HEALTH EFFECTS INSTITUTE

STATEMENT

Synopsis of Research Report 157

Air Pollution and Mortality in Two Indian Cities

BACKGROUND

Epidemiologic time-series studies have provided useful information about the association between short-term exposure to air pollution and health outcomes in single geographic locations. However, it is often challenging to compare results across locations because of differences among the methods used to collect and analyze the data. Recent multicity time-series studies have been conducted in cities in Canada, Europe, and the United States using similar analytic approaches, but considerable uncertainties remain regarding the extrapolation of this evidence to developing countries, including large populations in Asia that are exposed to relatively high concentrations of air pollution.

Given the extensive gaps in knowledge on the health effects of air pollution in Asia, HEI funded several coordinated time-series studies of air pollution and health in Asia under the Public Health and Air Pollution in Asia (PAPA) Program. The purpose of the program was to collect information that would be relevant to local populations, with the added goal of supporting capacity building in the region. After a first wave of four studies in China and Thailand was underway (research that was recently published as HEI Research Report 154), HEI's International Scientific Oversight Committee selected three additional investigator teams to conduct time-series studies of air pollution and mortality in Indian cities: Chennai, Delhi, and Ludhiana. The investigators coordinated their approaches by adapting the common protocol of the first-wave PAPA studies; differences in data availability and completeness in the Indian cities prompted the investigators to develop city-specific approaches. Substantial deficiencies in the available air pollution data in Ludhiana prevented that study from being completed, although recently those investigators estimated mortality risks using visibility as a surrogate for air pollution in that city.

APPROACH

The investigator teams in Chennai and Delhi conducted time-series studies on the relationship between daily all-cause mortality and daily concentrations of particulate matter less than or equal to 10 µm in aerodynamic diameter (PM_{10}) for the period between January 1, 2002, and December 31, 2004. Mortality data were provided by local registries of births and deaths in each of the two cities and were coded by trained medical professionals to exclude deaths from non-natural causes. Pollutant data for nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and PM_{10} were provided by the local government agencies in each city and met local quality control and assurance standards. Investigators initially followed an independent, standardized procedure to ensure both the completeness and representativeness of the average daily exposure of the population. Subsequently, the investigators developed alternative exposure models for their specific location using a novel zonal approach in Chennai and centering techniques in Delhi. Gaseous pollutants were included only in the Delhi analyses. Data from 5 and 10 air quality monitoring stations were included in Chennai and Delhi, respectively.

The teams in Chennai and Delhi used a generalized additive modeling approach to obtain the excess risk of daily mortality associated with daily increases in pollutant concentrations. The investigators fitted quasi-Poisson regression models to the data and carried out sensitivity analyses, such as the inclusion of various degrees of freedom for model parameters, different temperature lags, and alternative exposure models.

This Statement, prepared by the Health Effects Institute, summarizes two research projects funded by HEI. The Chennai study was conducted by Dr. Kalpana Balakrishnan at Sri Ramachandra University, Porur, Chennai, India, and colleagues. The Delhi Study was conducted by Dr. Uma Rajarathnam at The Energy and Resources Institute, New Delhi, India, and colleagues. The complete report, *Public Health and Air Pollution in Asia (PAPA): Coordinated Studies of Short-Term Exposure to Air Pollution and Daily Mortality in Two Indian Cities* (© 2011 Health Effects Institute), can be obtained from HEI or our Web site (see last page). **BALA/RAJA 157**

RESULTS

Using the core zonal model, the Chennai investigators reported an increase in the relative risk (RR) for nonaccidental, all-cause mortality of 1.004 (95% confidence interval [CI] = 1.002 to 1.007) per 10-µg/m^3 increase in PM_{10} concentration on the previous day. Alternative, nonzonal exposure series using single- or multiple-monitor models did not appreciably change the RR for mortality. Additional sensitivity analyses of the core zonal model results in Chennai showed that there was little variation in RR between males and females, but that the RRs for the age groups 5–44 years and 45–64 years were slightly higher than for the younger or older age groups. The RR for all-cause mortality associated with PM_{10} was slightly lower at lag 0 (same day) than at lag 1 (previous day) and was elevated at 2- or 3-day lags. No change in RR was found with a 7-day distributed lag for temperature and relative humidity compared with the core model. Varying the degrees of freedom for time, temperature, and relative humidity, stratifying by season, or excluding outliers in the exposure series did not appreciably change the RRs.

Using the core model with centered air quality data, the Delhi investigators reported an increase in the RR for nonaccidental, all-cause mortality of 1.0015 (95% CI = 1.0007 to 1.0023) per 10-µg/m^3 increase in PM_{10} concentration on the same day. The RR was slightly lower at 1 to 3 day lags and slightly higher at a cumulative lag of 0–1 days and when PM_{10} concentrations exceeding 400 µg/m^3 were excluded from the analysis. The investigators also reported an increase in RR for daily mortality of 1.0084 (95% CI = 1.0029 to 1.014) associated with a 10-µg/m^3 increase in NO_2 concentration; there was no evidence of an association between SO_2 concentration and mortality. Using two- and three-pollutant models, the RRs associated with PM_{10} and NO_2 concentrations were slightly attenuated.

Additional sensitivity analyses of the core model results in Delhi showed that the RR associated with PM_{10} was lower in males than females; the RR for the age group 5–44 years was higher than for the other age groups. There was considerable variability in RRs associated with PM_{10} among individual monitoring stations. However, the RRs for analyses that included the data from all 10 stations were similar to those for analyses that excluded the data from the one station with continuous data (which reported consistently higher pollutant concentrations). Using different lags for temperature did not appreciably change the RR, except for a decrease at longer cumulative lags (0–7 or 8–14 days).

TECHNICAL EVALUATION

The two time-series studies of air pollution and daily mortality in Chennai, India, and Delhi, India, have provided useful additional information on air pollution and health outcomes in developing countries. Results from Chennai (0.4% increase in risk per 10-µg/m^3 increase in PM_{10} concentration) and Delhi (0.15% increase in risk per 10-µg/m^3 increase in PM_{10} concentration) suggest a generally similar risk of mortality associated with PM_{10} exposure compared with the first four PAPA studies, as well as with multicity studies conducted in South Korea, Japan, Europe, and North America. The association of mortality with exposure to NO_2 observed in Delhi was also similar to values reported from other studies in Asia. The associations were fairly consistent in spite of the fact that concentrations of criteria air pollutants were substantially higher than those observed in the United States and Europe.

In its independent assessment of the Chennai study, the HEI Health Review Committee thought that the investigators had applied an innovative approach for exposure estimation in Chennai, assigning nearest ambient monitor values to each grid cell in the 10 zones to address heterogeneity in PM_{10} concentrations among monitors. Because the results from the core zonal model and alternative exposure series were fairly consistent, the Committee thought it would be unlikely that a different approach to exposure estimation would have yielded very different risk estimates, adding to confidence in the risk estimates. However, the Committee identified several caveats regarding the zonal approach. For example, the zonal model appears to ignore missing data, which may lead to spurious jumps in exposure estimates when data from one monitor are missing for a period; there may be important spatio-temporal variation even within zones; and monitors are not weighted in proportion to the population, because the population is unlikely to be uniformly distributed across grids.

In its evaluation of the Chennai mortality data analysis model, the Committee noted that the investigators used a relatively new, ambitious approach to select degrees of freedom for smoothing of time and meteorology covariates. This approach minimizes PM_{10} coefficient variability and bias using a resampling method. Whether this goal is achievable is uncertain and is the topic of ongoing HEI-funded work by James M. Robins and colleagues. The Committee commented that the degrees of freedom selected for temperature and relative humidity seemed high, which may indicate that those variables are strong predictors of pollution concentrations. The Committee noted that it is not advisable to use different

degrees of smoothing for individual monitors, in particular because of the high amount of missing data at a given site. However, because the final degrees of freedom were relatively similar across the different approaches, it is unlikely that the amount of temporal smoothing would substantially affect the results.

In its assessment of the Delhi study, the Committee thought that the use of a centering approach was appropriate for estimating exposure in the context of missing data, although other approaches could have been tried and compared. The Committee noted that there may have been residual confounding by weather in the main analyses. Recent insights reveal that more complex distributed lag models may be required to capture residual confounding by temperature effects in many cities. The Committee thought the Delhi team had conducted a limited but informative set of sensitivity analyses to assess the effects on mortality risk estimates. As was observed for Chennai, the results may be sensitive to temperature lag. Risk estimates based on single-monitor pollution data were sensitive to which single monitor was included in the sensitivity analyses, providing further support for averaging pollutant data across multiple monitors to estimate population exposure in the core model.

The Committee noted some unusual features of the statistical models used by the Delhi team. The degrees of freedom that describe the smoothness of the mortality function against temperature, relative humidity, and PM_{10} in sensitivity analyses (for the PM_{10}–mortality curve) were specified per year. However, the complexity of these curves (e.g., the temperature–mortality curves) was unlikely to increase over the duration of the study. Normal practice is to select degrees of freedom as a function of the number of years only for smooth functions of time.

DISCUSSION AND CONCLUSIONS

The broad general consistency of the results of the two Indian studies described here and in other Asian time-series studies of mortality with those in Europe and North America is reassuring. It suggests that the continued use of data from Western cohort studies to estimate the Asian burden of disease attributable to short-term exposure to air pollution is defensible. However, developing Asia currently differs from the United States and Europe with regard to energy use, air quality, and population health, which are also dynamically changing. The Indian studies highlight that regional differences in demographics (in particular, age structure and general health status of the population) may affect health outcomes of interest. Thus, estimates of the risk of mortality associated with air pollution that are based on even the most carefully executed U.S. studies must be used with appropriate caveats.

Given the data limitations faced by the investigator teams, they are to be commended for making the most of limited resources. They have blazed a trail for improved quality epidemiologic studies of air pollution in India. However, considerable uncertainties remain due to data limitations, potential residual confounding, and potential methodologic sensitivity, all of which will need to be revisited in any future epidemiologic studies. As the investigators pointed out, data limitations prevented a number of more in-depth analyses standard in time-series studies, for example, of specific causes of death or — in Chennai — different pollutant models. Such detailed analyses will only be possible once more detailed, consistent air pollution monitoring and health record collection are implemented.

The methodology applied in the PAPA time-series studies can provide a stronger foundation for further research in developing Asia. The lack of data on air quality and mortality, especially cause-specific mortality, remains a major impediment to conducting such studies in many parts of developing Asia. As a result, major population centers in South and Southeast Asia (India, Pakistan, Vietnam, Philippines, Indonesia, and Malaysia) remain understudied — although the two PAPA studies in India are starting to fill in some of those gaps. Expanded, coordinated multicity studies conducted across Asia could provide more definitive answers if they are designed and analyzed consistently with the additional methodologic improvements noted above and given rigorous quality control of air quality and health data.

Research Report 157

Public Health and Air Pollution in Asia (PAPA): Coordinated Studies of Short-Term Exposure to Air Pollution and Daily Mortality in Two Indian Cities

HEI Public Health and Air Pollution in Asia Program

HEALTH EFFECTS INSTITUTE

101 Federal Street, Suite 500
Boston, MA 02110, USA
+1-617-488-2300 phone
+1-617-488-2335 fax

pubs@healtheffects.org
www.healtheffects.org

Recycled Paper