Association of Air Pollution With School Absenteeism Due to Illness

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Objective: To assess the association of air pollution and school absenteeism among elementary students.

Design: Time-series analysis of air pollution and school absenteeism data with controlling for long-term trends, seasonality, day of the week, and holiday as well as meteorologic variables.

Setting: School absenteeism data for the period from March 2, 1996, to December 22, 1999, were collected from student attendance reports of one elementary school in Seoul, Korea.

Main Outcome Measures: The number of daily illness-related absences was analyzed against the daily levels of air pollution by generalized additive Poisson regression. The relative risks of absenteeism for air pollution exposure of interquartile ranges (the range from the lowest 25% of the value to the lowest 75% of the value) on absenteeism were calculated on the same day.

Results: Exposure to air pollutants such as particulate matter of 10 µm or less in aerodynamic diameter (PM$_{10}$), sulfur dioxide, and ozone, was associated with illness-related absenteeism. The estimated relative risks were 1.06 (95% confidence interval, 1.04-1.09) per 42.1-µg/m$^3$ increase in PM$_{10}$, 1.09 (95% confidence interval, 1.07-1.12) per 5.68–part per billion increase in sulfur dioxide, and 1.08 (95% confidence interval, 1.06-1.11) per 15.94–part per billion increase in ozone. There was no significant relationship between nitrogen dioxide level and illness-related absenteeism.

Conclusion: Air pollution is associated with illness-related absences among elementary students.

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Exposure to ambient air pollution is one of the main causes of respiratory disease among children. Air pollutants, including ozone, nitrogen dioxide, and particulate matter, aggravate respiratory symptoms and illnesses and increase visits to clinics or emergency departments. For children, short-term variations in level of air pollutants are associated with hospital admission due to respiratory symptoms. Nitrogen dioxide is associated with respiratory diseases in children younger than 2 years. Charpin et al reported that moderate daily changes in sulfur dioxide levels induce a significant but transient increase in the prevalence of respiratory symptoms in children. Particulate matter of 10 µm or less in aerodynamic diameter (PM$_{10}$) was also found to be a pollutant associated with respiratory symptoms and lung function changes. Among elementary students, elevated PM$_{10}$ concentration was associated with a statistically significant decline in peak expiratory flow, and it increased the incidence of respiratory diseases as well as the use of asthma medication.

Such effects of air pollution on children's health may increase school absences. Diette et al reported that school attendance may be affected by frequent awakening at night in children with asthma aggravated by air pollution. Children with asthma were reported to be absent 2 more days than the children without asthma in a school year. Therefore, we hypothesized that air pollution leads to an increase in the number of illness-related absences.

Absenteeism is an important index that relates not only to morbidity but also directly to daily activities. School absences may lead to a student's decline in school performance and overall education received. However, a number of studies that have dealt with absenteeism associated with air pollution produced inconsistent results. This study assesses the effects of air pollution on school absenteeism among elemen-
primary students after controlling for long-term trends, seasonality, day of the week, holiday, and meteorologic influences.

### METHODS

The protocol was approved by the institutional review board on human subjects at Ewha Woman’s University, Seoul, Korea.

#### ABSENCE DATA

School absentee data in the attendance reports of the students of one elementary school in Seoul were collected. This school is located in Kangnam Ku, where traffic is particularly heavy. The grades at this school ranged from the first to sixth grade, with 5 classes assigned per grade, and typically 45 students were in each class. Average enrollment count was 1264 (671 boys and 593 girls) in 1996. The study period extended from March 2, 1996, through December 22, 1999. An absence was defined as a day when a student did not attend school while school was in session. An absent day as a result of changing schools was not counted as an absence in this study. The numbers of illness-related absences were counted separately. A teacher recorded an illness-related absence, by parent’s report, in the attendance record for each class.

#### AIR POLLUTION DATA

The Ministry of Environment provided data on air pollution for Seoul. The pollution status of Seoul was evaluated by measuring pollution exposure during the study period at 27 monitoring sites. Levels of PM$_{10}$ (β-ray absorption method), carbon monoxide (nondispersive infrared photometry), nitrogen dioxide (chemiluminescence), sulfur dioxide (ultraviolet photometry), and ozone (ultraviolet photometry) were measured hourly. Twenty-four-hour pollutant concentration averages were constructed. For ozone, an 8-hour daytime average was used instead of a 24-hour average.

Meteorologic information from a station in the central part of Seoul was obtained from the National Meteorological Office, including 24-hour average temperature and relative humidity. Except for occasionally missing or excluded observations, data for air pollution and meteorologic measures were available for the period from March 1, 1996, to December 22, 1999.

#### STATISTICAL ANALYSIS

The absence data and exposure data were merged to create an analysis file with days. To allow for nonparametric relations between absence and predictor variables with respect to time and weather, we applied LOESS, a moving regression smoother, into a time-series analysis of the counts by means of a generalized additive model$^{17}$ with a log link and Poisson error allowing overdispersion. We also used a locally weighted running-line smoother$^{18}$ to check graphically the linearity assumption between air pollution and school absenteeism.

A model that best fit the data was selected with the use of Akaike’s information criteria.$^{19}$ Because the effects of pollutant exposure were likely to occur over several days, 1-day lag and 7-day moving average of the pollutant level were considered as well as the same-day concentrations. Because the same-day pollution best fit the model, we used the same-day concentration as the air pollution exposure in the results. To compare the effect of pollutants on school absence, we calculated the relative risks of illness-related absence in units of interquartile ranges (range from the lowest 25% of the value to the lowest 75% of the value) of each air pollutant. We used 2-pollutant models to estimate the effects of a pollutant after controlling for another pollutant. All analysis was done with S-PLUS 2000 (MathSoft Engineering & Education, Inc, Cambridge Mass).

The average number of daily absences was 5.89 (SD, 4.04) and the number due to illness was 4.20 (SD, 3.50). On the basis of the enrollment in 1996, the absence rate was 4.66 (95% confidence interval [CI], 0.94-9.38) per 1000 student-days and the illness-related absence rate was 3.69 (95% CI, 0.43-7.95) per 1000 student-days.

Table 1 summarizes the statistics on air pollution and weather in Seoul during the study period. The 24-hour average concentrations of PM$_{10}$, nitrogen dioxide, sulfur dioxide, and carbon monoxide were 68.11 µg/m$^3$, 33.12 parts per billion (ppb), 9.19 ppb, and 1.11 ppm, respectively. The 8-hour average concentration of ozone was 22.86 ppb.

Table 2 shows the correlation matrix for the air pollutant concentrations during the study period. The concentrations of carbon monoxide, nitrogen dioxide, sulfur dioxide, and PM$_{10}$ positively correlated with each other (0.56≤r≤0.76). However, the concentration of ozone negatively correlated with that of the other pollutants.

We compared relative risks of non-illness-related and illness-related absence for the interquartile range increase of air pollutant levels (Table 3). Illness-related absences occurred more frequently when levels of PM$_{10}$, sulfur dioxide, and ozone increased. Relative risks of the absences for the interquartile range increase of the pollutants were 1.06 (95% CI, 1.04-1.09), 1.09 (95% CI, 1.07-1.12), and 1.08 (95% CI, 1.06-1.11), respectively. The Figure shows plots of the relationship between these air pollutants and illness-related absenteeism. There was

| Table 1. Summary Statistics for Concentrations of PM$_{10}$, Nitrogen Dioxide, Ozone, Sulfur Dioxide, and Carbon Monoxide in Seoul, South Korea, 1996-1999$^*$ |
|----------------------------------|----|---------------|----------------|
| No. of Observations | Minimum | Maximum | Mean (SD) |
| PM$_{10}$, µg/m$^3$ | 1059 | 10.47 | 190.16 | 68.11 (29.90) |
| Nitrogen dioxide, ppb | 1075 | 10.22 | 63.07 | 33.12 (9.96) |
| Sulfur dioxide, ppb | 1075 | 2.68 | 28.11 | 9.19 (4.61) |
| Carbon monoxide, ppm | 1075 | 0.39 | 2.97 | 1.11 (0.40) |
| Ozone, ppb | 1075 | 3.13 | 69.15 | 22.86 (9.15) |

$^*$PM$_{10}$ indicates particulate matter less than or equal to 10 µm in aerodynamic diameter; ppb, parts per billion.
clearly a relatively linear positive relationship between the number of daily illness-related absences and concentrations of PM_{10}, ozone, and sulfur dioxide. The effects on illness-related absenteeism changed little when 2 pollutants were included in the model together (Table 4). However, a statistically significant association between nitrogen dioxide and absenteeism among elementary school students was not observed.

For non–illness-related absenteeism, air pollutants were not associated statistically significantly with absences, except for ozone and sulfur dioxide. Concentrations of ozone and sulfur dioxide were negatively associated with non–illness-related absences.

### Comment

Absenteeism is considered the index for showing the effect of air pollutants on daily activity before severe adverse events, such as hospitalization, occur. Work absences or restricted activity days have been reported to be associated with air pollution.\(^3\)\(^2\)\(^3\) However, the number of studies on the relationship between school absenteeism and air pollutants has been limited. A study that was done in Finland\(^1\) showed a significant association between levels of sulfur dioxide and absenteeism from day care centers, schools, and workplaces. Ransom and Pope\(^2\) found an association between PM_{10} and overall absenteeism among kindergarten children in a study done in Utah Valley, Utah. They observed that a 100-µg/m\(^3\) increase in the 28-day moving average of PM_{10} was associated with a 40% increase in overall absences. This association was observed even at PM_{10} levels below 150 µg/m\(^3\). Chen et al\(^4\) found that carbon monoxide and ozone levels were significant predictors of daily absenteeism in elementary schools. For every 1.0-ppm and 50-ppb increase in carbon monoxide and ozone levels, the absence rate increased 3.79% and 13.01%, respectively. However, PM_{10} concentration was negatively correlated with school absenteeism.

Although most absences are associated with illness, there could be other reasons for the absences. Therefore, illness-related absences rather than overall absences are more important for evaluating the effects of air pollutants on health. In a study done in Mexico, ozone was associated with absenteeism related to respiratory diseases among preschool children.\(^2\)\(^3\) However, other studies have not shown an association between air pollutants and absenteeism due to illness. Wayne and Wehrle\(^2\)\(^4\) failed to find a risk of air pollutants in respiratory disease related to school absenteeism in California. In a recent study, Gilliland et al\(^1\) reported an association between PM_{10} and all absences except illness-related ones. Increased daily PM_{10} exposure was associated with increases only in non–illness-related absences. A change of 10 µg/m\(^3\) in PM_{10} was associated with a 22.8% increase in all types of school absences and a 97.7% increase in non–illness-related absences, but a 5.7% increase in illness-related absences. However, an increase in ozone levels was associated with increases in respiratory illness–related school absences in children. Nitrogen dioxide had only a weak association with school absenteeism.

In our study, absenteeism was classified as illness-related and non–illness-related absenteeism. Increased levels of air pollutants such as PM_{10}, sulfur dioxide, and ozone were associated with the number of illness-related absences. Acute effect of nitrogen dioxide on school absenteeism was not shown in this study. Although nitrogen dioxide exposure may be associated with respiratory symptoms, we could not find any evidence that symptoms from nitrogen dioxide exposure resulted in school absences.\(^5\) Gilliland et al\(^1\) also reported that acute

### Table 3. Relative Risk and 95% Confidence Interval in Absenteeism Due to an Interquartile Range Increase in PM_{10}, Nitrogen Dioxide, Ozone, Sulfur Dioxide, and Carbon Monoxide, 1996-1999\(^*\)

<table>
<thead>
<tr>
<th>Pollutant (Interquartile Range Increase)</th>
<th>Total Absences</th>
<th>Non–Illness–Related Absences</th>
<th>Illness–Related Absences</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM_{10}, 42.1 µg/m(^3)</td>
<td>1.01 (0.99-1.03)</td>
<td>0.98 (0.95-1.02)</td>
<td>1.06 (1.04-1.09)</td>
</tr>
<tr>
<td>Nitrogen dioxide, 14.51 ppb</td>
<td>0.97 (0.96-0.99)</td>
<td>0.99 (0.96-1.03)</td>
<td>1.02 (0.99-1.04)</td>
</tr>
<tr>
<td>Ozone, 15.94 ppb</td>
<td>1.01 (0.99-1.03)</td>
<td>0.84 (0.80-0.87)</td>
<td>1.08 (1.06-1.11)</td>
</tr>
<tr>
<td>Sulfur dioxide, 5.68 ppb</td>
<td>1.03 (1.02-1.05)</td>
<td>0.95 (0.92-0.99)</td>
<td>1.09 (1.07-1.12)</td>
</tr>
<tr>
<td>Carbon monoxide, 0.52 ppm</td>
<td>0.95 (0.94-0.97)</td>
<td>0.99 (0.96-1.02)</td>
<td>0.96 (0.94-0.98)</td>
</tr>
</tbody>
</table>

\(^*\)PM_{10} indicates particulate matter less than or equal to 10 µm in aerodynamic diameter; ppb, parts per billion.

### Table 2. Pearson Correlation Coefficients for Pollution Variables in Seoul, South Korea, 1996-1999\(^*\)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>PM_{10} µg/m(^3)</th>
<th>Nitrogen Dioxide</th>
<th>Sulfur Dioxide</th>
<th>Carbon Monoxide</th>
<th>Ozone</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM_{10}</td>
<td>1.00</td>
<td>0.76</td>
<td>0.60</td>
<td>0.56</td>
<td>0.07</td>
</tr>
<tr>
<td>Nitrogen dioxide, ppb</td>
<td>1.00</td>
<td>0.68</td>
<td>0.70</td>
<td>−0.14</td>
<td></td>
</tr>
<tr>
<td>Sulfur dioxide, ppb</td>
<td>1.00</td>
<td>0.67</td>
<td>−0.18</td>
<td>−0.14</td>
<td></td>
</tr>
<tr>
<td>Carbon monoxide, 100 ppb</td>
<td>1.00</td>
<td>−0.46</td>
<td>−0.18</td>
<td>−0.14</td>
<td></td>
</tr>
<tr>
<td>Ozone, ppb</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

\(^*\)PM_{10} indicates particulate matter less than or equal to 10 µm in aerodynamic diameter; ppb, parts per billion.

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effects of nitrogen dioxide on school absenteeism were not observed.

Our results show that air pollutants such as ozone and sulfur dioxide are protective for the non–illness-related absences. Other pollutants also tended to decrease the number of non–illness-related absences. Because the causes of non–illness-related absences were not ascertained in our study, it is hard to explain why air pollutants decrease the number of such absences. One possible explanation is that air pollution decreases outdoor activities such as family tours or visits, thereby increasing attendance at school. Further studies including detailed causes of absences are needed.

In this study, the effect of air pollution on absenteeism, both illness related and non–illness related, was investigated separately. Because attendance records were used to obtain data, there may be no ascertainment bias. On the other hand, our study had some limitations. The specific reasons for non–illness-related absences could not be explored because we depended on the past records. The reasons for non–illness-related absences vary. Students might have such absences when they go away to visit relatives or have troubles with their teacher or friends. There was no detailed information about the reason for these absences in the attendance report. Teachers distinguish between an absence related to illness and that not related to illness by relying on the parent’s report. Since absence during elementary school does not affect performance grade and entrance to a higher level of school, there is no reason not to believe the parent’s report about the reason for absence.

In addition to the limitations, we did not consider individual-level covariates in the model. Even though including individual-level covariates in the analysis would give greater statistical power than the time-series model, our results clearly showed the significant effect of pollutants on illness-related absences.

In conclusion, air pollutants were associated with illness-related absences, which suggests that air pollution is closely linked to daily activities, particularly of school-aged children.

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### What This Study Adds

It has been known air pollution leads to respiratory illness among children. A few studies have shown that air pollution is related to school absence, but they have produced inconsistent results. Illness-related school absences are considered a comprehensive index for evaluating health-related effects of air pollution on children.

This study suggests that air pollution increases illness-related school absences. This result provides an important basis for establishing policy for ambient environment.

| Table 4. Relative Risk (RR) and 95% Confidence Interval (CI) in Illness-Related Absenteeism Due to an Interquartile Range Increase in PM$_{10}$ (42.1 µg/m$^3$), Ozone (15.94 ppb), and Sulfur Dioxide (5.68 ppb) Using 2-Pollutant Models$^*$ |
|---------------------------------|-----------------|-----------------|
| Model                          | Pollutant       | RR              | 95% CI          |
| PM$_{10}$ + sulfur dioxide      | PM$_{10}$       | 1.03            | 0.99-1.06       |
|                                | Sulfur dioxide  | 1.07            | 1.04-1.11       |
| PM$_{10}$ + ozone               | PM$_{10}$       | 1.06            | 1.04-1.08       |
|                                | Ozone           | 1.10            | 1.07-1.13       |
| Sulfur dioxide + ozone          | Sulfur dioxide  | 1.10            | 1.08-1.13       |
|                                | Ozone           | 1.10            | 1.07-1.13       |

$^*$PM$_{10}$ indicates particulate matter less than or equal to 10 µm in aerodynamic diameter; ppb, parts per billion.
REFERENCES