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Effects of Atmospheric Pollutants on Children Asthma Outbreaks

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Abstract: The effects of air pollutants, weather conditions, airborne pollen and spores on the incidence of emergency room (ER) visits of children for acute asthma attacks were investigated.

One-year retrospective study was done. Data on daily concentrations of air pollutants, airborne allergens and weather conditions were collected and compared with the ER visits of 2431 asthmatic children (age 1-18 years) in the Schneider Medical Center, near Tel Aviv.

ER visits of asthmatic children showed a negative correlation with the measured O_3 concentrations and with extreme ambient temperatures. A positive correlation was found with high barometric pressure with NO_2 and SO_2 concentrations. An exceptionally high incidence of ER visits of asthmatic children was observed during September, coinciding with the beginning of the school year. When September was excluded from the annual calculations the correlation between ER visits and environmental factors increased. 49% of the variance of ER visits were explained by O_3 alone, 46% by NO_2 alone, 54% by O_3+NO_2, and 31% by weather parameters. 58% of the variation was explained by the combination of air pollutants and weather parameters. Airborne particulates did not show any meaningful correlation with ER visits.

The major factors associated with severe asthma attacks were high NO_2 and SO_2. The negative correlation with O_3 implies that at certain concentrations, O_3 may have a beneficial effect. The particularly high number of ER visits at the beginning of the school year was presumably associated with an increase in viral infections combined with emotional stresses.

A worldwide increase in prevalence of asthma is well known [1-4]. A seasonal incidence of asthma attacks, especially in children is also well documented [5-7]. Aggravation of asthma is associated with respiratory infections, emotional stress, exposure to allergens, extreme weather conditions and air pollution [8-13]. However, the specific contribution of each of the pollutants to manifestation of asthma remains controversial [9-14].

Air pollutants comprise a serious hazards to the population's health in general, and to allergic patients in particular. However, while the aggravating effects of SO_2 and NO_2 are well established, contradictory data have been presented regarding the effects of O_3. For example, some studies have shown that an increase in O_3 concentration correlates positively with increased hospital admissions of asthmatic children [7,9,15-17]. Others have found the contrary, i.e., that under certain conditions ozone concentrations are negatively correlated with ER visits of asthmatic children and may have a "protective" effect [18, 19]. An apparent reverse correlation between O_3 concentration and asthma morbidity was also shown [5].

In order to clarify this issue, we reinvestigated the correlations between ozone, as well as of other environmental factors, and ER visits of asthmatic children.

SUBJECTS AND METHODS

Patients

The study population included all 2431 asthmatic children who presented at the pediatric Emergency Room (ER) of the Schneider Children's Medical Center of Israel from January 1 to December 31, 1995. The hospital receives patients from the whole Tel Aviv metropolitan area, where the environmental monitoring was done. There were 1556 boys (64%) and 875 girls (36%) ranging in age from 1 to 18 years. Children with wheezing under the age of 12 months were excluded from the study because of a possible confusion bronchiolitis. The data was extracted from the Hospital's ER records. The search was for Asthma, Wheezing, Children and for Allergy symptoms. The data was compiled into weekly clusters because the availability of public medical services in Israel differs through the week: on Sundays through Thursdays, the public clinics are open, but on Fridays and Saturdays, patients have access only to ER services.

Environmental Factors

The following environmental factors were measured in the center of Tel Aviv.

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Air Pollutants

Data on ozone (O_3), nitrogen oxide (NO_2), sulfur dioxide (SO_2) and particulates were obtained from the monitoring stations of the Ministry of the Environment and from the Electric Company of Israel. Measurements were taken every half-hour, but calculated as the daily average (0-24 hr). Ozone was monitored with a UV photometric ozone analyzer (Model 8810, Motor Labs); NO_2 by chemiluminescence with a NO_2 Analyzer (Model 8840, ML Monitoring Labs); SO_2 with a pulse fluorescence SO_2 analyzer (Model 43A, Thermo Electron Instruments); and particulates (PM_{10}) with an ambient particle monitor (Team Series 14001).

Airborne Allergens

Monitoring was performed with a pollen trap (Burkard Manufacturing Co., Rickmansworth, UK) and several Rotorod samplers (Model 1987, sampling Technologies, Inc., CA, USA). The pollen and spores were identified and counted by light microscopy, and their concentration was calculated according to the manufacturer's instructions. Special attention was addressed to the presence of the allergenic pollen of *Artemisia, Cupressus, Olea* and *Parietaria*, to pollen of the Poaceae, Chenopodiaceae and Amaranthaceae, as well as to the spores of *Alternaria, Cladosporium* and *Stemphylium*.

Weather Parameters

Data on daily temperatures, relative humidity and barometric pressure were obtained from the Meteorological Service of Israel.

Statistical Analysis

Data analysis was performed using Statistix 3.5 software package (Analytical Software, St. Paul, MN, USA).

Pearson's correlations (r) were calculated to establish relationships between the daily number of ER visits and each of the environmental parameters. Multiple correlation coefficients (R) were used to determine how much of the variance of the ER visits could be explained by a given set of environmental parameters.

The running means were used in order to identify the pattern of the relationships between the environmental effectors and the ER visits of asthmatic children without the subjective fixation of an artificial period of time.

The running mean of a variable for *n* days was defined as the values of the variable *x* measured on the first, second, third day, etc. The running mean (*rx*) for *n* days is:

$$rx_i = \frac{1}{n} \cdot \sum_{k=i}^{n+i-1} x_k \, , \; i = 1,2,3,\ldots$$

The running mean of a variable for one week (*n*=7) was calculated as the mean from Monday to Sunday, then from Tuesday to Monday, than from Wednesday to Tuesday, etc.

Various sets of independent variables were formed from the corresponding running means of each of the environmental parameters.

Analysis of the data using the Poisson regression was done by the S-Plus software using the function for general linear models (GLM). P values (for F-statistics) were calculated to determine the significance of the regression relationships.

RESULTS

The number of children with acute asthma seen in the ER, and the percentage of such children of the total number of patients seen in the ER (Figs. **1**, **2**) yielded a clear seasonal pattern. In general, asthma morbidity was higher in the autumn and winter and lower in late spring and summer.

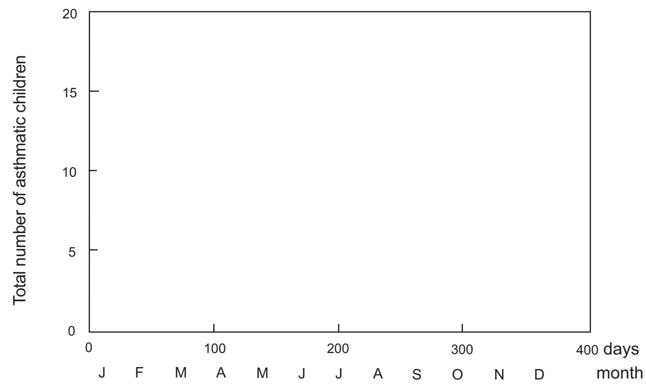

Fig. (1). Patients seen in the ER during 1995.

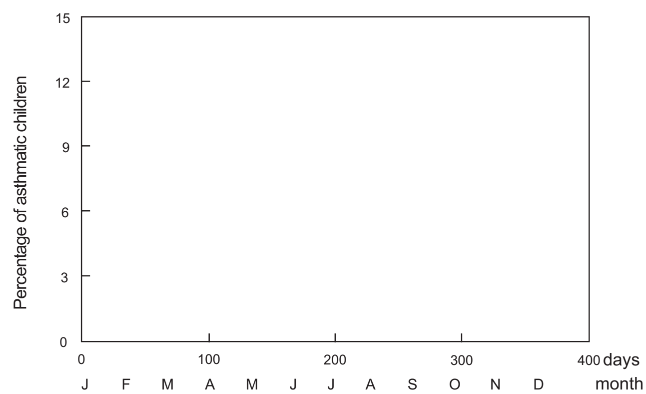

Fig. (2). Percentage of asthmatic children out of total number of patients.

The 7 days running mean of the ER visits was compared with the corresponding running mean of each of the environmental parameters (Table **1**). Among the environmental parameters, NO_2 and SO_2, were highly correlated with each other, both showing a seasonal pattern. A positive correlation was establishing between ER visits and ambient concentrations of NO_2 (Fig. **6**), SO_2 (Fig. **7**) and barometric pressure (Fig. **8**; Table **1**). ER visits showed a negative correlation with changes in O_3 concentrations (Tables **1**, Fig. **3**) and with minimal and maximal temperatures (Figs. **4**, **5**). However, the negative correlation between ER visits and the two later parameters was very low (0.27 and 0.29).

ER visits were exceptionally high during September. Apparently, additional factors played during September a role in the increased asthma outbreak. When the variables for this month were omitted from the annual calculation, the correlation coefficients improved dramatically, being more negative

Table 1. Pearson Correlation Coefficient (r) Between ER Visits of Asthmatic Children and Various Environmental Factors

Factor	Running Mean for 7 days	
	12 Months	11 Months*
O_3	-0.61	-0.70
NO_2	0.59	0.68
SO_2	0.50	0.60
Particulates (PM_{10})	0.32	0.33
Barometric pressure	0.49	0.54
Minimal temperature	-0.27	-0.40
Maximal temperature	-0.29	-0.42
Relative humidity	-0.21	-0.22

* Excluding September

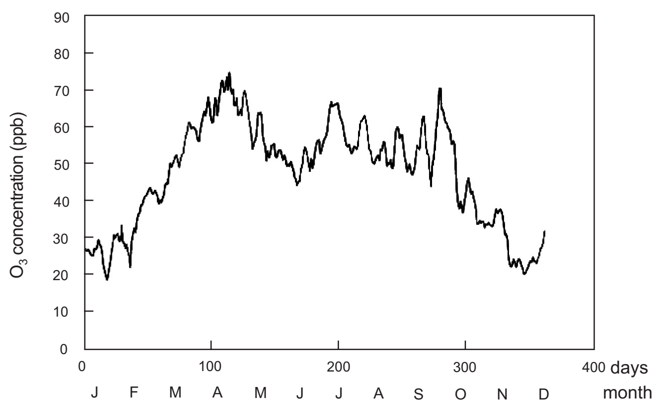

Fig. (3). Annual changes in O_3 concentration.

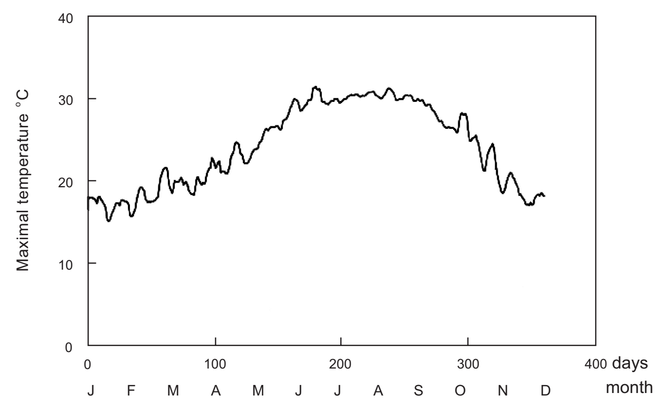

Fig. (5). Annual changes in Maximal temperature.

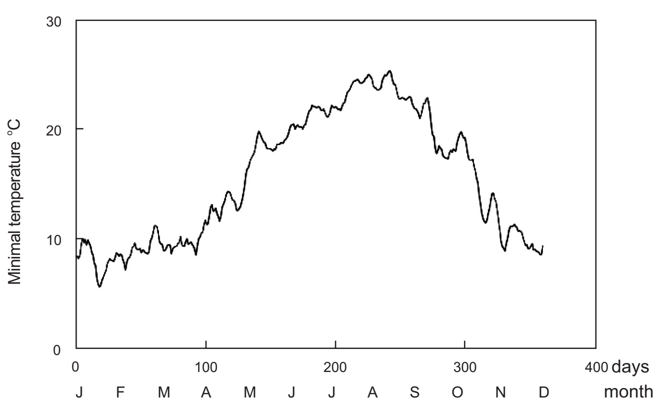

Fig. (4). Annual changes in Minimal temperature.

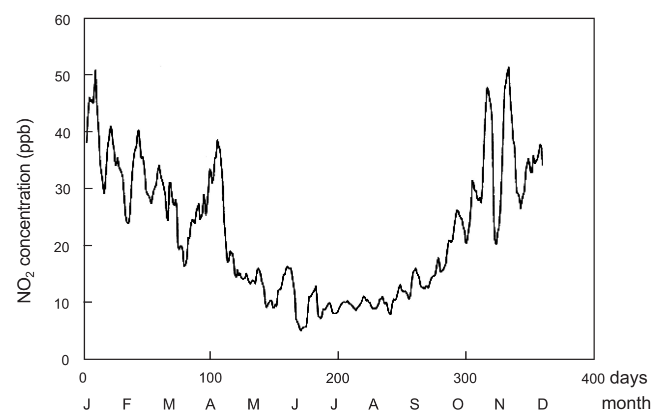

Fig. (6). Annual changes in NO_2 concentration in the air.

with O_3 concentrations (r=-0.70), with minimal temperatures (r=-0.40) and maximal temperatures (r=-.42) (Table **1**), and more positive with concentrations of NO_2 (r=0.68), SO_2 (r=0.60) and high barometric pressure (r=0.54). The correlation between ER visits and airborne particulates (PM_{10}) (Fig. **9**) or between ER visits and RH (Fig. **10**) was low, except for the month of September.

The concentrations of airborne pollen varied with the flowering season of each species. It was maximal during the spring (Fig. **11**). However, none of the pollen was significantly correlated with ER visits. A positive correlation was found between ER visits and concentrations of airborne spores (Fig. **12**).

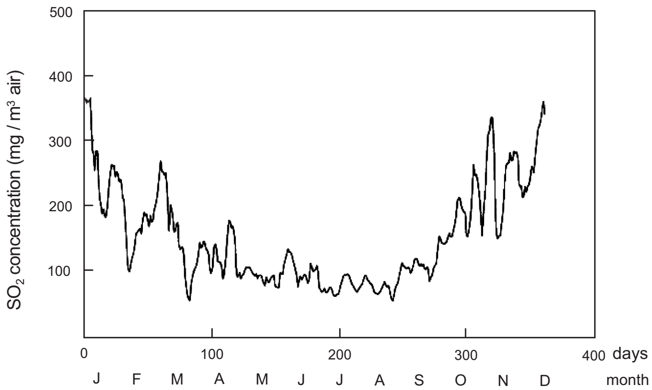

Fig. (7). Annual changes in SO_2 concentration in the air.

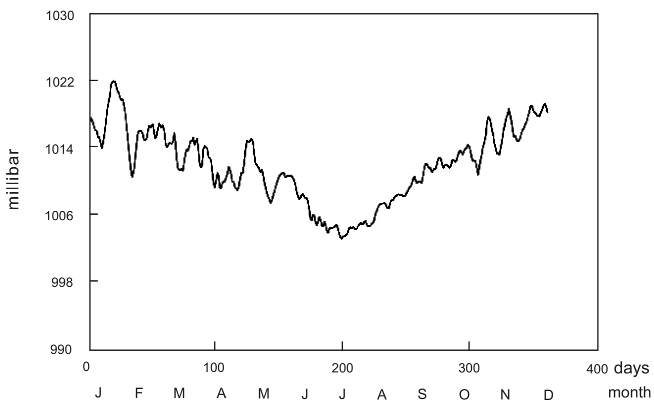

Fig. (8). Annual changes in Barometric pressure.

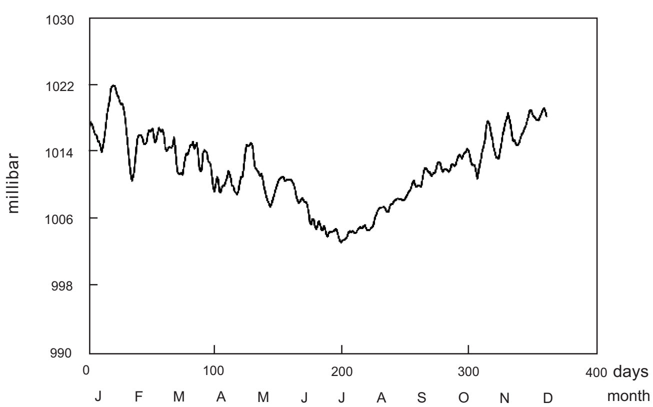

Fig. (9). Annual changes in Particulate (PM_{10}) concentration.

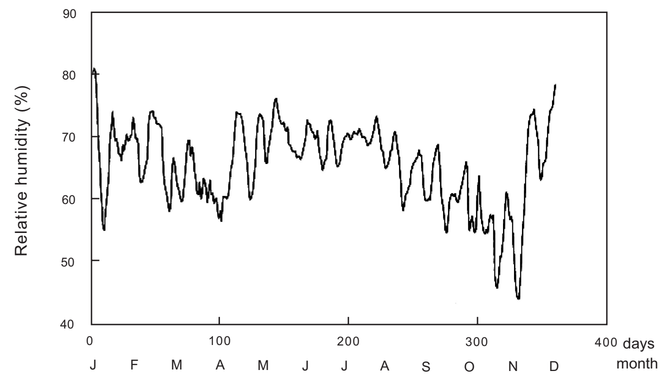

Fig. (10). Annual changes in Relative humidity.

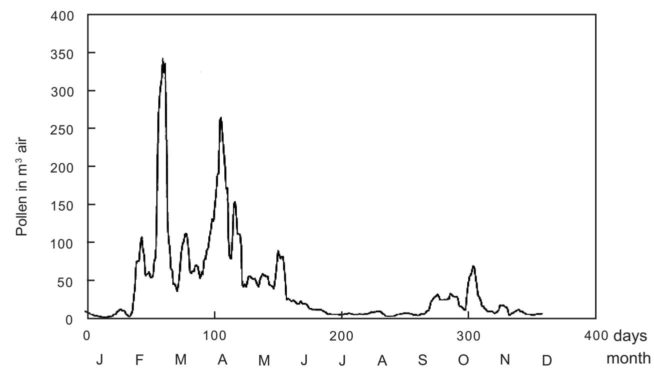

Fig. (11). Annual changes in airborne pollen count.

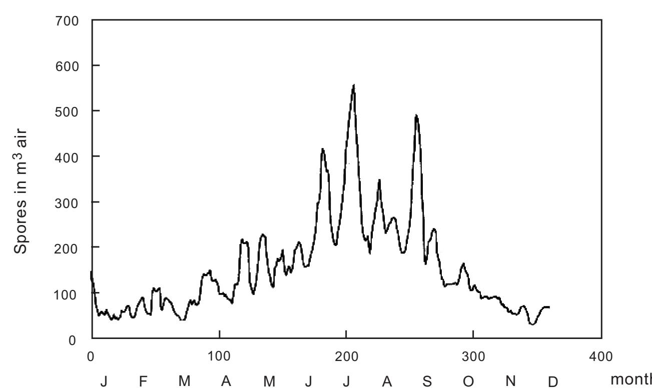

Fig. (12). Annual changes in airborne spore count.

The deviation from the mean annual ER visits has shown that approximately 37% of the variance in the number of ER visits during the entire year was explained by fluctuations in O_3, 35% by NO_2; 25% by SO_2, and 24% by barometric pressure. Changes in the minimal and maximal temperatures explained only 7% and 8% of the variance and therefore cannot be considered as major effectors. When the data for September were excluded, O_3 alone explained 49% of the variance, NO_2 explained 46% of the variance, SO_2 explained 36%, barometric pressure 28%, minimal temperature 16% and maximal temperature 18% (Table **2**). Regression analysis of sets of parameters revealed that 54% of the variance of the weekly running mean of ER visits was explained by O_3 + NO_2 or by O_3+NO_2+SO_2. The set of weather parameters explained 31% of the variance. The set of all air pollution and weather parameters calculated for the 11-month period (without September) explained 58% of the weekly variance (Table **2**).

Statistical analysis (F-test) of the correlation between the individual environmental factors and ER visits of asthmatic children and multiple regression analysis of ER visits versus

Table 2. Effects of Individual and Combined Environmental Factors (Multiple Regression Analysis) on Variance of 7-day Running Mean of ER Visits of Asthmatic Patients for 11 Month (Excluding September)

Factor	Percent of Variance of ER Visits of Asthmatic Children Explained by Factor
Polluting gases	
O_3	49
NO_2	46
SO_2	36
O_3+NO_2	54
O_3+NO_2+SO_2	54
Weather parameters	
Barometric pressure	28
Minimal temperature	16
Maximal temperature	18
Combined parameters	
Barometric pressure + minimal and maximal temperatures + relative humidity	31
O_3+NO_2+SO_2+barometric pressure	55
All parameters	
O_3+NO_2+SO_2+particulates+ barometric pressure + minimal and maximal temperature + relative humidity	58

P<0.001 for all values

the sets of environmental factors yielded highly significant values ($p<0.001$).

DISCUSSION

Air pollution is a serious health hazard, especially for people with allergic diseases. A significant connection between air pollution and respiratory symptoms or with increased use of bronchodilators was noted [9, 10, 19, 20].

Polluted air contains a mixture of substances. NO_2 causes increased bronchial reactivity in asthmatic children, potentiate s the effects of other gaseous air pollutants [20, 21] and of airborne plant allergens [9, 21-23]. People with asthma are particularly sensitive to high SO_2 concentrations [22, 24]. Exposure to SO_2 causes airway inflammation which is manifested by increased numbers of mast cells, alveolar macrophages and lymphocytes in the bronchoalveolar lavage.

The smaller particles (PM_{10}), a mixture of smoke, minerals and organic dust, seem to enter readily into the respiratory tract and to cause irritation of the lungs [10, 25] and asthma exacerbation [19, 20, 26]. Thus, it is interesting to note that according to our results, airborne particulates (PM_{10}) were not significantly correlated with the annual ER visits of asthmatic children, except for the month of September. During this month airborne particulates have probably contributed to asthma morbidity in addition to the "background" morbidity during the rest of the year.

Several environmental factors were correlated with severe asthma morbidity in children. In general, the effect of gaseous air pollutants throughout the year was stronger than that of extreme weather conditions. Negative correlations were established between ER visits and O_3 concentrations whereas positive correlations were found with NO_2, SO_2 and high barometric pressure.

When the data for September were excluded from the annual calculations, the correlation between the ER visits and the combined environmental conditions was significantly improved. September is the beginning of the kindergarten and school year, causing high psychological stresses and an increased incidence of viral infections [27]. Still, the effects of other confounding factors e.g., $PM_{10,}$ can not be ruled out [28, 29].

In the present study, as well as in our previous one [18], ozone concentrations correlated negatively with ER visits of asthmatic children. Ozone is generally known as a potentially damaging factor, affecting the respiratory tract tissues. The effects of ozone on the airways depends on its concentration, the duration of exposure, and the intensity of the subjects physical activity [14, 17, 30]. According to WHO recommendations, the threshold for ozone exposure are 76-100 ppb for 1hour or 50-60 ppb for 8 hours [31]. Concentrations of ~120 ppb can increase bronchial responsiveness to allergens in asthmatic patients, without affecting their baseline pulmonary functions [32]. Higher concentrations of O_3 (200-400 ppb) cause bronchial hyperactivity. The mechanisms underlying such relationships remain unclear and conflicting data were presented. Some authors have postulated that ozone causes an inflammatory reaction with vasodilatation and greater absorption of allergens [32]. Results of others failed to show significant changes until a threshold concentration of approximately 40 ppb was reached [33-37].

Reports from Vancouver [15], Seattle [38] and central USA [35] showed that ozone levels were either uncorrelated with asthma incidence or were inversely correlated with daily asthma attack rates [36]. A positive correlation between ER visits of asthmatic children and O_3 was reported from Spain, France and Singapore [39-42]. On the other hand, a negative correlation between certain ozone concentrations and ER visits of wheezing children, indicated that certain O_3 concentrations can be protective [19].

Seasonality in childhood asthma morbidity has been found in an extensive study (NCICAS) which included eight major cities in the United States [5]. The authors speculated that the cause of the seasonality was viral respiratory infections. No correlation between childhood asthma and O_3 concentration was found in this study, though an apparent reverse relationship can be seen between wheezing and O_3 concentration [5].

A significant negative correlation between previous day ozone concentration and several lung function parameters (forced vital capacity and expiratory flow) was found for children in the Netherlands [16].

Ozone can prime the bronchial airways for increased responses to subsequently encountered allergens [43] or air pollutants [44] and the effect of ozone may depend on a second insult. Support for this hypothesis was found in the time lag observed between exposure to ozone and a decrease in forced vital capacity [45, 46].

It is somewhat astonishing that no meaningful correlation was found in our study between the number of ER visits and the recorded levels of airborne pollen and spores. However, the lack of information regarding possible allergic responses of each of the examined patients to specific allergens prevented us from exploring the individual correlation between specific airborne allergens and asthma exacerbation.

The effects of individual environmental factors are intensified when they act in concert. Previous studies have shown that the combination of air pollutants with certain weather conditions has a cumulative effect on asthma exacerbation [11-12, 47]. The present study supports this concept. Most epidemiological studies on effects of pollution on human health are limited by the absence of information on the actual exposure of individual patients. Nevertheless, our data support the hypothesis that certain combinations of air pollutants, and weather parameters, are highly correlated with severe wheezing in children.

The superfluous number of ER visits of asthmatic children during September is interesting because it coincided with the beginning of the kindergarten and school year which may involve increased exposure to viral infections [8] and to psychological stresses.

A similar observation was reported from Brighton (UK) [5].

In conclusion, the present study raised at least two crucial points: a) The seasonality of asthma morbidity with a definite increase in ER visits of asthmatic children during September; b) The apparent “protective” effect of certain ozone concentrations on asthma exacerbations.

ACKNOWLEDGMENT

The authors thank the Israel Electric Company and the Meteorological Service of Israel for the environmental data; and Charlotte Sachs and Gloria Ginzach for their assistance.

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Received: June 04, 2008 Revised: November 04, 2008 Accepted: November 04, 2008