Assessment Abstract and Chapter Synopses

Technical Challenges of Risk- and Results-Based Multipollutant Air Quality Management

This NARSTO Assessment discusses the technical issues of moving from the current pollutant-by-pollutant approach to air quality management to an integrated air quality management paradigm that addresses multiple pollutants and sources, considers overall risk reduction as a principal decision metric, and uses retrospective analysis (also known as accountability) as a tool for assessing and improving air quality management. The assessment concludes that there are theoretical advantages to an integrated, risk-based approach, but achieving it will be an evolutionary process. This evolution will require improvements in exposure assessment and health and ecosystem response, changes in monitoring approaches to support these assessments, and it will require considerable advance planning to select appropriate accountability metrics and obtain the information needed to evaluate them.

The Assessment provides a review of risk assessment methodologies, environmental and emissions information, air quality measurements, modeling, and the underlying knowledge that supports risk assessment and accountability. The problem of how global-scale changes in emissions and changes in climate will affect future air quality management is also addressed. The Assessment reviews how closely past air quality management actions have met the objectives of risk- and results-based air quality management, and it concludes with recommendations on how a transition to such an approach could be facilitated.

Summary: Technical Challenges of Risk- and Results-Based Multipollutant Air Quality Management: A Summary for Policy Makers (W.T. Pennell)
This chapter provides an executive summary of the assessment with emphasis on its conclusions and recommendations.

Chapter 1: Introduction
This chapter describes the purpose of this assessment, and it provides a brief overview of the content of the subsequent chapters.

Chapter 2: Decision-Making Framework for Air Quality Management (G. Hidy, J.R. Brook, K.L. Demerjian, L.T. Molina, and R. Scheffe)
A decision-making framework for multipollutant air quality management in North America is described that includes risk assessment and accountability. The chapter begins with a summary of current air quality management structures in Canada, the United States, and Mexico including current capabilities and applications of measuring accountability. The chapter postulates a four-level transition from current air quality management practice to a risk- and results-based multipollutant air quality approach. This hypothetical four-level transition is used throughout the book to assess the ability of current science to support the degree of risk- and results-based air quality management represented in each of the four transition levels.

Chapter 3: Risk-Based Air Pollution Assessment and Management (B. Hubbell and C. Frey)
This chapter reviews current risk-based assessment and management procedures and their potential application to multipollutant air quality management. The chapter begins with a review of the elements of risk-based assessment and the use of risk and benefit analysis in informing air quality management decisions. The concept of accountability is introduced, and it is shown how retrospective analysis can be used to improve management decisions. After a review of how risk assessment is currently used in Canada, Mexico, and the United States, the problem of comparing risks across air pollutants is discussed. The latter problem can be difficult when risk information for some pollutants may be based on population exposure, while for others it may be based on individual exposure. Comparative risk assessment is even more difficult for decisions involving human and ecosystem health because there are no accepted metrics for comparing human health and ecosystem risks. The chapter concludes with a discussion of risk communication and the knowledge gaps limiting the use of risk assessment in multipollutant regulatory applications.

Chapter 4: Health Assessment in a Risk-Based, Multipollutant Air Quality Management Environment (J. Mauderly, R. Wyzga, M. Castillejos, H. Ozkaynak, and J. Samet)
Knowledge of the health impacts of air contaminants is key to both the development of risk-based multipollutant air quality management strategies and the evaluation of their success in reducing the health burden of air pollution. This chapter summarizes the present ability of health sciences researchers to produce evidence useful for informing the development of multipollutant air quality management and assessing the resulting health benefits, the advances in knowledge and research strategies that will be required to substantially advance that ability, and the progress we can reasonably expect over the next decade. The chapter deals with key elements of the risk assessment framework described in Chapter 3, especially assessing exposure, identifying causal pollutants and combinations, and determining exposure-response relationships (potency factors). It concludes that continued progress toward supporting multipollutant air quality management will occur in incremental steps as we become able to integrate increasing numbers of individual pollutants, pollutant groupings, and sources, and their corresponding health risks. Progress towards developing multipollutant air quality management strategies and accounting for their success will depend upon how well we understand the links between various pollutants and health, and how confidently we can measure pollutant-related changes in the health impacts we seek to reduce.

Chapter 5: Effects of Air Pollution on Ecosystems (T. Clair and D. Burns)
North America encompasses a wide range of climate and ecosystems types including Arctic tundra in northern Canada and Alaska, boreal forest, the Canadian prairies and American plains, temperate forests in eastern and western Canada and the United States, arid and semi-arid regions of the south-western United States and northern Mexico, as well as subtropical and tropical wetlands and forests in southern Florida and in Mexico. This diversity does not allow an easy generalization of air pollutant effects in North America. In this chapter, this challenge is approached by identifying the major air pollutants with widespread and

documented effects on terrestrial and aquatic ecosystems in North America (acidification, metal contamination, ground level ozone, persistent organic pollutants), and highlighting the ecosystems and regions that are most affected. The chapter describes how air pollution effects were first recognized, the current extent of these effects, and any significant changes or trends that have been identified over time. The chapter also describes past and current monitoring programs that document the ecosystem effects of air pollutants as well as some of the predictive ecosystem models that allow one to determine how these effects might vary with changes in air pollutant stressor intensity. The chapter discusses known and likely multipollutant interactions that affect ecosystems and recommends future monitoring needs and research priorities for advancing an integrated, multipollutant approach to ecosystem protection.

Chapter 6: Atmospheric Science of Air Pollution Phenomena: Current Directions Towards Exposure Characterization (K.L. Demerjian)

Any approach to multipollutant air quality management must consider the chemical transformation and fate of the relevant pollutant species that affect human health and welfare. Estimating exposure for a broader mix of pollutants (e.g. oxidants, hazardous air pollutants, or the chemical composition and size distribution of PM) requires improved understanding of the complex chemistry and physicochemical transformations of these compounds, their relevant precursors, and their lifetimes in time and space. This chapter provides insights into those processes most likely to affect this broad and complex mix of pollutants in terms of their distribution on the urban/regional and the local scale (i.e. 10's - 100's of meters from a source). It is not the intent of this chapter to provide comprehensive review of the chemistry of the atmosphere (these can be found elsewhere), but to provide an overview of the atmospheric processes important to a multipollutant approach to air quality management.

Chapter 7: Understanding Source Emissions for Risk- and Results-Based Multipollutant Air Quality Management (A. Miller)

This chapter discusses emissions inventories and emission control technologies in the context of a risk-based, results-oriented multipollutant air quality management program. As contemporary emission control technologies often achieve reductions in more than one pollutant, the chapter reviews major emissions reduction in North America as examples of multipollutant reduction strategies for both criteria pollutants and air toxics. The chapter then comments on developments in these technologies that will be required in the future. The chapter reaches four principal conclusions regarding the development of emissions inventories for risk- and results-based air quality management: 1) the need to consider the full range of factors influencing source emissions, from fuels to end-of-pipe control technologies; 2) the need for measurements to determine the direct effects of emission reduction programs; 3) the need for better understanding of the emissions important to determining health and ecosystem effects; and 4) the capability to respond to the rapid changes in generation and end-use technologies that could result from actions taken to mitigate greenhouse gas emissions. The chapter concludes with a series of recommendations for addressing these challenges.

Chapter 8: Air Quality Modeling for Exposure and Risk Assessment (C. Seigneur and R. Dennis)
Air quality models simulate the atmospheric concentrations and deposition fluxes to the Earth's surface of air pollutants by solving the mass conservation equations that represent the emissions, transport, dispersion, transformations and removal of those air pollutants and associated chemical species. Contemporary air quality models can be grouped into two major categories: 1) models that calculate the concentrations of air pollutants near a source (source-specific models) and 2) models that calculate concentrations of air pollutants over large areas ranging from an urban area, to a region, a continent and the globe (grid-based models). A few models combine both modeling approaches in a hybrid formulation. This chapter reviews the capabilities of current air quality models for estimating human exposure, ecological impact, risk assessment, and accountability. The chapter also discusses observations-based receptor models and their applications. The chapter summarizes the strengths and weaknesses of contemporary models in these application areas, and it provides recommendations for improving modeling capabilities.

Chapter 9: Air Quality Measurements for Supporting Risk- and Results-Based Air Quality Management (R. Scheffe, J.R. Brook, K.L. Demerjian, and G. Hidy)
Air quality measurements are essential supporting elements of current and future air quality management practice. Current measurement programs range from monitoring networks designed to determine regulatory compliance to specialized field observations for supporting process research. Under a risk- and results-based air quality management system, current monitoring protocols will require serious rethinking, especially if the measure of regulatory compliance shifts from achieving broad-scale ambient concentration goals to determining the risk of exposure to ambient pollutants. If risk reduction becomes the compliance metric, information on ambient concentration fields will be required at the spatial and temporal scales needed for determining exposure. These scales are much finer than is currently required for monitoring broad-scale ambient concentrations. This kind of information cannot be obtained using brute force measurement methods. This chapter reviews current capabilities of ambient measurement networks and methods, and it discusses the kinds of changes that will be required to achieve various levels of risk-based, results-oriented air quality management.

Chapter 10: Influences of Global Change on Future Air Quality Management (D. Jacob, W.T. Pennell, and D. Mauzerall)
World population growth, industrialization, energy demand, and environmental goals are presently driving rapid global change in emissions with complex consequences for climate, air quality, and ecosystems. As North America strives to reduce its pollutant emissions to meet air quality standards, rising global emissions may increase background pollutant concentrations and offset some of the gains. Climate change can have important impacts on air quality, and in turn, air pollutants are recognized to be major climate forcing agents. Policies to mitigate climate change could have important implications for air quality and vice versa. It is becoming increasingly important to view air quality from a global perspective and to integrate air quality and climate stabilization goals in the design of environmental policy. This chapter presents a review and analysis of these issues with

the air quality perspective focused on tropospheric ozone, particulate matter, and mercury.

Chapter 11: Examples of Changes, Trends, and Accountability for Past Air Quality Management Actions (G. Hidy, J.R. Brook, K.L. Demerjian, and R. Scheffe)
Historically, the primary direction for accountability assessment for exposure has relied on documentation of changes in emissions and ambient air quality as applied to the suite of regulated pollutants. Less attention has been given to retrospective evaluation of the projections for future changes as estimated from air quality modeling, and the evaluation or interpretation of changes in ambient air quality relative to projections. Even less attention has focused until recently on the determining changes or trends in improvement in human health or ecosystems resulting from air quality improvement. In this chapter, we concentrate on the aspects of accountability that should be documented in order to inform decision-makers regarding the effectiveness of management actions. The chapter shows that management actions have achieved pollution reductions, and that these actions have mitigated exposure to ambient air pollution. The principal measures of health and ecological trends over the last two decades have come from epidemiological studies and from measurement of surface water chemistry. The examples discussed do not represent a complete review of the range of actions taken and their consequences to air quality measures. However, they do provide the reader with some examples of change and trends relevant to multipollutant considerations, and give perspective to the use of management tools to achieve air quality goals.

Chapter 12: Towards an Accountability and Multipollutant Air Quality Management Framework – What's Next? (G. Hidy, J.R. Brook, K.L. Demerjian, L.T. Molina, and R. Scheffe)
The purpose of this chapter is to comment on the status and limitations of current tools for developing multipollutant air management strategies, and demonstrating accountability for results. A transition from today's regulatory practice to more complete, risk-based, results-oriented multipollutant management strategies is a major challenge for North American policy-makers. If such a path is chosen, a transition is envisaged along the lines discussed in Chapter 2 with four levels of change. The current approach to air quality management, a focus on achieving individual air quality standards with some consideration of efficiency in multipollutant emissions reductions, has provided major improvement in air quality as exemplified in Chapter 11. A pathway towards a full transition to risk- and results-based multipollutant air quality management is also described in Chapter 2. How far decision-makers could progress towards this goal depends on identifying appropriate indicators of exposure, health and ecosystem effects, combined with tools for determining "optimum" risk reduction.

Chapter 13: Conclusions and Recommendations
This chapter presents the principal conclusions and recommendations of this assessment of the technical capabilities for supporting a multipollutant, risk and accountability-based management strategy for North America. The conclusions and recommendations are presented in two parts: the first part addresses multipollutant and risk-based air quality management, and the second part addresses accountability. The conclusions and

recommendations reference the levels of transition to a full risk- and results-based air quality management approach outlined in Chapter 2, and they incorporate the principal conclusions and recommendations from Chapters 3 through 12. Although the conclusions and recommendations are discussed separately owing to their focus, they are in fact interrelated. Resolution of uncertainties and gaps in the tools and information needed to support risk assessment, assessment of exposure and system response, evaluation of the impact of climate or technological change, implementation of supporting measurement programs, and demonstrations of accountability will be required before a comprehensive multipollutant, risk-based, and results-based air quality management can be realized.