EXECUTIVE SUMMARY

Improving Emission Inventories for Effective Air Quality Management Across North America: A NARSTO Assessment examines the current state of emission inventories for Canada, the United States, and Mexico, and offers suggestions for improvement. Prepared to address the needs of a broad user base composed of decision makers as well as developers and users of emission inventories, the Assessment begins with a vision statement that sets the goal for future inventory development: **the ultimate emission inventory is one that includes all significant emissions from all sources, time periods and areas, with quantified uncertainties, and timely accessibility**. The Assessment concludes with prioritized recommendations and an action plan for achieving that vision.

The Assessment has four functions; it:

- Identifies many national, state or provincial, regional, local and specialty inventories and provides information for accessing them.
- Describes the methods used to generate emission inventories and discusses the strengths and weaknesses of these methods as well as of the resulting inventories.
- Directs considerable attention to methods for determining uncertainties in emission estimates, and provides comparisons between emission estimates and independent measurements for key emission sectors.
- Suggests ways to improve future inventories, characterize their uncertainty, and improve the delivery of emission data to users.

The motivation for the Assessment, the strengths and weaknesses of current emission inventories and emission models, and the recommendations and action plan for resolving these shortcomings are summarized below.

MOTIVATION FOR THE ASSESSMENT

Emission inventories are the foundation of air quality management. Although current inventories capably support many emission management and regulatory activities, they have shortcomings that could be reduced by application of improved inventory development, analysis, and dissemination techniques. In the past, most air quality management goals have focused on emissions from major, and relatively well characterized, source categories. As recently implemented regulatory programs take effect, however, emissions from these sources will decline substantially. The remaining emissions will be more evenly distributed over source categories that are much more difficult to measure or model. In this situation, errors in emission estimates from smaller individual sources will have greater consequences. These consequences could range from wrongly identifying a pollutant that should be controlled to overlooking source categories whose control could result in more cost-effective emission reductions.

The following text box illustrates this problem. It shows that the cost consequences of unreliable or incomplete emission information can be considerable. Incomplete or inaccurate information also limits the development of effective policies. Unreliable or incomplete information on sources of toxic air pollutants, for example, can lead to inaccurate assessments of exposure. Likewise, incomplete information on the chemical composition of fine particulate matter limits the characterization of the health effects of airborne particles and the development of more effective control measures. The policy consequences of poor information on emissions, therefore, are actions that may be misplaced or ineffective in achieving the goal of protecting human health and welfare.

Consequences of Incomplete Information

Incomplete or unreliable emission information can have serious consequences in terms of the cost and effectiveness of air pollution control strategies. The case in Houston, Texas is a good example. Houston is currently in noncompliance with federal air quality standards for ozone. The state had to devise a strategy that would result in compliance with the Clean Air Act ozone standards or face federal sanctions. Based on existing emission inventories, the state concluded that reducing NO_x emissions by 90 percent would be effective in meeting the standards. In 2000, a field experiment was conducted in Houston to examine the atmospheric chemistry of the Houston area and the emissions driving this chemistry. The study discovered sources of highly reactive volatile organic compounds that were not included in the existing inventory. Revised emission estimates and new modeling showed that achieving the desired air quality improvements would require reductions in these volatile organic compounds but only an 80 percent reduction in NO_x emissions. A NO_x-only strategy would not have been as effective as expected. It would also have been costly. Interest groups active in the decision process have asserted that ten years after implementation, a 90 percent reduction in NO_x emissions would result in 65,000 fewer jobs and a $9 billion smaller regional economy compared to a 79 percent NO_x reduction strategy that allowed emissions trading. While this analysis did not account for the costs of VOC controls, even when they are included the revised control strategy results in substantial annual cost savings. Clearly, obtaining accurate and complete emission estimates is very important.

STRENGTHS AND WEAKNESSES OF CURRENT INVENTORIES

Over the past 40 years, emission inventories in all three countries of North America have improved dramatically in terms of accuracy and completeness. Today, air quality managers have a good understanding of the emissions from major point sources, and they have used this knowledge in developing effective actions for reducing them. Models for estimating emissions from mobile sources have been continuously improved. The importance of natural, biogenic emissions has been recognized, and this knowledge has affected the design of air quality management strategies in regions where these emissions are significant. In Canada and the United States, emission inventories and models can provide quantitative estimates of emissions at national, state or provincial, and county (or their equivalent) levels for many source categories, and there is an improved understanding of the relative importance of various source categories to specific air quality problems. Air quality managers can use these inventories to track emission trends and to evaluate the effectiveness of measures designed to reduce these emissions. In Mexico, emission inventories have been completed for the Valley of Mexico and the states bordering the United States. The first national inventory will be released in the near future.

In spite of this progress, emission inventories in all three countries of North America have significant weaknesses or shortcomings that will become increasingly important for future air quality management problems. Addressing these problems is the focus of the findings and recommendations of this Assessment, and it is worthwhile summarizing them here:

- Quality assurance and quality control procedures are not strictly applied in the development of most emission models and inventories, and the documentation of uncertainties and data sources in emission inventories is not adequate.
- There are significant uncertainties in mobile source inventories particularly regarding the speciation of volatile organic compounds, the magnitude of carbon monoxide emissions, and the temporal trend of nitrogen oxide emissions.
- Emissions for many important categories such as fine particulates and their precursors, biogenic emissions, toxic air pollutants, ammonia, fugitive emissions, open biomass burning, and many other area sources are uncertain and inadequately characterized.

- Emission estimates are frequently based on a small number of emission measurements that may not be representative of real-world activity, either because the samples do not appropriately cover the range of real-world activity patterns or because the measurement methods are not intended to capture such patterns. Thus, the precision and accuracy of estimates developed from such measurements are limited.
- The process for developing information on emissions with the kinds of spatial and temporal resolution needed for location-specific air quality modeling is problematic and a source of unquantified uncertainty in model results.
- Methods used to estimate emissions of individual chemical species in many emission models are out of date and produce estimates that are not reliable.
- Current emission inventories are not developed and updated in a timely manner.
- Differences in current emission inventories in the three countries create difficulties for jointly managing air quality.

FINDINGS AND RECOMMENDATIONS

The Assessment culminates in eight principal findings and recommendations, applicable in all three countries of North America. The first of these is the most critical one. The remaining findings and recommendations are of roughly equal priority. This second tier can be divided into recommendations dealing with emission data (items 2, 3, 4 and 8) and with emission data processing (items 5, 6 and 7).

1. Reduce Uncertainties Associated with Emissions from Key Undercharacterized Sources

Finding

Comparisons of national emission inventories with ambient measurements and other independent measures indicate that emission inventories for certain source categories and pollutants, particularly gaseous emissions from electric utilities in the United States, are well characterized and reported. Emission inventories for other source categories and pollutants are much more uncertain. Of particular concern are nonpoint sources including transportation and fugitive emissions from industrial facilities, landfills, sewage disposal systems, and feedlots, as well as sources of organic compounds, carbonaceous particulate matter, ammonia, and hazardous air pollutants.

Recommendation

Focus immediate measurement and development efforts on areas of greatest known uncertainty within current emission inventories. Systematically continue to improve emission inventories by applying sensitivity and uncertainty analyses and by comparing them to independent sources of measured data. Such comparisons will help identify subsequent improvement priorities.

Resources must be targeted to reduce the greatest sources of uncertainty and focused on those source categories whose control will be most effective in reducing costs and health risks while achieving air quality management goals. Various expert panels have proposed lists of priority emission inventory development needs along these lines. The following list of emission sources, consolidated from these recommendations, represents the highest priority needs for improving emission inventories.

- Size-segregated, speciated emissions of fine particles and their precursors, including black and organic carbon emissions
- Toxic and hazardous air pollutants
- Emissions from onroad vehicles
- Emissions of ammonia from agricultural and other area sources
- Speciated, spatially and temporally resolved organic emissions from biogenic sources
- Emissions of volatile organic compounds and organic hazardous air pollutants from petrochemical and other industrial facilities
- Emissions from offroad mobile sources, including farm and construction equipment, aircraft and

airport ground equipment, commercial marine facilities, and locomotives

- Emissions from open biomass burning, including agricultural and forest prescribed burning, wildfires, and residential backyard burning
- Residential wood combustion in woodstoves and fireplaces
- Paved and unpaved road dust.

2. Improve Speciation Estimates

Finding

Contemporary air quality issues such as particulate matter and ozone nonattainment and identification of "hot spots" of hazardous air pollutant concentrations require detailed information about the species being emitted from sources.

Recommendation

Develop new and improve existing source speciation profiles and emission factors plus the related activity data needed to more accurately estimate speciated emissions for particulate matter and its precursors, volatile organic compounds, and toxic air pollutants.

3. Improve Existing and Develop New Emission Inventory Tools

Finding

Technical advances in instrumentation and computation have allowed measurements and analyses that were not previously possible; continuing development of these and other technologies is likely to further improve emission inventory measurements and analyses. Improvements in modeling and data processing capabilities provide the basis for more detailed and more accurate emission models and processors.

Recommendation

Continue the development of new and existing measurement and analysis technologies to enable expanded measurements of emissions and ambient concentrations. Apply these technologies in developing emission model and processor capabilities to allow models to more closely approximate actual emissions in time and space.

4. Quantify and Report Uncertainty

Finding

The emission inventories, processors, and models of Canada, the United States, and Mexico are poorly documented for uncertainties; as a result, the reliability of the emission estimates cannot be quantified.

Recommendation

Develop guidance, measures, and techniques to improve uncertainty quantification, and include measures of uncertainty (including variability) as a standard part of reported emission inventory data.

5. Increase Inventory Compatibility and Comparability

Finding

Numerous emission inventories have been developed by different organizations for different purposes and covering different spatial domains. Although there have been substantial improvements in reporting national emission inventories in a mutually consistent way by categories, estimation methods, and chemical constituents, further efforts are needed to make these diverse emission inventories more comparable across organizations, purposes, geographies, and time periods.

Recommendation

Define and implement standards for emission inventory structure, data documentation, and data reporting for North American emission inventories.

6. Improve User Accessibility

Finding

The accessibility of emission inventories or emission models is presently limited because of the sheer size of the databases and the cumbersome manner in which the data have been reported and archived. Improved accessibility to emission data is critical to meet the diverse needs of the user community.

Recommendation

Improve user accessibility to emission inventory data, documentation, and emission inventory models through the Internet or other electronic formats.

7. Improve Timeliness

Finding

Timely and historically consistent emission inventories are crucial elements for stakeholders to assess current conditions and estimate progress in improving air quality.

Recommendation

Create and support a process for preparing and reporting national emission inventory data on a yearly basis.

8. Assess and Improve Emission Projections

Finding

Emission projections are critical to developing control strategies for attaining air quality standards and goals, and for evaluating future year impacts associated with regulatory development.

Recommendation

Emission projection methodologies for all emission inventory sectors in North America should be evaluated to determine the accuracy of past projections and identify areas of improvement for future projections.

STEPS FOR IMPLEMENTATION

The authors of this NARSTO Assessment maintain that implementation of the above-listed recommendations over the next 10 years is essential to approach the vision of this Assessment. Progress toward achieving this vision will require cooperation among Canada, the United States, and Mexico. It will also require individual actions by these national agencies to assist state, local, and provincial agencies in meeting their inventory development responsibilities. It will require investments in educating the next generation of emission scientists and engineers, and it will require investment in the tools needed to construct the emission inventories of the future. Country-specific implementation plans will need to take into account the increasing trend toward integrated air quality management, and they should involve continued and extensive cooperation among the involved agencies at all levels of government as well as with stakeholders in industry and the research community.

Four actions are considered to be common to Canada, the United States, and Mexico in implementing the recommendations:

- Implementation efforts should be planned, coordinated, and executed by Environment Canada, the U.S. Environmental Protection Agency, and *Secretaría de Medio Ambiente y Recursos Naturales* (SEMARNAT) over the next 10 years. Interim milestones for emission inventory improvement should be developed to support regulatory deadlines in each country.
- Federal support for regional, state, and provincial emission inventory development and improvement needs to be on-going to ensure that emission inventories are able to provide the required quality of information.
- Interaction and collaboration among and across Canada, the United States, and Mexico should be maintained and enhanced.
- Increased training of agency staff at federal, state and provincial, and local levels and industrial stakeholders will be required to effectively implement these recommendations.

Development of complete implementation plans for Canada, the United States, and Mexico is beyond the scope of this Assessment. However, country-specific action plans with approximate estimated costs for taking the first steps towards full implementation of the recommendations of this Assessment are briefly outlined below.

INITIAL ACTION PLAN FOR CANADA

- Improve the emission inventory for $PM_{2.5}$ and its precursors.
- Improve speciation profiles for fine particulate matter and volatile organic compounds.

- Improve point source emission estimates.
- Update the national emission inventory database system.
- Improve the timeliness for the dissemination of the national emission inventory trends and projections.
- Engage appropriate stakeholder groups to develop a national strategy to implement the eight recommendations of this Assessment.

INITIAL ACTION PLAN FOR THE UNITED STATES

- Enhance the emission inventories and associated tools (such as SPECIATE) for $PM_{2.5}$ and its precursors, especially for carbonaceous particles.
- Establish emission inventory reporting requirements for hazardous air pollutants and integrate data into the National Emission Inventory.
- Improve the capacity of state, local, and tribal agencies to develop inventories to meet State and Tribal Implementation Plan and other regulatory requirements.
- Engage appropriate stakeholder groups to develop action plans to implement the full range of recommendations.
- Increase support of research to develop and improve emission inventories.

INITIAL ACTION PLAN FOR MEXICO

- Complete the National Emission Inventory for Mexico.
- Develop and implement a communication strategy to disseminate the results of the National Emission Inventory.
- Develop and fulfill requirements at the national level to enable emission inventory updates on a 3-year cycle.
- Build emission inventory development capacity among state environmental agencies.
- Expand capabilities among Mexican agencies.
- Continue to improve the capabilities to develop emission inventories through interactions with the United States.
- Improve programs to conduct direct emission measurements by identifying sources needed to develop Mexico-specific emission factors and by developing vehicle fleet characterization data for mobile sources.
- Develop a national emission data system.
- Increase human resources available for emission inventory compilation, maintenance and update.

The costs of implementing these initial steps, in $US, are estimated to be approximately $6 million per year for Canada, $35 million per year for the United States, and $7 million per year for Mexico over 3 to 5 years. These expenditures would be in addition to current investments in emission inventory development.

Current spending on emission inventories is roughly $40 million per year across North America. This is obviously a substantial sum. To put this sum into perspective, it has been estimated that the United States spent about $19 billion in 1999 to meet the requirements of the *Clean Air Act*. Thus, for every $1,000 spent to meet the *Clean Air Act* requirements, about $2 is spent to characterize emissions. Doubling this investment would significantly improve knowledge of emissions and the ability to design better-targeted air quality management strategies. Better-targeted strategies, in turn, should reduce the cost of regulatory compliance. A modest increase in expenditures on inventories should lead to far more cost-effective protection of our health and ecosystems.

CONCLUSION

Emission inventories, essential to achieving air quality improvements, face challenging requirements in the next 10 years. The findings, recommendations, and action plans included in this Assessment provide specific direction for future development and begin to identify the resources necessary to achieve these

improvements. The priorities and resources available for implementing this Assessment's recommendations and action plans will differ among Canada, the United States, and Mexico, but continued coordination and collaboration will enhance the effectiveness of individual efforts. Significant public and private expenditures will be needed to address priority and long-term needs.