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Air pollution success stories in the United States: The value of long-term observations

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ABSTRACT

We summarize past examples of the use of science to document the effectiveness of policy in air quality management. Our goal is to inform public discourse amidst attempts to negate the relevance and value of scientific data and fact-based analysis in favor of partisan opinion and ideology. Although air quality is fundamental to environmental and human health, air pollution has degraded natural systems and reduced economic and cultural benefits and services. The quality of air and fresh water across much of the United States vastly improved in recent decades in response to the Clean Air and Clean Water Acts and other rules and policies. We point to recently observed decreases in air pollution and its effects attributable to policy that have been informed by environmental monitoring and research. Examples include decreased environmental lead contamination due to the elimination of tetraethyl lead from gasoline, decreases in tropospheric ozone, improved visibility from reduced airborne particulate matter, declines in atmospheric sulfur and nitrogen deposition that acidify the environment and declines in atmospheric mercury and subsequent bioaccumulation of toxic methyl mercury. Pollutant reductions have provided environmental, social, and economic benefits, highlighting the urgency to apply these lessons to address current critical environmental issues such as emissions of greenhouse gases. These examples underscore the important role of data from long-term research and monitoring as part of fact-based decision-making in environmental policy.

1. Introduction

Air and water quality have been long-standing concerns in the United States and elsewhere. However, evidence-based policy decisions and management have contributed to large improvements in environmental conditions over the recent past. Socio-economic, environmental, and public health benefits have been substantial. Across the United States, the quality of air and fresh water has vastly improved, mainly in response to the Clean Air and Clean Water Acts enacted nearly a half century ago. We have recently observed decreases in air pollution attributable to policy that have been informed by environmental monitoring and research. Examples illustrated here include decreased lead contamination due to the elimination of tetraethyl lead from gasoline, decreased ground-level (tropospheric) ozone, improved visibility and human health from reduced airborne particulate matter, declines in atmospheric sulfur and nitrogen deposition that acidify the environment, and declines in toxic mercury. None of these environmental stressors have been completely eliminated and further progress is needed, but all have been measurably reduced in the United States and elsewhere by evidence-based policy decisions. As we highlight here

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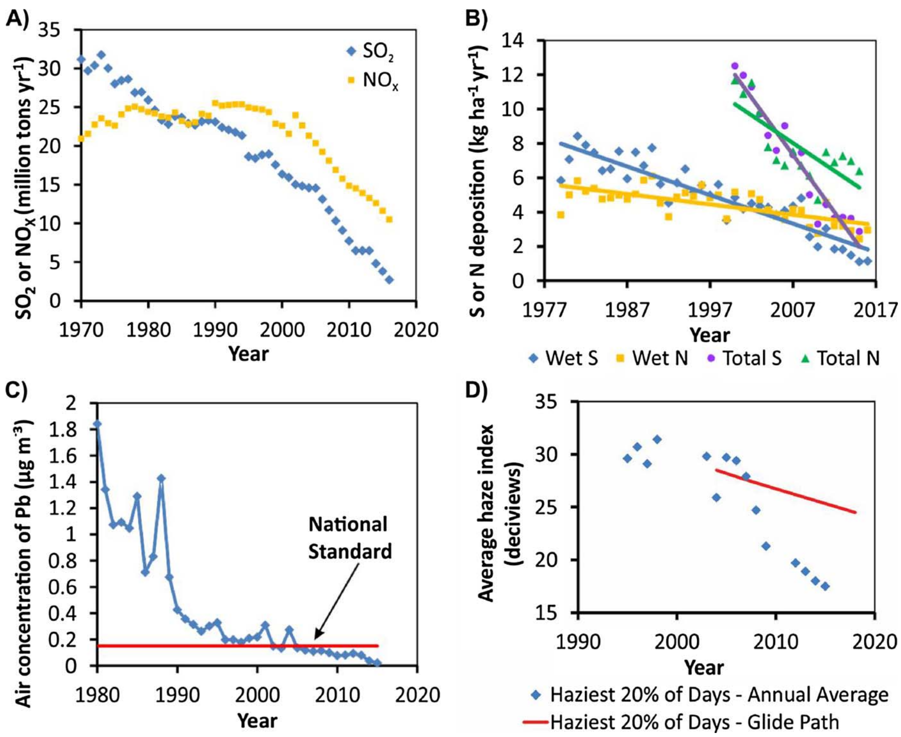

Fig. 1. Example time series trends in air pollution levels.
A) National emissions of oxidized nitrogen (NO_x) and sulfur dioxide (SO_2) throughout the U.S. from U.S. EPA's National Emissions Inventory.
B) Annual wet deposition of sulfur (S) and nitrogen (N) since 1979 as measured by the National Atmospheric Deposition Program at Huntington Forest, NY and total (wet plus dry) deposition estimated by Schwede and Lear (2014) since 2000 at Big Moose Lake, NY.
C) Mean air concentration of lead (Pb) measured at eight United States monitoring sites from 1980 to 2015. Data are annual maximum 3-month averages from U.S. EPA (https://www.epa.gov/air-trends/lead-trends).
D) Annual average haze index on the haziest 20% of days at Shining Rock Wilderness, NC, since 1995, plus the glide path of continuous improvement needed to meet the Regional Haze Rule requirement of zero human-caused haze by the year 2064. Data source: https://webcam.srs.fs.fed.us/graphs/vis/index.php?wilderness=shinin.

using examples across different regions and pollutants, substantial ecological and human health improvements and economic benefits to society have been realized. Many other examples are available, including regional measurements and model simulations that represent responses at dozens or hundreds of locations (cf., U.S. EPA 2013; Fakhraei et al., 2014; Driscoll et al., 2016; Fakhraei et al., 2016; Holmes and Likens, 2016; Sullivan, 2017). Evaluation of air pollution control policies and thresholds has been guided by advances in process science, monitoring data, and model development and application. Long-term measurements such as are reported here capture the accrued benefits of advances in science and technology that have supported the development of evidence-based regulations and public policy.

2. Analysis

2.1. Emissions and atmospheric deposition of oxides of sulfur and nitrogen

There have been pronounced decreases in emissions and atmospheric deposition of sulfur and nitrogen oxide pollutants since the 1970s, especially throughout the eastern United States (Fig. 1A and B), although legacy damages have been observed. Some pollutants are not readily sequestered, and chemical recovery can take many decades or longer. Sulfur and nitrogen forms of acidifying air pollution are typically lower in the western states, with notable exceptions where nitrogen emissions and associated tropospheric ozone remain high, such as in parts of southern California. Higher air pollution impacts in the eastern United States are driven, in part, by the human population density and use of fossil fuels for energy and transportation in eastern and midwestern states and the dominant west to east direction of prevailing winds across the continent (U.S. EPA, 2009a).

Emissions of sulfur, mainly from coal-burning power plants, and oxidized nitrogen, originating mainly from motor vehicles and power plants, have decreased continuously and substantially across the United States in recent decades (Fig. 1A). While changes in technology and the economy undoubtedly contribute to these trends, reductions in sulfur and nitrogen pollution have been primarily attributed to emissions controls associated with the Clean Air Act, its amendments, and other rules and legislation (U.S. EPA, 2009a).

The National Atmospheric Deposition Program (http://nadp.sws.uiuc.edu/) is an example of high quality environmental monitoring that informs evidence-based decision making. This program, and others, was established in response to enactment and requirements of the Clean Air Act. It includes 270 wet deposition monitoring locations across the United States. Multi-decadal precipitation chemistry trends at an example Adirondack Mountain, NY, lake monitoring site that has been used for research on the effects of acidic deposition have shown marked decreases in sulfur and nitrogen deposition (Fig. 1B) in response to decreases in sulfur dioxide and nitrogen oxide emissions. Dry deposition of air pollutants is more difficult to measure, and is often estimated from models based on monitored air quality and environmental parameters. Estimated total wet plus dry deposition of sulfur and nitrogen have decreased by more than half across much of the eastern United States since monitoring began in the 1970s (Fig. 1B).

2.2. Emissions and atmospheric deposition of mercury

Mercury is emitted into the atmosphere from a variety of sources, particularly coal-fired power plants. Mercury emissions from power plants, incinerators, industry, mining, and biomass burning can travel long distances before being deposited to the surface of the earth. In the United States, mercury emissions and deposition decreased substantially from a peak in the 1980s (Drevnick et al., 2012; Zhang et al., 2016), while in many other countries mercury emissions have continued to increase (Pirrone et al., 2010).

2.3. Acidification

Atmospheric deposition of nitrogen, and especially sulfur, contributes to acidification of soils and surface waters that can harm terrestrial and aquatic life. Nitrogen deposition also contributes to aquatic and terrestrial eutrophication. Key acidification metrics for lakes and streams include the sulfate concentration (largely from atmospheric deposition), the concentration of toxic dissolved inorganic aluminum (dissolved from soil), pH (or hydrogen ion concentration), and acid neutralizing capacity. For example, the acidity of precipitation at Hubbard Brook Experimental Forest, NH, as reflected by the hydrogen