HEALTH EFFECTS INSTITUTE

STATEMENT

Synopsis of Research Report 95

Association of Particulate Matter Components with Daily Mortality and Morbidity in Urban Populations

INTRODUCTION

Although evidence from epidemiologic studies supports an association between particulate matter (PM) and adverse health outcomes, many questions remain about how PM may cause such effects and who is affected. A major question is whether PM itself causes the effects, and if so, whether one of its components may be a better predictor of morbidity (illness) and mortality (death) than PM as a whole. Regulatory standards have focused on the size of PM particles and from 1971 to 1997 have moved to control successively smaller particles, from PM up to 40 µm in diameter (referred to as total suspended particles [TSP]), to less than 10 µm (PM_{10}), and less than 2.5 µm ($PM_{2.5}$).

By definition, each of the larger PM indices contains elements of the smaller indices, so it is difficult to determine the relative effects of different PM metrics. Also, PM is a mixture of chemically and physically diverse dusts and droplets, and some of these components may be important to its health effects, such as hydrogen ions (H^+), which reflect particle acidity, and sulfate (SO_4^{2-}). Another complication is that gaseous pollutants are associated with similar health outcomes. Few epidemiologic studies have attempted to assess the relative effects of PM by size-fractionated metrics, or by its individual components, on illness and death.

APPROACH

Dr Morton Lippmann and colleagues at the New York University School of Medicine attempted to identify and characterize components of PM and other air pollution mixtures that were associated with excess daily deaths and elderly hospital admissions in and around the area of Detroit, Michigan. The study used publicly available data for 1985–1990 and 1992–1994, including measures of several different PM components as well as other air pollutants. Statistical models were used to weigh the strength of one pollutant or two pollutants concurrently. Models using three or more pollutants were not attempted owing to the difficulty of separating the effects of pollutants that rise and fall closely together, or are correlated. To better assess relationships between pollutants and health outcomes, the authors evaluated the extent to which (1) air pollutants tended to vary together in space and time, (2) results depended on the specific location where pollutants were sampled, and (3) results were influenced by multiple hospital admissions of some individuals in the study population during the study period. The main statistical method used was Poisson regression, with a generalized additive model to adjust for the effects of time trends, meteorologic differences, and other variables.

RESULTS AND INTERPRETATION

To evaluate whether human health was associated with outdoor levels of PM, the authors compared day-to-day fluctuations in air pollution with day-to-day fluctuations in deaths and hospital admissions in the Detroit area. If air pollution and adverse health outcomes are closely linked in time, then a daily average value of air pollution will be associated with a daily measure of health. This relationship is estimated in the current study by the relative risk (RR), which is the relative increase in experiencing an adverse outcome (death or illness) given the presence of some risk factor (air pollutant), calculated for an increment in each air pollution variable equal to the difference between the 5th and 95th percentiles of their distributions.

Continued

This Statement, prepared by the Health Effects Institute, summarizes a research project conducted by Dr Morton Lippmann and colleagues of the New York University School of Medicine, Tuxedo NY. The complete Report can be requested from HEI (see reverse side).

For the period 1985–1990, the authors studied the risk of death due to TSP, PM_{10}, particles less than 40 µm and more than 10 µm in diameter (TSP-PM_{10}), sulfate from TSP (TSP–SO_4^{2-}), and several gaseous pollutants (sulfur dioxide, nitrogen dioxide, ozone, and carbon monoxide). The investigators reported that deaths from respiratory diseases were associated with PM_{10} and TSP. Ozone and nitrogen dioxide were also associated with all deaths together and with deaths due to circulatory causes. When the estimated effects of PM_{10} and one of the gaseous pollutants were determined concurrently, in a two-pollutant model, the association between PM_{10} and health outcomes remained the same, or became even stronger. This suggests that there was some effect of PM regardless of the presence of other pollutants. However, people are exposed to PM in a complex mixture of air pollutants, so assessing the results of a two-pollutant model (one PM metric and one gas) only begins to answer the question of whether PM is the cause of the observed effect.

For the period 1992–1994, the authors studied the risk of death and illness due to PM_{10}, $PM_{2.5}$, particles less than 10 µm and more than 2.5 µm in diameter ($PM_{10-2.5}$), H+, and sulfate without sampling error (artifact-free sulfate, or SO_4^{2-}), and gaseous pollutants (sulfur dioxide, nitrogen dioxide, ozone, and carbon monoxide). Overall, the relative risks were about the same for all three of the PM mass indices evaluated (PM_{10}, $PM_{2.5}$, and $PM_{10-2.5}$), and the PM mass indices were more significantly associated with health outcomes than H^+ or SO_4^{2-}. As the investigators pointed out, this result is inconsistent with their original hypothesis regarding the role of acidity in the air pollutant–mortality relationship.

The authors also highlighted their unanticipated findings for $PM_{10-2.5}$. Relative risks for $PM_{10-2.5}$ were similar to those for $PM_{2.5}$ and sometimes even higher—for example, with ischemic heart disease and stroke. However, the associations of elderly hospital admissions with $PM_{2.5}$ and $PM_{10-2.5}$ were significant for only a few one- or two-pollutant models; when $PM_{2.5}$ was evaluated with the gaseous pollutants in two-pollutant models, its estimated effect was often reduced. This was especially true when ozone was included in the model.

The authors also investigated the relationship between air pollutants and people geographically. Looking at a single pollutant across many sites, ozone, PM_{10}, and TSP tended to be at the same concentration level regardless of location within the general Detroit area. In an analysis of the TSP data for the time period 1981–1987, the investigators found no indication that the location where the air pollutant had been sampled influenced results.

This study compared the strength of association between different PM components and death and illness, but some features inherent to epidemiologic time-series studies complicate the comparison of estimated effects among air pollutants. Although the authors reported finding rates of death and illness associated with various pollutants, the data do not clearly support a greater effect of one pollutant over another, nor do they establish which pollutants are most likely to cause adverse health effects and which simply occur in a complex mixture with the causative pollutants. In general, determination of relative effect requires simultaneous consideration of multiple, relatively uncorrelated variables in a statistical model. Air pollutants exist in a mixture, have many common sources, and are therefore highly correlated, which makes it difficult to separate the effects of individual air pollutants.

The authors approached this question in analyses using size-fractionated PM metrics. Because $PM_{10-2.5}$ and $PM_{2.5}$ were not highly correlated in correlation coefficient and factor analyses, it is possible that the observed associations between coarse particles and health outcomes were not confounded by smaller particles. The finding of elevated and significant effects for $PM_{10-2.5}$ suggests that there may still be a rationale to consider the health effects of the coarse fraction as well as the fine fraction of PM.

Relatively few epidemiologic studies have evaluated the effect of $PM_{2.5}$ on human health. The current study could not definitively distinguish relative strengths of effect across the PM metrics, in terms of either particle size (TSP, PM_{10}, $PM_{2.5}$, and $PM_{10-2.5}$) or particle components (eg, H^+ or SO_4^{2-}), but the study does provide further general evidence that indicators of PM are associated with illness and death.

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