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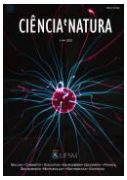

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Envionment

Study of the relation of air quality and meteorological variables in the occurrence of respiratory morbidity

Estudo da relação da qualidade do ar e variáveis meteorológicas na ocorrência de morbidade respiratória

Elisângela Conceição Lara[I], Aline Belem Machado[I], Lutieri Mateus Benetti[I], André Luís Machado Bueno[I], Daiane Bolzan Berlese[I], Daniela Montanari Migliavacca Osório[II]

[I] Universidade Feevale, Novo Hamburgo, RS, Brazil
[II] Universidade Estadual de Campinas, Campinas, SP, Brazil

ABSTRACT

Atmospheric pollution is responsible for several damages to human health. The respiratory system has direct contact with the external environment and can absorb harmful elements present in the atmosphere causing acute and chronic respiratory diseases. Therefore, this study aimed to investigate the associations among air quality, meteorological variables, and the number of hospital admissions for respiratory diseases in the city of Canoas/RS between January 2014 and December 2018. For the statistical correlation among these factors, the Pearson correlation (r) was used through the Statistical Package for the Social Sciences (SPSS) software, version 26.0 for Windows, considering significant when $p<0.05$. The air quality parameters, PM_{10}, NO_2, and O_3, exceeded the limits recommended by regulatory agencies. In the hospital admissions records, there was a greater registry of hospitalizations of males and in the elderly age group. It is possible to verify a significant correlation between air pollutants and hospital admissions, as well as meteorological variables. Therefore, it is necessary the implementation of effective policies and practices to minimize the health risks associated with air pollution and thus decrease the adverse effects related to this exposure.

Keywords: Respiratory Diseases; Particulate Matter; Atmospheric Pollutants

RESUMO

A poluição atmosférica é responsável por vários danos à saúde humana. O aparelho respiratório está em contato direto com o meio externo e possui a capacidade de absorver elementos nocivos presentes na atmosfera ocasionando doenças respiratórias agudas e crônicas. Diante disso, este estudo buscou investigar as associações entre a qualidade do ar, variáveis meteorológicas e o número de internações

hospitalares por doenças respiratórias no município de Canoas/RS, entre janeiro de 2014 a dezembro de 2018. Para a correlação estatística entre esses fatores foi utilizada a correlação de Pearson (r) através do software Statistical Package for the Social Sciences (SPSS), versão 26.0 para Windows, considerando significativo quando o valor de $p<0,05$. Os parâmetros de qualidade do ar MP_{10}, NO_2 e O_3, extrapolaram os limites preconizados pelos órgãos reguladores. Nos registros de internações hospitalares, foi evidenciado maior registro de internações no gênero masculino e na faixa etária dos idosos. É possível verificar correlação significativa entre poluentes atmosféricos e internações hospitalares, bem como nas variáveis meteorológicas. Portanto, torna-se necessário à implementação de políticas e práticas efetivas para minimizar os riscos à saúde associados à poluição do ar e assim diminuir os efeitos adversos relacionados a essa exposição.

Palavras-chave: Doenças respiratórias; Material particulado; Poluentes atmosféricos

1 INTRODUCTION

The accelerated urban growth, observed in many cities, aggravated the relationship between man and nature, generating pollution and promoting the degradation of the environment. The alteration in the air quality is one of the most concerning consequences, as the air does not undergo prior treatment and is contaminated by various toxic substances emitted by cars, industries, and other sources. The current levels of air pollution experienced by the greater part of the population can compromise the well-being and quality of life. Countless studies found evidence on the association between air pollution and the deleterious effects on human health (ARBEX *et al.,* 2012; MEDEIROS; GOUVEIA, 2005; POPE III *et al.,* 2008; RODRIGUES-SILVA *et al.*, 2012; SALDIVA *et al.,* 1995; SCHWARTZ, 2004). The improvement of technological industries, such as the emergence of combustion engine, steel and chemical products industries, and the burning of fossil fuel, were not followed by analyses that could evaluate their impact on the environment, the toxicity of the residues produced, or the probable damages to health (RAMANATHAN *et al.,* 2016). For this reason, in the last 50 years, we have faced the disastrous results of this disorderly process and struggled to understand what these residues from this developmental race are and avoid their deleterious effects on the planet and its inhabitants (WHO, 2016).

Air pollution also presents effects on the climate which, in turn, also influences human well-being. The climate and the different weather conditions (temperature variation, heat waves, dry season), when associated with air pollution, can be determinants in the occurrence of beneficial or harmful effects on human health. The dispersion of pollutants, for example, is influenced by local meteorological conditions. The relation among human health, pollution, and climate and weather conditions have been the subject of much research performed in the last decades (COÊLHO; SALDIVA, 2011; MORRIS; NAUMOVA, 1998). Studies show a direct relationship between air pollution and numerous diseases, especially respiratory ones. Therefore, to better understand this relationship, the following pathologies were selected, according to the International Statistical Classification of Diseases (ICD): asthma (J45), influenza (J11), pneumonia (J15), bronchitis and acute bronchiolitis (J20), bronchial and lung neoplasm (C34.9), and bronchitis, emphysema, and other diseases (J40-J47).

In this context, the present study aimed to evaluate the relationship between air quality and meteorological conditions in hospitalizations by respiratory complications in residents of the city of Canoas/RS.

2 MATERIAL AND METHODS

2.1 Site characterization

The city of Canoas, located near Porto Alegre, is considered the most populous in the Metropolitan Region (MRPA), with a territorial area of 130.7 km^2 (IBGE, 2019) and an estimated population of 348,208 inhabitants (IBGE, 2020), resulting in a significant demographic density of 2,470.1 inhabitants per Km^2 (IBGE, 2010) in the city's territory. It borders the cities of Porto Alegre, Cachoeirinha, and Esteio (IBGE, 2010). Canoas is home to large national and multinational companies, such as Alberto Pasqualini Refinery (REFAP), in addition

to important names in the gas, metal-mechanic, electrical, and transport sectors. It demonstrates great dynamism in industrial transformation activities and, consequently, awakening some problems of environmental origin (TIBULO *et al.,* 2020). Therefore, being aware of the city's anthropogenic influence and its particularities, we validated the choice of sampling location.

2.2 Health data

Data were from the Hospital Information System (HIS), made available by the Department of Informatics of the Unified Health System (DATASUS) from January 2014 to December 2018. Data of hospitalizations of adults (20 to 59 years old) and elderly (60 years or older) with a diagnosis of respiratory disease were used.

It should be noted that the HIS is managed by the Ministry of Health, along with the Health Assistance Department, State Health Department, and Municipal Health Department, being processed by the DATASUS (BRASIL, 2008). It is noteworthy that the data are made available by DATASUS in electronic spreadsheets, dispensing the use of a data collection instrument, and the researcher being responsible for structuring and organizing these data for analysis. The description of the variables respects the technical notes of DATASUS (2021).

Diseases are classified according to the tenth revision of the International Classification of Diseases (ICD-10). Among the illnesses listed in ICD-10 as diseases of the respiratory system are asthma (J45), influenza (J11), pneumonia (J15), bronchitis and acute bronchiolitis (J20), bronchial and lung neoplasm (C34.9), and bronchitis, emphysema, and other diseases (J40-J47) (BANCO DE SAÚDE, 2014).

2.2.1 Meteorological data

The National Institute of Meteorology (INMET) made available the meteorological data used in the study and consist of an annual average of the variables: mean temperature (°C), minimal temperature (°C), maximum temperature (°C), and mean relative air humidity (%), all collected daily. The Automatic Meteorological Station, code a801 of the 8th District of INMET, is located in Porto Alegre.

2.2.2 Air quality data

The State Foundation for Environmental Protection (FEPAM-RS) collected and disseminated the data regarding air quality, obtaining the mean of the hourly measurement on the following atmospheric pollutants: O_3 (ozone), PM_{10} (particulate matter), and NO_2 (nitrogen dioxide).

FEPAM monitors the air quality through the Network of Automatic Station (Rede Ar do Sul), where analyses are automatically performed when the air is sampled. These generated data are sent to a central, thus allowing online monitoring of air quality and meteorological conditions of the sites where the Monitoring Stations are installed.

2.3 Data analysis

The period that comprehends the data analyses (2014 to 2018) was divided into annual quarters, totaling 20 samples. The sample meets the normality criteria. The results are described by absolute (n) and relative (%) frequencies, minimum and maximum values, arithmetic mean, and standard deviation. To examine the existence of relations between environmental (PM_{10}, NO_2, and O_3) and meteorological (relative air humidity and air temperature) variables with hospitalizations due to class of respiratory diseases and demographic

characterization, the Pearson correlation (r) was used. All statistical procedures were performed in Statistical Package for the Social Sciences (SPSS) software (version 26.0), considering statistically significant when $p<0.05$.

3 RESULTS AND DISCUSSION

Table 1 presents the values of air quality parameters and meteorological data through environmental variables, PM_{10}, NO_2, and O_3; and meteorological, relative air humidity and air temperature, from 2014 to 2018 (n=20).

Table 1 – Descriptive statistics of environmental (PM_{10}, NO_2, and O_3) and meteorological (humidity and temperature) variables from 2014 to 2018 (n=20)

Variable	Period	Minimum	Maximum	$\bar{x}$	σ	WHO* (2005)
Mean PM_{10} (μg/m^3)	20	14.3	33.3	24.9	5.8	
Maximum PM_{10} (μg/m^3)	20	93.8	554.4	196.4	115.2	50
Mean NO_2 (μg/m^3)	20	7.0	29.3	18.9	5.9	
Maximum NO_2 (μg/m^3)	20	44.5	245.3	125.8	62.1	100
Mean O_3 (μg/m^3)	20	8.4	31.6	21.2	7.0	
Maximum O_3 (μg/m^3)	20	33.2	222.3	97.8	39.9	160
Relative Humidity (%)	20	66.7	84.6	78.2	4.4	
Mean Temperature (°C)	20	15.6	25.2	20.3	3.3	
Minimum Temperature (°C)	20	2.7	17.2	8.6	4.5	
Maximum Temperature (°C)	20	31.4	40.2	35.1	2.4	

$\bar{x}$ = arithmetic mean; σ = standard deviation. * Air Quality Standard
Source: authors (2021)

According to Table 1, the highest mean PM10 concentration recorded was 33.3 μg/m3, and the maximum concentration was 554.4 μg/m3. For this pollutant, the national air quality standard established by the National Council for the

Environment (CONAMA), Resolution No. 491 of 11/19/2018 (BRASIL, 2018), is 20 µg/m3 (primary standard, year). The quality standard exceeded during the study period by 27.72 times.

Regarding the NO2, the highest mean value recorded was 29.3 µg/m3, and the maximum was 245.3 µg/m3. During the study period, the NO2 surpassed the limits established by CONAMA of 40 µg/m3 per year by 6.13 times.

For O3, the highest mean value observed was 31.6 µg/m3, and the maximum was 222.3 µg/m3. According to FEPAM data and considering only the periods used in this study, the pollutant exceeded the national air quality standard (100 µg/m3, 8h) by 2.22 times from 2014 to 2018. Table 1 still demonstrates the results of the exploratory analysis of the temperature and relative air humidity variables for the studied period registered in the INMET stations. The highest mean value observed for temperature was 25.2 °C, and for humidity, the highest monthly mean value was 84.6%.

Table 2 shows the description of hospitalizations for pathologies and demographic profile through minimum and maximum values, arithmetic mean, and standard deviation, by the studied periods, where 2,171 hospitalizations by respiratory diseases were registered.

Table 2 – Descriptive statistics of hospitalizations by diseases and demographic groups, from 2014 to 2018 (n=20)

Variable	Periods	Minimum	Maximum	$\bar{x}$	σ
Asthma	20	13.0	69.0	35.7	14.9
BEORTD	20	40.0	99.0	62.1	18.1
BAB	20	4.0	170.0	58.3	47.0
Influenza	20	0.0	18.0	4.6	4.8
BLNEO	20	15.0	33.0	22.9	6.0
Pneumonia	20	160.0	489.0	306.6	102.3

Continued...

Table 2 – Conclusion

Variable	Periods	Minimum	Maximum	$\bar{x}$	Σ
ORD	20	2.0	19.0	9.1	4.4
Total Diseases	20	279.0	736.0	499.2	156.7
Adults (20 to 59 years old)	20	86.0	167.0	118.8	26.9
Elderly (> 60 years old)	20	141.0	341.0	231.1	62.4
Male	20	146.0	406.0	256.4	77.4
Female	20	131.0	360.0	242.9	81.5

$\bar{x}$ = arithmetic mean; σ = standard deviation. BEORTD - bronchitis, emphysema, and other respiratory tract diseases; BAB – bronchitis and acute bronchiolitis; BLNEO – bronchial and lung neoplasm; ORD – other respiratory disease.
Source: authors (2021)

In the analyses by pathologies, it was observed that the hospitalizations for pneumonia had the highest records of admissions with an average of 306.6, followed by bronchitis, emphysema, and other respiratory tract diseases with an average of 62.1, and bronchitis and acute bronchiolitis with an average of 58.3 of hospital records at all quarters.

In relation to the hospital admissions records on the demographic variable, when analyzing the age group, we found a higher hospitalization mean for the elderly (>60 years old) of 231.1 in comparison to adults (20 to 59 years old), with admission records of 118.8 by period. Regarding gender, hospital admissions by male prevailed over female, with a mean of 256.4, followed by 242.9 hospitalizations per period, respectively.

Table 3 demonstrates the sample characterization regarding the hospitalization rates through the variable groups of disease, adults (20 to 59 years old), elderly (>60 years old), and gender.

Table 3 – Hospitalizations rate by diseases and demographic groups, from 2014 to 201, per 100,000 inhabitants (n=20)

Variable	Periods	Minimum	Maximum	$\bar{x}$	σ
Asthma	20	3.8	20.2	10.4	4.4
BEORTD	20	11.7	28.9	18.1	5.3
BAB	20	1.2	49.4	17.0	13.7
Influenza	20	0.0	5.3	1.3	1.4
BLNEO	20	4.3	9.7	6.7	1.8
Pneumonia	20	46.4	143.3	89.6	30.0
ORD	20	0.6	5.5	2.7	1.3
Total Diseases	20	80.9	215.6	145.8	46.0
Adults (20 to 59 years old)	20	24.9	49.1	34.7	8.0
Elderly (> 60 years old)	20	41.2	99.9	67.5	18.4
Male	20	42.3	118.9	74.9	22.7
Female	20	38.0	105.5	70.9	23.9

$\bar{x}$ = arithmetic mean; σ = standard deviation. BEORTD - bronchitis, emphysema, and other respiratory tract diseases; BAB – bronchitis and acute bronchiolitis; BLNEO – bronchial and lung neoplasm; ORD – other respiratory disease.
Source: authors (2021)

Hospitalization rates for pneumonia obtained the highest records of admissions with an average of 89.3, followed by bronchitis, emphysema, and other respiratory tract diseases, with a mean of 18.1, and bronchitis and acute bronchiolitis with an average of 17.0 registries in all quarters.

Regarding the records of hospital admissions on the demographic variable, when analyzing the age group, we found a higher mean of hospitalization for elderly (> 60 years old) of 67.5 compared to hospitalizations for adults (20 to 59 years old), with records of 34.7 admissions, by the studied period. As for gender analysis, the hospital admissions per male prevailed over female, with respective registries averaging 74.9 followed by 70.9 hospitalizations on the studied period.

Table 4 demonstrates the existence of associations between the hospitalizations and sample profile variables through Pearson correlation coefficients.

Table 4 – Pearson correlation (r) between hospitalizations and environmental and meteorological variables (n=20)

		Mean PM_{10}	Max PM_{10}	Mean NO_2	Max NO_2	Mean O_3	Max O_3	Mean Humidity	Mean Temp	Min Temp	Max Temp
Asthma	*r*	0.143	0.086	0.151	0.121	0.160	0.180	0.012	0.608**	0.511	0.358
	p	0.546	0.717	0.526	0.611	0.499	0.447	0.959	0.004	0.021*	0.122
BEORTD	*r*	0.462	0.256	0.214	0.497	0.380	0.204	0.335	0.702	0.651	0.556
	p	0.040*	0.276	0.366	0.026*	0.098	0.388	0.148	0.001**	0.002**	0.011*
BAB	*r*	0.289	0.386	0.420	0.401	0.520	0.191	0.446	0.656	0.712	0.696
	p	0.216	0.093	0.065	0.080	0.019*	0.420	0.049*	0.002**	0.000***	0.001**
Influenza	*r*	0.427	0.164	0.024	0.368	0.191	0.187	0.182	0.496	0.390	0.489
	p	0.061	0.491	0.920	0.110	0.420	0.430	0.443	0.026*	0.089	0.029*
BLNEO	*r*	0.488	0.264	0.003	0.013	0.450	0.518	0.511	0.177	0.083	0.226
	p	0.029*	0.260	0.989	0.957	0.046*	0.019*	0.021*	0.455	0.727	0.337
Pneumonia	*r*	0.689	0.222	0.253	0.525	0.280	0.181	0.207	0.741	0.665	0.644
	p	0.001**	0.348	0.281	0.017*	0.232	0.445	0.382	0.000***	0.001**	0.002**
ORD	*r*	0.139	0.358	0.358	0.120	0.414	0.266	0.273	0.213	0.156	0.079
	p	0.558	0.121	0.122	0.614	0.070	0.257	0.244	0.368	0.511	0.739
Total Diseases	*r*	0.632	0.287	0.339	0.546	0.398	0.209	0.291	0.834	0.785	0.736
	p	0.003**	0.220	0.143	0.013*	0.082	0.376	0.213	0.000***	0.000***	0.000***
Adults	*r*	0.807	0.380	0.108	0.529	0.007	0.227	0.047	0.377	0.335	0.371
	p	0.000***	0.098	0.651	0.017*	0.978	0.335	0.843	0.101	0.149	0.107
Elderly	*r*	0.710	0.296	0.339	0.508	0.167	0.020	0.214	0.569	0.580	0.489
	p	0.000***	0.205	0.144	0.022*	0.481	0.932	0.364	0.009**	0.007**	0.029*
Male	*r*	0.650	0.286	0.321	0.527	0.347	0.182	0.168	0.797	0.756	0.686
	p	0.002**	0.222	0.168	0.017*	0.134	0.441	0.480	0.000***	0.000***	0.001**

Continued...

Table 4 – Conclusion

		Mean PM_{10}	Max PM_{10}	Mean NO_2	Max NO_2	Mean O_3	Max O_3	Mean Humidity	Mean Temp	Min Temp	Max Temp
Female	*r*	0.597	0.280	0.348	0.550	0.436	0.229	0.401	0.846	0.791	0.764
	p	0.005**	0.232	0.133	0.012*	0.055	0.331	0.080	0.000***	0.000***	0.000***

(*) significant when p ≤ 0,05; (**) significant when p ≤ 0,01; (***) significant when p ≤ 0,001; BEORTD - bronchitis, emphysema, and other respiratory tract diseases; BAB – bronchitis and acute bronchiolitis; BLNEO – bronchial and lung neoplasm; ORD – other respiratory disease.
Source: authors (2021)

According to the analyses, asthma was negatively correlated with the mean and minimum temperature. It evidences that as lower temperatures occur during the data collection period, a higher number of hospitalizations related to this pathology was observed.

Bronchitis, emphysema, and other respiratory tract diseases were positively correlated with mean PM10 and maximum NO2, indicating that as there is an increase in the concentrations of mean PM10 and NO2, there is also a record of increased hospitalizations for bronchitis, emphysema, and other respiratory tract diseases.

According to the meteorological variables, the temperature, either the mean or maximum registered in the period studied, demonstrates a negative correlation with the hospitalization rates in this group of diseases, in a way that, once there are low temperatures, there is an increase in hospitalization rates for this group.

Hospitalizations for bronchitis and acute bronchiolitis show a negative correlation with the O3 rate in the period studied, so low O3 rates were related to high hospital admission rates in this group of diseases.

The mean humidity registered from 2014 to 2018 demonstrated a positive correlation with the hospitalization rates for bronchitis and acute bronchiolitis.

The temperature recorded in this period influenced hospital admissions for bronchitis and acute bronchiolitis, especially when registering low temperature.

As for influenza, hospitalization rates showed a negative correlation with mean and maximum temperatures registered in the period studied, evidencing that low temperatures lead to higher hospitalization rates for this disease.

For bronchial and lung neoplasm, the increase in hospitalization rates was related to higher concentrations of mean PM10 and mean and maximum O3 rates, showing a negative correlation with mean humidity.

Hospitalization rates for pneumonia demonstrated a relation with high concentrations of mean PM10 and maximum NO2 and, on the other hand, to temperatures (mean, minimum, and maximum) recorded from 2014 to 2018.

The total number of hospitalizations for respiratory diseases in the period from 2014 to 2018 appeared to be significantly correlated with the concentrations of mean PM10 and maximum NO2 and inversely proportional to the temperatures (mean, minimum, and maximum) registered in the period.

The results of this study indicate some of the possible relations between the environmental and meteorological variables with the hospital admissions for respiratory diseases. In this study, we observed that PM10 is the most present pollutant in the city of Canoas, followed by NO2 and O3.

It was possible to observe that air quality variables exceeded the limits established by regulatory agencies. An air quality standard legally defines the maximum limit for the concentration of a given pollutant in order to assure the protection of the health and well-being of the population in general. These patterns are established by public policies of each country, depending on its economy, management, and development, and these guidelines and values are also in agreement with scientific evidence, making research in this area increasingly relevant (LAENDLE JR. *et al.,* 2019).

In Brazil, the air quality parameters established by CONAMA are above the parameters adopted in other countries (RIBEIRO *et al.,* 2019). According to Ostro

(2004), evaluating the consequences of exposure to atmospheric air can contribute to the definition of emission control priorities.

The NO2 is a reddish-brown gas with a very strong odor and very irritating, highly toxic, and relatively soluble in water (FEPAM, 2020). It is produced by natural sources, such as electrical discharges in the atmosphere, and anthropogenic sources, through nitric and sulfuric acids industries and combustion engines (main source). NO2 is produced during the burning of fuels at high temperatures, in thermal plants that use gas or incineration. It can cause damage to the bronchi and alveoli in the lung, in addition to increasing the reactivity to naturally occurring allergens. At high doses, it can cause pulmonary edema and, at lower concentrations, chronic bronchitis and emphysema.

Regarding the analyses of the levels of pollutants O3 and NO2, we observed that the maximum values remained above the ones recommended by WHO (100 and 40 μg/m3, respectively) (WHO, 2005). In view of this evidence, in which the levels of PM10, NO2, and O3 were above the established limits, these findings corroborate with other studies, such as by Leite *et al.* (2011), which demonstrated that in urban centers the days when the air reached critical levels of pollution were increasingly frequent, values that can be exacerbated when meteorological variations occur, such as thermal inversion and lack of wind.

As well as other studies, they also observed positive associations between air quality and hospitalizations for respiratory and cardiovascular diseases, demonstrating an association with, for example, high blood pressure, asthma, pneumonia, and ischemic heart disease (GOUVEIA *et al.,* 2017; NASCIMENTO *et al.,* 2017; RIBEIRO *et al.,* 2018).

Exposure to PM10, NO2, and O3 can cause implications for human health, and among the most reported effects are shortness of breath, coughing, eye irritation, and airway irritation. It is also known that repeated exposures to pollutants can affect lung defenses; aggravate the symptoms of pre-existing diseases, such as asthma; cause damage in the cardiovascular system; promote

harm to nasal mucosa; reduce lung function; among several other injuries (KÜNZLI; PEREZ; RAPP, 2010; WHO, 2016).

In Brazil, research on the impact of pollution on health is more focused in large capitals, such as São Paulo, with few studies performed in other cities or large centers. The city of Canoas, near Porto Alegre, is considered the most populous one in the Metropolitan Region of Porto Alegre (MRPA), a region that covers 34 cities in the state of Rio Grande do Sul. The Vehicle Pollution Control Program estimated that the emissions of air pollutants came from mobile sources and verified that the MRPA is responsible for 40% of pollutant emissions from vehicles in the state (SEMA, 2010). The city has considerable intercity vehicular traffic, and also has large national and multinational industries and, according to data referred to the period from 2002 to 2015 from the Foundation for Economic and Statistic (FEE), the MRPA concentrates the highest Industry Polluting Potential Index (INPP-I), being the city of Canoas the main contributor, with a 15% share (RIO GRANDE DO SUL, 2018), demonstrating great dynamism in its activities and, consequently, raising some concerns of environmental origin.

In addition to interactions with pollutants, hospital admissions showed an association in the period from 2014 to 2018, being influenced by a combination of factors, pollution, and meteorological conditions. The maximum temperatures were close to 30 °C and, and as a consequence of lack of rain, the relative air humidity also registered values above those recommended by WHO (60%). All these factors can collaborate with the aggravation of diseases, especially respiratory ones.

The temperature and humidity variables also played a role of risk in the outcomes of elderly and adults. In a beneficial or harmful manner, the climate and the different weather variations are environmental factors that can influence the human organism (MURARA; AMORIM, 2010). Certain illnesses may be more likely to occur in temperature variations, low humidity, and heatwaves.

Other studies suggest that the meteorological variables can modify the effects of pollutants on health, whether at high or low temperatures (MORRIS; NAUMOVA, 1998; WONG *et al.,* 1999; WONG *et al.,* 2014). According to Gordon (2003), high temperatures can make people more vulnerable to the effects of pollutants.

When analyzing the age group in which the respiratory problems were most present, it is noticed that the elderly aged 60 years or older prevailed, followed by the adult aged 20 to 59 years old. These data corroborate the literature, as the elderly are more susceptible to adverse effects of exposure to air pollutants once they have a less efficient immunological system, in addition to a progressive decrease in lung function that can lead to airway obstructions. Besides, there is a reduction in the chest wall compliance and pulmonary hyperinflation, causing an additional energy expenditure to perform the respiratory movements, as well to a functional decrease of organic systems (WHO, 2005).

Men were the most affected by respiratory problems compared to women. The literature shows different results regarding exposure to air pollutants between male and female in different age groups. However, it remains unclear whether the observed response is a result of sex-linked biological differences or variations in activity patterns, or even accuracy in measuring exposure (EPA, 2010). It is believed that the highest mortality rates for Chronic Obstructive Pulmonary Disease (COPD) in male are related to the history of tobacco consumption, in the beginning, a predominantly male behavior (WHO, 2009).

In relation to the prevalence of the health problems found, pneumonia, bronchitis and acute bronchiolitis, bronchitis, emphysema and other respiratory tract diseases, and asthma were the most prevalent in this population.

Moolgavkar, Luebek and Anderson (1997) investigated the relationship between air pollution and hospitalizations for COPD and pneumonia in the elderly in Minneapolis (measured pollutants: CO, NO2, O3, PM10, and SO2) and in Birmingham (measured pollutants: CO, O3, and PM10). They observed a weak

association between hospital admission for both diseases and the air pollution in Birmingham, contrary to the result found in Minneapolis, where a significant relationship between the hospitalizations and O3 was obtained.

Asthma presented a negative correlation with mean and minimum temperature, showing that as lower temperatures occur during the data collection period, a higher number of asthma-related hospitalizations was found. Epidemiological and toxicological studies have demonstrated an association between air pollution and bronchial asthma. Air pollutants are associated with an increase in emergency room visits and hospitalizations for acute asthma attacks, as well as an increase in expiratory wheezing, respiratory symptoms, and the use of rescue medication (KELLY; FUSSEL, 2011).

The prevalence of bronchial asthma has increased across the planet, especially in densely industrialized urban regions. Prospective studies suggested that exposure to air pollutants can lead to the development of new cases of asthma. One example is the large increase in the incidence of asthma in China after industrial development and, as a consequence, the great enhance of pollutants concentration (WATTS, 2006).

The increase in hospitalizations rates for bronchial and lung neoplasm seems to be related to higher mean PM10 concentrations and mean and maximum O3 rates, with a negative correlation with mean humidity.

Studies have demonstrated the effects of exposure to pollutants and the development of lung cancer, attributing both to the direct action of carcinogens present in pollution and chronic inflammation induced by them (WHO, 2005; YANG; OMAYE, 2009). A prospective study with 500,000 adults from 50 U.S. states showed an increase of 14% in the incidence of lung cancer, associated with a 10 µg/m3 increase in PM2,5 concentration (POPE III *et al.,* 2002). In a study performed in European countries, it was attributed that 5% and 7% of different types of lung cancer in non-smokers and ex-smokers, respectively, was caused by the effects of pollution (VINEIS *et al.,* 2007).

Hospitalization rates for influenza were negatively correlated with mean and maximum temperatures registered in the studied period, demonstrating that low temperatures lead to higher admission rates for this disease. In Brazil, the seasonality pattern of influenza varies among diverse regions, being more present in those with well-defined climate seasons, occurring more frequently in colder months, in temperate climates, or the rainy periods, in the tropical climate. Seasonal influenza can manifest by annual outbreaks of variable magnitude, gravity, and extension (BRASIL, 2009).

Regarding bronchitis and acute bronchiolitis actions, a negative correlation with O3 rate was observed in the studied period, so that low O3 rates appeared related to high hospitalization rates in this group of diseases.

According to PAHO/WHO (2008), alterations of temperature, humidity, and rainfall regime can increase the effects of respiratory diseases, as well as change the exposure conditions to air pollutants. In urban regions, some effects of exposure to air pollutants are increased when climate alterations occur, especially thermal inversions. This is verified in relation to asthma, allergies, broncho-pulmonary infections, and upper airway infections (sinusitis), mainly in more susceptible groups, which include children under 5 years old and people over 65 years old.

In relation to bronchitis, emphysema, and other respiratory tract diseases, a positive correlation with mean PM10 and maximum NO2 was observed, indicating that as there is an increase in the concentrations of mean PM10 and NO2, there is also an increase in hospitalizations for bronchitis, emphysema, and other respiratory tract diseases. In general, most studies on admissions for respiratory diseases in the elderly and mortality are associated with some air pollutants.

Hospitalization rates for pneumonia appeared to be related to high concentrations of mean PM10 and maximum NO2 and, on the other hand, to

temperatures (mean, minimum, and maximum) registered in the period from 2014 to 2018.

In the U.S., a large study, called The National Mortality, Morbidity and Air Pollution Studies (NMMAPS), was performed in 20 major U.S. metropolitan areas, where 50 million people reside. Its progress occurred from 1987 to 1994 (SAMET *et al.,* 2000). All-cause mortality increased by about 0.5% for every 10 μg/m3 increase in PM10. The study happened in 10 cities, with a population of 1,843,000 elderly individuals (over 65 years of age). Regarding hospital admissions, there was an increase in hospitalizations for COPD (1.5%) and cardiovascular diseases, 1.1% per 10 μg/m3 of PM10 (ZANOBETTI; SCHWARTZ; DOCKERY, 2000).

In Brazil, important studies were performed in the city of São Paulo. In one of the studies, databases referring to the SUS Hospital Information System were used. A time-series analysis was performed. All hospitalizations of the elderly (people aged 65 or older) and children (under 5 years old) that occurred from May 1st, 1996, to April 31st, 2000, in hospitals from the city of São Paulo were observed. As a result, a growth of 10 μg/m3 in the level of inhalable PM was associated with an increase of 4.6% in hospitalizations for asthma in children, 4.3% for COPD in the elderly, and 1.5% for ischemic heart disease also in the elderly. Therefore, a statistically significant association between the increase in the level of pollutants in the atmosphere and the increase of hospitalizations for diverse causes, in both age groups studied, could be established (GOUVEIA *et al.,* 2006).

In fact, it is observed that even air pollutants being within the established limits for air quality, they continue to affect the morbidity and mortality for respiratory problems, especially in the most vulnerable population. Therefore, it is suggested that the air quality limits should be reassessed, and effective actions should be taken in order to improve the environmental quality that directly impacts the population's health.

4 FINAL CONSIDERATIONS

The analyses performed in this study evidenced, through a model adjusted to the data set, the association between pollutants, meteorological variables, and hospitalizations for respiratory diseases.

Several factors that influence human health were not taken into consideration in the present study, such as nutrition, genetics, social status, hygiene, among others. However, the results obtained could predict, in quantitative terms, the risk posed to the population by air pollution, even when air quality standards were not exceeded.

The records used were from SUS, thus, the results presented represent the effects of pollution in a part of the population that uses this service, that is, most of the country's population. The records computed in the SUS database are performed for control and counting purposes; therefore, they are subjected to errors, which may present accuracy problems. Another possible problem related to the database is the double-counting of the same patient, as readmissions are not identified. Although the analyses were carried out for three pollutants and the individual effects were emphasized, air pollution is formed by a mixture of substances, harmful or not to health, being a complex task to verify the health effects of only one pollutant. Pollutants can also present synergy, the combined effects are potentiated in relation to individual effects. However, interactions among pollutants were not considered in this study. Anyway, the analyses performed in this study were satisfactory for predicting hospitalizations. The results are quite expressive and within the reality proposed in other studies.

The total number of hospitalizations for respiratory diseases from 2014 to 2018, in the city of Canoas, was significantly correlated with mean PM_{10} and maximum NO_2 concentrations, and inversely proportional to temperatures (mean, minimum, and maximum) registered in the period studied. In view of the importance attributed to health problems related to air pollutants, according to

our analyses, we established that PM_{10}, NO_2, and O_3 became a factor involved in the process of illness due to respiratory diseases.

It is expected that this research can significantly contribute to other investigations in this area, with the main purpose of supporting discussions able to produce mitigating measures for air pollution.

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Authorship contributions

1 – Elisângela Conceição Lara (Corresponding author)
Mestre em Qualidade Ambiental
https://orcid.org/0000-0002-5967-8014 • elisxulara@gmail.com
Contribuição: Redação, metodologia, conceituação e análise formal

2 – Aline Belem Machado
Estudante de Doutorado em Qualidade Ambiental
https://orcid.org/0000-0001-5425-6608 • linebmachado@hotmail.com
Contribuição: Autoria

3 – Lutieri Mateus Benetti
Enfermeiro
https://orcid.org/0000-0001-8458-6675 • lutimb@hotmail.com
Contribuição: Curadoria de dados, revisão, tabela, gráficos

4 – André Luís Machado Bueno
Curadoria de dados, revisão, tabela, gráficos
https://orcid.org/0000-0003-1558-3774 • andrebueno@feevale.br
Contribuição: Investigação, metodologia, revisão e edição

5 – Daniela Montanari Migliavacca
Doutora em Ecologia
https://orcid.org/0000-0002-9923-4514 • danielamigliavacca@hotmail.com
Contribuição: Conceituação, análise formal, supervisão

6 – Daiane Bolzan
Doutora em Bioquímica Toxicológica
https://orcid.org/0000-0002-5326-8065 • daianeb@feevale.br
Contribuição: Revisão e edição, conceituação, administração do projeto, supervisão

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