for ozone over the years 1999–2017 was statistically significant.
- From 1999–2017, the percentage of children living in counties with measured $PM_{2.5}$ concentrations above the level of the current 24-hour $PM_{2.5}$ standard at least once per year increased from 55% in 1999 to 62% in 2000 and then decreased to 28% in 2017. Over the same years, the percentage of children living in counties with a measured annual average concentration above the level of the current annual $PM_{2.5}$ standard increased from 37% in 1999 to 52% in 2000 and then declined to 8% in 2017.
- The decreasing trends for $PM_{2.5}$ were statistically significant.
- From 1999–2017, the percentage of children living in counties with measured sulfur dioxide concentrations above the level of the current one-hour standard for sulfur dioxide at least one day per year declined from 31% to 4%. Over the same years, the percentage of children living in counties with measured concentrations above the level of the current one-hour standard for nitrogen dioxide at least one day per year decreased from 23% to 4%.
- The decreasing trends for both sulfur dioxide and nitrogen dioxide were statistically significant.
- In each year since 1999, between 0.1 and 7% of children lived in counties with measured ambient lead concentrations above the level of the current three-month standard for lead. In 2017, 4 counties with 0.2% of U.S. children reported concentrations above the level of the three-month standard for lead.
- In 2017, 9% of children lived in counties with measured PM_{10} concentrations above the level of the current 24-hour standard for PM_{10} at least one day per year, and no children lived in counties with measured concentrations above the level of the current standard for carbon monoxide.

Indicator E2

Percentage of children ages 0 to 17 years living in counties with 8-hour ozone and 24-hour $PM_{2.5}$ concentrations above the levels of air quality standards, by frequency of occurrence, 2017



Data: U.S. Environmental Protection Agency, Office of Air and Radiation, Air Quality System

Note: EPA periodically reviews air quality standards and may change them based on updated scientific findings. Measuring concentrations above the level of a standard is not equivalent to violating the standard. The level of a standard may be exceeded on multiple days before the exceedance is considered a violation of the standard. See text for additional discussion.

America's Children and the Environment, Third Edition, Updated August 2019

Data characterization

- Data for this indicator are obtained from EPA's database of air quality monitoring measurements.
- Air pollution monitors are placed in locations throughout the country, with an emphasis on areas expected to have higher pollutant concentrations or that have larger populations. Not all counties in the United States have air pollution monitors.
- Some air pollution monitors do not operate every day, so some days with pollutant concentrations above the levels of the air quality standards may not be identified.
- In 2017, 26% of children lived in counties with no monitoring data for ozone, and 32% lived in counties with no monitoring data for PM2.5.

- In 2017, 7% of children lived in counties with measured ozone concentrations above the level of the 8-hour ozone standard on more than 25 days. An additional 9% of children lived in counties with measured concentrations above the level of the ozone standard between 11 and 25 days, and 18% of children lived in counties where concentrations were above the level of the standard between 4 and 10 days.

- In 2017, 1% of children lived in counties with measured $PM_{2.5}$ concentrations above the level of the 24-hour $PM_{2.5}$ standard on more than 25 days. One percent of children lived in counties with measured concentrations above the level of this standard between 11 and 25 days, and an additional 8% of children lived in counties with measured concentrations above the level of the 24-hour $PM_{2.5}$ standard between 8 and 10 days.
- In 1999, 37% of children lived in counties with measured ozone concentrations above the level of the current 8-hour ozone standard on more than 25 days. An additional 20% of children lived in counties with measured concentrations above the level of the ozone standard between 11 and 25 days, and 8% of children lived in counties where concentrations were above the level of the standard between 4 and 10 days. (See Table E2.)
- In 1999, 6% of children lived in counties with measured $PM_{2.5}$ concentrations above the level of the current 24-hour $PM_{2.5}$ standard more than 25 days. An additional 11% of children lived in counties with measured concentrations above the level of this standard between 11 and 25 days, and 1% of children lived in counties with measured concentrations above the level of the 24-hour $PM_{2.5}$ standard between 8 and 10 days. (See Table E2.)

Indicator E3: Percentage of days with good, moderate, or unhealthy air quality for children ages 0 to 17 years, 1999–2017

About the Indicator: Indicator E3 presents data from EPA's Air Quality Index (AQI). The AQI produces a rating of the air quality for each county on each day, considering all monitoring results available on that day for carbon monoxide, ozone, nitrogen dioxide, particulate matter, and sulfur dioxide. Air quality in each county is considered to be "good," "moderate," or "unhealthy" based on comparison of the monitored pollutant concentrations to breakpoints defined by the AQI. The indicator is calculated by considering the number of children in counties with each rating for each day of the year, then summing the number of children for all days in the year.

Air Quality Index

EPA's Air Quality Index (AQI)[xii] represents air quality for each individual day and is widely reported in newspapers and other media outlets in metropolitan areas. The AQI is based on daily measurements of up to five of the six air quality criteria pollutants (carbon monoxide, ozone, nitrogen dioxide, particulate matter, and sulfur dioxide). The standard for lead is not included in the AQI because it requires averaging concentrations over a three-month period, and it can take several weeks to collect and analyze lead samples.

The specific pollutants considered in the AQI for each metropolitan area depend on the pollutants monitored in that area each day. Each pollutant concentration is given a value on a scale relative to the air quality standard for that pollutant. The daily AQI is based on the single pollutant with the highest index value that day. An AQI value of 100 corresponds to the level of the short-term (e.g., daily or hourly) NAAQS for each criteria pollutant. An AQI value of 50 is defined either as the level of the annual standard, if one has been established (e.g., $PM_{2.5}$, NO_2), or as a concentration equal to one-half the value of the short-term standard used to define an index value of 100 (e.g., CO).

EPA has divided the AQI scale into categories. Air quality is considered "good" (referred to as "code green") if the AQI is between 0 and 50, posing little or no risk. Air quality is considered "moderate" ("code yellow") if the AQI is between 51 and 100. Some pollutants at this level may present a moderate health concern for a small number of individuals. Air quality is considered "unhealthy for sensitive groups" if the AQI is between 101 and 150 (referred to as "code orange"). On code orange days, members of at-risk populations such as children may experience health effects, but the rest of the general population is unlikely to be affected. Air quality is considered "unhealthy" if the AQI is between 151 and 200 ("code red"). The general population may begin to experience health effects, and members of at-risk populations may experience more serious health effects. Values of 201 to 300 are designated as "very unhealthy" ("code purple"), while values of 301 to 500 are considered "hazardous" ("code maroon"). Decisions about the pollutant concentrations at which to set the various AQI

[xii] Available at http://www.airnow.gov/.

breakpoints that delineate the various AQI categories draw directly from the underlying health information that supports the reviews of the NAAQS.

Data Presented in the Indicator

Indicator E3 is based on the reported AQI for counties in the United States. EPA calculates an AQI value each day in each county for five major air pollutants regulated by the Clean Air Act: ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide. The highest of these pollutant-specific AQI values is reported as the county's AQI value for that day.

Indicator E3 was developed by reviewing the AQI designation for each day for each county and weighting the daily designations by the number of children living in each county. The calculation, therefore, is a summation of the AQI values for all children in the United States, based on county of residence, for each day of the year. For example, the number of days of good air quality during the year is counted up for each child in the population based on the daily air quality in the county where they live. The overall indicator reports the percentage of children's days in each year considered to be of good (AQI 0–50; code green), moderate (AQI 51–100; code yellow), or unhealthy (AQI greater than 100; codes orange, red, purple, and maroon combined) air quality.[xiii] The percentage of children's days with no AQI value available (representing the absence of monitoring data) are also reported in Indicator E3.

Whereas Indicator E1 presents an annual analysis of counties in which concentrations were above the level of a standard for a pollutant, the AQI data used in Indicator E3 are based on the concentrations for all pollutants for which an AQI has been established in each county over the course of a year. The E3 method uses data on the air quality category for each day, rather than simply reporting whether a county ever exceeds the standard for each pollutant during the year. However, the AQI method has some limitations. The AQI is based on the single pollutant with the highest value for each day; it does not reflect any combined effect of multiple pollutants or the effects of pollutants that were not measured on a given day.

Indicator E3 starts in 1999 because this was the first year of widespread monitoring for $PM_{2.5}$. The indicator uses a consistent set of pollutant concentrations to define good, moderate, or unhealthy air quality for all years shown, 1999–2017.

Tables E3a and E3b show the percentage of children's days of exposure to good, moderate, or unhealthy air quality in 2017 by race/ethnicity (Table E3a) and family income (Table E3b). These calculations do not account for any possible variation in air quality within a county, and thus may not fully reflect the variability in air quality among children of different race/ethnicity and income.

[xiii] As discussed above, an AQI value of 100 generally corresponds to the level of a short-term national ambient air quality standard. When AQI values are above 100, air quality is considered to be unhealthy—at first for certain sensitive groups of people (101 to 150), then for everyone as AQI values get higher.

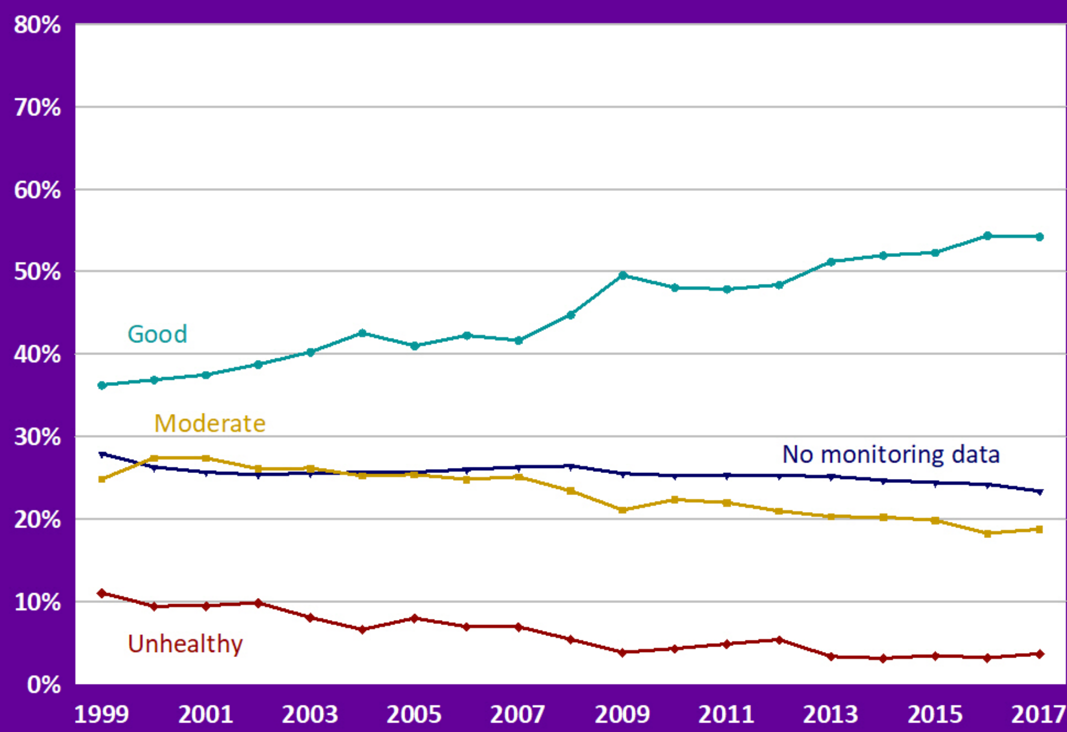
Statistical Testing

Statistical analysis has been applied to Indicator E3 to evaluate trends over time in the percentage of children's days of with good, moderate, or unhealthy air quality. These analyses use a 5% significance level, meaning that a conclusion of statistical significance is made only when there is no more than a 5% probability that the observed trend occurred by chance ($p \leq 0.05$). The statistical analysis of trends over time is dependent on how the annual values vary as well as on the number of annual values. For example, the statistical test is more likely to detect a trend when data have been obtained over a longer period.

A finding of statistical significance is useful for determining that an observed trend was unlikely to have occurred by chance. However, a determination of statistical significance trend over time does not imply anything about the magnitude of the increase or decrease in indicator values. Furthermore, a lack of statistical significance means only that occurrence by chance cannot be ruled out. Thus, a conclusion about statistical significance is only part of the information that should be considered when determining the public health implications of trends.

Indicator E3

Percentage of days with good, moderate, or unhealthy air quality for children ages 0 to 17 years, 1999-2017



Data: U.S. Environmental Protection Agency, Office of Air and Radiation, Air Quality System

Note: Good, moderate, and unhealthy air quality are defined using EPA's Air Quality Index (AQI). The health information that supports EPA's periodic reviews of the air quality standards informs decisions on the AQI breakpoints and may change based on updated scientific findings. See text for additional discussion.

America's Children and the Environment, Third Edition, Updated August 2019

Data characterization

- Data for this indicator are obtained from EPA's database of daily Air Quality Index (AQI) values for each county in the United States.
- Air pollution monitors are placed in locations throughout the country, with an emphasis on areas expected to have higher pollutant concentrations or that have larger populations.
- AQI values are based on daily monitoring data for up to five criteria air pollutants. Some counties do not have monitors, and some monitors do not operate every day, so some days do not have AQI values.
- For this indicator, the available monitoring data are used to assign a value of "good," "moderate," "unhealthy," or "no monitoring data" for each day in each U.S. county.

- The percentage of children's days that were designated as having "unhealthy" air quality decreased from 11% in 1999 to 4% in 2017. The percentage of children's days with "good" air quality increased from 36% in 1999 to 54% in 2017. The percentage of children's days with "moderate" air quality decreased from 25% in 1999 to 19% in 2017.

- The 1999 to 2017 trends in "unhealthy," "good," and "moderate" air quality days were statistically significant.

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