Harvard Center for Risk Analysis

Using Decision Science to Empower Informed Choices about Health, Safety, and Environmental Risks

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Risk in Perspective

THE MEXICO PROJECT

In early 2000 with support from the Metropolitan Environmental Commission and funding from the Environmental Trust Fund of the Mexico City Metropolitan Area, a collaborative project entitled "Project for the Design of an Integrated Strategy for Air Quality Management in the Mexico City Valley 2001-2010" was initiated under the leadership of Nobel Laureate Mario Molina. The project involved scientists and engineers from a variety of Mexican institutions working in collaboration with counterparts from MIT and Harvard to devise a ten-year plan for improving air quality in Mexico City.

We at the Harvard Center for Risk Analysis were responsible for assessing the human health risks posed by current and anticipated levels of air pollution in Mexico City, and for estimating the economic value of the health burden imposed by air pollution.

The research team included scientists from Harvard, Instituto de Salud, Ambiente y Trabajo, and Universidad Autonoma Metropolitana-Xochimilco:

- **Harvard School of Public Health** — John Evans, Jon Levy, Jim Hammitt, Jack Spengler, Helen Suh, Paulina Serrano-Trespalacios, Leonora Rojas-Bracho
- **Instituto de Salud, Ambiente y Trabajo (ISAT)** — Carlos Santos-Burgoa, Horacio Riojas-Rodriguez, Mario Caballero-Ramirez
- **Universidad Autonoma Metropolitana-Xochimilco** — Margarita Castillejos
- In addition, Dr. Mauricio Hernandez, of the National Institute of Public Health (INSP-CISP), provided us with supporting GIS analysis of demographic and pollution data.

Other research groups were responsible for analysis of air pollution emissions, atmospheric fate and transport of pollutants, transportation planning, land use planning, utility and industrial sources and controls, and development of an integrated assessment methodology.

FINDINGS

EXPOSURE

We focused on two categories of ambient air pollution. The first, *criteria air pollutants*, includes particles, ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide and lead. Our analysis looks at all of these, except for lead, since the policy decision has already been made to control atmospheric lead by eliminating leaded gasoline. The second category is toxic air pollutants. We focused on six of these compounds - benzene, 1,3-butadiene, formaldehyde, diesel smoke and related PAHs, and chromium - which have been found to be the dominant sources of cancer risk in previous studies of air pollution.

Table I summarizes our estimates of the population exposures to the criteria pollutants of interest. These values, derived from air pollution data for 1998 from the Mexico City air monitoring network (Red Automatica de Monitorio Ambiental (RAMA)) and population density data from the census, are accurate to within 10 - 20%. While concentrations fluctuate over time, we believe that these figures reflect current conditions.

Table I. Criteria Pollutant Exposures for 1998

Pollutant	Exposure (ug/m^3) (Population Average)
PM_{10}	90
Sulfur Dioxide	30
Nitrogen Dioxide	40
Ozone	50
Carbon Monoxide	2000

<u>The levels of exposure to criteria pollutants in Mexico City are high, but comparable to those in several of the largest cities in the world.</u>

Table II summarizes our estimates of population exposure to the six air toxics we considered. These pollutants are not routinely monitored in Mexico City. Consequently, our exposure estimates have been derived from a single study (P. Serrano, HSPH Thesis) or by extrapolating results from studies conducted outside of Mexico City. As a result these exposure estimates should be regarded as relatively uncertain (perhaps known to within a factor of 2).

Table II. Air Toxics Exposures

Pollutant	Exposure (ug/m^3) (Population Average)
Diesel Smoke (PAH)	5 (0.05)
Benzene	8
1,3 Butadiene	1
Formaldehyde	3
Chromium	0.01

<u>The levels of exposure to air toxics in Mexico City are relatively similar to levels found in urban areas in the US.</u>

IDENTIFYING POLLUTANTS OF MOST CONCERN

Much of our knowledge of the health effects from air pollution comes from studies of the daily fluctuations in deaths, hospital admissions, and respiratory symptoms in response to daily fluctuations in the levels of air pollution in large cities (e.g., Philadelphia, London, Mexico City) throughout the world. These studies have looked for the effects of many of the criteria air pollutants.

The clearest and most consistent findings are for increases in daily mortality due to particles, measured as PM10 (particles with aerodynamic diameters less than 10 um, small enough to be inhaled). Studies on particle pollution suggest that for each 10 ug/m3 increase in levels of PM10, an increase in daily mortality on the order of 1% would be expected. Most of these deaths are cardiovascular deaths, perhaps of relatively elderly people already suffering from coronary heart disease. There is, however, recent (but unconfirmed) evidence that some premature deaths may be among infants.

In a population the size of Mexico City, about 20 million, with a baseline death rate of approximately 5/1000, these acute mortality studies imply that a 10 percent reduction in PM10 could reduce premature mortality in Mexico City by on the order of 1000 deaths each year, one percent of the overall baseline death rate. In addition, there is the possibility that chronic mortality may also be affected — with the effect possibly several times this large.

While it seems clear that PM 10 leads to increased mortality, it is less clear whether fine (PM 2.5) or coarse (PM10 - PM 2.5) particles are responsible for the effect. Most studies which have examined this question suggest that fine particles are responsible for the effect, but the only study in Mexico City to consider the issue found that coarse particles seemed more toxic than fine particles.

We also considered two other air pollution issues; ozone, and cancer caused by various forms of ambient air pollution.

Ozone

Much attention has been paid to ozone levels in Mexico City, in that local meteorological and geographic conditions exacerbate this particular pollutant. The effect of ozone on mortality is not as clear as the effect of particles. In studies that do not account for the effects of other pollutants, there appears to be an ozone effect. However, in more comprehensive analyses, which simultaneously consider ozone and other pollutants (especially particles), the effect of ozone on mortality becomes weak (and often statistically insignificant).

Control of ozone and its precursors is still important. Ozone has strong effects on respiratory function, and on hospital admissions for asthma and other respiratory conditions. Control of ozone precursors limits ozone formation and also may reduce the formation of secondary particles and the concentrations of nitrogen oxides or volatile organic compounds.

Cancer

Most analyses of the cancer risks from "air toxics" suggest that exposure to diesel exhaust (and/or polycyclic organic matter) poses the greatest risk. Studies of railroad workers exposed to diesel smoke suggest that, for each 1 ug/m3 increase in diesel smoke, the lifetime risk of developing lung cancer may increase by as much as 2 cases per 10,000 people. If we assume a proportional relationship between exposure and risk, then a 10 percent reduction in diesel smoke levels in Mexico City might reduce lung cancer risks by up to 30 cases per year.

Similar percentage reductions in the levels of other air toxics, such as benzene, 1,3-butadiene, and formaldehyde, would be expected to reduce cancer risks by only 1 or 2 cases per year per pollutant, with the total risk reduction being on the order of 10 cases.

COST-EFFECTIVENESS

There are no direct estimates of the value of reducing health risks in Mexico. These values have been estimated by extrapolating from work done in other countries, such as the United States. These extrapolations are uncertain because of limited knowledge about the relationship between the value of health and the economic and cultural factors that differ between countries. A second important uncertainty concerns the value of preventing premature fatalities. If people who die because of air pollution would have soon died of other causes (e.g., elderly people with cardiovascular disease), the value of prolonging their lives may be much smaller than standard estimates.

A rough indication of the magnitude of the health benefits of a 10% reduction in air pollution in Mexico City may be obtained by considering only the acute mortality benefits. The magnitude of the benefit depends on the adjustments made for differences in income and other factors between the two countries, but a value between $100,000 and $3 million per death averted is plausible. These estimates suggest that

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it would be worth spending as much as $100 million to $3 billion per year to achieve a 10% reduction in PM10.

SUMMARY

It appears that the major focus of air pollution control programs in Mexico City should be on reducing the peak and longer-term levels of exposure to criteria pollutants, in particular PM10 and ozone, and perhaps diesel smoke. Of course, any cost-effective opportunities for reducing population exposures to other air toxics and criteria pollutants should also be pursued.

We urge policy makers to give greater emphasis to programs which reduce the chronic levels of exposure of the entire population rather than focusing exclusively on the reduction of episodic peak levels of exposure (contingencies).

Further, we recommend development of control strategies based on formal cost-benefit analysis comparing various alternatives, with particular emphasis on controls which have the potential to reduce population exposures to PM10 and ozone.

Finally, while we believe that the estimates provided in our report are useful in establishing broad guidelines for the control of air pollution in Mexico City over the next ten years, we readily acknowledge that there are uncertainties inherent in our analysis. Scientific research that helped resolve these issues could lead to more efficient strategies for pollution control. We recommend that research focus on:

1. Whether long-term exposure to particulate matter and other criteria pollutants has (chronic) mortality effects above and beyond the effects observed in the time-series studies.
2. Which pollutants are responsible for the observed mortality, with an emphasis on determining whether fine or coarse mode particles are more toxic and whether there are significant differences in the toxicity of particles (within a size class) depending on their source or chemical composition. The possible health effects of ozone and carbon monoxide also require further investigation.
3. Whether air pollution exposure causes increases in infant mortality and, if so, whether this is a large component of the overall mortality observed in time-series studies.
4. Determining willingness to pay for improvements in mortality and morbidity based on studies conducted in Mexico City.

PROJECT STATUS

The first phase of the project was completed late this Fall. The final report was presented to Mexican government officials, representatives from industries and academia and the media on November 7 and is available on the web at (http://eaps.mit.edu/megacities/).

We plan to conduct a second phase of the health risk assessment which will include probabilistic characterization of the dose-response functions for the key health effects, field studies of economic valuations of key health effects, and a formal value of information analysis designed to assist in the prioritization of research programs.

Editor's Note: In our September issue, we misspelled beryllium, the disease berylliosis, and incorrectly stated that beryllium is radioactive.