Association between Ozone and Asthma Emergency Department Visits in Saint John, New Brunswick, Canada

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This study examines the relationship of asthma emergency department (ED) visits to daily concentrations of ozone and other air pollutants in Saint John, New Brunswick, Canada. Data on ED visits with a presenting complaint of asthma (n = 1987) were abstracted for the period 1984–1992 (May–September). Air pollution variables included ozone, sulfur dioxide, nitrogen dioxide, sulfate, and total suspended particulate (TSP); weather variables included temperature, humidity, dewpoint, and relative humidity. Daily ED visit frequencies were filtered to remove day of the week and long wave trends, and filtered values were regressed on air pollution and weather variables for the same day and the 3 previous days. The mean daily 1-hr maximum ozone concentration during the study period was 41.6 ppb. A positive, statistically significant (p<0.05) association was observed between ozone and asthma ED visits 2 days later, and the strength of the association was greater in nonlinear models. The frequency of asthma ED visits was 33% higher (95% CI, 10–56%) when the daily 1-hr maximum ozone concentration exceeded 75 ppb (the 95th percentile). The ozone effect was not significantly influenced by the addition of weather or other pollutant variables into the model or by the exclusion of repeat ED visits. However, given the limited number of sampling days for sulfate and TSP, a particular effect could not be ruled out. We detected a significant association between ozone and asthma ED visits, despite the vast majority of sampling days being below current U.S. and Canadian standards.

**Key words:** air pollution, asthma, emergency department, ozone. *Environ Health Perspect* 104:1354–1360 (1996)

Recent evidence has implicated ground-level ozone as a contributor to both mortality (1) and morbidity, including hospital admissions (2–4), emergency department visits (5–9), symptoms (10,11), pulmonary function changes (11,12), and inflammatory changes in the respiratory tract (13,14). Data on emergency department (ED) visits have been used to examine the effects of a variety of air pollutants including particulates, ozone, sulfur dioxide, nitrogen dioxide, sulfate, and hydrogen sulfide (5–9,15–21). As health endpoints, ED visits have the advantages of reflecting an adverse health event of clear clinical significance, which at the same time is more frequent in occurrence than death or hospital admission. Conversely, abstracted ED visit data in a form amenable to analysis together with environmental exposure data are not widely available. In this study, we employed ED visit data that had previously been abstracted from clinical records for administrative and quality-of-care assessment purposes.

The primary objective of this study was to further examine the relationship between daily ozone concentrations and emergency department visits for asthma, including analysis of lag periods ranging from 0 to 3 days, assessment of the impact of other pollution and weather variables on the ozone effect, and examination of differences in effects between children and adults. Unique features of our analysis include an examination of the shape of the dose–response function and assessment of the impact of repeat ED visits on the strength of the association.

**Methods**

This study was carried out in Saint John, New Brunswick, a city of approximately 75,000 people (surrounding metropolitan area with an additional 50,000) on Canada’s Atlantic coast. Local air pollution sources include a large petroleum refinery, two oil-fired generating stations, and two pulp mills. The area is also subject to long range transport of air pollutants from eastern Canada and the eastern United States. The city has two hospital emergency departments, with a combined annual volume of approximately 90,000 visits. Access to emergency services is universal under Canada’s publicly provided health care system.

Data on ED visits were obtained from the Saint John Regional Hospital’s ED visit database, which consists of electronic records created by the registration clerk at the time each patient enters the emergency department. Data were obtained for the period 1984–1992 (May–September only) for visits with a presenting complaint of asthma. At the time of registration, the patient provided a presenting complaint to the registration clerk, who then coded the complaint from a predefined menu, which included a category (other) for complaints that did not clearly fit the menu. In addition to the presenting complaint, extracted information included patient’s age and sex and the date of visit. Original ED charts for all visits made between May and September 1987 were also reviewed manually by research nurses, and data were abstracted for both presenting complaint and discharge diagnosis. This permitted an analysis of the relationship between presenting complaint and discharge diagnosis, as well as agreement between the database and manual reviewers on coding of presenting complaint.

Air pollution data (ozone (O₃), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), sulfate (SO₄²⁻), total suspended particulate (TSP)) and meteorological data (temperature, dewpoint, relative humidity, and humidity) were obtained from Environment Canada and the New Brunswick Ministry of Environment. Where data were available from more than one monitoring station, mean values were used. Ozone was measured continuously using instruments based on the UV absorption method. The instrument types employed were either a Monitor Labs (Model 8810; Englewood, CO) or a Dasibi (Model 1003; Glendale, CA). SO₂ was measured continuously using the pulsed fluorescence detection method (Monitor Labs Model 8850) and NO₂ was measured continuously using the chemiluminescence detection method (Monitor Labs Model 8840). TSP samples were collected over 24-hour periods using standard high-volume samplers and Teflon-coated glass fibre filters (Palfflex, Putnam, CT). Particulate sulfate on the high volume samples was determined using ion chromatography. Daily O₃, NO₂, and SO₂ data were utilized, while only every third to fifth day was coded.
sixth day $SO_2^{\text{max}}$ and TSP data were available. No inhalable or respirable particulate data were available. Humidity is an index in which a certain number of degrees Celsius are added to the dry bulb temperature to account for the additional discomfort associated with excessive humidity.

Analysis was conducted on an IBM RS-6000 mini computer (IBM, Armonk, NY) using UNIX-based SAS statistical software (SAS, Cary, NC). Daily frequencies of asthma visits were filtered to remove day of the week and long wave (e.g. seasonal) trends, which might otherwise confound the relationship with air pollution. Daily frequencies were related to air pollution and weather variables by the regression equation:

$$B(y_t) = (S, D_t/C)(\alpha + \beta x_t),$$

where $B(y_t)$ is the expected number of ED visits on the $t$th day of sampling; $y_t$ is the actual number of ED visits on the $t$th day of sampling; $D_t$ is the average number of ED visits by day of the week (seven distinct values);

$$C = \left(\sum_{i=1}^{T} S_i D_i\right)/T$$

is a normalizing constant;

$$S_i = \sum_{j=1}^{9} \Phi_i x_{i-j}$$

is a 19 day symmetric linear filter, where $\Phi_0, \ldots, \Phi_9$ are unique weights given by 0.0874, 0.0857, 0.0807, 0.0729, 0.0629, 0.0518, 0.0404, 0.0296, 0.0200, and 0.0123 with $\Phi_i = \Phi_{9-i}$; $22$; $\alpha$ and $\beta$ are the regression intercept and coefficient, respectively; and $x_t$ is the value of the environmental variable on the $t$th day. Because the daily frequency of visits was small, the variance was assumed to be proportional to the expected response (i.e., $V(y_t) = \theta E(y_t)$, where $\theta$ is a proportionality constant). The relationship between pollutant/meteorological variables, lagged 0–3 days, and ED visit frequency was assessed using the SAS NLIN procedure (23), setting the regression weights equal to the inverse of the expected response. This is equivalent to a generalized estimating equation approach and is identical to Poisson regression when the variance is equal to the expected response (i.e., $\theta = 1$ above) (24). This procedure is more general than Poisson regression and allows for Poisson over and under dispersion (i.e., $\theta > 1$ or $\theta < 1$) (24). Because the daily frequency of asthma ED visits may be serially autocorrelated (i.e., the frequency of visits on day $t + 1$ may be related to the frequency of visits on day $t$ due, for example, to repeat visits by the same patient in relation to the same asthma episode or to multi-day pollution episodes), first order autocorrelation was assessed using the autocorrelation coefficient and Durbin-Watson $d$ statistic. These were derived from the SAS REG procedure, setting the regression weights equal to $[S, D_t/C] (\alpha + \beta x_t)^{-1}$, where $a$ and $b$ are, respectively, estimates of the regression intercept, $\alpha$, and coefficient, $\beta$, estimated based on the NLIN procedure. Failure to control for autocorrelation could result in biased estimates of the statistical significance of air pollution effects. Positive autocorrelation would result in underestimates of the standard errors of regression coefficients, while negative autocorrelation would result in overestimates (25).

### Results

A descriptive summary of air pollution and meteorological data is presented in Table 1, together with Pearson correlation coefficients. There was generally weak correlation among air pollution variables, although $SO_2^{\text{max}}$ and TSP were moderately correlated, and as expected, maximum temperature and maximum dewpoint temperature were highly correlated with maximum humidity. Canada’s National Ambient Air Quality Objective for ozone (80 ppb) was exceeded on 3.7% of study days, while the U.S. standard (120 ppb) was exceeded on 0.4% of days. Pearson correlations between daily 1-hr maximum and daily average concentrations were high for ozone, $SO_2$, and NO$_x$ (0.9; $p = 0.0001$).

During the study period, 1,163 individuals made a total of 1987 ED visits with a presenting complaint of asthma. Forty-seven percent of asthma ED visitors were male and 49% were 15 years of age or younger. Respectively, 1.5, 6.5, and 10.2% of asthma ED visitors (including admitted and discharged patients) made a return visit within 24 and 72 hr and 14 days. For the period May–September 1987, presenting complaints coded by research nurses based on a manual review of ED charts agreed with those contained in the ED database 97% of the time. Ninety-three percent of visits with a presenting complaint of asthma were assigned a discharge diagnosis of asthma (the remaining 7% received discharge diagnoses of upper respiratory infection, pneumonia, bronchitis, chronic obstructive pulmonary disease, croup, and noncardiorespiratory conditions). Conversely, visits with a presenting complaint of asthma accounted for 43% of all visits with a discharge diagnosis of asthma.

The average number of visits per day with a presenting complaint of asthma (henceforth referred to as asthma visits) was 1.5 (minimum of 0 and maximum of 8). There were no asthma visits on 27% of days, one visit on 30% of days, two visits on 24% of days, and more than two visits on 19% of days. Significant variability was observed in visit frequency by day of the week, ranging from a mean of 1.3 visits per day on Wednesday and Friday to 1.7 visits per day on Sunday. Variability was also observed by month, with the greatest number of visits in May and September, relative to the other months. The impact of filtering on temporal

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Table 1. Descriptive summary of pollution and meteorological data, May–September 1984–1982

| Variable | No. | Mean | Range | 95th percentile |
|----------|-----|------|-------|-----------------|
| $O_3$, 1 hr maximum (ppb) | 1338 | 41.6 | 0–160 | 75 |
| $SO_2$, 1 hr maximum (ppb) | 1239 | 38.1 | 0–390 | 110 |
| NO$_x$, 1 hr maximum (ppb) | 1188 | 25.2 | 0–120 | 60 |
| $SO_2^{\text{max}}$, 24 hr (μg/m$^3$) | 199* | 5.5 | 1–23 | 14 |
| TSP, 24 hr (μg/m$^3$) | 217* | 36.7 | 5–108 | 70 |
| T (maximum) | 1355 | 19.4 | 4–33 | 27 |
| DT (maximum) | 1355 | 12.4 | -6–23 | 19 |
| RH (maximum) | 1354 | 95.9 | 61–100 | 100 |
| HX (maximum) | 1355 | 21.0 | 0–36 | 31 |

Pearson correlation coefficients

| | $SO_2$ | NO$_x$ | $SO_2^{\text{max}}$ | TSP | T | DT | RH | HX |
|---|-------|-------|-----------------|-----|---|---|----|----|
| $O_3$, 1 hr maximum (ppb) | 0.04 | 0.16* | 0.29* | 0.30* | 0.19* | 0.11* | 0.19* |
| $SO_2$, 1 hr maximum (ppb) | -0.03 | 0.23** | 0.16* | 0.10* | 0.08** | 0.19* |
| NO$_x$, 1 hr maximum (ppb) | 0.16* | 0.15* | 0.11* | 0.01 | -0.04 | 0.08** |
| $SO_2^{\text{max}}$, 24 hr (μg/m$^3$) | 0.53* | 0.27* | 0.38* | 0.17* | 0.35* |
| TSP, 24 hr (μg/m$^3$) | 0.28* | 0.12 | -0.11 | 0.25* |
| T (maximum) | 0.63* | 0.09** | 0.52* | 0.84* |
| DT (maximum) | 0.52* | 0.84* |
| RH (maximum) | 0.26* |
| HX (maximum) | 0.26* |

Abbreviations: TSP, total suspended particulates; T, temperature (°C); DT, dewpoint temperature (°C); RH, relative humidity (%); HX, humidex (°C).

*Measured every sixth day.

*p<0.05; **p<0.01; ***p<0.001.
variability in visit frequency is revealed in Figure 1, which plots data for 1990, the year during which the greatest seasonal variability was observed. In Figure 1A, the value of the filter ($S_j$), which smooths daily oscillations in visit frequency, is overlaid on the unfiltered visit frequency data ($y_j$). Figure 1B plots the filtered data, $F_j = y_j/(S_jD_j/C)$, which reflect the removal of seasonal trends from the raw data.

Scatter plots were produced of the relationship of pollutant and meteorologic variables to filtered asthma ED visits in order to screen for nonlinearity. Only ozone appeared to have a nonlinear relationship with visit rates. Based on this screening analysis, for daily average and daily 1-hr maximum ozone concentrations, ED visit rates were regressed on an indicator variable representing days above and below the 95th percentile concentration, as well as linear, quadratic, and linear-quadratic ozone terms. Visit rates were regressed linearly on other individual pollutant and meteorologic variables.

Of all pollutants considered, only ozone exhibited a consistently positive association with asthma visit rates 2 days later, which was statistically significant ($p<0.05$) or borderline significant in all model forms (see Table 2). Compared to the linear model, the nonlinear models revealed stronger associations between both daily average and maximum ozone and asthma ED visits, based on the model $p$-value. A plot of data collapsed into $<30$th percentile, 30–60th percentile, 60th–95th percentile, and >95th percentile for daily 1-hr maximum ozone concentration reveals the apparent nonlinearity of the ozone effect (Figure 2) (a similar trend was observed for daily average concentration). The first order autocorrelation coefficient for the filtered daily visits series for both daily average and 1-hr maximum models was low and negative (-0.142 and -0.137, respectively), and the Durbin-Watson statistic was close to 2 (2.284 and 2.274, respectively), indicating that there was no important autocorrelation in the filtered visit data. The frequency of asthma ED visits (filtered as above) was 33% higher (95% CI, 10–56%) when the daily 1-hr maximum exceeded 75 ppb (the 95th percentile). Ozone was not significantly associated with asthma visits for other lags ($p>0.05$).

To assess whether the ozone effect (lag 2 days) was confounded by other pollution and weather variables, days above and below the 95th percentile for daily 1-hr maximum ozone concentration (lag 2 days) were compared with respect to the other pollution and weather variables. As shown in Table 3, average SO$_2$ (lag 0 days) was lower on high ozone days, while maximum NO$_2$ (lag 2 days), SO$_2$ (lag 3 days), TSP (lag 3 days), maximum temperature (lag 1 day), maximum humidex (lag 1 day), maximum dewpoint temperature (lag 2 days), and mean relative humidity (lag 1 day) were all higher on high ozone days. (The

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**Figure 1.** (A) Unfiltered asthma visit frequency, $y_j$ and filter, $S_j$; (B) filtered asthma visit frequency, $F_j$, May–September 1990.

**Table 2. Results of models relating asthma ED visits and ozone (lag 2 days)**

| Model                                      | $\beta$ (SE)     | $p$-value (model) |
|--------------------------------------------|------------------|--------------------|
| Ozone daily average (lag 2 days)            |                  |                    |
| Linear                                     | 0.0049 (0.0027)$^a$ | 0.0623             |
| Quadratic                                  | 0.0001 (0.0004)$^b$ | 0.0106             |
| Linear–quadratic                           | -0.0221 (0.0081)$^a$ | <0.0001            |
| Indicator (> vs. 95th percentile)           | 0.0004 (0.0001)$^b$ | 0.0715             |
| Ozone daily 1-hr maximum (lag 2 days)       |                  |                    |
| Linear                                     | 0.0035 (0.0018)$^a$ | 0.0485             |
| Quadratic                                  | 0.00004 (0.00002)$^b$ | 0.0101             |
| Linear–quadratic                           | -0.0125 (0.0060)$^b$ | <0.0001            |
| Indicator (> vs. 95th percentile)           | 0.4537 (0.1593)$^b$ | 0.0045             |

$^a$Visits/ppb/day.  
$^b$Visits/ppb$^2$/day.  
$^c$Visits/exceedance of 95th percentile/day.

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**Table 3. Results of models relating asthma ED visits and pollutants**

| Model                                      | $\beta$ (SE)     | $p$-value (model) |
|--------------------------------------------|------------------|--------------------|
| Ozone daily average (lag 2 days)            |                  |                    |
| Linear                                     | 0.0049 (0.0027)$^a$ | 0.0623             |
| Quadratic                                  | 0.0001 (0.0004)$^b$ | 0.0106             |
| Linear–quadratic                           | -0.0221 (0.0081)$^a$ | <0.0001            |
| Indicator (> vs. 95th percentile)           | 0.0004 (0.0001)$^b$ | 0.0715             |
| Ozone daily 1-hr maximum (lag 2 days)       |                  |                    |
| Linear                                     | 0.0035 (0.0018)$^a$ | 0.0485             |
| Quadratic                                  | 0.00004 (0.00002)$^b$ | 0.0101             |
| Linear–quadratic                           | -0.0125 (0.0060)$^b$ | <0.0001            |
| Indicator (> vs. 95th percentile)           | 0.4537 (0.1593)$^b$ | 0.0045             |

$^a$Visits/ppb/day.  
$^b$Visits/ppb$^2$/day.  
$^c$Visits/exceedance of 95th percentile/day.
lag periods for the pollution and weather variables shown in this table were those for which the strongest association with asthma visits was observed in single variable regressions.) These variables were then added to the model for daily 1-hr maximum ozone indicator (lag 2 days) (the effects of TSP and SO$_2^2_2$ were examined separately from the other pollution and weather variables because of the smaller sample size resulting from every sixth day sampling frequency). As seen in Table 4, the ozone coefficient increased slightly in both models and remained statistically significant in model 1, which had a larger sample size based on daily data. Of the other variables, only the effect of mean relative humidity (lag 1 day) was statistically significant.

The appropriateness of the 95th percentile as a cutoff point in the ozone models was examined by removing days with the top 5% of ozone concentrations and rerunning the regressions. Ozone no longer exhibited a statistically significant association with ED visits in this subset of the data [e.g., for the daily 1-hr maximum ozone linear model (lag 2 days)], $\beta = -0.0013$ visits/ppb and $p = 0.5758$.

 Differences in ozone effect for adult (>15 years of age) and childhood (≤15 years of age) asthma visits were also examined. As shown in Figure 3, the rate of ED visits was slightly higher for adults than children, as was the proportional increase in visits when daily 1-hr maximum ozone concentration was above the 95th percentile (47% and 15%, respectively). In regression models, the association of ED visits with daily 1-hr maximum, as well as daily average ozone concentration, was statistically significant for adults but not for children (see Table 5).

Specificity of the ozone effect was assessed by examining the relationship between ozone and visits with respiratory presenting complaints other than asthma (cough, congestion, wheeze, shortness of breath, or difficulty breathing). This constituted a heterogeneous group of 8238 visits, a significant proportion of which were assigned a nonrespiratory discharge diagnosis (30% in the case of shortness of breath and difficulty breathing). None of the pollutants exhibited a statistically significant association with this group of visits ($p>0.05$).

Although we did not detect important first order autocorrelation in the data, we did note (see above) that a small but nontrivial proportion of individuals making asthma visits made repeat visits within 14 days. Because this might spuriously increase the apparent association between asthma visits and ozone, we reran the NLIN procedure, excluding repeat visits within 24 and 72 hr and 14 days of an earlier visit. As seen in Table 6, coefficients were reduced slightly, but remained statistically significant. The 95% confidence intervals on these coefficients overlapped those derived from analyses that included repeat visits. The largest reduction in coefficient occurred with the exclusion of repeat visits within 72 hr and 14 days, which reduced the coefficient for daily 1-hr maximum ozone by 13%.

## Discussion

We have found that asthma ED visits increased by 33% when the daily 1-hr maximum ozone concentration exceeded 75 ppb. This is consistent with findings in New Jersey where asthma ED visits increased by 26% when the daytime mean ozone concentration (10 A.M. to 3 P.M.)
exceeded 60 ppb (5), in Atlanta, Georgia, where pediatric asthma ED visits increased by 37% following days when the daily 1-hr maximum ozone concentration exceeded 110 ppb (7), and in Mexico City where pediatric asthma visits increased by 68% following 2 days on which the 1-hr maximum ozone concentration exceeded 110 ppb (8). In other studies, however, ozone has not exhibited a significant association with respiratory or asthma visits (15–19). While there are a variety of factors that may account for these differences, in Vancouver (15) and Barcelona (16,18), ozone levels were relatively low compared to other studies in which significant ozone effects were observed.

Effects of daily average and daily 1-hr maximum ozone concentration were similar in magnitude and statistical significance in our study. It has been suggested that a measure of maximum cumulative exposure such as the daily maximum 8-hr moving average may be more relevant than daily average measures in terms of cumulative exposure (26). White et al. (7) found a high correlation ($r = 0.95$) between daily 1-hr maximum and daily maximum 8-hr moving average ozone concentrations, as well as apparently similar effects on asthma visits. Romieu et al. (8) also found a high correlation ($r = 0.91$) between these two ozone metrics, and on this basis only examined the effect of daily 1-hr maximum concentration on ED visits. We found a high correlation of average ozone concentration between 8 A.M. and 8 P.M. with both daily 1-hr maximum ($r = 0.85$) and daily average ($r = 0.94$) concentrations. Results of regressions relating average ozone concentration between 8 A.M. and 8 P.M. with asthma visits were consistent with results for the other metrics. The lack of a clearly stronger predictor of asthma visits among the three metrics probably reflects the high degree of collinearity.

In our study, a 2-day lag was observed between elevated ozone concentrations and increased asthma ED visits. In ED studies in New Jersey and Baton Rouge, Louisiana (5,6,9), the strongest effects were for same day ozone concentration (i.e., lag 0 days), while in the Mexico City study, the best fitting model included ozone concentration (lag 1 day) (8). In a study of air pollution and hospital admissions in Ontario (3), the largest ozone effects for all respiratory admissions were for lags of 1 and 2 days, while in a similar study in New York State (4), the largest effects differed by city and diagnosis, with the peak asthma admission effect at 3 days and 1 day in Buffalo and New York City, respectively. We were not able to detect an ozone effect for multiple lag periods, in contrast to other studies (3–6,8). It is not clear why various studies differ with respect to the observed lag between ozone concentrations and asthma ED visits or hospital admissions, although possible factors include both methodological differences and differences in study populations, exposure characteristics, and outcomes studied (e.g., hospital admissions vs. ED visits).

To better understand the lag between exposure and effect in our study population, we conducted preliminary analyses of 3 months of enhanced ED data (July–September 1994) being collected in a subsequent phase of this study, in which ED visitors were interviewed in detail both at the time of their visit and in follow-up 2 weeks later. These analyses indicated that for asthma patients the median number of days between symptom onset and ED visit was 2.0 (mean of 4.6) (27). Although this appears to be slightly longer than in some reports (28–31), it is consistent with one other study among children in Toronto (32) and corresponds to the 2 day lag effect we observed for ozone. While this is not sufficient evidence to infer a causal association, it does suggest that on average, the timing of the ozone effect is consistent with the temporal pattern of asthma exacerbations in this population.

In our study, quadratic, linear–quadratic, and indicator models consistently fit the data better than the linear model, suggesting that ozone effects are reduced or absent below a certain concentration. This is consistent with the finding of White et al. (7) that there appeared to be no effect of ozone on pediatric asthma visits when ozone concentrations were below 110 ppb. This is contrary to the findings in the Ontario hospital admission study in which there appeared to be no concentration at which ozone effects could not be detected (3). Again, interstudy differences could reflect a variety of factors. Emergency department visitors may, for example, be less sensitive to lower levels of air pollution than patients admitted to hospitals.

We did not detect significant effects of co-pollutants, either on their own or in terms of their impact on the ozone effect. Given the limited number of sampling days for sulfates and TSP, however, we cannot rule out an association between particles and asthma ED visits. The effects of these variables in other ED visit studies is inconsistent. As noted earlier, in some ED visit studies, other pollutants have had significant effects while ozone did not. In one study in Southern California (20), a significant ozone effect was noted in the region with the highest ozone levels, while sulfate effects were dominant in other regions. In Saint John, acid aerosols are a potentially important unmeasured co-pollutant in this analysis (33), and daily measurement of particle strong acidity is now under way to be used in future analyses with respect to ED visits. With respect to weather variables, temperature appears to be an inconsistent explanatory variable in ED visit studies. In one study, it was positively associated with ED visits for various respiratory conditions (20); in another study, a positive association was observed in winter and a negative association in summer (21), while in other studies, temperature was negatively associated (5,6,16,18,19).

We observed positive associations between ozone concentration and asthma ED visits for both adult and childhood asthma, although the subgroup analysis for children was not statistically significant. Burnett et al. (3) found that the age group with the largest proportion of asthma hospital admissions attributable to ozone was 0–1 year of age; however, asthma remains an unclear diagnosis in infants (34). In those above 2 years of age, the largest ozone effects were in those above 35 years of age (3), which is more consistent with our results. Age alone may be of limited usefulness as a subgrouping variable for asthmatics. Baseline severity, premorbid asthma management, and other coincident exposures (e.g., viral infections, allergens, tobacco smoke) may be more clinically relevant. These variables are currently being measured in a subsequent phase of this study.

We observed that a small proportion of ED visits were followed by repeat visits. 

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**Table 6. Results of regression modeling after exclusion of repeat visits**

| Exclusions                      | Ozone metric     | β (SE)*   | p-value (model) |
|---------------------------------|------------------|----------|-----------------|
| Repeat visits within 24 hr      | Daily average    | 0.56 (0.19) | 0.002          |
|                                 | Daily 1-hr max   | 0.43 (0.16) | 0.005          |
|                                 | Daily average    | 0.65 (0.18) | 0.003          |
|                                 | Daily 1-hr max   | 0.39 (0.15) | 0.011          |
| Repeat visits within 72 hr      | Daily average    | 0.54 (0.18) | 0.004          |
|                                 | Daily 1-hr max   | 0.39 (0.15) | 0.011          |

SE, standard error.
*Visits/exceedance of 95th percentile/day.
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Student Job Opportunities

The National Institute of Environmental Health Sciences (NIEHS) is currently accepting applications for temporary employment under the Student Temporary Employment Program. The Student Temporary Employment Program provides an excellent opportunity for students to gain valuable work experience and earn income while pursuing a degree. Students may work full-time during the summer or when school is closed and arrange their work schedule around their academic schedule while school is in session. To be eligible, students need to be at least 16 years of age, be enrolled or accepted for enrollment as a degree-seeking student taking at least a half-time academic, vocational, or technical course load in an accredited high school, technical or vocational school, 2 year or 4 year college or university, graduate school, or professional school. Student Temporary Employment Program employees are paid commensurate with their qualifications and the assigned duties of the position, with a minimum of $6.18 per hour (GS-1) or $6.78 per hour (WG-1).

How to Apply
Although the Federal Government does not require a standard application form, we do need certain information to evaluate your qualifications and determine if you meet legal requirements for Federal employment.

What to Submit
A current copy of your resume; SF-171, Application for Federal Employment; OF-612, Optional Application for Federal Employment; or any other written format you choose which includes education, work experience, and any other job related qualifications.

A letter from the Registrar’s Office verifying your academic standing and enrollment status. Graduate and undergraduate college transcripts or OPM Form 1170. Green Card if permanent resident.

Where to Apply  
NIEHS Human Resource Management Branch  
Student Temporary Employment Program  
PO Box 12233 (MD 1-01)  
Research Triangle Park, NC 27709  
FAX 919-541-3659

Contacts  
Emily Starnes at 919-541-3317 starnes@niehs.nih.gov  
JoAnne Moore at 919-541-3377 moore2@niehs.nih.gov  

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