Executive Summary

This Guidance Document is a reference for air quality policy-makers and managers providing state of the art, evidence-based information on key determinants of air quality management decisions. The Document reflects the findings of the five annual meetings of the NERAM (Network for Environmental Risk Assessment and Management) International Colloquium Series on Air Quality Management (2001-2006), as well as the results of supporting international research. The topics covered in the Guidance Document reflect critical science and policy aspects of air quality risk management. Key messages highlighting policy-relevant findings of the science on health effects (Chapter 2), air quality emissions, measurement and modeling (Chapter 3), air quality management interventions (Chapter 4), and clean air policy challenges and opportunities (Chapter 5) are provided below:

Air Quality and Human Health

- A substantial body of epidemiological evidence now exists that establishes a link between exposure to air pollution, especially airborne particulate matter (PM), and increased mortality and morbidity, including a wide range of adverse cardiorespiratory health outcomes. Many time-series studies, conducted throughout the world, relate day to day variation in air pollution to health with remarkable consistency. A smaller number of longer-term cohort studies find that air pollution increases risk for mortality.
- Health effects are evident at current levels of exposure, and there is little evidence to indicate a threshold concentration below which air pollution has no effect on population health.
- It is estimated that the shortening of life expectancy of the average population associated with long-term exposure to particulate matter is 1-2 years.
- Recent epidemiological studies show more consistent evidence of lung cancer effects related to chronic exposures than found previously.
- In general, methodologic problems with exposure classification tend to diminish the risks observed in epidemiological studies so that the true risks may be greater than observed.
- Human clinical and animal experimental studies have identified a number of plausible mechanistic pathways of injury, including systemic inflammation, that could lead to the development of atherosclerosis and alter cardiac autonomic function so as to increase susceptibility to heart attack and stroke.
- The question of which physical and chemical characteristics of particulate matter are most important in determining health risks is still unresolved. There is some evidence to suggest that components related to traffic exhaust and transition metal content may be important.
- Despite continuing uncertainties, the evidence overall tends to substantiate that PM effects are at least partly due to ambient PM acting alone or in the presence of other covarying gaseous pollutants.
- Several studies of interventions that sharply reduced air pollution exposures found evidence of benefits to health. New findings from an extended follow up of the Harvard Six City study cohort show reduced mortality risk as $PM_{2.5}$ concentrations declined over the course of follow-up. These studies provide evidence of public health benefit from the regulations that have improved air quality.

Emission Inventories, Air Quality Measurement and Modelling

- Three essential tools for managing the risk due to air pollution are multi-pollutant emission inventories, ambient measurements and air quality models. Tremendous advances have and continue to be made in each of these areas as well as in the analysis, interpretation and integration of the information they provide.
- Accurate emission inventories provide essential information to understand the effects of air pollutants on human and ecosystem health, to identify which sources need to be controlled in order to protect health and the environment, and to determine whether or not actions taken to reduce emissions have been effective.
- Air quality measurements are essential for public health protection and are the basis for determining the current level of population health risk and for prioritizing the need for reductions. They are also critical for evaluating the effectiveness of AQ management strategies and altering such strategies if the desired outcomes are not being achieved.
- Air quality models quantify the links between emissions of primary pollutants or precursors of secondary pollutants and ambient pollutant concentrations and other physiologically, environmentally, and optically important properties. They are the only tool available for detailed predictions of *future* air concentration and deposition patterns based on possible future emission levels and climate conditions.
- Air quality problems tend to become more difficult to address as the more obvious and less costly emission control strategies are implemented. This increases the demand for advanced scientific and technological tools that provide a more accurate understanding of the linkages between emission sources and ambient air quality.
- Despite scientific advancements, including improved understanding of the impacts of poor air quality, the pressure to identify cost-effective policies that provide the maximum benefit to public health push our current tools and knowledge to their limits and beyond.
- Due to scientific uncertainties, highly specific control options that target specific chemical compounds found on fine particles, specific sources or source sectors or that lead to subtle changes in the overall mix of chemicals in the air (gases and particles) remain extremely difficult to evaluate in terms of which options most benefit public health. Lack of a complete understanding of exposure and health impacts of the individual components in the mix and their additive or synergistic effects pose further challenges for health benefits evaluation. However, progress is being made and new ways of thinking about air quality and pollution sources, such as the concept of intake fraction, help to provide some perspective.
- A broader perspective, including consideration of environmental effects and the implications of climate change on air quality and on co-management of air pollutants and greenhouse gases, will be increasingly important to embrace.

Air Quality Management Approaches and Evidence of Effectiveness

- While North America, the European Community, and Asia have a unique set of air pollution problems – and approaches and capacities to deal with them – there is a clear portfolio of comprehensive management strategies common to successful programs. These include the establishment of ambient air quality standards that define clean air goals, strong public support leading to the political will to address these problems, technology-based and technology-forcing emission limits for all major contributing sources, and enforcement programs to ensure that the emission standards are met.

- Initially, many regions focused their air pollution control efforts on lead, ozone, and large particles (i.e., TSP, PM_{10}). However, newer epidemiological studies of premature death, primarily conducted in the U.S. with cohorts as large as half a million participants, have made it clear that long-term exposure to $PM_{2.5}$ is the major health risk from airborne pollutants. While WHO, US EPA, Environment Canada, and California Air Resources Board (CARB) rely on the same human health effects literature, there are striking differences, up to a factor of three, in the ambient air quality standards they set. In addition, how these standards are implemented (e.g., allowable exceedances, natural and exceptional event exceptions) can greatly reduce their stringency.
- Worldwide, command-and-control has been the primary regulatory mechanism to achieve emission reductions, although the European Community has successfully used tax incentives and voluntary agreements with industry. Over the past four decades, the California Air Resources Board set the bar for US EPA and European Union motor vehicle emission standards that are now being adopted in many developing countries, particularly in Asia.
- Since the emission standards are technology-based or technology-forcing, industry has been able to pursue the most cost-effective strategy to meeting the emission target. As a result, actual control costs are generally less than originally estimated. In the US, total air pollution control costs are about 0.1% of GDP, although this has not necessarily resulted in overall job and income loss because the air pollution control industry is about the same size. In addition, the US EPA estimated that each dollar currently spent on air pollution control results in about a $4 of reduced medical costs as well as the value assigned to avoided premature deaths
- A comprehensive enforcement program with mandatory reporting of emissions, sufficient resources for inspectors and equipment, and meaningful penalties for noncompliance ensures that emission standards are being met. While air quality management through standards for vehicles and fuels have resulted in measurable reductions in emissions, regulation of emissions for in-use vehicles through I/M programs poses greater technical challenges.
- An alternative to command-and-control regulations is market-based mechanisms that results in more efficient allocation of resources. The SO_2 cap and trade program in the US resulted in rapid emissions reduction at lower cost than was initially anticipated. Efforts to extend the cap and trade system to SO_2, mercury and NO_X emissions in the Eastern US were less successful due to several issues related to heterogeneous emissions patterns which could worsen existing hot spots, allocation of emissions allowances, procedures for setting and revising the emissions cap, emissions increases following transition to a trading program, and compliance assurance.
- Emission reduction initiatives at the local level also play a critical role in air quality management. Local governments can contribute to cleaner air through emission reduction measures aimed at corporate fleets, energy conservation and efficiency measures in municipal buildings, public education to promote awareness and behaviour change, transportation and land use planning; and bylaws (anti-idling etc). Many large urban centres such as the City of Toronto are following the policy trend towards an integrated and harmonized approach to cleaner air and lower greenhouse gas emissions.
- An evidence-based public health approach in the assessment of health impacts of air pollution may not lead to essential policy changes. Environmental advocacy must develop more effective methods of risk communication to influence public demand for cleaner air and strengthen political will among decision-makers.
- Average daily visibility has been declining in Asia over two decades. Visibility provides a measure, with face validity, of environmental degradation and impaired quality of life; and a risk communication tool for pollution induced health problems, lost productivity, avoidable

mortality and their collective costs.

- Although scarce, information from both planned and unintended air quality interventions provides strong evidence in support of temporal association and causality between pollution exposures and adverse health outcomes. Even modest interventions, such as reductions in fuel contaminants and short-term restrictions on traffic flows, are associated with marked reductions in emissions, ambient concentrations and health effects. Coal sales bans in Ireland and fuel sulfur restrictions in Hong Kong, successfully introduced in large urban areas within a 24-hour period, were economically and administratively feasible and acceptable, and effective in reducing cardiopulmonary mortality.
- While some air quality problems have been eliminated or greatly reduced (i.e., lead, NO_2, SO_2), particulate matter and ozone levels remain high in many large cities, resulting in hundreds of thousands of deaths per year and increased disease rates. Air quality management agencies are developing innovative approaches, including regulation of in-use emissions, reactivity-based VOC controls and exposure-based prioritization of PM controls. Several cooperative, multi-national efforts have begun to address transboundary issues. Newly recognized challenges also need to be integrated into air quality management programs, ranging from the microscale (e.g., air pollution "hotspots", ultrafine particles, indoor air quality) to global scales (e.g., climate change mitigation, international goods movement).

Clean Air Policy: Challenges and Opportunities

- The issue of air quality management is beginning to take on global dimensions, where the linkages between climate change and air pollution, how to control their sources pollutants (greenhouse gases (GHGs) and criteria air contaminants), and how they may interact to pose a cumulative risk to human health are emerging as important challenges.
- Urban areas, especially emissions and health effects associated with particulate matter (PM), are a major concern for air quality management. Other areas of concern include environmental justice and hemispheric air pollution transport.
- Adopting a risk management approach in the form of exposure-response relationships for PM is more suited for developed countries, whereas in developing countries a more traditional approach is more appropriate where recommended guidelines are expressed as a concentration and averaging time.
- For pollutants with no effect threshold such as $PM_{2.5}$ it will generally be more beneficial for public health to reduce pollutant concentrations across the whole of an urban area as benefits would accrue from reductions in pollution levels even in relatively "clean" areas.
- The European Commission's adoption of an exposure reduction target in addition to limit the absolute maximum individual risk for European citizens embodies a form of environmental justice, where policy measures should lead to a uniform improvement in exposure.
- Hemispheric air pollution transport poses significant challenges to the scientific community and policy makers, even at the level of local air quality management.
- The interaction between climate change and air quality poses additional challenges for policy makers. Much of the focus to date has been in the area of atmospheric chemistry, with less emphasis on specific emission reduction technologies and measures that will reduce emissions of all key pollutants (air pollutants, air toxics and GHGs).
- Examples drawn from the EU (especially the UK) and North America (especially Canada) demonstrate the challenges of integrating climate change into the development of air quality policy strategies.

- The health benefits from integrating climate change and air quality management decisions can be non-linear, synergistic and in some cases counteractive. Measures must be taken that result in reductions in emissions of all key pollutants, rather than at the expense of one or the other.
- Opportunities for adopting an integrated approach to air quality management include energy, transport and agriculture. There is no silver bullet among these sectors; hence, a wide suite of effective measures will be required.