ORIGINAL ARTICLE

AIR QUALITY AND CONFIRMED CASES OF COVID-19 IN THE METROPOLITAN REGION OF PORTO ALEGRE/RS: ECOLOGICAL STUDY

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Highlights: (1) Higher number of female infected. (2) Pollutants levels above the indicated level. (3) Positive relationship between SO2 levels and COVID-19 cases.

PRE-PROOF

(as accepted)

This is a preliminary, unedited version of a manuscript that was accepted for publication in Revista Contexto & Saúde. As a service to our readers, we are making this initial version of the manuscript available, as accepted. The article will still be reviewed, formatted and approved by the authors before being published in its final form.

http://dx.doi.org/10.21527/2176-7114.2025.50.14127

How to cite:
Hübner SL, Machado AB, da Costa FM, Osório DMM, Bueno ALM, Berlese DB. Air quality and confirmed cases of covid-19 in the metropolitan region of Porto Alegre/RS: Ecological study. Rev. Contexto & Saúde, 2025;25(50): e14127

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AIR QUALITY AND CONFIRMED CASES OF COVID-19 IN THE METROPOLITAN REGION OF PORTO ALEGRE/RS: ECOLOGICAL STUDY

ABSTRACT

This study aimed to investigate the relationship between air quality in the municipalities of Canoas and Esteio/RS and reported cases of COVID-19 from March 1, 2020 to February 28, 2021. The analysis was realized by searching and relating air quality data for NO_2, SO_2, MP_{10} and $MP_{2.5}$ obtained from the database of the Fundação Estadual de Proteção Ambiental Henrique Luis Roessler- RS (FEPAM) and data from patients reported with COVID-19 provided by the Federal Government. A prevalence of patients infected by COVID-19 in females (54%) between 30 and 39 years old (23%) was observed in both municipalities. The most listed symptoms were dyspnea (83%) and sore throat (74%) and the most common comorbidities presented by infected patients were asthma (5.37%) in Canoas and Chronic Heart Disease (6.17%) in Esteio. The pollutant values analyzed showed fluctuations and even exceeded the established limits, and a positive statistic (<0.001) was observed between the SO2 levels and the number of confirmed cases of COVID-19 in the evaluated municipalities. With the results showing the positive relationship between air quality and COVID-19 cases, it's expected to be able to contribute to the development of public policies that improve air quality and reduce the damage they cause to human health, as well as educational and preventive measures to increase awareness among the general population about the importance of air quality.

Keywords : SARS-CoV-2. Pollution. Air quality .

INTRODUCTION

In January 2020, a new virus was identified, called Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) [1] . The virus, whose transmission was still unknown at the time, caused symptoms such as fever, headache, myalgia and malaise, and could progress to a more advanced condition with dry cough, dyspnea and hypoxemia. The World Health Organization (WHO) classified the disease as a pandemic with high global risk [2] . After this classification, cases of the disease increased significantly in Brazil and worldwide [3] .

On the other hand, air pollution has been considered a public health problem by the

WHO for years, affecting 91% of the world's population[4]. In Brazil, the National Environmental Council (CONAMA) determines and defines air pollution standards that do not cause harm to human health and the environment, while states and municipalities carry out data assessment [5] . Children and the elderly suffer the most from the effects of air pollution, along with individuals who already have some type of respiratory problem [6] . Particulate matter (PM_{10} and $PM_{2.5}$) is the most studied air pollutant, due to its toxicity and dangerousness in relation to damage to human health, due to its ability to penetrate tissues and organs, causing systemic damage to individuals [4] . GONZALES et al. [7] found that individuals who live in municipalities with high levels of air pollution have a reduced innate immune capacity, which is proportional to the amount of phagocytosed material. These mechanisms of immune dysregulation are related to chronic diseases, which are considered aggravating factors for patients infected with SARS-CoV-2, and may increase the chances of the disease progressing to a serious condition with an increased risk of death [8] .

The present study aims to investigate the relationship between air quality in the municipalities of Canoas and Esteio/RS and reported cases of COVID-19 in the period from March 1, 2020 to February 28, 2021, since both municipalities have automatic air quality stations and no studies have been carried out on the relationship of the data with confirmed cases of COVID-19 to date.

MATERIALS AND METHODS

It was an ecological, cross-sectional and descriptive study [9] , of the possible relationship between air quality and COVID-19 cases in the municipalities of Canoas and Esteio in the period from March 1, 2020 to February 28, 2021. The air quality data were provided by the Fundação Estadual de Proteção Ambiental (FEPAM) [10] and the data on patients diagnosed with COVID-19 were acquired through the COVID Panel Database provided by the federal government.

Characterization of the study area

The study area includes the municipalities of Esteio and Canoas and the selection criterion was locations that have real-time air quality monitoring data provided by FEPAM. The municipalities of Esteio and Canoas are located in the metropolitan region of Porto Alegre (RMPA), which is the most urbanized axis of the state of Rio Grande do Sul. The RMPA area corresponds to 3.7% of the total area of the state and concentrates approximately 38.2% of its population. The two municipalities chosen for the study are neighbors, being 8 km apart [11].

The municipality of Canoas has an area of 130.789 km² and had a population of 323,827 inhabitants in the last census carried out by the IBGE, in 2010. The geographic density of the municipality is 2,470.15 inhabitants per km². Neighboring Cachoeirinha, Esteio and Porto Alegre, Canoas is located 29 meters above sea level and has the following geographic coordinates: Latitude: 29º 55' 8" South, Longitude: 51º 10' 41" West. 92.9% of the households in the municipality have adequate sanitation, 81.9% of households in urban areas are on public roads with trees and 59.6% of urban households are on public roads with adequate urbanization, considering the presence of storm drains, sidewalks, paving and curbs [12].

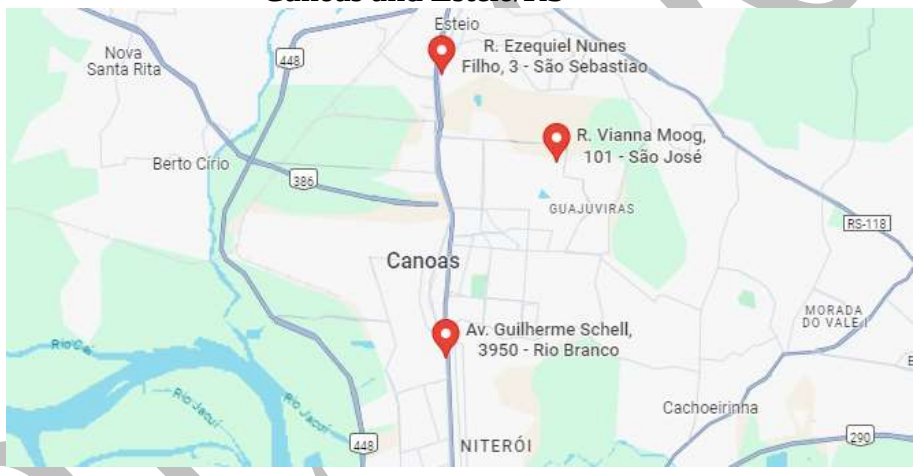
The municipality of Esteio has an area of 27.626 km² and had a population of 80,755 inhabitants in the last census carried out by the IBGE, in 2010. The geographic density of the municipality is 2,917.87 inhabitants per km². Neighboring Sapucaia do Sul, Canoas and Nova Santa Rita, Esteio is located 12 meters above sea level and has the following geographic coordinates: Latitude: 29º 51'40" South, Longitude: 51º10'51" West. 90.8% of the households in the municipality have adequate sanitation, 87.2% of households in urban areas are on public roads with trees and 61.6% of urban households are on public roads with adequate urbanization, considering the presence of drains, sidewalks, paving and curbs [12].

Air quality data

Air quality data were obtained through automatic air quality stations of the Fundação Estadual de Proteção Ambiental (FEPAM) in the municipalities of Canoas and Esteio/RS.

The air quality parameters evaluated were: sulfur dioxide (SO_2), nitrogen oxides (NO_2) and particulate matter (MP_{10} and $MP_{2.5}$). The data monitoring stations are located at the following addresses: Ezequiel Nunes Filho Street, No. 3, São Sebastião-Esteio; Viana Moog Street, No. 101, São José neighborhood- Canoas and Guilherme Schell Avenue, No. 3950, Fátima neighborhood- Canoas, as shown in Figure 1.

Figure 1 – Location map of automatic air quality stations in the municipalities of Canoas and Esteio/RS



The monitoring stations only measure the concentration of MP_{10} in both municipalities. Following WHO guidelines, the concentration of $MP_{2.5}$ was defined using a conversion factor based on the daily concentration of MP_{10}. The conversion factor used was 0.5 [13].

Health data

The COVID Panel platform provided by the Federal Government was used to analyze confirmed cases of COVID-19. All individuals who test positive for the RT-PCR test or antigen test for COVID-19 are notified to the federal government. The symptoms that the patient presented are also mentioned: fever, cough, sore throat, dyspnea, and others.

The data were tabulated monthly in a Microsoft Excel spreadsheet by sex and age, and data were listed as aggravating comorbidities presented by the patients. The comorbidities described in the database were: asthma, diabetes, neuropathy, lung disease, immunosuppression, Down syndrome, renal syndrome, obesity, heart disease, hematologic syndromes, and hepatopathologies.

Data analysis

Descriptive statistics were used to describe the results through absolute (n) and relative (%) frequencies, minimum and maximum values, arithmetic mean and respective standard deviation. Comparisons of the prevalence of sociodemographic profiles, symptoms and comorbidities between the municipalities of Canoas and Esteio were analyzed using the Chi-Square test ($\chi 2$). To explain the COVID-19 notification events, we used Poisson regression. All statistical procedures were performed using IBM® SPSS® software (version 26.0), adopting a significance level of $p \leq 0.05$.

To verify whether environmental variables (SO_2, NO_2, MP_{10} and $MP_{2.5}$), sociodemographic variables and clinical conditions are related to the occurrence of confirmed COVID-19 contamination, we structured the database based on a temporal perspective to analyze using Poisson regression. Thus, the data were reorganized in the form of daily statistical summaries containing the number of cases, the respective metrics of the environmental indicators evaluated and the sociodemographic and clinical variables. The average number of daily confirmed COVID-19 cases in Canoas and Esteio was 87 cases/day. Then, following the event probability equation, according to the Poisson distribution, we have equation 1:

$$P(X = k) = \frac{e^{-\lambda} . \lambda^{k}}{k!}$$

The Poisson general linear model (GLM) was used using the stepwise technique, where influential variables were considered only if they were significant ($p \leq 0.05$).

The database has 41 variables, being 1 dependent variable (Cases/Diaries) and 40 independent variables: demographic counts (municipality, sex, age groups), counts of symptom

profiles (fever, cough, sore throat, dyspnea and other symptoms), counts of comorbidities (none and the list of 17 identified comorbidities) and the daily averages of the scores of environmental variables (SO_2, NO_2, MP_{10} and $MP_{2.5}$).

RESULTS

In Table 1 we can see the number of cases per municipality and per month during the study period.

Table 1 – Number of confirmed cases of COVID-19 in the municipalities of Canoas and Esteio/RS in the period from March 1, 2020 to February 28, 2021.

Variable	Year – Month	Canoes		Mainstay		Total	
		N	%	N	%	N	%
Period	2020 – March	6	0.028	1	0.015	7	0.025
	2020 – April	29	0.134	12	0.176	41	0.144
	2020 – May	110	0.510	53	0.779	163	0.574
	2020 – June	745	3,452	263	3,866	1008	3,552
	2020 – July	2354	10,909	623	9,158	2977	10,489
	2020 – August [to]	2488	11,530	1072	15,758	3560	12,543
	2020 – September	1787	8,281	558	8,202	2345	8,262
	2020 – October [to]	2140	9,917	514	7,555	2654	9,351
	2020 – November	3051	14,139	983	14,450	4034	14,213
	2020 – December	**3572**	**16,553**	**1135**	**16,684**	**4707**	**16,584**
	2021 – January	2053	9,514	644	9,466	2697	9,503
	2021 – February	3244	15,033	945	13,891	4189	14,759

[a] $\chi^2 = 134.725$; gl = 11; $p < 0.001$.

Source: study data.

The highest number of cases can be observed in December 2020 in both municipalities. There was a significant difference between the number of confirmed patients in the two municipalities considered: in August, the municipality of Esteio presented statistically higher values in relation to the number of cases when compared to Canoas, and in October Canoas presented a higher number when compared to Esteio (Table 1).

Table 2 shows the confirmed cases of COVID-19 in each municipality, separated by sex and age group.

Table 2 – Number of confirmed cases of COVID-19 by municipality, sex and age group in the municipalities of Canoas and Esteio/RS

Variable	Categories	Canoes		Mainstay		Total	
		N	%	N	%	N	%
Sex	**Feminine**	**11,618**	**53.8**	**3,699**	**54.4**	**15.317**	**54.0**
	Masculine	9,961	46.2	3.104	45.6	13,065	46.0
Age Range	0 to 9 years old	485	2.2	284	4.2	769	2.7
	10 to 19 years old	1.084	5.0	430	6.3	1,514	5.3
	20 to 29 years old	4.069	18.9	1.188	17.5	5.257	18.5
	30 to 39 years old	**5.204**	**24.1**	**1,532**	**22.5**	**6,736**	**23.7**
	40 to 49 years old	4.232	19.6	1,247	18.3	5,479	19.3
	50 to 59 years old	3.107	14.4	1.008	14.8	4.115	14.5
	60 to 69 years old	2.063	9.6	628	9.2	2,691	9.5
	70 to 79 years old	879	4.1	349	5.1	1,228	4.3
	80 years or +	456	2.1	137	2.0	593	2.1

[a] $\chi^2 = 117.398$; gl = 8; $p < 0.001$.

Source: study data.

Females were the most affected in both municipalities, with similar percentages. The most affected age group was 30 to 39 years old, also in both municipalities. There was a significant difference in the number of cases between the municipalities in the age groups 0 to 19 years old, and 70 to 79 years old, with a higher prevalence in the municipality of Esteio. In the age group 20 to 49 years old, this significant difference occurred with a higher prevalence of cases in the municipality of Canoas (Table 2).

Table 3 presents data related to the symptoms presented by patients diagnosed with COVID-19 in both municipalities.

Table 3 – Characterization of COVID-19 Symptoms in the Municipalities of Canoas and Esteio/RS

Variable	Categories	Canoes		Mainstay		Total	
		N	%	N	%	N	%
Fever	No	7,645	35.4	2.132	31.3	9,777	34.4
	Yes [to]	13,934	64.6	4,671	68.7	18,605	65.6
Cough	No	9,389	43.5	2,642	38.8	12.031	42.4
	Yes [b]	12.190	56.5	4.161	61.2	16,351	57.6
Throat	No	5.614	26.0	1,677	24.7	7.291	25.7
	Yes [c]	15,965	74.0	5.126	75.3	21.091	74.3
Dyspnea	**No**	**4.170**	**19.4**	**1.020**	**15.0**	**5.190**	**18.3**
	Yes [d]	**17,378**	**80.6**	**5,783**	**85.0**	**23.161**	**81.7**
Others	No	12.030	55.7	4.008	58.9	16,038	56.5
	Yes [and]	9,549	44.3	2.795	41.1	12,344	43.5

[a] $\chi^2 = 38.295$; gl = 1; $p < 0.001$; [b] $\chi^2 = 46.272$; gl = 1; $p < 0.001$; [c] $\chi^2 = 5.049$; gl = 1; $p = 0.025$; [d] $\chi^2 = 65.687$; gl = 1; $p < 0.001$; [and] $\chi^2 = 21.103$; gl = 1; $p < 0.001$.
Source: study data.

Dyspnea was the symptom most frequently reported by patients in both municipalities during the study period. There was a significant difference between the percentage of symptoms reported by patients in Canoas and Esteio, where the second municipality had a higher number of infected individuals reporting fever, cough, sore throat, and dyspnea.

The comorbidities cited in the notification of confirmed cases of COVID-19 in both municipalities participating in the study are presented in Table 4.

Table 4 – Characterization of comorbidities of patients with COVID-19 in the municipalities of Esteio and Canoas/RS

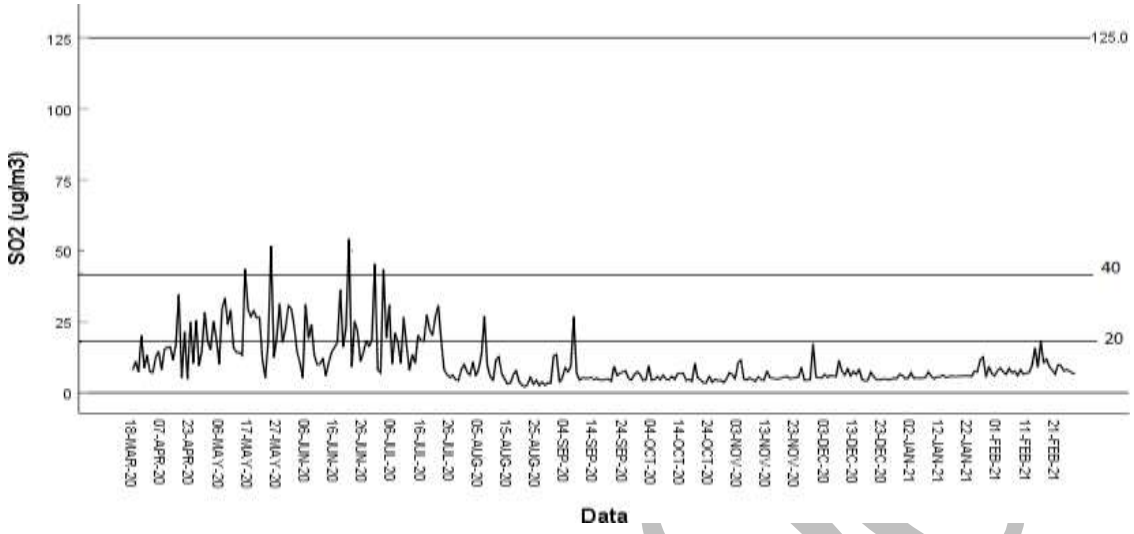
Comorbidities [b]	Canoes		Mainstay		Total	
	N	%	N	%	N	%
None	18.203	84.36	5.639	82.89	23,842	84.00
Asthma	**1,159**	**5.37**	21	0.31	1,180	4.16
Chronic Heart Disease	662	3.07	**420**	**6.17**	1.082	3.81
Diabetes Mellitus	486	2.25	336	4.94	822	2.90
Chronic Kidney Disease	654	3.03	36	0.53	690	2.43
Decompensated Chronic Respiratory Disease	467	2.16	179	2.63	646	2.28
Chronic Cardiovascular Disease	45	0.21	248	3.65	293	1.03
Obesity	261	1.21	**0**	**0.00**	261	0.92
Chronic Lung Disease	100	0.46	156	2.29	256	0.90
Chronic Neurological Disease	119	0.55	38	0.56	157	0.55
Pregnant / Postpartum	113	0.52	33	0.49	146	0.51
Immunosuppression	102	0.47	40	0.59	142	0.50
Chronic Hematological Disease	117	0.54	**0**	**0.00**	117	0.41
Immunodeficiency	68	0.32	18	0.27	86	0.30
Chromosomal / Immunological Fragility	14	0.07	19	0.28	33	0.12
Chronic Liver Disease	22	0.10	8	0.12	30	0.11
Down syndrome	3	0.01	3	0.04	6	0.02
Others	520	2.41	59	0.87	579	2.04

[a] $\chi^2 = 1710.187$; gl = 17; $p < 0.001$.
[b] The sum of the percentages (%) exceeds 100% due to multiple comorbidities.
Source: survey data

In the municipality of Canoas, the most reported risk factor was asthma and in Esteio it was chronic heart disease. In the municipality of Esteio, no patients with obesity or chronic hematologic disease were reported during the study period.

Below, data on the average daily concentration of air pollutants from March 1, 2020 to February 28, 2021 for the municipalities of Canoas and Esteio are presented, compared with the air quality standards established by CONAMA 491/2018 [5] and the new standards established by the WHO [4] (Figure 2, Figure 3, Figure 4, Figure 5).

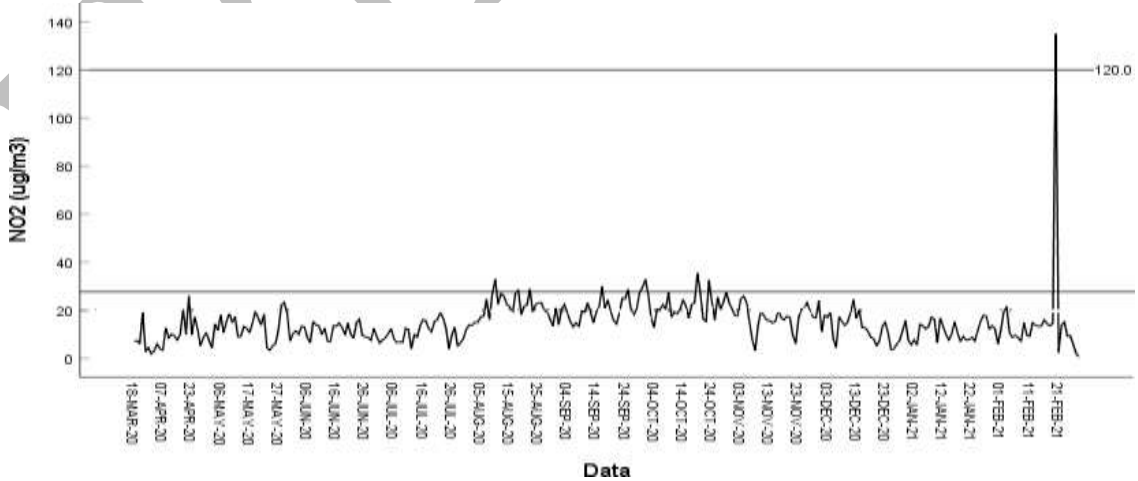
Figure 2 – Average daily concentration of SO2 in the municipalities of Canoas and Esteio/RS



Source: Research data .

It is possible to observe that during the study period the concentration of SO_2 presented values above the daily reference value established by CONAMA 491/2018 (20µg/m^3) [5] on dates from March/2020 to September/2020. Compared with the standards established by the WHO (40µg/m^3) [4], the atmospheric pollutant was outside the limits only on dates from May/2020 to July/2020.

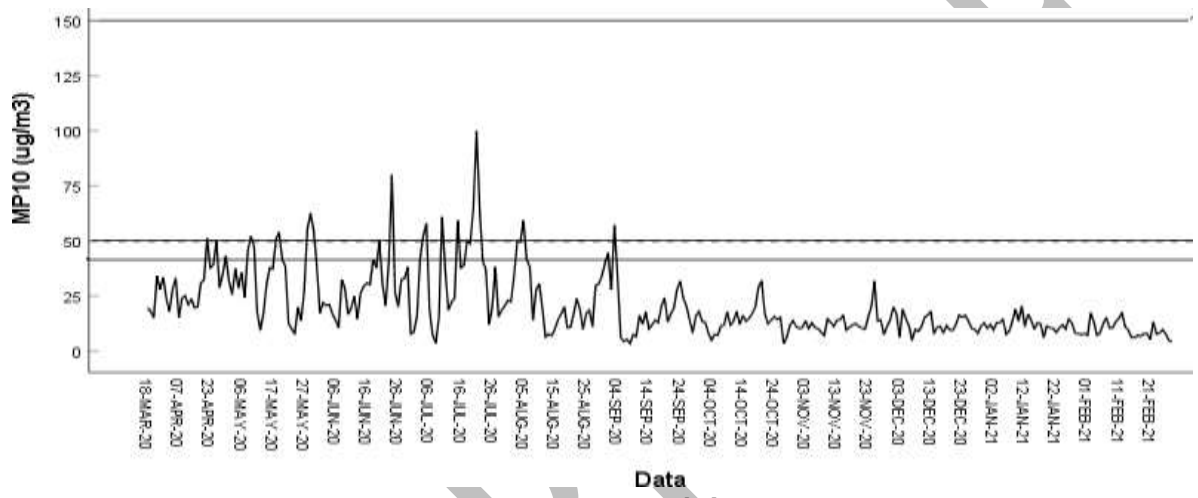
Figure 3 – Average daily concentration of NO_2 in the municipalities of Canoas and Esteio/RS



Source: Research data.

It is possible to observe that during the study period the NO2 concentration presented values above the standards established by the WHO (25µg/ m^3) [4] from August/2020 to November/2020, with a peak in February/2021. The analyte was not compared with the values established by CONAMA 491/20185 [as] it only presents the hourly average value.

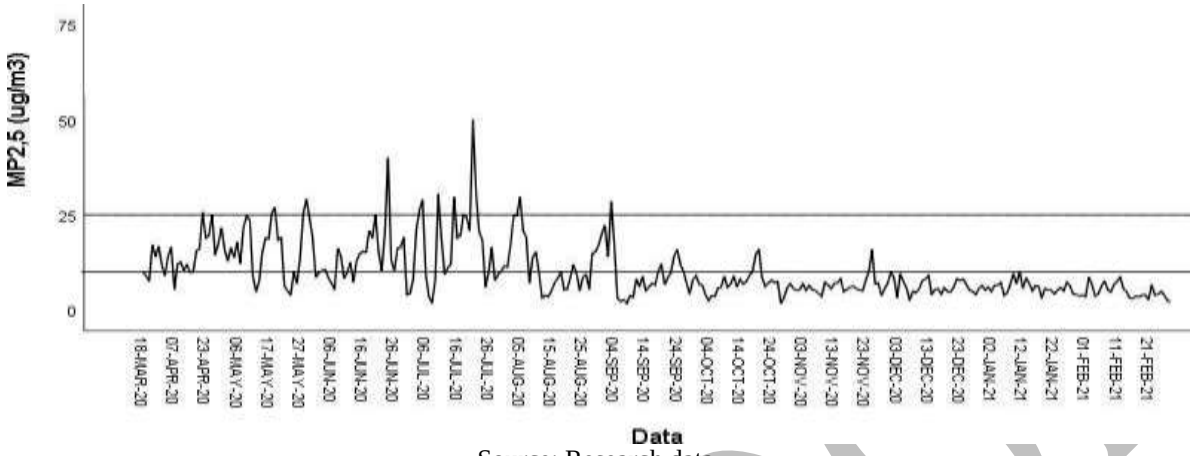
Figure 4 – Average daily concentration of MP $_{10}$ in the municipalities of Canoas and Esteio/RS



Source: Research data .

It is possible to observe that during the study period the concentration of MP $_{10}$ presented values above the daily reference value established by CONAMA 491/2018 (50 µg/m ^{3}) [5] and by the WHO (45 µg/m ^{3}) [4] on dates from April/2020 to September/2020.

Figure 5 – Average daily concentration of PM $_{2.5}$ in the municipalities of Canoas and Esteio/RS



Source: Research data.

It is possible to observe that during the study period the concentration of MP $_{2.5}$ presented values above the daily reference value established by CONAMA 491/2018 (25 µg/m ^{3}) [5] and by the WHO (15 µg/m ^{3}) [4] on dates from April/2020 to September/2020. In October/2020 and November/2020, the value remained only above the values stipulated by the WHO.

Table 5 shows the results of the Poisson analysis, where it is possible to evaluate the variables that explain the occurrence of COVID-19 cases during the study period.

Table 5 – Variables that explain the occurrence of COVID-19 cases using Poisson analysis

Variable	*p*
Sore throat	0.002
Dyspnea	0.004
Asthma	0.047
Chronic hematologic disease	0.021
SO $_2$	**<0.001**

(*) significant $p \leq 0.05$; (*) significant $p \leq 0.01$

Source: research data.

According to Poisson analysis, COVID-19 cases in Canoas and Esteio do not depend on sociodemographic data, such as the municipality of residence, sex or age group of the individual. Two symptoms: sore throat and dyspnea combined with the presence of comorbidities asthma and chronic hematologic disease, together with the variability of SO2

concentration are the factors that explain the occurrences of COVID-19 in the studied municipalities.

DISCUSSION

The total number of confirmed COVID-19 cases from March 2020 to February 2021 was 21.585, indicating that slightly less than 7% of the city's total population was infected. The total number of confirmed COVID-19 cases in Esteio/RS during the study period was 6.803, corresponding to 8.5% of the city's total population.

According to the Federal Government, from the beginning of the pandemic in Brazil, which was recorded in March 2020, until the final date of data collection for this study, February 28, 2021, 10.551.259 cases of COVID-19 had been confirmed and reported [3]. Considering that the country's population estimated by the IBGE in 2021 is 213.3 million inhabitants, it is possible to state that approximately 5% of the country's total population had been infected by the virus. The rate of infection in Rio Grande do Sul in the period analyzed was a little over 6.5% of the total population, higher than the national average [14]. Canoas had a number of infected people similar to the state average, but higher than the national average. The municipality of Esteio had an average of cases higher than the state and national average.

In both municipalities, the month with the highest number of confirmed cases of the disease was December 2020, which accounted for around 16.5% of the total cases in the period analyzed. These data are at odds with data from the state of Rio Grande do Sul, where the month with the highest number of reported cases was February 2021 (21% of cases). December 2020 came in second place, with just under 18% of cases [14].

Most cases were diagnosed in women in both municipalities, with an approximate rate of 54% of cases. In Rio Grande do Sul, the average number of COVID-19 cases by sex is similar to that observed in the survey, in which 53% of the total cases were confirmed in women. The age group most affected in both municipalities was 30 to 39 years old (23% of cases), similar to the average for the state of Rio Grande do Sul, with a higher number of cases in the same age group (21% of total cases) [14].

Several factors may influence the higher prevalence rate in women, including higher

estrogen levels and X-linked factors that increase the antiviral response in women [15]. The reason for the higher number of cases in female patients is still unknown, but some statistics can infer this finding. The Brazilian population is composed of a greater number of women than men (51.8%) [16]. In addition, approximately 65% of workers in both the private and public healthcare sectors are women. Thus, with direct contact with infected patients working on the front lines during the pandemic, the chances of contamination in women ended up being greater than that of men.

The symptom most frequently cited by infected patients in both municipalities was dyspnea, followed by sore throat (Table 3). The symptoms found to be prevalent in this study were also cited by Iser et al. [17], after conducting a literature review in electronic databases and publications from the Ministry of Health, which also observed the relationship between dyspnea and cases that progress to greater severity and possible death of the infected person. In patients who tested positive for SARS-CoV-2 during the study period, the most frequently cited comorbidity in Canoas was asthma (5.37%) and in Esteio it was chronic cardiovascular disease (3.65%). Asthma is a highly prevalent, non-communicable chronic disease that affects 4.4% of the world's population. Respiratory viruses, such as influenza and coronaviruses, which have already caused worldwide outbreaks, can trigger asthma exacerbations; however, this relationship has not yet been confirmed for SARS-CoV-2 [18]. Asthma was cited in only 1.6% of studies on the virus up to June 2020, a low percentage considering its frequency in the population. Part of this may be due to increased prophylactic treatment by patients [19]. The severity of COVID-19 infection, on the other hand, is not influenced by the presence or absence of asthma in patients [20].

Patients with chronic cardiovascular disease are at greater risk of a worse prognosis when infected with SARS-CoV-2. According to data from the American College of Cardiology published in 2020, patients with previous heart disease are 50% more likely to be hospitalized than unaffected patients [21].

In this study, it was possible to verify that asthmatic patients had a positive relationship with an increase in cases in the municipalities studied, together with cases of patients with chronic hematological diseases, which were not frequently mentioned by the reported patients but, when present, showed an increase in cases (Table 4). Patients who have some chronic

hematological pathology have up to a 38% chance of dying when infected by the SARS-CoV-2 virus, which can reach 40% when patients have hematological neoplasms. One problem found in these patients is the in-hospital acquisition of COVID-19, which was important in increasing the chances of death in these patients [22].

CONAMA 491/2018 [5] establishes air quality standards for atmospheric pollutants. These values are management instruments for air quality, indicating concentration values of an atmospheric pollutant to ensure the preservation of the environment and the health of the population against possible risks of damage caused by atmospheric pollution. The municipalities evaluated presented values for all atmospheric pollutants above those indicated as the final standard by this and by the WHO [4] on some dates during the study period.

A survey conducted by FEPAM [10] evaluated data from municipalities where air quality is monitored in Rio Grande do Sul in April 2020, when restrictive measures began due to the COVID-19 pandemic, with data from April of previous years. No significant difference was observed in any of the atmospheric pollutants evaluated, a fact that can be explained by the maintenance of operations of industries located where monitoring is carried out, by the fact that the diesel-powered vehicle fleet was not strongly affected, and by climatic factors such as low rainfall, which kept the pollutants emitted throughout the period in the location. In contrast, in the state of Rio de Janeiro there was a 30% reduction in CO concentration, 40% in NO concentration, 22% in $NO_{2\ \text{concentration}}$, 26% in NO_X, but only 0.3% in $PM_{2.5\ \text{values}}$ [23].

After analyzing the data, a positive relationship was observed between the increase in $SO2_{\text{and}}$ the increase in COVID-19 cases in Canoas and Esteio. This pollutant is easily absorbed by the upper respiratory tract, generating health risks and aggravating existing problems in patients. Even when presented in concentrations within the limits established by CONAMA, it is associated with an increase in care for severe pneumonia and influenza in the elderly, in addition to an increase in hospitalizations for respiratory diseases [24].

A study by Ciaula et al. [25] showed that higher levels of NO_2 increase the chance of infection by COVID-19 due to the immunological changes caused by it. Patients who die after infection have a high number of leukocytes, especially neutrophils, and a decrease in the number of lymphocytes compared to patients who recovered from the disease. Exposure to NO_2 in the two weeks prior to infection by the virus causes a decrease in the number of CD45, CD3

and CD4 T cells in patients, a factor that reduces their immune response to the virus and consequently increases the risk of the disease progressing to a lethal condition. In another literature review study carried out until August 2021, it was shown that long-term exposure to NO_2, MP below 2.5 and SO_2 and even short-term exposure to NO_2 have a positive relationship with the increase in the number of COVID-19 cases [26]. The association between air pollution and COVID-19 infections has been studied in several countries. However, it is very difficult to establish this association. After the first SARS outbreak, recorded in 2002, the scientific community mobilized to establish an association between air quality and COVID-19 cases and mortality. Results of the study carried out by Kan et al. [27] demonstrated that PM levels in Beijing could be responsible for a high mortality rate from SARS, in agreement with Cui et al. [28], who found evidence of the harmful effect of polluted air on the prognosis of patients with SARS.

Chronic exposure to high levels of air pollutants has been widely associated with increased incidence of asthma, rhinitis, and chronic obstructive pulmonary disease, lung cancer mortality, reduced lung function, and impaired lung development during childhood. According to the WHO, these are aggravating factors for the severity of SARS-CoV-2 cases [29]. The municipalities evaluated in the present study presented air pollutant values within the limits established by CONAMA, but even exposure to these levels of pollutants can trigger inflammation of the respiratory mucosa and cause harm to the individual. Exposure to pollutants increases lung permeability, allowing access of pathogens and pro-inflammatory mediators to the basolateral side of the epithelium, allowing viral dissemination and inflammation. Studies have shown that exposure to O_3, NO_2, and PM disrupts hermetic junctions in the lungs, reduces levels of tight junction protein, and results in neutrophil infiltration into the lungs [30-32]. Exposure to MP can suppress mucociliary clearance and promote mucus hypersecretion in the respiratory tract. This excess mucus has been implicated as an underlying cause of hypoxia in COVID-19 patients [33-34].

Deek [35] evaluated the influence of $MP_{2.5}$ on the severity and increased mortality rate of COVID-19 infection, noting that chronic exposure to this material triggers impairments in lung function, in addition to causing an interruption of the hypothalamic-pituitary-adrenal system, leading to a drop in the individual's immune response.

Short-term exposure to pollutants can also cause harm and increase disease severity.

Higher exposure to PM four to ten days after symptom onset can increase the number of confirmed cases per day and per municipality, as well as increase the mortality rate [36].

Sarmadi et al. [37] also observed, in the United States, that the influence of exposure to pollutants, especially NO_2, can contribute to the spread and increase in the number of COVID-19 cases, associated with other variables such as population density and the economic situation of the region.

In 2022, a study evaluated the short-term exposure of individuals to pollutants and its relationship with COVID-19 cases in Sweden. The researchers evaluated the average daily exposure to PM of individuals and the number of positive tests for SARS-CoV-2 in the same period and identified an increase in positive tests for the virus infection after days of greater exposure to particles, indicating a potential increased risk for infection with greater exposure to pollutants. Indicating that the severity after infection by the disease may also be increased in individuals with greater exposure to pollutants, thus showing that reducing air pollution levels is a public health issue [38].

A study in the city of Limeira, located in the state of São Paulo, evaluated the relationship between PM and meteorological variables, where a positive relationship was found between PM levels and COVID-19 cases in the region. In addition, they found an inverse relationship between relative humidity, rainfall, and the rate of compliance with social distancing policies and total suspended particulate matter, and between PM_{10} and relative humidity, precipitation, and pressure, showing that meteorological variables can also influence the transmission of SARS-CoV-2 [39].

This study may have suffered limitations due to the use of data provided by DATASUS, since the correct completion of data such as symptoms and comorbidities depended on the professionals who provided the first care to the patients. Due to the large number of cases and shortage of professionals, the collection of patient information may have often been neglected. Both municipalities evaluated had around 84% of the infected population without any type of comorbidity, although this value may be lower.

The results obtained in this study indicate that air quality was inadequate in some of the periods analyzed, but that only SO_2 had a direct impact on the association with COVID-19 cases. This fact may guide authorities on the need to increase the number of air quality monitoring

stations in the country. However, this topic requires more consistent studies so that measures can be taken to associate air quality and the impact of the environment on human health.

FINAL CONSIDERATIONS

It is possible to observe that individuals with high exposure to air pollutants have an increased risk of acquiring several comorbidities that can aggravate COVID-19 infection, requiring hospitalizations and increasing the chances of death. In addition, the physiological changes caused by chronic exposure to pollutants can cause situations that make SARS-CoV-2 infection more intense, with more severe symptoms and increased chances of long-term health risks.

It was also possible to observe that asthmatic patients and those with chronic hematologic diseases have a greater chance of becoming infected with COVID-19. In the municipality of Esteio, there were no reports of obese patients during the study period. This fact may have occurred due to reporting errors by those responsible for UNASUS, making correct data analysis difficult. Exposure to $SO2_{was}$ an important factor in the increase in the number of cases of SARS-CoV-2 infections in Canoas and Esteio.

The results found corroborate several studies carried out, showing that controlling pollution levels in municipalities is a crucial factor that can impact the number of COVID-19 cases.

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Submitted: August 3, 2023

Accepted: August 28, 2024

Published: March 17, 2025

Authors' contributions:

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All authors approved the final version of the text.

Conflict of interest: There is no conflict of interest.

There is no financing.

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Editor-in-Chief: Adriane Cristina Bernat Kolankiewicz. PhD