The Health Benefits of Air Pollution Control

Like many other large cities, Mexico City is extremely polluted. The government of Mexico City is searching for approaches to improve the air quality of the city and is faced with several difficult decisions. It must decide how much improvement of air quality is feasible, which pollutants and sources to target, and which specific strategies to pursue. Most of these strategies will require additional expenditures or will impose restrictions on the behavior of individuals or firms, and each strategy will result in reductions of different combinations of pollutants from different emission sources. Since the primary rationale for improved air quality is improved public health, it is logical to attempt to quantify the health benefits of various air pollution control policies. This can help policymakers allocate limited resources to the most significant environmental problems. Within this chapter, we focus on developing a framework to help quantify the health benefits of air pollution control in Mexico City and to determine areas requiring further research.

Quantification of health benefits from emission reductions requires synthesizing evidence from a number of disciplines. Once the emission reductions have been determined, atmospheric modeling can be used to estimate the incremental effect on ambient concentrations. This change in ambient concentrations will have some impact on the magnitude and distribution of pollution-related health effects. Finally, we can place economic values on estimated health benefits to combine a number of outcomes into a single measure that can be compared with costs of control. We focus exclusively on these last two steps within this chapter.

To estimate the overall risk of current exposure, it suffices to evaluate how the total mixture of pollutants in Mexico City influences public health. However, this is not the most relevant question, since it does not inform policymakers about the differences among pollution control policies or about the pollutants that should be considered higher priority. To more effectively inform policymakers, it is important to determine the pollutant-specific benefits that would accrue when air pollution concentrations are incrementally reduced from current levels.

Given this framing, we focus on four major questions:

- How much reduction in the rates of morbidity and mortality in Mexico City can be expected if the ambient levels of various pollutants are reduced by specific amounts?
- What is the monetary value of these health improvements to the population of Mexico City?
- Which pollutants and health outcomes contribute most substantially to the health benefits of air pollution control, and
- What are the most significant sources of uncertainty in estimating the health benefits of further air pollution control in Mexico City?

Answering these questions requires careful scrutiny of evidence collected both within Mexico City and in other locations. For many pollutants and health effects, multiple studies have been conducted in the US or Europe while limited information is available from Mexico City. We must therefore address the question of the appropriateness of applying studies of populations that may differ substantially from the at-risk population in Mexico City. Our approach is to combine the evidence from the international literature with the growing body of evidence from research performed in Mexico City, evaluating differences and determining estimates with appropriate characterization of uncertainty.

We limit our focus largely to the pollutants and health effects that contributed greatly to health benefits in past studies, such as the benefit-cost analysis of the Clean Air Act in the US (US EPA, 1999). While the concentrations of pollutants and the risks of various health effects may differ between the US and Mexico City, our approach is likely to address most of the major effects. We also consider a limited number of pollutants that were not evaluated within past studies, to illustrate the magnitude of the benefit in relation to the most significant contributors. Thus, we determine concentration-response functions for:
- Particulate matter: Mortality and chronic bronchitis
- Ozone: Mortality and restricted activity days
- Air Toxics: Cancer

For each pollutant, we estimate the population average ambient concentration within Mexico City to estimate the magnitude of the total burden and determine the level from which benefits will be measured. For particulate matter and ozone, we discuss evidence from key epidemiological studies. Epidemiologic studies examine the differences in rates of disease or death among human populations facing different levels of exposure to air pollutants. For air toxics, we rely on toxicological studies and epidemiology. Toxicologic studies are controlled experiments in which laboratory animals are exposed to known levels of suspected carcinogens. For the health outcomes quantified, we determine the appropriate economic value to place on the outcome, discussing issues related to the application of studies conducted in countries with different standards of living. Finally, we make some simple calculations of the magnitude of health benefits that would flow from a hypothetical 10% improvement in air quality. These indicate which pollutants and health outcomes generate the most significant health benefits and are useful in making comparisons with other studies of air pollution benefits in Mexico City.

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Discussion and Conclusions

This chapter has considered the evidence relevant to estimating the health benefits of improvements in air quality in Mexico City. Information from exposure assessment, epidemiology, toxicology, and economics has been reviewed and synthesized using the framework of risk analysis.

The two major findings are that the health benefits of air pollution control are potentially quite large and, at the same time, are highly uncertain. It is plausible that a 10% reduction in levels of air pollution in Mexico City could yield health benefits worth on the order of $3 billion per year. But it is also possible that the benefits could be an order of magnitude, or more, smaller.

The estimates of health benefits from improvement of air quality in Mexico City are dominated by effects attributed to exposure to inhalable particulate matter (PM$_{10}$). The benefits of reducing ambient levels of ozone appear to be only about 1/10th as large as the benefits attainable through similar reductions in PM$_{10}$. Reductions of ambient levels of air toxics by 10% would be expected to reduce the number of new cases of cancer among the population of Mexico City by, at most, 100 cases each year.

The primary reason that PM$_{10}$ benefits are thought to be larger than ozone benefits is that PM$_{10}$ has been implicated as a cause of mortality in cohort mortality studies and ozone has not. The risks attributed to air pollution in the cohort mortality studies are larger than those in the time-series mortality studies and the impact on life expectancy of each death in the cohort studies is arguably greater than of the deaths seen in the time-series studies.

One reason that the benefit estimates for Mexico City are highly uncertain is that no cohort mortality study has been conducted in Mexico City. As a result, estimates of this key component of health impacts have been derived from two cohort studies conducted in the US on the assumption that similar results would be expected in Mexico City. There are some concerns about the plausibility of this assumption in view of differences in the age structures of the populations and disease-specific causes of mortality in Mexico and the US. Furthermore, the cohort studies are potentially more susceptible to confounding than are the time-series studies. Finally, the assumption that the entire impact is due to fine particles is a bit speculative.
If for the sake of argument we ignore the cohort studies, the residual health benefits of a 10% improvement in air quality in Mexico City would be projected to be on the order of $1 billion per year. This estimate would also be dominated by PM$_{10}$ effects, but would be somewhat less uncertain because it would depend largely upon evidence about the mortality impacts of PM$_{10}$ from time-series studies. Not only have there been several recent time-series mortality studies in Mexico City, but the results of these studies have been corroborated by approximately 30 similar studies conducted in large cities in the US and other parts of the world. An effect of ozone on mortality has also been found in time-series studies both in Mexico and elsewhere, but the studies suggest a smaller impact of ozone than particles and the results are less consistent.

The major source of uncertainty in the interpretation of the time-series mortality studies is not whether the observed relationship reflects a causal linkage between particulate air pollution and mortality, but rather whether the fine fraction (PM$_{2.5}$), the coarse fraction (PM$_{2.5-10}$), or both are responsible for the effect. A second key question is whether the deaths are primarily among elderly individuals with pre-existing cardiopulmonary disease or whether the deaths involve infants and healthy young people.

Even if epidemiological estimates of air pollution health risks could be substantially improved, there would be considerable uncertainty in estimates of the health benefits of improvements in Mexico City’s air quality arising from issues related to valuation of health effects. No empirical study of willingness to pay for air pollution improvements has been conducted in Mexico and as a result values developed from studies in the US form the basis for the valuations used in our analysis. This entails using the “benefit transfer” approach which assumes that Mexican valuations can be approximated by scaling US valuations by a power of the ratio of per capita gross domestic product in the two countries. The power, or elasticity, is unknown and arguably can take values between 0.5 and 2. We have used an elasticity of 1 in the calculations given above, but our estimates of health benefits could plausibly be almost an order of magnitude smaller or as much as 3 times larger depending on the assumption made about income elasticity.

Levels of air pollution in Mexico City are quite high. The population-weighted annual mean ambient PM$_{10}$ concentration (based on the gravimetric measurements) is approximately 80 g/m$^3$ and the corresponding annual mean ambient ozone concentration is about 50 g/m$^3$ (or 35 ppb). Concentrations of carcinogenic air toxics are also high.
Decision makers recognize the pressing need to improve Mexico City’s air quality, but must do so in a manner that maximizes public health benefits by targeting control expenditures on strategies that appear to present the most cost-effective approaches for risk reduction. Their job is complicated by the presence of substantial uncertainties in current forecasts of the health benefits afforded by various control strategies and policies.

There may be the temptation to delay the implementation of control strategies until further research resolves many, if not most, of the key sources of uncertainty. It is clear that research which could determine -- (i) whether exposure to PM$_{10}$ contributes to chronic mortality in Mexico City; (ii) what the relative importance of the fine and coarse fractions is in Mexico City; (iii) whether infants deaths are involved in the risks seen in the time-series studies; (iv) how to value improvements in morbidity and mortality in Mexico City; (v) the background incidence of chronic bronchitis and mRADs in Mexico City; (vi) the role of PM$_{10}$ as a cause of chronic bronchitis in Mexico City; (vii) the role of ozone as a contributor to mRAD incidence in both adults and children in Mexico City; and (viii) the population weighted exposures to PM10, ozone and air toxics -- would be of great value in better targeting air pollution control strategies. Research efforts in several of these areas could pay large social dividends.

But any propensity to adopt the view that the implementation of controls should be deferred until these uncertainties are completely resolved must be tempered by the realization that such research will take years, if not decades, to conduct. Large social costs in the form of deaths and illness that could have been prevented may occur while decision makers wait for improved information. Only through careful evaluation of the likely costs and benefits of both control strategies and research strategies can the tradeoffs between acting now on the basis of weak information and acting later on the basis of improved information be understood. Decision analysis (and value of information analysis) may be useful tools in conducting such an evaluation.