Revista Brasileira de Ciências Ambientais
Brazilian Journal of Environmental Sciences

Microplastics and particulate matter: assessment of atmospheric pollution in the Region of Hortênsias, Brazil

Microplásticos e material particulado: avaliação da poluição atmosférica na Região das Hortênsias, Brasil

Patriane Noschang Pletsch[1], Gustavo Marques da Costa[2], Fernando Dal Pont Morisso[1], Daniela Montanari Migliavacca Osório[3], Daiane Bolzan Berlese[1], Daniela Müller de Quevedo[1]

ABSTRACT

Atmospheric pollution is one of the main consequences of anthropogenic activities in the environment. The insertion of particles suspended in the air, which are composed of dust, fumes, microplastics, and aerosols emitted by industries, vehicles, and constructions, alters the quality of the environment they are inserted into, impacting both human health and the environment. Therefore, this study aimed to identify the atmospheric particles that may influence the air quality in the Region of Hortênsias (municipalities of Canela and Gramado) in Rio Grande do Sul state. The concentrations of the particulate matter $PM_{2.5}$ and $PM_{2.5-10}$ were evaluated at two sites from April 2021 to April 2022. The fine and coarse particulate matter sampler (FCS) was used to collect samples at the site located in Canela. In Gramado, besides the FCS, a dichotomous sampler was also used. The filters were observed under a microscope to evaluate the presence of polymeric material. The selected particles were then analyzed by scanning electron microscopy (SEM) coupled with energy-dispersive x-ray spectroscopy (EDS). Six samples of $PM_{2.5}$ did not meet the air quality standards recommended by the World Health Organization guideline. The results demonstrated low air quality, and the microscopic analysis detected the presence of particles with polymeric material characteristics. These particles suggest traces of microplastics, in addition to the presence of vehicular soot and fly ash when analyzed by SEM/EDS.

Keywords: air quality monitoring; particulate matter analysis; environmental health; fine and coarse particles.

RESUMO

A poluição atmosférica é uma das principais consequências das atividades antrópicas no meio ambiente. A inserção de partículas suspensas no ar, compostas por poeiras, fumos, microplásticos e aerossóis emitidos por indústrias, veículos e construções, altera a qualidade do ambiente em que estão inseridas, impactando tanto a saúde humana quanto o meio ambiente. Portanto, este estudo teve como objetivo identificar as partículas atmosféricas que influenciam a qualidade do ar na Região de Hortênsias (municípios de Canela e Gramado) no Rio Grande do Sul. As concentrações do material particulado $MP_{2,5}$ e $MP_{2,5-10}$ foram avaliadas em dois locais no período de abril de 2021 a abril de 2022. O amostrador de material particulado fino e grosso (AFG) foi utilizado para coleta de amostras no local localizado em Canela. Em Gramado, além do AFG, também foi utilizado um amostrador dicotômico. Os filtros foram observados ao microscópio para avaliar a presença de material polimérico. As partículas selecionadas foram então analisadas por microscopia eletrônica de varredura (MEV) acoplada à espectroscopia de raios x por dispersão de energia (EDS). Seis amostras de $MP_{2,5}$ não atendiam aos padrões de qualidade do ar recomendados pelas diretrizes da Organização Mundial da Saúde. Os resultados demonstraram baixa qualidade do ar, e a análise microscópica detectou a presença de partículas com características de material polimérico. Essas partículas sugerem vestígios de microplásticos, além da presença de fuligem veicular e cinzas volantes quando analisadas por MEV/EDS.

Palavras-chave: monitoramento da qualidade do ar; análise de material particulado; saúde ambiental; partículas finas e grossas.

[1]Universidade Feevale – Novo Hamburgo (RS), Brazil.
[2]Instituto Federal do Rio Grande do Sul – Caxias do Sul (RS), Brazil.
[3]Universidade Estadual de Campinas – Campinas (SP), Brazil.
Corresponding author: Daiane Bolzan Berlese – Universidade Feevale – Câmpus II, RS-239 – CEP:93525-075 – Novo Hamburgo (RS), Brazil. E-mail: daianeb@feevale.br

Funding: National Council for Scientific and Technological Development (CNPq): Research Productivity Grant – PQ, process 311917/2022-4.
Conflicts of interest: The authors declare no conflicts of interest.
Received on: 09/17/2024. Accepted on: 03/21/2025.
https://doi.org/10.5327/Z2176-94782280

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Introduction

Air quality is a significant public health concern (Li, T et al., 2018). It is estimated that nearly the entire global population inhales polluted air that exceeds the limits set by the World Health Organization (WHO, 2021) guidelines. The main atmospheric pollutant present in the environment in high concentrations is particulate matter (PM), which can reduce the average life expectancy by 2.2 years worldwide (Aqli, 2020). The origin of these particles is directly associated with anthropogenic emissions and their effects are related to systemic inflammation, oxidative stress, and mutagenicity in cells throughout the body, affecting organs such as the lungs, heart, and brain (Yurak and Fedorov, 2024).

PM is a set of pollutants composed of dust and fumes and any other solid or liquid matter dispersed in the air. These particles have aerodynamic properties, including their diameter, which is used to classify them. Inhalable coarse particles have less than 10 µm diameter, capable of passing through the upper respiratory tract and reaching the lungs. In contrast, fine particles have a diameter of 2.5 µm or less and are considered a main indicator of population health (Payne et al., 2023).

PM concentration in the atmosphere is associated with stationary sources, such as combustion processes in boilers and mobile sources, with an emphasis on vehicle emission (Guimarães, 2017). In large urban centers, the growing number of vehicles has brought impacts on the environment and citizens' quality of life, such as the soot expelled from vehicle exhaust that accumulates on streets and facades of buildings. It is possible to verify the immediate effect, as the flow capacity in vehicle traffic becomes reduced, resulting in increased fuel burning and emission of pollutants substances into the air (IPEA, 2011; Crispim et al., 2012). Depending on the stability of the atmosphere, topography, and meteorological conditions of the region, PM can propagate over long distances and form complex compounds of pollutants with varied physical-chemical properties and toxicities (Guimarães, 2017).

The presence of PM is also associated with polymeric particles, that can be found in the form of fragments, films, and fibers due to their widespread use throughout the world (Pal et al., 2025). Microplastic particles are synthetic organic compounds characterized by having a size smaller than 5 mm. When released into the environment, these compounds undergo continuous processes of photooxidation and chemical weathering, which can alter their structure and result in their fragmentation. The toxicity of microplastics involves exacerbated oxidative stress and cytotoxicity, as well as the translocation of the material through the bloodstream to peripheral tissues, leading to probable potential inflammatory lesions due to their affinity with tissues (He et al., 2023).

The shape of microplastics has been used to associate with their origin and transport. Among the types and shapes most commonly reported in the literature are filaments and fibers, which are associated with the degradation and erosion processes of plastic particle surfaces, as well as the time they remain in the environment. In a study conducted by Li, Y et al. (2018), microplastic fibers were detected in abundance, with over 80% of the fibers analyzed by scanning electron microscopy (SEM) measuring less than 20 µm. The main sources of contribution were identified as dust from the surface and construction sites.

According to the Environmental Company of the State of São Paulo (CETESB, 2019), air quality can also be altered depending on meteorological conditions that determine a higher or lower concentration of PM in the atmosphere. Due to its harmful effects on the environment and human health, PM is used as an indicator of air quality. This pollutant is used as an indicator because it is linked to a higher frequency of occurrences and damaging effects on the environment and human health.

The municipalities included in this study are located in a region where the local economy is largely driven by tourism activity, focused on economic factors. However, this economic activity impacts negatively, such as overcrowded facilities and vehicle congestion (Vidal and Riedl, 2016). These occurrences reflect the introduction of atmospheric pollutants into the air, from stationary sources, such as combustion processes in boilers, and mobile sources, in particular vehicular emissions (Crispim et al., 2012).

Thus, atmospheric monitoring is an important tool that assists in the evaluation of current air quality conditions and ensures that the guidelines are being implemented. The absence of such monitoring can hinder the assessment of pollution's impact on public health (WHO, 2021).

Therefore, the present work aimed to perform a case study to (i) evaluate the concentration of $PM_{2.5\text{-}10}$ and $PM_{2.5}$ in two selected sites in the municipalities of Canela and Gramado, located in the Region of Hortênsias (RS); (ii) analyze the morphology of particles present in $PM_{2.5\text{-}10}$ and $PM_{2.5}$; (iii) evaluate the presence of microplastics; and (iv) compare the PM concentrations with the standards established by the WHO guidelines.

Methods

Study area

The PM samples were collected from two urban areas in the municipalities of Canela and Gramado, located in the Region of Hortênsias in the state of Rio Grande do Sul, Brazil. These cities mainly rely on tourism as their economic activity. Gramado has the largest tourist infrastructure in the state, attracting an average of 6.5 million people per year, and is considered a national reference in the promotion of events. It is also considered one of the ten most visited and safest destinations in Brazil (Ministério do Turismo, 2020), with an estimated population of 36,384 inhabitants and a territorial area of 239.341 km^2, being delimited to the North by the municipality of Canela, which has 45,857 inhabitants and covers an area of 253 km^2 (IBGE, 2022).

According to the State Department of Transit (DETRAN, 2022), Gramado had a fleet of 21,418 vehicles in 2012, and as of 2022, this number increased to 30,529, representing 41% of new vehicles circulating in the municipality over the past decade. Statistical data on the vehicle fleet reported between January and July 2021 by the Empresa Gaúcha de Rodovias (EGR) demonstrated that more than 1.3 million vehicles entered Canela and Gramado through the toll plazas on the access paths to these municipalities, resulting in approximately 3.6 million visitors during this period. The highest vehicular traffic record was reported in July 2021, allowing access to more than 732,000 tourists (EGR, 2021).

The sampling site in Gramado is located in a central area 230 meters from the RS-235 highway and 650 meters from the RS-115 highway. The sampling site in Canela is also located in a central area, 260 meters from the RS-235 highway and 270 meters from one of the main tourist attractions in the city, the Catedral de Pedra. These highways serve as the main access route to these municipalities. Some of the observed impacts are overcrowded facilities and intense vehicle congestion (Vidal and Riedl, 2016).

The sampling sites were in areas influenced by activities that attract visitors, such as the gastronomic and hotel sectors, as well as areas characterized by the intense flow of vehicles, according to the American Society for Testing and Materials (ASTM), which defines the conditions under which the sampler must be installed (ASTM, 2006). Figure 1 shows the location on the map of the PM sampling sites in the Region of Hortênsias in the municipalities of Canela and Gramado.

Particulate matter sampling

The $PM_{2.5}$ and $PM_{2.5\text{-}10}$ samples were collected between April 2021 and April 2022 for 24 hours, covering all seasons of the year. However, sample losses were registered in May and June 2021 for Gramado and in April and November 2021 for Canela. In this study, a total of 44 samples were gathered (n=11 for $PM_{2.5}$ and n=11 for $PM_{2.5\text{-}10}$ in Gramado and n=11 for $PM_{2.5}$ and n=11 for $PM_{2.5\text{-}10}$ in Canela).

The MCZ Dichotomous Particulate Sampling System (MicroPNS-Dichoto model) was used to collect 12 samples in the city of Gramado (n=6 for $PM_{2.5}$ and n=6 for $PM_{2.5\text{-}10}$), from November 2021 to April 2022. The equipment performs the inertial separation of fine and coarse particles by a virtual impactor, dividing the sample flow into two separate systems and fractioning the air sample at a sampling flow rate of 900 L min^{-1} ($PM_{2.5}$) and 100 L min^{-1} ($PM_{2.5\text{-}10}$). The $PM_{2.5\text{-}10}$ particles are directed to the first deposition layer and deposited on a 47 mm diameter polycarbonate membrane filter, while the $PM_{2.5}$ particles are collected separately in another membrane with the same specification (Costa et al., 2018).

All collections in Canela were performed using the fine and coarse sampler (FCS), and an additional 10 samples were taken in Gramado during May and October 2021 (n=5 for $PM_{2.5}$ and n=5 for $PM_{2.5\text{-}10}$). The equipment has two polycarbonate filters arranged in series, with the first stage retaining the coarse fraction ($PM_{2.5\text{-}10}$), while the second stage is composed of a 2 μm pore filter and is responsible for the collection of $PM_{2.5}$. The sampler is connected to a vacuum pump, and the airflow measurements are performed using a volumetric gas meter (LAO brand, G1.6 model), which remains connected to the equipment during the sampling period (Teixeira et al., 2011).

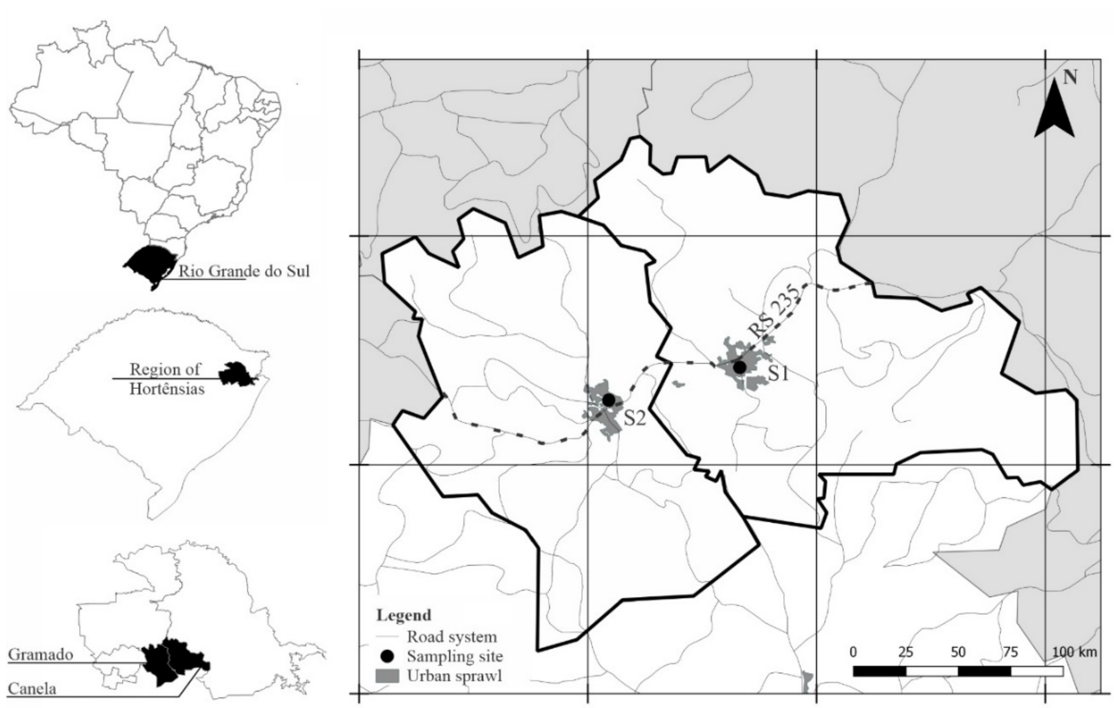


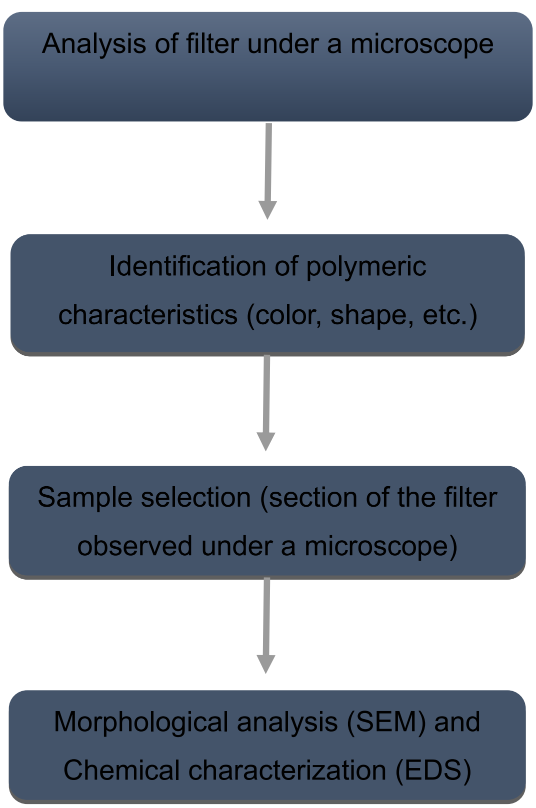
Figure 1 – Sampling sites in the cities of Canela (S1) and Gramado (S2).

The sampling filters were weighed before and after each collection and then stored in a desiccator for 24 hours to remove moisture. The PM concentrations were calculated using a gravimetric method, with a Shimadzu analytical balance model AUW220D.

Microscopic analysis

The mapping of particles, such as microplastics, was carried out using an optical microscope (Olympus CX41 model) with a sampling effort of 15 minutes for each sample and magnification up to 400 times. Optical light microscopy was the first characterization technique used to investigate microplastics, providing information on their size, thickness, degradation stage, and color. The light transmitted by the light source is focused and intensified by a lens that illuminates the object of interest, and the magnification produced by the image is determined by the powers of the ocular and objective lenses. Most of the objective lenses are designed for imaging air samples (Mertz, 2019).

In this study, 24 samples presented characteristics of polymeric particles, such as color and shape. Part of the filter section that contained the particle of interest was removed and subjected to morphological analysis and chemical characterization, following the steps detailed in Figure 2.



SEM: scanning electron microscopy; EDS: energy dispersive x-ray spectroscopy.
Figure 2 – Step flowchart for microscopic analysis through scanning electron microscopy, and energy dispersive x-ray spectroscopy.

Morphological analysis and chemical characterization

The scanning electron microscope (SEM) was used for morphological analysis. Twenty-four samples were selected and preliminarily assessed by an optical microscope. The analysis provided sample characterization by employing an electron beam accelerating voltage of 10 and 20 kV, combined with energy dispersive x-ray spectroscopy (EDS). These techniques made it possible to analyze particles individually, allowing for the description of their composition and morphology at a magnification of up to 6,000 x (Micic et al., 2003).

Meteorological data

The meteorological data were obtained from the National Institute of Meteorology (Instituto Nacional de Meteorologia – INMET) station located in the municipality of Canela, which was chosen due to its proximity to the sampling site. The station is identified as Canela A-879, with code OMM 86990, and is located at an altitude of 831 meters, with coordinates of latitude -29.368788º and longitude -50.827231°.

The wind direction and speed data obtained from the monitoring station during the sample collection period were used to prepare a wind rose. These meteorological data were then used to evaluate the relationship between wind conditions and PM concentrations observed in this study.

The WRPLOT View 8.0 software was used for graphical representation, enabling a wide view of the distribution of wind speed and direction in a given location. Figure 3 represents the distribution of wind in the North, South, East, and West directions during the studied period, allowing for the identification of the prevailing winds on the days of the collections.

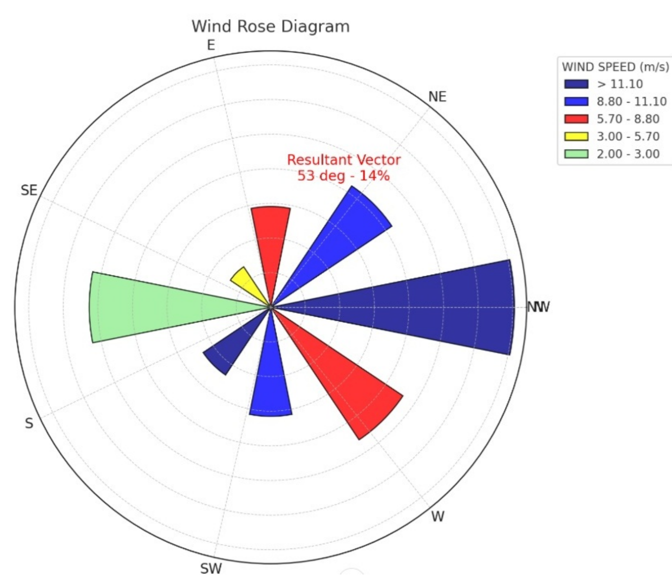


Figure 3 – Wind rose of the sampling sites from April 2021 to April 2022.

Figure 3 reveals that the predominant wind direction occurred from North to South, with a predominant wind speed between 3.60 and 5.70 m s^{-1}, followed by a portion of wind speed between 2.10 and 3.60 m s^{-1}. As for the speed of the South to North winds, it was observed a range between 2.10 and 3.60 m s^{-1}, followed by calm winds, with speeds between 0.50 and 2.1 m s^{-1}. The resulting vector was 53° and represented 14.1% of the total winds, indicating that the directions fluctuated frequently during the sampling period. Calm winds in this study represented only 0.71% of the total. The predominant wind speed (21.5%) was recorded between 2.10 and 3.60 m s^{-1}.

Results and Discussion

Fine and coarse particulate matter

Figure 4 presents the concentrations of $PM_{2.5}$ and Figure 5 shows the concentrations of $PM_{2.5\text{-}10}$, including values obtained at the collection sites in Canela (S1) and Gramado (S2) between April 2021 and April 2022. It was noted that the concentrations obtained for both $PM_{2.5}$ and $PM_{2.5\text{-}10}$ were higher for the municipality of Gramado compared to Canela. The results demonstrated that five samples of $PM_{2.5}$ and six samples of $PM_{2.5\text{-}10}$ were not in accordance with the air quality guidelines established by the WHO.

The highest concentrations of $PM_{2.5}$ were reported in December 2021 in Canela (21.52 µg m^{-3}) and Gramado (102.50 µg m^{-3}), exceeding the air quality standards recommended by the WHO guidelines (15 µg m^{-3}). Although Brazilian legislation (CONAMA 491/2018 [Brasil, 2018]) establishes less restrictive conditions (60 µg m^{-3}), the WHO global air quality guidelines, updated in 2021, provide new evidence-based standards concerning the air pollution's impacts on health (WHO, 2021).

High concentrations were also recorded in Canela (S1) and Gramado (S2) in October 2021. Such periods (October and December) comprise the time when major events occur in the cities. The festivities were estimated to attract over 3.7 million visitors.

The concentration of $PM_{2.5}$ (18.41 µg m^{-3}) reported for Gramado (S2) in October 2021 was observed under the incidence of prevailing winds blowing from the South to Northeast, with speeds ranging from 2.10 to 3.60 m s^{-1}. To the South of this location are the two main routes that receive significantly vehicles accessing the city. Alves et al. (2020) demonstrated that vehicular and industrial emissions were the primary sources contributing to the incidence of PM in the cities of São Leopoldo and Canoas in Rio Grande do Sul, Brazil. The impacts of atmospheric particles are indicated in epidemiological studies that provided sufficient evidence for the WHO to determine that short- and long-term exposures to $PM_{2.5}$ are related to negative effects on respiratory health (WHO, 2021).

Regarding $PM_{2.5\text{-}10}$, six samples collected in Gramado (S2) between November 2021 and April 2022 showed concentrations that exceeded the values considered safe for public health (60 µg m^{-3}) according to the WHO (2021) guidelines. Conversely, the results obtained for Canela (S1) were in accordance with the air quality standards for $PM_{2.5\text{-}10}$, with the highest concentration observed in December 2021 (35.08 µg m^{-3}). Coarse particles commonly have their origin associated with natural sources and can be generated through the resuspension of solid materials under conditions of great atmospheric stability. The transportation of PM at higher altitudes can occur over long distances, leading to pollutant concentrations at ground level, even in the absence of nearby pollution sources (Hwang et al., 2024). Alves et al. (2020) correlated atmospheric particles found in $PM_{2.5\text{-}10}$ samples with natural sources associated with the Earth's crust. However, since the sample content was not subjected to more advanced analysis, the association of these particles with natural sources remains suggestive in this study.

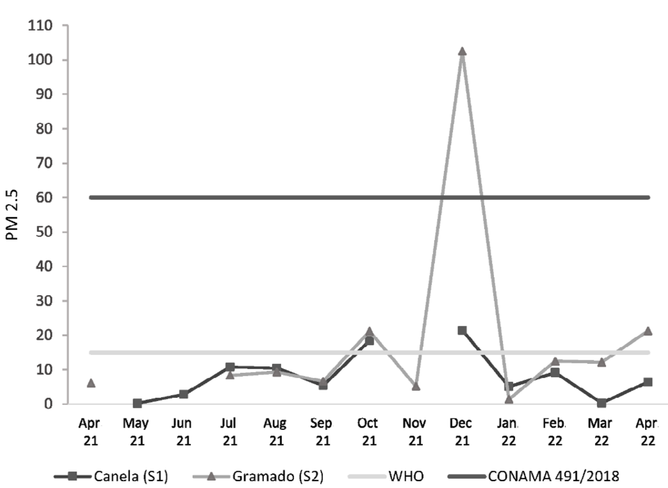


Figure 4 – Concentrations of $PM_{2.5}$ in Canela (S1) and Gramado (S2) between April 2021 and April 2022.

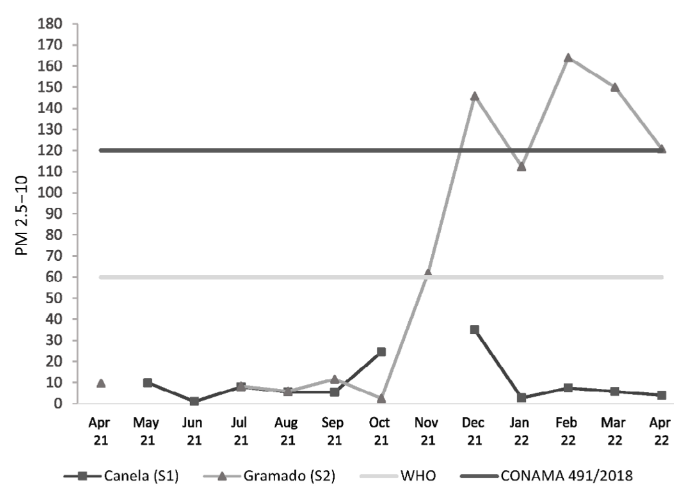


Figure 5 – Concentrations of $PM_{2.5\text{-}10}$, in Canela (S1) and Gramado (S2) between April 2021 and April 2022.

Microscopic analysis

The criteria for the identification and classification of particles under the microscope followed the procedures described by Dehghani et al. (2017), regarding the analysis of color and shape of particles. The shape of polymeric particles is attributed to fibers, fragments, and spheres. The colors can be varied; predominantly among them, are the colors black and blue. Figure 6 presents some of the particles analyzed under the microscope.

The atmospheric particles indicated in Figures 6A, 6B, and 6C correspond to $PM_{2.5}$, while the particles identified in Figures 6D, 6E, and 6F correspond to $PM_{2.5-10}$. Most of these samples were collected in the municipality of Gramado. It is observed that the atmospheric particles had an elongated shape, with a predominant black color and a lesser amount of blue and green, corroborating Torres-Agullo et al. (2021), who also found a prevalence of black color for fibers and fragments and a significant presence of blue color in fibers.

Analyses by scanning electron microscopy coupled with energy-dispersive x-ray spectroscopy

The morphological analyses were performed using SEM coupled with EDS. Figure 7 shows the atmospheric particles collected in the municipality of Gramado with traces of artificial polymeric fibers and their elemental composition.

Anthropogenic activities are the primary contributors to the insertion of microplastic into the atmosphere (Yao et al., 2022).

Figure 7A shows a particle detected in Gramado. A study conducted by Li, Y et al. (2018) in Beijing observed these particles on surface dust and classified them as artificial polymeric fibers composed mainly of silicon and oxygen (Si and O) (Figure 7B). These particles are characterized as being fibrous or in a regular bar-shape and some of them have varied compositions, including silicon, magnesium, and aluminum (Si, Mg, and Al) or silicon, aluminum, and potassium (Si, Al, and K), indicating a mixture of minerals and fibers. In this sense, the high levels of Si and O (Figure 7B) and the morphology of the particle demonstrated in Figure 7A are in accordance with the findings reported by Li, Y et al. (2018), suggesting that this particle may be a polymeric fiber of artificial origin. Such particles represent an important fraction of inorganics, being contained in construction materials such as tiles, cement, and thermal insulation materials (Khadem et al., 2018). Thus, there may be a relationship between the identified particles and ongoing construction activities in the city of Gramado. According to the Union of the Region of Hortênsias (Sinditur), the hotel sector alone has experienced substantial growth, with the addition of over 35 thousand beds, due to the increasing number of visitors in the region (Sinditur, 2020).

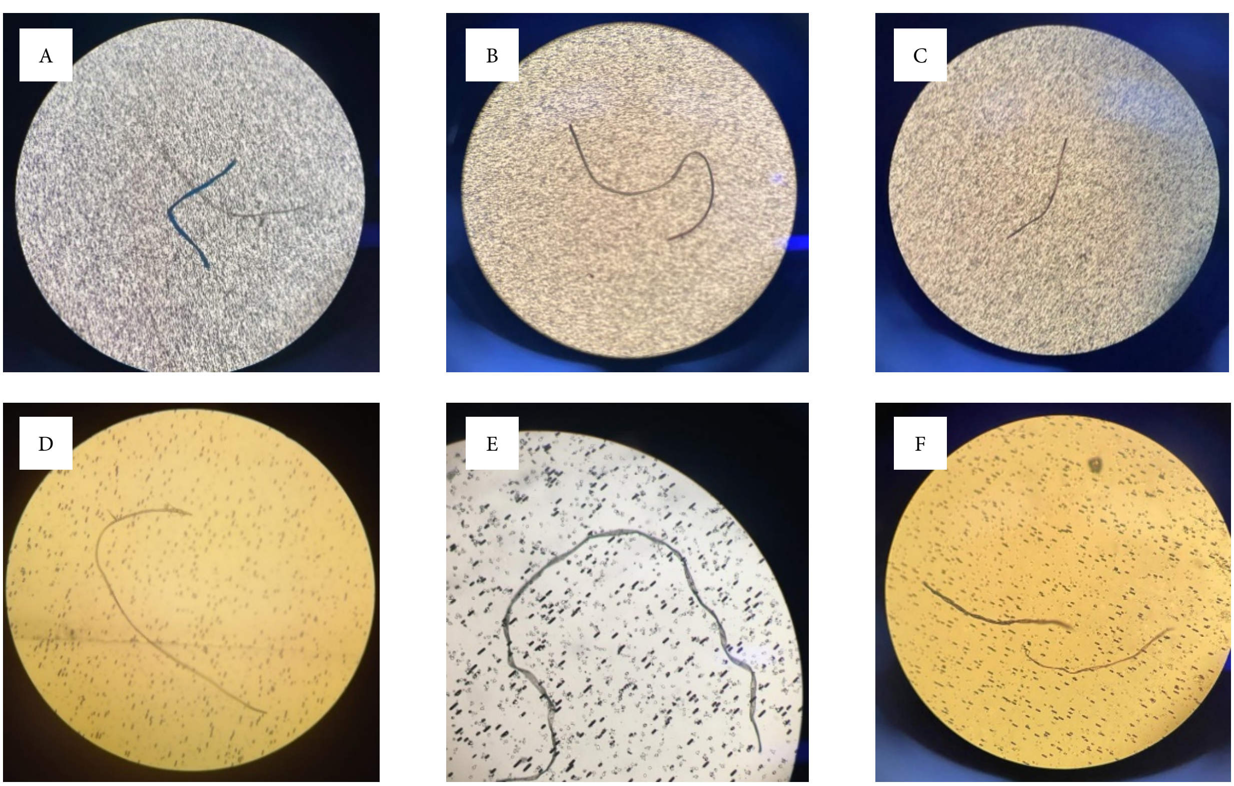


Figure 6 – Particles with polymeric trace identified by microscope in $PM_{2.5}$ (A, B, C) and $PM_{2.5-10}$ (D, E, F). Particles found in Canela (B, D) and Gramado (A, C, and F).

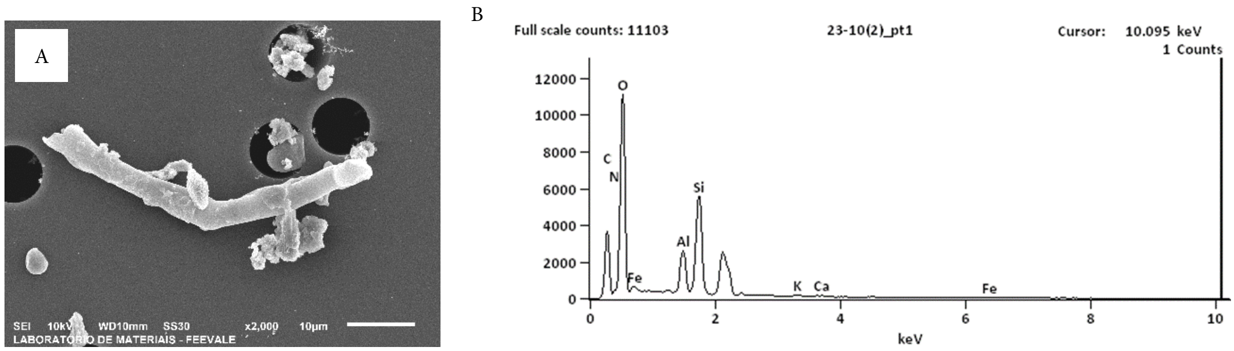


Figure 7 – Particles of artificial fibers and their chemical characteristics. Atmospheric particles with traces of artificial polymeric fibers identified in Gramado in $PM_{2.5\text{-}10}$ (A) and their chemical characterization (B).

Figure 8 shows atmospheric particles in Gramado that demonstrate characteristics suggestive of microplastic fibers, along with their corresponding chemical composition as identified by EDS. Li, Y et al. (2018) also conducted a similar study to characterize microplastic fibers, associating the regular shape and predominant composition of carbon and oxygen (C and O) in these particles, in addition to small amounts of sodium (Na), Mg, Al, Si, K, and calcium (Ca). Similar results were reported by Dehghani et al. (2017) who found microplastic fibers that presented traces of Al, Na, Ca, Mg, and Si, in addition to C and O. The authors related the street dust as a potentially significant source for the contamination of microplastics. Polymeric materials with low density are likely to be suspended and resuspended in the atmosphere by the action of winds and vehicle flow (Yao et al., 2022). All particles shown in Figures 8A, 8B, 8C, 8G, and 8H had regular shapes and elevated peaks for C and O, similar to that reported by Dehghani et al. (2017) and Li, Y et al. (2018).

Liao et al. (2021) used the FTIR spectroscopy technique for microplastic characterization, identifying about 20 types of suspect plastics with a size range of 10–300 µm. This technique is widely adopted and was applied to identify polymeric particles in a study on microplastics in China. In the present study, the size of the atmospheric particles varied between 20 and 120 µm. The variability among the results of the studies from airborne microplastic may stem from the lack of standardized methods for collecting, quantifying, and interpreting data.

According to Niu et al. (2024), after being released into the environment, these particles continue to physically decompose into smaller particles over time; however, particles smaller than 500 µm are difficult to be accurately determined when using visual observation alone. Besides, measurements of atmospheric microplastics using active pump sampling, like the one employed in this study, are very scarce, since for this type of evaluation, most of the studies use the passive deposition method (Liao et al., 2021).

Due to the scarcity of methodologies and studies related to the concentration and dispersion of atmospheric particles that contain plastic material, this work found limitations in the records of polymeric particles. Therefore, secondary analyses are necessary to confirm suspicion and evaluate the degradation of these particles in the environment.

Figure 9 shows the atmospheric particles of varying origin found in the present study, $PM_{2.5}$ (Figures 9a and 9b) and $PM_{2.5\text{-}10}$ (Figure 9c).

Small soot spheres are formed in internal combustion engines from the explosion of gaseous mixtures of air and hydrocarbons (Micic et al., 2003). A study conducted by Alves et al. (2020) in the city of São Leopoldo (RS), Brazil, identified vehicular soot in the samples, similar to that illustrated in Figure 9A in our work. Among the factors that contribute to this occurrence, the proximity of the collection point to the RS-235 highway, which serves as an access route to Gramado, can be mentioned as favoring the appearance of this type of particle in $PM_{2.5}$.

Figure 9C shows a particle of a spheric shape, recorded in $PM_{2.5}$ in Gramado. Similar particles were identified by Micic et al. (2003) as a spherical agglomerate of fine fly ash particles from local power plants in the region of Belgrade, Serbia. The fly ash particles have a perfectly spherical shape, generated by the solidification of molten silicate materials in the flow of smoke and flames, and soot particles can be absorbed on their surface. Although in the region of this study there are no coal plants, atmospheric pollutants can spread across continents, especially those with little reactivity and particulate matter that depend on the atmospheric stability, topography, and meteorological conditions of the region (Guimarães, 2017). Figure 9B represents a particle found in $PM_{2.5\text{-}10}$ in Canela, a similar particle was suggested by Alves et al. (2020) as coming from the Earth's crust, having a natural origin.

It is observed that atmospheric particles identified in Figures 7 and 8 have a different morphology when compared to atmospheric particles from known sources, such as vehicle soot and fly ash, reinforcing the indication that these particles may be polymeric particles. However, there are not enough studies to evaluate the presence of microplastics in the atmosphere of the study region.

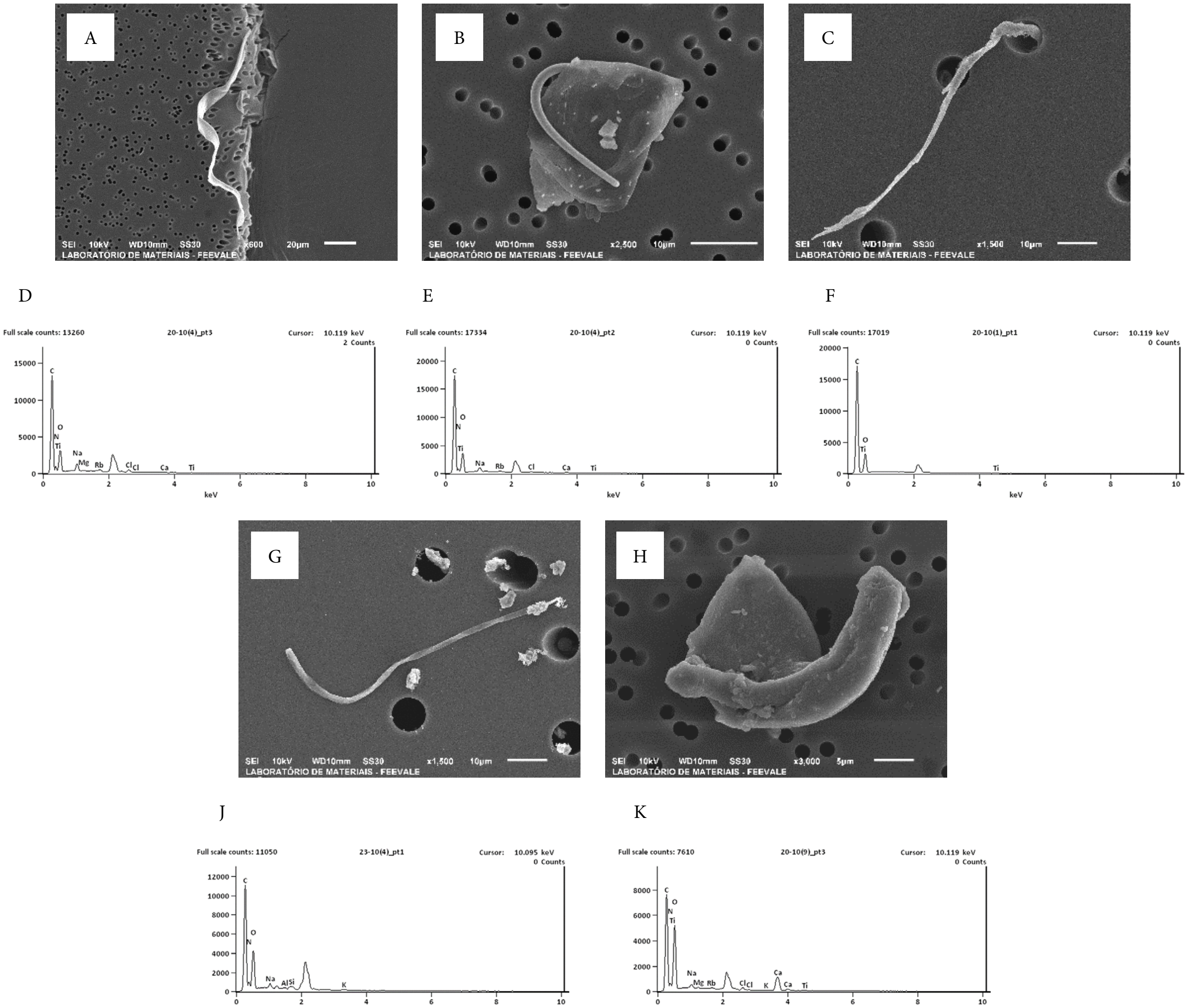


Figure 8 – Particles suggestive of microplastic fibers and their respective chemical characteristics in Gramado. $PM_{2.5}$ (A, B, H) and their respective chemical characterization (D, E, K). $PM_{2.5\text{-}10}$ (C, G) and their respective chemical characterization (F, J).

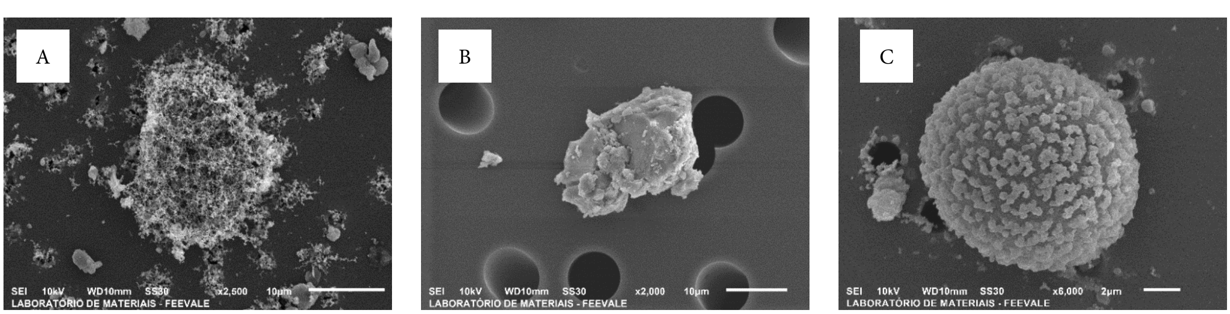


Figure 9 – Particles of varying origins identified in Gramado and Canela. Vehicle soot particle identified in $PM_{2.5}$ in Gramado (A); particles found in $PM_{2.5\text{-}10}$ in Canela (B); and particle found in $PM_{2.5}$ in Gramado (C).

Studies reported that the atmosphere is an important route for transporting microplastics and influences the flow of plastic pollution in other environments, such as land and sea. Microplastic particles have already been found in the urban atmosphere and remote regions, far from any source of emission of these particles (Evangeliou et al., 2020). This indicates that if the presence of plastic material is confirmed in the sampling area of this study, environments and areas close to the municipalities of Canela and Gramado may be influenced by the presence of this material. However, systematic studies on microplastic patterns in the air are needed to understand the exposure to these particles transported in different environments.

Conclusions

The study sought to identify atmospheric particles in the Region of Hortênsias in Rio Grande do Sul state (Brazil) through sampling at two sites, located in the municipalities of Canela and Gramado, from April 2021 to April 2022. The analyses revealed the presence of particles with traces of polymeric material, vehicular soot, and particles suggestive of fly ash. $PM_{2.5}$ and $PM_{2.5\text{-}10}$ concentrations in Gramado were consistently higher than in Canela, with several samples exceeding WHO air quality standards. This suggests that air quality in the region is affected by anthropogenic activities, particularly those related to tourism and heavy vehicular traffic.

The detection of particles with characteristics of polymeric material, including microplastics, is particularly concerning. These microplastics can originate from various sources such as synthetic fabrics, tire abrasion, and urban dust.

The data obtained in this study provide an important basis for air quality management in the region. Local authorities can use this information to develop policies and mitigation strategies aimed at reducing atmospheric pollutant emissions, especially in areas with high concentrations of tourism activities and vehicular traffic. Additionally, further studies are needed to better understand the dispersion patterns of microplastics and their implications for public health and the environment.

Authors' contributions

Pletsch, P.N.: conceptualization, data curation, formal analysis, investigation, methods, project administration, resources, validation, visualization, writing – original draft, writing – review & editing. **Da Costa**, G.M.: visualization, writing – original draft, writing – review & editing. **Morisso**, F.D.: investigation, methodology, writing – original draft, writing – review & editing. **Osório**, D.M.M.: conceptualization, investigation, methodology, supervision, validation, writing – original draft, writing – review & editing. **Berlese**, D.B.: supervision, validation, writing – original draft, writing – review & editing. **Quevedo**, D.M.: conceptualization, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing – original draft, writing – review & editing.

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