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# Analysis of the influence of climatic changes and atmospheric pollutants on respiratory diseases in children in an emergency setting

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# Analysis of the influence of climatic changes and atmospheric pollutants on respiratory diseases in children in an emergency setting

**Luciana Abrantes Pontes de Azevedo,* Marli Berenstein,* Fabio Ferreira de Carvalho Junior****

*ABSTRACT*

***Background:*** *In pediatric practice, the influence of external factors (pollutants and/or climate) in the triggering or worsening of respiratory disease is a frequent point of debate.*
***Objective:*** *To evaluate the importance of and correlation between climatic factors (temperature and relative air humidity) and atmospheric pollutants (particulate matter, sulfur dioxide and carbon monoxide) on the incidence of respiratory diseases, classified by the ICD from 460 to 519, in children evaluated at the Emergency Department of the Hospital Professor Edmundo Vasconcelos between January and June 1998.*
***Results:*** *A total of 4,315 children (up to five years of age) were attended. Their distribution was compared on a daily basis with data provided by the Companhia de Tecnologia de Saneamento Ambiental (CETESB) (Environment Sanitation Technology Company), using simple and multiple linear regression methods.*
***Conclutions:*** *A slight but significant influence of minimum temperature (inverse correlation) and particulate matter concentration (explaining 32% of occurrences in conjunction with minimum temperature) was detected on the incidence of respiratory diseases in the children evaluated at the Emergency Department during this period.*

***Key words:*** *Respiratory diseases, children, climatic factors, atmospheric pollutants, emergency* department.

RESUMEN

**Antecedentes**: En la práctica pediátrica, se discute frecuentemente qué tanto los factores externos (la contaminación y/o el clima) influencian sobre el desencadenamiento o empeoramiento de las enfermedades respiratorias.
**Objetivo:** Evaluar la importancia de y la correlación entre los factores climatológicos (temperatura y humedad relativa del aire) y los contaminantes atmosféricos (partículas, dióxido de sulfuro y monóxido de carbono) de un lado y del otro lado la incidencia de enfermedades respiratorias, clasificadas por el Código Internacional de Enfermedades a partir del 460 a 519, en los niños atendidos en el Departamento de Urgencias del Hospital Profesor Edmundo Vasconcelos entre enero y junio de 1998.
**Resultados:** Se evaluó a un total de 4,315 niños (hasta cinco años de edad). La distribución del número de niños por día fue comparada con una base diaria con los datos proporcionados por la

* MD, Resident in Pediatrics at the Hospital Professor Edmundo Vasconcelos (HPEV)
** MD, Master's Degree in Pediatrics, Specialist in Allergy and Immunology.
Study done at the Pediatric Emergency Department of the Hospital Professor Edmundo Vasconcelos, São Paulo, Brazil.

Companhia de Tecnología de Saneamento Ambiental (CETESB), con métodos simples y múltiples de regresión lineal. La evaluación estadística mostró una pequeña, pero significativa, influencia de la disminución de la temperatura mínima (relación inversa) y de la concentración de partículas (relación directa) sobre el número de niños atendidos.
**Conclusiones:** La asociación entre la temperatura mínima y concentración de partículas explica cerca de un tercio (32%) de las enfermedades respiratorias en esta población estudiada.

**Palabras clave:** Enfermedades respiratorias, niños, factores climatológicos, contaminantes atmosféricos, servicio de urgencias.

## INTRODUCTION

The influence of external factors (pollutants or climatic) on the triggering or worsening of respiratory disease has been studied for a long time. It remains however, a frequent, almost daily inquiry by concerned mothers in pediatric practice and very often the physician's answer either has no scientific basis or is simply based on personal experience.

The importance of respiratory diseases in an emergency setting is unquestionable. Upper respiratory infections are the most frequent acute infections in preschool children (one or more episodes per month during the first year of kindergarten on average). It is generally rhinitis, frequently associated with pharyngitis, otitis, sinusitis (from 4 years of age onwards), laryngitis, tracheitis and/or bronchitis.

Asthma is a frequent respiratory disease of childhood. It is a chronic disease, characterized by sporadic attacks of dyspnea and cough due to bronchial constriction and edema of the bronchial mucous membranes, where allergens, emotional stress, bronchopulmonary and upper airway infection (sinusitis) and *atmospheric conditions* are factors which may aggravate the disease.

Other important respiratory diseases are allergic rhinitis and bronchopneumonia.

Several epidemiologic studies correlate climatic variations with respiratory disease.

The level of air pollution is measured by the quantification of its polluting substances. A substance is considered an air pollutant, when —by its concentration— it may render the air improper, noxious or injurious to one's health, inconvenient to the public health, harmful to inert matter, fauna or flora and also harmful to the security in the use and enjoyment of property and normal activities of the community.

On determining a pollutant's concentration in the atmosphere, one measures the following: the degree of receptors' (human beings, animals, plants and inert matter) exposition as the final result of the emission of pollutants into the atmosphere by their sources, as well as their interaction in the atmosphere like physical dilution and chemical interaction.

It is important to note that even though emission of pollutants may be kept at a constant rate, the quality of air may change according to atmospheric conditions which determine their dilution to a greater or lesser degree. This is the reason why the quality of air worsens in winter, when atmospheric conditions are the most unfavorable for pollutant dispersion.[1]

The most frequent pollutants are :

1) *Particulate matter:* produced by coal and oil combustion, it is found in diesel emissions. They are particles with an aerodynamic diameter equivalent to less than 10 nm, whose effect on health is dependent on the airways' capacity to remove the inhaled particles, retaining them or not into the lungs. Among the inhaled particles, the larger ones are retained in the upper airways. The smaller the particles, the deeper they are able to penetrate, reaching pulmonary alveoli. It is the smaller particle which causes greater damage.

2) *Sulfur dioxide:* The effect of gases on human health is directly associated to their solubility into the airway lining [wall], which will determine the quantity of the pollutant able to reach the deepest parts of the respiratory system. There is evidence that sulfur dioxide aggravates preexisting respiratory diseases as well as contributes to their appearance. Alone, this gas produces airway irritation and if absorbed and reaching deeper parts, it may produce pulmonary tissue damage. Epidemiologic and clinical studies show that some people are more sensitive to sulfur dioxide than others.

3) *Carbon monoxide:* effects of exposition depend on the blood's capacity of oxygen transport. Carbon monoxide competes with oxygen to combine with blood's hemoglobin, and the latter's affinity for carbon monoxide is 210 times greater than for oxygen. Once the hemoglobin molecule receives a carbon monoxide molecule, carboxihemoglobin is formed with subsequent decrease in oxygen transport capacity.

4) *Photochemical oxidants:* This is the term used to designate the mixture of secondary pollutants formed by the reaction of hydrocarbons and nitrogen oxides in the presence of sunlight, of which the gas ozone is the principal ingredient.

Their presence in the atmosphere has been associated with reduction in pulmonary capacity as well as aggravation of respiratory diseases like asthma. Animal studies show that ozone causes premature aging, pulmonary structural lesions and decrease of resistance to pulmonary infections.

Of all nitrogen oxides, only nitrogen dioxide ($NO_2$) is noxious by itself. Due to low solubility, it may penetrate deeply into the pulmonary tree, giving origin to nitrosamines, some of which may be carcinogenic. Nitrogen dioxide is also a powerful irritant, causing symptoms reminiscent of emphysema.[2]

Among pollutants frequently mentioned as potentially important in respiratory diseases, are particulate matter and ozone. Examples of the effect of these substances include increase in chronic cough, thoracic and bronchial disease, increase in the incidence of hospital admissions for various respiratory conditions and worsening of pulmonary function where chronic exposure to environmental pollution may have long-term deleterious effects, especially in adults with chronic obstructive pulmonary disease.[3] Respiratory symptoms increase a lot, especially in children with asthma or wheezing.

Schwartz et al studied the children of five cities in Germany and were able to correlate an increase of the incidence of viral croup with an increase in the number of pollutants, especially suspended particulate matter and nitrogen dioxide. However, these authors were unable to identify the association of obstructive bronchitis with a particular pollutant.[4]

Rhomberg et al (1992) reported higher incidence of asthma and other respiratory diseases in urban and industrialized compared with less polluted areas. In a region of Austria with high concentrations of ozone, children had a higher incidence of asthma and alterations in their pulmonary function tests than those living elsewhere.

In a study of preschool children in Birmingham, there was a significant correlation between hospital admissions for asthma and heavy traffic volume. This was also true for children who lived within a distance of up to 500 m from a highway (Edwards et al, 1994).

Sudden temperature changes also seem to influence children's health in a negative way, either by contributing to precipitate respiratory diseases or by decreasing pollutant dispersion, thereby leaving these irritating substances in contact with the airways over longer periods of time. Vidal et al studied this aspect among children in Pennsylvania (USA), finding an increase in lower and upper respiratory infections associated with a fall in temperature.[5]

Geographically, the Metropolitan area of São Paulo is situated in a lower compartment of the Atlantic Plateau with a temperate climate, a cold dry winter and a humid hot summer. Temperatures vary between 8° C in the colder months and 30° C in the hot months. The annual rain fall is about 1,500 mm, the major part of which occurs between October and March.

Systematic observations of climate and weather in this region permit the determination of two distinct periods: one from September to April when a sea breeze due to great atmospheric instability favors pollutant dispersion; the other, from May to August, is critical due to great atmospheric stability with thermal inversions at lower levels of the atmosphere and poor pollutant dispersion, especially at night as well as during the early hours of the mornings and lasting several hours.

In Brazil, several studies have been performed to emphasize especially the negative aspects of temperature and atmospheric pollution on the people living in the town of São Paulo.[6,7]

Carvalho Jr et al in 1989 described the importance of temperature variation on the increase of the incidence of upper airway infections and asthma attacks in a group of children seen at a Pediatric Emergency Departement in São Paulo. They failed to relate these diseases to external pollutants.[8]

Data about respiratory morbidity and mortality are scarce in Brazil. Naspitz et al found an increase in the mortality due to asthma and respiratory diseases in a population of São Paulo aged 5 to 34 years over the 10 year period from 1984 to 1994.[7] However, they were unable to establish an association between the level of pollutants and the coefficient of mortality. However, Saldiva et al, who studied a population of children up to four years of age, were able to identify an association between increase of nitrogen particles and mortality due to respiratory diseases. Neither of these studies however, were able to correlate any temperature changes with an increase in the incidence of respiratory diseases.[8]

Our objective was to study the correlation between atmospheric and climatic factors and the number of respiratory events (airway infections, asthma attacks, laryngitis and rhinitis) in children attending the Pediatric Emergency Department of the HPEV between January and June 1998.

## MATERIAL AND METHODS

### Clinical material/patients

A retrospective study was realized of the number of children from birth to five years of age who were evaluated at the Pediatric Emergency Department of the HPEV with a diagnosis classified by the ICD numbers 460 through 519 (respiratory diseases including bronchial asthma), and seen between January and June 1998. These particular months were chosen as it is known that between January and April, pollutant dispersion is more easily achieved, while this does not occur in May and June. The children were grouped on a daily basis and separated every month. The population of children studied was 4315 as seen in *table 1*.

During the study period, the climatic seasons were well defined.

**Table 1. Average (median), total and monthly number of children with diagnosis of Respiratory Disease in Childhood (RDC), attended at the Emergency Department-HPEV, Jan/Jun. 1998.**

| January | February | March | April | May | June | Average/month | Total |
|---|---|---|---|---|---|---|---|
| 336 | 403 | 557 | 882 | 1217 | 920 | 719.17 | 4,315 |

Source: Medical Archives and Statistics-HPEV.

**Table 2. Median/Average monthly levels of external pollutants and climatic alterations in the Metropolitan Area of São Paulo during Jan/Jun/ 1998.**

| | CO (ppm) | IP (µg/m³) | $SO_2$ (µg/m³) | URA Max (%) | URA Min T (%) | Max T (° C) | Min (° C) |
|---|---|---|---|---|---|---|---|
| January | 2.99 | 42.23m | 7.82 | 97.33 | 51.01 | 29.51 | 20.47 |
| February | 3.14 | 38.25 | 6.77 | 99.06 | 57.76 | 28.38 | 20.45 |
| March | 3.56 | 45.5 | 10.89 | 98.87 | 56.29 | 27.93 | 19.65 |
| April | 3.35 | 51.39 | 11.47 | 98.11 | 56.18 | 25.52 | 17.84 |
| May | 4.05 | 61.15 | 16.63 | 97.99 | 56.6 | 22.06 | 14.19 |
| June | 3.62 | 57.96 | 18.26 | 97.33 | 53.1 | 20.77 | 12.77 |

Source: CETESB of São Paulo, 1998. CO = Carbon monoxide; PM (IP) = Inhalable particles; $SO_2$ = Sulfur dioxide RAH(URA) max, min = Relative air humidity, maximum, minimum. T = Temperature.

**Environmental variations:** atmospheric pollution and climatic conditions.

The daily quantities of $SO_2$ (sulfur dioxide), PM (particulate matter), $NO_2$ (nitrogen dioxide) and CO (carbon monoxide) were obtained from CETESB, as well as the daily minimum and maximum temperatures (°C) and the relative air humidity (%) at minimum and maximum values for the Metropolitan Area of São Paulo. The data are those for the year 1998 at Ibirapuera, Parque D. Pedro II, Congonhas, Inner-City and Osasco Stations. These are the stations existing in the Metropolitan Area of São Paulo, from which all children attended in the study originated. The values used are the median / average daily value *(Table 2)*. It must be noted that during the study, no atmospheric levels compatible with «Alarm State» were present.

**Statistical analysis:**

Univariate methods were used: the Pearson linear regression coefficient, simple linear regression analysis and multivariate multiple linear regression using the «Stepwise» method for choice of variables. The significance level of 0.05 ( = 5%) was adopted. Descriptive (p) levels inferior to this value were considered significant and are represented by*.

RESULTS

***Results of statistical evaluation.***

**Results of Linear Regression:** simple linear regression with occurrence of respiratory disease and other above mentioned parameters for children from birth up to the age of 5.

— relative to the month

number of events = 5.29857 + 5.29757 x month
EP = 1.77 EP = 0.45
$R^2$ = 0.43
r = 0.66 P < 0,001*

— relative to CO quantity

r = 0.12 P = 0.1000 ⟶ regression not significant

— relative to inhalable particles

number of events

— relative to $SO_2$ quantity

number of events = 16.16496 + 0.15558 x IP
EP = 2.56 EP = 0.05
$R^2$ = 0.06
r = 0.24 P = 0.001*

— relative to the relative air humidity-maximum
r = - 0.04 P = 0.613 ⟶ regression not significant

— relative to the relative air humidity- minimum
r = - 0.03 P = 0.711 ⟶ regression not significant

— relative to maximum daily temperature
number of events = 57,10366 - 1,29635 x Tmax.
EP = 5.25 EP = 0.20
$R^2 = 0.19$
r = - 0.43 P < 0.001*

— relative to minimum daily temperature
number of events = 62.26896 - 2.19440 x Tmin.
EP = 4.42 EP = 0.25
$R^2 = 0.30$
r = - 0.55 P < 0.001*

Results of Multiple Linear Regression with respiratory disease events and other parameters:

Number of events = 3.96985 + 6.09998 x month - 0.57419 x $SO_2$ + 0.10534 x IP
EP = 2.23 EP = 0.56 EP = 0.20 EP = 0.05
$R^2 = 0.46$

Results of Multiple Linear Regression with respiratory disease and other above mentioned parameters for children up to the age of five years *without* the inclusion of the «month» variable:

Number of events = 56.18734 - 2.08842 x Tmin + 0.08521 x IP
EP = 5.28 EP = 0.25 EP = 0.04
$R^2 = 0.32$

It can be concluded from the coefficients of linear correlation and analysis of simple regression that the «month» variable was the variable which showed greatest correlation with the number of occurrences, representing thus an association between number of events and the season of the year.

The CO quantity, maximum and minimum air humidity data did not show significant correlation. The $SO_2$ and IP data showed significant but very slight correlation. The minimum and maximum temperature measurements showed a significant inverse correlation, that is, the higher the temperature, the less daily events occurred.

Multiple regression permits the verification of the presence of variables associated between themselves and capable of explaining the variation between daily occurrences.

The first model showed that the «month» variable was the most important (greatest coefficient) followed by the «$SO_2$ measurement» with a negative association (negative coefficient) and the «Inhaled Pollutants measurement». This set of variables is responsible for 46% of the number of occurrences ($R^2$ = 0,46)

The proposed regression analysis (multiple linear regression) was the non-inclusion of the variable «month», as it could be «carrying» other variables closely associated to it. To explain it better, the variable «month» showed correlation with the studied parameters as follows: with CO: r = 0.23 P = 0.002*; with RAH max : r = 0.01 P = 0.895; with RAH min: r = 0.04 P = 0.579; with IP: r = 0.35 P < 0.001*; with $SO_2$: r = 0.59 P < 0.001*; with Tmax: r = 0.69 P < 0.001* and with Tmin: r = 0.82 P < 0.001*.

At the second analysis, the most important variable was «minimum temperature» with inverse association and «IP» with direct association. This set of variables is responsible for 32% of the number of occurrences ($R^2$ = 0.32)

## DISCUSSION

The Metropolitan Area of São Paulo suffers from atmospheric pollution due to growing industrialization, urbanization and intrinsic geographical conditions.

In 1980, Whitemore et al showed an increase in the number of asthma attacks on days with increased levels of oxidizing material, pollutant particles, cold temperature as well as on Saturdays.[9] Perry et al in 1982 described an increase in the use of bronchodilators with atmospheric variations of nitrates, which was not noticed with variations in sulfates, coal, CO, $SO_2$, $O_3$, temperature and barometric pressure.[10] Dockery et al in 1982 showed an important decrease in pulmonary function with increased concentrations of sulfur dioxide in the atmosphere.[11] Schwartz et al in 1991 demonstrated a relationship between the quantity of particulate matter and coughing.[4]

Pierson and Koening in 1992 described an increase in the susceptibility to allergic disease as well as adverse effects on allergic diseases with increased pollution.[12]

In the presence of high levels of particulate material and $SO_2$ in the air, there is a decrease in pulmonary function according to Dassen et al in 1986, Charpin et al in 1988 and Pope III et al in 1991.[13]

Studies in 1987 by Vedal et al demonstrated that cold temperature had no influence on wheezing, secretions or Peak Expiratory Flow (PEF) in the presence of $NO_2$, $SO_2$, $O_3$, maximum and minimum temperature variations.[5]

At Emergency Departments, Yamamoto et al in 1993 showed an increased number of admissions for wheezing (not specifying age-range of the population studied) depending on climatic and infectious conditions («sic») during certain months of the year.[14]

There is a general consensus in the literature that with atmospheric conditions at levels of «state of attention», there is an exacerbation of asthmatic symptomatology, decrease in pulmonary function and aggravation of respiratory diseases in children.

Children are particularly vulnerable to particulate material (The ERA Children's Environmental Yearbook

1994): they spend more time outdoors or engage in more vigorous physical exercises with higher respiratory rates than adults, which lead them to inhale greater amounts of particles.[15]

Burr in 1995 demonstrated that variations in the levels of particulate matter are associated with higher levels of hospital admission due to asthma attacks, school absenteeism and decrease in pulmonary function.[16]

More recent data from the Committee of Environmental Health of the American Academy of Pediatrics (1993) and the Committee of Environmental and Occupational Health of the American Society of Thoracic Diseases (1996) clearly demonstrated the influence of external pollutants on the genesis of respiratory disease in childhood (RDC), with special emphasis on nitrogen oxides, carbon monoxide and particulate material.[17,18]

Results in our study show a notable increase in the number of children affected with respiratory diseases during the months of May and June, which in Brazil represent the months of the winter season where this is normal in all age groups, especially for respiratory disease of viral origin. They are the months with a concurrent decrease in dispersion of external air pollutants . After exclusion of seasonal variation (irregular distribution during the months), multiple linear regression demonstrated that the increase in Emergency Department attendance in our hospital relative to Infectious Respiratory Disease (IRD) was due to decrease in temperature (inverse relationship with minimum temperature) and quantity of particulate material (direct relationship). These data reinforce the hypothesis that temperature and levels of external pollutants (particulate material) have a direct influence on IRD episodes in children. These observations corroborate data from the literature and results from clinical observation.

These data also reinforce the necessity to elaborate collective and individual action to control the triggering factors proposed in this study. Collectively, there is a necessity of efficient government action to control external pollutant levels, a function already efficiently realized by CETESB and which should be frequently stimulated. A better quality of life for the individual person is synonymous with sanitary education of people, resulting also directly from efficient control measures of atmospheric pollutants.

Individually, pediatric orientation for IRD prevention is fundamental. Mothers must constantly be reminded, especially during winter months, that their children must be clothed adequately, according to climatic conditions. They must also remain attentive to the following matters: indoor humidity should be kept constant through the use of air humidifiers and dryers and their children should be kept away from great agglomerations of people in closed rooms, a common occurrence in winter as well as from atmospheric conditions with known high concentrations of air pollutants, e.g. traffic jams or near polluting factories.

These orientations are even more important for high risk children like asthmatic or cystic fibrosis children in whom climatic variations and external pollutants will aggravate their symptoms.

It is always important to emphasize that particulate material, carbon monoxide, sulfur dioxide and nitrogen dioxide are but four of the four thousand different chemical, carcinogenic or airway irritating compounds present in cigarette smoke, which is one of the most important domestic pollutants.

We are aware that environmental factors are not solely responsible for the precipitation of and/or aggravation of respiratory disease: they act in conjunction with hereditary genetic predisposition and other important triggering factors like indoor pollutants and infectious processes.

## CONCLUSION

During the period studied, there was a small but significant influence of outdoor alterations (minimal temperature and particulate material) on the incidence of Respiratory Diseases of Childhood (RDC) among the children attended at the Emergency Department of HPEV.

This study brings but a small contribution to the research on the influence of external factors on RDC: population studies with standardized methods should be undertaken to establish a definite relationship between atmospheric pollutants and climatic factors on RDC.

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Address:
Fabio F. de Carvalho Junior
Rua Comendador Miguel calfat, 183 ap. 21B
São Paulo/ SP Brasil
CEP 04537-080
E-mail: ffcarvalho@sti.com.br