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COMPARISON OF MICROPLASTICS LEVELS IN THE AIR OF AGRICULTURAL AND URBAN AREAS OF THE CITY OF COCHABAMBA, BOLIVIA

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Microplastics are considered emerging pollutants and, in recent years have been found in all environmental compartments, even in living organisms. Their relationship with health problems was highlighted. Cochabamba is one of the cities most affected by air pollution in Latin America and there are marked differences in air quality levels between the south and north zones. La Maica, in the southern zone, is the last agricultural area of the city of Cochabamba and the northern zone is a urban area. Thus, the southern zone is characterized by higher levels of particulate matter (PM10) than the northern zone. The study seeks to compare the levels of microplastics in the air between these two zones of the city. Microplastics were characterized using commonly used density separation and optical identification techniques. The results highlighted the presence of microplastics in the air of the two zones and showed that the levels of microplastics and PM10 particles are inversely proportional under the monitoring conditions of the study. This result can be related to the environmental and socioeconomic conditions of each zone.

Keywords: microplastics; air pollution; particulate matter; agricultural and urban areas

COMPARACIÓN DE NIVELES DE MICROPLÁSTICOS EN EL AIRE DE ZONAS AGRÍCOLAS Y URBANAS DE LA CIUDAD DE COCHABAMBA, BOLIVIA

Los microplásticos son considerados como contaminantes emergentes y, en los últimos años han sido encontrados en todos los compartimientos del medio ambiente hasta dentro de organismos vivos, además de evidenciarse su relación con problemas de salud. Cochabamba es una de las ciudades más afectadas por la contaminación atmosférica en Latinoamérica y en esta se tienen diferencias marcadas de niveles de calidad del aire entre la zona sur y norte. La Maica, en la zona sur, es la última zona agrícola de la ciudad de Cochabamba y la zona norte es urbana. Así la zona sur se caracteriza por tener mayores niveles de material particulado (PM10) que la zona norte. El estudio busca comparar los niveles de microplásticos en el aire entre estas dos zonas de la ciudad. Se caracterizaron los microplásticos empleando técnicas de separación por densidad e identificación óptica comúnmente utilizadas. Los resultados confirmaron la presencia de los microplásticos en el aire de las dos zonas y mostraron que los niveles de estos y de las partículas PM10 son inversamente proporcionales bajo las condiciones de monitoreo del estudio. Este resultado se puede relacionar a las condiciones ambientales y socio económicas de cada zona.

Palabras clave: microplásticos; contaminación atmosférica; material particulado; zonas agrícolas y urbanas

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1. Introduction

Plastic is one of the most widely materials used on the planet and due to its persistence and the effects it can cause, it generates contamination problems in different environmental compartments and in the health of the population and ecosystems (Castañeta et al., 2020).

The degradation of plastics gives rise to the generation of microplastics (MPs), which are plastic particles smaller than 5 mm in size that, due to their interaction with other substances in the environment and living organisms, have increased the interest in the study of this pollutant in the environment and living organisms (Shao et al., 2022). Thus, in Bolivia, the first study on the presence of MPs in the air of the city of Cochabamba was carried out at the Research Center for Exact Sciences and Engineering (CICEI, for its acronym in Spanish) of the Bolivian Catholic University (UCB, for its acronym in Spanish) (Oporto et al., 2021).

Microplastics can be emitted directly into the atmosphere from different sources or can be generated from the fragmentation or degradation of tires and plastic debris found in the environment, these being the main sources of airborne MPs (Abbasi et al., 2019; Crawford & Quinn, 2017; Zhang et al., 2020).

MPs smaller than 10 microns in the air have a similar behavior to particulate matter smaller than 10 microns (PM_{10}), where these particles are suspended for a longer time and can be transported over greater distances than larger particles and can be found in regions far from their source of emission; however, the dispersion of this pollutant in the atmosphere is still being studied (Castañeta et al., 2020; Munyaneza et al., 2022).

On the other hand, the geographic and climatological characteristics of a region are determinant for the dispersion and/or for the concentration of atmospheric pollutants in a given region. The city of Cochabamba is a central valley that lacks good gas dispersion, especially in the early morning hours, resulting in a higher concentration of air pollutants, especially PM_{10}, exceeding the values of local regulation and air quality guidelines, with marked differences between the northern and southern areas of the city (Oporto et al., 2021).

Therefore, in regions with high concentrations of atmospheric pollutants, it is necessary to have adequate air quality monitoring systems and to pay attention to emerging pollutants that may have a significant impact on the health of the population. In regions such as Cochabamba, this can be complicated due to the marked differences in activities and development conditions between the different areas of the city of Cochabamba, which makes it necessary to evaluate exposure to MPs due to their dispersion in different areas of the city, which can contribute to better decision-making policies to improve the air quality of Cochabamba city.

2. Objective

To compare the dispersion of MPs air contamination in the northern and southern zones of the city of Cochabamba.

3. Methodology

The present work is a continuation of the study conducted by Oporto et al. (2021) in which the air concentrations of MPs were determined in the La Maica area (south zone) and the Tupuraya area (north zone) of the city of Cochabamba.

Due the specific characteristics of the zones, being the La Maica area an agricultural zone and the northern area a residential zone, the dispersion and emissions of pollutants can be different between the two zones.

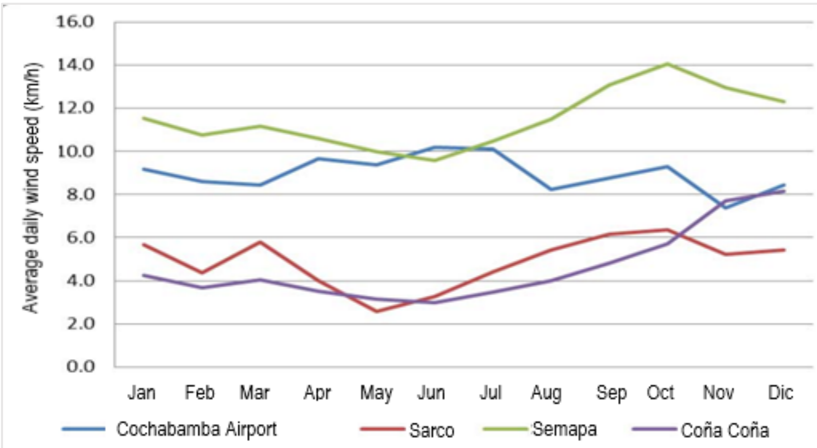
First, the characteristics of the study area are described, followed by the models used for the determinations of MPs emissions index, and finally the dispersion model for MPs and its correlation with particulate matter.

3.1. Study area

The main sources of air pollution in the city of Cochabamba are the automobile fleet (90%), artisanal brick kilns (7%), and dispersed industries (3%) (Departamento de Gestión Atmosférica, 2022).

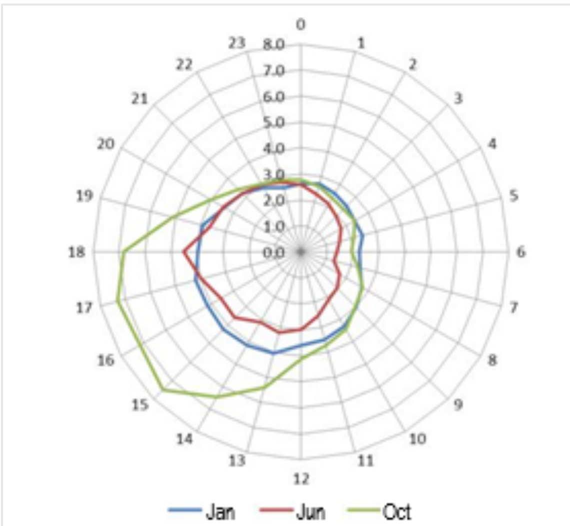
This study takes into account the La Maica zone (southern agricultural zone of Cochabamba) and the Tupuraya zone (northern urban zone) for which wind speed and direction information are available from meteorological stations near these zones in Cochabamba, there are four meteorological stations in the city. The predominant wind direction in both zones is from the southwest with an average speed of 3 m/s (Figure 1 and Figure 2) (Montenegro & Lujan, 2017). The stations that are near the monitoring zones are Semapa and Cochabamba Airport.

Figure 1: Wind speed, from meteorological stations in Cochabamba



Source: (Montenegro & Lujan, 2017)

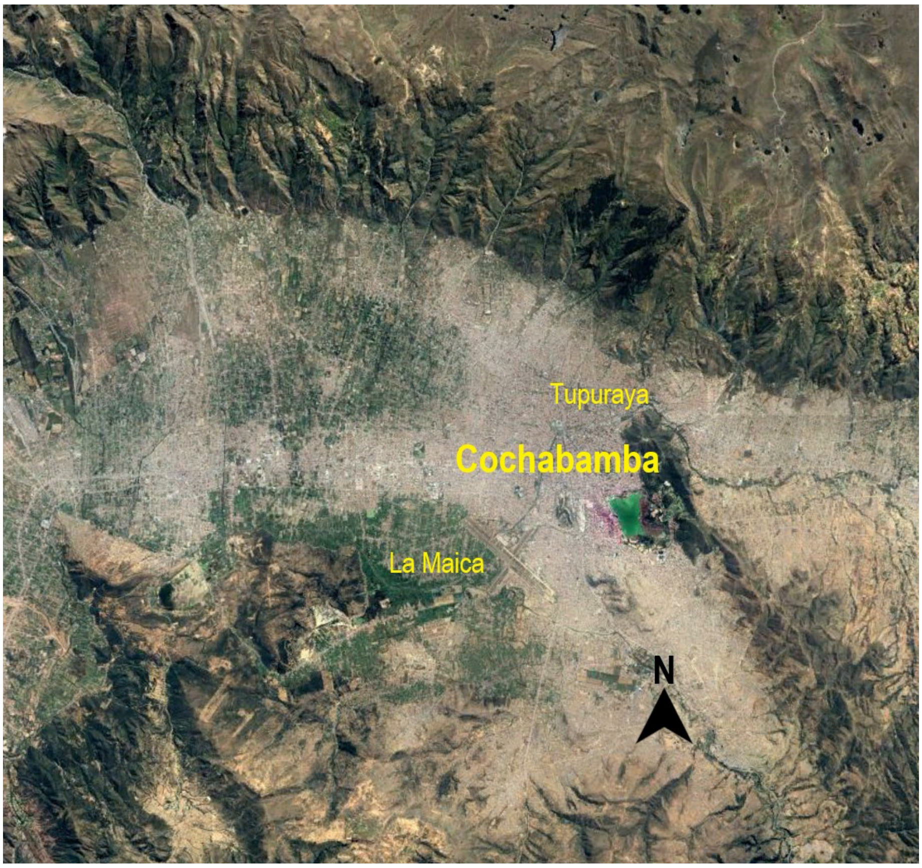
Figure 2: Wind direction at Semapa station



Source: (Montenegro & Lujan, 2017)

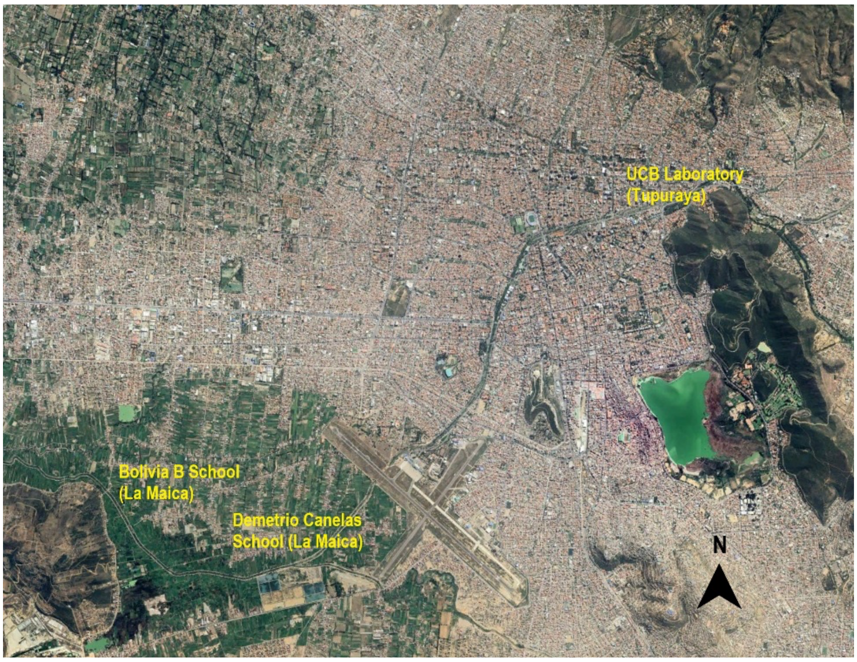
The La Maica area is mainly agricultural with an extension of 1.4 km^2, with medium vehicular traffic and paved main streets and secondary dirt roads. The Tupuraya zone is an urban zone with an extension of 2 km^2 with high vehicular traffic and paved streets (Oporto et al., 2021).

Figure 3: Study area



Source: (Google, 2022)

Figure 4: MPs and particulate matter monitoring points



Source: (Google, 2022)

3.2. Steady state box model

This model is used to calculate the concentration of pollutants in the air. For this purpose, the monitoring points, wind speed and emission sources within the study area and the background concentration entering the area are considered, using equation 1 (de Nevers, 1998).

$$c=b+\frac{q\cdot L}{u\cdot H} \quad (1)$$

Where c is the concentration of the pollutant in the study area, b is the background concentration, q is the rate of emissions per area unit, L is the length of the study area, u is the wind speed and H is the mixing height.

The model will be used to determine the emissions rate to be used in the dispersion model.

3.3. Screen View dispersion model

Screen View is a dispersion model that can be used in different types of conditions, such as complex terrain with or without buildings, as in the case of the monitoring zones, the La Maica zone is a simpler terrain without buildings and the Tupuraya zone is a more complex zone with buildings. It considers variables such as wind speed, atmospheric stability, emissions, terrain type and distances (Lakes Environmental Software, 2018).

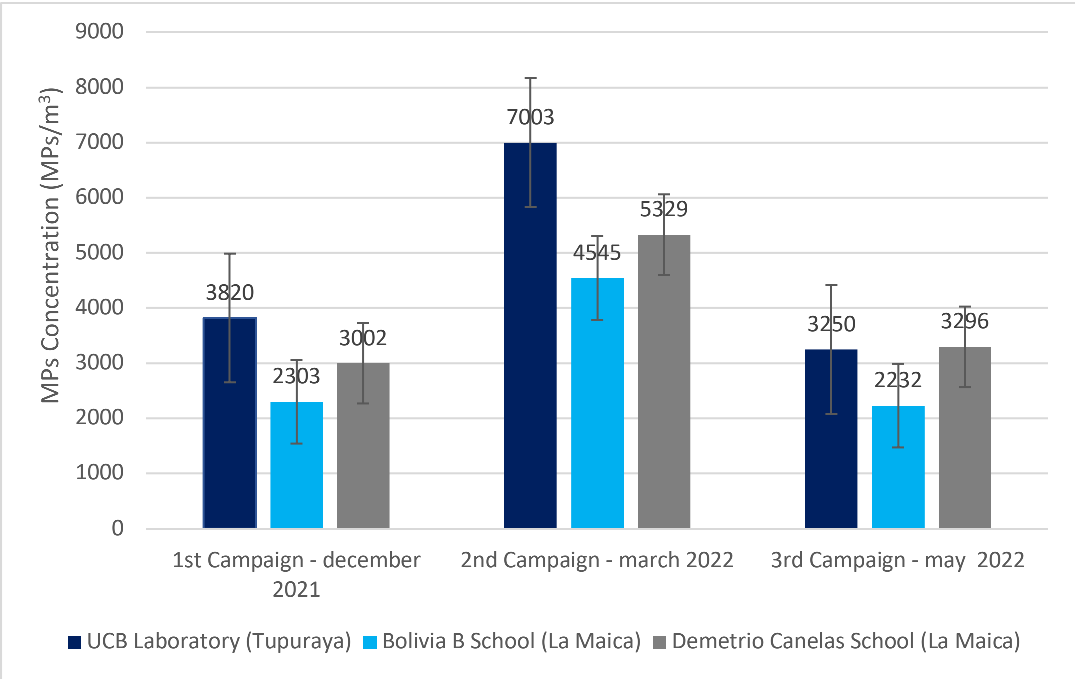
3.4. Correlation rate

The correlation coefficient makes it possible to observe whether there is a relationship between the observed variables, explaining whether the variation or presence of one variable defines the variation or presence of another variable (Guo et al., 2017).

4. Results and discussion

The results obtained in previous work (Figure 5) (Oporto et al., 2021) shows much higher concentrations of MPs than those found in other studies, for example, in Indonesia MPs were found to range between 132.7 and 174.97 MPs/m^3 (Amobonye et al., 2021). Also, the concentrations of PM_{10} and MPs found in the southern and northern zones of Cochabamba are different, with higher levels of PM_{10} but lower concentrations of MPs in the southern zone compared to the northern zone. This data was introduced into equation (1) as the variable c, which allowed determining the emission index in the monitoring areas. For the southern zone the following emission factor per area was determined: 7,888 MPs/(s·m^2) and for the northern zone an emission factor of 10,722 MPs/(s·m^2) were determined.

Figure 5: Concentration of MPs in the north and south of Cochabamba



Source: (Oporto et al., 2021)

Emission rates were entered into the Screen View model which showed the dispersion of this pollutant within the study area. The results are shown in Figures 6 and Figure 7.

Figure 6: MPs dispersion in North zone

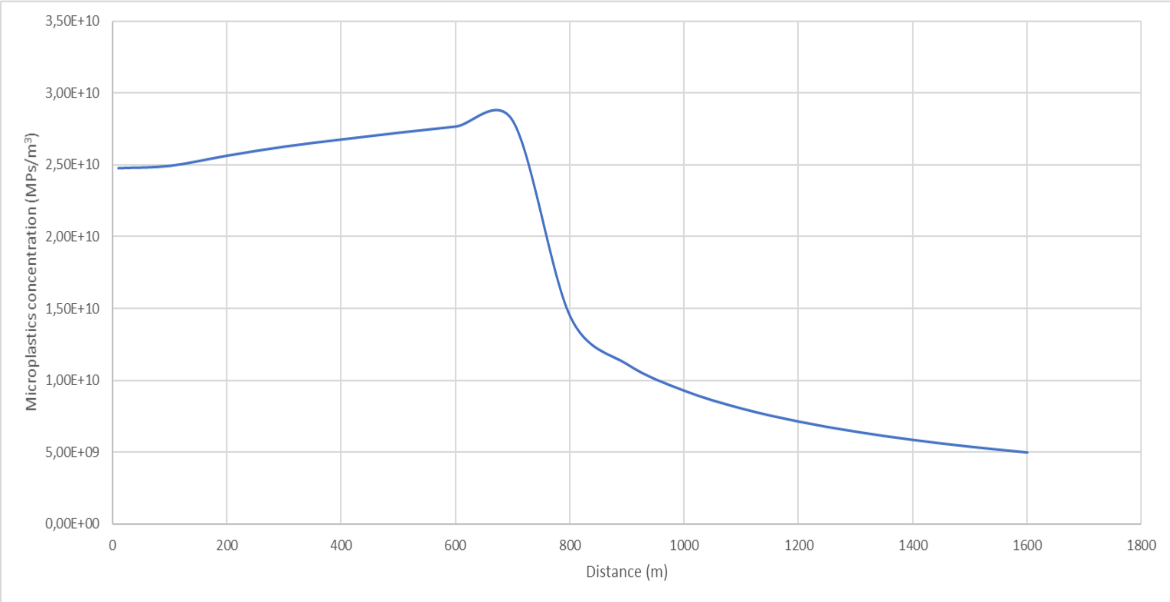
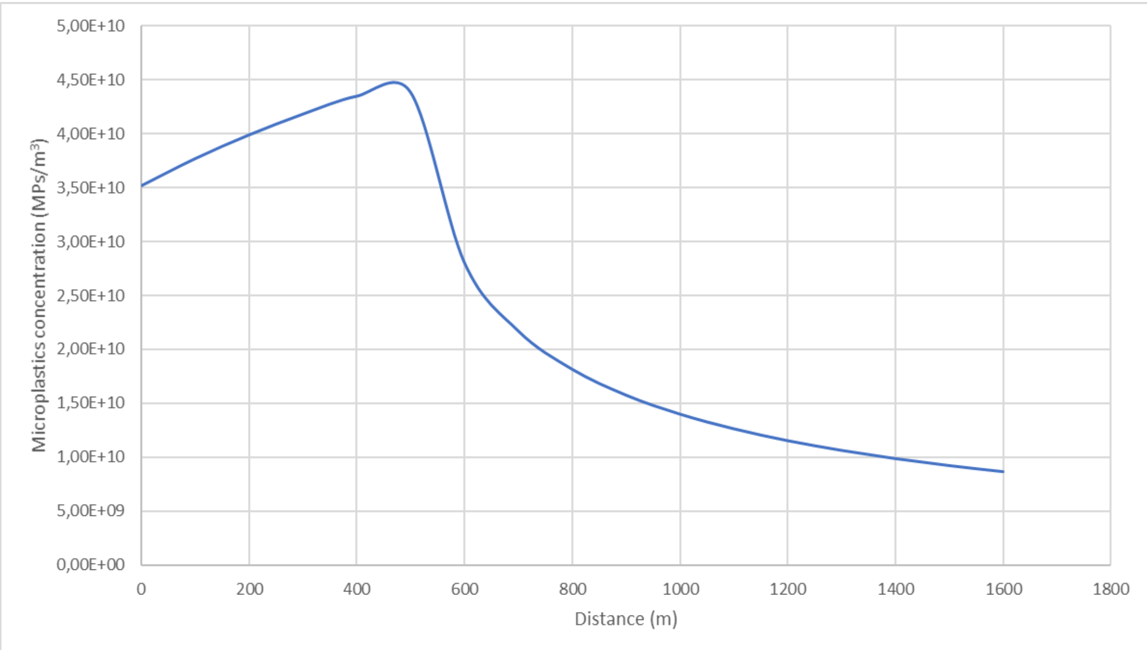


Figure 7: MPs dispersion in South zone



The southern zone has lower levels of contamination by MPs and a lower emission index than the northern zone. However, it is observed that in the worst scenario, there is a higher concentration of MPs than in the northern zone. In addition, in La Maica a maximum level is reached at 500 m, unlike the northern zone, which has the highest concentration at 700 m. It should be noted that the maximum concentration reached in the northern zone represents approximately half of the concentration in the southern zone.

This is because the southern area is a rural area, without many obstacles that facilitate the dispersion of MPs, as can be seen in Figure4, and these are not deposited by impact or precipitation as it may be the case in the northern area (Ghenai & Lin, 2006). For this reason, the graphs show a more pronounced increase in the southern zone than in the northern zone in the first 700 meters.

Although the immission values obtained by monitoring in the northern area are higher than those in the southern area. The results highlight that the population closest to the monitoring points in La Maica may be exposed to higher levels than in the northern zone by the dispersion of MPs under the conditions of this area. This can be of concern for individuals exposed to high concentrations of MPs, as the can be inhaled and potentially have a greater impact on people's health (Vianello et al., 2019).

On the other hand, a correlation analysis was also carried out with the concentration averages between PM_{10} and MPs of the 3 monitoring campaigns carried out (Figure 7).

Figure 8: Correlation between mean concentrations of MPs y PM10

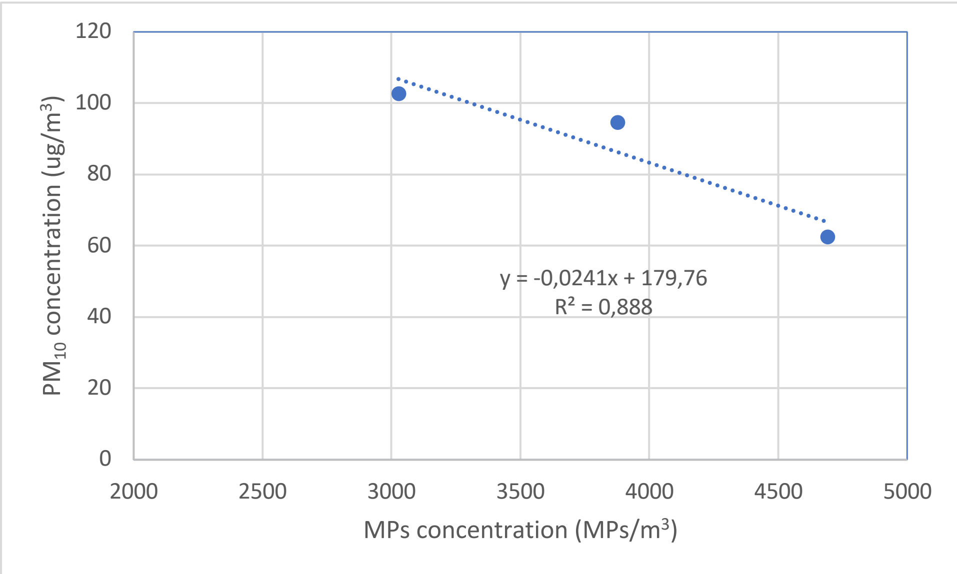


Figure 8 shows a negative correlation in Cochabamba between the concentration of PM_{10} and MPs. Thus, the higher the concentration of particulate material, the lower the concentration of microplastics is. This can be due the to the increased tire abrasion caused by their rolling on paved streets, as the wear of car tires is a source of microplastics. Additionally, tire wear is a significant source of PM_{10} pollution (0.8-8.5% mass fraction of PM_{10} in the air) (Amato-Lourenço et al., 2020). Moreover Shruti et al. (2022) results show high levels of microplastics pollution near urban and industrial areas, as the results presented in this study.

However, it must be considered that most of the streets near the monitoring points in the southern zone were in poor condition or are dirt roads that can increase the concentration of particulate matter (Williams et al., 2008) being this an important factor for the high PM_{10} values found in La Maica. So, further studies are required to validate the negative correlation between PM_{10} and MPs, given that if using daily data of the different zones there is a greater dispersion of the data but nevertheless, the negative correlation is maintained.

These differences on the concentrations can be attributed to different factors. The northern zone of Cochabamba is an urban area with higher activity in transportation and commerce, as well as a higher population density. These factors can contribute to a higher concentration of MPs in the air, as there is greater exposure to plastic materials that may undergo degradation due to climatic factors and abrasion of this materials thus releasing MPs into the air.

Also, one of the main sources of air pollution in Cochabamba is transportation, which also appears to be associated with the higher concentration of MPs found in the northern zone of Cochabamba. This is because there is a higher circulation of vehicles on paved roads, which can lead to increased tire abrasion and the subsequent release of MPs into the air due to tire degradation on paved roads.

In the southern zone, the levels of MPs are not as high as in the northern zone. This could be due to the primarily agricultural activities carried out in this area, as well as lower commercial and transportation activity.

Although the southern zone has lower concentrations of MPs compared to the northern zone, the concentrations of PM_{10} in the southern zone are higher. This may be because the activities conducted in the southern zone, combined with automobile transportation and winds, can cause the suspension of particulate matter, thus increasing the concentration of PM_{10} in this area. On the other hand, the northern zone has lower concentrations of PM_{10} compared to the southern zone, despite having higher transportation activity. This is because the streets in this zone are paved, resulting in less suspension of particulate matter caused by vehicles and winds.

5. Conclusions

Currently in Bolivia, there are no established limits for concentrations of MPs suspended in the air, but there are stablished limits for PM_{10}. The daily values established in Bolivian regulations (150 ug/m^3) for PM_{10} are not exceeded in the monitoring campaigns of this study. However, they do exceed the limits established by other air quality standards, such as those set by the World Health Organization.

The dispersion models showed different results for both zones, as in the monitoring results. The models made it possible to observe that despite the fact that there are lower concentrations of MPs in the southern zone of Cochabamba. The factors that affect their dispersion can expose the closest population to higher concentrations than in the northern zone (which presents more obstacles that may hinder the dispersion of contaminants or the retention of the MPs). This can potentially cause even greater health impacts for individuals exposed to high concentration of MPs. This is due to the terrain characteristics of both zones. The southern zone has a simpler terrain with fewer large buildings and relatively flat land that facilitate the dispersion of MPs, while the northern zone has a more complex terrain with buildings that can contribute to the retention of MPs.

A negative correlation is found between PM_{10} and MPs concentrations in this study. However, the geographical characteristics and activities conducted in these zones are different. In addition, a greater number of observations are needed to confirm the relationship between the presence of MPs and particulate matter in the air. The results shown are not entirely conclusive with this correlation, but a trend towards a relationship can be observed, inversely proportional between these pollutants.

Finally, automobiles appear to be a significant source of microplastic emissions in Cochabamba, in addition to being one of the primary sources of air pollution in the city. Furthermore, the specific characteristics of each area influence the presence and dispersion of microplastics in Cochabamba.

6. References

Abbasi, S., Keshavarzi, B., Moore, F., Turner, A., Kelly, F. J., Dominguez, A. O., & Jaafarzadeh, N. (2019). Distribution and potential health impacts of microplastics and microrubbers in air and street dusts from Asaluyeh County, Iran. *Environmental Pollution*, *244*, 153–164. https://doi.org/10.1016/j.envpol.2018.10.039

Amato-Lourenço, L. F., dos Santos Galvão, L., de Weger, L. A., Hiemstra, P. S., Vijver, M. G., & Mauad, T. (2020). An emerging class of air pollutants: Potential effects of microplastics to respiratory human health? *Science of The Total Environment*, *749*, 141676. https://doi.org/10.1016/j.scitotenv.2020.141676

Amobonye, A., Bhagwat, P., Raveendran, S., Singh, S., & Pillai, S. (2021). Environmental Impacts of Microplastics and Nanoplastics: A Current Overview. *Frontiers in Microbiology*, *12*. https://doi.org/10.3389/fmicb.2021.768297

Castañeta, G., Gutierrez, A., Nacarette, F., & Manzano, C. (2020). Microplásticos: un contaminante que crece en todas las esferas ambientales, sus características y posibles riesgos para la salud pública por exposición. *Revista Boliviana de Química*, *37*(3).

Crawford, B., & Quinn, B. (2017). *Microplastic Pollutants*. Elsevier. https://doi.org/10.1016/C2015-0-04315-5

de Nevers, N. (1998). *Ingeniería de control de la contaminación del aire*. McGraw-Hill.

Departamento de Gestión Atmosférica. (2022). *Contaminación atmosférica. Gestión 2021.*

Ghenai, C., & Lin, C. X. (2006). Dispersion modeling of PM10 released during decontamination activities. *Journal of Hazardous Materials*, *132*(1), 58–67. https://doi.org/10.1016/j.jhazmat.2005.11.085

Google. (2022). *Google Earth Pro* (2.3.6). Google.

Lakes Environmental Software. (2018). *Screen View* (USA EPA SCREEN3). Lakes Software.

Montenegro, E., & Lujan, M. (2017). Análisis de la variación estacional de la contaminación atmosférica y su relación con variables climáticas en el valle central de Cochabamba, Bolivia. *Acta Nova*, *8*(3).

Munyaneza, J., Jia, Q., Qaraah, F. A., Hossain, M. F., Wu, C., Zhen, H., & Xiu, G. (2022). A review of atmospheric microplastics pollution: In-depth sighting of sources, analytical methods, physiognomies, transport and risks. *Science of The Total Environment*, *822*, 153339. https://doi.org/10.1016/j.scitotenv.2022.153339

Oporto, V., Escobar, I., Lujan, M., & d'Abzac, P. (2021). Evaluación de la contaminación del aire por microplásticos suspendidos en la zona de La Maica (Cochabamba, Bolivia). *Acta Nova*, *10*(2).

Shao, L., Li, Y., Jones, T., Santosh, M., Liu, P., Zhang, M., Xu, L., Li, W., Lu, J., Yang, C.-X., Zhang, D., Feng, X., & BéruBé, K. (2022). Airborne microplastics: A review of current perspectives and environmental implications. *Journal of Cleaner Production*, *347*, 131048. https://doi.org/10.1016/j.jclepro.2022.131048

Vianello, A., Jensen, R. L., Liu, L., & Vollertsen, J. (2019). Simulating human exposure to indoor airborne microplastics using a Breathing Thermal Manikin. *Scientific Reports*, *9*(1), 8670. https://doi.org/10.1038/s41598-019-45054-w

Williams, D. S., Shukla, M. K., & Ross, J. (2008). Particulate matter emission by a vehicle running on unpaved road. *Atmospheric Environment*, *42*(16), 3899–3905. https://doi.org/10.1016/j.atmosenv.2008.02.003

Zhang, Y., Kang, S., Allen, S., Allen, D., Gao, T., & Sillanpää, M. (2020). Atmospheric microplastics: A review on current status and perspectives. *Earth-Science Reviews*, *203*, 103118. https://doi.org/10.1016/j.earscirev.2020.103118

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