

Effects of air pollution on children's health in a city in Southeastern Brazil

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Keywords

Air pollution, health effects.
Respiratory diseases. Pneumonia.
Children health. Ecological study. Time series.

Abstract

Objective

Of the effects of air pollution on children's health, increased pneumonia admission rate is one of the most important. The study aimed at estimating the association between pneumonia admissions and increased air pollutants.

Methods

An ecological time-series study was carried out in the municipality of São José dos Campos, Southeastern Brazil, in the years 2000 and 2001. Daily records of pneumonia admissions, air pollutants (SO₂, O₃, and PM₁₀) and weather conditions (temperature and humidity) were analyzed. The correlations between the study variables were estimated using Pearson's correlation. The associations between pneumonia and air pollutants were estimated using generalized additive Poisson regression models. The percentage increase (and their respective 95% CI) in pneumonia admission rate was estimated for the interquartile range of each air pollutant studied.

Results

The three pollutants analyzed presented lagged effects on pneumonia admission rate, beginning at lag 3 or 4 and lasting for no more than two days. The 8-day cumulative effect estimate showed that an increase of 24.7 mg/m³ in PM₁₀ concentration increased pneumonia admission rate in 9.8%.

Conclusions

The study corroborates that adverse health effects of air pollutants can be observed even in medium-sized cities. The magnitude of the effect was similar to that found in the city of São Paulo. Moreover, children are highly susceptible to air pollution exposure.

INTRODUCTION

Anthropogenic air pollution agents are known to enter the body mostly through inhalation and thus cause major effects in the respiratory system.¹

Exposure to environmental pollutants has been established as an important risk factor for hospital admissions in children,^{4,5,9} school absenteeism,¹¹ intrauterine mortality¹² as well as birth defects.¹³ There is strong evidence showing the association of air pollution and significant increase in the risk of death

and chronic diseases in children, adverse pregnancy outcomes and severe illnesses.^{4,12,15} The most prominent air pollutants associated to these outcomes are sulphur dioxide (SO₂), ozone (O₃) and particulate matter having an aerodynamic diameter of less than 10 μm (PM₁₀).

Absorbed in the upper airways, SO₂ deposits in the lower respiratory tract and pulmonary parenchyma, noticeably producing respiratory irritation. This agent can cause reduced pulmonary function⁶ and pulmonary necrosis have described in animals.

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The major sources of sulphur dioxide emissions are mineral coal- and oil-fired plants as well as fossil-fuelled motor vehicles.

Under solar radiation, pollutants that remain close to the Earth surface undergo photochemical reactions producing O₃. This agent is able to reach the deepest pulmonary cell layers causing inflammation and reduced pulmonary function.⁶ A powerful oxidative agent, O₃ is involved in intra and extracellular reactions catalyzed by major metabolic enzymes.

Particulate matter, mostly originated by fossil fuel burn-up, may have a half-life of days or even years. It has been associated to increased respiratory symptoms and illnesses in children, frequent severe asthma episodes^{6,9} and, more recently, to low birth weight³ and increased infant mortality.¹⁰ PM₁₀ can affect pulmonary alveoli.

Most studies carried out in Brazil to assess the association between air pollution and respiratory conditions have been developed in large urban centers, such as the cities of São Paulo, Rio de Janeiro and Curitiba.^{2,4,5,8,12} Yet little is known on the effects of air pollution resulting largely from plant and motor vehicles emissions outside the geographic outreach of large metropolitan areas.

The present study aimed at exploring the association between exposure to air pollutants and respiratory disease in children, which was characterized by pneumonia admissions.

METHODS

A study was carried out in the municipality of São José dos Campos, a middle-sized urban center with a large industrial park and sizeable motor vehicle fleet. São José dos Campos is located in Alto Vale do Paraíba in the state of São Paulo, about 80 km far from the capital, and has a population of approximately 550,000 inhabitants living over an area of 1,142 km².

An ecological time-series was conducted comprising daily pneumonia admissions (ICD-10: J12-J18) of children aged up to 10 years in the period between May 1st, 2000 and December 31, 2001. Data was collected from the Information System and Information Technology Department of the Brazilian National Healthcare System (Datusus). For ascertaining hospital admission data, the first three months of the year 2002 were assessed for any information concerning admissions up to December 31, 2001.

Daily records of SO₂, O₃ and PM₁₀ pollutant and

weather conditions, such as temperature and humidity, were obtained from the São Paulo State Environmental Agency (Companhia de Tecnologia de Saneamento Ambiental - Cetesb), which collects data at two local air pollution control stations. Data collection for all pollutants would start at the first hour of the day and last for 24 hours; all pollutant measurements were in µg/m³. Daily means was calculated for each pollutant. Beta monitor, coulometry and chemiluminescence were used for measuring PM₁₀, SO₂ and O₃ emissions, respectively.

Descriptive analyses of all variables were carried out and it was estimated the correlation between those variables of interest using Pearson's correlation coefficients. The association between daily pneumonia admission rate and air pollution was estimated using generalized additive Poisson regression models (GAMs).

Pneumonia admission rate is a counting event, and thus follows Poisson's distribution. Since the relationship between the dependent variable and long-term seasonality (time) is not necessarily linear, GAMs allowed the inclusion of semi-parametric and nonparametric smoothing functions in the regression model. By including a smoothing function of time, long-term basic seasonal patterns can be removed, eliminating thus random variability. For that, a nonparametric moving average smoother (Loess) was applied and the smoothing parameter was chosen as residual self-correlation could be minimized.

To minimize miscalculation of effect estimates and related standard errors,⁷ a single nonparametric smoothing function and convergence parameters more restrictive than those set as standard in GAMs of the statistics package used (S-PLUS) were included.

A linear relationship was assumed between service visits and air pollutants, minimum temperature and average humidity.

Health outcomes caused by pollution seem to follow a lagged pattern where biological manifestations take a time lag to develop after exposure to pollutants. This means that service visits recorded at a given day can be related to the level of air pollution on that same day as well as to that of preceding days. For more accurately defining the model to be used in the analysis, it is crucial to determine an optimal lag structure. Therefore, there were used models including lags up to seven days after exposure.

The effects were expressed in terms of increased hospital admission rates (and related 95% confidence

Table 1 - Descriptive analysis of atmospheric variables. São José dos Campos, Brazil, 2000-2001.

Variables	Descriptive analysis						
	Minimum	Quartile 1	Mean	SD*	Median	Quartile 3	Maximum
Hospital admission	0.0	1.0	2.1	1.8	2.0	3.0	9.0
PM ₁₀ (µg/m ³)	3.4	23.9	40.2	26.9	33.1	48.6	196.6
SO ₂ (µg/m ³)	0.8	3.7	6.2	3.9	5.1	7.5	36.0
O ₃ (µg/m ³)**	16.3	47.9	65.0	24.6	61.9	80.6	143.1
Temperature (°C)	4.1	16.7	19.0	3.5	19.6	21.7	25.6
Humidity (%)	47.1	76.3	81.6	9.4	81.8	87.7	98.5

*Mean standard deviation

**42 daily records missing during the study period

intervals) resulting from increased levels of air pollution, by means of pollutant interquartile range, expressed by the following formula:

$AP_{PN} = (e^{(\beta \cdot VIQPOL)} - 1) \cdot 100$, where AP_{PN} is the percentage variation in pneumonia admissions, and $VIQPOL$ is the difference between the upper limit values of the third and first quartiles of each pollutant concentration.

All analyses were carried out using SPLUS and SPSS 10.0 for Windows at a 5% significance level.

RESULTS

There were 1,265 pneumonia admissions of children aged between zero and 10 years during the study period. At the same time, the daily mean PM₁₀ and SO₂ concentrations were below the annual average air quality concentrations (50 and 80 µg/m³ respectively). In regard to the upper limit values for both pollutants, during three days, PM₁₀ showed daily peaks above the allowed upper limit (150 µg/m³). Unlike PM₁₀ and SO₂, O₃ did not show a clear seasonal variation during the study period; the former showed increased levels during cold days but they did not exceed the hourly upper limit (235 µg/m³) at any time (Table 1 and Figure 1).

While 42 O₃ daily records were missing, hospital admission information was obtained for all days during the study period. To confirm the last day of the study period, there were assessed records of the first three months of 2002 for additional information on hospital admissions as of December 31, 2001. There was no missing information for the variables temperature and humidity.

Table 2 shows the correlation matrix between the study variables. Small positive correlations were seen for the pollutants studied. Pneumonia admissions had positive correlations with PM₁₀ and SO₂ and a negative correlation with O₃. The weather variables showed negative correlations with hospital

admissions and pollutants, except for temperature and O₃, which had a positive correlation.

Table 3 shows Poisson regression coefficients for the three pollutants studied in each one of the lag structure days (exposure day up to seven days later) and for the daily sum of effects. The effects on hospital admissions were not immediately seen, i.e., at the day of increased pollutant levels, but they could be noticed three days after exposure and lasted for 24 to 48 hours, as in the case of PM₁₀. SO₂ had small positive effects during the study period with an increase on day 7 after exposure but this effect was not statistically significant. O₃ showed a pattern similar to PM₁₀, a 24-hour lag with positive effects that were greater at day 4 and day 5 after exposure.

When analyzing the cumulative effects for the 8-day period after exposure, it could be noted an increase of about 10% in pneumonia admission rates in children aged up to 10 years (Figure 2). Though the magnitude of cumulative effects for the 8-day-period for O₃ and SO₂ were similar to those found for PM₁₀, they were not statistically significant.

DISCUSSION

Time-series studies have showed an association

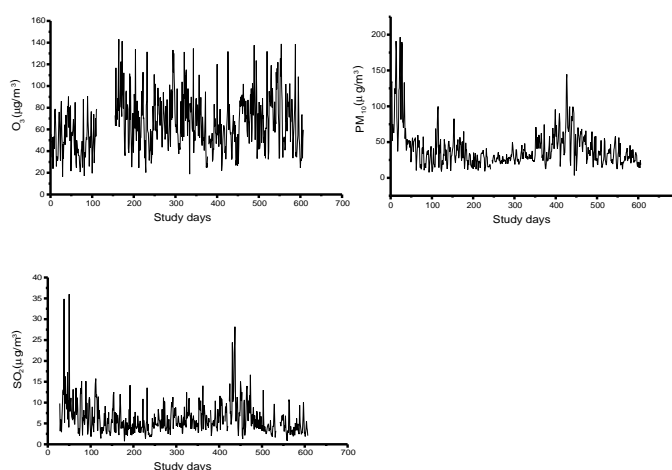


Figure 1 - Daily pollutants during the study period. São José dos Campos, Brazil, 2000-2001.

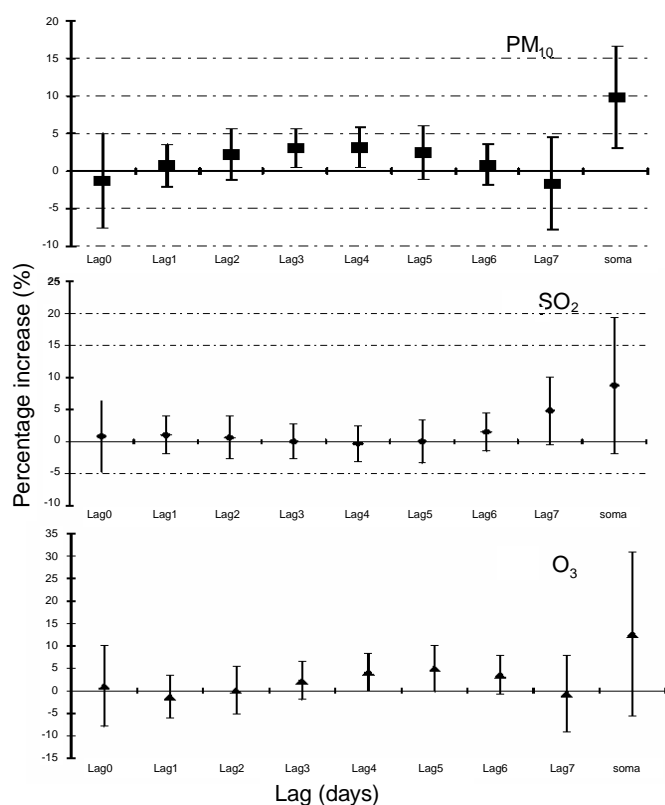


Figure 2 - Percentage increases (and their related 95% confidence intervals) in pneumonia admission rates for increases in interquartile pollutant concentration at each day of the lag structure and for the sum of effects of the 8-day period studied. São José dos Campos, Brazil, 2000-2001.

between levels of air pollutants and hospital admission rates due to respiratory conditions in the city of São Paulo.^{4,5,9} However, in the present study, which was conducted out of a metropolitan center, air pollutants showed to have seasonal distribution and their average levels were below those found by Braga et al⁴ in the city of São Paulo in the early 1990's.

The magnitude of association found between the air pollutant studied and pneumonia admission rates was similar to that found in other studies^{4,5,9} in São Paulo. This is an expected finding since both cities have just about the same sources of pollutants, i.e., especially moving sources as well as fixed sources (plants), thus producing similar toxic effects.

The study methodology is similar to that of other

studies conducted in Brazil^{2,4,5,9} and in other research centers worldwide.^{9,14} The confounders included in the regression models were those characteristically included in studies on health effects of air pollutants. São José dos Campos lies in a geographic region where the climate does not show wide temperature ranges and low temperatures are uncommon, as in the city of São Paulo. This fact has allowed for controlling the effects of temperature and humidity, which was made possible using linear indicators of these parameters' 2-day moving averages. By using a single nonparametric smoothing function for long-term seasonality, potential errors of effect estimates and its related standard errors were minimized.

Of the three environmental pollutants studied, the effect of PM₁₀ remained statistically significant. Besides showing an immediate effect, i.e., on the same day of exposure, PM₁₀ produced an effect that lasted for days. The study showed that PM₁₀ effect on admission rates became significant only three to four days after exposure. The same pattern was evidenced for O₃, which had significant effects mostly on day 4, day 5 and day 6 after exposure. In contrast to those described by Braga et al,⁵ SO₂ did not show significant effects. This pollutant seems to have an effect at greater lags than those studied in São Paulo.^{4,5,9} In a recent study assessing children's visits to public outpatient clinics due to respiratory conditions,² both PM₁₀ and O₃ showed to have a significant effect.

A more complex modeling is required for studying ozone effects since this pollutant has peak levels during both hot and cold days. This is explained by either greater solar radiation during summer days and oxidant precursors lasting longer in the atmosphere during winter days due to poor gas dispersion. Nevertheless, an association was found between O₃ and admission rates within a 4-day lag.

As stressed by Fioravante,⁸ local air pollution is formed not only by autochthonous sources but also

Table 2 - Pearson's correlation matrix between all atmospheric variables. São José dos Campos, Brazil, 2000-2001.

	Hospital admission	SO ₂	O ₃	PM ₁₀	Temperature
Hospital admission	1.00				
SO ₂	0.18*	1.00			
O ₃	-0.06	0.08*	1.00		
PM ₁₀	0.21*	0.30*	0.09*	1.00	
Temperature	-0.24*	-0.23*	0.40*	-0.14*	1.00
Humidity	-0.03	-0.18*	-0.23*	-0.38*	-0.12*

*p<0.05

Table 3 - Regression coefficients and related standard errors of the study pollutants for all days of the lag structure studied and for the sum of effects. São José dos Campos, Brazil, 2000-2001.

	PM ₁₀		SO ₂		O ₃	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Lag 0	-0.00053	0.00125	0.00206	0.00719	0.00032	0.00134
Lag 1	0.00029	0.00057	0.00273	0.00385	-0.00038	0.00073
Lag 2	0.00089	0.00069	0.00167	0.00428	0.00004	0.00080
Lag 3	0.00122*	0.00053	0.00007	0.00350	0.00068	0.00064
Lag 4	0.00126*	0.00055	-0.00088	0.00356	0.00125	0.00063
Lag 5	0.00098	0.00071	0.00000	0.00439	0.00147	0.00077
Lag 6	0.00035	0.00056	0.00392	0.00385	0.00108	0.00066
Lag 7	-0.00067	0.00123	0.01210	0.00676	-0.00020	0.00129
Sum	0.00378*	0.00134	0.02160	0.01330	0.00362	0.00262

SE: Standard error
*p<0.05

by “carryover” phenomenon where, depending on wind conditions, pollutants generated in the city of São Paulo may reach areas up to 300 km away. São José dos Campos lies in a valley where winds usually blow from westward to eastward and can carry over pollutants from the metropolitan capital.

The study results indicate that middle-sized cities with large industrial parks can be affected by air pollution changes, which would have an effect on the occurrence of children's respiratory illnesses, and be

a matter of concern not restricted to large metropolitan areas.

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