Associations between air quality, meteorological variables, and respiratory disease hospitalizations

Associações entre qualidade do ar, variáveis meteorológicas e internações por doenças respiratórias

Asociaciones entre la calidad del aire, variables meteorológicas e internaciones por enfermedades respiratórias

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ABSTRACT
Air pollution plays a crucial role in environmental health and is linked to various respiratory diseases. This study aims to investigate the associations between air quality, meteorological variables, and the number of hospitalizations due to respiratory diseases in adults and the elderly. The study was conducted in Novo Hamburgo, in the Metropolitan Region of Porto Alegre, RS. Pollutants such as NO_2, CO, O_3, $PM_{2.5}$, and PM_{10} were analyzed, along with average temperature, minimum temperature, maximum temperature, and relative humidity. Health information on respiratory diseases was obtained from the Ministry of Health. A significant correlation was observed between air quality, meteorological variables, and hospital admissions. The results indicate that higher concentrations of atmospheric pollutants (NO_2, CO), lower temperatures, and higher relative humidity are associated with an increase in hospitalizations for respiratory diseases. These findings high light the need for public policies and expanded air quality monitoring to mitigate the health impacts of pollution.

Keywords: Particulate Matter. Hospitalizations. Air Pollutants. Public Health.

RESUMO
A poluição do ar desempenha um papel crucial na saúde ambiental e está relacionado a várias doenças respiratórias. Assim, este estudo tem como objetivo investigar as associações entre a qualidade do ar, variáveis meteorológicas e o número de internações hospitalares por doenças respiratórias, em adultos e idosos e foi realizado em Novo Hamburgo, na Região Metropolitana de Porto Alegre – RS. Foram analisados poluentes como NO_2, CO, O_3, $PM_{2.5}$ e PM_{10}, temperatura média, temperatura mínima, temperatura máxima e umidade relativa e as informações de saúde foram extraídas do Ministério da Saúde para as doenças respiratórias. Foi observada uma correlação significativa entre a qualidade do ar, variáveis meteorológicas e o número de internações hospitalares. Os resultados

indicam que maiores concentrações de poluentes atmosféricos, NO_2, CO, temperaturas mais baixas e maior umidade relativa estão associadas a um aumento nas hospitalizações por doenças respiratórias. Esses achados ressaltam a necessidade de políticas públicas e de ampliar o monitoramento da qualidade do ar para reduzir os impactos da poluição na saúde.

Palavras-chave: Material Particulado. Hospitalizações. Poluentes Atmosféricos. Saúde Pública.

RESUMEN

La contaminación del aire desempeña un papel crucial en la salud ambiental y está relacionada con diversas enfermedades respiratorias. Este estudio tiene como objetivo investigar las asociaciones entre la calidad del aire, las variables meteorológicas y el número de hospitalizaciones por enfermedades respiratorias en adultos y personas mayores. El estudio se llevó a cabo en Novo Hamburgo, en la Región Metropolitana de Porto Alegre, RS. Se analizaron contaminantes como NO_2, CO, O_3, $PM_{2.5}$ y PM_{10}, junto con la temperatura promedio, temperatura mínima, temperatura máxima y humedad relativa. La información sobre salud y enfermedades respiratorias se obtuvo del Ministerio de Salud. Se observó una correlación significativa entre la calidad del aire, las variables meteorológicas y los ingresos hospitalarios. Los resultados indican que mayores concentraciones de contaminantes atmosféricos (NO_2, CO), temperaturas más bajas y una mayor humedad relativa están asociadas con un aumento en las hospitalizaciones por enfermedades respiratorias. Estos hallazgos resaltan la necesidad de políticas públicas y de ampliar el monitoreo de la calidad del aire para mitigar los impactos de la contaminación en la salud.

Palabras clave: Materia Particulada. Hospitalizaciones. Contaminantes del Aire. Salud Pública.

1 INTRODUCTION

It is estimated that seven million annual deaths are caused by exposure to atmospheric pollutants from fixed and mobile sources, in both urban and rural areas (WHO, 2018). Air quality is influenced by pollutant emissions, topography, land use, and weather conditions. Monitoring pollutant concentrations and understanding the factors affecting their dispersion are crucial for effective atmospheric quality management (MMA, 2020; Manisalidis et al., 2020). Additionally, urbanization exposes 90% of the global population to pollution levels that exceed the limits set by the World Health Organization, especially regarding fine particles.

The elderly population, as reported by Santos et al. (2021), is expanding due to the rise in life expectancy. They are vulnerable to the detrimental impacts of exposure to atmospheric pollutants because of their less efficient immune system (immunosenescence) and gradual decline in lung function, which may result in restricted physical activity. A recent study by Cheng et al. (2024) highlights that air pollution poses a significant health risk to the elderly, potentially discouraging their engagement in physical activity. The study found that higher levels of air pollution, measured by the Air Quality Index (AQI) and concentrations of $PM_{2.5}$ and PM_{10}, were inversely associated with physical activity levels among older adults. Specifically, an increase in AQI and $PM_{2.5}$ levels corresponded to a significant reduction in daily walking steps and minutes of light, moderate, and moderate-to-vigorous physical activity. These findings underscore the importance of improving air quality to promote physical activity and overall health among the elderly population.

In a study conducted in Beijing, China, Wu et al. (2020) observed a significant increase in hospital admissions for pneumonia associated with air pollution among the elderly, compared to younger age groups. Additionally, a cohort study carried out in the USA by Zhu et al. (2019), using data from Medicare (the government-managed insurance system), revealed that acute exposures to fine particulate matter and ozone during the hottest months of the year (spring and summer) between 2000 and 2012 were linked to an elevated risk of all-cause mortality among older adults. Remarkably, this effect persisted even on days when pollutant concentrations were below the air quality limits set by the Environmental Protection Agency.

Air quality in Brazil presents significant challenges, especially in metropolitan regions. Recent studies indicate that the air quality monitoring network in the country is insufficient and unevenly distributed, with 80% of the stations concentrated in the Southeast Region. The implementation of effective public policies and the expansion of the monitoring network are essential to mitigate the impacts of air pollution and protect public health, especially among the most vulnerable groups, such as children and the elderly (Saldiva et al., 2021; Vormittag et al., 2021; Silva et al., 2022).

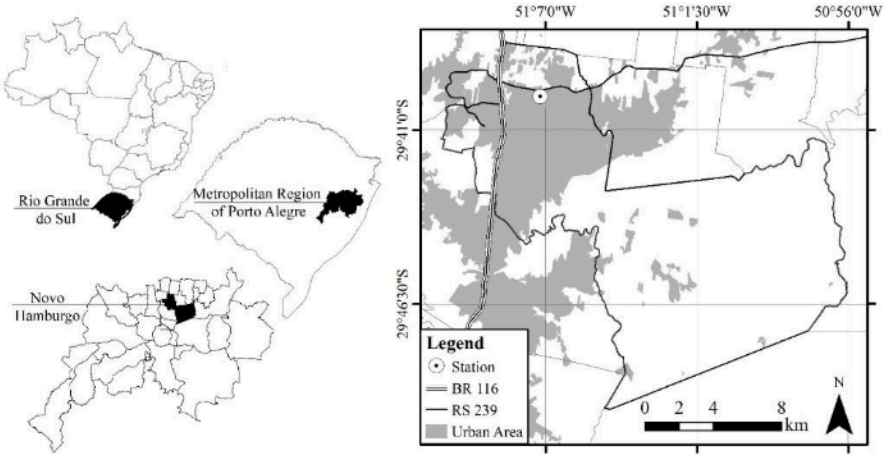
This study aims to investigate the associations among air quality, meteorological variables, and the number of hospital admissions for respiratory diseases in a municipality within the Metropolitan Region of Porto Alegre, focusing on adults and elderly individuals during the period from 2016 to 2019. This study provides evidence for the formulation of public health policies, in this way, robust monitoring systems can be established to improve air quality and reduce the burden of respiratory diseases in communities, especially among the most vulnerable individuals, such as the elderly.

2 STUDY AREA

The municipality of Novo Hamburgo/RS (Figure 1), situated within the Rio dos Sinos Hydrographic Basin, encompasses an area of 223,821 km² with an estimated population of approximately 247,000 inhabitants (IBGE, 2020). It comprises 26 urban neighborhoods and one rural area (Lomba Grande), which covers around 156 km², constituting roughly two-thirds of the municipality's total territorial expanse.

Within the municipality (Figure 1), 92.1% of households have access to adequate sewage, 90.3% of urban residences are located along public roads adorned with trees, and 71.7% of urban homes benefit from adequate urbanization (including features such as manholes, sidewalks, paving, and curbs) (IBGE, 2020).

Figure 1: Map illustrating the location of Novo Hamburgo within Brazil, in comparison with the Metropolitan Region of Porto Alegre.



Source: Authors, 2024.

3 METHODOLOGY

The methodology of this study was designed to investigate the associations between air quality, meteorological variables, and the number of hospital admissions for respiratory diseases in the municipality of Novo Hamburgo, RS. For this purpose, environmental, meteorological, and health data were used, covering the period from 2016 to 2019. The decision to limit the database to the year 2019 was made to eliminate the potential effects of the COVID-19 pandemic from the study.

3.1 AIR QUALITY DATA

For the collection of environmental data, the database generated previously by the Feevale Automatic Air Quality Monitoring Station (EAMQA) was used for the period from 2016 to 2019. This time frame was selected due to the complete availability of the databases. The EAMQA continuously monitors nitrogen dioxide (NO_2), carbon monoxide (CO), and ozone (O_3). These pollutants' daily average concentrations are provided.

For particulate matter smaller than 10μm (PM_{10}) and smaller than 2.5μm ($PM_{2.5}$), measurements were conducted using a dichotomous analyzer, resulting in monthly averages based on a total of 48 samples. The analyses were conducted at the Clean Technologies Center (CTL) at Feevale University.

The evaluated parameters were compared against reference values established by the World Health Organization (2021). Annual limits were used for comparison, with 4 mg/m^3 serving as the limit for CO. For O_3, the permissible value is 60 µg/m³, while NO_2 has a restrictive limit of 10 µg/m³, and SO_2 is capped at 40 µg/m³. Additionally, PM_{10} adheres to reference values up to 15 µg/m³, and $PM_{2.5}$ concentrations can reach up to 5 µg/m³.

3.2 METEOROLOGICAL DATA

The meteorological data utilized in this study were sourced from the National Institute of Meteorology (INMET). The dataset comprises annual averages of the following variables, all collected daily: Average Temperature (°C); Minimum Temperature (°C); Maximum Temperature (°C); Average Relative Humidity (%).

3.3 HEALTH DATA

The data analyzed in this study were sourced from the Hospital Information System (SIH), which was made available by the Department of Informatics of the Unified Health System (DATASUS). The dataset spans the years 2016 to 2019 and specifically focuses on hospital admissions related to respiratory diseases.

The study population includes adults (aged 20 to 59 years) and elderly individuals (aged 60 years or older). These individuals were diagnosed with various respiratory system disorders.

Diseases are classified according to the tenth revision of the International Classification of Diseases (ICD-10). Among the respiratory system disorders cataloged in ICD-10, the following are included: Asthma (J45); Influenza (J11); Pneumonia (J15); Bronchitis and Acute Bronchiolitis (J20); Neoplasia of the Bronchi and Lungs (C34.9); Bronchitis, Emphysema, and Other Diseases (J40-J47) (Banco De Saúde, 2022).

3.4 STATISTICAL ANALYSIS

Descriptive statistics were employed to summarize the results, including absolute frequencies (n), relative frequencies (%), minimum and maximum values, arithmetic mean, and standard deviation. To investigate the relationship between air quality, meteorological variables, and the incidence of respiratory disease hospitalizations, we utilized a multiple regression model with the Stepwise method. All statistical analyses were conducted using IBM® SPSS® software (version 26.0). Statistical inference was applied, considering a significance level of 5%.

4 RESULTS AND DISCUSSIONS

Table 1 presents the quantification of hospital admission records, categorized by year and specific pathologies. These pathologies include asthma, influenza, pneumonia, bronchitis and acute bronchiolitis, bronchial and lung cancer and bronchitis, emphysema, and other respiratory diseases. The data covers the period from January 2016 to December 2019 in the municipality of Novo Hamburgo-RS.

Table 1: Hospital Admission Records in the Municipality of Novo Hamburgo-RS, from 2016 to 2019.

Variables Period	Novo Hamburgo (n)	(%)
2016	791	28.16%
2017	809	28.8%
2018	628	22.36%
2019	581	20.68%
Total	2,809	100%

Source: Prepared by the author with data from DATASUS.

The total number of hospital admissions was 2,809, with admissions recorded for chronic diseases including asthma, influenza, pneumonia, bronchitis, bronchiolitis, neoplasia of the bronchi and lungs, and emphysema in the city of the present study. Notably, in 2017, there was a higher recorded number of

hospitalizations at 28.8%, followed by 2016 with 28.16%, 2018 with 22.36%, and 2019 with 20.68%.

Table 2 presents the demographic data of the subjects who underwent hospital admissions in the city of Novo Hamburgo-RS during the study period. The variables considered were gender and age group.

Table 2 – Demographic Characteristics of Hospitalized Subjects in Novo Hamburgo-RS, Brazil, from 2016 to 2019

Variables Period	Man (n)	Woman (n)	Adult (20-59 years old)	Elderly (+60 years)
2016	411	380	248	543
2017	431	378	248	561
2018	339	289	207	421
2019	297	284	192	389

Source: Prepared by the author with data from DATASUS.

In Table 2, we observe that the highest number of hospital admissions occurred among male subjects throughout the study period, compared to female subjects. Additionally, hospital admissions in the elderly age group predominated over those in the adult age group between 2016 and 2019.

In the municipality of Novo Hamburgo, Rio Grande do Sul, from 2016 to 2019, respiratory diseases disproportionately affected the elderly due to their heightened vulnerability to disease development and emergence. A retrospective study analyzed hospital admission records in the Coronary Unit of a Teaching Hospital in São José do Rio Preto, São Paulo, focusing on patients over 60 years old hospitalized with cardiovascular diseases. The study concluded that disease incidence increases with age and disproportionately affects male patients (Silva & Ribeiro, 2012). Scientific evidence supports these findings, revealing a prevalence of hospital admissions among males.

This pattern extends to the elderly age group (age 60 and above), where the highest records of hospital admissions occurred compared to adult admissions (ages 20-59) during the study years. Oliveira et al. (2018) further corroborate this result by analyzing the profiles of 123 patients from a teaching hospital in Goiânia, Goiás, Brazil. Their analysis of gender, age, race/color, ostomy time, type of ostomy, etiology, complications, and hospital admissions associated with

colostomy revealed that the elderly and males are more vulnerable to chronic non-communicable diseases (NCDs).

This demographic pattern of hospital service utilization by age group aligns with findings from other evidence. It is well-established that emissions of contaminating substances into the air exacerbate respiratory and cardiovascular diseases, particularly affecting children and the elderly (Ignotti et al., 2010). Additionally, meteorological variables play a crucial role. Short-term climatic events, such as extreme cold or heat waves, can expose the elderly to marginal conditions, exceeding their regulatory capacity and potentially worsening serious illnesses (Genaro, 2011).

Table 3 presents records of hospital admissions categorized by specific pathologies, including asthma, influenza, pneumonia, bronchitis, acute bronchiolitis, bronchial and lung cancer, and other related diseases. These records pertain to the municipality of Novo Hamburgo-RS during the period from 2016 to 2019.

Table 3 – Hospital Admissions by Pathology in Novo Hamburgo-RS, Brazil, from 2016 to 2019

Period	Asthma n (%)	Influenza n (%)	Pneumonia n (%)	Bronchitis and Bronchiolitis n (%)	Bronchial and Lung Neoplasia n (%)	Emphysema n (%)	Total n (%)
2016	02 (0.25)	07 (0.88)	496 (62.71)	0 (0)	60 (7.59)	226 (28.57)	791 (100)
2017	04 (0.49)	0 (0)	485 (59.95)	0 (0)	84 (10.38)	236 (29.17)	809 (100)
2018	05 (0.8)	01 (0.16)	322 (51.27)	01 (0.16)	109 (17.36)	190 (30.25)	628 (100)
2019	03 (0.52)	0 (0)	275 (47.33)	01 (0.17)	122 (21)	180 (30.98)	581 (100)

Source: Prepared by the author with data from DATASUS.

Conducting pathological analyses, we observed that the highest hospital admission rates were for pneumonia, followed by emphysema, bronchial and lung cancer, and influenza in 2016. Asthma admissions occurred in 2017, 2018, and 2019, while bronchitis and bronchiolitis were the final categories.

Murara et al. (2013) identified a moderate correlation (43%) between climatic factors and hospitalizations for major respiratory system diseases (RSD) in Florianópolis, Brazil. The highest hospitalizations for diseases like influenza,

pneumonia, chronic obstructive pulmonary disease, and asthma occurred in winter and autumn, correlating with monthly average temperatures and atmospheric pressure.

Azevedo et al. (2017) demonstrated that in regions with well-defined climatic seasons, hospitalization peaks were typically observed in months associated with winter. Factors such as population crowding due to low temperatures and increased rainfall during specific times of the year contribute to greater virus transmissibility.

Santos et al. (2021) confirm that vaccination plays a role in reducing hospitalizations due to influenza. This finding may justify the low number of influenza-related hospitalizations during the evaluated period compared to other pathologies.

Among the diseases studied, pneumonia accounted for the highest number of hospital records, totaling 1,578 cases during the study period. According to Santos & Souza-Machado (2018), adolescents and adults experienced milder pneumonia complications compared to individuals in more extreme age groups, such as the elderly and children.

During the research period, there were only two recorded hospitalizations for bronchitis and bronchiolitis. This notably low figure may be attributed to the higher prevalence of these conditions among children. Literature indicates a significant correlation between these diseases and hospital admissions among neonatal or pediatric patients, with comparatively sparse instances in adult and elderly populations (Carvalho et al, 2007; Araújo, 2022).

The study conducted by Neto (2022) revealed an upward trend in mortality rates due to bronchial and lung neoplasia among both men and women from 1996 to 2018. This increase was observed across nearly all age demographics, with the notable exception of men aged 50 to 59 years. Consequently, it can be inferred that demographic and health characteristics may partially elucidate the observed trends in mortality from bronchial and lung neoplasia, as well as from other neoplasms and non-communicable diseases.

Table 4 presents air quality data, including pollutant concentrations: O_3 (ozone), CO (carbon monoxide), NO_2 (nitrogen dioxide), SO_2 (sulfur dioxide),

$PM_{2.5}$, and PM_{10} (particulate matter). These concentrations were previously generated by the Feevale Automatic Air Quality Monitoring Station (EAMQA) and are expressed in μg/m³. Additionally, meteorological variables—relative humidity (RH) (%), average temperature (°C), minimum temperature (°C), and maximum temperature (°C)—were obtained from the INMET database for the period spanning January 2016 to December 2019. The values are reported as means with standard deviations.

Table 4 – Air Quality Data and Meteorological Variables in the Municipality of Novo Hamburgo-RS, from 2016 to 2019 (n=48)

Variables	2016		2017		2018		2019	
	Average	DP	Average	DP	Average	DP	Average	DP
O_3 (μg/m³)	20.6	5.28	14.58	3.12	12.35	4.33	25.41	8.64
CO (μg/m³)	0.4	0.1	0.47	0.12	0.49	0.12	0.34	0.11
NO_2 (μg/m³)	24.81	13.2	36.61	17.69	16.61	3.75	12.64	5.29
SO_2 (μg/m³)	10.05	4.86	16.92	3.35	9.49	5.96	15.16	3.82
$PM_{2,5}$ (μg/m³)	13.73	2.61	13.93	3.25	13.55	4.33	14.81	3
MP_{10} (μg/m³)	27.46	5.22	27.83	6.52	27.1	8.66	29.62	6.01
Relative humidity Average (%)	75.58	5.53	73.93	4.44	73.37	8.74	75.44	7.05
Average temperature (°C)	18.97	5.12	20.77	3.59	20.15	4.27	20.72	4.04
Minimum temperature (°C)	18.44	4.98	20.11	3.57	19.51	4.2	21.13	3.51
Maximum temperature (°C)	19.54	5.21	21.41	3.62	20.81	4.34	21.3	4.1

Source: Prepared by the author with data from IMNET and EAMQA.

When analyzing the air quality parameters presented in Table 4, several important trends are observed. Ozone (O_3) concentrations reached their maximum average in 2019, with 25.41 μg/m³, and decreased in subsequent years: 20.6 μg/m³ in 2016, 14.58 μg/m³ in 2017, and 12.35 μg/m³ in 2018. Regarding carbon monoxide (CO), the maximum average concentration was recorded in 2018, with 0.49 μg/m³. Exposure to ozone (O_3) is associated with a range of respiratory problems, including asthma, bronchitis, and other pulmonary diseases. Studies indicate that ozone exposure can lead to airway inflammation and reduced lung function, especially in children and the elderly. A recent study by Turner et al. (2023) demonstrated that ozone exposure is related to an increase in hospital admissions for respiratory diseases.

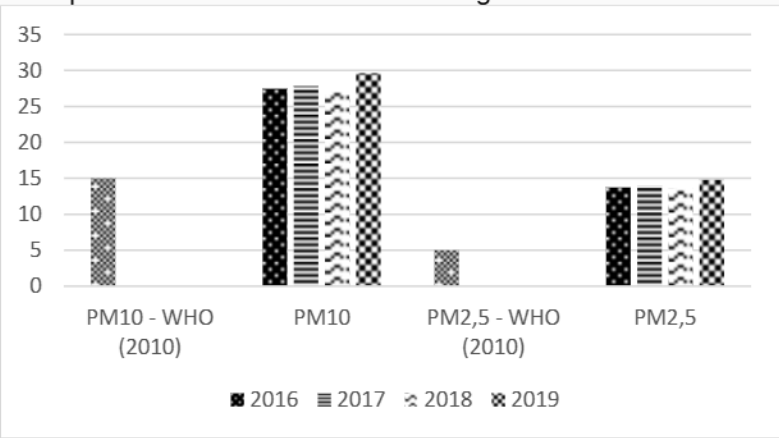
The average concentrations of nitrogen dioxide (NO_2) were highest in 2017, with an average of 36.61 µg/m³, followed by 24.81 µg/m³ in 2016, 16.61 µg/m³ in 2018, and 12.64 µg/m³ in 2019. Sulfur dioxide (SO_2) also showed a maximum average in 2017, with 16.92 µg/m³.

Regarding particulate matter ($PM_{2.5}$ and PM_{10}), the average concentrations of $PM_{2.5}$ were highest in 2019. PM_{10} concentrations also peaked in 2019, with 29.62 µg/m³. Particulate matter ($PM_{2.5}$ and PM_{10}), especially $PM_{2.5}$, can penetrate deeply into the lungs and enter the bloodstream, affecting all major organs of the body. Exposure to $PM_{2.5}$ is associated with cardiovascular and respiratory diseases, including myocardial infarction, stroke, lung cancer, and chronic obstructive pulmonary disease (COPD). Pope et al. (2023) demonstrated that long-term exposure to $PM_{2.5}$ is associated with increased mortality from cardiovascular and respiratory diseases.

Meteorological variables also showed significant variations. Relative humidity (RH) had the highest index in 2016, with 75.58%, while the average temperature varied over the years, presenting the highest average of 20.77°C in 2017. The minimum average temperature was recorded in 2016, with 18.44°C. Lower temperatures and high relative humidity significantly impact health, increasing hospital admissions for respiratory diseases like asthma and bronchitis. Anderson et al. (2023) demonstrated that extreme temperature variations are correlated with a rise in hospitalizations for these conditions. In Brazil, studies on the impacts of pollution on health focus on large cities. Novo Hamburgo, influenced by intermunicipal traffic and industrial activities, faces environmental challenges that may affect air quality and increase hospitalizations for respiratory diseases, especially among the elderly.

When comparing the particulate matter (PM) collected with the World Health Organization (WHO) parameters (2021), we observed that the average exceeds the recommended levels for both PM_{10} and $PM_{2.5}$ in all years (see Figure 2).

Figure 2: Comparison of PM2.5 and PM10 Averages with WHO Parameters (2021).

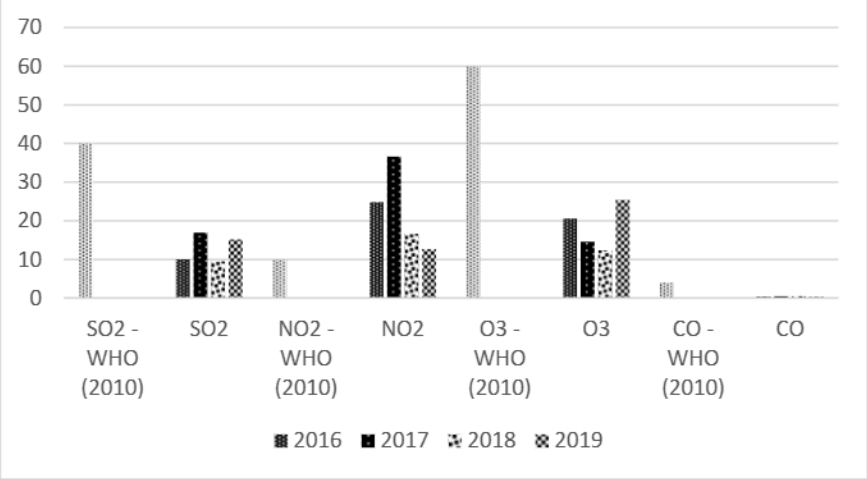


Source: Authors, 2024.

In Figure 2, we observe that the World Health Organization (WHO) annual parameters (2021) for PM_{10} predict values of up to 15 µg/m³, while $PM_{2.5}$ concentrations can reach up to 5 µg/m³. In 2016, EAMQA recorded PM_{10} levels of 27.46 µg/m³ and $PM_{2.5}$ levels of 13.73 µg/m³. Similarly, in 2017, PM_{10} levels were 27.83 µg/m³ and $PM_{2.5}$ levels were 13.94 µg/m³.

For 2018, the values were 27.1 µg/m³ (PM_{10}) and 13.55 µg/m³ ($PM_{2.5}$), while in 2019, PM_{10} reached 29.62 µg/m³ and $PM_{2.5}$ reached 14.81 µg/m³. Notably, the atmospheric pollutants SO_2, O_3, and CO remain within the WHO parameters (2021). However, the pollutant NO_2 exceeds the recommended limit (see Figure 3).

Figure 3: Comparison of Pollutants with WHO Air Quality Guidelines (2021)



Source: Authors, 2024.

The World Health Organization (WHO) recommends the following air quality guidelines for atmospheric pollutants in micrograms per cubic meter (µg/m³): SO_2 (Sulfur Dioxide): 40 µg/m³; NO_2 (Nitrogen Dioxide): 10 µg/m³; O_3 (Ozone): 60 µg/m³; CO (Carbon Monoxide): 4 µg/m³.

To identify possible relationships between air quality parameters, meteorological variables, and the number of hospitalizations due to respiratory diseases, a multivariate regression analysis was applied. This approach allowed us to demonstrate the correlation between carbon monoxide (CO) exposure and asthma. Specifically, higher concentrations of CO were associated with an increased number of asthma-related hospitalizations (as shown in Table 5).

Table 5: Linear Regression Analysis of Carbon Monoxide (CO) and Asthma

Coeficients	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Standard Error	Beta		
(Constant)	-0;42	0.36		-1.14	0.26
CO (carbon monoxide)	1.7	0.84	0.29	2.03	0.05

Source: Authors, 2024.

Silva et al. (2021) demonstrated that local processes significantly impact the levels of primary pollutants such as PM_{10}, CO, and NO_2, with variations observed across different monitoring stations. In a related study, Almeida & Steinke (2016), found that hospital admissions for asthma were closely correlated with meteorological variables, exhibiting a pronounced correlation with rainfall and extreme temperatures (both maximum and minimum) indicating an inverse relationship with the incidence of hospital admissions for asthma.

In the municipality of Novo Hamburgo, the recorded cases of hospital admissions for asthma revealed a statistically significant association with the pollutant CO, as determined through regression analysis. There were 14 hospitalizations noted during the study period, predominantly occurring in months characterized by lower temperatures and increased relative humidity. According to Negrisoli & Nascimento (2013), high concentrations of CO in the environment are linked to the onset and exacerbation of respiratory ailments, including asthma and pneumonia, a finding further supported by Zhou et al. (2022).

Utilizing the linear regression model, we identified an association between nitrogen dioxide (NO_2), minimum temperature, and pneumonia. Specifically, higher NO_2 concentrations or lower temperatures were correlated with an increased number of pneumonia-related hospitalization records. Conversely, when temperatures were high, the incidence of pneumonia-related hospitalizations decreased (as indicated in Table 6).

Table 6: Linear Regression Analysis of Meteorological Variables (Temperature), Air Quality (NO2), and respiratory diseases (Pneumonia)

Coeficients	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Standard Error	Beta		
(Constant)	64.37	7.45		8.65	0
Minimum temperature	-1.94	0.34	-0.6	-5.64	0
NO_2 (nitrogen dioxide)	0.31	0.1	0.34	3.16	0.003

Source: Authors, 2024.

Pneumonia-related respiratory infections are a major cause of hospitalization, with children and the elderly being the most vulnerable. Regional disparities may be influenced by climate, especially in the south and southwest, where cold winters, high humidity, and hot summers play a role (COSTA et al., 2022).

Another finding derived from the linear regression model revealed an inverse relationship between maximum temperature and emphysema. Specifically, as the temperature increases, the incidence of hospitalization due to emphysema decreases (refer to Table 7).

Table 7: Association Between Maximum Temperature and Pulmonary Emphysema Data

Coeficients	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Standard Error	Beta		
(Constant)	33,18	3,17		10,48	0
Maximum Temperature	-0,76	0,15	-0,6	-5,11	0

Source: Authors, 2024.

Concerning pulmonary emphysema, Gama & Silva (2022) have noted that the most prevalent conditions predominantly affect the older age cohorts. Theoretically, this demographic pattern suggests increased rates of disease progression, protracted recovery periods, and more extensive and costly treatment and hospitalization requirements.

Recent studies by Zhou et al. (2022), have established a correlation between high concentrations of NO_2 and the incidence of pneumonia induced by Streptococcus pneumoniae. Figure 3 illustrates that the levels of the pollutant NO_2 surpass the parameters set by the World Health Organization (WHO) in 2021, thereby constituting a significant risk to public health. Additionally, Table 6 delineates the association between NO_2 concentration and the frequency of hospital admissions for pneumonia, which is a predominant factor contributing to the increased rate of hospitalizations due to the disease within the municipality.

Considering the outcomes delineated in this investigation, one can discern the correlation between air quality and meteorological parameters, alongside the incidence of hospitalizations attributable to respiratory ailments within the confines of Novo Hamburgo.

5 CONCLUSION

The present study demonstrated the associations between air quality, meteorological variables, and the number of hospital admissions due to respiratory diseases among adults and the elderly in the municipality of Novo Hamburgo, RS, from 2016 to 2019. The findings indicate that higher levels of carbon monoxide (CO) and nitrogen dioxide (NO_2) were respectively associated with an increase in cases of asthma and pneumonia, while lower temperatures and high relative humidity also contributed to a greater number of hospitalizations.

These results highlight the need for improved monitoring and control of air pollution, as well as for the implementation of integrated strategies that consider both air quality and meteorological conditions. Such measures are essential to safeguard public health, particularly among vulnerable populations such as the

elderly, and provide valuable input for the development of effective public policies and preventive actions.

The outcomes of this research offer important contributions to both society and the academic community. The data reinforce the urgency of concrete actions aimed at improving air quality, especially in urban and industrial regions, while also providing relevant support for interdisciplinary research in fields such as public health, climatology, urban planning, and environmental policy. Furthermore, the study presents an empirical basis for comparative analyses in other Brazilian regions.

Among the limitations of this study is the use of monthly averages to address missing data in the daily air quality monitoring records, which may smooth out important variations. Additionally, other relevant environmental variables—such as topography, vegetation cover, land use, and wind direction—were not included in the analysis, though their inclusion could enhance understanding of pollutant behavior and its effects on human health.

For future research, it is recommended to use time series with more robust data quality control, expand the analysis to include other vulnerable groups, such as children, and incorporate spatial and socioeconomic variables to enable more detailed studies of exposure and health risks. Moreover, the application of predictive and geospatial modeling could further enrich the understanding of the impacts of air pollution on population health.

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