PREFACE

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The task of identifying sound air quality management strategies to improve human health and the environment involves a number of scientific, technical, and economic considerations embedded within a social and political context. While lack of full scientific certainty limits our ability to identify optimal policy interventions, research findings on ambient air quality, source apportionment, and health effects can help to guide the development of local, regional and continent wide air pollution management strategies. Policy analysis tools incorporating air quality modeling further support decision-makers in the development and evaluation of air quality management policies by estimating impacts of policies on ambient air quality, health, the environment, and the economy.

"Strategies for Clean Air and Health," the fourth in a series of five NERAM Colloquia, was organized jointly with the AIRNET European Network on Air Pollution and Health and the Rome E Health Authority to identify directions for air quality policy development and research priorities to improve population health. Two hundred air quality scientists, policymakers, and representatives from industry and non-governmental organizations from 22 countries convened in Rome, Italy on November 5-7, 2003 to exchange perspectives on the interface between science and policy relating to air pollution health effects, air quality modeling, clean air technology, and risk management policy tools. The conference was sponsored by US EPA, Health Canada, Ontario Ministry of Environment, Shell International, the Canadian Petroleum Products Institute, the European Commission, and the Rome E Health Authority.

This volume includes twenty-one peer reviewed conference papers from North America and Europe addressing the following critical topics in air quality risk management: i) ambient air quality, ii) health effects, iii) mechanism of effect, iv) policy tools and approaches and v) science-policy issues. In addition, a Conference Statement based on the discussions that took place at the meeting provides guidance from the perspective of an international group of scientists, regulators, industries and interest groups on a path forward to improve the interface between science and clean air policy strategies to protect population health. The Statement emphasizes that air pollution in an important local, national, and global population health concern that requires further attention in specific airsheds throughout the world, despite uncertainty in our knowledge of the most harmful components. Policies strategies most likely to be successful are those that are aimed at achieving broad population health co-benefits, including those that integrate clean air goals within urban planning, health promotion, and climate change/energy demand management initiatives. Emission reduction strategies should focus on the toxicologically most important sources of ambient air pollution and consider predicted effectiveness, benefits and costs, as well as implementation time and feasibility. Public and stakeholder outreach is important in building support for policy changes, including the public health community and those at high risk of adverse health impacts. Continued communication among scientists, policy makers, stakeholders and the public is critical for improving the science-policy interface. The Statement identifies the need for innovative approaches to further support policy development including cross-disciplinary health effects research and studies to assess the effectiveness of control strategies. Finally the Statement recommends an international forum for evaluation of scientific evidence on health effects and a methodology for integration of evidence for air quality risk management policy development.

Part I provides a Canadian and European perspective on ambient concentrations of air pollutants in major cities and characterizes the role of local transportation and industrial emission sources.

Brook et al. and Jerrett et al. present a Canadian perspective on sources of $PM_{2.5}$ impacting southern Ontario and its major city of Toronto. Brook et al. use monitoring data to estimate that 30-45% of $PM_{2.5}$ is locally generated, which implies that 55-70% are transported into the area. Using two different receptor-based analyses it was determined that motor vehicle related emissions (exhaust and road dust), most likely of local origin, were responsible for about 20% of the $PM_{2.5}$. Secondary $PM_{2.5}$ from coal-fired power plan emissions was a significant contributor and also played a

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role in enhancing production of secondary organic carbon mass on fine particles. The paper cautions that while the results of receptor-based analyses can be used to inform potential strategies for reducing ambient $PM_{2.5}$, it is important to also consider the relative toxicity of the mix of emissions from the various sources in order to target reduction strategies to those which will provide the greatest public health benefit.

Jerrett et al. report on the first North American study to characterize intra-urban traffic pollution with a land use regression model. Land use regression seeks to predict pollution pollution concentrations at a given site based on surrounding land use and traffic characteristics. This work is important in addressing some of the uncertainties in exposure assessment methodology in order to guide effective traffic pollution control strategies. The results indicate that predictive maps from the land use regression method appear to capture small area variations in traffic pollution (NO_2). These variations are likely important to the exposure experience of the population and may detect health effects that would have gone unnoticed with other exposure estimates. The paper suggests that further empirical work in North American be conducted to assess the adequacy of different predictive variables.

Marconi et al. discuss the results of two years of fine and ultrafine particle measurements in a traffic-related site, and an urban background site in Rome Italy. The study was conducted to establish validated and consistent data sets of particle number concentrations in Rome to be used in epidemiological analyses of cardiovascular health effects associated with exposure to ultrafine particles. Peak particles number count (PNC) events were found during winter and during the morning and evening rush hours. CO, NO and NOx were all highly correlated with the particle number concentrations. Consistent with other studies, daily $PM_{2.5}$ and PM_{10} levels were found to be poorly correlated with the daily particle number count, suggesting that independent measurement systems are required if the relationships between health outcomes and ultrafine number concentrations are to be assessed. The results emphasize the importance of primary particles originating from road traffic and the influence of meteorological conditions on particle number concentrations.

Fierens et al. assess the impact of pollutant emissions from two iron and steel plants and two municipal solid waste incinerators (MSWIs) on the exposure of residents of Wallonia, Belgium. The concentrations of dioxins, PCBs, cadmium, mercury and lead in blood and urine of subjects living in the vicinity of two sinter plants and two MSWIs were compared with levels found in referent subjects recruited in a rural area with no industrial source of pollution. After adjusting for covariates, the results show that dioxins and coplanar PCBs emitted by MSWIs located in the rural area can accumulate in nearby residents, however the accumulation requires a regular consumption of local animal products contaminated by relatively high emissions of dioxins. The authors note that it is unlikely that the increased dioxin body burden occurs around MSWIs complying with emission standards currently in force in most countries. Emissions from the sinter plants were not associated with an increased dioxin body burden of residents. This was likely due to the lower dioxin emissions and lower local animal fat consumption of residents around these facilities.

Part II provides an overview of health effects associated with exposure to ambient air pollution based on North American and European studies and explores uncertainties in their estimation using Canadian data. The impact of urban air pollution on less severe morbidity outcomes among children and the elderly in Italy is described. Evidence of early airways inflammation among children exposed to high ozone levels during smog episodes is presented.

Samet and Krewski provide a review of the current state of science on the human health impacts of air pollution. The review is based on the framework and findings of the U.S. National Research Committee (NRC) on Research Priorities for Airborne Particulate Matter. The paper addresses key questions underlying air quality risk management policy decisions.

Krewski and Rainham summarize more than 35 research posters presented at the conference addressing exposure, toxicological and epidemiological studies of air pollution. The studies provide important new findings from more than 41 cities and metropolitan areas across Europe and further support previous evidence that both short and long-term exposures to particulate air pollution have adverse population health impacts, including effects on children. Cellular studies suggest that air pollution can cause mutagenic and oxidative effects, raising concerns about carcinogenicity and cellular regeneration. Studies of biomarkers provide further evidence of air pollution effects at the cellular level. Improved exposure assessment models support the close association between traffic patterns and

air pollution concentrations. Collectively, the findings present opportunities and challenges for the development of policies to improve air quality and human health.

Sahsuvaroglu and Jerrett assess the sensitivity of air pollution health effects estimates in Hamilton, Canada to a wide range of possible uncertainties including baseline pollution levels, single versus multipollutant effects, local or pooled estimates, and chronic effects. Given the wide ranging estimates of mortality and hospital admissions, the authors suggest the need to reach consensus on formats for reporting study results and burden of illness and mortality estimation conventions. To improve the completeness of the health effects estimates, the paper identifies the need for chronic health effects studies, multipollutant studies and studies on health outcomes that are likely to have large population health impacts.

Bedeschi et al. and Vigotti et al. explore the association between exposure to urban air pollution and daily emergency room visits for respiratory disorders among children and elderly in Italy. Using single pollutant models, significant associations were found between road traffic pollutants (PM_{10} or TSP and NO_2) and emergency room visits for respiratory disorders among children residing in a small city of Northern Italy (Reggio-Emilia). These associations were independent of the effect of temperature, humidity and pollen trend. Using single pollutant analyses, Vigotti et al. found statistical associations between PM_{10} concentrations and emergency room visits for respiratory complaints among children and the elderly in Pisa, Italy. Evidence of these less severe health outcomes suggests the need for further action to prevent deterioration of respiratory health among susceptible populations.

Nickmilder et al. assess the effect of ambient ozone on lung function and airways inflammation among healthy children attending summer camps in rural areas in the South of Belgium. While lung function tests did not show any consistent pattern of decrease at ozone concentrations ranging from 48 to 221 $\mu g/m^3$ (1 hour maximal concentration), a highly significant increase in exhaled nitric oxide levels was found in all subjects from an ambient 1 hour ozone level of 167 $\mu g/m^3$. The authors note that the increased exhaled nitric oxide is a marker for inflammation and oxidative stress in the lung that passes undetected with spirometric tests. These impacts were observed at levels that are slightly below US and EU air quality standards, suggesting the need for greater use of this non-invasive test in the assessment of the health risks of ozone and the subsequent derivation of health-based air quality standards.

Part III includes two papers investigating biomarker methods to assess exposure levels and mechanisms of effect. de Burbure et al. assess the protective role of selenium dietary supplementation with respect to nitrogen dioxide lung toxicity in an inhalation study on Wistar rats. The protective role of selenium status was evident for both long term and acute exposures, however its negative impact on Clara cell protein (a natural anti-inflammatory and immunosuppressor) indicates that caution should be used prior to advocating selenium supplementation.

Beskid et al. studied the impact of air pollution containing higher concentrations of carcinogenic polycyclic aromatic hydrocarbons in three European cities using the fluorescence in situ hybridization (FISH) technique as a biomarker indicator of chromosomal changes related to cancer. The findings suggest that police officers in Prague (Czech Republic), Kosice (Slovakia) and Sofia (Bulgaria) as well as bus drivers in Sofia represent a group with increased genotoxic risk. The differences in genetic effects observed in the occupationally exposed and control populations reflect the longer exposure to polluted air experienced by the former population. Further work is needed to analyze factors affecting the genomic frequency of translocations and to establish how to translate the findings for risk assessment.

Part IV describes tools and approaches to guide the development of air quality policy. Case studies of policy development strategies in Europe point to the challenges that policy makers face in devising sound risk reduction strategies. Reid et al. present an overview of atmospheric models and their application to the development of air quality policy. The paper reviews modeling case studies to identify issues associated with model validity and accuracy and provides guidance on the requirements for credible modeling. Rabl et al. offer a brief review of the need for cost-benefit analysis and the available policy instruments for assessing externality costs associated with air pollution. The paper describes the ExternE (External Costs of Energy) project series of the European Commission (EC) and the Life Quality Index as examples of approaches to assess the costs and benefits of pollution control strategies as well as the inherent uncertainties in their estimation. Davidson describes the Environmental Benefits Mapping and Analysis Program (BenMAP) developed by the U.S. Environmental Protection Agency (U.S. EPA) to

assist in the benefit-cost analysis of air pollution control policies. Two $PM_{2.5}$ pollution control policy scenarios are reviewed to demonstrate BenMAP's capabilities. Brody et al. describe a project aimed at building capacity to set environmental priorities in the Ukraine through the use of comparative risk assessment and economic analysis. The project is a partnership between the U.S. EPA and Ukraine's Ministry of Environmental Protection. The paper describes the Russian experience with risk assessment and progress achieved in applying risk assessment to setting environmental priorities in Ukraine. Periera et al. report on trends in annual sulphur dioxide (SO_2) concentrations in the Oporto Metropolitan Area of Portugal before and after the implementation of European Union legislation in 2000 to reduce the sulphur content in fuels (Auto-Oil Directives). Annual SO_2 emissions and concentrations had decreased since implementation of the policies as well as a significant decrease in the number of exceedances of SO_2 recommended limit values. Improvement in fuel quality, the application of emission control programmes and recent technological innovations are believed to be responsible for these improvements. Glorennec and Monroux estimate the health impacts of acute and chronic exposure to PM_{10} in Caen, a city in northwestern France. The authors estimate that a 10% daily decrease in pollution would reduce the number of expected deaths from short-term exposure by 19%, while achieving compliance with European Union regulations (daily mean in 2010: 50 $\mu g/m^3$) would reduce them by less than 3%. The paper concludes that pollution peaks do not contribute significantly to long-term exposure, the impact of which is greater than acute exposure and suggests that local risk management policy aimed exclusively at avoiding exposures exceeding regulatory levels will have only a marginal impact on public health.

In Part V, issues arising during the interface between science and the development of robust policy strategies are discussed from a European stakeholder perspective. Maas describes uncertainties in the source-effect chain and identifies policy strategies for particulate matter abatement that are consistent with a certain set of assumptions, as well as the risks that are associated with such strategies. The paper offers a systematic approach to developing sound PM control policy that considers the appropriate balance between environmental and economic precaution. Wallis offers a critical appraisal of the air quality science-policy interface in the UK. The paper identifies shortcomings in the systems for reporting on progress in reducing air pollution levels and advising the public on precautionary actions. Weaknesses in standard setting on PM and the lack of attention in the policy setting process to ultrafine particles and health effects on the unborn are discussed. The paper emphasizes the vital need for ENGO participation within a stakeholder process that incorporates effective communication and accountability in public information and policy setting. van Bree discusses critical issues underlying the interface between air quality science, stakeholder participation and policy development within the context of the European AIRNET Network multi-stakeholder project. The paper argues that the process and mechanisms by which the science-policy interface operates are as important as the content of the air pollution and health science and offers lessons learned in establishing a multi-stakeholder air quality network to bridge the gap between the policy, stakeholder, public and scientific communities.

This unique collection of international perspectives on air quality science and risk management policy issues serves as a comprehensive resource to inform the development of future air quality policy strategies. A special thank you is extended to Addy Mitchell for formatting the papers and co-ordinating the preparation of this volume, to host Francesco Forestiere of the Rome E Health Authority, to Addy Mitchell and Laurie MacDonald of NERAM, Suzanne Therien of the McLaughlin Centre for Population Health Risk Assessment, Eef van Otterloo and Marjan Tewis of the AIRNET management team and Ingrid Dahmen of the Institute for Risk Assessment Science (IRAS) for their roles in the planning and execution of a successful meeting in Rome.