HOW HEALTH RELATED ISSUES ARE LIKELY TO DRIVE DISPERSION MODELING OVER THE NEXT DECADE

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BACKGROUND

President Nixon signed the U.S. Clean Air Act on the final day of 1970. This Act established the Environmental Protection Agency (EPA) by consolidating a number of offices and activities initially distributed across several U.S. government departments. At the signing, Nixon paid tribute to his predecessor, Theodore Roosevelt, who had spoken so eloquently over sixty years previously "about a goal of clean air, clean water, and open spaces for the future generations of America" (*John Woolley and Gerhard Peters).*

At the start of 1970, Nixon had stated that "this would be the year of the environment." Throughout 1970 Congress wrestled with developing the Clean Air Act. The efforts were fruitful and on the last day of the year, the bill passed both the Senate and House of Representatives, and was signed by the President.

With the momentum and vision for U.S. environmental regulation and policy provided by the highest U.S. official, an evolutionary path based on several key concepts and questions was born — How clean is "clean"? How safe is "safe"? How much is enough? This paper explores this evolutionary path from a historical perspective and sheds light on the future of air quality assessments, in particular, air quality modeling and techniques.

INTRODUCTION

The Clean Air Quality Act of 1967 required the National Air Pollution Control Administration (one of the offices consolidated into the EPA by the 1970 Act) to "develop and issue to the States such criteria of air quality that …. may be requisite for the protection of public health and welfare." A series of documents was produced summarizing the effects of sulfur dioxide (AP-50), nitrogen oxides (AP-84), hydrocarbons (AP-64), and photochemical oxidants (AP-63). Based on these documents, EPA proposed the National Ambient Air Quality Standards (NAAQS) in early 1971 and published the final NAAQS values in November. Surprisingly, the values for sulfur dioxide and nitrogen oxides have not changed over 36 years, but major changes have been made in the standards for particulate matter and ozone due to new information revealed in numerous studies on their effects on health.

EVOLUTION OF DISPERSION MODELS AND TECHNIQUES

Early dispersion models were used to analyze the effects of a single source; however, as modeling capabilities developed and computers advanced, models could handle multiple sources by about 1976. Coincidentally, the NAAQS documents tended to examine the effect of pollutants independently, with the exception of the interaction of sulfur dioxides and particulate matter, not the interacting effects of all pollutants.

Looking back, these early models were relatively simple, almost crude, and served a good purpose at the time. Similarly, the ideas of what constituted clean air were straight-forward. Much has happened over the past 30 to 35 years and our level of understanding and sophistication has increased enormously. Over the past 30 years, several generations of models have been born, corresponding to numerous scientific advancements. One of the first major improvements, about 1980, was the addition of structure downwash. Various convective turbulence models were then developed starting about 1986. Some of these early versions included names such as TUPOS and HPDM. In Europe, ADMS and OML were developed. With more and more development and advancement, the EPA formed a steering committee in 1991 to guide the development of AERMOD. Early versions of AERMOD were available about 1996 and 1997. In addition, the initial numerical models were developed to analyze photochemical reactions over short distances. In time, models such as CALPUFF, Models-3 CMAQ, and EMEP grew to include atmospheric reactions over longer range transport distances.

THE "BRIGHT LINE" OF AIR QUALITY

While model development was proceeding, epidemiologists were studying the effects of air pollution on human health. When the NAAQS document was written, the thought was that a "bright line" existed between bad and good. If concentrations were greater than the bright line value, the air would be unsafe for humans; if concentrations were less than the value, then the air would be safe. Lawyers who assist in driving air quality enforcement have benefited from this idea. However, the continuing plethora of studies has pointed to many subtle health effects and the fact that a bright line does not exist, but rather an enormous range of values in air quality impacts.

In recent years, arguments have centered on whether to set a NAAQS value at 15, or 13, or 12, with lower values protecting larger populations and higher values protecting fewer. These standards have become less scientifically based and more politicized. Standards are based on questions, including: Should a reasonable attainable standard be set now and then tightened later? Would it be better to set a tight standard now so that it is technology-forcing? If there are areas that have unsatisfactory air outside, should some measures be used to limit construction or population in these areas? Moreover, how often should the standards be allowed to be exceeded?

This last question leads to a broad range of answers. Since air quality measurements are, by their nature, statistical, an allowance should be made for the standard to be exceeded. Otherwise the ambient standard would become the standard for in-stack concentrations. If a one-hour standard is allowed to be exceeded once annually, the second highest value is about 80% of the highest value, based on examining a number of Q-Q plots. If a one–hour standard is allowed to be exceeded 24 times annually, then the 25th highest value (complying 99.73% of the time) is about 55% of the highest value. Thus, the selection of the form of the standard affects more than the idea of what is "safe" because it affects which values are chosen.

DRIVING ASPECTS FOR BETTER AIR QUALITY

Going back to the comments made by President Nixon, he focused not just on clean air and clean water but also on the open spaces and, by implication, visibility. This idea was embodied in the 1967 Act that spoke about the welfare, not just health, of a population. So where has visibility been regulated?

In a paper presented at the 10th Harmonization Conference, we described the sources of visibility impairment and how the U.S. was beginning to regulate visibility. Briefly, visibility is impaired when gas-phase reactions occur and ammonia interacts with sulfates and nitrates causing molecules to agglomerate. In addition, these new substances tend to be hygroscopic and grow to light-scattering dimensions, generally a little less than one micron. This occurs especially in more humid air. Unlike ozone that reacts in a matter of five to ten hours, the visibility impairing reactions can take as long as a day or two to be completed. Elemental carbon particles, thought to come primarily from diesel engines and the combustion of biogenic materials, often are found in these agglomerated particles. Thus, a solution to improving visibility includes further controlling sulfur dioxide, nitrogen oxides, ammonia, and elemental carbon emissions; a path now being taken. Visibility may seem to be an aesthetic pleasure, but the visibility impairing pollutants are largely the same pollutants regulated by the NAAQS, just regulated differently.

In September 2005, the EU Commission published an Impact Assessment on the Thematic Strategy on Air Pollution. This document was accepted by the Council on 15 March 2006. The substance of the Assessment was that fine particle matter ($PM_{2.5}$) from air pollution is responsible for much of the loss in statistical life expectancy in Europe. In contrast, ozone was found to be responsible for a much smaller fraction of hastened mortality. The document describes the interactions of sulfates, nitrates, and ammonia and their role in forming "secondary particles" or "secondary aerosols." The document calls for more stringent measures to control nitrogen oxides, ammonia, and sulfur oxides as a means to both extend the lives of Europeans as well as reduce the acid deposition and eutrophication. Although the document mentions visibility once (p. 162), it states that this impact is not currently quantifiable. On the other hand, the effects of emission reductions associated with the Kyoto Protocol compliance are limited to a "tax" of between €12 and €20 per tonne of CO_2. Above this amount, other means of compliance, including sequestration, are projected to be used.

Europe has not focused on the welfare aspect of visibility. Instead, much of the European effort has been directed to anthropogenic sources that are thought to contribute to global climate change. The focus is to create an extremely energy efficient economy with minimum carbon emissions. A side benefit that Europe will gain is that energy efficiency creates improved visibility as well as extended statistical lives. In contrast, the U.S. approach to climate change is to invest capital in demonstration projects to define technologies and the associated costs of carbon capture and storage In addition, investment capital has provided much improved methods of methane capture. On a weight basis, methane is 21 times as potent a greenhouse gas as carbon dioxide.

Despite different approaches, the U.S. and Europe are moving towards a more common goal — placing less emphasis on individual sources and more emphasis on aggregations of sources whose complex emissions produce unacceptable air quality, whether air quality is defined by health effects or visibility. The difficulty arises with the availability of data, including the inadequacy, or even secrecy, of emission inventories. Finally, differing forms of standards may impair the ability to interpret results across national boundaries.

What does this all mean to the dispersion modeling community in the decade ahead and where is model use and model development likely to be focused?

First, we will continue to model new and modified sources for their local impacts. We are unlikely to spend much effort modeling emission reductions from individual sources. Thus, models that address single sources using "representative" meteorological data from a single station are unlikely to be emphasized.

Second, ozone and fine particulate matter will likely continue to be the subject of great scrutiny and yet, both are produced, for the most part, by atmospheric reactions. Hence, efforts will be focused on developing models that can accurately simulate atmospheric chemistry.

Third, we are also likely to model metropolitan areas as well as large regions — domains including hundreds or even over one thousand kilometers — in an effort to understand the sources and control strategies that may help improve air quality. To conduct the latter, models that accept meteorological data, not from a single representative site but from a network of observations, will be required. The observations will use assimilated data produced by global fluid dynamic simulations since these are the best way to assess wind trajectories more than 300 meters above the surface. The use of such gridded meteorological data, coupled with accurate emission inventories, chemical transformation simulations, and sophisticated deposition and depletion algorithms, will form the basis for estimating realistic dispersion and transformation in the decade ahead.

Fourth, epidemiologists will continue their research and sort out health effects from pollutants in the atmosphere. It is likely that new health and welfare based relationships will be found that will cause a shift in our present approaches.

CONCLUSION

Models that use a single source of meteorological data, such as AERMOD, OML, or ADMS, are likely to see incremental improvement, but it appears that we are nearing the end of their development as aggregations of sources displace individual sources as the main area for air pollution control.

Greater applications will involve models, such as CALPUFF, SCIPUFF, CAMx, CMAQ, or the Unified EMEP model, which draw on sophisticated treatment of various scientific aspects, including the use of gridded meteorological data, atmospheric reactions, and long-range transport. These models can be used in support of policy development for regional air quality issues.

The development and validation of such large domain models will require teamwork and sharing of resources from several institutions. The future of dispersion modeling will move away from small teams toiling away in a research center or university to teams of scientists from several countries sharing ideas on improving models to help the world create healthier air for everyone.

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