AIR POLLUTION
at the Local, Regional, and Global Scale

A summary of the 2014 Air Pollution Workshop
in Guadalajara, Mexico.

Substantial progress has been made in reducing air pollution in North America and Europe since the 1st Air Pollution Workshop, held at The Pennsylvania State University in 1969. However, elevated levels of atmospheric pollutants remain a major problem across the globe. Combined with climate change, we require multidisciplinary research and decision-making to verify and manage the complex interactions and effects of atmospheric pollutants on ecosystems and society. Following is a summary of the topics discussed during the 46th Air Pollution Workshop held earlier this year at the University of Guadalajara in Mexico.
The 46th Air Pollution Workshop, held April 8–10, 2014, in Guadalajara, Mexico, coincided with the 50th anniversary of the Schools of Agriculture and the Veterinary Sciences at the University of Guadalajara. The workshop drew scientists and graduate students from Mexico, India, the United States, Canada, and Europe to discuss current and emerging air quality issues. Workshop sessions covered the following themes: Spatial and temporal aspects of air quality, greenhouse gases (GHGs), and global change; direct and indirect effects of atmospheric nitrogen (N); air quality and climate change interactions with ecosystems, biodiversity, and food security; technology transfer between developed and developing countries; and public policies and perceptions on air quality and climate change.

Despite substantial efforts to reduce air pollutants at the local, regional, and global scale, ecosystems and people remain exposed to harmful levels of atmospheric pollution. Although between 1990 and 2006 sulfur dioxide (SO₂) emissions were reduced by 36% in the United States and Canada, and by 70% within the European Union—thanks to policies such as the U.S. Clean Air Act, the Canada–U.S. Air Quality Agreement, and the United Nations Economic Commission for Europe’s (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP) and its Gothenburg Protocol—emissions of reactive N compounds have remained high throughout much of the world.

The consequences of increased emissions and deposition of reactive N are striking as reactive N compounds contribute to biodiversity and ecosystem structure, and function via both acidification and eutrophication. Although not well publicized, human activities now perturb the global N cycle to a greater extent than those of carbon (C) and sulfur (S). While tropospheric carbon dioxide (CO₂) has increased ~30% from pre-industrial levels, atmospheric deposition of N has more than tripled.

Trends in Air Quality

Despite decreases in SO₂ emissions, in 2012 much of the Eastern United States received precipitation with a pH < 5.1 (i.e., acidic precipitation). This is partly due to persistently elevated sulfate (SO₄²⁻) deposition originating from local and regional SO₂ sources. Although S emissions were the main driver of acid deposition and the acidification of soils and freshwater in the 1970s and early 1990s, and (c) 2050.
and 1980s, reactive N compounds, particularly ammonia (NH₃), are playing an ever-increasing role.⁷⁻⁹ High exposures to NH₃ are more likely to produce visible foliar injury than exposures to nitrogen oxides (NOₓ). NH₃ also causes imbalanced plant nutrition, decreased growth, reduced frost hardiness, changes in root mycorrhizae, and increased insect susceptibility.¹⁰ Finally, excess N can be leached (primarily as nitrate [NO₃⁻]) into ground- and surface-water contributing to eutrophication and acidification.⁴⁻⁹,¹⁰

Global emissions of reactive N compounds and subsequent deposition are expected to increase further in coming years. However, the major sources, form and magnitude of N emissions vary across space and time (see Figure 1). For example, the largest anthropogenic sources of NOₓ are related to fossil fuel combustion,³ while animal and crop agriculture contribute ~60% of global atmospheric NH₃ emissions and up to 90% in the United States.⁹⁻¹¹ Moreover, catalytic converters in today’s automobiles contribute substantially to atmospheric NH₃.¹²,¹³ Agriculture is also an important source of GHGs, contributing ~60% of nitrous oxide (N₂O) and ~50% of methane (CH₄) emissions globally,¹⁴ and ~72% of N₂O and ~29% of CH₄ emissions in the United States in 2006.¹⁵

As NOₓ emissions act as precursors for surface ozone (O₃), the negative effects of elevated N deposition are accompanied by those of O₃. While peak O₃ concentrations have declined in both North America and Europe, O₃ distributions are becoming narrower due to an upward trend in background concentrations from increases in global precursors, particularly from South and East Asia. Based on future emission scenarios, the European threshold for plant damage (40 parts per billion, ppb) will be exceeded over most continents by 2100.¹⁶ Moreover, O₃ formation may be further enhanced under a sunnier and warming climate. Numerical modeling of the impacts of a changing climate on future O₃ concentrations revealed that the O₃ season will be extended, and peak O₃ levels will increase by as much as 8 ppb in the Northeast United States.¹⁷ Ground-level O₃ also acts as a GHG adding complexity to O₃ assessment and management.¹⁸

Tools for Managing Air Pollution
The O₃ sensitivity of plants varies markedly depending on genotype. Visible O₃ injuries, first noted in California in 1944,¹⁹ are relatively easy to diagnose and most chronic (species-specific) injury types observed in the field have been validated by controlled fumigation experiments.¹⁰ These readily observable symptoms provide opportunities for utilizing sensitive plants as bioindicators of multiple pollutants, providing an economical means of identifying high pollution areas. Plants may be introduced to a system, exist naturally, indicate disturbance, accumulate pollutants, or indicate ecosystem changes.²¹

Atmospheric monitoring is the most effective tool for identifying air quality problems or non-compliance with regulatory standards. However, air monitoring, especially for multiple pollutants over large geographical areas, is costly. Passive samplers provide a relatively inexpensive means of measuring contaminant exposure over a defined period and offer an alternative or supplement to active monitoring networks.²²

Air quality models are often used to supplement measurements, or to provide estimates of pollutant concentrations at a high spatial resolution over a large area. Models are useful tools for air quality management and policy-making, and can help resolve issues presented by interactions between air pollutants and climate change.

Science must play an active and decisive role in the development of air pollution and emissions policies. A combination of techniques, such as bioindicator plants, passive samplers, and dispersion modeling, can be especially effective in informing policy decisions, particularly in developing economies such as Mexico.

Challenges for Future Air Quality Research and Policy
Despite current knowledge on the negative effects of air pollutants and climate change, and measures taken to reduce emissions, air pollution remains a global problem. Due to the transboundary nature of air pollutants, local and national policies are sometimes
unsuccesful in improving local air quality, and policy
of a more global scale is required to manage issues,
such as the long-range transport of Asian particulate matter (PM), mercury, SO$_2$, NO$_x$, and ammonium (NH$_4$)$_2$ to western North America; or the transport of O$_3$ from North America to Europe. Although global policies (e.g., UNECE’s CLRTAP) have been effective in reducing multiple pollutants across some international borders, national air pollution regulations have addressed air quality issues one pollutant at a time. However, air pollutants do not exist in isolation, and in combination can act additively, antagonistically or synergistically, having a range of effects. This complexity combined with additional disturbances and climate change, presents the greatest challenge facing the makers of air quality policy today.

According to a 1992 definition provided by the Air & Waste Management Association, ‘clean air’ is “represented by air that is essentially odorless, tasteless, looks clear and has no measurable short- or long-term effects on people, animals, or the environment”. Although air pollution continues to be a major issue in the developed and developing countries, we have come a long way from the first Air Pollution Workshop that was held 45 years ago. 

References
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