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Indoor and outdoor airborne particles concentrations and their relations with respiratory symptoms in volunteers from the education sector

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A B S T R A C T

Studies that relate air pollution and health in medium-sized urban areas are scarce, especially in healthy adults. In addition, there is no consensus in the literature regarding a safe level of airborne particulate matter. Therefore, research at these sites may contribute to a better understanding of health and air pollution associations. From the point of view of the respiratory system, healthy adults were evaluated using the validated British Medical Research Council (BMRC) questionnaire. Measurements of particulate matter (PM), black carbon equivalent (BCe), and particle number concentrations (PNC) were performed during summer and winter in indoor and outdoor environments at two University Institutions (P1 and P2), located in the urban area. Although with different characteristics in the surroundings, the sites presented similar concentrations of particles, and between the seasons were dissimilar and higher during the winter. The average prevalence of respiratory symptoms increased by 13% in the winter compared to summer. We found a significant positive association ($p < 0.05$) between the explanatory variables and respiratory symptoms. The period, PM_{10}, $PM_{2.5}$, and $PNC_{2.5}$ variables were risk factors for the univariate model. The relative risk (RR) for PM_{10} was 1.031 (CI: 1.016-1.110) with an increase in concentrations of 11 µg m^{-3}. For the multivariate model, $PM_{2.5}$ (RR 1.054; CI 1.045- 5.383) and $PNC_{2.5}$ (RR 1.018; CI 1.002-1.071) for cough and phlegm for the group of adults considered healthy. Air pollution increases showed adverse effects, even in healthy adults and below guidelines, expanding the groups susceptible to its effects.

Keywords: air pollution, respiratory symptoms, questionnaire, particulate matter, longitudinal study.

Concentrações de partículas aerotransportadas internas e externas e suas relações com sintomas respiratórios em voluntários do setor de educação

R E S U M O

Estudos que relacionam poluição do ar e saúde em áreas urbanas de médio porte são escassos, principalmente em adultos saudáveis. Além disso, não há consenso na literatura quanto a um nível seguro de material particulado no ar. Portanto, pesquisas nesses locais podem contribuir para uma melhor compreensão das associações entre saúde e poluição do ar. Do ponto de vista do sistema respiratório, adultos saudáveis foram avaliados por meio do questionário validado do British Medical Research Council (BMRC). Medições de material particulado (MP), black carbon equivalente (Bce) e concentração do número de particulas (NP), foram realizadas durante o verão e inverno em ambientes internos e externos em duas Instituições Universitárias (P1 e P2) localizadas na área urbana. Embora com características diferentes no entorno, os locais apresentaram concentrações de partículas semelhantes, e entre as estações foram dissimilares e maiores durante o inverno. A prevalência média de sintomas respiratórios aumentou 13% no inverno em relação ao verão. Encontramos associação positiva significativa ($p < 0,05$) entre as variáveis explicativas e os sintomas respiratórios. As variáveis período, MP_{10}, $MP_{2,5}$ e $NP_{2,5}$ foram fatores de risco para o modelo univariado. O risco relativo (RR) para PM10 foi de 1,031 (IC: 1,016-1,110) com aumento nas concentrações de 11 µg m-3. Para o modelo multivariado, $MP_{2,5}$ (RR 1,054; IC 1,045- 5,383) e $NP_{2,5}$ (RR 1,018; IC 1,002-1,071) para tosse e catarro para o grupo de adultos considerados saudáveis. O aumento da poluição do ar mostrou efeitos adversos, mesmo em adultos saudáveis e abaixo das diretrizes, ampliando os grupos suscetíveis aos seus efeitos.

Palavras-chave: poluição do ar, sintomas respiratórios, questionário, material particulado, estudo longitudinal.

Introduction

Air pollution is a problem for the health public, which kills millions of people globally, mainly those living in low-middle income countries. In 2015, more than 6.5 million deaths were attributable to air pollution, with projection to increase by more than 50% until 2050(WHO, 2016; Landrigan et al., 2017; WHO, 2018). According to World Health Organization (WHO, 2018), outdoor and indoor air pollution is the second major cause of deaths by non-communicable diseases worldwide.

There are several studies relating indoor/outdoor air pollution and short-term effects on population respiratory health (children, young people, adults, elderly, and immunocompromised) (Madureira et al., 2009; Annesi-Maesano et al., 2013; Madureira et al., 2015; Strosnider et al., 2019; Li et al., 2021). Measurements performed in Portugal schools found an increase in cough associated with exposure to $PM_{2.5}$ (Odds ratio of 1.26) and PM_{10} (Odds ratio of 1.36). The indoor concentrations were higher than those recommended by WHO, ranging from 39 to 244 μg m^{-3} para $PM_{2.5}$ (Madureira et al., 2015).

Despite a large number of studies concerning air pollution and health effects, still relevant studies addressing these issues since there is no consensus regarding a safe level of airborne particulate matter concentration (Barnett et al., 2005; Curtis et al., 2006), being able to contribute to a better understanding of the associations between health and air pollution, even below the current guidelines (Wei et al., 2019; Fasola et al., 2020).

In Brazil, the number of studies of air pollution and respiratory symptoms in midsized cities are reduced concerning other countries, mainly between the age group of 18 and 60 years old, which is the worker fraction (Graff et al., 2009; Louwies et al., 2013; Schultz et al., 2017). In a review article with the primary Brazilian studies relating to air pollution and respiratory diseases, it is possible to observe that the focus is on the elderly and children in São Paulo city (Santos et al., 2021). Studies in medium-sized cities are essential as those in large metropolises (Braga et al., 2001; Nenna et al., 2017; Rancière et al., 2017). These medium-sized cities could be serving as a laboratory to study the effects of development on air quality, estimating, for example, the contribution of each source to degradation of air quality as well the impact on a healthy population. A relatively more minor complexity of sources and level of urbanization than megacities could improve the accuracy of association between air quality and health outcomes.

Almeida et al. (2018) and Moreira et al. (2018) measured personal exposure and its potential damages to health in a medium-sized Brazilian city. The studies found possible harm to health in the groups of volunteers analyzed, and the most affected were those who worked near avenues with heavy vehicle traffic.

In this way, the present study analyzed the indoor and outdoor PM concentrations, Particles Number Concentrations (PNC), and Black Carbon equivalent (BCe) in two University Institutions. The sampling occurred in a medium-sized Brazilian city during the summer and winter, to correlate possible respiratory symptoms in healthy adults due to short-term exposures.

Methodology

This is a longitudinal epidemiological study of repeated measures (Goldstein, 1968; Martins et al., 2013). The study was approved by the Research Ethics Committee of the Federal University of Technology, Paraná (UTFPR) number 54301415.8.0000.5547

Study Area

Measurements were carried out in two University Institutions located in distinct regions of Londrina (PR), a typical medium-sized urban area of Brazil, with more than 500,000 inhabitants and a fleet of 360,000 vehicles. Two places were chosen to verify the hypothesis that the work exposure for both groups (education sector) are similar, even the Institutions being in distinct regions.

The region's climate is subtropical and presents warmer summers and milder winters (Alvares et al., 2013). The highest rainfall occurs in summer and the lowest in winter, characterizing the local rain regime with rainy summers and dry winters.

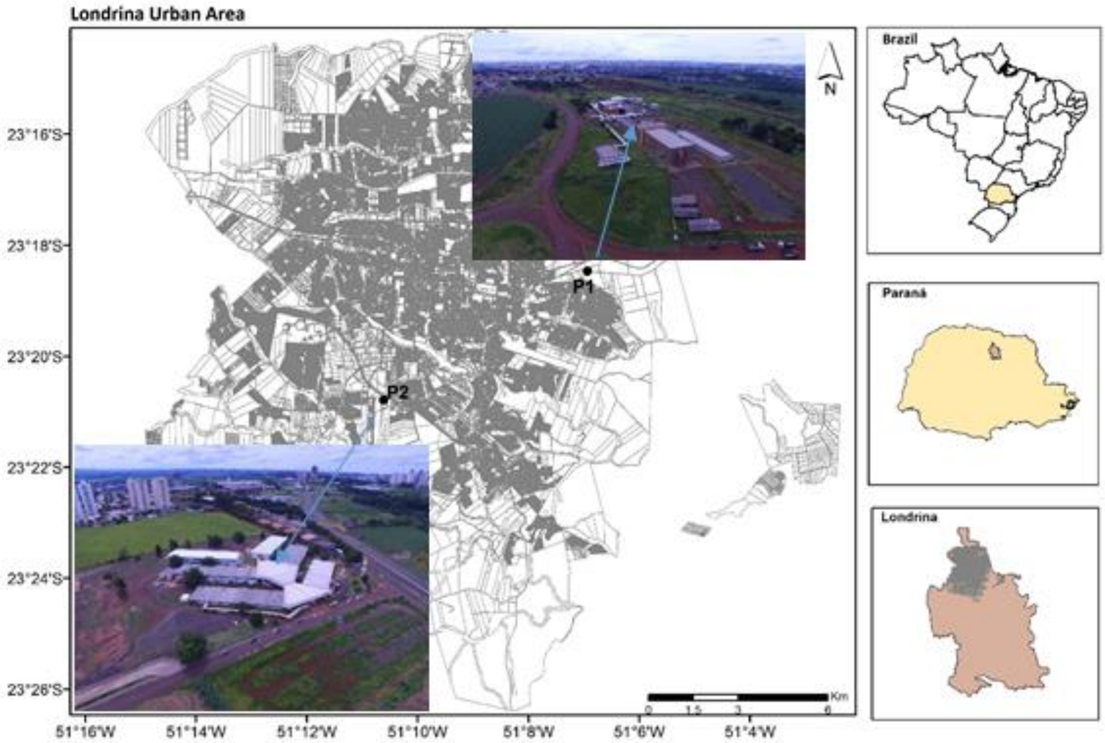
One of the institutions is in the eastern region (P1), an urban area in expansion, with residential and small industrial activities. The peculiarity of this site is the constant biomass burning and general waste (grass, garbage, tire, residual oil, etc.). The burning occurred on almost every day of sampling.

The other institution is in the southwest region (P2), and the sampling point is in an urbanized area, close to a highway with an intense flow of light and heavy vehicles. Figure 1 shows the localization of urban area and the view from sampling places.

Period and study population

The sampling was performed during 2016, in the transition from summer to fall (from March 21 to April 08) and winter (from August 03 to August 25), totalizing 42 samples. These are periods considered with lower and higher particle concentrations in the region (Beal et al., 2017).

Figure 1: Study area location.



The sample population focus of this study was healthy adults from the point of view of the respiratory system. This sample was selected based on the voluntary answers of the validated questionnaire applied, which was provided as supplementary material. The study population is from the education sector, considering their exposure more related to place than activities performed. Teachers, students, and administration workers from education institutions have more homogenous and lower exposure when compared with others occupation classes, which allows viewing the influence of the environment on the health of the population. In addition, the social and economic inequalities are expected to be lower among people in this occupation.

In this study, the voluntaries were students or any employee of both Institutions. The criteria to include the voluntary in the survey were: age over 18 years old and the time of remaining in the institution for a minimum of four hours per day for at least five consecutive days. Individuals who had just joined the institution or who were about to graduate were excluded from the survey. The value of 15% was utilized to calculate the sample size (baseline) (Teodoro and Andrade, 2000; Missagia, 2012; Rodriguez-Villamizar et al., 2012) and 24% to the prevalence of respiratory diseases in low and high pollution conditions, respectively, based in results obtained by Rodriguez-Villamizar et al. (2012).

A sample of 303 individuals was estimated and added 20% to possible losses, resulting in a total sample of 364 individuals.

Data collection and instrumentation n

The data collection consisted on measure and collect by 24 hours PM in indoor and outdoor environments, in two seasons of the year, in two sites (P1 and P2) at the same time, and applying a questionnaire about respiratory symptoms (Ramos, 1983; Publio, 2008; Augusto Junior et al., 2014). In addition, meteorological variables compiled from close stations to the sites were used in the analysis.

In indoor environments, the equipment was placed in a room with similar characteristics in both institutions. The rooms were acclimatized during the commercial time (from 8:00-18:00) and with moderate flow of people. The outdoor measurements were also similar environments, i.e., near the area of higher circulation of students and employees.

Particles and Black Carbon equivalent

For the measurements of particles, six equipment were used, listed in Table 1. All the equipment used has a calibration certificate, and it was previously made a comparison among the concentrations measured, which are statistically similar, based on answers from the Shapiro-Wilk and Mann-Whitney tests.

Table 1: Equipment used and variables measured in each institution.

Equipment	Variable	Flow (L min^{-1})	P1	P2
Outdoor				
Partisol	$PM_{2.5}$; PM_{10}	16.7	-	X
Cyclone	$PM_{2.5}$	16.7	X	X
Reflectometer	BCe	-	X	X
Indoor				
Aerocet 831	PM_1; $PM_{2.5}$; PM_4 PM_{10}; *STP	2.83	X	X
Aerocet 804	$PNC_{0.3}$; $PNC_{0.5}$; $PNC_{1.0}$; $PNC_{2.5}$	2.83	X	X

*STP= suspend total particles

Two monitors were installed in the indoor environment (Aerocet 831 and 804, Met One Instruments, USA) in both Institutions to measure the PM (µg m^{-3}) and PNC (particles L^{-1}) in the sizes presented in Table 1. Two collector equipment (cyclone - URG Corporation, USA; partisol - Thermo Scientific, USA) were installed in the outdoor environments in both institutions, and the final $PM_{2.5}$ concentrations were obtained in quartz fiber filters (QM-A, Whatman) from the gravimetric analysis.

The BCe concentrations were quantified in the filters by the method of light reflectance using a reflectometer (Diffusion Systems Ltd. Model 43 (M43D) (Beal et al., 2017; Squizzato, 2017).

Questionnaire

For this study, a validated questionnaire for respiratory symptoms (Medical Research Council – MRC) was applied. This questionnaire was applied during the measurements period and started after four sampling days. We define acute effects of air pollution as all those that occur within one or a few days of exposure (maximum 5 days). The questionnaire addresses questions related to respiratory symptoms, such as cough and phlegm (frequency and intensity issues) and wheezing (with/without shortness of breath) (Publio, 2008). As mentioned, the sample in this study is healthy adults from the point of view of the respiratory system. Those who answered had any of the previous respiratory symptoms for a minimum of 3 months (cough and phlegm) and 1 year (wheezing) were not selected because they had some chronic respiratory disease. In addition, questions were asked to identify the profile of the population interviewed (gender, age, educational level, habits of smoking and do physical activities), as well as the environmental characteristics of residence area (address and region of residence, type of residence construction, use of wood, coal or wood stove in residence and about the existence of potential emissions sources of pollutants near their home) that served as a control for possible bias. Forty-three questions were asked covering all these issues. The interviews were performed in the summer and repeated with the same individuals during the winter.

Statistical Analysis

Firstly, descriptive statistical analysis was performed for all the measured PM, PNC, and BCe concentrations. Then, a more detailed statistical analysis was carried out, based on the factor analysis, correlation, and regression between the variables measured with the data obtained by the questionnaires during the summer and winter campaigns.

The factorial analysis aims to summarize and reduce a large number of data without losing its original character, thus helping select representative subsets that describe the data in a smaller number of concepts (Costa et al., 2007). The factorial analysis was done for the mass concentrations (PM_1, $PM_{2.5}$, PM_4, PM_{10}, STP, and BCe) and the number of particles ($PNC_{0.3}$, $PNC_{0.5}$, $PNC_{1.0}$, and $PNC_{2.5}$), besides that, the meteorological values of average temperature (T) and relative humidity (RH) were inserted.

The regression model used in this study was the Generalized Estimation Equations (GEE) because the variables are dependent, and the data were continuous and categorical (Ballinger, 2004; Guimarães & Hirakata, 2012). First, the univariate model by GEE was applied for each explanatory variable individually and after using the multivariate model. The variables used in the multivariate model were defined based on the coefficients estimated by the univariate model.

In the univariate model, the variables used were T, RH, period, $PM_{2.5}$, PM_{10}, BCe, $PNC_{0.3}$, and $PNC_{2.5}$, which were selected from the results of the Pearson correlation analysis performed for all data. In the multivariate model, $PM_{2.5}$, PM_{10}, $PNC_{2.5}$, BCe, T, RH, and period were used. From the estimated coefficients and considering a significance of 5% ($p = 0.05$), the relative risk (RR) and the confidence interval (CI) were calculated (Wagner and Callegari-Jacques, 1998; Ostro and WHO, 2004; Coelho and Massad, 2012). A flowchart summarizing the steps mentioned above is presented in Figure 2.

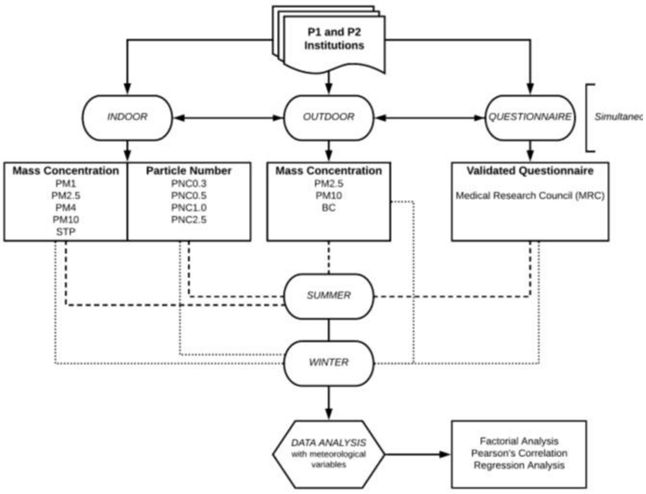


Figure 2: Flowchart of the steps performed in the survey.

Results and discussions

General analysis of particles concentrations

Figure 3 shows the average concentrations of $PM_{2.5}$, and BCe obtained during summer and winter campaigns for the outdoor environment at P1 and P2. The mean outdoor $PM_{2.5}$ concentrations were higher in the winter campaign when compared to the summer, and the variation between maximum and minimum was higher. Mean concentrations of $PM_{2.5}$ in summer were 7.1 ± 5 and 4.8 ± 3 µg m^{-3}, increasing in winter to 10.6 ± 7 and 11 ± 7.5 µg m^{-3}, respectively at points P1 and P2. The increase of concentrations is associated with changes in meteorological conditions from summer to winter.

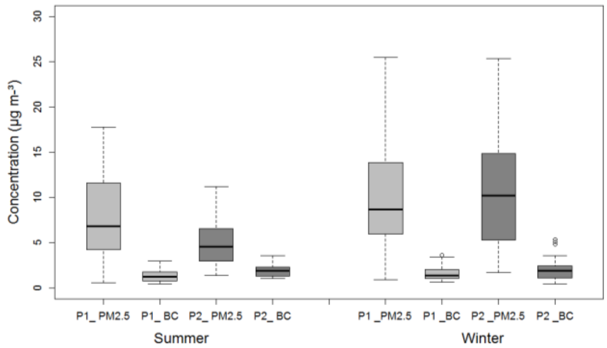


Figure 3: Mass concentrations of $PM_{2.5}$, and BC, from the outdoor environment obtained during the summer and winter campaigns in P1 and P2.

On the other hand, the average BCe concentrations did not vary significantly between the campaigns nor between the sites, which can be justified by BC being a water-insoluble particulate and because the emission sources remaining relatively constant in both campaigns. The mean summer BCe concentrations were 1.3 ± 0.7 and 1.7 ± 0.8 µg m^{-3} in P1 and P2, respectively, increasing slightly during the winter to 1.6 ± 0.92 µg m^{-3} in P1 and 2.1 ± 1.5 µg m^{-3} in P2. The slightly higher values in P2 are probably due to the proximity of the site with the PR-445 highway, which presents a large flow of light and heavy-duty vehicles. Figure 4 brings the average of the indoor PM concentrations into five size ranges measured at P1 and P2 for the summer and winter campaigns. At both sites, the concentrations in all five intervals increased compared with summer, and indoor PM concentrations did not present significant differences between P1 and P2.

On average, the indoor concentrations remained close to the outdoor concentrations. In addition, throughout the sample period, the concentrations showed a significant influence of external conditions among the environments. As pointed, for example, by Barraza et al. (2014), the outdoor $PM_{2.5}$ concentrations contribute significantly to indoor concentrations, and this influence is greater the higher the rate of air exchange between environments. Therefore, the results are consistent with the characteristics of indoor places since they presented a greater rate of air exchange through the doors and are often cleaned.

The different meteorological conditions between the periods, mainly of the T, RH, and wind intensity justify the differences in the concentrations of PM found. The winter presents greater stability of the atmosphere and unfavorable conditions to the dispersion of the pollutants, besides smaller events and volume of precipitation, thus providing a more significant accumulation of contaminants in the atmosphere. However, the BCe concentrations did not vary significantly between the campaigns because the emission sources were the same remaining constant in both campaigns nor between sites. In addition, BCe is water-insoluble particulate and present in the finer fraction of the particulate, showing less sensitive removal to these conditions (Raes et al., 2002). Beal et al. (2017) also found similar results for site P1.

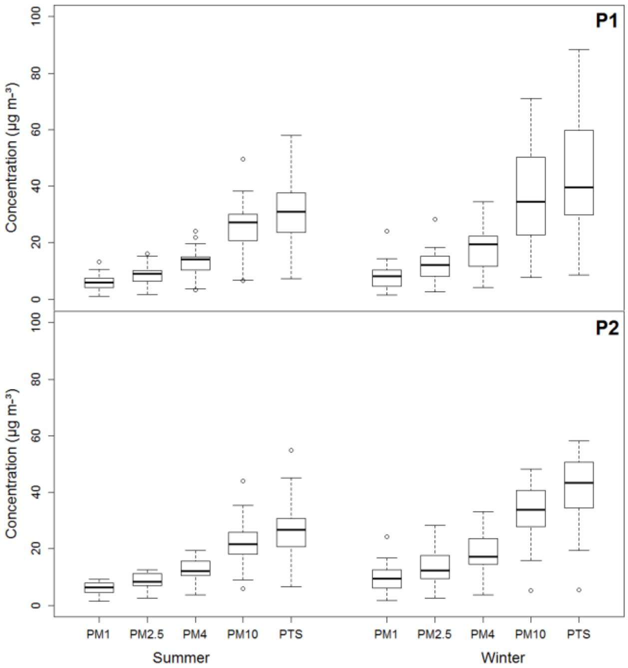


Figure 4: Concentrations of particles of the five mass ranges, from the indoor environment obtained during the summer and winter campaigns, in P1 and P2.

During the summer campaign, $PM_{2.5}$ and PM_{10} concentrations did not exceed the limits recommended by the WHO. However, during the winter campaign, there were two overtaking, which could be attributed to the influence of regional events, as showed in Martins et al. (2018). The long-range transport added to local events, non-occurrence of rain, and stable atmospheric conditions resulted in these high concentrations.

Figure 5 shows indoor PNCs obtained in summer and winter campaigns, at P1 and P2. It is possible to notice that the smaller particle diameter presented the greater concentrations in both sites. The PNC between the points was relatively close, slightly higher in P1. In mean terms, winter concentrations were higher than summer concentrations as observed for PM. The meteorological conditions observed during the campaigns are typical for the region when compared with the climatology.

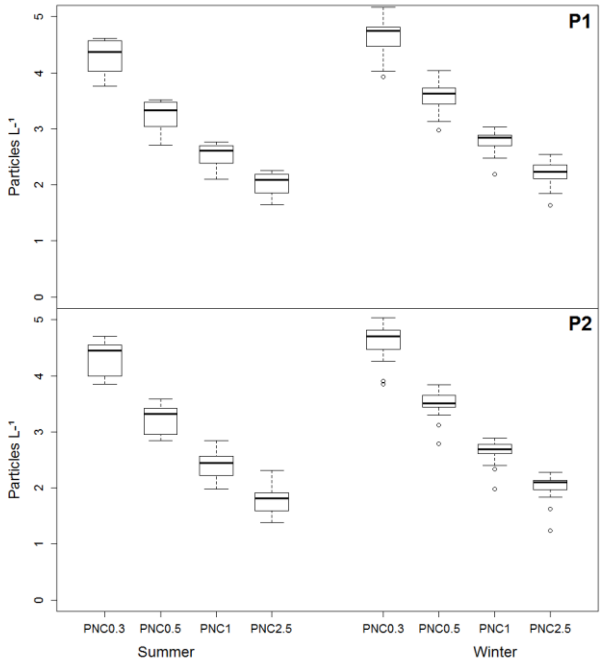


Figure 5: Particle number concentrations (particles L^{-1}), plotted on a log 10 base scale, in the summer and winter seasons at sites P1 and P2.

Questionnaire analysis and respiratory symptoms

During the summer campaign (first interview), 410 individuals were interviewed, of which 241 were valid. Of the remaining interviewees, 35% presented chronic respiratory symptoms, and 6% did not meet the established criteria and therefore were excluded.

In the second interview (winter campaign), 36 individuals could not be interviewed again (14% reduction). The number of valid interviews was 34% lower than the number proposed in the sample calculation and will be treated as a convenience sample. It was expected that, on average, 15% of the interviewed population presented some chronic respiratory symptoms, but 35% of the respondents showed the symptoms, which was considered high (Teodoro and Andrade, 2000; Rodriguez-Villamizar et al., 2012).

There are few studies on the prevalence of respiratory symptoms in Brazil, and the values found in the literature were significantly lower than those found in this study. A study carried out in the Federal District estimated the prevalence of 5.7% (CI, 2.4-9.0) for Estrutural and Varjão and 4.8% (CI, 1.6 -7.9) for Itapoã (Freitas et al., 2011). Others studies for Vitória and Belém found a percentage of 4% and 10% of symptomatic, respectively (Moreira et al., 2010; Rodrigues & Cardoso, 2010). These studies worked with a population of individuals over 15 years old.

Table 2 shows the results of the summer and winter campaigns at both sites for the total number of respondents (241 valid) by sex and age group. The number of male respondents was higher in both sites and campaigns. Regarding the age group, the highest incidence was between young/adult individuals in both sites, and the range of up to 29 years was the most representative.

Table 2 - Distribution in number (n) and percentage (%) of interviews by sex and age group in the two sample sites (P1 and P2) during the campaigns (summer and winter).

	P1	P2	P1	P2
	Summer		Winter	
Gender	n (%)	n (%)	n (%)	n (%)
Female	55 (45.8)	57 (47.1)	52 (45.2)	41 (45.6)
Male	65 (54.2)	64 (52.9)	63 (54.8)	49 (54.4)
nº of interviewed	120	121	115	90
nº of smokers interviewed	13	19	4	11
Total	241		205	
Age Group	n (%)	n (%)	n (%)	n (%)
up to 29 years old	58 (48.3)	78 (64.5)	56 (48.7)	59 (65.6)
30 to 50 years old	51 (42.5)	37 (30.6)	51 (44.3)	28 (31.1)
over 50 years old	11 (9.2)	6 (4.9)	8 (6.9)	3 (3.3)

The age group distribution remained more homogeneous in P1 than P2 due to the characteristics of the institutions. P1 is a public institution characterized by older teachers and employees, and P2 is a private institution with younger employees.

Table 3 - Number (n) and percentage (%) of the symptoms presented during the campaigns, in the two sampling sites (P1 e P2).

	P1		P2	
	S	W	S	W
Symptoms	n (%)	n (%)	n (%)	n (%)
Total Cough	9 (7.5)	20 (17.4)	7 (5.8)	6 (6.7
Total Sputum	2 (1.7)	13 (11.3)	2 (1.7)	6 (6.7)
Cough + Sputum	11 (9.2)	33 (28.7)	9 (7.5)	12 (13.3)

S = Summer; W= Winter

Of 241 interviewed persons in the summer, 120 are from P1 and 121 from P2 Institutions, of which 10.8% and 15.7% were considered smokers. Therefore, most of the volunteers interviewed were not smokers to explain the value of 35% found in this survey.

Table 3 shows the prevalence of cough and sputum symptoms during the summer and winter campaigns in P1 and P2. P1 presented a higher percentage of positive responses than P2, mainly in winter. In a recent study about respiratory infection among adults, the prevalence was higher in winter and varied between 10% and 32% (Kirwa et al., 2021).

The prevalence of symptoms (cough and sputum) presented in P1 for summer and winter was 9.2% and 28.7%, respectively. For P2, the prevalence of symptoms was 7.5% in the summer and 13.3% in winter. Thus, considering the average in both sites, they have 8% (summer) and 21% (winter). Therefore, there was a 13% increase in the prevalence of symptoms during the winter campaign. We performed the statistical analysis considering the environmental conditions (temperature and humidity) mentioned in section 2.4.

Factorial Analysis and Correlation

The factorial analysis indicated that the PM (except BCe) concentrations are similar between localities (indoor and outdoor) and institutions (P1 and P2). Then, allowed in the regression analysis using only indoor concentration, due to the similarity between the environments for $PM_{2.5,}$ and to analyze both sites as a single site. However, a correlation test was performed before the regression analysis to reduce the variables.

The correlation analysis indicated high correlations (>0.7) among PM sizes and PNC, which are physically consistent. Thus, the variables of $PM_{2.5}$, PM_{10}, $PNC_{0.3}$, and $PNC_{2.5}$ were selected for regression analysis. We included the meteorological variables of T and RH and the black carbon concentrations because they presented moderate correlations (0.5 to 0.7) (Mukaka, 2012) when analyzed with the other variables.

Association between respiratory symptoms and air pollution

Table 4 presents the RR and the CI (95%) for univariate and multivariate models. Concerning the period, the RR of an individual having symptoms in the winter is 2.044 times greater than in the summer. For PM_{10}, the individual is 1.031 times more likely to present symptoms due to this pollutant in the winter than in the summer and for an increase of 11 µg m^{-3}.

For $PNC_{2.5,}$ the RR value was 1.006 for an increase of 54 particles L^{-1}. Atkinson et al. (2010) found an association of PNC with cardiovascular diseases, and for respiratory outcomes, other variables were more important, such as $PM_{2.5}$.

The variable that presented a greater association was the period because we found a significant difference between winter and summer. Moreover, in the variable period for its analysis are inserted, indirectly, all other variables analyzed. The period is influenced by a sum of factors, not ruling out the possibility of the absence of some measure that could have influence.

The variables that presented RR greater than one were used in the multivariate model. In addition, the variables of T and RH were inserted in the model to control possible biases that compromised the validity of the results. Group analysis resulted in an increased influence of $PM_{2.5}$ on RR, absence of PM_{10} ratio, and a slight increase for $PNC_{2.5}$. The other variables did not present significant values and, therefore not discussed.

In the multivariate model, variables that presented a risk factor for the study population were $PM_{2.5}$ and $PNC_{2.5}$, which are, in this model, the sum of fine particles in terms of mass and number. The fine particles contributed to the emergence of respiratory symptoms in healthy adults in this study. The RR of individuals presenting symptoms in the winter was 1.540 and 1.018 times greater than in the summer for $PM_{2.5}$ and $PNC_{2.5}$, respectively. These results agree with the literature since, from the point of view of the health effects the $PM_{2.5}$ has a strong association with health indicators (Linares & Diaz, 2010).

According to our finds, $PM_{2.5}$ concentrations and $PNC_{2.5}$ have positive and significant associations with respiratory symptoms in healthy adults. Short-term (Wei et al., 2019) and long-term (Burte et al., 2020; Fasola et al., 2020) exposure studies also showed positive associations for risk of hospital admission and respiratory diseases, respectively, even at medium-low levels of air pollution.

In an ecological study, Shaughnessy et al. (2015) found a 0.6% increase in the rate of emergency visits for upper respiratory infections to increase 10 µg m^{-3} of PM_{10} in a group of healthy youngsters/adults. And Strosnider et al. (2019) found a 10 µg m^{-3} increase in $PM_{2.5}$ and 20 ppb in O_3, a rate ratio of 1.008 (1.004-1.012; CI 95%) and 1.051 (1.046-1.056; CI 95%) for respiratory emergency department visits among adults with under 65 years, respectively.

Other studies indicate that traffic-related pollutants may increase the risk of respiratory infection in adults (Kirwa et al., 2021) and may contribute to the development of asthma in adults (Künzli et al., 2009). The studies bring a different approach, although they all showed positive associations between air pollution and respiratory symptoms, either by a percentage of prevalence, hospital admissions, or questionnaires.

Table 4 – Relative Risk (RR) and confidence interval (CI) using the univariate and multivariate models.

	Univariate		Multivariate	
Variables	RR	CI (95%)	RR	CI (95%)
Period	2.044	[1.129 - 3.702]		
PM_{10}	1.031	[1.016 - 1.110]	0.874	[0.599-0.973]
$PM_{2.5}$	1.164	[1.109 - 1.656]	1.540	[1.045-5.383]
$PNC_{0.3}$	1.000	[1.000 - 1.000]		
$PNC_{2.5}$	1.006	[1.004 - 1.020]	1.018	[1.002-1.071]
BCe	1.413	[0.756 - 2.641]		
T	0.933	[0.858 - 1.014]		

RH	0.974	[0.652 - 1.183]

Δ = 2 µg m^{-3} for PM_{10}, $PM_{2.5}$; Δ = 2 particles L^{-1} for $PNC_{2.5}$; Δ = 10 particles L^{-1} for $PNC_{0.3}$; Δ = 1 µg m^{-3} for BCe; Δ = 1 °C for T and Δ = 5 % for RH

Conclusion

The study showed that although the sample sites P1 and P2 were located in distinct regions with differentiated environmental characteristics, the PM concentrations were similar in both sites and indoor and outdoor environments. In addition, the PM concentrations were higher during the winter than in the summer due to different meteorological conditions.

The prevalence of symptoms (cough and sputum) increased 13% in winter, and we found associations between respiratory symptoms in healthy adults and $PM_{2.5}$ and $PNC_{2.5}$. Therefore, we can conclude that not only susceptible classical groups are affected by air pollution, but also healthy adults from a medium-sized city that are exposed to $PM_{2.5}$ concentrations below the limit recommended by WHO. Reducing the entrance of air pollutants in the workplaces and eliminating biomass burning is imperative to decrease these health damages.

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