Completion of the 1999 Mexico National Emissions Inventory – Lessons Learned

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ABSTRACT

The 1999 Mexico National Emissions Inventory was recently completed. This inventory includes annual estimates for seven pollutants (NO_x, SO_2, VOC, CO, PM_{10}, $PM_{2.5}$, and NH_3) for point, area, on-road motor vehicle, nonroad mobile, and biogenic sources. The inventory includes emissions for each of the 32 Mexican states (including the Federal District) as well as for each of Mexico's 2,443 municipalities. The project was sponsored by the U.S. EPA, Western Governors' Association, North American Commission for Environmental Cooperation, and Mexico's Secretariat of the Environmental and Natural Resources and the National Institute of Ecology.

This paper provides an overview of the objectives and scope of the 1999 Mexico NEI, building upon previous papers written on the process and progress in the past. Results are presented by pollutant, source type and source category. Also, the process used to develop the emissions modeling files is described, including quality assurance and gap-filling techniques used to provide all of the information required for the NIF and SMOKE/IDA formats and subsequent air quality modeling. (Note that another paper by Iniestra, et al. describes the details of the SMOKE/IDA processing and air quality modeling of the 1999 Mexico NEI emissions using CAMx.)

The project team shares its perspective on "lessons learned" during planning, data collection and dissemination, and reporting of the Mexico NEI, with the objective of providing a basis for improving the quality of available information, and generating information that is currently not available for inventory purposes. For example, certain source categories were not included in the 1999 Mexico NEI such as paved and unpaved road dust; the reasons for this will be explained and suggestions will be made for including these sources in future versions of the inventory. Perspectives related to the human and material resources that are needed to successfully complete such an extensive effort will be provided, along with plans for the future such as developing emission projections for future years.

INTRODUCTION

The Mexico National Emissions Inventory (NEI) is the culmination of many years of hard work and partnership between Mexico's Secretariat of the Environment and Natural Resources (Secretaría de

Medio Ambiente y Recursos Naturales—SEMARNAT) and National Institute of Ecology (Instituto Nacional de Ecología—INE), the U.S. Environmental Protection Agency (U.S. EPA), Western Governors' Association (WGA), and the North American Commission for Environmental Cooperation (CEC). Representatives from these partners, along with other stakeholders from government, academia, and the private sector, participated in the Technical Advisory Committee (TAC) and provided technical guidance for development of the Mexico NEI.

The Mexico Emissions Inventory Program began in 1994 with a vision to increase capacity within Mexico for development of emission inventories and focused on the development and implementation of the methodology manuals and training. In 2001, the focus expanded to include the development of the Mexico NEI in three phases:

- Phase I: Planning and methodology development;
- Phase II: NEI for the six northern states; and
- Phase III: NEI for the entire country (32 states).

Details on the methodologies and data used in the development of the final 1999 Mexico NEI are presented in other papers, books, and presentations.[1, 2, 3, 4, 5] Also, the final 1999 Mexico NEI report, finalized in October 2006, is available on the U.S. EPA Technology Transfer Network, along with the emissions data that have been formatting using the U.S. NEI Input Format (NIF3.0) and the Sparse Matrix Operator Kernal Emissions (SMOKE) Inventory Data Analyzer (IDA) formats.[6] This paper focuses on the results of Phase III (i.e., the final Mexico NEI), describes the development of model input files, and explores some lessons learned during this 10-year multi-national project.

Mexico NEI Objectives and Scope

The objectives of the Mexico NEI are as follows:

- Comply with the Mexican Federal Environment Law mandate to integrate and update a National Emissions Inventory for Mexico;
- Promote Mexican institutional capacity-building to compile, maintain, and update emissions inventories;
- Provide a technical basis for improved air quality and health impact analyses in Mexico and the U.S.;
- Assist with regional haze requirements in the U.S.; and
- Support the development of a tri-national emissions inventory of criteria pollutants for Mexico, the U.S., and Canada.

Some specific end uses for the Mexico NEI are to provide the technical data needed for national-level analyses of air emission sources affecting air quality and public health in Mexico, and to provide the input data needed to conduct air quality modeling of criteria and visibility pollutants.

- The scope of the Mexico NEI is defined by its geographic domain, base year, pollutants, and source types. The geographic domain is the country of Mexico, its 32 states and 2,443 municipalities (Figure 1). The base year of 1999 was chosen because most governmental agencies possessed complete sets of the types of data needed to estimate emissions for that year. Also, the year of 1999 corresponds with U.S. EPA's National Emissions Inventory triennial reporting cycle. The pollutants for the Mexico NEI include the air pollutants,

Figure 1. The Country of Mexico

State Code	State Name
1	Aguascalientes
2	Baja California
3	Baja California Sur
4	Campeche
5	Coahuila
6	Colima
7	Chiapas
8	Chihuahua
9	Distrito Federal
10	Durango
11	Guanajuato
12	Guerrero
13	Hidalgo
14	Jalisco
15	México
16	Michoacán
17	Morelos
18	Nayarit
19	Nuevo León
20	Oaxaca
21	Puebla
22	Querétaro
23	Quintana Roo
24	San Luis Potosi
25	Sinaloa
26	Sonora
27	Tabasco
28	Tamaulipas
29	Tlaxcala
30	Veracruz
31	Yucatán
32	Zacatecas

or their precursors, for which Mexico has air quality standards: nitrogen oxides (NO_x), sulfur oxides (SO_x), volatile organic compounds (VOC), carbon monoxide (CO), and particulate matter (PM) smaller than 10 micrometers (μm) in aerodynamic diameter (PM_{10}). Also, the Mexico NEI includes estimates of PM smaller than 2.5 μm in aerodynamic diameter ($PM_{2.5}$ – a visibility pollutant) and ammonia (NH_3 – a potential precursor to visibility species).

The Mexico NEI includes estimates for all source types, including anthropogenic sources as well as natural (i.e., biogenic and geogenic) sources of air pollution. However, there are several factors contributing to likely overestimates of natural (biogenic) NO_x and VOC emissions (e.g., lack of seasonal crop data, data gaps and inaccuracies in the cloud cover and temperature data, and the land use data set used in the model used to estimate biogenic emissions). Therefore, this paper focuses on anthropogenic sources, only.

1999 Mexico NEI Results

Table 1 summarizes the 1999 Mexico NEI, by (anthropogenic) source type, by pollutant. Specific source categories contributing to these emissions are discussed below:

- On-road motor vehicles are the most significant contributor of NO_x, followed by nonroad mobile sources and power plants. On-road motor vehicles, power plants, and nonroad mobile sources emit approximately 67 percent of NO_x emissions (i.e., approximately 1,057,000 tons/year).
- Power plants are the most significant contributors of SO_x emissions, followed by manufacturing and other industrial processes, petroleum and coal product manufacturing (i.e., refineries), and industrial fuel combustion (an area source). These sources emit over 93 percent of the SO_x emissions (i.e., approximately 2,950,000 tons/year).
- Solvent utilization, on-road motor vehicles, fuel distribution (i.e., gasoline and liquefied petroleum gas [LPG]), and other fuel combustion (i.e., mainly residential wood combustion) are the most significant VOC emitters. These four categories emit over 84 percent of the VOC emissions (i.e., approximately 2,416,000 tons/year).
- CO emissions are mainly from on-road motor vehicles with over 62 percent of the total CO inventory, followed by other fuel combustion (i.e., mainly LPG in the transportation sector) with approximately 27 percent of the total CO inventory.
- Other fuel combustion is the most significant source of PM_{10} and $PM_{2.5}$ emissions, followed by manufacturing and other processes. Combined, these sources comprise approximately 14 percent and 34 percent of the total PM_{10} and $PM_{2.5}$ emissions, respectively.
- Livestock, fertilizer application, and domestic generation of NH_3 are responsible for the majority of the NH_3 emissions. Only very minor contributions come from on-road motor vehicles.

Table 1. Summary of the 1999 Mexico NEI (tons), by source type.

Source Type	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
Point	494,745	2,903,265	273,239	184,800	327,678	219,269	
Area	304,461	214,479	1,921,757	2,756,593	484,081	353,037	1,430,586
Mobile	480,164	26,902	631,594	5,149,744	22,622	20,724	8,346
Nonroad	290,752	3,840	38,764	169,316	41,047	39,816	
Total	**1,570,121**	**3,148,486**	**2,865,354**	**8,260,453**	**875,428**	**632,846**	**1,438,933**

Development of Model Input Files

The Mexico NEI provides the best available Mexican inventory to the Western Regional Air Partnership (WRAP), the other Regional Planning Organizations (RPOs), and U.S. EPA for air quality modeling purposes to represent the regional haze baseline planning period 2000 to 2004. The WRAP sponsored a task under the Mexico NEI project to develop model input files from the 1999 Mexico NEI data for use in its "base02a" modeling runs by the WRAP Regional Modeling Center (RMC), and made those data publicly available for use by the Mexican government, RPOs, U.S. EPA, and U.S. states.[6]

Formatting the area, on-road motor vehicle, and nonroad files was very straightforward. The emissions data were formatted into both National Emissions Inventory Format (NIF) version 3.0, and SMOKE/IDA formats. However, formatting of the point source data presented some challenges that required additional work to resolve; these are explained below.

For Mexico NEI point source inventory, facility-level emissions estimates, facility location, and geographic coordinates, were provided by SEMARNAT. For most of these facilities, the coordinates were reported by the facility and, in cases of erroneous or missing data, ERG gap-filled any missing coordinates using the locality (community equivalent) centroid in which the facility was located.

Current Mexican law allows public access to emissions data (i.e., facility name, North America Industry Classification System [NAICS] code, facility location, stack parameters, and annual emissions) only for those industries under federal jurisdiction. Although the federal jurisdiction sources comprise most of the significant point sources in the Mexico NEI, and even though current Mexican law allows the release of such data for the industries under federal jurisdiction, it was still necessary to receive permission from SEMARNAT to do so. However, for those facilities not under federal jurisdiction (i.e. mostly under state jurisdiction), it was not possible to disclose the real identity of the facility, including facility name, and applicable NAICS codes, location, etc. Originally, the work plan called for these to be treated as area sources, however, another solution was developed which allowed these to be treated as point sources after all. For these point sources, the original NAICS codes were retained where there were four or more facilities within one municipality that had the same NAICS code. In the case of fewer than four facilities, an NAICS code of 339999 and an SCC of 399900 (all other miscellaneous manufacturing) was assigned to the manufacturing facilities. In the case of fewer than four non-manufacturing point sources, an SCC 399999 (miscellaneous industrial process) was assigned. Also, the name of each of the nonfederal jurisdiction facilities was given as "Undisclosed" in order to maintain confidentiality of the facility identity.

However, even after performing the gap-filling for SCCs and location coordinates as described above for point sources, several issues still needed to be resolved pertaining to the point sources. These issues were due mainly to the fact that the Mexico NEI point source inventory was developed at the facility level and no individual stack data were readily available. To remedy this, several steps were performed. First, ERG assigned six-digit SCC codes to each facility record, based on their corresponding NAICS codes. These codes were incorporated into the IDA files and sent to the WRAP RMC. The WRAP RMC used SMOKE to perform some initial processing, including assigning default stack parameters based on six-digit SCC. (The WRAP RMC had developed the six-digit SCC defaults by compiling the U.S. EPA eight-digit defaults and calculating the median default for each of the SCCs in the Mexico NEI data set.)

Once this assignment was complete, the data were sent to SEMARNAT for review and comment. Several changes were made by SEMARNAT to replace some of the default stack parameters with actual stack data for certain facilities, as well as to add several new emission units/stacks to certain

facilities. ERG incorporated these changes into the point source NIF and SMOKE/IDA files. The modeling files were developed at the end of Phase II for the six border states. The modeling files for the remaining 26 states in Mexico were developed at the end of Phase III, along with a revision to the Phase II modeling files to incorporate some updates to point and nonroad source mobile source emissions. All NIF and SMOKE/IDA files are located on the U.S. EPA's Technology Transfer Network. Note that details of the actual SMOKE/IDA processing are described by Iniestra, et al.[7]

Lessons Learned and Opportunities for Improvement

The objectives of this section are to identify areas and data that are deficient and need to be improved in the future, to facilitate the development of projections to future years, and to assist with capacity building for emission inventories developed in Mexico.

Information Gaps

Point Sources – The basis for the point source emissions inventory is the data report by individual facility on their Annual Operating Reports (Cédulas de Operación Annual – COAs). However, the number of facilities submitting COAs needs to be increased. Currently, SEMARNAT is making significant progress in coordinating with the state environmental agencies (SEAs) to yield better COA data from the state jurisdiction point sources. Providing SEAs with guidance on consistent reporting formats will also help to ensure data are consistent across all states, thus making the inventory process more efficient and results more accurate. For example, SCC- or process-level data are currently not collected, and point sources do not report ammonia emissions. Also, continued development and implementation of electronic submittal tools is recommended for improving the quality and quantity of emissions data submitted by the SEAs. Also, currently, NH_3 emissions are not recorded by facilities on their COAs. These should be included in the future to provide a comprehensive set of emissions data for air quality analyses. Finally, estimates of VOC emissions from industrial facilities are not consistently estimated and reported. Developing industry-specific methods for testing and/or estimating these emissions (along with the other pollutants) would increase the quantity and quality of the emissions data.

The majority of the point source emissions in the Mexico NEI come from power plants, oil and gas industry (i.e., refineries, oil and gas exploration, and bulk terminals), and nonmetallic minerals products industries. These sectors could be used to set priorities for development of Mexico-specific emission factors.

Current WRAP modeling of the 1999 Mexico NEI relies entirely upon U.S.-based default temporal profiles. Because the WRAP modelers are focusing on long-range transport, temporal profiles of longer time scales are preferred over temporal profiles of shorter time scales (e.g., seasonal or monthly over diurnal or hourly) for visibility modeling. Ideally, the Mexican point source inventory would contain operational data that provides the seasonal or monthly operational schedules for each source; however, these data are not available from the current data collection mechanism for point sources (i.e., the COA). Alternatively, continuous emissions monitoring (CEM) data could be used to develop temporal profiles. Although some CEMs have been installed on a few point sources in Mexico (i.e., approximately 10 EGUs, 2 cement kilns, and a few industrial boilers), the data reported are not reliable and are not recommended for use in developing temporal profiles for Mexican sources at this time.

As a first-cut approach to understanding the monthly and seasonal fluctuation of combustion sources, it is easy to examine the fuel sales activity from PEMEX, the national petroleum company of Mexico. PEMEX monthly fuel sales data, based on barrels per day (bbl/day) sold at each of the 24 bulk terminals in the six northern Mexican states, were examined. Monthly fuel sales in terms of a percentage

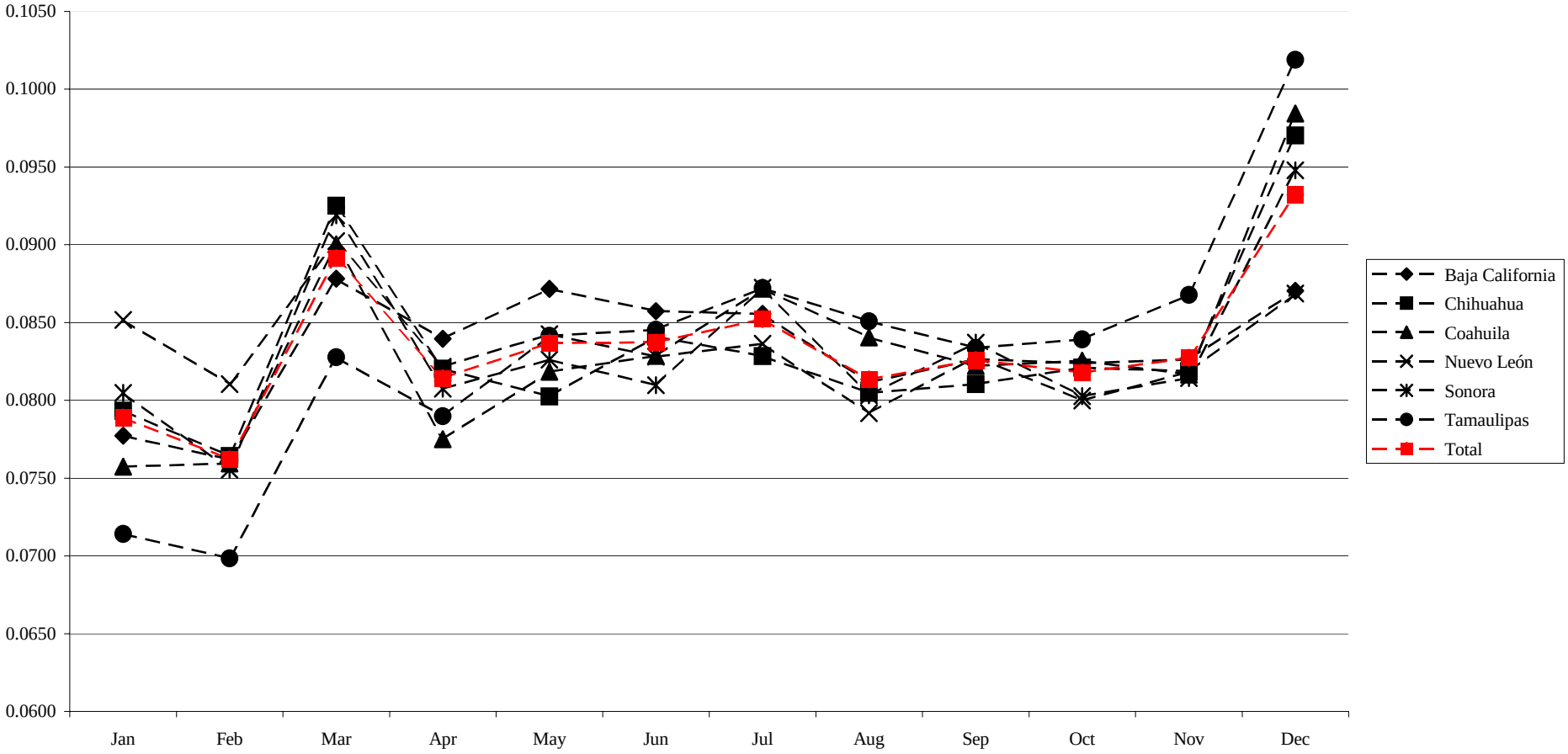
of the annual fuel sales within each state is shown in Figure 2 for Magna gasoline (i.e., equivalent to regular unleaded gasoline in the U.S.). Figure 2 shows that the least amount of fuel is sold in the month of February (after the holiday season), while the highest level of fuel sales occurs in December (during the holiday season). Also, in 1999, Easter occurred on April 4, and the increase in fuel sales in March relative to February and April, likely reflects travel during the week preceding Easter. Monthly fuel sales could be used to determine the monthly, or seasonal profiles for mobile sources. Also, sales of other types of fuels (e.g., fuel oil, diesel) could be used to depict temporal activity of other combustion sources. SEMARNAT has suggested that a special survey be conducted to obtain monthly or seasonal data for the most significant industrial sources (e.g., power plants, cement plants, natural gas processing plants, automobile assembly plants). This information could be collected under agreements between SEMARNAT with the appropriate agency (e.g., Secretariat of Energy, PEMEX, etc.) or trade association.

Area Sources – Evaporative VOC sources include many different types of source categories. For some VOC categories, trade associations provided national-level activity data (i.e., paint and ink statistics and dry cleaning solvent statistics). Unfortunately, for other VOC categories (i.e., consumer solvents and degreasing), an appropriate trade association could not be identified. Consequently, U.S. default per capita or per employee emission factors were used to estimate emissions instead of Mexico-specific activity data which resulted in the VOC emissions from both consumer solvents and degreasing being relatively significant as compared to the emissions from other VOC sources. These emission estimates for degreasing and consumer solvents in the Mexico NEI are highly uncertain because of the use of U.S. emission factors. Identifying and obtaining information from the appropriate trade associations will improve the accuracy of the emission estimates for these categories.

Agricultural sources include a wide variety of fugitive dust sources (i.e., agricultural tillage and beef cattle feedlots), ammonia sources (i.e., livestock ammonia and fertilizer application), combustion sources (i.e., agricultural burning) and evaporative VOC sources (i.e., pesticide application). A key source of activity data for the agricultural sector is the Secretariat of Agriculture, Livestock, Rural Development, Fisheries, and Food (Secretaría de Agricultural, Ganadería, Desarrollo Rural, Pesca y Alimentación – SAGARPA), but the data that they were able to provide were limited to some estimates of crop acreage and livestock population. On-going and increased interaction with SAGARPA is needed to identify and/or develop other needed activity data for use in the Mexico NEI in the future. These activity data include region-specific agricultural practices (i.e., field and pruning burning, fertilizer application, and pesticide application), as well as crop calendars and other detailed activity data.

Unpaved and paved road dust can be very significant sources of PM_{10} and $PM_{2.5}$ emissions. However, these were not included in the Mexico NEI since the estimation methodologies incorporate emission factor equations that require a large number of location-specific input parameters (i.e., silt loading, silt content, average vehicle speed, average vehicle weight, average silt moisture content, and number of precipitation days). With the exception of the number of precipitation days, the other relevant input parameters were only available for a few locations in Mexico (i.e., the cities of Ciudad Juárez and Chihuahua). Future development of these location-specific input parameters will enable the estimation of unpaved and paved road dust emissions. For example, for the Western Arizona Sonora Border Air Quality Study (WASBAQS), the Arizona Department of Environmental Quality is sponsoring several tasks for development of a criteria and hazardous air pollutant emissions inventory. This project includes work to collect silt samples in the San Luis Río Colorado, Sonora. These data will be used to develop local unpaved and paved road dust emissions factors, and estimate emissions from these sources in the portion of northern Sonora, Mexico.

Figure 2. Monthly distribution of Magna gasoline sales for 1999 – Northern Mexico Border States



On-Road Motor Vehicles – Vehicle activity data (i.e., vehicle kilometers traveled [VKT]) and fleet distribution information in Mexico is very limited or not readily available. In several of the emissions inventories documented at the time the inventory was compiled, VKT were estimated using vehicle registration statistics combined with assumed daily VKT based upon some limited traffic count statistics, informal surveys, and anecdotal information. However, these data were not available for the entire country at the municipality level and it was not feasible to collect this information due to time and economic constraints.[6]

As an alternative approach, fuel sales data could be used to estimate VKT, if assumptions regarding fuel efficiencies for various vehicle classifications were made. However, fuel sales data provided by PEMEX were not available at the municipality-level. Another alternative was to consider the results of traffic demand models (TDMs) used by transportation planning authorities to estimate vehicle activity; however, these are not widely used in Mexico. Furthermore, it was determined that, due to the complexity of TDMs and the considerable technical, financial and human resources needed to develop TDMs for the entire country, it was not technically or economically feasible to use them for development of the Mexico NEI.

As a consequence, on-road motor vehicle emissions were calculated using daily per capita emission rates obtained from the combined use of TDMs and emission factors generated by the MOBILE6-Mexico emission factor model for seven representative urban areas. Mexico-specific emission factors were estimated for seven different aggregated emission classifications using the MOBILE6-Mexico emission factor model, which was developed from U.S. EPA's MOBILE6.2 model and modified using limited Mexico-specific testing data (conducted in Mexico City, Ciudad Juárez, and Aguascalientes), very limited information on fleet characteristics, as well as U.S. data which were assumed to represent conditions existing throughout Mexico. Emission results for SO_x, PM_{10}, and $PM_{2.5}$ were adjusted to account for gasoline and diesel sulfur contents provided by PEMEX. Per capita emission rates were then used to calculate emissions in other urban areas in the country, based on population counts. As part of the first-time development of the Mexico NEI (i.e., a national inventory with municipality-level detail), this methodology was appropriate. However, additional collection and development of travel demand models, motor vehicle fuel statistics, vehicle registration statistics, and other motor vehicle-related surveys can be used.[6]

The TDM-based methodology used for estimating vehicle activity data will most likely not be used by individual local authorities in future updates of the inventory, due to the considerable financial, technical and human resources needed to develop the models. Thus, recommendations to fill information gaps for this estimation are centered in the collection of site-specific activity data (i.e. VKT) and information on fleet characteristics (i.e. registration data, fleet age distribution, VKT mixes, etc.), to improve data quality and reduce overall uncertainty in future inventory updates. Also, since the MOBILE6-Mexico was built upon fairly limited vehicle testing, additional vehicle testing was also recommended to improve the quality of the basic emission rates used in the 1999 Mexico NEI. [6]

Building upon these recommendations, INE has planned a set of complementary projects aimed at collecting information from the vehicle fleet in several cities in Mexico, in 2007 and 2008. One such project will include a series of measurement campaigns using remote sensing equipment in several Mexican cities along the U.S.-Mexico border. The objective of these campaigns will be to measure tailpipe emissions (CO, VOC, NO_x and, if possible, PM) from as many vehicles as possible in several cities along the border. The measurements will also provide vehicle data to better characterize (by type, age, etc.) the vehicle fleet in the border, including high-emitting imported vehicles. An additional project is a follow-up of a previous project (2004-2007) performed in the Mexico City Metropolitan Area (MCMA).[8] The main outcome of the MCMA project was a considerable amount of information on

vehicle fleet distribution, vehicle activity (i.e., number of cold and warm start-ups, speed on different types of roadways) and emissions. This information, besides serving as input for the International Vehicle Emissions Model (IVEM), served as the foundation to develop a driving cycle for the MCMA. INE plans to expand this experience to other cities in Mexico to gather the same type of information from a selection of "representative" cities (in terms of population, altitude, economic activity, etc) in Mexico. The data gathered from the "representative" cities could then be extrapolated to other similar urban areas in their efforts to estimate emissions from mobile sources. Complementary efforts include activities to build capacity among local authorities on the collection of information relevant to motor vehicle emission estimation and on the compilation, maintenance and use of on-road motor vehicle emission inventories.

Nonroad Mobile Sources – Nonroad mobile sources in previous Mexican emissions inventories have been limited to aircraft, locomotives, and commercial marine vessels (included as area sources in this report). The Mexico NEI includes two additional types of nonroad mobile sources that have not been previously included in Mexican emissions inventories: agricultural equipment and construction equipment. There are, however, a number of other nonroad equipment types that are not included in the Mexico NEI (i.e., industrial/commercial equipment, recreation vehicles and boats, lawn and garden equipment, oil field and airport service support equipment, and logging equipment). Although these have been identified as being less significant source categories in U.S. emissions inventories, it is currently unclear to what extent they are important in Mexico. Future work concerning nonroad mobile sources may focus on development of activity data for these categories that are currently excluded. In addition, the Mexico NEI nonroad mobile source estimates used equipment populations that were either only available on the state level (i.e., for agricultural equipment) or extrapolated from U.S. data (i.e., for construction equipment). The nonroad mobile source emission estimates can be improved by obtaining Mexico-specific equipment population statistics at the local level. This will require coordination with various government agencies and/or industry associations. Also, a survey of Mexico nonroad equipment operations would provide a more accurate estimate of annual hours of operation.

Human Resources

In Mexico, human resources are considerably limited for emission inventory compilation, maintenance and update. A total of four staff at the Under-Secretariat of Environmental Management are in charge of maintaining and updating emission inventories at the regional and national levels. At INE, an additional three people perform emission inventory work, mainly related to developing tools and technical guidance for emission inventory development. At the local level, human resources within the State Environmental Agencies (SEAs) are even more limited; tasks pertaining to air quality issues (e.g., monitoring, inventories, permitting, enforcement, etc.) are often carried out by only one person, who is also in charge of managing other environmental programs within the state. From the beginning of the Mexico NEI process, these limitations were clear, so the decision was made to provide INE and the Under-Secretariat of Environmental Management with personnel who could be dedicated to the project. Without these personnel, the chances of meeting the program objectives on time would have markedly decreased.[9]

While the Mexico NEI project was a success as a result of collaborative efforts between Mexico and the U.S., and the support of several U.S. and trilateral agencies, a number of critical needs for the future have surfaced over the course of its development. Mexico requires a strong investment in capacity building within the Mexican states. Since the states have first-hand knowledge of specific situations and issues within their borders, their work is critical. In order to maintain and update the Mexico NEI, state environmental authorities require basic emission inventory development capacity. Intensive training is required for state government officials and technicians in the areas of information retrieval, emission

factor use, quality assurance/quality control activities, and inventory compilation in general. Interaction with SEMARNAT to integrate the Mexico NEI will be facilitated if all state agencies act upon the same technical baseline. Mexican agencies at the federal and state level often have access to data and facilities that will significantly expand the ability of SEMARNAT to develop emission inventories and updates. Expanding the capabilities of these other agencies to measure and collect emission and activity data will substantially facilitate future Mexico NEI development.[9,10]

Another important outcome of the project was that it demonstrated that effective partnerships can be created where a common need is well defined. The Mexico NEI provides a blueprint for how to build trust and effective working relationships that can be fruitful into the future. Partnerships to enhance Mexico's emission inventory development capacity have been of enormous value to both Mexico and the U.S. and need to be continued. Where appropriate, such efforts should be expanded across North America through NARSTO, the NACEC, and similar multinational entities. Also, partnerships at the state level, such as with the WGA, are highly beneficial to increase local capacity in this regard. Areas requiring special attention include training for Mexican inventory developers at the federal and state levels, and emission measurement pilot project activities to develop Mexico-specific emission factors.[7,9]

Material/Capital Resources

The first NEI for Mexico required substantial support from the partners involved, in terms of financial resources. The U.S. EPA, through the WGA, was the primary supporter of this effort, mainly providing contractor fees for the development of inventory work and specific materials for emission inventory training. The NACEC also supported this project, providing financial support to carry out several workshops and meetings, as well as training activities. These two organizations together contributed more than $2,000,000 during the last four years of the project. Additionally, SEMARNAT and INE provided the institutional support to contact and involve other stakeholders in the inventory process and assigned $175,000 in personnel time to complete this project.

The road ahead for the Mexico NEI requires financial resources to achieve a more solid, comparable and timely NEI for Mexico in the medium term. According to NARSTO's assessment of emissions inventories in North America, Mexico's NEI could be greatly enhanced if several recommendations were implemented.[9] It is necessary to invest considerable resources in the coming years to carry out the following activities:

- Develop and fulfill requirements at the national level to enable emission inventory updates on a three-year cycle;
- Develop and implement a communications strategy to disseminate the results of the Mexico NEI;
- Build emission inventory development capacity among state environmental agencies;
- Expand existing capabilities among Mexican agencies;
- Continue to improve the capabilities to develop emission inventories through interactions with the U.S. and Canada (e.g. training for Mexican inventory developers at the federal and state levels, and emission measurement pilot project activities to develop Mexico-specific emission factors);
- Improve programs to conduct direct emission measurements by identifying sources needed to develop Mexico-specific emission factors and fleet characterization data for mobile sources;
- Develop a national data system; and
- Increase human resources available at federal and local levels for emission inventory compilation, maintenance and update.

Overall, it is estimated that the implementation of these recommendations will require roughly $27 million in the next three to five years.

CONCLUSIONS

The first ever national emissions inventory for Mexico is complete, and its results (i.e., final report, NIF and SMOKE/IDA files) are available on the U.S. EPA's Technology Transfer Network.[6] This inventory is the culmination of over 10 years of effort by Mexico's SEMARNAT and INE, with the sponsorship of U.S. EPA, WGA, NACEC, and other entities such as the WRAP. Through this process, a great deal has been learned about the availability of data, the procedures used by the Mexican government and the Mexican industries to estimate emissions and disseminate information, and the needs of the various government agencies to sustain the Mexico NEI into the future.

Certain technical improvements are noted for the future, including collection of better resolved point source emissions data, the need for locally-developed activity data for estimating emissions from area and nonroad mobile sources. INE has already implemented a program to develop local data for estimating more accurate onroad motor vehicle emissions in the future.

Human resources available at federal and local levels for emission inventory compilation, maintenance and update need to be increased. The first ever Mexico NEI was compiled by the limited personnel available at Mexican federal and state agencies with the help of a consulting team. However, to effectively follow up on the most pressing next steps, more personnel and resources (i.e., estimated as $27 million for the next three years) are needed for the compilation, maintenance and update of data. This would assure continuity of the Mexico NEI efforts.

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