

India PM10 Emission Inventory Training and Capacity Building Programs: EPA Efforts for Developing a Sustainable Foundation

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ABSTRACT

Between 2003 and 2006, the U.S. Environmental Protection Agency (USEPA), with funding support from the U.S. Agency for International Development (USAID), organized, sponsored, and deployed four unique emission inventory training and capacity building projects in India. These projects were developed and planned through a Memorandum of Understanding between USEPA and the Indian Ministry of Environment and Forests (MoEF). They are part of an ongoing partnership between the U.S. and India to enhance in-country capabilities to better understand and improve air quality in India. In addition to emission inventory projects, the overall EPA/India urban air quality program includes projects related to air quality monitoring, modeling, control strategy development, source apportionment, and health assessment efforts. This work is supported by multiple sponsors and collaborators, which has included training and technical support from the California Air Resources Board for the emission inventory projects.

This paper focuses on the four emission inventory capacity building projects created to provide a foundation for developing sustainable emission inventory programs within India's cities, states, and ultimately, at the national level. Each project was completely distinct, ranging from traditional classroom sessions, to highly interactive, hands-on intensives for developing actual emission estimates. We will discuss the objectives of each project, the ways in which they succeeded, areas for improvement, and the benefits of the entire program to date. Our hope is that this work, and the lessons learned, will also assist other countries that are in the early stages of developing their emission inventory programs.

INTRODUCTION

Since January 2002, the United States Environmental Protection Agency (USEPA) and the Indian Ministry of Environment and Forests (MoEF) have been working together under a Memorandum of Understanding to improve air quality management practices in India. As part of this effort, significant training and field study activities have been undertaken.

The USEPA has been working closely with a variety of Indian Federal, state, and local agencies, academic organizations, industry groups, and non-government organizations on this project with support from the U.S. Agency for International Development (USAID) and the U.S.-Asia Environmental Partnership (USAEP). Project activities include work on air quality monitoring, emissions inventory development, air quality modeling, control strategy development, source apportionment, and health benefits assessment. There is substantial work ongoing in each of these project areas through these partnerships



Discussing construction site emissions and controls in Gurgaon with project participants.

This paper focuses on the emission inventory component of the urban air quality efforts in India. In 2003, the effort began with an emission inventory overview training in Pune, India. Approximately 30 scientists, students, regulators, and managers participated in this first training. Based on feedback from the first training, in 2004 a new hands-on interactive training program was developed and a team returned to Pune where the training engaged a team of 40 participants in an intensive effort to develop an initial PM₁₀ emission inventory for the full Pune region. Pune has a population of about 4.5 million people and is about 180 kilometers south east of Mumbai (Bombay).

In 2005, the third project focused on the technical work of integrating and refining emission inventory and modeling data for Pune. In 2006 the fourth project drew on the lessons learned from the 2004 Pune pilot project, and created a new project which developed an emission inventory spreadsheet tool to provide practical PM₁₀ inventory development training to 45 participants from 7 cities. The 2006 training was held at the National Environmental Engineering Research Institute (NEERI) Zonal Laboratory in New Delhi.

Each project has been successful and well received, and has built on each other. The results are noteworthy:

- Emission inventory training was provided to over 110 individuals in India.
- The first comprehensive emissions inventory developed for an Indian city, with lessons learned now being shared with other interested cities and organizations.
- Air Quality Cell established for Pune Municipality.
- Effort of Pune Municipal Corporation acknowledged with “Government Most Committed to Air Quality Improvement Award” at 2004 Better Air Quality for Asian Cities Conference.
- Extensive array of Emissions Inventory training materials developed and disseminated.
- First demonstration in India of integrated decision support system that combines monitoring, emission inventory and modeling data to correlate emissions with concentration of air pollution.
- Heightened commitment and awareness by various levels of government on importance building science-based urban air quality management systems for crafting most cost-effective mix of control strategies.
- Embarked on multi-city replication program to expand results and promote capacity building and professional networking on emission inventory.

The remainder of this paper provides an overview of each of the four emission inventory projects, followed by a discussion of lessons learned and what it takes to make these types of projects work. We conclude with some thoughts about how India’s emission inventory efforts are moving forward and possible next steps.

OVERVIEW OF PROJECTS

To date, the program has provided four emission inventory training projects in India. With the exception of the first project, which was a broad overview training, we strived to develop projects that were extremely hands-on, collaborative, and practical, with clear products required from the participants at the project conclusion. The table below summarizes the dates, objectives, and participants in each of these projects.

USEPA Supported Emission Inventory Projects in India.

Project Date and Location	Objectives	Trainers	Participants
Training 1 2003 October 14-21 Pune	Provide general overview emission inventory training over 4 days. Meet with agency staff to discuss next steps. Meet with Chair of CPCB to discuss goals.	Ted MacDonald, USEPA OIA Bill Kuykendal, USEPA OAQPS Laurel Driver, USEPA OAQPS Patrick Gaffney, CARB Nichole Davis, UC Riverside, CE-CERT	Thirty participants representing national, state, and local governmental agencies, and members of academia and industry.
Training 2 2004 March 16-24 Pune	Over 7 days, work with participants to develop a preliminary PM10 emission inventory and database system for Pune region in India	Patrick Gaffney, CARB Michael Benjamin, CARB John Mooney, USEPA Region 5	A diverse team of 40 participants from several of India's governmental agencies, technical institutes, educational institutions, and industry
Training 3 2005 November 14-18 Pune	Work with technical staff for 4 days to refine and integrate modeling and emission inventory data and methods. Provide general emissions and modeling training to project students.	Alan Cimorelli, USEPA Region 3 Akula Venkatram, UC Riverside Ajay Ojha, Pune Municipal Corporation Patrick Gaffney, CARB Michael Benjamin, CARB John Mooney, US EPA Region 5	Key technical staff from Pune Municipal Corporation, the India Center for Development of Advanced Computing, NEERI, and several university students
Training 4 2006 December 4-9 New Delhi	Using a spreadsheet-based calculation and documentation tool, train participants from 7 cities and various agency staff over 6 days to develop preliminary emission estimates.	Patrick Gaffney, CARB John Core, Core Environmental Consulting Ajay Ojha, Pune Municipal Corporation	Forty-five participants from seven cities (Delhi, Agra, Ahmedabad, Gurgaon, Nashik, Visakhapatnam and Mumbai), NEERI laboratories, CPCB, and other agencies

TRAINING 1 – OCTOBER 2003, Pune Emissions Inventory Overview

The 2003 project objectives were:

- Over four days, provide emission inventory training to India's environmental scientists representing national, state, and local governmental agencies. Members of industry and academia also participated.
- Provide networking and coordination opportunities for those attending. About 30 students participated and the event was hosted by the Automotive Research Association of India (ARAI).
- Host a 1-day "next-steps" brainstorming session with agency staff.
- Brief the Chairman of India's Central Pollution Control Board about the training session and barriers to developing a more complete emissions inventory.
- Brief members of the U.S. Embassy and USAID India staff regarding the training, levels of participation, issues identified, and future needs.



The format of the project in 2003 was fairly simple and traditional. Using PowerPoint slides developed by an EPA contractor and fine-tuned by the trainers, the program consisted of units that were 1-3 hours in duration on pollutant types, emission inventory fundamentals, emission estimation methods for point sources, on-road and off-road mobile sources, non-point sources (areawide), and natural sources. These presentations were interspersed with a few case studies in which the students did some instructor-guided emission inventory calculations using example data.

The training days were long, and perhaps a little tedious for both the trainers and the students. Four days locked in a darkened training room, listening to people talk, no matter how enthusiastically and expertly, can be a challenge. However, on the bright side, some of us first time visitors to India were introduced to the civility of morning and afternoon tea breaks and the pleasures of daily Indian food buffet lunches.



Pune 2003 team. Top left photo seated from left – Dr. M.K. Chaudhari (ARAI), Ted MacDonald, Bill Kuykendal, Patrick Gaffney, Nicole Davis, Laurel Driver.

Most of the project students had little or no prior knowledge regarding emission inventory techniques. Nevertheless, most of the class was surprisingly engaged, and had numerous interesting and insightful questions. The training also provided a relatively rare opportunity for numerous key people working on air pollution to interact together in the same room. Many connections were made and a better understanding was gained of what agencies in India have information available that could be used for developing emission inventories.

During this 2003 inventory project, students indicated that their efforts could be improved if it was more clear which state, local, and federal agencies had which data. We also observed that there seemed to be a general lack of comfort about sharing information between agencies and institutions. During the project we repeatedly stressed the value of being open with data, even if, like most emission inventory



Pune 2003 participants and trainers.

data, it is incomplete, imperfect, and open to criticism. Through partnerships, any emission inventory results will not only be more complete and accurate, they will be better accepted by those stakeholders affected by the inventory estimates.

The training concluded with a full day meeting with key members of several of the participating agencies and environmental scientists to discuss the next steps for developing an emission inventory for the Pune region. This meeting was good for getting a better understanding regarding the regional bounds of the inventory, the sources to be included, and the people that should be involved. The course provided a good overview and orientation to emission inventory, its purpose and value, and generated interest and willingness to further pursue an emission inventory for Pune. It was also evident however, that this one classroom-style course did not equip the participants with enough applied experience to actually develop a useful PM10 emission inventory. Through participant feedback and many follow-up communications, we developed the second Pune inventory training project and returned to Pune during March 2004.

TRAINING 2 – March 2004, Pune Pune Regional Emissions Inventory Study

The 2004 project objectives were:

- Develop and lead an intensive, hands-on and practical, emission inventory training experience.
- Over 7 days, create an initial framework PM10 emission inventory for the overall Pune region as a tool to teach participants emission inventory skills.
- Work with and manage a team of 40 participants, representing local, State and National government, education and research organizations, and industry representatives, to develop the regional inventory.
- Give the participants an interactive teamwork experience, in which they must take on multiple roles and responsibilities, and integrate their efforts with those of other participants.
- Create an initial emission inventory for the Pune region that could be refined by the participants following the project, based on specific improvements identified during the project.



Project Summary. For the 2004 Pune study, the Team developed the concept and materials to provide fully immersive training project that culminated in developing a PM10 emission inventory for the city of Pune, India, and the surrounding region. Pune is a rapidly growing city with a population of about 4.5 million people and covering a region of about 243 square kilometers. Pune is in the state of Maharashtra and is approximately 180 kilometers south-east of Mumbai.

To develop an initial framework PM10 emissions inventory for the Pune region, a diverse team of 40 participants from several of India's governmental, educational, and industry institutions came together in Pune during March 2004. The project design, materials, and training were prepared and executed by Gaffney and Benjamin, with planning, logistics and coordination managed by USEPA, and in-country arrangement coordinated primarily



Some of the Pune 2004 participants and the trainers: Gaffney, Mooney, Benjamin, center back row.

through the Pune Municipal corporation and USAID staff in Mumbai.

To give a sense of the broader organizational involvement in the project, the list below shows the participating agencies.

- U.S. Environmental Protection Agency (USEPA)
- U.S. Asia Environmental Partnership (USAEP)
- Pune Municipal Corporation (PMC)
- Andhra Pradesh Pollution Control Board (APPCB)
- Society of Indian Automobile Manufacturers (SIAM)
- Centre for Development of Advanced Computing (C-DAC)
- U.S. Agency for International Development (USAID)
- India Institute of Technology – Mumbai (IIT-Mumbai)
- National Environmental Engineering Research Institute (NEERI)
- University of Pune (PU)
- Automotive Research Association of India (ARAI)
- Traffic Police, Pune City
- Regional Transportation Organization, Pune (RTO Pune)
- Maharashtra Pollution Control Board (MPCB)
- Central Pollution Control Board (CPCB)

Project Approach. Because of the complexity of the project, the limited time, and large number of participants with little or no emission inventory experience, the training team developed comprehensive milestone schedules as shown on the following page. These schedules, and others for all aspects of the project, were printed out as large posters and displayed throughout the main training room to keep goals and progress clearly in sight and documented.

Nearly twenty participants worked on developing emissions estimates over the course of the project. The other participants worked a combination of database, website, and inventory tasks. During the first day, the group was given a quick summary of what an emissions inventory is and general guidance on emissions estimation techniques. The emissions sources were subdivided into stationary point sources, areawide sources, and mobile sources. The emission inventory group was then assigned to teams for each major PM₁₀ source category.

Following source assignments, the group collectively discussed the data needs for each emissions category and identified possible contacts or agencies that might have the needed data. On day two, each team proceeded to collect necessary input data from the relevant agencies. In conjunction with data collection, groups also worked to identify the most appropriate emissions estimation methodologies for each source type.

Figure 1: Schedule for Pune Region Prototype Emission Inventory

Daily Schedule Overview	TUES	WED	THURS	FRI	WEEKEND	MON	TUES	WED
Emissions Inventory								
Case Study		☐ ■						
Identification of Sources		☐ ■						
Category Assignments		☐ ■						
Planning Document		☐ ■						
Inventory Source Worksheets		☐ ■						
Methods & Data Sources Discussion		☐ ■						
Identify Methods & Data				☐				
Review Source Worksheets		☐						
Problems & Issues		☐						
Full Group Input on Problems			☐					
Example Spreadsheets			☐ ■					
Emission Factor & Activity Data Collection			☐					
Staff Begin Spreadsheets			☐					
Begin Populating Spreadsheets			☐					
Rating Data Quality				☐ ■				
Ongoing Emissions Work				☐				
Group Assistance on Key Sources				☐				
Presentation of Draft Emissions						☐ ■		
Reasonableness Evaluation						☐		
Identify Quick Fixes						☐		
Finalize Emissions						☐		
Document Methods						☐		
Resolve Remaining Issues							☐	
Assist With Data Loading							☐	
Resolve QA & Other Issues							☐	
Complete Documentation							☐	
Finalize & Document Spreadsheets							☐	
Compile All Documentation							☐	

Note: Boxes marked with "□■" indicate that there will be a presentation and discussion lead by the facilitator.

The following table briefly summarizes the steps used in developing emissions estimates for each source category. In many cases there were deviations from this template, but it was used to provide a series of milestones to guide and track participant progress.

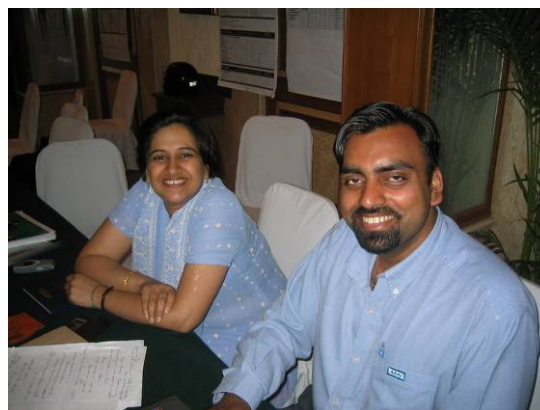
Figure 2: Summary of Steps Used for Emissions Estimation

Areawide Sources	TUES	WED	THURS	FRI	WEEKEND	MON	TUES	WED	Primary Responsibility
Paved Road Dust									Ajay Ojha, Prashant Pawar, Deepak Kapoor
Identify Staff		■							
Evaluate Methodologies			■						
Select Methodology			■						
Evaluate Emission Factors				■					
Calculate Emission Factors				■					
Evaluate Available Activity Data				■					
Develop Activity Data				■					
Develop Spreadsheet				■					
Calculate Emissions						■			
Check Assumptions & Calcs							■		
Format Emissions for Database							■		
Load & Validate Data							■		
Document Methodology & Assumptions							■		
Identify Areas for Improvement (spatial, temporal, EFs, activity)							■	■	

Though an informal peer review process, the input data, methods, assumptions, and approximations for each emissions source were evaluated to develop the most reasonable, Pune specific, PM10 emissions estimates possible within the time and resource constraints of the project. All methods and assumptions were documented in an abbreviated format to allow for easy review of each emissions estimate.

After estimating emissions and documenting methodologies, the emissions team converted their emissions estimates into a machine readable spreadsheet transaction format so the data could be automatically loaded to the database system by a loader developed by the database team.

Results Summary. Following seven very long days of intensive, interactive, hands-on effort, the project team successfully developed the first comprehensive PM10 emissions estimates for the majority of the emissions sources in the Pune region. Here by “comprehensive” we do not necessarily mean precise or accurate, or even complete, although we strived for this



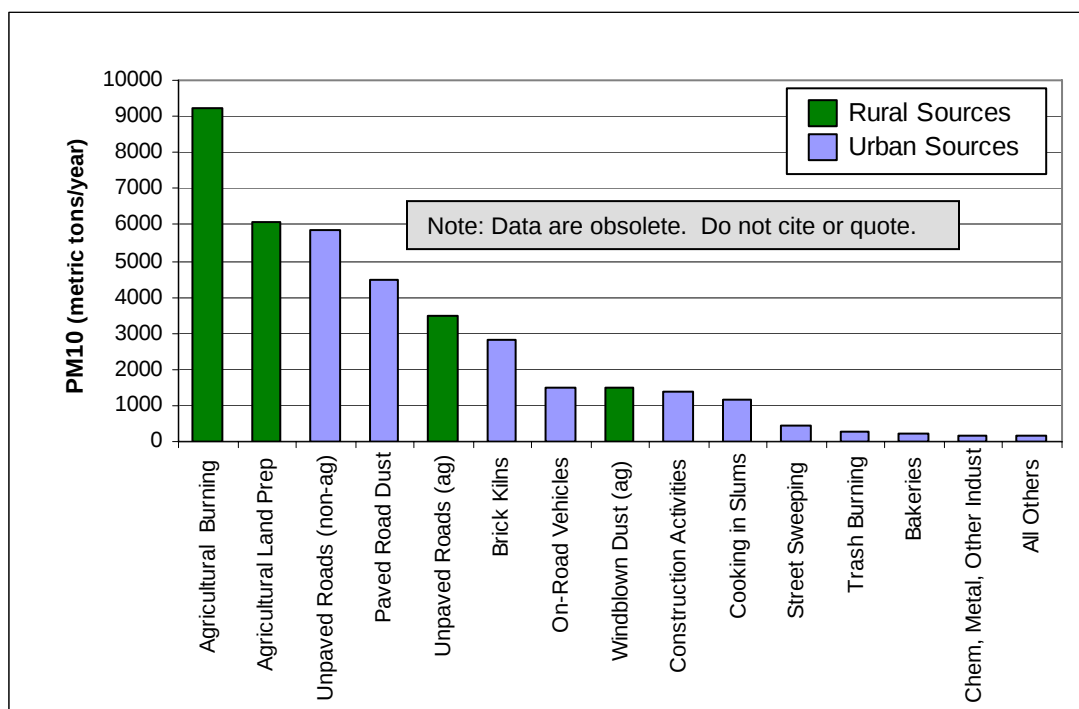
under the limited time constraints. When we say comprehensive, we mean that we attempted to include at least some emission estimate, no matter how approximate, for any potentially significant PM10 emission source in the region. In addition to the emission estimates, the team created a prototype relational database system to store, query, and report the emissions inventory data.

All emissions estimates were developed and validated by the project group through an extensive local data gathering and computation effort. Over a dozen different agencies and offices were contacted for data such as hectares of agricultural land, vehicle traffic information, number of street sweeping employees, fuel quantities and types used for cooking, and so on. All of the agencies contacted were extremely helpful in supporting the project.

Volunteers from Pune University also developed and hosted a project website to document the project findings, reports, and methods. Documentation on the inputs and assumptions used for the emissions estimates are located on the 2004 PREIS project website hosted by the Pune University Department of Environmental Sciences at: <http://www.unipune.ernet.in/dept/env/pei/index.html>

The following graph shows the initial 2004 PM10 emission estimates developed during the Pune project, which has total PM10 emissions of about 38,710 tons/year of PM10. However, this graph was later to become a source of confusion, and ultimately criticism of the project. More will be discussed on this later, but in summary, for those not involved in the project, there was surprise and confusion to see so much fugitive dust and open burning in the inventory.

Figure 3: Preliminary Draft PM10 Inventory – Full Pune Region 2004



The reasons for some confusion regarding the project results were twofold.

- First, we made an effort to estimate the PM10 emissions in the overall region, not just within the urban city boundaries, which was a new concept for some. This created questions because some were perplexed to see agricultural burning emissions for an assumed, “Pune City” emission inventory, since urban cities do not have agricultural burning. This ambiguity led to some public and private criticism of the project results.
- Second, we included fugitive dust (agriculture, roads, construction) and open burning sources in the regional inventory. Some prior inventory efforts in India focused primarily on those sources being considered for regulation, such as industry and mobile sources. By including all of the emission sources in an inventory, as we did, it could create ambiguities regarding control strategies, unless air quality modeling tools are employed, as was done in the subsequent 2005 Pune project.

Even with this post-project confusion and some criticism, the 2004 Pune PM10 emission inventory project was a tremendous success. Through the combination of good logistical support, a clear and complete plan of attack, extremely capable enthusiastic participants, and engaged cooperating agencies, this collaboration in Pune built the first-ever comprehensive draft PM10 emissions inventory for the Pune region. This initial inventory was an important building block in the foundation needed to understand and improve air quality for the region.

All of the participants developed much better understanding about what an emission inventory is, and how to use available data and methods to estimate emissions. Most importantly, the participants gained real-world, hands-on experience in developing emission estimates in a high pressure, team environment. This experience is invaluable as India continues its proactive efforts to better understand their sources of air pollution, and to develop cost effective solutions to improve air quality throughout the country.



One of the biggest success stories of the 2004 project and the data generated came several months later when the Pune Municipal Corporation (basically the city/county government) established the Pune Air Quality Management Cell. The cell was formed with some initial start-up funding from USAID, and support from USEPA, the US Asia Environmental Partnership, the Maharashtra Pollution Control Board, NEERI, MoEF/CPCB, and other stakeholders. This cell, or group, provided resources and staffing for ongoing air quality monitoring, inventory, and modeling activities,

coordinated by Dr. Ajay Ojha. The Air Quality Management Cell continued working to improve the initial emission inventory estimates for key categories, developed in-house air quality modeling expertise through the USEPA/MoEF program, and methodologically collected ambient air quality data for Pune. This ultimately led to Training 3, held during November 2005 in Pune.

TRAINING 3 – November 2005, Pune Modeling and Inventory Integration Workshop

This project was initially planned as a multi-city training for emission inventory development and modeling in Bangalore to share with other cities in India the lessons learned in Pune. The interconnection between the modeling and inventory tools would be used to more fully understand the sources of air pollution in a region and what can be done about it. Unfortunately, the training venue in Bangalore was flooded by torrential rains and there were other logistical problems leading the team to develop an alternative plan on short notice.



For this Plan B, members of previous emission inventory and modeling training teams returned to Pune for 4 days to work with the Pune Air Quality Management Cell and others to refine and integrate modeling and emission inventory data and methods for the region. The modeling work was led by modeling experts from EPA Region 3 and from University of California, Riverside, and emission inventory work was led by the CARB team. The newly trained Director of the Pune Air Cell supported both the modeling and emission inventory components. Additional modeling support was provided by the Centre for Development of Advanced Computing in Pune to process meteorological input data, NEERI also provided overall in-country support, and USEPA provided trip logistics, planning, and coordination.

Those attending the project included representatives of the Pune Municipal Corporation, the Maharashtra Pollution Control Board, the Indian Institute of Technology, the National Environmental Engineering Research Institute, the University of Pune, the Center for the Development of Advanced Computing, and the Pune Municipal Corporation Air Quality Cell.

Objectives of the 2005 Pune workshop included:

- Using modeling and inventory data to evaluate the magnitude and extent of the Pune regional PM10 air pollution problem.
- Collecting and processing relevant Pune meteorological data.
- Better understanding the temporal and spatial patterns of the emissions through a combination of inventory and modeling tools.
- Analyzing which PM10 sources contribute most to high PM10 events.
- Performing quality assurance on emission inventory estimates and refining spatial and temporal allocations.
- Gaining a better understanding about what type of meteorology produces the worst PM10 impacts in the Pune region.
- Using ambient PM10 air quality measurements, modeling, and emission inventory data, use an iterative process to improve the model performance and refine the emission inventory estimates.

The project was planned as an expert to expert working group, with days to be spent huddling over laptops and delving into the analysis and details of modeling and inventory data. However, to keep us on our toes, on arrival we were surprised to discover about 10 additional participants that were there to “watch and learn.” Some people may be able to effectively learn by watching others work on inventory spreadsheets and modeling output, but it would be a unique skill.

Due to the addition of the new people, the team unexpectedly had to split its attentions. Half the time was spent half providing ad hoc basic training on emission inventories and modeling to the new participants, and the other half of the time grinding into the technical details of modeling and inventory (during which time we had to ignore our basic training crew). This jumble was all occurring while also dodging ongoing daily rolling blackouts.

It was decided that the air quality modeling source domain would include a 30 kilometer radius around the city of Pune plus other large emission sources. The receptor domain would include the city of Pune, and would include sensitive receptors such as hospitals and schools. Initial analysis assumed flat terrain and utilized available meteorological data. The team used the further refined emission inventory data provided by the Pune Air Quality Cell. These data were based on initial estimates developed during the 2004 inventory project which was substantially improved for key categories by the Pune Air Management Quality Cell.

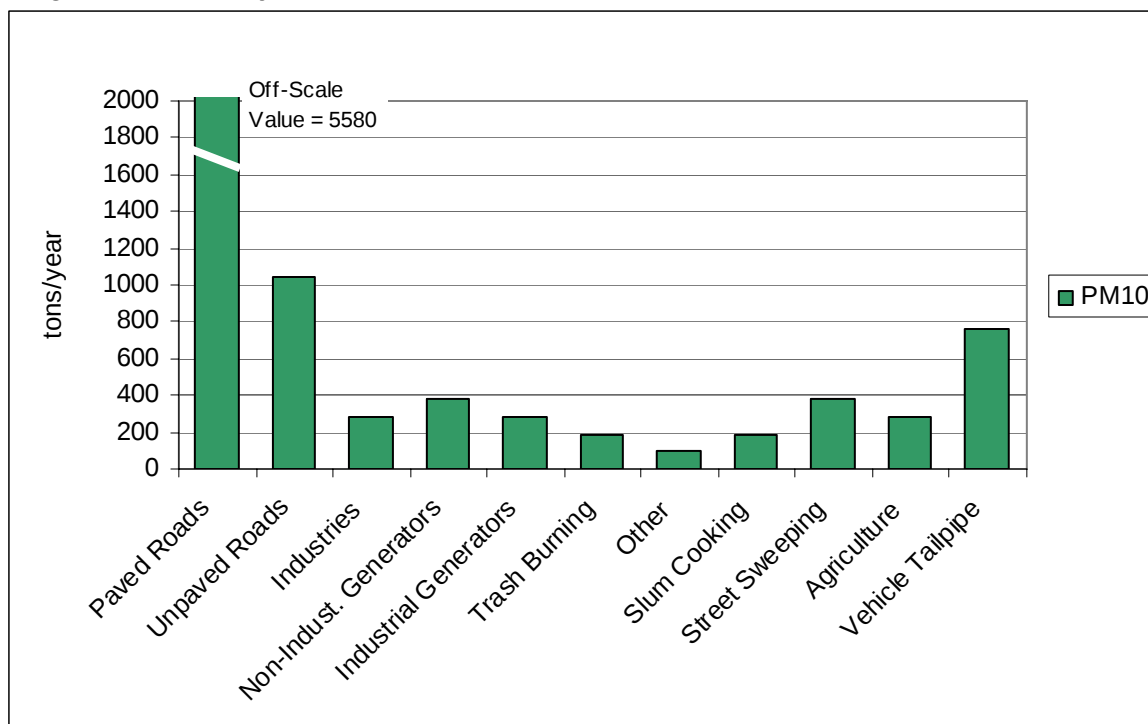


PM10 air monitoring in Pune.

The updated PM10 emission inventory data for Pune City are shown below¹. In this improved 2006 inventory, only the urban sources are included, which has a total of 9,458 metric tons of PM10 per year. Compare this to the initial 2004 emission estimates of 37,810 tons PM10/year for the entire Pune *region*, which included many rural agricultural and other non-urban sources. Because smaller particles are of greatest concern from a health effects perspective, work is also ongoing to develop a PM2.5 (particles 2.5 microns or less in size) inventory for the region. For a PM2.5 inventory, combustion sources such as vehicles, industrial sources, and generators are a much larger contributor to emissions than in the PM10 inventory, which is dominated by fugitive dust emissions. Based on planning objectives, focusing on PM2.5 could substantially affect control strategy development, particularly in urban areas.

During this event, when not providing basic inventory and modeling training, we spent the bulk of our time running the air quality model (AERMOD), comparing it with ambient measurements, digging into the inventory data, making refinements, running the model again, checking the meteorology, modifying modeling assumptions and running it again, improving the inventory spatial and temporal allocations, running the model again, comparing it with ambient measurements, and so on. The objective of this circular exercise was to tune the model and the inventory, so that in concert they could begin to reasonably represent the reality measured by the ambient monitoring data in Pune.

Figure 4. Pune City PM10 Emissions Draft Estimates for 2006.



¹Cimorelli, A.J., Venkatram, A., *Air Quality Planning Development of a PM10 Control Strategy In Pune, India (unpublished draft)*. Graphic adapted for this paper from data by Ajay Ojha and Pune Air Quality Management Cell.

Project Results. Through these interactive sessions we discovered and corrected some inaccuracies in the emission inventory data and improved some of the most important estimates. We also refined the spatial and temporal data inputs, which improved model performance.

Based on the modeling analysis (and direct observation), it appears that the highest PM10 concentrations in Pune occur in the early morning and late evening hours when nighttime meteorological conditions, including low wind speeds and mixed layer heights, restrict dispersion. This indicates that reducing the nighttime and early morning emissions of some of the more significant PM10 sources such as vehicle traffic or illegal garbage burning, might help limit the highest concentration events².

Also, the initial 2004 Pune regional emission inventory allocated roughly 25% of the total PM10 emission to Pune city, with the remainder, such as agricultural burning or land preparation, assigned to rural areas outside of the city core. Based on the overall *regional* PM10 inventory, it might appear that controlling agricultural sources would be a priority for improving Pune's air quality. However, the preliminary modeling exercises during this study, along with other ongoing work, indicate that agriculture likely plays a relatively small role in Pune's urban PM10 problems. If air quality dispersion modeling had not been brought into the process, considerable time and energy could have been wasted reducing emissions from less important emission sources based strictly on the mass of emissions. This helps to illustrate the need to combine modeling, inventory, and air quality data in prioritizing and developing reasonable, cost effective PM10 control strategies.

The modeling work also showed that a relatively simple urban dispersion models could provide valuable insight into the relationship between emissions and concentrations of PM10. The modeling results indicated that at this stage, a steady state model, such as AERMOD, can provide useful information on emission control approaches and source identification. The steady state modeling has limitations, but due to the lack of input data needed to run more sophisticated models, the approach makes the most sense under the current situation for most Indian cities².

From this work and the questions it raised, a field study that measures the diurnal behavior of PM10 concentrations and meteorological variables is very important to understanding air pollution in Pune. Results from such a study, particularly if supplemented with chemical mass balance analysis to identify key source types, would be very useful for understanding air pollution in Pune and other urban areas in India. Fortunately, such data should be forthcoming under the work now being performed under the source apportionment component of the USEPA-MoEF urban air quality program.

² Venkatram, A., Cimorelli, A. J., *On the role of nighttime meteorology in modeling dispersion of near surface emissions in urban areas*, Atmospheric Environment 41 (2007) 692–704.

Although there were certain challenges during the project, we made significant progress. This third activity brought the inventory, modeling, and ambient air quality data together and integrated it into a synergistic system, a critical step in understanding and developing solutions for air quality problems. Many of the key participants in our projects are now experts, and are leading trainings themselves. Pune now has a self-sustaining air quality program and an active stakeholder community is involved in the efforts.

Another result of this project was the development of a new educational workbook for school children to help them understand air pollution and what they can do about it, developed by the Centre for Environmental Education in Pune, and supported by USAID. The air quality management work in Pune, and the commitment and support from the Pune Municipal Corporation, has garnered international recognition and growing support from the Maharashtra State Pollution Control Board (MPCB) and the Central Government environmental agencies. Of particular importance under this overall program, there have also been growing collaboration and institutional commitments from NEERI, the MPCB, the Central Pollution Control Board (CPCB), and MoEF in further expanding the reach of this effort, and to further refine, adapt and disseminate these tools for improving science based urban air quality management in India.

TRAINING 4 – December 2006, New Delhi Multi-City Emission Inventory Training Using a Spreadsheet Tool

In 2006, the Team designed a multi-city training project from scratch to provide a unique and highly dynamic learning experience. In this project the goal was to bring together members of multiple cities in India, and as teams, develop some preliminary PM₁₀ emission calculations for their cities. The hope was to further spread the knowledge needed to develop emission inventories, and to continue building momentum beyond Pune for emission inventory development.

Key 2006 project objectives included:

- Providing an overview of air quality and emission inventory concepts.
- Using a spreadsheet emissions tool, developed by the instructors, to perform emission estimates for key sources, understand resources needed for estimates, and to identify data gaps.



- Using Indian projects, data, and experts, provide case studies for mobile, point, and area emissions estimation.
- Clearly identify limitations of emission estimates and prioritize future improvements.
- Provide training on air quality management, including how inventory data is used with modeling and monitoring data, drawing heavily on the experience and lessons from the Pune project.



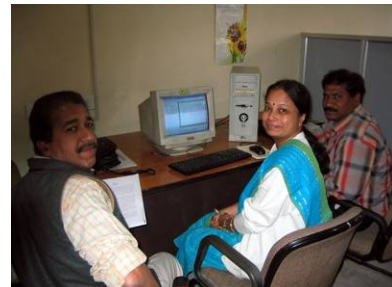
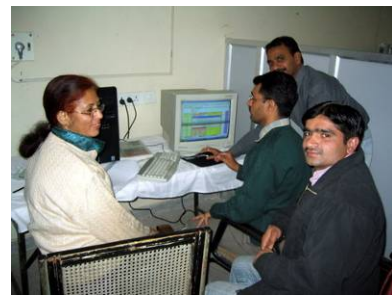
Overview. In cooperation with the USEPA, the Indian Ministry of Environment and Forests, India's Central Pollution Control Board (CPCB), the National Environmental Engineering Research Institute (NEERI), the U.S. Embassy Science Office, the U.S. Agency for International Development, and the Asian Development Bank (ADB), a six-day workshop was convened at the New Delhi NEERI Zonal Laboratory on December 4th through 9th, 2006³. Forty-five participants from seven cities participated (Delhi, Agra, Ahmedabad, Gurgaon, Nashik, Visakhapatnam and Mumbai), and representatives from NEERI, the CPCB, and other agencies attended the workshop.

Methodology. To maximize student participation and learning, the participants were split into seven city groups, who worked together as teams. Each team used an interactive spreadsheet tool developed by Core and Gaffney to learn the fundamentals of emission inventory development. To help accelerate progress, prior to the training the trainers provided a fairly extensive "shopping list" of data for the participants to collect and bring to the training. These data included information such as listings of large facilities, road network maps, vehicle registration data, fuel use, population data, and other resources. Some participants were able to bring these data to the project which helped their efforts, while others collected needed information during the course of the project.

Where data permitted, the city teams calculated initial emission estimates for some of the PM sources in their cities, to be used for future refinement efforts. Throughout the workshop, city-team collaboration was intense as each group worked to research emission inventory activity data input values, emission factors, methods, and how to use the inventory spreadsheet tool.

³ Patrick Gaffney and John Core developed and lead the training program. EPA handled the planning, funding, and interagency coordination for the project, including engaging the Asian Development Bank as a project co-sponsor. On-site, Ajay Ojha assisted with the training, and the project was tremendously enhanced by a variety of guest experts from India who discussed their emissions-related projects in India, including results from a recent ADB supported project in Kolkata. Dr. Rakesh Kumar, NEERI, Mumbai, and Er. J.K. Bassin, NEERI, Delhi, provided outstanding technical, logistical, and overall moral support for the project.

To keep the efforts in context and on track over the six days of training, lecture presentations were provided to teach the fundamentals of air quality management, modeling, emission inventory, data presentation, and quality control. In addition, Indian air pollution experts provided presentations highlighting ongoing efforts to better understand air pollution sources and solutions in India. The training also included a field trip to Gurgaon to visit two construction sites and an aluminum-casting auto parts factory where we discussed sources at these facilities, how to estimate their emissions, and potential emission control measures. For the project conclusion, each city team gave a presentation on their efforts, findings, and next steps for continuing development of a PM10 emission inventory for their city.



City workgroups hard on the job using the emissions spreadsheet tool at the NEERI Zonal Laboratory in New Delhi.

Figure 5. Screenshot of one of the over 30 pages of the emission inventory spreadsheet tool.

The screenshot shows a Microsoft Excel spreadsheet titled "IndiaMultiCityEmissionsTool12_02_06.xls". The active sheet is "Overview", which is part of a multi-tabbed workbook. The "Overview" tab contains a "Class Exercise" section for "Brick Kiln Emissions".

Class Exercise

Brick Kiln Emissions

Objective: Compute particulate matter emissions from brick kilns in region

OPTION 1

Emission Factor and Local Activity Data

General Approach: Emissions = Emission Factor x Activity Data

1) Identify Emission Factor

Two emission factor sources are available, one uses wood as the fuel, the other uses coal. Determine which fuel is most representative of regional brick kiln operations. For this example, assume that coal is the primary fuel.

Enter

PM10 Emission Factor (EF)	Source
EF (pounds PM10/ton brick production)	US EPA AP-42, Table 11.3-1, Uncontrolled coal fired kiln
	http://www.epa.gov/ttn/chief/ap42/ch11/index.html
	Sum of PM10, and condensable components
	1.35

Convert EF to metric units

EF (kg PM10/ton brick production)	kg PM10/metric ton	0.453592 lbs/kg	Conversion Factor

2) Activity Data

The emission factor is based in units of emissions per ton of brick production, so it is necessary to determine the mass of bricks produced in the region of interest. For this example, Kolkata will be used for the city.

Input Data

Input Data	Value	Source
Total Kolkata brick production facilities	397 facilities	Source unknown; For Pune, info from MPCB
Bricks produced by each unit per day	7,000 bricks	Source unknown; Note: Value set to 10,000 for Pune
Weight of each brick, kg	2.2 kg	From EPA methodology referenced above
Daily brick production in Kolkata	tons/day	number of facilities x number of bricks x mass of bricks
Days of kiln operation per year	275 days	Estimated

Compute

Annual tons of brick production	tons/year	tons produced per day x days of operation

The spreadsheet also includes a navigation bar at the bottom with tabs for: Overview, Index, City Data, Summary, Example Bricks, Example Road Dust, Example Mobile, Mobile Emissions, Trains, Off-Road, Cooking, Trash, Doc Example, and Generators.

Workshop Results. Considering the sometimes highly technical nature of the training, the project participants were remarkably enthusiastic, engaged, and interested in nearly all aspects of the workshop. City-teams used the provided spreadsheet model (example shown above) to estimate PM10 emissions from a variety of source categories using local information that they brought to the workshop or collected during the project. Categories estimated included a wide variety of mobile, point, and area sources with some city-teams making initial emission estimates for as many as 20 different source types.

Each city group presented an overview of their initial emission estimates and findings on the last day of the workshop, followed by questions from the audience. There was discussion of unexpected results, areas where additional source activity or emission factors are needed, incomplete data, and comparisons between city emissions. Dr. Sengupta, the Central Pollution Control Board Member Secretary, attended this session and had an opportunity to provide feedback on the presented results. For the

training, emphasis was placed on the learning process, not on the actual emissions calculated, recognizing that these initial inventory calculations would require substantial additional work by the city participants to develop a credible or



Many of the New Delhi emission inventory training participants and instructors.

complete estimate of the city emission sources. The project goal was to provide sufficient hands-on experience and confidence in developing emissions estimates to enable teams to return to their cities and further refine and fill gaps in data in order to ultimately develop credible inventories.

In addition to working with the excellent participants, one of the most satisfying parts of the 2006 workshop was observing the growing emission inventory expertise within India. We had several reshufflings of the schedule to accommodate various presenters working on interesting inventory projects in India. We are hoping that before long, these key people will begin planning and deploying their own trainings. We leave behind all of our schedules, templates, presentations, and other materials, to assist however needed to create programs within India. Using the spreadsheet tool was also an effective way to have people to perform concrete, relevant emission inventory work, document their efforts, and have something to take home to continue and track their efforts.

LESSONS LEARNED – WHAT IT TAKES TO MAKE IT WORK

The four India emission inventory training projects have been very successful. To bring these projects together and make them work effectively, it takes hundreds of decisions and activities, and a cadre of focused people both in front of and behind the scenes. This section discusses some of what was learned during the various India emission inventory training programs.

Logistical Support is Crucial. The three major emission inventory training projects were fairly large, with 30-40 participants. Planning a multi-day training project like this in the U.S. is a significant undertaking. Planning such a project in India can be daunting. What was one of our most frustrating problems during our second Pune training? Collecting activity data? Developing methods? No, it was having printers that did not work and a very limited number of computers (5 + 2 instructor laptops that became virus-infected). The third Pune project included random rolling power blackouts

for two hours every day to keep us on our toes. The New Delhi trip had an unexpected four hours of driving for a three hour field trip, putting a significant glitch in the schedule. Also, despite India's reputation as a major force in the global IT business, during our trainings at times we struggled with very slow or sometimes non-existent internet access. As a result, key information resources need to be brought either on hardcopy or CD, because it may not be possible to just look them up online (although this is changing quickly).

All in all, these problems were relatively minor. But, the situation could have easily been much, much worse than simply developing a database system with 10 people crammed into a dark hotel suite (the notorious sweltering Ming Suite) with two computers and no air conditioning. What saved us over and over is that we had amazing and dedicated logistical support from our collaborators within India and those coordinating the trips within EPA and through USAID/Mumbai and the US Embassy in New Delhi. For anyone envisioning such projects in far away places, if you do not have true champions and partners to work the systems on both sides of the projects (in the US and in-country), you are in trouble.



The Ming Suite and participants in Pune, 2004.

This support cannot only be logistical, it must also be organizational. You will need someone who can grease the skids at in-country agencies to get participants released from their normal duties, someone who can actually help select qualified, interested participants, and someone who can sell the project to members of the government. Twice we have learned the importance of this support the hard way. The first time, we were trying to move a project forward in Bangalore without adequate support. In this case, the activity was scuttled by torrential rains that flooded the city and venue so we had to cancel the project two weeks prior to departure. The second time, with four weeks until the project start and no participants identified, it was clear that the plug needed to be pulled and the project rescheduled. These cancelled projects eventually became the 2006 New Delhi multi-city project.

In addition to in-country support, those of us doing the training have been tremendously fortunate to have outstanding assistance from EPA's Office of International Affairs, which has been instrumental in bringing together the ideal mix of U.S. technical experts (from both within and outside of EPA), funding agencies (USAID, US-AEP, Asian Development Bank), U.S. Embassy and USAID India support, collaborators from Indian academic, institutional, and governmental agencies, and overall level-headed planning support and patience.

Provide Comprehensive Planning and Schedules. In developing the hands-on training projects, the training team developed very detailed schedules and objectives to continue driving the work forward and to provide feedback to the participants on progress (see examples for Pune 2004 project). These schedules helped provide clarity and direction in the projects that the students appreciated. We gave clear goals, provided general guidance, and the participants helped us fill in the emission inventory blanks we outlined for them. In addition, to assist the project organizers, we provided detailed specification regarding training facilities, computers, software, breakout rooms, and other needs.

Be Prepared for Data Challenges. Through our projects, at times we were amazed how easy it was to obtain certain data that are centrally maintained (number of generators, number of trains, etc.). But, in many other cases we were hindered by the difficulty of getting source activity data or even basic meteorological information that is sometimes required to develop emission estimates. Information such as detailed vehicle traffic studies, census data, industrial activity data, and meteorological data that we often take for granted in the United States can be very difficult to obtain in India or may not exist at all.

For example, in some jurisdictions it may be very difficult to obtain “basic” information from a coal-fired power plant such as amount of coal burned, sulfur content, status of emission control systems, hours of operation, and so on. In addition, India, and Asia in general, has a vast number of small-scale, family “industries” that are widely scattered throughout urban areas. Unlike large point-source industries, inventorying this multitude of small area-source industries is a major undertaking as the governments and municipalities may have little or no data on these activities.

Further, many of the default emission factors in USEPA documents and other resources were developed for general U.S. and regional conditions, not for conditions in India. For example, in estimating paved road dust we relied on EPA’s methodology. However, in some Indian cities many of the roads lack curbs or paved shoulders, which produce extremely high silt loading levels and associated emission factors. Do the U.S. factors accurately represent India paved road dust emissions? We are not sure, but at the very least they provide a starting point for discussion and refinement. Initial emission approximations also can provide an incentive or justification to collect more complete local input data or even perform localized studies to more accurately reflect the local emissions. Efforts to integrate the emissions inventory and modeling data also enabled us to begin some data sensitivity analysis to identify data gaps and uncertainties that are most important to address in future efforts.

Because of many challenges, emission inventory development in India can be a very different experience than in the U.S. For some source categories, developing estimates requires a great deal of in-field primary data gathering using survey methods rather than using existing off the shelf data resources. This is field work is very time consuming and labor intensive.

Barriers to collecting Indian emission inventory input data can be both technical and bureaucratic. Some information has not yet been developed or collected. Other times, there are concerns or resistance to sharing certain data sources that would be helpful or necessary for emission estimates. In both cases, these issues are being resolved as India continues to improve its air quality programs.

Hands-On Training Provides the Best Results. It is not a surprise, but people really like doing work themselves. They are not very happy or stimulated with excessive slideshows and lectures. Our most successful work, and most satisfying for us and the students, are the times when the students get to collaborate in small groups to solve real-world problems. For example, how many cars are in your city, how many miles do they travel, what emission factors and tools are available to estimate the PM10 emissions from cars in the city? How much trash is burned and what are the emissions? Who can tell you how much kerosene or dung is used for cooking?

Lectures and generic case-studies have their place, but in a multi-day training, they should not be more than 25-40% of the time. If it is more than that, identify what the goals of the project are. We all know that listening to day-long lectures does little to enhance our ability to do new work and teach practical skills. The hands-on skill teaching can be a little messier, it is less predictable and more dynamic than lectures, but the rewards are greater. Would you rather watch a bunch of dull-eyed participants listening to you drone on for two hours of slides after lunch, or watch them huddled together in front of computers debating the question of how best to estimate activity data and emissions from all of the small generators that fire-up across the city when the power goes out?

Bring Patience and Flexibility.

Without patience and flexibility, these projects would probably not have occurred and succeeded. For every project that has occurred, at least that

Mr. Anoop Mahajan Student Pune University, Environmental Sciences Department, PU, ES, Pune	Database – Develop source coding system and general assistance Website design and development co-leader and implementation	
Ms. Snigdha Mehta M. Tech. Student CESE, India Institute of Technology, Bombay, CESE, IIT-BOMBAY, Mumbai	Emissions: On-road mobile source exhaust emissions	
Mr. Hrishu Mittal MSc Student Pune University, Environmental Sciences Department, PU, ES, Pune	Database – Develop source coding system and general assistance Website design and development co-leader and implementation	
Mr. John Mooney United States Environmental Protection Agency, USEPA, Chicago, USA	Facilitator & Logistics Emissions: On-road mobile sources	
Dr. Utpal Mukherjee Scientist-C Central Pollution Control Board Synergy House II, Subhanpura CPCB, Vadadara 390023	Emissions: Stationary Source Coordination; biomedical waste, brick kilns, various industry sources, dry cleaning, stone pulverization, food industry, metal industry	
Ajay Qija National Environmental Engineering Research Institute, NEERI, Mumbai	Emissions: Paved & unpaved road dust, street vendor cooking (kerosene & LPG), cooking in slums (firewood, LPG, kerosene), on-road mobile source exhaust emissions	
Ms. Leena Pandey Executive Officer Society of Indian Automobile Manufacturers, SIAM, New Delhi	Emissions: Industrial and non-industrial diesel generators, agricultural tractors, agricultural pumps, on-road mobile source exhaust emissions	

An excerpt from our Pune 2004 participant directory to assist with networking and follow-up.

number has been partially planned and cancelled. For every project plan developed, another has been modified and turned inside out to meet the goals of many stakeholders. For every day in a classroom, trying to keep a schedule or meet an objective, there are five changes and distractions to pull the project off course. Of course, this is not so different from most of our regular work, but being in a new country, trying to do something constructive with people you barely know, can feel a bit like working without a net. But, in engaging these new partners, it is clear that they are the best allies in devising your Plan B (or even Plan C) when roadblocks are confronted.

Let the Participants Talk, Have Them Present. As trainers, a component of the training we particularly enjoy is providing time for the participants to make presentations on their progress, what they learned, and their ideas about what to do next. Hearing these presentations and the perspectives of the students is extremely interesting and gives a sense of ownership and engagement that does not happen in more passive approaches. In addition, the presentations give the participants great experience talking about their work in front of a group, gives them visibility among their peers, and provides some great question and answer feedback within the training session. For the Delhi training we provided PowerPoint templates to each city team that included the key topics we wanted them to cover, which helped to provide a nice structure and consistency to their presentations. For any training, we highly recommend including a half a day or more to turn the tables and have the students do the presentations while the instructors listen and ask questions.

Stay Healthy. All of us have had our experiences of being sick during our training journeys. And yet, the show must go on, which can be an ultimate test of fortitude and endurance under the best of conditions. If possible, it is best to avoid blue cocktails with ice, street vendor snacks, and other questionable dining or drinking activities.

Keep Coming Back. In some ways, these training projects can feel like throwing a rock into the ocean. There is a nice satisfying sound, splash, and ripple at the moment of impact, during and immediately following the training, but it soon becomes lost in all of the other waves and the immensity of the sea. This can be particularly true in a country like India where most cities are just formulating a sustainable air quality program, with virtually no staff focused full-time on air quality issues. This is understandable. Air quality is just one of many large competing priorities these cities are facing. But, pressures such as the recent Indian High Court orders mandating at least 16 major cities to develop air pollution action plans is raising the stakes for Central, State and local governments to address their air quality. These trainings, and the broader EPA-MoEF agenda to promote more science-based urban air control strategies, are meant to assist decision makers in finding the most cost-effective means to reduce air pollution, in light of these competing demands for resources.

In addition to funding constraints, it is eye-opening to consider the air quality management challenges due to staffing constraints. In the U.S., we have thousands of professionals working full time on air pollution issues in the country. In India, with just a small fraction of this staffing, the challenge is enormous. Yet, in just four years, we are

already experiencing some substantial changes. During the most recent training in 2006, we saw several familiar faces from the previous projects, and these people are now regularly working on air pollution issues. Some have now even become co-trainers in our program, and are prepared to do their own training courses. In addition, some of the technical and academic institutions now have staff dedicated to researching and evaluating air pollution, and governmental support of air quality efforts is continuing to grow.

For example, our 2006 training included participants from the cities of Delhi, Agra, Ahmedabad, Gurgaon, Nashik, Visakhapatnam and Mumbai, and each team developed prototype PM10 emission calculations for their city. Now we have seven cities and another 45 people that know what an emission inventory looks like, the components needed to put it together, how it can help them improve air quality, and tools to continue their work. That is progress. So, each time we return, we plant a few more seeds. Some do not get to move into air pollution work, but a few do, and those set off new waves which are continuing to propagate and sustain through parts of India.



Beware of men wielding snakes.

Consider Policy Implications and Your Broader Audience. During our Pune 2004 project and our recent New Delhi project in 2006, we learned that it is important to keep in mind how the data we generate in this training can be used (or misused) in a policy context, and not simply in an engineering context. In Pune, we developed an initial emission inventory for the complete Pune region which included both the city, as well as outlying rural and agricultural areas (see the Pune 2004 project summary). Later, when policymakers viewed the emissions summaries, they saw significant particulate emissions from land preparation, agricultural burning, and unpaved road dust. Having been mostly familiar with city inventories, some criticized the Pune inventory work, since surely there are not agricultural emissions in a city, so the results must be erroneous.

We committed a few errors in this case. First, had we known our audience or these pitfalls better, we would have created separate Pune City and Pune Outlying Area emission inventories, clearly identifying the spatial domain of each inventory. This would have alleviated some of the confusion and criticism. We did not realize that some people might misinterpret or even misuse the data presented in this way, even though the report text included various caveats and cautions, and underscored the need to improve input data and spatial allocation of the emissions within the larger Pune region.

The graphic bar chart is what stuck in people's minds, and not all of the written explanations and disclaimers.

Also, in Pune during 2004, we did not fully grasp that including some of the rural sources, which can affect regional air quality, might be in conflict with some potential policy needs. For example, there was concern that agricultural burning should not be in the inventory since it could not reasonably be controlled. There was some sensitivity that including such a large rural emission source, or even some important urban emission sources such as road dust or trash burning, in the inventory could undermine the ability of regulators to control emissions from other emission sources, such as vehicles. Automotive and other sources could argue that, based on the regional PM₁₀ inventory, they are not the most important contributor to ambient PM₁₀ levels, so other more significant sectors (on a mass basis) should be addressed first.

In this case, we did not fully appreciate the ramifications of releasing a full regional inventory, even if the draft included many caveats regarding its limitations. Many previous emission inventories in India focused only on limited sectors of interest, so including the complete regional emissions picture was a new concept to some. Some unfairly labeled the work as flawed. Certainly the work was a starting point and incomplete, but the main flaw is that we did not fully understand how the initial data might be used or interpreted. Fortunately some of the later Pune air quality and modeling work in 2005 and 2006 that focused the PM₁₀ inventory on the urban emission sources helped to alleviate many of these issues.

In New Delhi during 2006, we had a similar experience. Here, we focused on the project too much from an engineering and science perspectives, and did not fully grasp the perspectives of policymakers who might view the work. Throughout the training we emphasized the preliminary nature of any emission estimates, and that all our work would be merely a starting point. However at the end of the project we had all of the student teams present their "inventory" calculations for their cities. The idea here was to have an open discussion and informal quality assurance session with the group to view each others work.



Some spirited debate in New Delhi at NEERI.

For the final city-team presentations, we were pleased to have some senior policymakers join us as the teams shared the work that had been done and the great progress the participants made during the week. Unfortunately, projecting pie charts of incomplete and rough emissions data up on a screen for all to see turned out to be a somewhat unpleasant experience. Some of the city-teams were roundly criticized by an official about their draft data, even though we repeatedly emphasized the limitations and

objectives of the brief six day training session. In the end, we understood that there was significant discomfort with showing these crude “inventories” even though the trainers and students knew that they were only meant as calculation mock-ups that were designed to be refined over time.

Another issue is that recent PM10 inventories developed for India cities and regions include a significant component of fugitive dust, with a large part being contributed by paved road dust due a general lack of curbing, shoulders, or sweeping. A key administrator present thought that these and other “natural” emissions such as burning should not be included in the inventory, and efforts should be placed on estimating emissions of human-caused emissions such as vehicles and industry. For some, there seemed to be a perspective that incorporating inventory estimates of PM10 from sources that cannot be controlled through typical means (such as paved road dust), could undermine the ability of regulators to reduce emissions from traditionally regulated sources such as vehicles or industry.

In this case, we were so excited with the vast progress made by the students, and the fact that each team had assembled nice presentations summarizing their results, that we did not consider how an outsider might interpret the “results”. It did not occur to us that we might create some distress by having the students make on-screen presentations of their initial calculations to the larger group, as well as some outsiders not involved in the full effort. However, in hindsight, we can see the possibility for discomfort in displaying the results of six days of effort as any kind of framework, preliminary, working, mock-up, or draft inventory. We should have thought through the ramifications more fully of having people display their draft calculations as pie charts and tables. We learned that in the future, we need to develop an alternative approach to displaying the results of the team’s work that will be less susceptible to misinterpretation and criticism, while still providing an opportunity for participants to present their progress to the full group.

Leave Resources and Materials. At the end of the trainings, the participants are very happy to receive anything we can leave to help them continue their work. For us, it is now standard practice to leave a disc with all of the project materials. We include all of the presentations in editable formats, the schedules, spreadsheets, and usually a folder full of various papers and resources. Basically, everything they would need to give the presentation themselves. Remember to leave time to burn the CDs. For the 2004 Pune project we first hunted all over town to get 50 blank CDs and cases, and found ourselves in a very late night session of burning CDs to have them for our final meeting the next day.

For the Pune 2004 and New Delhi 2006 projects we also brought a full series of large format posters, schedules, and milestone charts. For the Delhi training we prepared a large poster for each city team that included satellite imagery of the region, lists of the potential emission sources, and tables to include emissions and other data for the region collected during the project. The city teams were very glad to be able to take

these completed posters back to their offices to show the work they had done, and hopefully inspire them to continue their efforts.

Of course, following the training it is crucial to provide an official certificate to each participant to indicate their successful completion of the project. These are very valuable to the students for their professional files. Also, do not be surprised if you are asked to be included in dozens of photographs. Many of the participants want to document the event, and it is entertaining feeling like a minor celebrity for a few moments, which is pretty uncommon in the emission inventory training world.

CONCLUSIONS

These projects, which are helping India better understand their air pollution problems, are incredibly satisfying. The effort provides tangible building blocks that will grow and help improve the quality of life and health for millions and millions of Indians. Certainly, the hardest and most important work will be performed by those living and working in India every day. However, by sharing our knowledge and enthusiasm, we help to move the process forward a little bit further each time we visit. In addition, with the growing concerns about global warming, this emission inventory foundation will be directly applicable to refining and developing greenhouse gas (GHG) emission inventories. This expertise will help those in India to more fully understand and define cost-effective opportunities to reduce their contribution to global carbon dioxide and other GHG emissions, another important focus area of U.S.-India environmental cooperation.

Each of us involved with these projects has had occasional difficulties, and sometimes even frustration, with the organizational, timing, travel, and other complexities that can be part of the efforts. Nevertheless, we keep returning and keep wanting to return. Actually, some of us have even volunteered our time to develop and lead the trainings. The people of India are amazing to work with. They are extremely engaged and amazingly appreciative of our willingness to come share our experience with them. The projects are a phenomenal amount of work both to prepare and to present in India. It is a huge effort by the trainers, the supporting agencies, our collaborators in India, and of course, the project participants. Yet, the satisfaction and the challenges of the work make it something we hope to see continue.

Yet ironically, as we continue to succeed, our help will be needed less and less as the air quality expertise in India continues to grow. Our hope is that soon key participants and agencies will be hosting their own emission inventory training, or even organize



periodic Emission Inventory networking events, similar to the EPA supported Annual International Emission Inventory Conference for which this paper and companion presentation have been prepared . Since the 2006 training in New Delhi, there have been discussions about adding a user-friendly front-end to parts of the spreadsheet tool used for the training to be done by our partners at the National Environmental Engineering Research Institute. In addition, the Central Pollution Control Board has been assisting some of the training participants to get data they need to improve their emission estimates, and the idea is being considered to begin development of an emission inventory reference guide that would include India-specific emission factors and methods. The initial planning has also begun on developing an emission inventory training program designed and presented by the emissions experts within India. When that day happens, we will know that our efforts have truly come to fruition and the torch has been passed to our good air quality friends in India.

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DISCLAIMER

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