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Transport of Particulate Matter in the Pampas/Peru District During August and September 2024

Transporte de Material Particulado no Distrito de Pampas/Peru Durante os Meses de Agosto e Setembro de 2024

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ABSTRACT

This contribution evaluates the transport of particulate matter in the district of Pampas during August and September 2024, located in the department of Huancavelica - Peru. To estimate the air quality, the *Ministerio do Ambiente* methodology is used for particles in fine and coarse mode. Results from August to September 2024 demonstrated the air quality was poor for fine mode particulate matter. Therefore, it is concluded that the environment for the months of August and September was harmful to people's health, and underlines the importance of addressing air quality not only as a public health problem, but also as a critical factor in sustainable development.

Keywords: Air quality; Tayacaja; Meteorology

RESUMO

Esta contribuição avalia o transporte de material particulado no Distrito de Pampas durante agosto e setembro de 2024, localizado no departamento de Huancavelica - Peru. Para estimar a qualidade do ar, a metodologia Ministerio do Ambiente é usada para partículas fina e grossa. Resultados de agosto a setembro de 2024 indicam que a qualidade do ar foi ruim para material particulado em modo fino. Portanto, conclui-se que o ambiente para os meses de agosto e setembro foi prejudicial à saúde das pessoas e ressalta-se a importância de abordar a qualidade do ar não apenas como um problema de saúde pública, mas também como um fator crítico no desenvolvimento sustentável.

Palavras-chave: Qualidade do ar; Tayacaja; Meteorologia

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1 Introduction

Air pollution is one of the most pressing environmental problems of the 21st century, posing significant threats to human health and the well-being of ecosystems worldwide. This problem is not simply a local or regional concern; it has far-reaching global implications that demand international cooperation and innovative solutions. In urban areas, where population density, industrial activities, and transportation converge, air pollution tends to be more concentrated and its impact more severe (Yuan, Ng & Norford 2014). Cities are often hotspots for emissions of pollutants such as nitrogen dioxide (NO_2), particulate matter (PM2.5), and carbon dioxide (CO_2) (Coelho *et al.* 2023). As a result, urban populations are particularly vulnerable to the adverse effects of polluted air, including respiratory diseases, cardiovascular diseases, and reduced quality of life (Kaur & Jhamaria 2021). Air quality is a critical concern with direct implications for public health, particularly in urban and suburban areas where several anthropogenic activities contribute to the dispersion of particulate matter (PM) (Sicard *et al.* 2019). Particulate matter is considered one of the most serious hazards to human health, the environment and the climate on a global scale (Engelbrecht & Derbyshire 2010). Several factors influence the spatiotemporal variability of PM10 dynamics, including land-use structures (Ku 2020); physical and chemical characteristics of soil (Lenschow *et al.* 2001), meteorological variables (Bodor *et al.* 2020; Cheewinsiriwat *et al.* 2022) and spatial characteristics of road networks (Jung, Park & Kim 2019). Climatic variables, including temperature, wind speed, and atmospheric stability, are crucial for dispersing and transforming PM10 in the atmosphere (Diapouli *et al.* 2017). Air quality in rural areas has generally been considered healthier than in urban areas due to lower primary anthropogenic emissions, coupled with higher dispersion and lack of the "heat island" effect (Harrison 2018).

Urban areas, in particular, face significant challenges due to high concentrations of pollutants resulting from industrial activities, vehicular emissions, and other anthropogenic sources. Monitoring and managing air quality in cities is essential to safeguard public health and ensure sustainable urban development (Kasimgaliev *et al.* 2023). The need to study the ecological state of the atmosphere to plan sustainable cities is emphasized in the works of Menconi *et al.* (2023), Wang *et al.* (2023), Zaini *et al.* (2023), and many others.

Therefore, the present research is to evaluate the concentration of particulate matter and its transport from *in situ* measurements in the Pampas district during August and September 2024.

2 Methods

2.1 Site Description

The study site is located at a southern latitude of -12.38 and a western longitude of -74.88, located in the province of Tayacaja, department of Junin/Peru (Figure 1), located 3,276 meters above sea level and covering an area of 109.07 km², this region experiences a temperate climate with moderate rainfall and dry winters. Annual precipitation ranges from 500 to 1,500 mm, and its primary sources of income are livestock and agriculture (Saldaña-Chafloque *et al.* 2024).

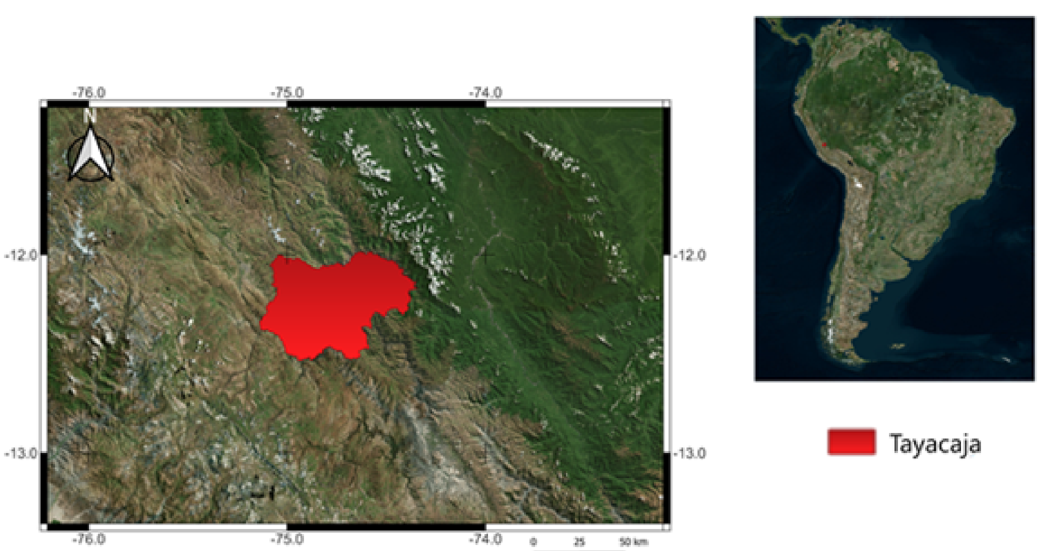

Figure 1. Location map of monitoring de particulate matter.

2.2 Air Quality Index

The National Air Quality Index (NAQI) of Peru has an optimal value between 0 and 100, which complies with the Environmental Air Quality Standards (Ministerial Resolution No. 181-2016-MINAM, 2016). Tables 1, 2 and 3 show the NAQI calculations for particulate matter.

2.3 Meteorological Station Marca Lufft and Purpleair Sensor

The WS601-UMB is a compact all-in-one weather sensor with measurement of temperature, relative humidity, air pressure, precipitation, wind direction and wind speed (Figure 2A). Likewise, the purple air sensor (Figure 2B) performs continuous measurements using a laser device at a temporal resolution of 1 minute of fine mode particulate matter (particle diameter less than 2.5um) and coarse mode (particle radius greater than 2.5um and less than 10um) (Endale *et al.* 2024).

2.4 Hysplit Model

The HYSPLIT model, developed by the Atmospheric Resource Laboratory of the National Oceanic and Atmospheric Administration (NOAA), is a widely used Lagrangian single-particle transport model. It is employed to calculate air parcel trajectories both forward and backward, following atmospheric currents, and to assess the distance traveled and the direction in which atmospheric pollutants are dispersed. In this study, the potential origin of air masses contributing to aerosol concentrations in the Peruvian city of Pampas, located in Huancavelica department. A monthly surface-level backward trajectory analysis was conducted using the HYSPLIT model (Estevan *et al.* 2019) and data from the Reanalysis for different altitudes, from August to September 2024. Trajectories for each month were calculated with 6-hour intervals and a transport duration of up to 120 hours. The target origin points were set at surface level in Pampas.

Table 1. Classification of INCA values.

NAQI interval	Equation
0-50	
51-100	$I(PM2.5) = \frac{((PM2.5) \times 100)}{25}$
101-500	
>500	

Table 2. INCA calculation for Particulate Matter (PM2.5) for 24 hours.

Classification	Values NAQI	Colors
Good	0-50	Green
Moderate	51-100	Yellow
Bad	101-VUEC*	Orange
VUEC*	>VUEC*	Red

Table 3. INCA calculation for Particulate Matter (PM10) for 24 hours.

NAQI interval	Equation
0-50	
51-100	$I(PM10) = \frac{((PM10) \times 100)}{150}$
101-167	
>167	

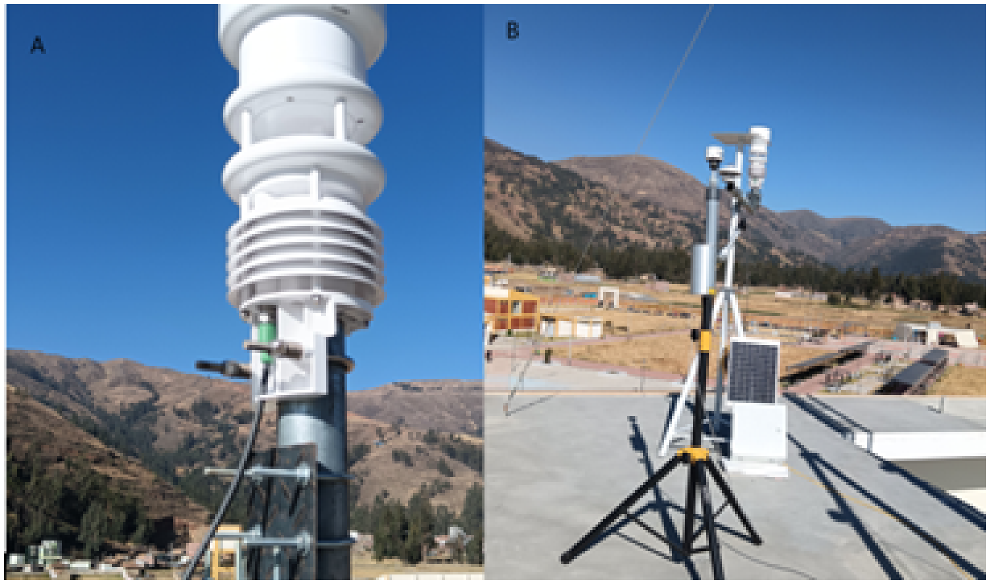

Figure 2. A. Meteorological station; B. Purple air sensor.

3 Results

3.1 Particulate Matter

In Figure 3, the concentration of PM2.5 and PM10 particulate matter in August and September 2024 is shown, represented by boxplot diagrams where the monthly average of 66 and 91 ug/m^3 is shown for the months of August and September in fine mode (Figure 3A) respectively. Likewise, for coarse mode (Figure 3B), the monthly average of 20 and 32 ug/m^3 is shown for the months of August and September respectively. It should be noted that for fine mode particulate matter it presents the maximum value of 30 ug/m^3 in the month of September and for coarse mode it presents the maximum value of 35ug/m^3 in the month of September. Also using the t-Student and Tuckey test, it is observed that there is a difference in the means ($p<0.05$) of fine and coarse mode concentrations between both months.

Likewise, Figure 4 indicates that for fine-mode particles in the months of August and September, 34.5%, 54.6% and 10.9% of the data is classified as good, moderate and bad respectively; and for coarse-mode 100% data, it is classified as good; this is due to the predominance of vegetation burning.

3.2 Wind Speed and Direction

In Figure 5, it can be seen that the wind trajectory is towards the south at a speed of 11 m/s. Also, in Figure 5A it is shown that the high concentration values of fine mode (5 to 31 ug/m^3) are dispersed towards the south at an average speed of 6 at 11 m/s. Also, in Figure 5B it is shown that the high concentration values of coarse mode (6 to 37 ug/m^3) are dispersed towards the south at an average speed of 6 at 11 m/s.

It is also observed that the air masses and wind trajectories at the mesoscale level are towards the Andean region of Peru how Pampas province (Figure 6). It is also shown that the air masses in August come from Bolivia and Brazil; and in September they only come from the Brazilian Amazon. This indicates that the atmospheric pollution events that occurred in the regions indicated in Brazil and Bolivia according to Figure 6; such as vegetation burning, can be transferred to Pampas/Peru.

3.3 Analysis Statistic

Cluster analysis was used to compare the daily and monthly behaviors of fine mode particulate matter (Figure 7A) and coarse mode particulate matter (Figure 7B). It is observed that there are 10 daily groups that have the same daily behavior of fine mode particulate matter for August and September. Likewise, for coarse mode particulate matter, it is observed that 11 daily groups have the same behavior regarding their particulate matter concentration for the months under study.

4 Discussion

Likewise Vardoulakis and Kassomenos (2008) indicates that the negative correlations between PM10 and wind speed and precipitation weaken during warm

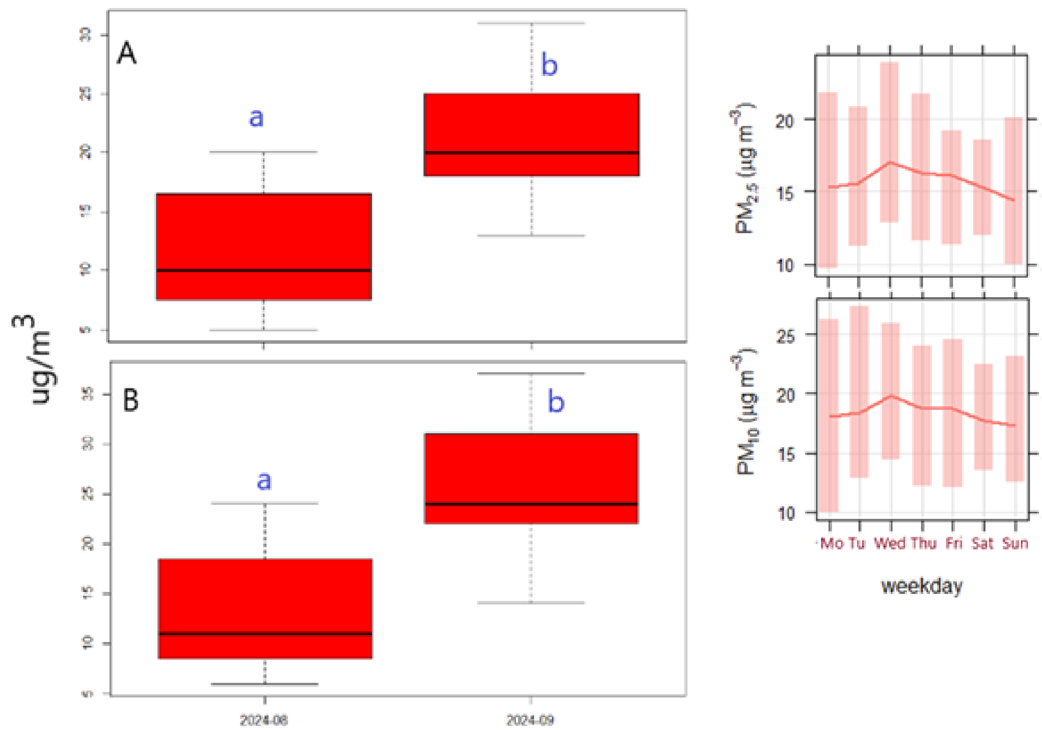

Figure 3. Concentration of Particulate Matter (ug/m3): A. PM2.5; B. PM10.

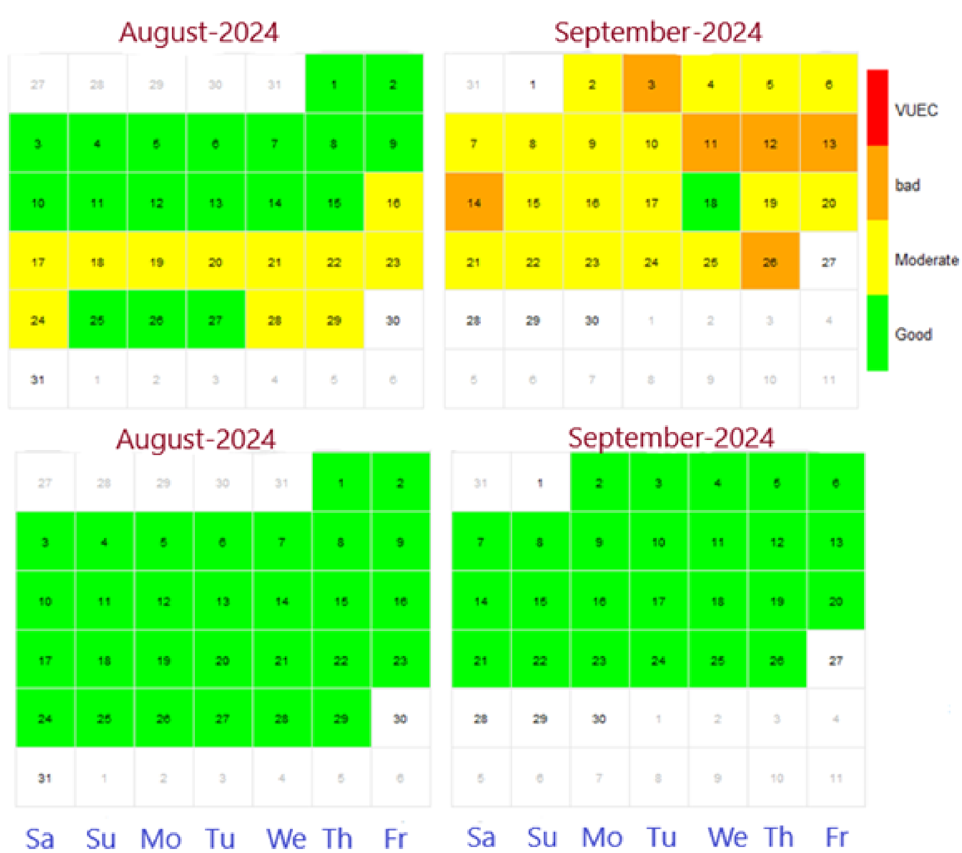

Figure 4. Air quality index during August and September 2024 for: A. Fine mode; B. Coarse mode.

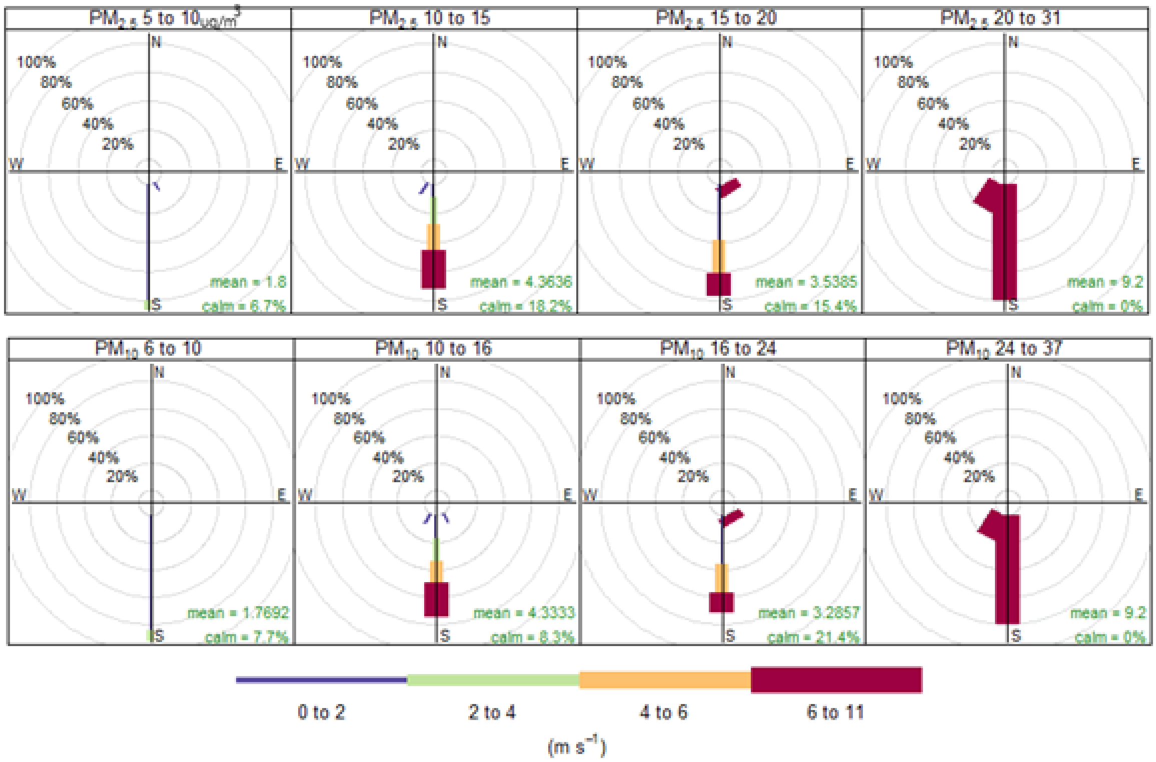

Figure 5. Wind speed and direction during August and September 2024.

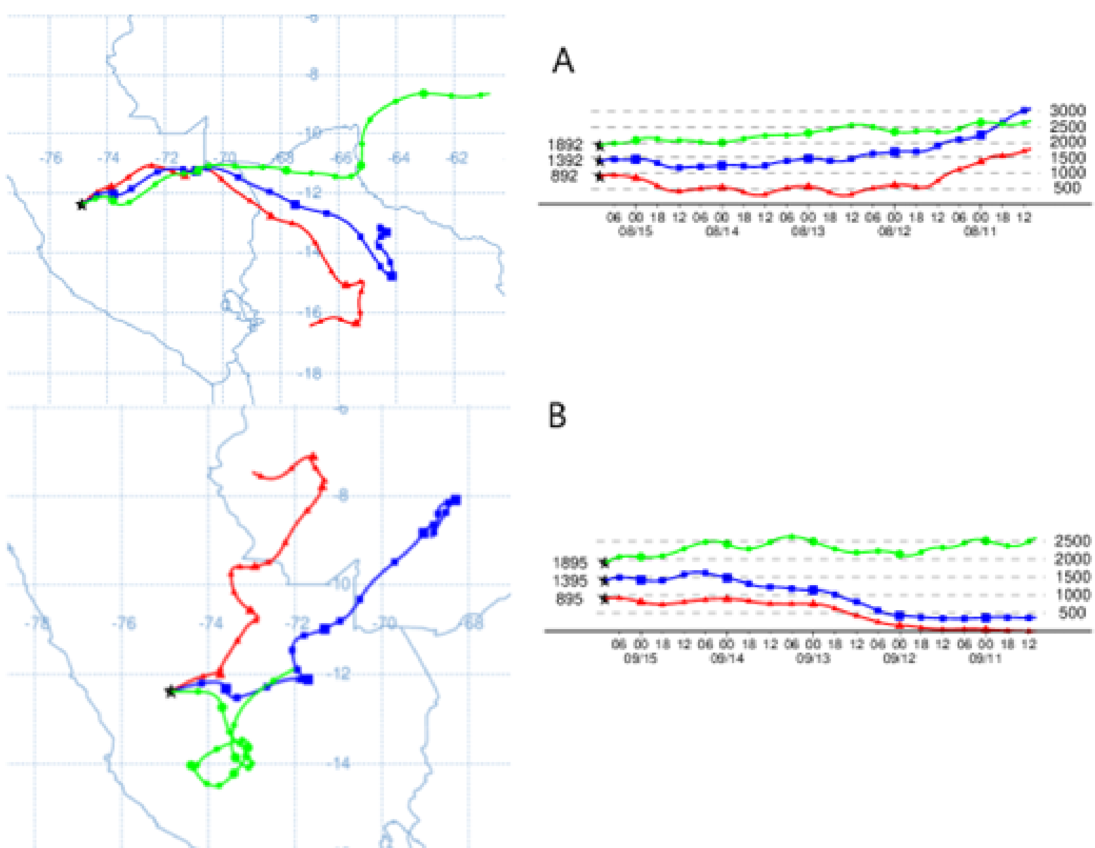

Figure 6. Air mass trajectories towards Pampas/Peru during: A. August 2024; B. September 2024.

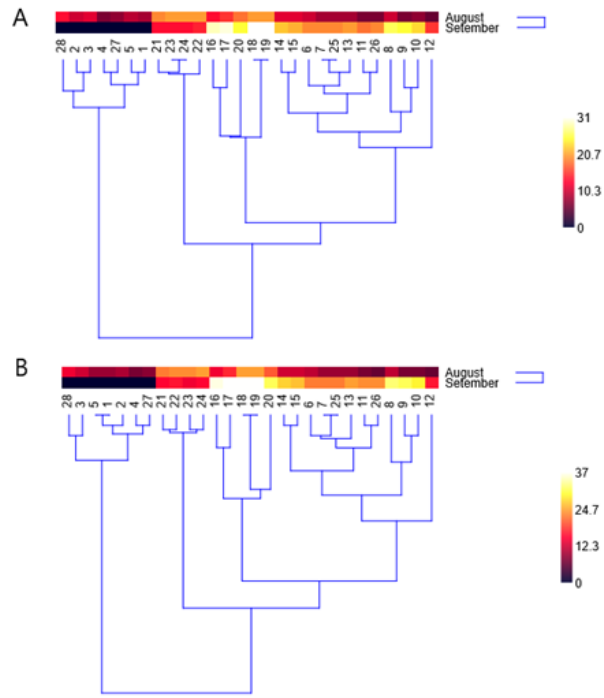

Figure 7. Cluster analysis of particulate matter for the months of August and September 2024: A. Fine mode; B. Coarse mode.

seasons, probably due to the formation of secondary aerosols and increased resuspension of soil dust. In summer, PM10 production is mainly related to secondary inorganic production (Carnevale, Pisoni & Volta 2010). In contrast, Birim *et al.* (2023) found that temperature was not statistically significant on PM10 concentrations, while wind speed was negatively correlated with PM10, similarly to studies (Bodor *et al.* 2020). However, this result contradicts the findings of Pi *et al.* (2022) who found that annual PM10 emissions decreased from 1958 to 2018 and that this trend was significantly associated with decreasing wind speed. The findings of Safarov *et al.* (2024) show broader implications beyond air quality management, particularly in the areas of tourism-related infrastructure, transportation, and logistics. Furthermore, the identified spatial variability in pollutant concentrations and pollution hotspots near industrial areas provide critical information for planning and developing sustainable urban infrastructure. By integrating pollution data into urban planning, cities can develop more efficient and environmentally friendly transportation systems that minimize exposure to pollutants (Elgohary, Samra & El-Madawy 2024). The expansion of green spaces can serve a dual purpose: improving air quality and creating an attractive and healthy environment that enhances the city's tourist appeal and provides logistical advantages by improving urban aesthetics and reducing the heat island effect (Picone *et al.* 2024).

5 Conclusions

In conclusion, this research provides valuable information on the transport of particulate matter and its fine and coarse mode size distribution in the Pampas district during August and September 2024.The study found that air quality for PM2.5 and PM10 are classified as bad and good air quality, respectively. Pampas faces significant environmental challenges such as biomass burning, with high concentrations of fine-mode particulate matter negatively affecting public health and quality of life. It is also worth highlighting and proposing the formation of public and private air quality monitoring networks as essential for comprehensive management (Safarov *et al.* 2024). This research underlines the importance of addressing air quality not only as a public health issue, but also as a critical factor in sustainable development.

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Author contributions

Julio Miguel Angeles Suazo: conceptualization; formal analysis; methodology; validation; writing-original draft; writing – review and editing; visualization; statistical analysis; analysis of results; conceptual discussion. **Roberto Angeles Vasquez**: methodology; validation; writing-original draft; writing – review and editing; statistical analysis; analysis of results; conceptual discussion.

Conflict of interest

The authors declare no conflict of interest.

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