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Particulate matter originating from biomass burning and respiratory

ABSTRACT

OBJECTIVE: To analyze the effects of exposure to fine particulate matter from burning on hospital admissions due to respiratory diseases in children and the elderly.

METHODS: This is an ecological time series study that took place in the city of Cuiaba, Mato Grosso, in Brazil's Amazon Region, in 2005. Information on the daily levels of fine particulate matter $PM_{2.5}$ was made available by the Brazilian National Institute for Spatial Research. The model included variables related to temperature, relative humidity and adjusts for seasonality and calendar effects. Poisson regression with generalized additive models was used.

RESULTS: A 10 μg/m^3 increase in the level of exposure to $PM_{2.5}$ was associated with increases of 9.1%, 9.2% and 12.1% in hospital admissions due to respiratory diseases in children for moving averages of 1, 2 and 5 days, respectively. For the dry season, the level of exposure to particulate matter was associated with increases of 11.4%, 21.6% and 22.0% in hospital admissions in children for moving averages of 1, 5 and 6 days, respectively. No significant link was noticed in the elderly.

CONCLUSIONS: The results show the influence of $PM_{2.5}$ on hospitalizations for respiratory disease in children under 5 in the region studied.

DESCRIPTORS: Child. Aged. Respiratory Tract Diseases, epidemiology. Particulate Matter, toxicity. Air Pollution, adverse effects. Ecological Studies.

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INTRODUCTION

Burning biomass releases carbon gaseous compounds particulates. In its final stage, products of incomplete combustion are released, such as organic particles, among them particulate material, which is the most associated with health problems. Fine particulate material has diameters ranging from 0.1 μm to smaller than 2.5 μm ($PM_{2.5}$) and represents between 60% and 70% of total particulate material.[6]

The groups most susceptible to the harmful effects of atmospheric pollution are children, the elderly and those with a history of respiratory (RD) and cardiovascular disease. Respiratory disease in children, especially acute respiratory infections, asthma and bronchitis are related to high levels of air pollution and are a common cause of mortality.[a] Respiratory disease is still the main cause of hospital admission among the elderly. Susceptibility to atmospheric pollution in this age group may be exacerbated by physical debility, low physiological resilience and respiratory disease or other prevalent diseases.[b]

The principal characteristic of air pollution originating from burning biomass is its well defined seasonality, with high levels of smoke produced in short, restricted periods, varying between three and six months.[c] These peaks often occur during the dry season between June and November.

Brazil contributes a significant part of the global atmospheric pollutants due to burning biomass. The Amazon region is the most critical region in the country. The pattern of atmospheric circulation means that emissions from the Amazon rainforest are dispersed toward the Northeast and North of the South America continent, over the tropical Pacific Ocean and the South Atlantic, reaching as far as the Caribbean region.[7] Smoke from biomass burning in the Mato Grosso state of the Amazon, in the north and northeast of the state, moves toward the other municipalities of the south and central regions of the state. In addition to the effects of burning on the Amazon ecosystem, the pollutant emissions contribute to increased respiratory morbidity in municipalities in the Amazonian deforestation arc.[8]

Global concerns about climate change and the large scale deforestation have awakened interest in controlling the biomass burning in South America. Although evidence exists demonstrating the risks posed by smoke from burning tropical forests on the health of the exposed population groups, the few epidemiological studies which have been carried out in this region are very recent.[10]

This study aimed to analyze the effects of exposure to fine particles from burning biomass on hospitalizations for respiratory disease in children and the elderly.

METHODS

This was an epidemiological study, with an ecological time series design, of daily records of hospitalizations for respiratory disease in children aged < 5 and elderly aged ≥ 65 in hospitals affiliated with the Brazilian Unified Health System (SUS) in the city of Cuiabá, Mato Grosso state, Midwestern Brazil, between 1st January and 31st December 2005. These age groups were selected as they are the most vulnerable to the effects of atmospheric pollution.[a]

Data on hospitalizations due to respiratory causes, according to the International Classification of Diseases (ICD-10), categories JOO to JNN and to place of residence, were obtained from the Ministry of Health, database using SUS Hospital Admission Authorizations (HAAs) for 2005.[d]

Estimates of daily $PM_{2.5}$ concentrations, meteorological and calendar (days of the week and holidays) variables were used. Estimates of $PM_{2.5}$ were produced based on the Coupled Aerosol and Tracer Transport model to the Brazilian Developments on the Regional Atmospheric Modeling System (CATT-BRAMS), developed by the National Institute of Space Research (INPE), which provided measurements every three hours.[4] Daily arithmetic means of $PM_{2.5}$ concentrations were calculated. Data on temperature and relative humidity were provided by the National Meteorological Institute (Inmet) in the city of Cuiabá.[e]

The municipality of Cuiabá has a population of 550,562[f] and is located in the geomorphological unit called the Cuiabana Depression, considered the gateway to the Amazon rainforest. The rainy season is between

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[c] Carmo CN, Hacon S, Longo KM, Freitas S, Mourão D, Louzano F, et al. Queima de biomassa e doenças respiratórias na região amazônica: uma aplicação de modelos aditivos generalizados. XLI Simpósio Brasileiro de Pesquisa Operacional 2009 - Pesquisa Operacional na Gestão do Conhecimento. Bahia, BR. Bahia: SOBRAPO; 2009. p.1472-77.
[d] Ministério da Saúde. DATASUS. Informações em Saúde. Brasília (DF); 2011 [cited 2010 Nov 21]. Available from: http://w3.datasus.gov.br/datasus/datasus.php
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December and April. During the rest of the year the masses of dry air above the center of Brazil inhibit the formation of rain. During these months, cold fronts from the south of the country are common, making the climate milder and humid. The heat means that the relative humidity falls to low levels when these fronts dissipate. Mean annual precipitation is 1,469.4 mm^3 reaching maximum intensity in January, February and March. The maximum mean temperature reaches 34.1ºC, but absolute maximums can rise to above 40ºC and the minimum mean in July, the coldest month, is 16.7ºC.[g]

To analyze the data, the generalized additive model technique was used.[13] The strategy of analysis consisted in modelling the trends and seasonality of the series using the spline functions for time; days of the weeks and holidays using dummy variables; meteorological conditions using the splines of temperature and relative humidity. Diagnostics were performed analyzing regression in order to evaluate the inclusion or exclusion of terms in the model and the final model's quality of fit. The terms corresponding to the daily concentrations of pollutants were added to the model, assuming that the association with the dependent variable is linear. Two periods were analyzed: the whole of 2005 and the dry period including the months of July and December. According to meteorological data for 2005, the year can be characterized as atypical. Associations between exposure on the same day with time lags of up to seven days, and moving averages from two to seven days before the outcome were investigated. The moving averages represented accumulated exposure in the days prior to the event. Thus, it was possible to calculate excess hospitalizations.

Relative risks (RR) for hospital admissions corresponded to an increase of 10 $\mu g/m^3$ in $PM_{2.5}$ levels, which is an internationally accepted parameter. The analyses were carried out using the R version 2.11 and the Ares library programs,[h] a collection of routines for analyzing time series in the R statistical program. A level of significance of 5% was adopted in the analyses.

This study was approved by the Research Ethics Committee of the *Escola Nacional de Saúde Pública/ FIOCRUZ* (Protocol nº 164/08).

RESULTS

There were 1,020 elderly people and 1,152 children admitted to hospital with respiratory disease in the city of Cuiabá during 2005. The daily mean of hospitalizations for respiratory disease was 3.1 for children and 2.8 for the elderly. The daily $PM_{2.5}$ mean was 50% higher in the dry season than in the year overall (Table 1).

Table 1. Descriptive statistics of hospital admissions for respiratory diseases in children and the elderly, meteorological variables and $PM_{2.5}$ data. Cuiabá, Midwestern Brazil, 2005.

Variável	Daily mean	Standard deviation	Minimum	Maximum
Hospitalizations				
Children	3.1	2.2	0.0	11.0
The elderly	2.8	1.8	0.0	9.0
Meteorology				
Temperature (°C)	30.8	3.8	16.0	38.4
Relative humidity (%)	55.4	15.6	22.0	98.0
$PM_{2.5}$ (µg/m3)				
Annual	7.5	10.4	0.1	91.4
Dry season	11.9	13.1	1.2	91.4

The series for $PM_{2.5}$, temperature and relative humidity for 2005 are shown in Figure 1. There was an increase in $PM_{2.5}$, characteristic of the burning season in the Amazon and began at the end of July and beginning of August, persisting until the end of November, small oscillations in temperature and typical reduction in relative humidity characteristic of the dry season.

Analysis of correlation did not show an association between pollution and the outcome variables. There was a statistically significant correlation between temperature and children's hospitalizations with RD and an inverse correlation between humidity and $PM_{2.5}$ and humidity and temperature, both statistically significant (Table 2). This justifies the use of such measures as variables in the models' fit.

Exposure to $PM_{2.5}$ was associated with hospitalization for RD in children throughout the year of 2005 and the dry season, for both lagged and moving averages. Throughout the entire period of 2005, there was an increase in hospitalizations in relation to the moving averages, this being 9.1% in one day (95%CI 1.8;18.1), 9.2% in two days (95%CI 0.1;19.4) and 12.0% in five days (95%CI 0.2;25.5) (Figure 2a). The associations were greater in the dry period. In this latter period there was increase in the moving averages of 11.4%, in one day (95%CI 1.7;22.2), 21.6%, in five days (95%CI 4.9;41.1) and of 22.0% in six days (95%CI 4.3;42.8) (Figure 2b). No statistically significant associations were found between exposure to $PM_{2.5}$ and hospitalization for RD in the elderly in any of the periods (Figures 2a and 2b).

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Table 2. Pearson correlation matrix of the variables. Cuiabá, Midwestern Brazil, 2005.

Variable	$PM_{2.5}$	Temperature	Humidity	The elderly	Children
$PM_{2.5}$	1				
Temperature	0.10	1			
Humidity	-0.14[a]	-0.60[a]	1		
The elderly	-0.03	0.04	-0.05	1	
Children	0.09	0.11[b]	-0.07	0.16[b]	1

[a] $p < 0.001$
[b] $p < 0.05$

DISCUSSION

The link between atmospheric pollution and higher occurrence of respiratory disease in populations of different countries has appeared in the literature since the middle of the last century. Episodes such as those in Donora (USA) in 1948 and London, England in 1952 constitute examples of these relationships[i,j] and led to the formulation of laws aiming to control air pollution, especially in the United States in the 1970s.[5]

Air pollution resulting from biomass burning occurs in a different way to that in urban centers. In these centers, it is characterized by long periods of exposure and low levels of pollutants, whereas biomass burning is characterized mainly by having well defined seasons[11] and high levels of fine particulate material, reaching up to 91.4 μg/m^3 in 2005 (Table 1).

Using fire in natural areas and forests is criticized by environmentalists, scientists and society in general. However, in reality it is a common practice in tropical and subtropical regions, especially in those characterized by a pronounced dry season. This situation is common in various regions of the country, especially in the Brazilian Amazon. In Mato Grosso state, it is also common to observe forest affected by fire close to pastures, encouraged by land owners to renew the soil. This habit leads to large forest fires in times of severe drought and to the intense exacerbation of the population's health problems.[3]

A INPE survey[k] identified 9,070 fires set in Brazil between 16 and 17thAugust 2010, and more than three million tons of Carbon Monoxide were released into the atmosphere in the state of Mato Grosso alone between the beginning of the year and mid-August 2010. This situation means that in the city of Cuiabá, in 2010, the numbers seeking outpatient care for respiratory disease was double the mean for the preceding years.[l] The rate of hospitalizations for respiratory disease in Cuiabá, was four times higher than that of the metropolitan region of the city of São Paulo, SP, Southeastern Brazil, during the same period.[m]

Exposure to $PM_{2.5}$ from burning biomass is associated with an increase in hospital admissions for respiratory disease in children aged < 5 in Cuiabá, in the south of the Mato Grosso region of the Amazon. These results are in concordance with those found in other studies of biomass burning.[4,12]

A time series analysis study carried out in the city of Piracicaba, SP, Southeastern Brazil, in 1997 and 1998 quantified daily hospital admissions for RD in children, adolescents and elderly aged > 65.[4] There was a 32.05 increase in the number of hospitalizations for RD in children and adolescents, associated with interquartile variation of PM_{10} and $PM_{2.5}$. Lopes & Ribeiro[9] (2006), using geoprocessing techniques, verified the correlation between products of burning sugar cane and incidence of respiratory problems in affected regions from 2000 to 2004 in the state of São Paulo. There were more cases of respiratory disease in regions where burning took place. Arbex et al[1] (2004) studied the effect of burning sugar cane on outpatient care in the municipality of Araraquara, SP, Southeastern Brazil, in 1995, using time series analysis, and found a higher rate of hospitalization in the periods when most sugar cane was burnt. Carmo et al[c] (2009) found 2.9% and 2.6% increases in outpatient care for respiratory disease in children on the sixth and seventh days following exposure to $PM_{2.5}$ but found no significant associations between hospitalizations in the elderly, in the municipality of Alta Floresta, situated in the Mato Grosso area of the Amazon. Botelho et al[3] (2003) found higher rates of hospital admission among children aged < 5 in the dry season compared to the rainy

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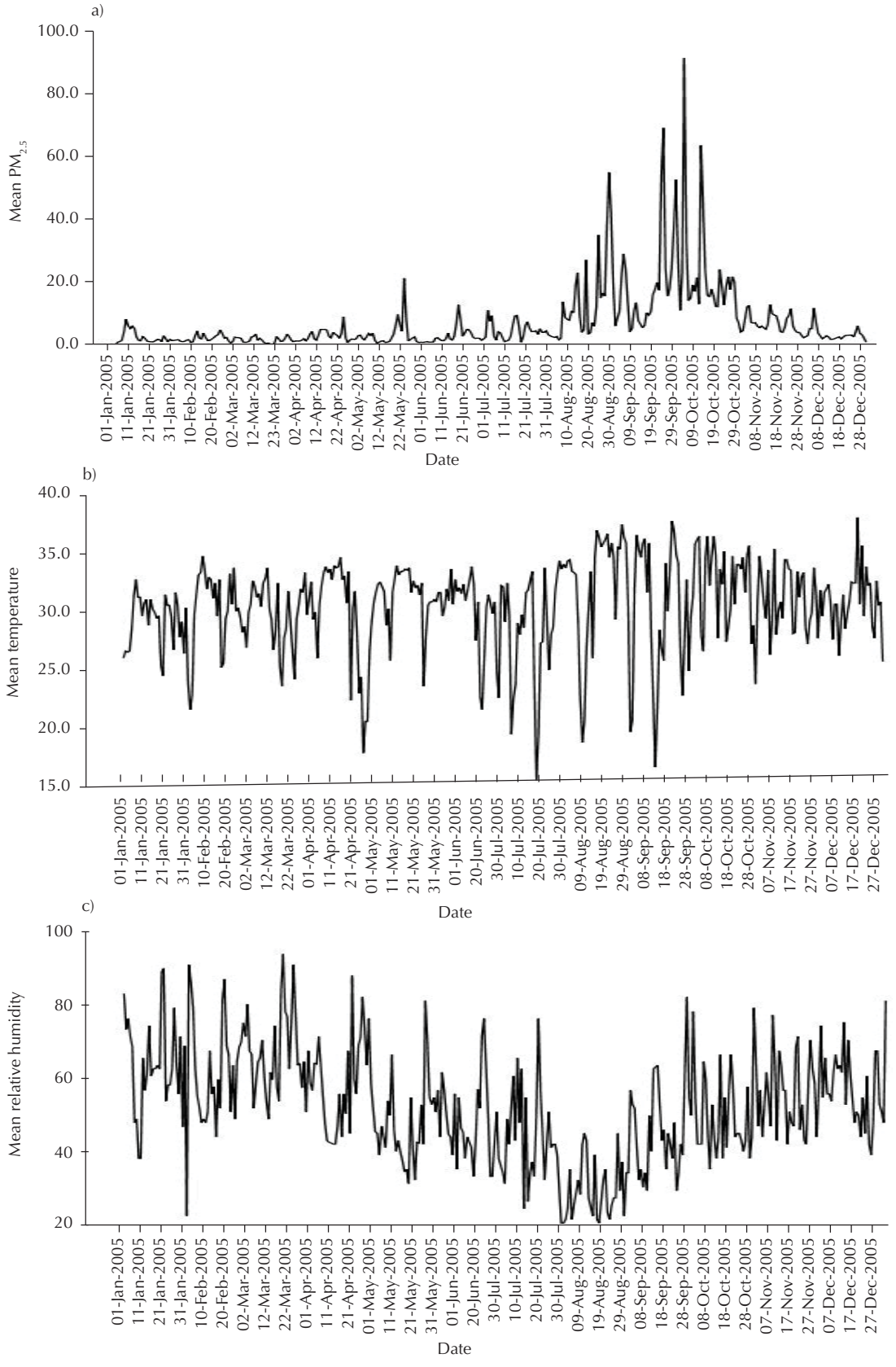

Figure 1. Time series for $PM_{2.5}$ (µm/mm3) (a), Mean temperature (ºC) (b) and relative humidity (%) (c) included in the study. Cuiabá, Midwestern Brazil, 2005.

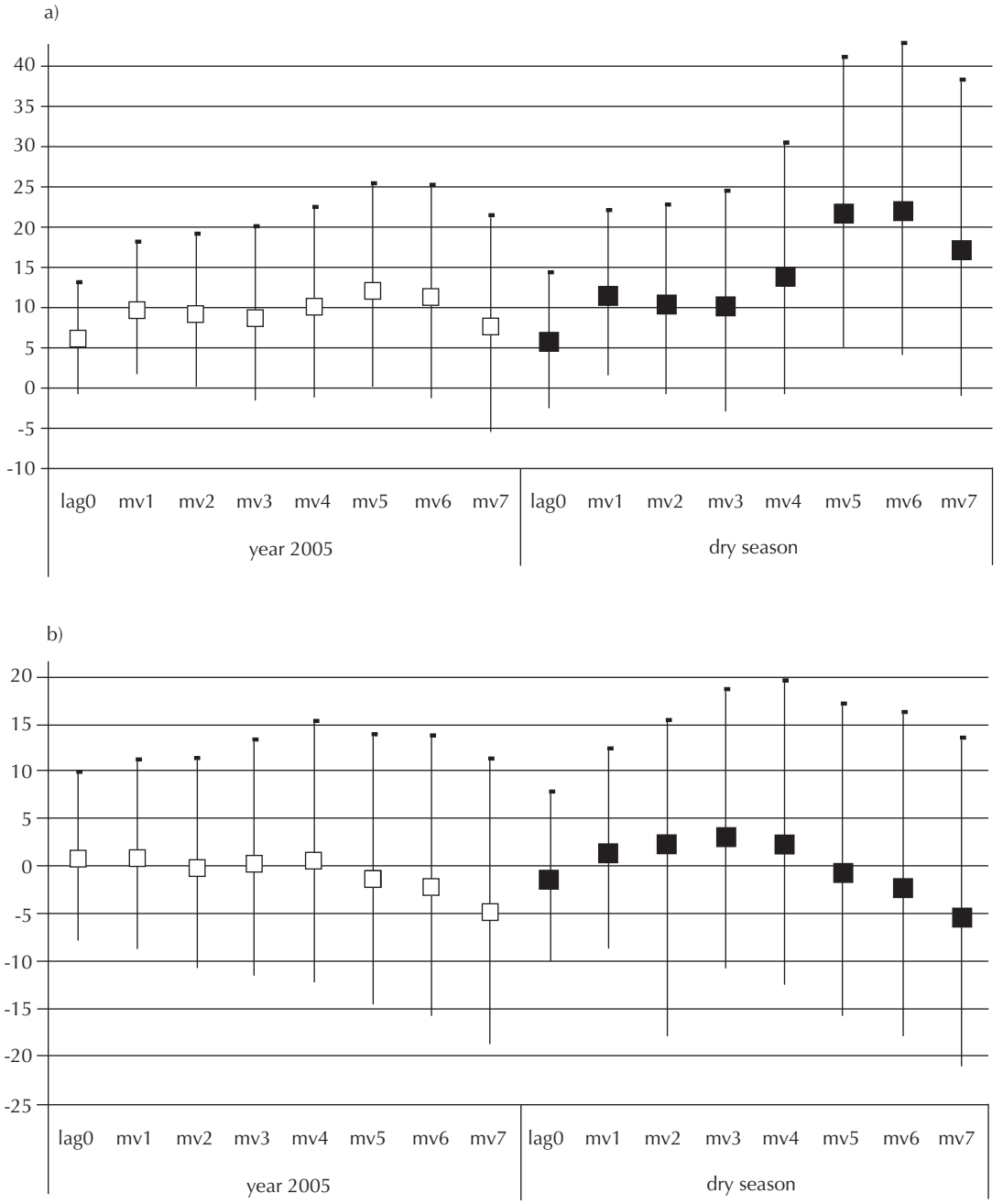

Figure 2. Percentage increment and confidence intervals for hospitalizations for respiratory disease in children (a) and in the elderly (b) according to the 10 µg/m3 increase in the concentration of $PM_{2.5}$ during 2005 and during the dry season. Cuiabá, Midwestern Brazil, 2005.

season when analyzing emergency care for respiratory disease in Cuiabá. Silva et al[12] (2010), in a study which used the same estimates as the Coupled Aerosol and Tracer Transport Model to the Brazilian Developments on the Regional Atmospheric Modeling System (CATT-BRAMS) spatially analyzed the effect of exposure to $PM_{2.5}$ in respiratory disease in children aged between one and four years old and in the elderly aged ≥ 65 in Mato Grosso in 2004. Statistically significant associations were found between the occurrence of hospitalizations for respiratory disease and the percentage of annual critical hours of particulate material.

Cases requiring hospitalization are at higher risk than those which require medical consultation in the primary care network. In this study, it was not possible to conduct a survey of outpatient care, which impedes evaluation of the risks which pollution from $PM_{2.5}$ may present for respiratory disease requiring less complex levels of care.

There is accumulated risk between the moving averages of exposure from the first to the seventh day in the dry season, due to the permanent association between them and the risk of children being hospitalized for respiratory disease, despite some comparisons not showing statistical significance (Figure 2a). This data indicates the distinctive and persistent effect of $PM_{2.5}$ on these morbidities in this age group in Cuiabá. The associations found in this study were greater than those found in similar studies. This suggests that the seriousness of the Cuiabá children's cases of respiratory disease is greater than that of cases which occur in metropolitan regions and in other cities belonging to the Amazon. The study design used did not allow individual exposure to $PM_{2.5}$ to be measured, preventing the joint analysis of other factors and outcomes which may contribute to explaining this phenomenon.

No association was observed between exposure to $PM_{2.5}$ and hospitalization for respiratory disease in the elderly. In this segment of the population, in addition to the respiratory damage caused by pollutants from the biomass burning, there are also associated comorbidities which may contribute to the lack of association.[11] However, the different methodologies used in studies for analyzing the levels of exposure cannot be ruled out, in addition to differences in the studied populations.

In this study, data on hospitalizations for respiratory disease were used. In the study by Bittencurt et al[2] (2006) it is notable that the Hospital Information System (SIH), which provided the data on the hospitalizations, used HAAs and not the individual patients as the unit of analysis. Thus, the use of hospitalizations to estimate the number of cases of illness is a weakness. However, this is still regarded as one of the best indicators of respiratory health problems.[14]

Cuiabá is located in the Amazon, in the middle of the Mato Grosso savannah. It is known that air pollutants partially come from anthropogenic sources (mobile and stationary) and other from burning pasture, forest and yards. The intense burning which takes place in the south of the Amazon is located in a region adjacent and close to Cuiabá. The CATT-BRAMS produces modelling of pollutants using a computational system created to simulate and study the atmospheric transport of products originating from burning biomass. Thus, it can predict the concentration of $PM_{2.5}$ in the Amazon region and in Cuiabá with a good degree of accuracy, considering the influence of the additional effect of these diverse sources of pollutants. Comparison of estimates of this model with actual measurements of $PM_{2.5}$ made in situ were evaluated and deemed satisfactory.[7] This model does not consider direct exposure to $PM_{2.5}$ from other anthropogenic sources, as no chemical analysis of the particulate was carried out. Other particulates, as well as those from burning biomass, are probably present albeit in smaller quantities.

The results of this investigation showed the influence of $PM_{2.5}$ on the occurrence of hospitalizations for respiratory disease in children < 5 in the city of Cuiabá. It is probable that this is also occurring in other cities and regions which experience large scale biomass burning.

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The authors declare that there are no conflicts of interest.