Newsletter
Volume 4, Fall 2003

Integrated Program on Urban, Regional, and Global Air Pollution

Easter Season Iztapalapa Ester Plumes*

Charles Kolb, Brian Lamb, Berk Knighton, Scott Herndon, Erik Velasco and Miguel Zavala

Obtaining a better understanding of the atmospheric concentrations, emission sources, and emission fluxes of volatile organic compounds was a major goal of the 2003 Spring MCMA field measurement campaign (see vol. 3, Spring 2003 Newsletter). Continuous monitoring of volatile organic compounds (VOCs) in the atmosphere and identification and quantification of their emission sources is complicated by two factors: first, there are hundreds of different VOC species released daily into the Mexico City Metropolitan Area (MCMA) atmosphere, and, second, few real-time (1-10 s) measurement techniques have been available to provide the high resolution spatial and/or temporal data usually required to locate VOC emission sources and measure their flux strengths. To address these challenges the MCMA-2003 field campaign deployed a newly available real-time VOC measurement technique, proton reaction transfer mass spectrometry (PTR-MS). Use of this capability allowed MCMA-2003 campaign researchers to track down and experimentally quantify a significant source of the VOC ester, ethyl acetate, in the Iztapalapa region.

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Mexico City Program Transportation Activities

Joseph Sussman

The linkage between air quality in Mexico City and transportation has been well established in several years of research. The challenge that we face is assuring the mobility of people and goods and services around the MCMA, while lessening the negative air quality impacts of various transportation activities. Retaining mobility is central to the economic growth agenda of Mexico City; yet if air quality continues to deteriorate, this will be a drag on human health, productivity and, indeed, economic growth itself.

Over the past several years, as part of the Integrated Program on Urban, Regional and Global Air Pollution: Mexico City Case Study (or Mexico City Program), we have considered a number of aspects of the transportation system and the MCMA, with an eye to understanding transportation impacts on air quality and developing various options that could be used to limit negative impact on the environment. Among the studies we have performed are the following:

- The Metro system and associated land-use changes (Michael Gilat, "Coordinated Transportation and Land Use Planning in the Developing World -- The Case of Mexico City," Master's Thesis, MIT, June 2002.)
- Freight transportation and especially trucks in the MCMA (Alejandro Bracamontes, "Managing Freight Transportation and Air Quality in the Mexico City Metropolitan Area," Master's Thesis, MIT, June 2003.)
- Understanding the performance of the transportation network and its implications on air quality -- the relationship between emissions and congestion (Dan Amano, "Macroscopic Modeling on a Microscopic Scale: A Road-Based Network Model of Mexico City," Master's Thesis, MIT, August 2003; Julia Gamas, "Impacts of Urban Transportation Congestion and Pollution Reduction Policies: Analytical Studies of Two Latin American Cities," Doctoral Thesis, Boston University, December 2003.)
- Emissions from surface-based public transportation modes -- buses, taxis, colectivos (i.e., all public transportation except the Metro) (Ali Mostashari, "Design of Robust Air

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Addressing the Politics of Air Pollution

Christina Rosan

Improving air quality in Mexico City requires that scientists and policymakers work together. While the science about what causes air pollution continues to improve, improving air quality in the Mexico City metropolitan area (MCMA) demands that institutional and political barriers to metropolitan cooperation be addressed. Politically, the MCMA is divided into different jurisdictions (Federal, State of Mexico, and the Federal District), with their own needs and concerns. From an environmental perspective, to manage air quality there must be coordinated reforms in transportation, land-use, environmental, and industrial policies. However, the ability to think and act at a metropolitan level in the MCMA is currently limited by the city's political structure.

The work done by Drs. Mario and Luisa Molina and their team of US and Mexican researchers has demonstrated the complexity of the air pollution problem in Mexico City from a scientific and policy perspective. In the next phase of the Mexico City Program, the goal is to work with policymakers in the MCMA to discuss how they can develop a more sustainable and integrated plan for air quality improvement. In order to start a metropolitan dialogue, the Mexico City Program at MIT, with the assistance of Dr. Lawrence Susskind, Ford Professor of Urban and Environmental Planning at MIT and President of the Consensus Building Institute, is currently initiating an issue assessment in the MCMA to help identify areas of agreement and disagreement among different policy actors. The Issue Assessment is the first step in what will be a larger consensus building process aimed at helping stakeholders in the MCMA reach agreement on a technically desirable and politically plausible air pollution reduction strategy.

Starting in January, a team of Mexican and U.S. researchers led by Dr. Lawrence Susskind, Dr. Luisa T. Molina, and two MIT doctoral students, Tina Rosan and Dong-Young Kim, will conduct face-to-face confidential interviews with a group of more than 50 representatives from all levels of government, citizen groups, NGOs, universities, and business. The researchers will summarize the concerns of members of key stakeholder groups on a range of air quality management issues, without attribution by name, title, or organization. The findings of these interviews will be analyzed and the opportunities for and reaching agreement, as well as the obstacles, will be assessed. If appropriate, the Mexico City Program will help to design a consensus building process that will take place next year.

The Issue Assessment will find out whether or not policymakers in the MCMA think the existing institutional arrangements to deal with environmental, transportation, and land use management are effective. It will also assess the likely benefits and costs associated with implementing stricter environmental regulations in the MCMA to reduce air pollution. The report will determine whether assisted negotiations (dialogue among the stakeholders that is assisted by a professional neutral) will likely lead to a constructive resolution of the institutional composition of metropolitan and environmental management in the MCMA. The final product of the Issue Assessment will be a report that analyzes the issues, the stakeholders, their interests, their willingness and capacity to participate in negotiations, and their views on the issues requiring attention.

One of the primary functions of the Issue Assessment is to produce changes in the way stakeholders view issues like air quality management. The interview process gives those interviewed an opportunity to express their views, to raise concerns, and to directly shape any process that may ultimately emerge. It also forces them to clarify their concerns and encourages them to test their arguments "out loud" in front of a neutral party. The goal of this activity in many ways is to start to "think about new options." In the process of discussing their opinions about the way that the current institutional framework in the MCMA is designed, stakeholders may start to imagine different alternative solutions to the problems at hand.

For almost twenty years, governments in numerous countries worldwide have been experimenting with the use of consensus building techniques and strategies. For example, the US Congress now requires every federal agency to explore all possible ways of incorporating "alternative dispute resolution" techniques for regulatory, planning, and enforcement activities. At the same time, some of the world's largest corporations, such as IBM and Home Depot, have helped to sponsor consensus building efforts at the municipal, regional, state and national levels, on issues ranging from urban development, transportation, and energy policy to growth management and natural resources conflicts. Some of the world's leading environmental activists and public interest organizations have also participated in consensus building processes, and are now advocates of the use of these techniques when the conditions are right.

Christina Rosan is a Ph. D. candidate in the Department of Urban Studies and Planning and a research assistant with the Integrated Program on Urban, Regional and Global Air Pollution at MIT.

Design of the Fine Particles Monitoring Network in the Mexico City Metropolitan Area

Rafael Ramos Villegas

The Mexico City Metropolitan Area (MCMA) is located within the Valley of Mexico basin at 2,240 meters above sea level. Consequently, combustion processes are less efficient and generate more pollution. Additionally, the MCMA receives a large amount of incoming solar radiation all year long, which,

Rafael Ramos Villegas is the director of the Red Automática de Monitoreo Atmosférico (RAMA) of the Government of the Federal District, Mexico.

in turn, promotes the formation of photochemical pollutants such as ozone. Suspended particulate matter is another pollutant of concern in the MCMA since its concentrations are above the corresponding health standards.

Fine particles are defined as suspended matter with an equivalent aerodynamic diameter equal to or less than 2.5 microns, and are therefore also known as $PM_{2.5}$. Due to their small size, they can remain suspended for long periods and travel long distances before being removed from the air. They are practically invisible to the human eye, but their presence causes light dispersion and reduced visibility, and they are capable of producing significant detrimental effects on human health, altering the balance of ecosystems, and producing deleterious effects on exposed outdoor materials.

Some fine particles are emitted directly, by, for example, diesel vehicles. Other fine particles are formed from the photochemical reactions of organic materials. Still other fine particles are created when nitric acid or sulfuric acid, which are by-products of combustion related pollution, react with ammonia in the air.

A number of studies demonstrate that the actual concentrations of $PM_{2.5}$ in the MCMA often exceed the US EPA standard of 65 $\mu g/m^3$. As a result, in July 2002, the Mexican Health Secretariat issued a modification of the Official Mexican Standard No. NOM-025-SSA1-1993 that established maximum allowable limits for the concentration of Total Suspended Particles (TSP) and PM_{10} in the ambient air. The modification sets a maximum average $PM_{2.5}$ concentration of 65$\mu g/m^3$ daily and 15 $\mu g/m^3$ annually.

In order to monitor fine particles to determine whether the new

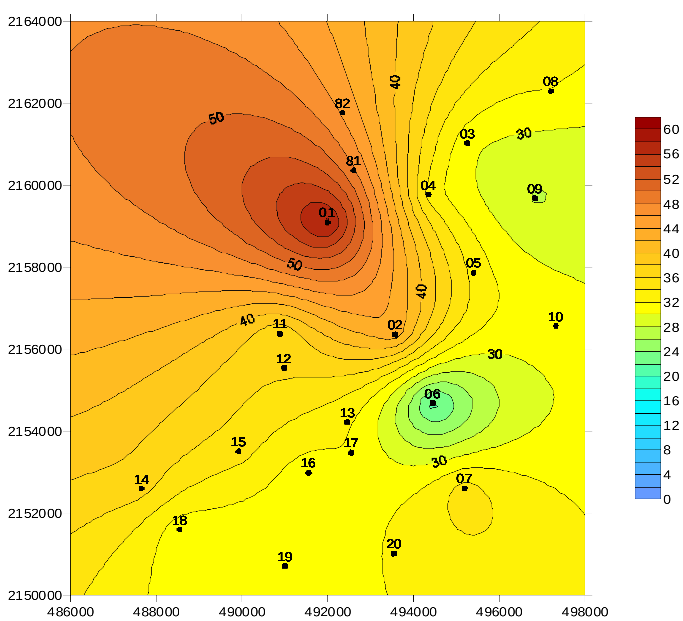


Fig. 1. $PM_{2.5}$ distribution on 03/25/2002. Note maximum concentrations around Xalostoc sampling site.

standards are being met, the Government of the Federal District, through the Environmental Secretariat, committed to the design and implementation of a PM2.5 monitoring network for the MCMA. The financial support for this network was provided

Fig. 2. Testing Station in Xochimilco

by the Metropolitan Environmental Trust Fund (on the order of $970,000 USD).

The MCMA $PM_{2.5}$ monitoring network reinforces and expands the existing ambient air monitoring system (Red Automática de Monitoreo Atmosférico or RAMA) for criteria air pollutants and meteorological parameters, as well as the Manual Network for TSP and PM_{10} and the Atmospheric Deposition Network for dry-wet deposition. The MCMA Ambient Air Monitoring Network is operated by the Environmental Secretariat of the Government of the Federal District. With the addition of $PM_{2.5}$ monitoring, the number of remote stations will increase to 36. The design of the $PM_{2.5}$ monitoring network was based on two one-year studies which determined where sampling sites should be located and what monitoring equipment should be used.

These studies were conducted with the participation of The National Institute of Nuclear Research and the National Center for Environmental Research and Training (CENICA of the National Institute of Ecology). Approximately 1,400 samples of $PM_{2.5}$ were collected from 80 potential sites in the urban area. Each sector, of 20 sites each, was sampled in periods of two weeks five times during the year in order to account for the seasonal variations of the pollutant. The most representative sites in terms of risk exposure and spatial and temporal coverage were selected after treating the information with three different statistical methods. In the end, eight sites for automatic monitoring and seven sites for manual sampling were selected. The statistical methods employed were: 1) Representative Coefficients (determines the spatial representativeness of a monitoring site in relation to the surrounding area); 2) Analysis of Variance (ANOVA), which considers the effects of the daily climatic variations; and 3) geospatial analysis using Kriging interpolation method. The final selection of the monitoring sites took into consideration practical issues such as local security and availability of electric power and telephone lines for data transmission.

The equipment selection was conducted by the Metropolitan Autonomous University, Xochimilco campus, by comparing commercially available instruments for $PM_{2.5}$ determination under practical use conditions in two different locations in the MCMA. The first area was Xalostoc in the northeast of the city. Xalostoc is a heavy industrialized area with some highly populated urban zones. It is very polluted and has high concentrations of suspended particles. The second was Xochimilco in the southeast of the city. Xochimilco is an urban area near agricultural lands with much lower concentrations of fine particles. The period of study in Xalostoc was from December 20, 2001 to June 30, 2002 and in Xochimilco from July 15, 2002 to January 31, 2003.

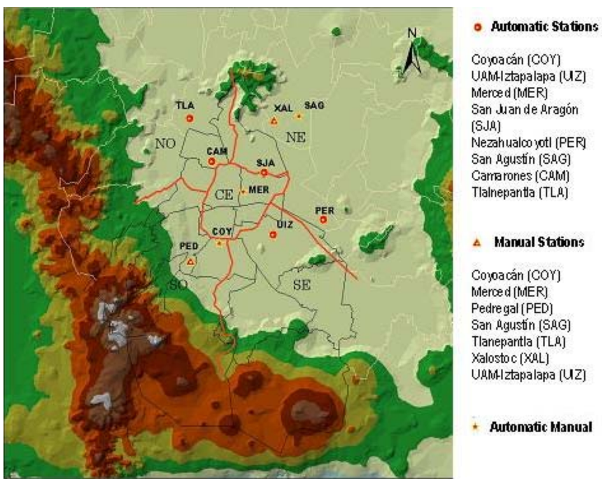


Fig. 3. PM2.5 Monitoring Network in MCMA

The automatic equipment tested was the Rupprecht & Patashnick (R&P) TEOM 1400a; the Thermo Andersen (ThAn) Beta Gauge model FH62C14; the R&P TEOM 1400a coupled to a Filter Dynamics Measurement System (FDMS) model 8500; and the ThAn Continuous Aerosol Mass Monitor (CAMM). The performance of these instruments was compared against a reference method by the US EPA using procedures listed in Appendix L of 40 CFR Part 50, which describes a manual sampling method though a filter media followed by the gravimetric determination of the sample. As a result of this study, the technologies selected for the automatic sites in the heterogeneous conditions of the complex MCMA atmosphere were TEOM, Beta Gauge and TEOM-FDMS. The manual equipment for the sampling sites was an R&P model Partisol 2000 FRM.

The $PM_{2.5}$ monitoring network began transmitting data in mid July 2003. The official inauguration was on August 9, 2003. Since then hourly fine particle concentrations have been posted on the website (www.sma.df.gob.mx).

Influence of Meteorology on Ozone Trends in the Mexico City Metropolitan Area

Pablo Cicero Fernández

While ozone concentrations reached dramatic levels in the Mexico City Metropolitan Area (MCMA) during the early 90s, a downward trend has been observed in the past several years. These trends could be, at least in part, due to air pollution control actions. Such actions introduced during the past decade included: new vehicle emission standards, fuel improvements, vehicle inspection and maintenance, substitution of natural gas, vapor recovery, relocation of industrial and utility facilities, and the controversial "a day without driving (*Hoy No Circula).*" The location of the MCMA makes it particularly susceptible to ozone formation. Its geographic location at 19.5^{o} N, 2,240 meters above sea level, receives more solar radiation throughout the year than northern, sea-level cities. Additionally, the mountains surrounding the MCMA promote air mass stagnation. Meteorology and time scales also contribute to ozone formation. In fact, due to such influences, air pollution concentrations may vary dramatically from one day to the next even with the same level of emissions in the region. The present study examines the ozone trends for 1990 to 2002 and the influence of meteorology on these trends. To correct or adjust the air quality trends by meteorology, clear relationships among air pollutants and meteorological parameters must be established. Many researchers in the United States have reported temperature, solar radiation, atmospheric stability, and wind direction as factors affecting the concentrations of ozone (1). A survey of meteorological adjustment methodologies was conducted at the beginning of this study. Classification (2, 3), regression (4), and time series spectral analysis (5, 6) were among the more common methods applied to adjust for meteorology.

To elucidate the influence of meteorology on the ozone trends, two distinct approaches were used in this study. The first approach included a trend term, or a coefficient for time in the regression accounting for other meteorological or classification parameters. For example, the coefficients for the influence of temperature, wind speed and time (in years) were calculated simultaneously in a multiple regression model. In the second approach, the influence of meteorology on ozone concentration in a specific day or month was estimated, and then the concentration was adjusted accordingly. Using the meteorological variables an estimate of how much ozone would be expected for such conditions was calculated. The deviation between the predicted and the observed ozone was due to factors not included in the model. Using this unaccounted deviation from the predicted ozone, the trend was calculated.

Pablo Cicero Fernández is a researcher at the University of California, Los Angeles campus. This work is supported by the Integrated Program on Urban, Regional and Global Air Pollution with funds from Comisión Ambiental Metropolitana.

Base Trends

The trends for the study period of 1990 to 2002 are presented in Table 1. The maximum and median ozone in the MCMA had a raw (no meteorology included) decreasing rate of -0.004

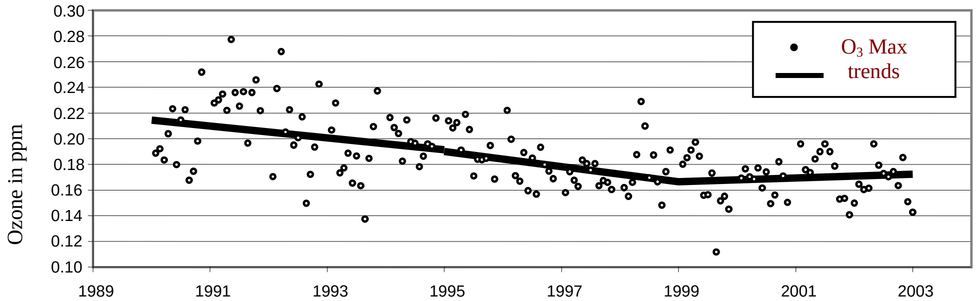


Fig.1. Maximum of ozone concentration and raw trends by subperiods (1990-1994, 1995-1998, 1999-2002)

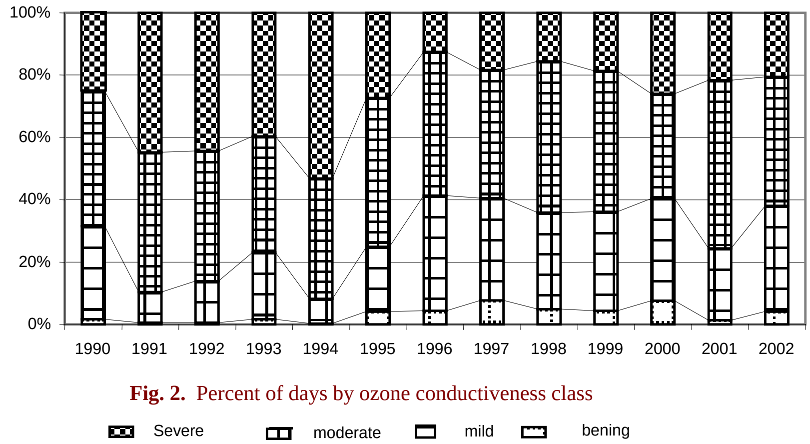


Fig. 2. Percent of days by ozone conductiveness class

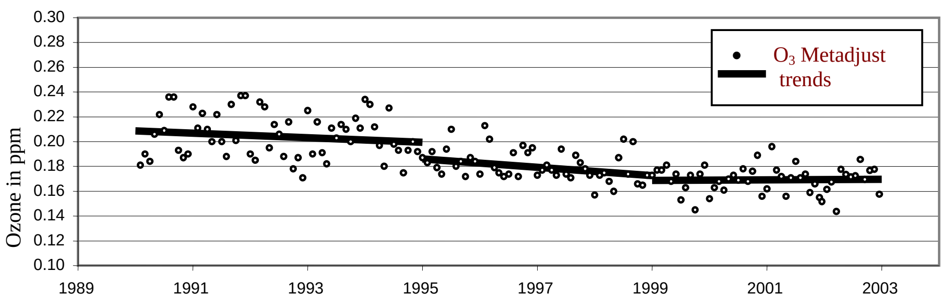


Fig. 3. Meteorologically adjusted maximum ozone and trends by subperiods (1990-1994, 1995-1998, 1999-2002)

ppm/y. Raw rates were also calculated for three different subperiods: Period 1, from 1990 to 1994; Period 2, from 1995 to 1998; and Period 3, from 1999 to 2002. The maximum and median ozone experienced the highest decreasing rate in the intermediate period with rates of –0.006 ppm/y. During the first period, statistically non-significant decreasing rates were experienced. In the last period a small, statistically non-significant increase of 0.001 ppm/y was observed for the maximum ozone concentration. Figure 1 presents the graphical representation of these partial raw rates.

Alternatively, logistic regression was used to calculate the probability of exceeding the ozone Mexican Air Quality Standard (0.11 ppm in one hour) and the prealert level (0.233 ppm in one hour). The trends for exceeding the ozone standard were statistically non-significant, while the probability of reaching the prealert level decreased from 39% in 1990 to 6% in 2002. This trend was statistically significant.

Segregation by Temperature and Classification by Ozone Conductiveness

Days with high temperatures are more likely to have high ozone concentrations. Using logistic regression for the three periods, the probability of reaching the prealert level was calculated at maximum temperatures of 28°C. The probabilities decreased from 40% in the first period, to 24% in the second period, and to 9% in the third period.

In addition to maximum temperatures, other meteorological variables can explain ozone concentrations. Using four meteorological variables, minimum wind speed, median wind speed, and maximum and miniumu temperature, a classification for ozone conductiveness was developed. A binary scale was used following the direction of the association of these variables and ozone. Non-conductive days were assigned a 0, conductive days, a 1. We selected the median of each variable for the period as the cutoff to define conductiveness. For the case of the wind speed regional median, if the value was less than or equal to 1.7 meters per second a 1 was applied, otherwise a 0 was applied. In the case of the minimum wind speed, 0.2 meters per second was used as the selecting cutoff but with different direction. If the value was greater or equal to 0.2 meters per second a 1 was applied, otherwise a 0 was applied. In the case of temperatures, a 1 was applied for maximum temperatures above or equal to 25.3°C. In the case of minimum temperature, an opposing criteria was used. If the minimum temperature was equal to or below 9.3°C, a 1 was applied. An ozone conductiveness index was developed by adding all the binary indicators per day. The conductiveness class index took the value of the summation. A value of 3 was assigned to the highest value of 4. The classes may be described as benign, mild, moderate, or severe. Their distributions for the study period are presented in Figure 2. Note that particularly severe years included 1991 to 1994 and 2001. The classification index reasonably separates the ozone means of each class per year, from low mean concentration (index equal to zero) to high mean concentrations (index equal to 3). Each level change in the class added 0.024 ppm. The difference between the lowest conductiveness class and the highest conductiveness class was 0.072 ppm for the maximum ozone concentration and 0.063 ppm for the median ozone concentration. The trend term for maximum and median ozone was –0.003 ppm/y, lower than the raw trends calculated in the previous section. This reflects the influence of overall meteorological conditions on ozone concentrations.

Meteorological Adjustment

The influence of meteorology on ozone concentration in a specific day or month was estimated with the variable set with the best coefficient of determination and statistically significant variable coefficients. Later the expected ozone concentration was estimated for such conditions. The deviation between the predicted and the observed ozone concentrations, the residual, was due to factors not included in the model. This unaccounted deviation from the predicted ozone was added to the mean predicted ozone for the period. This estimator corresponds to the meteorologically adjusted ozone concentration; the trend was calculated for this adjusted variable. Table 1 presents the trends of the meteorologically adjusted ozone concentrations. These trends were substantially lower than the raw trends presented earlier. For the maximum ozone concentration the decreasing rate was –0.001 ppm/y and for the median ozone concentration the decreasing rate was –0.002 ppm/y, compared to the raw trend of–0.004 ppm/y. The rates for the meteorologically adjusted ozone concentrations were also calculated for the three different subperiods from 1990 to 1994; from 1995 to 1998; and from 1999 to 2002. These rates are also presented in Table 1. The decreasing rates from the earlier period reflected more severe meteorological conditions while the incipient increasing and non-statistically significant rates of the later period reflected the severe meteorological conditions in 2001. From 1995 to 1998, the meteorologically adjusted maximum and median ozone concentration showed a statistically significant –0.003 ppm/y decreasing rate. In the last period, from 1999 to 2002, the rate was non-statistically significant and very close to zero. A graphical representation of the rates for the maximum ozone concentration by period is presented in Figure 3. It is important to mention that the adjustment is only valid within the study period or sub period. In addition, it is relevant to notice that the net average ozone concentration for the periods was decreasing in time showing a net progress in air quality.

Conclusions

A downward trend was observed for ozone concentrations and prealert level exceedances. The earlier half of the period was more conducive for ozone formation than the later half. Meteorology was responsible for some of the downward trends. Particularly severe years included 1991 to 1994 and 2001. Wind speed and temperature variables were the most important parameters influencing ozone in the MCMA. Raw trends for the period were estimated at –0.004 ppm/y. Decreasing trends in the probability of reaching the prealert levels at high temperatures also were observed, a good sign for air quality progress. When the trends accounted for ozone conductiveness, they were smaller at –0.003 ppm/y. The difference between the lowest and the highest conductiveness classes was as large as 0.072 ppm. Finally, when ozone concentrations were adjusted to typical meteorological conditions, the trends were between –0.001 to –0.002 ppm/y. Nevertheless these modest trends were statistically significant. We can conclude that ozone concentration experienced decreasing rates due to factors other than meteorology, likely air pollution control strategies and emission reductions during the study period.

Table 1. Annual trends of maximum and median ozone and probabilities of exceeding the prealert level

Trend coefficients (ppm/y)		O_3 max	O_3 med
Raw	1990-2002	-0.004	-0.004
Period 1	1990-1994	*-0.005*	*-0.0002*
Period 2	1995-1998	-0.006	-0.006
Period 3	1999-2002	*0.001*	*-0.003*
Adjusted	1990-2002	-0.001	-0.002
Period 1	1990-1994	*-0.002*	*-0.002*
Period 2	1995-1998	-0.003	-0.003
Period 3	1999-2002	*0.0002*	*0.000*

Accounting for ozone conductiveness class, all study periods		
	O_3 max	O_3 med
Class coefficient (ppm)	0.024	0.021
Trend coefficient (ppm/y)	-0.003	-0.003

Probability of exceeding the prealert level		
		($O_3 \geq 0.233$ ppm)
	in 1990	39%
	in 2002	6%
at a temperature of 28°C		
Period 1	1990-1994	40%
Period 2	1995-1998	24%
Period 3	1999-2002	9%

Note: coefficients in *italics* are non-significant

Historical Changes in Mexico City's Basin: Water Availability and Geospheric Characteristics

Carmen Durán de Bazúa, Alfonso Durán-Moreno, Rosa María Ramírez-Zamora

Mexico City lies in a basin that once housed the Aztec capital of Mexico-Tenochtitlan, founded by the Aztecs in 1325 and conquered by Cortés in 1521. Taking a different approach to city building than that employed by their predecessors, the Spanish conquerors fought against nature to build the new metropolis in the image of other medieval European cities with disastrous ecological consequences. This fight still continues in 2003. Now, as in the sixteenth century, we have chosen to ignore the 480-year old root problems of the region, and continue to export ecological damage to other areas rather than confront it at home. Our practices have changed little since the sixteenth century, when Spaniards began pumping contaminated water out of the basin; these actions are now taking a toll on the soil and the subterranean structure of what was once the "most transparent region on Earth" - now one of the most polluted. In this article, these issues will be analyzed and recommendations will be presented to help re-establish the ecological equilibrium that was lost between 1522 and 2002. Reversing the region's extensive ecological damage will require the ingenuity and support of both Mexican and international experts.

Geographic Considerations

Mexico City is located in a closed basin, not a valley. The surrounding mountains originally impeded water from exiting the basin (ignoring losses by evaporation or infiltration). It is considered an endoreic basin since pluvial precipitation in the surrounding mountains is concentrated in the lowest (normally central) part of the basin. The basin is around 9,000 square kilometers in area and originally was dotted with a system of lakes that included Zumpango, Xaltocan, Ecatepec, Texcoco, and Chalco-Xochimilco. These lakes were maintained at constant levels by water flow into the basin. When the Aztecs founded Tenochtitlan, several points rose above the water's surface, including the Peñon del Marques, Peñon de los Baños, Peñon de Tepeapulco (Viejo), and the Cerro de la Estrella (Huizachtecatl). The Azteces established public places such as temples and markets on a few larger islands like Tenochtitlan and Tlatelolco. Tenochtitlan and Tlatelolco were located on Texcoco, one of the shallowest of the water bodies. During heavy rains or longer than usual rainy seasons, the water level in the lakes would rise. For the Aztecs, this was not a problem, since the islands were only inhabited by the priest-governors and warlords. The population lived in the surrounding land and, therefore, was unaffected by these occasional fluctuations.

Once the Spanish conquerors started to build their churches and palaces on Tenochtitlan and Tlatelolco islands, at precisely the lowest point in the basin, periodic flooding became a serious concern. In 1604, civil works started in the Huehuetoca region to transform the closed basin into a valley, opening the mountain "collar" to drive excess water towards the Gulf of Mexico through the Moctezuma river, affluent of the Panuco. For this monumental civil project, several million tons of earth were removed by creating an artificial tunnel. Unfortunately, the tunnel sank and floods destroyed the city over a five year period from 1629-1634. Instead of abandoning the overpopulated lakebed and repopulating the surrounding land, the authorities decided to reestablish the city on its original location. The decision was made based on a simple calculation: the city was worth 40 million pesos and the sewage system restoration project would cost 10 million. Construction of the outlet for excess rain water began once again. These civil works continue today, nearly 400 years later. Every year, the rainy season brings floods to several parts of the city, and water is drained into the neighboring state of Hidalgo, through the canals that drive sewage towards the Tula river, affluent of the Moctezuma. Over the years the lakes have continued to dry, and the concentration of suspended particles, blown throughout the city by easterly winds, has increased dramatically. The salty Lake Texcoco is a particularly large source of these contaminants. Suspended particles occur in higher concentrations in the winter when grass no longer covers the dry lake beds.

Human Considerations

On the other hand, instead of promoting the reduction of the size of the city, the Europeans allowed the population to grow exponentially, from around 700,000 inhabitants in 1910 to almost 10 million in 2000. The inhabitants continued to rob land from the lakes (the latest victim is Chalco-Xochimilco) by dumping garbage and other solid materials and polluting the surface water and natural sources of the former basin. The incidence of flooding has been reduced, and the flat areas are now costlier, forcing the region's poorest inhabitants to live in the surrounding mountains. These new inhabitants pollute both sources of rain water and subsoil water sources by using septic tanks or simply dumping their wastewaters onto the land. The former rivers and springs in the Mexico City basin no longer exist and are instead used for sewage. This is particularly important in the Xochimilco, Tláhuac, Milpa Alta, Álvaro Obregón, and Magdalena Contreras areas, where most of the residents are countryside "refugees" that came to Mexico City looking for better living conditions. The original owners took advantage of the situation by selling their communal or "ejidal" properties to increase their meager incomes. The result has been the contamination of aquifers and the remaining lakes and rivers, garbage sent to river banks, woodland reduction, etc. Once the springs disappeared, drinking water was no longer available, and the authorities, again going against nature, built a

This article is based on the presentation given by Dr. Carmen Durán at the Sixth Workshop on México City Air Quality in January 2003. Carmen Durán de Bazúa and Alfonso Durán-Moreno are with the Program for Environmental Chemical Engineering and Chemistry, Faculty of Chemistry, UNAM; Rosa María Ramírez-Zamora is a researcher at the Institute of Engineering, UNAM.

civil project known as the Cutzamala system to bring water for city inhabitants from outside of the mountainous “collar.” The project continues to create political tension between the Federal District and the neighboring State of Mexico.

Drinking water is also obtained by pumping it from subterranean sources. Two problems are associated with this practice: First, subsoil water is becoming polluted by the irregular settlements established in the mountains. These poor households have no sewage systems and have not learned to maintain spring water or the rainy downflows. Instead, they use these natural sources of water for disposing their residues. The second problem is that clays, maintained moist for millennia, can become dry and lose their natural chemical equilibrium. As a result, they fracture and shrink, causing the buildings built above them to sink an average of 6 cm per year and above-ground streets and avenues to fracture. Unfortunately, these effects are visible throughout the city, not just where the water is physically pumped. Mexico City is also located in a geological area where earth movements are very frequent. Moist, flexible clays dampen earthquake movements by rocking back and forth. Fractured clays move more violently during tremors and are therefore more dangerous. Some studies promote “cleaning” wastewaters and repumping them into the subsoil to mitigate the environmental damage. This approach, however, fails to address the structural problems of the subsoil. Much of the damage already done is irreversible.

Possible Solutions

Some possible solutions and a few examples and comments on each of these strategies are provided below:

1. Water use reduction and recovery of rainwater

Breaks in underground pipes can cause two types of problems: first, water is lost when drinking water pipes fail, and, second, contaminated water can mix with the subsoil if pipes carrying sewage leak. In a seismic region, these breaks occur frequently. The first and most important solution to the problem is to maintain the piping system above the surface of the earth. Under this system, pipes can be repaired without tearing apart surface streets. The new piping must be made of durable materials such as high quality steel and should be set in an adjoining conduction support, on the sidewalk, or in the pedestrian area (blue piping) to avoid heavy trucks and limit the impact of earthquakes. These new installations will benefit both the construction and steel industries in Mexico.

2. Separation of gray and black sanitary waste water

The sewage system can also be “divided” into two subsystems: the existing runoff piping for rain water, and sanitary piping made of stainless steel or any durable material for sewage. Sanitary piping should be located 20 cm below drinking water piping on the lateral side of streets, and should only be connected to households, restaurants facilities, office buildings, and schools that do not release toxic substances. The new pipes should also be painted red to denote their special purpose.
Small industries and hospital and health facilities should pre-treat their sewage *in situ* before dumping it into the red piping. This solution will probably take one generation to fully implement but will ultimately prove to be cost effective – because they no longer transport rain water, the new pipes will handle smaller flows and will therefore have longer lifetimes.

Pluvial runoff can be sent to the existing wastewater treatment facilities (WWT) for treatment and reuse for industrial and green area irrigation. Sewage can be sent to smaller WWT plants strategically built in every colonia or group of colonias, depending upon the geographical and geomorphological structure of the area. Treated wastewater will be made available for irrigation, and any excess can be sent through the pluvial system.

Large facilities such as condominiums, hospitals, and industrial parks can separate the rain water coming from roofs, patios, and parking facilities and collect it in cisterns and tanks for reuse. For that purpose, construction normativity should emphasize obligatory actions by architects and engineers to separate rain water from roofs, parking areas, and yards. This water will be reused within the premises (in the WC lines and for green areas irrigation). The excess, if any, would be sent to the runoff municipal sewage line. Construction normativity should also plan for “black” sewage effluents (WC, kitchens, dishwashers, and clothes washers) to be sent directly to the “red piping” sewage, and for “gray” sewage effluents (hands basins, bathtubs, and showers) to be sent to an in situ facility for treatment and reuse by WCs and for green area irrigation. These solutions will probably not be applicable to older buildings, but if all new construction follows these regulations the water savings will be considerable within a generation.

3. Installation of conscious-minded WWT facilities

In Europe, the trend is towards the installation of smaller WWT facilities that avoid the gruesome maintenance costs of long sewage pipelines. In the huge Mexico City basin (9,000 square kilometers) these installations could significantly reduce the costs of maintenance on the sewage network.

4. Separation of industrial wastewaters from municipal sewage and *in situ* treatment

It should be obligatory for engineering staffs to separate industrial wastewaters by their chemical characteristics, and to separate sanitary effluents of industrial and commercial or residential origin. In this way, in situ treatment facilities will receive smaller flows of specific wastewaters, and the process will be simpler and much less expensive. Recovered and treated wastewaters may be used for WC and cooling facilities. This solution, like contingency actions for air protection, has to be backed by strict regulations, since most industries (medium, big, and transnational) possess wells beyond the control of government regulators. Unfortunately, there is no water saving education for personnel of most facilities. These wastewaters should be treated *in situ* to remove potentially toxic substances that diminish the efficiency of the government-owned WWT facilities (when they exist and are properly operated). In fact, much of these measures are beneficial in the long run for industries, since some raw materials are recovered during the process and cleaner technologies often result in considerable reductions in operating costs.

5. Reducing the amount of water pumped out of the valley: "Public Awareness" and "Saving the Mexico City Rivers" strategies

Presently, authorities and citizens are not aware of the benefits of water segregation. In Germany, most rivers were "saved" after the Second World War by a joint effort of the government and the population at large; now the entire society appreciates the benefits of clean rivers and creeks in cities. A conscious policy to save the rivers of the Mexico City basin is a must. Currently, almost all rivers are being used as sewage conveyors. One of the problems is that the population of the Mexico City basin is comprised mostly of newcomers from other parts of the country that view rivers as open sewage lines – an attitude common throughout the country. Often, congressmen and women view converting rivers into sewage pipelines as an achievement - an easy way to send liquid wastes out of the basin and into neighboring states. Instead, they should be planning with and changing the minds of the residents of their districts, convincing them that rivers are the only way for nature to collect rain water and transport it. Intelligent river use involves keeping the water within the basin, eliminating the need to import it from outside.

The only way to influence this "polluted" way of thinking is by mass education and comprehensive action by governmental authorities. For this purpose, city authorities and citizens must work together to avoid garbage dumping and illegal sewage connections. Mass public education through radio and TV spots should emphasize the following:

- that garbage should not be disposed into rivers. Government authorities should promote home separation of garbage into glass, carton, paper, plastic, metal, used containers, and organic waste, and allow for daily recycling collection and composting.
- that households and small enterprises should not pump sewage directly into rivers. Government authorities should be careful to ensure that every household within Mexico City is properly connected to the "red piping" and that rainwater from roofs and patios be drained to runoff sewers so it can be treated by WWT facilities before being dumped into rivers. As mentioned above, this is particularly important in the Xochimilco, Tláhuac, Milpa Alta, Álvaro Obregón, and Magdalena Contreras areas, where most of the households and small enterprises are polluting the aquifers and remaining rivers by sending garbage and wastewater to rivers and river banks, and reducing woodland by illegal constructions.
- that clean rivers are an important component of positive changes in climate and air quality, particularly if trees are planted along riverbanks. Pathways covered with "tezontle" and benches for walkers greatly improve the urban experience.
- that clean rivers are a safe and good way to recharge aquifers.

Strengthening environmental awareness of both the authorities and the citizenry at large will ultimately lead to the recovery of lakes in the Federal District and the State of Mexico, and to the improvement of the environment of Mexico City overall. Treated wastewater and rain runoff can be combined and sent to the surviving lakes of Xochimilco and Texcoco.

Protection to the Endangered Population Settled in Former Lakes Basins

Inhabitants of the former Chalco and Xochimilco lakebeds can begin changing their physical environment with government support for the Venice concept of water equilibrium. Support from the United Nations Environment Program and other internationally funded agencies can be tapped for these programs. The first set of actions to take is to stop building households and industrial or commercial facilities at ground level and, instead, to leave at least two or three meters of foundation to avoid damage caused by naturally flowing rainwater. For pre-existing buildings, ground level installations may be used as foundations for inhabited areas on the second story and above. Second, the connection of human settlements to "red piping" and the construction of WWT facilities are a must. These lake basins may once again become lakes within one or two generations, and residents will be able to traverse them in "acales" (a Spanish word for "acalli" or boat in Nahuatl, from "atl" = water and "calli" = house), as they were able to do at the beginning of the 20th century.

Benefits of the Public Awareness Policies:

- Greatly improved climatic and atmospheric conditions.
- A reduced water deficit in the basin and lesser need for imported water from neighboring states.
- A more humane city environment for all Mexico City inhabitants, with a cleaner atmosphere, cleaner water sources, and cleaner streets and water channels. These channels will beautify the city and recreate some of its original features.

MCP Transportation Activities

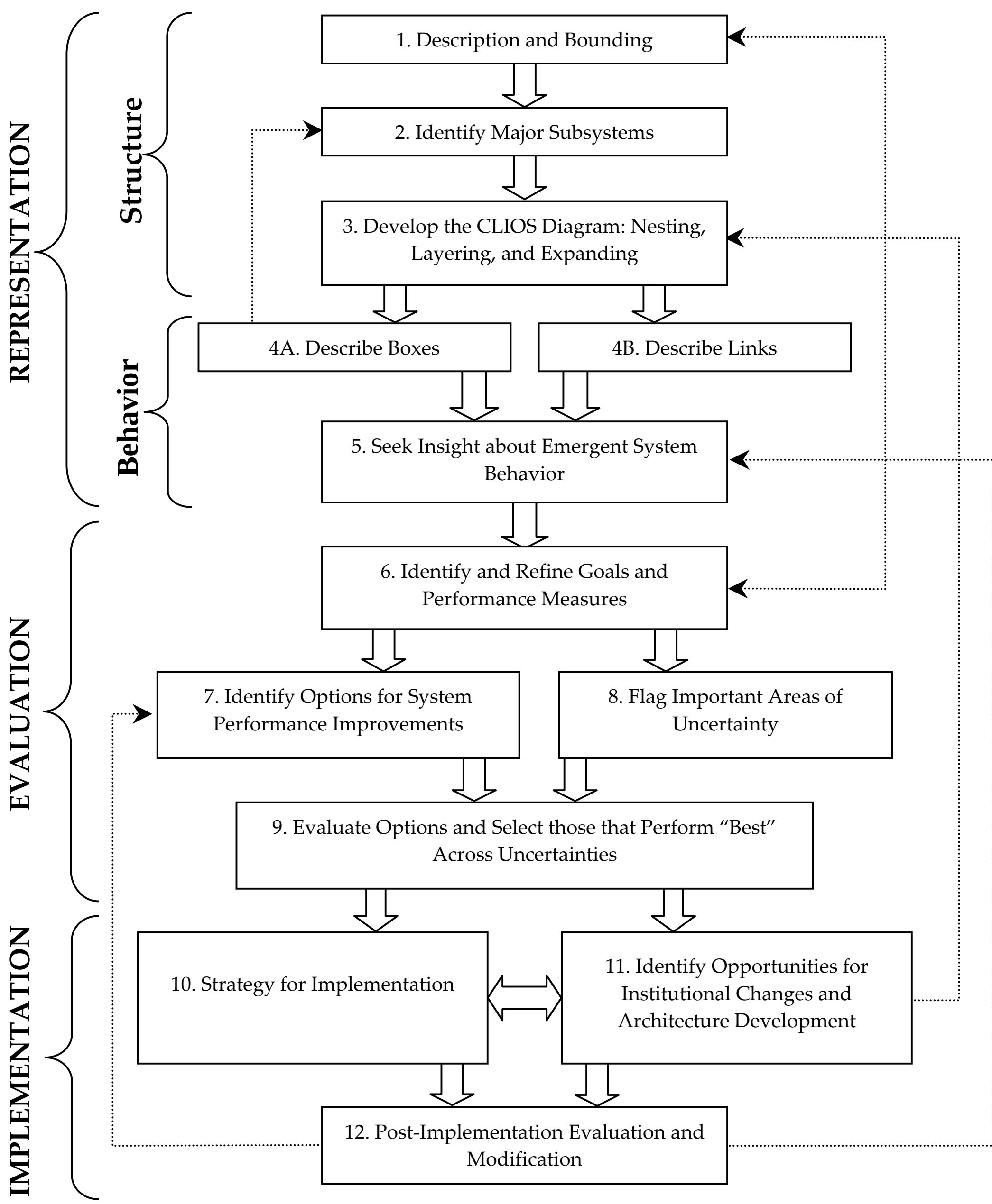
Continued from Page 1

Quality Measures for the Road-Based Public Transportation Sector in Megacities: The Case of the Mexico City Metropolitan Area (MCMA)," Master's Thesis, MIT, June 2003.)

- Institutional factors in the development of transportation/air quality policies (R. Dodder and J. Sussman, "The Concept of a CLIOS Analysis: The Mexico City Case," Proceedings of the MIT ESD Internal Symposium, Cambridge, MA, May 2002.)

All these approaches consider the triplet of technology, systems and institutions, wherein we must consider:

- Technological possibilities (e.g., catalytic converters, intelligent transportation systems for congestion relief).
- Systems issues, which involve understanding the interrelationship among various societal systems, especially transportation, environmental and economic development.
- Institutional factors, the relationships among various agencies as well as private-sector organizations and how they must come together to provide for a better air quality system in the MCMA without draconian cutbacks in mobility.



We have used the concept of a "CLIOS" (Complex, Large-Scale, Integrated, Open System) analysis (see Dodder & Sussman above) to develop a subtle understanding of the interactions among various components of the Mexico City/Air Quality system and as a mechanism for developing strategies that can lead to sustainable improvements in air quality in the context of virtually assured traffic growth.

The 12-Step CLIOS Analysis shown in the figure considers not only the complex physical systems of transportation, land use, and the environment, but also the complex institutional system, which includes various government agencies and private organizations and interests. Without resolving many of the issues relating to the institutional system, implementing positive changes in the physical system is difficult, if not impossible.

What is clear from our studies is that there is no "silver bullet" for solving Mexico City's transport-related air quality problems. Rather, Mexico City must work diligently on this problem on many dimensions to identify cost effective strategies. Under current investigation are the following: i) the benefits of passenger intermodalism; ii) an examination of Intelligent Transportation Systems (ITS) to ameliorate congestion and as a mechanism to implement congestion pricing in Mexico City; iii) detailed network modeling to identify congestion "hot spots" and to calculate emission factors for Mexico City at large (knowing that congested traffic generates much more emissions/VMT than uncongested traffic); iv) the establishment of freight terminals to eliminate the need for large diesel trucks to enter Mexico City.

Our findings indicate that in terms of technological strategies, incremental improvements will have modest effects in the long-term, whereas aiming for the best technology available at any given time will result in cost-effective emission reductions. Our findings also stress the importance of supply/demand management strategies, which can be relatively low-cost and yet have major emission reduction benefits.

We seek improvements in air quality that must be sustained over the 25-year planning horizon of our study -- no mean feat when, by virtually all accounts, traveler and freight transportation demand will continue to grow, perhaps substantially. Because of the tremendous uncertainties involved when attempting to forecast the future demand for transportation over a 25-year time horizon, we have instead used scenario planning as a method to think systematically about the future environment in which possible transportation strategies will be played out. We consider the use of scenarios or "future stories" to be a more flexible tool for developing long-term strategies, because it allows analysts and decision makers to consider possible disruptions or deviations from the "business-as-usual" trend. Using the three future stories for Mexico City -- *Divided City*, *Changing Climates*, and *Growth Unbound* -- we can then test the robustness of strategies across a range of future conditions.

While we have focused on the use of future stories as a method to design more robust strategies that work reasonably well across a range of conditions, scenario building can also serve as a neutral platform for a dialogue about the future of transportation and air quality in Mexico City. Given the institutional fragmentation and lack of a shared metropolitan vision among the many policymakers, decision makers and stakeholders who influence different parts of the transportation system, a scenario building exercise could be a pathway to forming that vision and developing a consensus about how to reach it. This type of scenario-based dialogue has precedent in much more volatile environments, ranging from post-Apartheid South Africa to civil-war torn Colombia.

We recognize that Mexico City faces a daunting problem in the realm of transportation and air quality. Only through a broad-based system approach, recognizing subtle interactions between various factors -- land use, economic activity, technology deployment, institutional relationships, and so forth -- are we likely to make long-range progress.

Coordinated Transportation and Land Use Planning in the Developing World – The Case of Mexico City

Michael Gilat, Joseph M. Sussman

The Prospects for Coordinated Transportation and Land Use Planning in the Developing World

In the United States, planners in recent decades have sought to contain suburban sprawl and its negative social, economic and environmental effects. A series of interrelated policies and ideas have been developed, including downtown revitalization, urban growth boundaries, New Urbanism, "Smart Growth" and Transit-Oriented Development (TOD). These policies share a desire to use existing land resources more efficiently, reduce auto trips, promote non-motorized travel (walking and biking), and increase transit ridership.

The three main principles of TOD are the "Three D's": Density of residents and jobs near transit stations; Diversity of land uses (residential, commercial) near stations; and Design, i.e., urban design elements that make the station more integrated with the surrounding area and more accessible to pedestrians and bicyclists.

TOD has been shown to work given the following conditions:

- An extensive transit system covering a big part of the city;
- Government organization with planning and taxation powers concentrated above the level of the single town (i.e. at the metropolitan or regional level);
- Government incentives to developers;
- Most importantly, a strong local economy and real estate market.

The question is whether TOD can be transplanted to the developing world, where many people are poor and do not own automobiles. The cities are growing rapidly, and many of the poorest people live on the outskirts, where they depend on expensive informal low-capacity transit, and usually spend a greater percentage of their income on transportation than people with high income. This diminishes their economic opportunities. Mixed land uses still prevail in the centers of developing world cities, including apartments, commerce (both formal and informal), and in some places light industry.

These conditions also present opportunities for TOD and other methods of coordinated transportation and land use planning. With proper planning and investment, the urban form of rapidly growing cities can be designed to be transit-oriented. This can slow down the onset of motorization and sprawl and mitigate

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their effects when they do occur, so that transit and non-motorized transportation maintain relatively high mode shares even after per capita income has risen to near-Western levels. TOD can also have beneficial socio-economic and environmental effects by concentrating the population along corridors served by high-capacity transit, which has lower operating costs and emissions per seat, and can charge lower fares.

It is sometimes possible to implement TOD citywide, along a significant part of the transit system (often as it is being built). This can significantly increase the attractiveness of transit, since it greatly increases the number of possible origins and destinations that are accessible by a combination of transit and walking. The combination of dense, mixed land uses near stations and pedestrian-friendly station areas on a system-wide scale gives people who live near transit a much larger choice of destinations.

Although the opportunities are great, there are some serious barriers to TOD in the developing world, most of them institutional. Planning institutions have fewer resources than their counterparts in the developed world, and often cannot afford to collect much of the data required to inform the planning process. Interdisciplinary planning and metropolitan planning are often poorly developed. Corruption and cronyism are often a problem. Where zoning codes exist, enforcement is sometimes lax or nonexistent. Another major obstacle is the high cost of infrastructure to support TOD. Even cities in the developed world often have difficulty in obtaining financing for major transit investments. In the developing world, the situation is often worse. Cities spend large amounts of money on a single rail line, which fails to attract adequate ridership because it does not reach enough people and destinations. However, less-expensive technologies like bus rapid transit (BRT) allow cities in the developing world to develop extensive, affordable transit systems.

The Prospects for Coordinated Transportation and Land Use Planning in the MCMA

Mexico City's altitude, location, land-use patterns and increasing auto ownership combine to create a severe air pollution problem, but this problem may possibly be mitigated by coordinated transportation and land use planning, built around increased Metro use.

The Mexico City Metro system is one of the world's most extensive, with the lowest operational costs of any major world Metro. It transports 4.5 million daily passengers, and ridership on its busiest lines approaches 1 million daily passengers. However, it does not extend deeply into the State of Mexico (EM), where half the population lives. Almost all the lines terminate at the Federal District – State of Mexico (DF-EM) boundary, and the stations there are the busiest in the system. Many passengers transfer from colectivos to the Metro at these stations. The expansion of the system can reduce the use of colectivos and their emissions, and reduce the travel expenses of low-income people living on the outskirts. The downtown is still the main destination of trips in the MCMA, and the busiest lines are those that pass through it. However, due to disagreements between the DF and the EM over financing of Metro expansions, the next phase of expansion will occur exclusively in the DF, even though a strong argument can be made that the EM is where expansion is needed most. The recently opened line B, which does go into the EM, has so far performed very well, and has eliminated some colectivo trips.

Another major problem is that the Metro is used primarily by the lower-income population. Middle and high-income people regard the Metro as crowded and unsafe. Although the poor are the majority of the population in the MCMA, the fact that other people avoid the Metro means that there is less political willingness to invest in it. The government would rather invest in highway projects that cater to the interests of auto owners. While there is an ambitious Master Plan for the Metro and light rail and some parts of it may be built in the near future, it is doubtful whether it will be completed on schedule in 2020.

The MCMA has many of the prerequisites for TOD. It is densely populated, despite the lack of high rises, although it could perhaps be denser, particularly the downtown areas. The population density in the MCMA is about 12,000 people per square kilometer. This density is remarkably uniform across most of the inhabited parts of the MCMA. The center of the city has mixed land uses. In fact, the informal commerce present at many Metro stations provides many of the benefits of mixed land use, since the poor, who are the majority of Metro riders, can use it for shopping on their way to and from work. While urban design around Metro stations is not very developed, most stations are easily accessible from the surrounding neighborhoods.

The MCMA has some of the institutional structure required to support coordinated transportation and land-use planning, but more needs to be done. Zoning in the DF is in the hands of the "delegaciones", while the DF government collects property taxes and can veto zoning decisions. This situation makes it easier for the DF government to pursue a citywide policy of coordinated transportation and land use planning. If the delegaciones had the power to collect property taxes, they would compete with each other, pursuing their own interests (e.g., attracting big office developments and high-income housing) at the expense of the interests of the rest of the city (e.g., mobility, accessibility, equity, environment).

The MCMA suffers from insufficient interdisciplinary planning. Location decisions for public housing, schools, hospitals, etc. are made without sufficient consideration to access to public transportation. The urban development trends in the MCMA highlight the need for greater coordination between transportation and land use planners, as well as between the DF and the EM. Recent urban growth in the MCMA has concentrated in the EM and outer delegaciones of the DF, while heavy industry has been moving out of the MCMA to other parts of the country. American-style shopping malls and office parks have been built in the more affluent western areas, often without adequate transit access. The EM's ambitious transportation plan includes intercity roads that would bypass the DF. These will have profound impacts on the urban form of the MCMA, and could lead to further sprawl, which in turn could result in longer and more numerous colectivo and automobile trips and diminish the effectiveness of the Metro system. Coordinated transportation and land use planning at the metropolitan level is the key factor in maintaining control over the urban form of the MCMA.

The DF government has recently imposed curbs on development anywhere outside its four central delegaciones. However, this merely causes more development to occur across the border in the EM, where no such restrictions exist. This highlights the need for planning at the metropolitan level. A stronger metropolitan planning organization with more powers (e.g., zoning, transportation planning) may be able to control the urban form of the metropolitan area and facilitate the provision of high-capacity transit, while taking into account the economic interests of both the DF and EM.

The Metro can serve as a backbone for efforts to redensify the steadily depopulating downtown and create infill development there, thereby contributing to the containment of sprawl. There are also opportunities for TOD along a proposed suburban rail line in the northwestern part of the MCMA, which will be privately operated. The suburban rail line will run through decaying industrial areas and near middle-income neighborhoods. It provides an opportunity to create a transit corridor along which many people can live and work, centered around a new transit system that middle-class people might be willing to use. This corridor will feature the high densities, mixed land uses and urban design elements typical of TOD. Real estate development in and around Buenavista station in the DF (the southern terminus of the line) is already being considered, and it can be expanded to the rest of the alignment and planned so that it is integrated into the new transit system.

The various options require different levels of institutional effort and commitment. Each option can have some local impact without extensive involvement by the municipal governments of the MCMA, but can have larger impacts if the government does become involved:

- Government commitment to building affordable housing, and locating most or all of it near Metro, light rail or suburban rail stations could lead to a significant increase in Metro ridership. If this housing is located near underutilized Metro lines, it could increase ridership on those lines and perhaps help alleviate congestion on the saturated ones.
- Downtown redevelopment is already occurring, although it is mostly confined to commercial high rises and hotels, but with government involvement in the form of affordable housing and incentives for mixed use, it can slow down the depopulation of the central city.
- Some development will probably happen along the suburban rail alignment, for example in the Buenavista terminal in the DF. However, metropolitan coordination in the form of a joint DF-EM suburban rail corridor plan can significantly increase the potential for the development of a high-density, mixed-use transit-oriented corridor along the suburban rail alignment.
- The addition to the Metro Master Plan of a detailed study of real estate opportunities in Metro stations, together with aggressive marketing of these opportunities for TOD, can improve the chances of their development, bring money to the STC Metro and reduce its dependence on subsidies from the DF government.

If more people can be concentrated near Metro stations through an expansion of the system and a policy of locating housing and other developments near it, the equity and environmental effects can be considerable. People who have the option of using the Metro without a colectivo feeder trip have significantly lower transportation expenses. They are not affected by road congestion, and can reach their destination more quickly and predictably. This could increase their job opportunities. In short, TOD can be a great force for equity in the developing world. Mexico City's extensive Metro system positions it to take full advantage of this concept.

The ideal urban form created by coordinated transportation and land use planning would preserve the importance of the downtown area and channel development outside that area into corridors served by the Metro, light rail or suburban rail for maximum accessibility by people of all income levels.

On the environmental side, TOD can significantly reduce colectivo-related emissions by eliminating and/or shortening colectivo trips. However, the most significant environmental effect of TOD is indirect and long-term – creating a transit-oriented urban form, where people will continue using high-capacity transit (at least for the trip to work) even after they can afford an automobile, thereby mitigating the increase in pollution that accompanies motorization. As part of a policy of transit-oriented affordable housing, Mexico City can include limitations on parking supply before the residents can afford automobiles, thereby averting some of the political backlash.

TOD is, of course, a long-term policy and cannot be expected to deliver immediate results, but a series of changes to the planning culture in the MCMA could help sow the seeds for a transit-oriented urban form that would be both socially and environmentally more sustainable. The key is thinking of land use and transportation as a coordinated system.

Easter Plume

Continued from Page 1

VOC Detection via PTR-MS

PTR-MS was developed by the late Werner Lindinger and his co-workers at the University of Innsbruck in the mid-1990s. It is a very sensitive chemical ionization technique for rapidly identifying organic compounds with proton affinities greater than that of water vapor and is chiefly used to measure unsaturated (aromatics and alkenes), oxygenated (alcohols, aldehydes, ketones, organic acids), and amine VOCs. Recently, research-grade commercial instruments have become available from a company founded by Lindinger and his colleagues, and the technique has been adopted for a variety of atmospheric chemistry, process monitoring, and medical breath analysis applications. A PTR-MS was first deployed onboard the Aerodyne Research, Inc. (ARI) mobile laboratory by Berk Knighton of Montana State University (MSU) during our exploratory field campaign in February 2002 (see Vol. 2, Fall 2002 newsletter), where it provided high temporal resolution measurements of acetaldehyde and a variety of aromatic compounds at several sites. For the Spring 2003 field campaign Knighton and John Jayne of ARI retrofitted the MSU PTR-MS with more rugged turbomolecular pumps and an improved fast flow sampling system so that it could make fast response measurements in the mobile lab, both on-road and during stationary deployments. Furthermore, a second PTR-MS was deployed on the roof at the National Center for Environmental Research and Training (*Centro Nacional de Investigación y Capacitación Ambiental* or CENICA) supersite by Tom Jobson and Mike Alexander of the U.S. Department of Energy's Pacific Northwest National Laboratory (PNNL). This latter instrument provided nearly continuous high time resolution measurements of a range of aldehyde, aromatic, and alcohol VOCs and could also be interfaced with the eddy flux measurement system deployed on the CENICA roof tower by Brian Lamb and co-workers of Washington State University (WSU).

Both the MSU PTR-MS operating on-board the ARI van and the PNNL instrument on the CENICA roof sporadically detected two novel PTR-MS mass signals during the first part of the spring campaign. After some detective work, these signals where assigned to the ester species, ethyl acetate ($CH_3C(O)OC_2H_5$). Esters are compounds formed by the combination of an organic acid and an alcohol, resulting in the elimination of a water molecule. Ethyl acetate is not toxic; indeed, like many esters, it has a fruity flavor and aroma and is used as a flavoring agent in pharmaceutical products. However, its main industrial use is as a solvent in a wide range of manufacturing processes involving polymers. When released into the atmosphere, it reacts relatively rapidly with the OH radical, producing acetic acid and the highly reactive CH_3CO radical, contributing to photochemical smog.

Ethyl Acetate Plume Mapping

Intrigued by the unexpected plume signature, investigators studying the MSU PTR-MS in the ARI mobile laboratory used the device's mapping mode to track the plume back to it source. The plume mapping data is displayed in Fig. 1, where the global positioning system (GPS) coordinates of the mobile laboratory track are plotted on a map of a section of the Iztapalapa area in a logarithmic scale. The brightest colors represent the highest ethyl acetate concentrations. The source of the plume was narrowed to a cluster of industrial buildings. Subsequent investigations by the Government of the Federal District (GDF) identified two plastics fabrications plants in this cluster that appear to be the source of the plume.

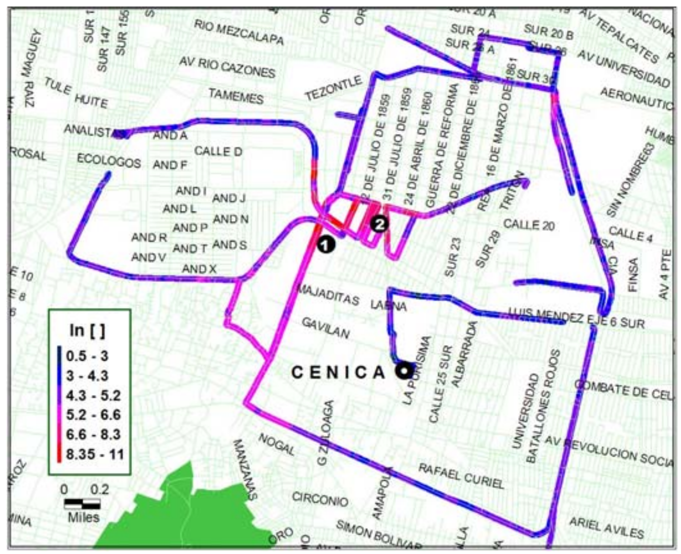

Fig. 1. Track of MSU PTR-MS Ethyl Acetate Plume Map from ARI Mobile Laboratory

Modeling Ethyl Acetate Plumes

Knowing the plume source location and the local meteorological conditions, the time resolved ethyl acetate data taken by the PNNL PTR-MS at CENICA was used to estimate the plume's emission flux strength. To calculate the emission rate of ethyl acetate from the identified source, Erik Velasco, Brian Lamb, and Hal Westberg of WSU applied a simple plume model to back-calculate the source strength from the ratio of observed and predicted ethyl acetate concentrations. The modeling system consists of the CALMET diagnostic wind field model and the CALPUFF Gaussian puff dispersion model. The meteorological input data were obtained from a sonic anemometer, and temperature and relative humidity data were gathered by a sensor installed at the top of the WSU flux tower, 37 m above ground level at the CENICA site. Vertical profiles were obtained from 3 daily radiosondes (00:00, 12:00 and 18:00 h) launched for the campaign. The wind field was obtained from surface and upper meteorological observations

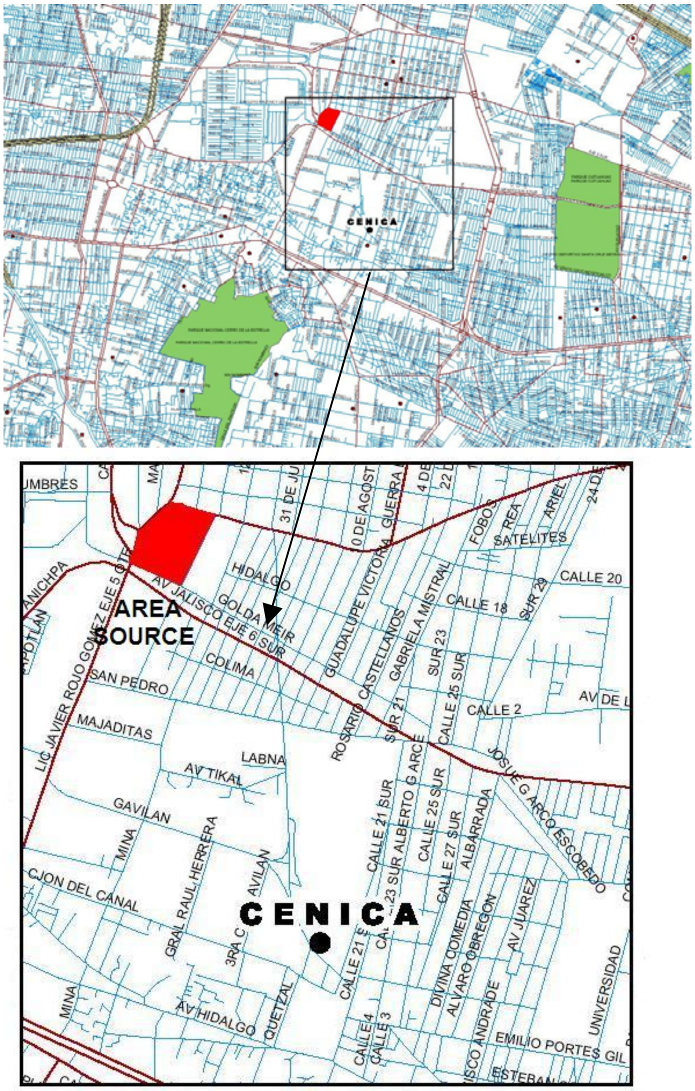

Fig. 2. Modeling region of 50 × 50 cells of (50 m x 50 m grids). The red area represents the modeled source emitting ethyl acetate, and the black dot indicates the CENICA site.

and the diagnostic model CALMETv5.22. The modeling domain was defined as a grid of 50 cells in both the *X* and *Y* directions, with a grid spacing of 50 m (Fig. 2). Nine vertical layers were used with variable spacing of 20, 40, 80, 160, 320, 1000, 1500, 2200, and 3000 m. The entire domain was modeled as urban with flat terrain at 2240 m above sea level. The dispersion simulation was made with CALPUFF v5.511. The ethyl acetate was modeled as a trace gas, assuming no chemical reactions and no deposition, with an arbitrary source strength of 10 g m^{-2} s^{-1} for the source area represented in red.

Figures 3 and 4 present 6 hour average concentration maps of ethyl acetate, and Figure 5 shows the time series of one hour average concentrations at CENICA. These results show that the plume reached CENICA only in the mornings between 6:00-12:00 h. Using the arbitrary emission rate, the maximum predicted one hour average concentration reached a value above 90 mg m^{-3} on the first day, and up to 72 mg m^{-3} on the second. In terms of normalized concentrations (C/Q), these values correspond to 0.009 s m^{-1} and 0.0072 s m^{-1}. The plume dispersion strongly depends on the observed wind direction and speed; comparing Figures 3 and 6 shows that the plume only reached the receptor site for periods when the wind speed was lower than 2 m s^{-1}, although the surface wind direction was not exactly aligned along the source-receptor line. This may be due to the influence of upper air observations in the interpolated CALMET wind fields. The maximum concentrations coincided when thermal mixing was starting, a few hours after sunrise. Although, north and northwest wind directions at surface level were mainly observed in both days between 12:00 and 18:00 h, the plume did not reach the receptor site, probably because upper wind conditions were different from surface conditions. It should be noted that the upper air observations were not obtained at the CENICA site, but were located elsewhere in the basin.

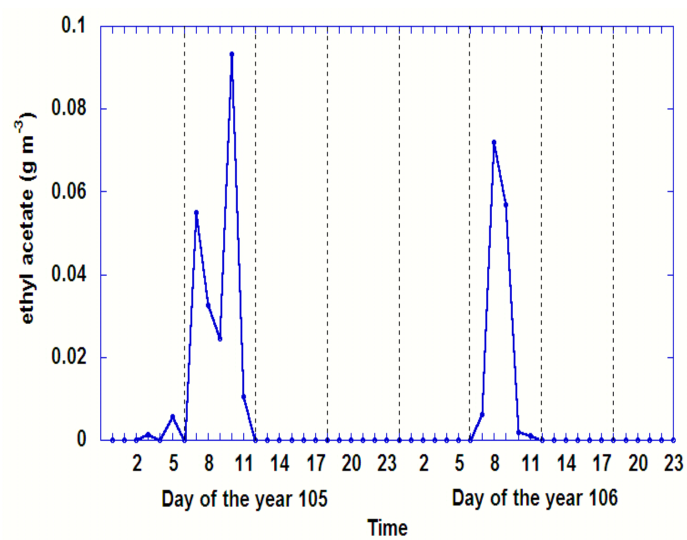

Fig. 5 Modeled ethyl acetate concentrations at CENICA during April 15-16, 2003

During April 15-16 (the period modeled with the CALMET/CALPUFF system), observations of ethyl acetate were available for only part of each day from the PTR-MS on the roof at CENICA. On April 16 measured concentrations peaked at approximately 36 μg/m3. If this observation is used with the modeled peak concentration (approx 70000 μg/m3) and the modeled source strength of 1 g/s, a initial estimate of the actual ethyl acetate source strength can be obtained as 1.8 g/hr. This is only an example of how the modeling application can be used with temporally resolved observed concentrations to estimate source strength for nearby sources. Further work is needed to improve the model analysis and to apply it to this and other cases when there is clear evidence of the ethyl acetate plume at CENICA.

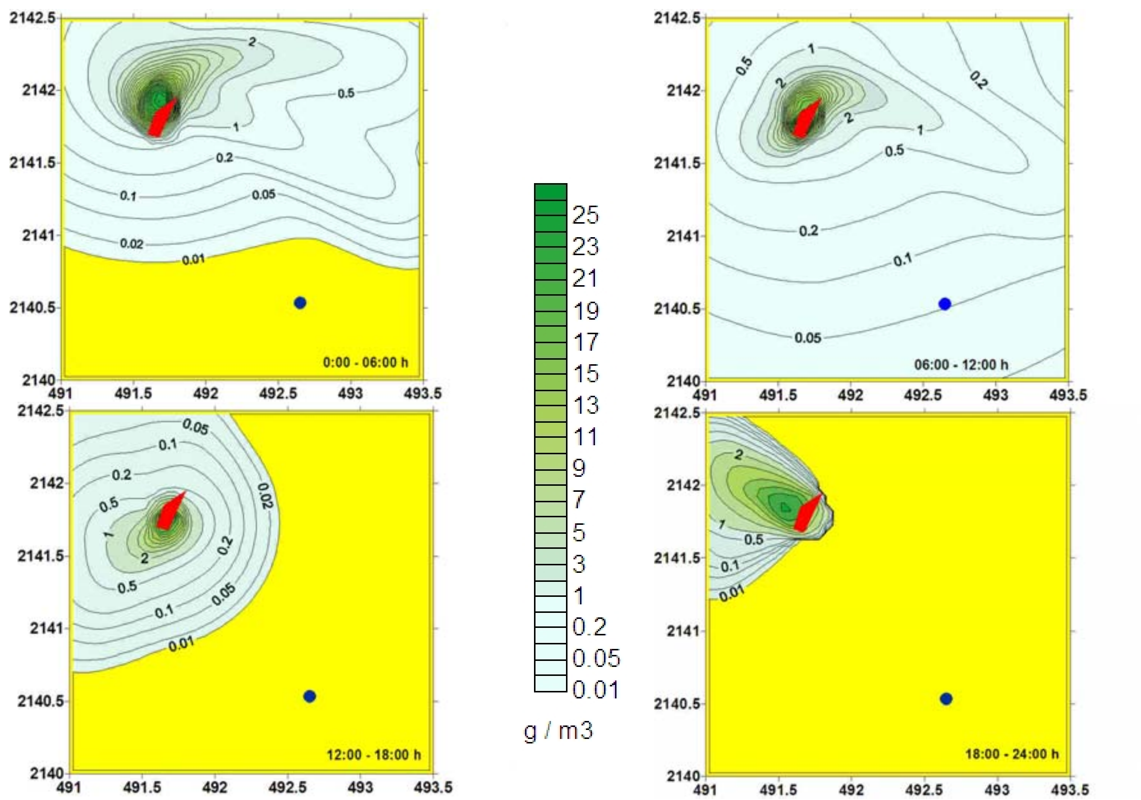

Fig 3. Six-hour average concentration of ethyl acetate emitted during April 15, 2003. The red area indicates the area source and the blue dot indicates the CENICA site.

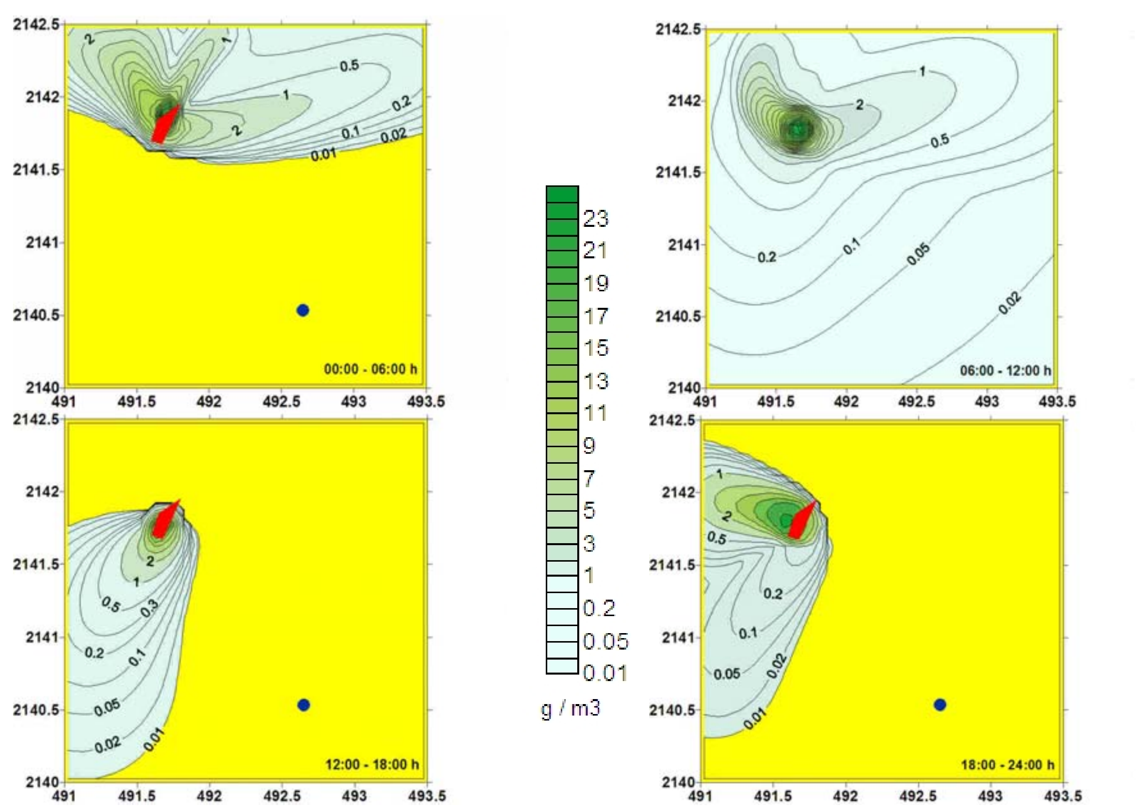

Fig 4. Six hour average concentration of ethyl acetate emitted during April 16, 2003. The red area indicates the area source and the blue dot indicates the CENICA site.

Public Participation in Environmental Impact Assessment in Mexico: A Review of Recent Practice

Dong-young Kim, Javier Warman and Lawrence Susskind

Today, virtually every environmental policymaking effort acknowledges the importance of public (i.e. stakeholder) involvement. For developing country experts who must now undertake environmental and integrated assessments of various kinds, they need to know which participatory methods have a chance of working in their political and institutional context.

Environmental impact assessments (EIAs) are analogous in some respects to comprehensive or integrated assessments (IAs), although often scaled-back in scope and complexity. First, both are used as tools to help decision-makers make choices concerning project or policy approval by providing technical information about the probable consequences of alternative courses of action and the likely effectiveness of mitigation strategies. Second, both kinds of assessments are prepared mainly by professionals, or experts. Third, required consultation with stakeholders or various segments of the public are part of both types of assessments.

A research team at MIT led by Professor Larry Susskind and Dong-Young Kim sought to trace the current pattern of public participation in environmental impact assessment in Mexico and draw implications for the first major integrated environmental assessment (of Air Quality Management Options) being prepared for the Mexico City region by faculty and staff at MIT. They focused on EIAs having to do with roadway construction in the Mexico City area because highway construction decisions interact with regional air quality management.

EIA in Mexico

The three cases of roadway construction around Mexico City are (1) Double-decker highway in Mexico City; (2) Barranca del Negro in Mexico City Metropolitan Area (MCMA); and (3) Queretaro. Information was gathered on all EIAs involving public participation in roadway construction projects in the Mexico City region since 1996 (i.e. when the public participation provisions were established in the LGEEPA amendment). Three kinds of participation were postulated: 1) participation in "before-the-fact" expert assessments (scoping), 2) participation in public reviews of Environmental Impact Statements produced by assessors, and 3) participation outside of the EIA process through litigation or demonstrations. For each, EIS documents, comments generated by the consultation process, EIA resolutions, and newspaper articles were examined. Also, interviews were conducted with key informants including 1) Government officials, 2) Environmental Lawyers, 3) NGOs, 4) Academics, 5) Consulting firms, and 6) Developers (including Transportation agencies).

Findings Regarding Public Participation in Mexican Environmental Impact Assessment for Roadway Construction

1. No public consultation during the impact assessment

All three cases showed that there was little or no public consultation by experts or professionals as they prepared assessment reports. As a result, public participation occurred too late in the decision-making process to influence the selection of project alternatives or key project variables, such as technology, size or location.

2. No rigorous scientific analysis and limited scoping

Under most circumstances, EIAs for road construction look at impacts on the surrounding environment and possible mitigation measures. Impacts during both construction and operation are normally considered. Likely impacts from road construction usually include air quality, noise, and water quality. The EISs in the three cases we studied barely mentioned any such impacts likely to be caused by the proposed projects. The main source of pollution during operations is likely to be emissions from moving vehicles. Thus, these three assessments should have included traffic forecasts, air dispersion modeling, emission inventories, and so forth. However, they did not.

3. Litigation rather than participation is the preferred option for project opponents.

Two of the three cases demonstrate that Mexican activists know how to use the courts to express opposition to government infrastructure building efforts. This is true for many other controversial development projects in Mexico. With the help of environmental lawyers and NGOs, organized citizen groups filed suits against the project proponents both before the EIA process even started (Case 2) and after the EIA was completed (Case 1). There is a tendency to initiate litigation rather than to use the opportunity for participation mandated by the EIA law to express opposition. When there is no consensus on the likely potential impacts of a proposed project among government professionals, agency personnel and the public, the issue usually

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becomes politicized. When that happens, there is usually a call for a political solution such as a referendum (Case 1).

4. Both government and the public tend to concentrate on procedural features of EIA rather than on substantive matters of environmental impact.

In the litigation mentioned above, citizen groups criticized what they charged was government mismanagement of the EIA process. For example, they argued that the agencies involved did not respond to comments from the public and did not notify people of the public hearing in a timely fashion. In case 1, when the governmental agencies briefly responded to some of the feedback they received at the mandated hearing, they belittled the comments submitted as outside the scope of the EIA process. Thus, people who wanted to make certain arguments, but failed to do so in substantively appropriate ways, had no choice but resort to legal action to challenge what they saw as procedural flaws. All told, comments received from the public played almost no role in shaping the final EIS or subsequent government decisions.

5. The government does not seem to be especially responsive to comments received during public consultation.

In the public consultation process for the double-decker highway, 194 comments were filed. These stimulated no additional assessment at all. Many of the 194 comments reflected the substantial magnitude of the controversy surrounding the project. However, only 15 responses were forthcoming from the government. Thus, the resulting EIS was hardly improved in reaction to the stakeholder views expressed.

Analysis of the Causes

The research team has identified what it believes are three key causes of the failure to use EIA, and particularly the public participation requirement, more effectively in Mexico:

1. The public's attitude toward road construction in Mexico

It was assumed that the level of interest in and the style of public participation in EIA would vary according to the kinds of decisions that had to be made. Roadway construction can be seen as a particularly technical matter best left to engineering professionals. In other places around the world, however, as EIA experience has accumulated, roadway and other transit EIAs are now seen as a setting in which larger political debates about the objectives of economic development, fairness in the allocation of public resources, and the importance of promoting sustainability can be argued. In other words, decision-makers can calculate what the impacts of construction projects are likely to be, but stakeholders and the public-at-large are likely to be interested in a wider analysis of alternative transportation flows as well as a whole range of other concerns.

2. Wrong assumptions about public participation and distrust of other actors

One possible reason for a lack of participation in the EIA process can be distrust on the public's part of the seriousness of the government's commitment to take citizen concerns seriously. In Case 1, people were contacted, and asked to give comments on the EIS, but their opinions did not influence decision making at all. They believed government had already determined a course of action (and they were correct). Consequently, citizens tended to dismiss the offer to participate as a kind of cooptation by government. They took legal action instead. On the other hand, the governmental agencies and project proponents often perceive public participation in EIA as a device for blocking projects, instead of a means of constructive engagement. From the developers' point of view, the EIA process also means more paperwork and more time allocated for interaction with government agencies. Project proponents may try to rush through the requirements of public participation to avoid delays. In such cases, citizen involvement does indeed become a means to halt a project or force further consideration of mitigation measures. A common response among EIA professionals is that "if the public only knew what we know, they would agree; how can they be taught that what we are doing is right?" This is based on a presumption that professionals are fully informed and better able than citizens-at-large to make appropriate judgments.

3. Minimal experience with participatory measures

It was not until 1996 when the LGEEPA was reformed that public participation provisions were instituted in the EIA process in Mexico. The lack of successful instances in which public involvement has improved the quality of environmental decision-making leaves governmental agencies unconvinced about the need to identify relevant stakeholders and unsure about how to involve the public at each stage of the EIA process. In the same way, the public has not experienced meaningful participation and thus has not bothered to learn more about this means of expressing its views.

Implications for Integrated Assessment (IA) Experts Working in Mexico

Based on the previous analysis, the following lessons and recommendations can be offered to professionals initiating integrated assessments of major environmental management decisions in Mexico. Certainly, any and all public participation techniques should be suited to the culture and the affected publics. IA practitioners will have to work to correct many wrong assumptions and misperceptions caused by current EIA practice in Mexico if they are going to have success in involving stakeholders and the public-at-large in the process of generating integrated assessments of major environmental policy decisions. More specifically, we suggest:

1. Be creative, flexible, and proactive in terms of public participation

One of the big differences between EIA and Integrated Assessment is that while EIA is based on institutionalized and regulated routines, integrated assessment is not. Thus, generally, the institutionalization of public participation in the EIA process tends to make EIA practitioners see public participation as a formal obligation, which should be happening at a later stage in any event, rather than a necessity. However, there are no regulations requiring public or stakeholder participation in integrated assessment at any stages; nor are there regulations allowing citizen to file law suits for inappropriate assessments by IA experts. Accordingly, in our opinion, IA practitioners are in a position to be more flexible and creative than EIA practitioners.

2. The sooner participation begins, the better the results will be

As seen in previous cases, the public is rarely consulted by EIA professionals when they are planning and conducting assessment activities. In fact, during the initial scoping process, local citizens or stakeholders should have been invited to comment on the proposed project before the EIS was prepared. They might have helped identify problems, which otherwise could have become sources of conflict, or even suggested solutions which professionals might have overlooked. In addition, earlier public participation before the EIS is produced provides excellent opportunities for dispute resolution. Avoiding potential policy disputes is not an efficient strategy. Those seeking redress will find ways to exert political pressure or use the judicial system, which ultimately may stall a project.

3. Focus on substantive issues not just procedural concerns

The cases of Mexican EIAs for roadways suggest that agency personnel have missed the substantive benefits of participation. The process of participation became a means of meeting procedural requirements rather than solving problems or resolving disputes. IA experts should design participatory programs in a way that raises and confronts substantive disagreements. In practice, learning is more likely to occur in situations where participants are active rather than passive. When people are given opportunities to “do”, to participate in tasks, to speak from their experiences, and to be “players”, they are more likely to learn than when they only observe.

4. Information must be geographically and linguistically accessible

In three cases, people often refused to read about a proposed project in an EIS, but then complained vigorously about how the same project was described in the media. One of the reasons why people are reluctant in being involved in an EIA process is because EISs are often difficult to read. Thus, IA reports that are understandable will allow greater levels of public and stakeholder participation. Thus, substantial attention should be focused on producing IA reports that citizens or stakeholders can understand.

Conclusions

Their analysis suggests that the experience in Mexico with public participation in EIAs, at least for roadway construction, has not been very positive. It should be recognized, however, that Mexico is in a transition period in terms of democratic decision-making and retains a huge potential as a place where public involvement in environmental decisions can achieve great significance. In their view, the key to successful public involvement in assessments of all kinds is the attitude that assessment professionals bring to their work. If they make it clear that only those living and working in a place have the “deep” knowledge and experience required to complement technical forecasts, the public-at-large may be willing to invest the time and energy required to make such dialogues worthwhile. Effective public participation in decision-making does not happen by accident, it requires a carefully designed and managed partnership between government, industry and the public-at-large. A proactive effort that goes beyond minimal hearing requirements is time-consuming, sometimes expensive, and often highly confrontational. It is hardly worth the effort unless some care has been taken to lay the groundwork for productive dialogue. However, the research team are confident that even one high profile, successful integrated assessment will encourage a whole new level of effort to ensure that participatory decision making practice in Mexico is given the attention it requires.

GURME Air Quality Forecasting Workshop for Latin American Cities

As a part of the air quality forecasting activities of the World Meteorological Organization’s (WMO) Global Atmosphere Watch (GAW) Urban Research Meteorology and Environment (GURME) project, a meeting of experts in air quality forecasting was held in October 2002 in Cuernavaca, Mexico. The meeting was convened by WMO, co-sponsored by National Oceanic and Atmospheric Administration (NOAA), and hosted and organized by the Integrated Program on Urban, Regional and Global Air Pollution. The workshop led to the GURME pilot project “Improvement of Air Quality Forecasting in Latin American Cities.”

Fig. 1. Participants of the GURME workshop

São Paulo, Mexico City and Santiago de Chile are large cities that share common air quality problems, and there is a large potential to learn from WMO and from each other about air quality issues. A number of collaborative programs are being developed between these cities concerning topics such as photochemical modeling, atmospheric measurements, transportation, and urban development. It is clear that air quality forecasting is a topic where scientific exchange and collaboration is extremely useful. The project will improve the air quality forecasting methodology currently implemented in Mexico City, Santiago and São Paulo and will help to transfer knowledge from these three cities to other cities in Latin America.

The first GURME Air Quality Forecasting Workshop for Latin American cities was held in Santiago, Chile on October 13-16, 2003 at the University of Chile. Approximately 60 people attended the Workshop representing a good cross-section of the air quality management and forecast professionals in Latin America (Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru), Europe (Denmark, Russia), Australia and USA.

The Workshop started with an introductory session on the GURME program and the air quality problems in Chile, followed with presentations from Brazil, Mexico, USA, Denmark, Israel and Australia featuring challenges to air quality forecasting. Representatives from Ecuador, Peru, Colombia and Russia also presented the environmental management programs in their countries. The Workshop featured breakout sessions on Measurements and Air Quality Modeling; the recommendations from the breakout sessions were presented on the final day.

Topics raised in the measurement breakup session were: a) Data availability from the control agencies, individual research projects and national meteorological services; b) Quality assurance and quality control of the data collected; c) Establishment of a discussion forum with a network of Latin American GURME scientists on the web; d) Capacity building in Latin America.

The modeling working group reported that Chile, Brazil and Mexico all have advanced photochemical modeling capabilities. Santiago and Mexico city have similar meteorological conditions (basin flow) and all three cities have a problem with the NOx/VOC ratio in the emissions inventory. It was proposed that all three groups could utilize the WRF-Chem model. This would promote collaboration and create synergies between the groups. WRF-Chem was chosen because it makes good use of the existing capabilities of MM5 (all MM5 users will switch, sooner or later, to WRF), contains state-of-the-art science modules and will be under current development by a number of groups around the world. It is expected that in the medium to long term many of the modules developed for CMAQ (the EPA model) will be implemented within WRF leading to a convergence of models. In addition, there are strong arguments for using an on-line (coupled meteorology/chemistry) model for cities in mountain basins with complex flows.

Fig. 2. During the visit to Santiago, Dr. Mario Molina met with Chilean President Ricardo Lagos, who asked for his advice on various environmental issues.

Part of the proposal would be to organize a WRF-Chem workshop for Latin America, to be hosted by the University of São Paulo, to bring all the groups together and build on experience with previous models. It is hoped that Mexico, Brazil and Chile can form a core-modeling group that can serve as an entry point for other Latin American countries wishing to start modeling activities of their own.

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