

Association between atmospheric pollution and diseases of the circulatory system using estimated data, in the city of Taubaté -SP, Brazil

Associação entre poluição atmosférica e doenças do sistema circulatório utilizando dados estimados, na cidade de Taubaté -SP, Brasil

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ABSTRACT

High rates of pollutants are emitted daily into the atmosphere due to urban development, while thousands of dollars are spent on hospital stays in major cities. Effects of exposure to air pollution in hospitalizations for diseases of the circulatory system are known, thus becoming a risk factor for the health of the population. The cost of these hospitalizations in a medium-sized city in Brazil generated an estimated expenditure of US \$ 1.3 million in 2015. An ecological time-series study conducted in the city of Taubaté, state of São Paulo, performed with PM 2.5 [47 μ g / m³] and carbon monoxide concentrations (CO) [197 ppb] obtained from CPTEC-INPE, as well as data from daily hospitalizations, records obtained from Brazilian Ministry of Health site; these records were categorized by sex [774]. Statistical analysis uses a generalized linear model of Poisson Regression, with a lag of up to 7 days [lag0 to lag7]. In the multi-pollutant analysis, exposure to pollutant CO had a significant and positive association in lag7 for male sex and to PM2.5 in lag2, lag3 and lag4 for male and in lag 6 for female; 10 μ g/m³ increase on PM2.5 concentrations increases 7% in hospitalizations risk and implies an approximate excess of costs of US \$ 93.3 thousand/year. All these data highlight the importance of the study of concentrations of air pollutants in the big cities, paying attention to the emission control in the atmosphere.

Keywords: circulatory system diseases; air pollution; fine particulate material; carbon monoxide; ecological study.

RESUMO

Altas taxas de poluentes são emitidas diariamente para a atmosfera devido ao desenvolvimento urbano, enquanto milhares de dólares são gastos em estadias hospitalares nas principais cidades. Os efeitos da exposição à poluição do ar nas hospitalizações por doenças do sistema circulatório são conhecidos, tornando-se assim um fator de risco para a saúde da população. O custo dessas hospitalizações em uma cidade de médio porte no Brasil gerou um gasto estimado de US\$ 1,3 milhões em 2015. Um estudo ecológico de série temporal realizado na cidade de Taubaté, estado de São Paulo, realizado com PM_{2,5} [47µg / m³] e concentrações de monóxido de carbono (CO) [197 ppb] obtidas do CPTEC-INPE, bem como dados de internações diárias, registros obtidos do site do Ministério da Saúde brasileiro; estes registros foram categorizados por sexo [774]. A análise estatística utiliza um modelo linear generalizado de Regressão de Poisson, com uma defasagem de até 7 dias [lag0 a lag7]. Na análise multi-polvente, a exposição ao CO polvente teve uma associação significativa e positiva na lag7 para o sexo masculino e à PM_{2,5} na lag2, lag3 e lag4 para o masculino e na lag6 para o feminino; 10 µg/m³ aumento nas concentrações de PM_{2,5} aumenta 7% no risco de hospitalizações e implica um excesso aproximado de custos de US \$ 93,3 mil/ano. Todos estes dados destacam a importância do estudo das concentrações de poluentes atmosféricos nas grandes cidades, prestando atenção ao controle das emissões na atmosfera.

Palavras-chave: doenças do sistema circulatório; poluição do ar; material particulado fino; monóxido de carbono; estudo ecológico.

1 INTRODUCTION

The population in large urban centers has grown exponentially over the years, consequently increasing the number of the vehicle fleet which in some cities are as big the number of inhabitants; this vehicle fleet can cause an increase in the concentrations of air pollutants that may be associated with hospitalizations due to cardiovascular and respiratory diseases. Excessive air pollution can reach alarming levels like some episodes of red alert that occurred in China in 2015, increasing the number of deaths in the period¹.

The most commonly studied air pollutants are particulate matter (PM₁₀) and its fine fraction (PM_{2.5}), carbon monoxide (CO), nitrogen dioxide (NO₂), sulfur dioxide (SO₂) and Ozone (O₃). PM_{2.5} is a fine particulate material with an aerodynamic diameter of less than 2.5 µm, which can penetrate more deeply into the respiratory tract reaching the pulmonary alveoli. CO, on the other hand, is an odorless and colorless gas derived from the incomplete burning of organic fuels, its main source being motor vehicles. SO₂ comes from the burning of fuels that contain sulfur, and one of the main causes of acid rain. O₃ and NO₂ are secondary pollutants, formed by the chemical reaction of volatile organic compounds and nitrogen, being harmful to health and

vegetation².

For the control of pollutant emissions, the World Health Organization (WHO) defines standards for pollutants at levels that are considered acceptable, thus alerting when such emissions are a health risk factor, some cities have an environmental agency responsible for measuring such pollutants; on the other hand, in cities that do not have metering stations, there are alternatives such as the Environmental Information System Integrated with Environmental Health (SISAM) which is National Space Research Institute (INPE) site, a database composed of variables obtained from satellite images and numerical analysis with estimated data from PM_{2.5} and CO^{3 4}. Some Brazilian studies used data estimated by this model to estimate hospitalization risk due to respiratory and cardiovascular diseases^{5 6 7 8}.

Studies have been carried out indicate an association between exposure to air pollutants and hospitalizations due to cardiovascular diseases. In the state of São Paulo, hospitalizations due to ischemic heart diseases were associated with PM 2.5 exposure to be in the city of Taubaté⁹, and also in Cubatão associated with O₃ and SO₂ exposure¹⁰. In some cases, the difference in responses according to sex was demonstrated^{11 12 13}.

Due to the harm caused to the population and the planet, and also to the high cost generated by the excess of pollution, this study aims to analyze the association between hospitalizations for cardiovascular diseases and air pollutants in the municipality of Taubaté, located in the state of São Paulo - Brazil, during 2015, and separate it according to sex.

2 METHODS

STUDY AREA LOCATION

Taubaté is located in the mesoregion of the Paraíba Valley, in the state of São Paulo, between the two largest economic axes of Brazil: 130 km from São Paulo and 280 km from Rio de Janeiro. Its geographical coordinates are 23°01'S and 45°33'W, and it has an approximate population of 300,000 inhabitants in a territorial area of 625 km²¹⁴. It has a humid subtropical climate¹⁵ and lies alongside the Dutra Highway, which links São Paulo to Rio de Janeiro and is characterized by intense vehicular traffic. It has two hospitals that attend patients within the Brazilian National Health System (Sistema Único de Saúde, SUS).

Statistical analysis. An ecological time-series study was carried out from January 01 to December 31, 2015, in the city of Taubaté, state of São Paulo, based on air

pollutants and hospitalizations for cardiovascular diseases [International Classification of Diseases 10th revision, codes I 00 up to I 99). These hospitalization data were obtained from the Ministry of Health site called DATASUS, where the files downloaded in a compact form were expanded, through the TabWin program, made available by the site itself. The values were organized in the Excel program, arranged in columns, separated by municipality code, date of admission, diagnosis and age ¹⁶.

The pollutants analyzed were fine particulate matter (PM_{2.5}) and carbon monoxide (CO), data were obtained from the Environmental Information System Integrated with Environmental Health (SISAM) which is a portal of the national space research institute (INPE) ⁴. This site provides the average, maximum and minimum values of each pollutant, in addition to providing the temperature and relative humidity in the air.

For data analysis, the dependent variable was the number of hospitalizations due to cardiovascular diseases and independent variables were the concentrations of the pollutants CO, PM_{2.5}, temperature and relative humidity. Generalized Linear Model of Poisson Regression was used. Days of the week and day of the year were included in the model as control short and long-term trend (seasonality) respectively. With the database formed, the frequency distribution of the different variables expressed in mean, standard deviation and minimum and maximum values were performed, using the STATA version 7 software. As the effects of the exposure can occur not only on the same day but also on later days, lags of 0 up to 7 days, after the beginning of the exposure were used, (lag 0 up to lag 7).

This model provides coefficients that the relative risk of the outcome of a study. Analyzes were performed using all pollutants simultaneously (multipollutant model) and adjusted for temperature and humidity, controlled by short and long-term trend (seasonality) variables, and later for the sexes separately.

The Generalized Linear Model of Poisson Regression is expressed by equation (1):

$$\text{Ln (HA)} = \beta_0 + \beta_1 (\text{CONC}) + \beta_2 (\text{RH}) + \beta_3 (\text{T}) + \beta_4 (\text{SEASON}) + \beta_5 (\text{D}) \quad (1)$$

where: β 's are regression coefficients;

HA is the number of hospitalizations;

CONC is the concentration of air pollutants;

RH is the relative humidity value;

T is the temperature value;

SEASON is the long-term trend (seasonality);

D is the day of the week.

In the analyzes, an increment of 10 $\mu\text{g} / \text{m}^3$ was calculated, for both sexes and for the male and female separately, represented in relative risk [RR], represented by equation $RR = \exp(\beta * C)$ β is the Poisson regression coefficient value; and C is the pollutant concentration.

The present study was not submitted to the Research Ethics Committee, as there is no access to the identification of hospitalized patients.

3 RESULTS

There were 1470 admissions for diseases of the circulatory system [ICD I-00 to I-99], from January to December 2015, with 774 (52.3%) of admissions for males and 696 (47.7%) for females. The pollutant values expressed as mean, standard deviation and minimum-maximum, can be seen in Table 1.

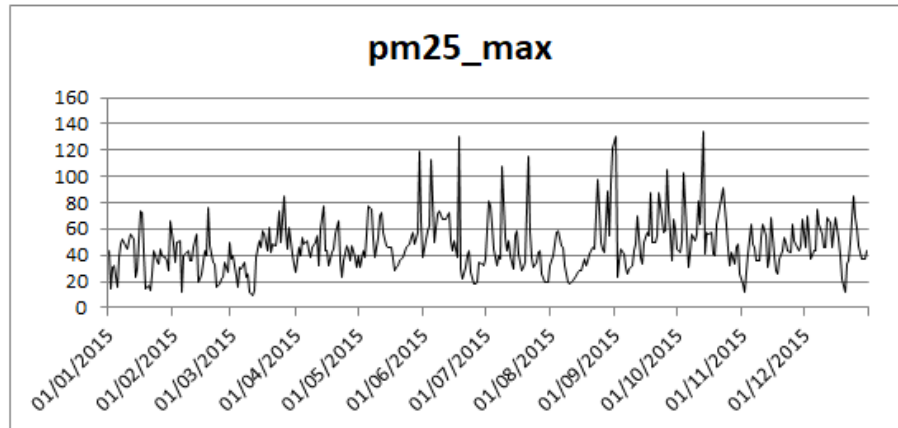
Table 1: Mean, standard deviation (SD), minimum (MIN) and maximum (MAX) values of variables study, Taubaté, Brazil, 2015.

	MEAN (SD)	MIN	MAX
CO (ppb)	196.7 (4.8)	71,2	843,0
PM_{2,5} ($\mu\text{g}/\text{m}^3$)	46,8 (1,1)	9,5	134,6
TEMP ($^{\circ}\text{C}$)	18.0 (0,1)	10,8	23,4
HUMID (%)	60,04 (0,8)	20,4	94,5
HA	4,03(0,13)	0,0	13,0
MALE	2,12(0,09)	0,0	10,0
FEMALE	1,91(0,08)	0,0	11,0

TEMP = Temperature HUMID – Relative Humidity HA hospital admission

In relation to the emission of pollutants, CO remained for a year with values within the acceptable levels, with maximum values of 843 ppb, while PM_{2.5} behaved differently, maintaining most of the year above the value acceptable by WHO, which is 40 $\mu\text{g} / \text{m}^3$, reaching peaks in the cold months of up to 134.6 $\mu\text{g} / \text{m}^3$, which can be seen in Graph 1.

Graph 1: evolution of PM_{2.5}, Taubaté, Brazil, 2015.



The effects of exposure pollutants for diseases of the circulatory system with a lag of up to 7 days [lag0 to lag7], showed a positive association with pollutant PM_{2.5} and CO, with values at relative risk, which can be observed in table 2.

Table 2: Relative risk of pollutants in relation to cardiovascular diseases for both sexes, and separately, Taubaté, Brazil, 2015

		<i>Análise Multipolvente RR[95% Conf, Interval]</i>		
		BOTH	MALE	FEMALE
PM_{2.5} <i>(max)</i>	<i>Lag0</i>	0.998[0.995-1.002]	0.998[0.994-1.003]	0.998[0.993-1.003]
	<i>Lag1</i>	1.001[0.997-1.004]	0.999[0.995-1.004]	1.002[0.997-1.007]
	<i>Lag2</i>	1.001[0.998-1.005]	1.005[1.001-1.010]*	0.997[0.992-1.002]
	<i>Lag3</i>	1.004[1.000-1.007]*	1.006[1.002-1.011]*	1.001[0.996-1.006]
	<i>Lag4</i>	1.003[1.000-1.007]*	1.006[1.000-1.009]*	1.002[0.997-1.007]
	<i>Lag5</i>	1.001[0.998-1.005]	1.002[0.997-1.006]	1.001[0.996-1.006]
	<i>Lag6</i>	1.002[0.999-1.005]	0.999[0.994-1.003]	1.006[1.001-1.011]*
	<i>Lag7</i>	0.999[0.995-1.002]	0.999[0.991-1.001]	1.002[0.997-1.007]
CO <i>(max)</i>	<i>Lag0</i>	1.000[0.999-1.001]	1.000[0.999-1.001]	0.999[0.999-1.001]
	<i>Lag1</i>	0.999[0.999-1.001]	1.000[0.999-1.001]	0.999[0.998-1.001]
	<i>Lag2</i>	1.000[0.999-1.001]	0.999[0.999-1.001]	1.001[0.999-1.002]
	<i>Lag3</i>	0.999[0.999-1.000]	0.999[0.998-1.000]	0.999[0.998-1.001]
	<i>Lag4</i>	0.999[0.999-1.001]	1.000[0.999-1.001]	0.999[0.999-1.001]
	<i>Lag5</i>	1.000[0.999-1.001]	1.000[0.999-1.001]	0.999[0.999-1.001]
	<i>Lag6</i>	0.999[0.999-1.001]	1.001[0.999-1.002]	0.999[0.9979-1.000]
	<i>Lag7</i>	1.000[0.999-1.001]	1.001[1.000-1.002]*	0.999[0.998-1.001]

*p value<0.05

For both sexes in lag3 and lag4, when separated by sex, is female positive association occurred after six days of exposure to PM_{2.5} [lag6], while the male sex association occurred after two, three and four days of exposure to the pollutant [lag2,

lag3 and lag4]. Exposure to CO had significance only for the male sex, in lag7, while for both sexes and for the female sex it was not significant.

Reduction of $10 \mu\text{g} / \text{m}^3$ in PM concentrations, could contribute to a reduction of 109 hospitalizations with savings of \approx the US \$ 100 thousand / year.

4 DISCUSSION

This study presents the significant effect of exposure to $\text{PM}_{2.5}$ in hospitalization due to cardiovascular diseases in Taubaté, Brazil besides the output of the difference in males and females.

In a study carried out in greater Vitória, the $\text{PM}_{2.5}$ pollutant remained within the quality standards reaching a maximum of $23 \mu\text{g} / \text{m}^3$ between the years 2013 to 2014, another study carried out in the city of Taubaté from August 2011 to July from 2012 demonstrated that the $\text{PM}_{2.5}$ concentration reached a maximum of $41 \mu\text{g} / \text{m}^3$ in the city of Taubaté, a value below that found in the period of 2015 in this present study, which was $134.6 \mu\text{g} / \text{m}^3$ in the city of Taubaté, regardless since in the model used by Ribeiro et al⁹ the data were estimated, as well as the data found in this study are estimated data from the SISAM portal^{17,9,4}.

The association of air pollutants with hospitalizations due to cardiovascular diseases has been found in several studies, which point out that even in cities with low levels of pollution, significance can be found in relation to hospitalizations, as in the case of the study carried out in São José dos Campos¹⁸ who related deaths from stroke to PM_{10} exposure in lag 0, going against our study that related diseases of the circulatory system to the effects of pollutants with a lag of up to 7 days [lag0 to lag7], showing a positive association to $\text{PM}_{2.5}$ exposure for both sexes in lag3 and lag4. When comparing studies at world levels, in China there are also some studies relating the pollutant $\text{PM}_{2.5}$ to deaths, after two episodes of redfin due to excessive pollution¹; these facts go against a study done in the city of Cubatão in São Paulo¹⁰, a chronically polluted city, which also showed an association of pollutants with hospitalizations for cardiovascular and respiratory diseases. Taubaté, despite not being chronically polluted, nor having episodes of excessive pollution alert, it has an important geographical factor that emphasizes the role of air pollutant concentrations; in this case, the fine particulate material ($\text{PM}_{2.5}$) suspended in the air has difficulty dispersing due to the Sea Hill (the Serra do Mar in Portuguese) and Mantiqueira Hill (Serra da Mantiqueira, in Portuguese) that surround the city².

Other studies have also highlighted the difference in response according to sex, as in a study carried out in the city of São José dos Campos ¹¹, where male and female sex was associated with ischemic heart disease, in male sex presenting a later association than female. In our study, only the male gender was associated with carbon monoxide exposure in lag 5, which is different from that found in São José dos Campos, given that the multi-pollutant model was associated with more pollutants, than in the present study, where the pollutant model was composed only by CO and PM_{2.5}.

Another study also pointed out the difference and response between the sexes, associating the fine particulate material PM_{2.5} with ischemic heart disease, where both sexes showed a positive association, with the male sex showing a later response in relation to the female sex when exposed to the pollutant.

When we reduce 10 µg / m³ to the PM_{2.5} concentrations, it possibly quantifies the hospitalizations number reduction as well as monetary cost reductions of approximately US \$ 100 thousand / year in the city of Taubaté, a medium-sized city. If we applied this to a large city, the economy would be even greater, emphasizing the importance and relevance of studying air pollutant emissions in order to find a way to reduce them. As demonstrated in other studies, the importance of reducing pollutants and consequently reducing public health costs¹⁹.

5 CONCLUSION

Exposure to CO and PM_{2.5} had a positive association with hospital admission due to cardiovascular diseases Taubaté-SP, it was possible to identify different responses when the genders were analyzed separately, showing the importance of carrying out analyses with the sexes separately.

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