

The role of air quality management programs in improving public health: A brief synopsis

John J. Vandenberg, PhD *Research Triangle Park, NC*

Observations of adverse effects of air pollution on public health, illustrated by the London smog events in the 1950s, led to legislation in the United States requiring development of federal, state, and local air quality management programs. The implementation of management programs has resulted in significant reductions in air pollutant emissions from stationary and mobile sources and hence their ambient concentrations and associated health risks. Evidence of benefits from improvements in air quality can be identified from studies in which rapid changes in air quality have occurred. Health risk assessment and benefits estimates also can be predictive, resulting in mean estimates of avoided mortality in excess of many thousands of cases per year as a result of implementation of air quality management programs in the United States. (*J Allergy Clin Immunol* 2005;115:334-6.)

Key words: Air pollution, Clean Air Act, public health

The goal of environmental regulations is to protect public health and the environment from the adverse effects of pollution. Observations of significant air pollution effects on public health, illustrated by the London smog events in the 1950s, led to the initiation of a series of expanding legislative requirements embodied initially in the Air Pollution Control Act of 1955. This act was subsequently replaced by the Clean Air Act (CAA) of 1963, which was amended in 1967, 1970, 1977, and 1990 to reflect an expansion of air quality management issues, approaches, and congressional direction. The CAA requires the development of federal, state, and local air quality management programs. The implementation of these programs has led to significant reductions in the emissions from stationary and mobile sources of most major air pollutants (eg, carbon monoxide, sulfur dioxide, and lead) or their precursors and their ambient concentrations. Efforts in the United States to reduce air pollution

Abbreviations used

CAA: Clean Air Act

EPA: Environmental Protection Agency

NAAQS: National ambient air quality standards

PM: Particulate matter

SIP: State implementation plan

have resulted in significant benefits to public health in the form of reduced disease and mortality.¹ In this article a framework for air quality management is presented to provide context for the air quality standards that have been promulgated to protect public health. The adequacy of these standards is addressed by reviewing studies targeted to determine, in human populations, reductions in mortality and disease burden associated with air quality improvements, and through prospective assessment of the public health benefits estimated to result from air quality management practices.

The CAA is based on a partnership of federal, state, local, and tribal authorities, with the states having primary responsibility for attaining and maintaining acceptable air quality. The federal role principally is targeted to provide cross-cutting science and technology support to the states, which, in turn, can delegate management responsibilities to local agencies. States can implement programs and establish standards that are more stringent than federal requirements, but these standards must not be less stringent.

The implementation of most air quality programs in the United States is based on a framework for air quality management that includes 5 basic steps. In the first step the goal of the program is identified in terms of acceptable air quality (ie, identification of an ambient level that protects public health with an adequate margin of safety or an acceptable health risk level). Decisions on setting a standard, and hence the standard's adequacy, reside with the administrator of the US Environmental Protection Agency (EPA).

In the second step ambient air quality conditions are evaluated to determine whether the standards are being met. Data from an extensive network of ambient monitors are evaluated to determine whether an air shed or designated area is in attainment with the standards (see www.epa.gov/airs). In addition, the sources of pollutants are identified, and emissions inventories are created on the basis of approaches, such as emissions measurements (eg,

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Reprint requests: John J. Vandenberg, PhD, Office of Research and Development (B248), US Environmental Protection Agency, Research Triangle Park, NC 27711. E-mail: Vandenberg.john@epa.gov.

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stack tests), mass balance approaches, and engineering judgment.

In the third step the states develop strategies to attain the standards in areas not currently in attainment, to maintain acceptable air quality in areas that meet the standards, and to prevent significant deterioration of air quality in areas that are particularly valued (eg, national parks). Data from the monitoring network and the emissions inventories and air quality models are used to estimate reductions needed to attain the standards and to identify sources that might be most important to address through control strategies. State implementation plans (SIP) embody the strategic approaches, which might include technology requirements or emissions limits on stationary sources and inspection and emissions testing for automobiles.

In the fourth step the states implement the SIP requirements through state regulations and enforcement and compliance programs. The federal role is to review and approve the SIPs and to audit and provide oversight of state actions to implement their programs.

In the last step trends in emissions and air quality are evaluated to determine whether progress toward the goals is being made and to support identification and implementation of program adjustments and new data collection.

These 5 steps are iterative, with air quality management program implementation, evaluation, and adjustment being key steps of a continuous process. The standards-setting process by which the goals are established is not influenced by the success of management programs in meeting the standards but rather is based on protection of health (and the environment). Difficulty in attaining the standards and cost considerations are not inputs to the process of setting standards, although such features can be considered as states evaluate options during their SIP development.

The US EPA has promulgated national ambient air quality standards (NAAQS) to protect public health, with an adequate margin of safety for 6 air pollutants known to arise from numerous and diverse mobile and stationary sources. These pollutants are commonly known as the *criteria air pollutants* and are carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter (PM), and sulfur dioxide. The PM standards are further separated by size into standards for PM of less than 10 μm in diameter (PM_{10}) and for PM of less than 2.5 μm in diameter ($\text{PM}_{2.5}$). Setting a NAAQS requires the selection of a pollutant indicator (eg, ozone), averaging time (eg, 24-hour and annual), form (eg, fourth highest level monitored), level (eg, 0.08 ppm), and other conditions (eg, data completeness criteria to ensure adequate monitoring data are evaluated). The CAA requires that the EPA reviews and, if necessary, revises each standard every 5 years. A key feature of the review of air quality standards is the incorporation of expert peer review by the Clean Air Scientific Advisory Committee of EPA's Science Advisory Board.

It is difficult to directly evaluate the adequacy and effect of current air quality standards. This difficulty stems from the relatively low but widespread risks posed by air

pollution and the gradual improvement in air quality resulting from air quality management programs. In contrast to the London smog events of the 1950s, wherein the relationship between daily increases in mortality with increased levels of air pollution was obvious, it is rarely possible to directly associate pollutant decreases with public health benefits.² In a few instances, however, rapid changes and improvements in air quality have been found to be associated with observations of changes and improvements in health measures. A few recent examples in which dramatic changes in ambient air conditions were associated with significant changes in health outcomes include the Utah Valley³ and Dublin, Ireland.⁴

The Utah Valley, in Utah, United States, is an air shed dominated by a single large integrated steel mill, with wintertime inversions resulting in frequent PM_{10} excursions of greater than the 24-hour NAAQS when the facility was in operation, occasionally exceeding 300 $\mu\text{g}/\text{m}^3$ (well above the 24-hour standard of 150 $\mu\text{g}/\text{m}^3$). Because of a labor problem, the mill closed during a 13-month period in the late 1980s, including the winter of 1986-1987, and then it reopened. Concentrations of PM_{10} when the mill was closed averaged 35 $\mu\text{g}/\text{m}^3$ compared with 50 $\mu\text{g}/\text{m}^3$ when the mill was open. Children's respiratory hospital admissions in the Utah Valley from before, during, and after the facility shutdown provided strong evidence of a decrease in childhood illness resulting from the lower PM_{10} concentrations when the mill was closed.³ Notably, the epidemiology findings from this intervention situation were extended through clinical and animal toxicology studies. Filters from ambient air monitors in the Utah Valley were obtained for the period before, during, and after the mill closure, and soluble extracts were obtained and used in bronchial instillation studies in adult human volunteers⁵ and in intratracheal instillation in rats.⁶ Markers of pulmonary inflammation (eg, neutrophil influx and cytokines) were evaluated. These controlled exposures in both human subjects and rats demonstrated that the soluble extracts when the mill was closed were far less potent producers of an inflammatory response than the extracts when the mill was open. This set of studies provides strong and contemporary evidence that changes in air pollution might result in changes in the health of exposed populations.

In Dublin, Ireland, a ban on the sale of coal took place in September 1990.⁴ Evaluating this intervention, researchers conducted statistical analyses of standardized mortality rates before and after the effective date of the ban on coal sales and air pollution levels. Pollution levels decreased significantly, approximately 70% for black smoke, which is a measure of PM, and approximately 34% for sulfur dioxide. Age-standardized mortality rates were significantly reduced for total (−5.7%), cardiovascular (−10.3%), and respiratory (−15.5%) mortality after the ban but not for mortality from other causes, indicating a benefit associated with improvement in air pollution indices.

In each of the cases above, air pollution levels decreased over a short time period, and indicators of public

health were observed to show a decrease in air pollution–relevant markers, such as mortality, respiratory or cardiovascular hospital admissions, or medication use, indicating the benefits of the improved air quality. Relatively few other such studies have been conducted (eg, an intervention study in Hong Kong⁷), and this is an area of active research interest (see, for example, <http://www.healtheffects.org/>).

Health risk assessment methods also have been used to estimate the potential health benefits of air quality control programs. A comprehensive evaluation of the human health effects of the criteria air pollutants and the health benefits resulting from improved air quality was published in 1999.¹ In this EPA assessment the difference in expected incidence of adverse health effects, including mortality, chronic illness, hospitalization for respiratory and cardiovascular disease, and other adverse health effects, between 1990 and 2010 resulting from reductions in pollutant emissions and human exposures to the criteria pollutants caused by implementation of the 1990 CAA amendments in the continental United States was estimated. The method required a number of assumptions, and there are many uncertainties regarding changes in air quality estimated to be associated with control program implementation, in model formulation and population exposure estimation, and in selection and application of concentration-response functions. The assessment resulted in a central estimate of avoided mortality caused by reductions in PM exposures of 23,000 avoided deaths in 2010, with 5% to 95% bounds from 14,000 to 32,000 avoided deaths, respectively. Extending these results to estimate the economic benefits of air pollution control activities resulted in an estimate of \$68 billion in annual benefits to public health (in 2000 dollars) in the form of reduced disease and mortality.¹

Air quality management programs have been developed to respond to concerns about the public health effects of air pollutant exposures. A framework for air quality management has been constructed and used in the United States to organize the methods, models, and data needed to set acceptable exposure levels, to identify current air quality conditions and needed reductions to attain and maintain

acceptable air quality, to identify and target sources contributing to unacceptable air quality, and to implement programs and track air quality changes over time. An evaluation of the benefits of these efforts can be difficult because of the gradual implementation of most management programs. In some cases, however, opportunities exist to evaluate rapid improvements in air quality, and studies of these events indicate the potentially large role of air pollution improvements on public health. Furthermore, prospective health risk assessment of the implementation of the 1990 amendments to the CAA suggest that in 2010 there might be many thousands of cases of avoided mortality in the continental United States, with significant economic benefits. A challenge for the future is to identify additional opportunities to assess the full set of potential health improvements brought about by air quality management programs. Identifying and conducting highest-priority health effects, exposure, atmospheric sciences, emissions characterization, risk assessment, and control technology research fosters the most effective air quality management and public health protection.

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