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Association of environmental and meteorological factors on the spread of COVID-19 in Victoria, Mexico, and air quality during the lockdown

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ABSTRACT
This study aims to analyze the correlation between environmental factors and confirmed cases of COVID-19 pandemic in Victoria, Mexico. The analysis is performed at the micro-level, filtering only confirmed cases of COVID-19 that are located near air quality monitoring stations, within an approximate coverage of 2.5 km, in order to identify a possible specific association between PM$_{2.5}$, PM$_{10}$, carbon monoxide (CO), relative humidity, temperature, absolute humidity, and total confirmed cases of COVID-19. The results evidenced that the cases of COVID-19 were very strongly associated with CO concentration. Our results also suggested that particulate matter pollution (PM$_{2.5}$ and PM$_{10}$) exposure have a significant correlation for confirmed cases of COVID-19. Furthermore, we studied the changes in air quality during the COVID-19 outbreak by comparing the average concentration of the four weeks before lockdown (February 16 to March 14, 2020) and the following twelve weeks during the partial lockdown (March 15 to June 06, 2020), revealing a very significant decrease of pollutants.

1. Introduction

Nowadays, a new virus has been identified in China as the causative agent of a high number of cases of pneumonia, called severe acute respiratory syndrome (SARS-CoV-2) (WHO, 2020a). This virus causes a disease called coronavirus disease 2019 (COVID-19), which spreads rapidly through human-to-human transmission. For this reason, the World Health Organization (WHO) recommends implementing policies of intense quarantine and social distancing measures when suspicious and positive cases are identified to decrease the degree of spread of the coronavirus. In preliminary studies, person-to-person contact has been demonstrated to increase the risk of COVID-19 infection (Chan et al., 2020; Li et al., 2020), thereby verifying the potential for person-to-person transmissibility of the virus (Huang et al., 2020), raising concern about a global spread (Chen et al., 2020). Person-to-person transmissibility of SARS-CoV-2 can occur between two people with prolonged and unprotected exposure (Chinai et al., 2020).

According to data published by the WHO on the number of confirmed cases of COVID-19 (WHO, 2020b), Mexico is in a complicated situation regarding the management and containment of the pandemic. In this sense, the number of deaths of the COVID-19 epidemic in Mexico is very high, over 50,000 deaths as of August 06, 2020; only after the United States and Brazil (WHO, 2020b; JHU, 2020). The meteorological conditions of Mexico are diverse; the partial lockdown began in the springtime, currently, in the summer period, the temperatures range between 10 °C and 28 °C in the central region of the country, maintaining a high level of infection. In the northern region of the country, the weather is warmer and with temperatures between 25 °C and 45 °C. Similarly, very accelerated growth in the number of confirmed cases of COVID-19 is observed. Notwithstanding the restriction measures implemented by the Federal Government to protect people’s health and prevent the spread of the outbreak, the flattening of the epidemic curve has not been achieved during the 140 days of partial lockdown. In our case, there is no evidence to support that the number of positive cases of contagion by COVID-19 decreases with warmer weather, as has been reported in (Ma et al., 2020; Tosepu et al., 2020), and it is consistent with that reported in (Xie and Zhu, 2020).

The restriction measures implemented were the reduction of public transport, shut down schools, colleges, and universities, as well as curtailed local business travel and closing of businesses and industries. Moreover, the confinement of the population and established numerous quarantines were applied to reduce the disease’s spread. These lockdown measures led to a considerable decrease in levels of urban air pollution. Air pollution is associated with infectious disease
transmission, such as increased influenza incidence (Landguth et al., 2020). Meteorological factors can also affect the transmission of infectious diseases, including influenza and severe acute respiratory syndrome (Moriyama et al., 2020). Recent studies raise the possibility that certain meteorological conditions favored the transmission of COVID-19 (Zhu et al., 2020a; Sarkodie and Owusu, 2020; Bolano et al., 2020; Menebo, 2020), for example, higher mean temperature and intermediate relative humidity (Auler et al., 2020), as well as the association between these meteorological factors with poor air quality. Emerging evidence suggests that exposure to higher concentrations of pollutants such as PM\(_{2.5}\), PM\(_{10}\), CO, NO\(_2\), and O\(_3\) can increase the risk of health complications for individuals infected with COVID-19 (Stieb et al., 2020; Zhu et al., 2020b; Ogen, 2020; Fattorini and Regoli, 2020). Exposure to poor air quality can lead to more cases of severe COVID-19 infections. In this way, van Doremalen et al. (2020) demonstrated in laboratory conditions the long viability of SARS-CoV-2 in environmental aerosols, which could be an important source of COVID-19 transmission (Luo et al., 2020). Consequently, air pollution, meteorological factors, and its relationship with the new cases of COVID-19 have been an on-going research focus (Tobías et al., 2020; Kerimray et al., 2020; Frontera et al., 2020; Nakada and Urban, 2020; Xie and Zhu, 2020).

In this paper, we present an air quality analysis (PM\(_{2.5}\), PM\(_{10}\), and CO) with data from 4 weeks before the lockdown versus the 12 weeks after the lockdown. These collected data were used to calculate each pollutant’s mean levels both before and during the partial lockdown, allowing to observe a considerable decrease in the concentration levels of air pollutants. On the other hand, we performed a correlation analysis based on Pearson to examine the relationship between the variables of total confirmed cases of COVID-19 and the concentration levels of PM\(_{2.5}\), PM\(_{10}\), and CO, as well as relative humidity, temperature, and absolute humidity, in a determined period. This analysis is carried out at the micro-level, that is, confirmed cases of COVID-19 near the location of the air quality monitoring station are studied, including only confirmed COVID-19 cases that are located within an approximate 2.5 km coverage radius.

2. Methods

We collected the data on the air pollutants that were provided by the Air Quality IoT (AQ-IoT) stations project of the Autonomous University of Tamaulipas. The AQ-IoT stations can sense data of particulate matter with a diameter of less than 2.5 μm (PM\(_{2.5}\)), particulate matter with a diameter of less than 10 μm (PM\(_{10}\)), carbon monoxide (CO), carbon dioxide (CO\(_2\)), relative humidity, temperature, and heat index. The data is transmitted to a private cloud over the Internet in real-time. The project consists of six (6) AQ-IoT stations distributed in Victoria City, in the state of Tamaulipas, in northeast Mexico. The stations were installed at the neighborhood level to monitor industrial, commercial, residential, downtown, and suburban areas. In addition, the city’s meteorological and topographic conditions were considered because the city is located next to a mountain area. This allowed defining the monitoring stations’ coverage capacity of approximately 2.5 km, which was verified through a mobile monitoring station to have certainty and confidence in the data collected by the monitoring stations. Fig. 1 shows the location of the monitoring stations and the coverage area of each station.

The air quality data used in our experiment is from February 16 to June 06, 2020. From each station, daily data (24 h/7 d) was collected from February 16 to March 14, 2020 (four-weeks before partial lockdown) were used to calculate the mean levels of each pollutant for each week. Similarly, data from March 15 to June 06, 2020 (twelve-weeks during partial lockdown) were used to calculate the mean levels of each pollutant during the partial lockdown. In addition, variations in
The number of confirmed cases is from March 23 to June 06 and was collected from the COVID-19 website of the Secretariat of Public Health of the State Government of Tamaulipas. In this sense, we selected the confirmed cases of COVID-19 near the stations’ location, with a coverage of 2.5 km around each station, to carry out a micro-level analysis of the probable relationship between the positive cases of COVID-19 and the concentration of pollutants. We generate a data set with the number of confirmed cases accumulated per week and monitoring station, allowing alignment with the average data per week of air pollutants and the meteorological factors of each monitoring station.

Furthermore, Pearson correlation analysis was used to examine the relationship between COVID-19 cases and PM$_{2.5}$, PM$_{10}$, and CO levels, as well as with meteorological factors (temperature, relative humidity, and absolute humidity). Absolute humidity represents the vapor content of air irrespective of temperature (T), which can be of greater biological significance for many organisms (Shaman and Kohn, 2009). It is essential to mention that the partial lockdown was extended to October 31, 2020, in the State of Tamaulipas, Mexico.

The normalized processing was needed before analysis because the dataset had a non-normal distribution. We fixed the distributions of variables understudy with a log-transformation. This was verified previously by the Shapiro-Wilk normality test, and afterward, it was verified with the same test to confirm the normality of the distributions.

3. Results and discussion

In the meteorological conditions, relevant differences were evidenced between February 16th to March 14th (winter) and March 15th to June 06th (spring). In the first period had a mean temperature of 23°C, and on windy days the wind reached an average speed of 3.47 km/h, without rainy days. In contrast, in the partial lockdown period, with an average rainfall of 3.7 mm, a mean temperature of 30.5°C, and the windy days achieved an average wind speed of 5.22 km/h. Fig. 2 shows the weekly averages of the meteorological factors of temperature (°C), relative humidity (%), and wind speed (km/h), as well as the absolute humidity (g/m$^3$) calculated from the temperature and relative humidity variables. We calculated the absolute humidity using the Clausius Clapeyron equation (Iribarne and Cho, 1980; Bolton, 1980) as follows:

$$ AH = \frac{6.112 \times 10^{-3} e^\frac{21674}{T + 273.15} \times RH^2}{2.1674} $$

where AH is the absolute humidity, RH is the relative humidity, T is the temperature in degrees °C, and e is the base of natural logarithms equal to 2.71828.

During the study time, the daily minimum temperature was 20°C and the daily maximum temperature was 33°C. Data represented in the graph below (Fig. 2), a change in the daily temperature between the winter and the spring period is evidenced. In the fifth week of the study (March 22), an increase in the daily temperature is identified and remained constant in the weeks in the spring period. In addition, the decrease in relative humidity is observed from the eighth week (April 12), coinciding with the increase in temperature; therefore, the air becomes drier, and the relative humidity decreases, which is a characteristic meteorological condition of the geographical region in which the study was developed.

The accumulated confirmed cases during the study period were 266 positive cases, with a daily maximum of 17 confirmed cases of covid-19. Fig. 3 shows the daily increase in infected people confirmed by the Secretariat of Public Health.

After twelve weeks of lockdown, urban air pollution decreased similarly among pollutants (Table 1). PM$_{2.5}$ averaged concentrations decreased by −44.52% in the urban stations. Fig. 4 shows the decline observed in the PM$_{2.5}$ concentration during the COVID-19 contingency, in the six monitoring stations studied. The concentration of PM$_{2.5}$ with the lowest decrease during the partial lockdown was recorded in the AQ-IoT-1 monitoring station (−38.26%), coinciding with the record of the lowest decrease in the average concentration of PM$_{10}$ (−36.87%), which was obtained in the same monitoring station. For PM$_{10}$, the reduction was larger, an average concentration of −44.56% in the urban stations. In the AQ-IoT-2 and AQ-IoT-3 stations, low PM$_{10}$ concentration recorded with a decrease of −50.20%, and −50.79%, respectively. These stations captured the greatest reduction in PM$_{10}$ concentration. In the partial lockdown period, the official reference values for PM$_{2.5}$ (30 μg/m$^3$) and PM$_{10}$ (50 μg/m$^3$), published by the Ministry of Health of the Government of Mexico in the official environmental health norm, were not exceeded in any of the urban areas monitored by the six stations (NOM, 2014), as shown in Figs. 4 and 5.

For CO concentration during the partial lockdown, we observed high levels of variation when compared to the four-week period before the partial lockdown (Table 1). The average CO levels decreased during the partial lockdown by −46.20%, and the area monitored by the AQ-IoT-6 station recorded a decrease of −50.31% in the same period (Fig. 6). However, the CO values are high compared to the values reported in the recent literature (Connerton et al., 2020; Nakada and Urban, 2020); we observed that the primary source of CO emission is motor vehicles (86%) because a non-emission vehicle pollutant verification standard has not been implemented by the State Government. Fig. 6 shows the decrease in CO in the air during the twelve weeks after lockdown, a notable decrease in the concentration of several pollutants is identified between the fourth and sixth week of the study (from March 14 to 28).

The improvement in air quality in recent months has been significant in our area. The decrease in air pollutants has been observed in most cities of the world due to the confinement and reduction of economic activities caused by the pandemic, which positively impacts the environment (Zambrano-Monserrate et al., 2020). Bashir et al. (2020) concluded that reducing economic activities, less traffic, and the mandatory measures of staying at home on the local level have contributed to reducing emissions of PM$_{2.5}$, PM$_{10}$, NO$_2$, CO, and SO$_2$. Mahato et al. (2020) reports a 50% reduction in PM$_{2.5}$ and PM$_{10}$ concentration levels and a 30% reduction in CO concentration. Also, Stratos and Nuthammachot (2020) reported a decrease of 21.8% in the concentration of PM$_{2.5}$ and a 22.9% decrease in PM$_{10}$. Chauhan and Singh (2020) found a decline in PM$_{2.5}$ in New York, USA, with pronounced linear reduction of 20% in March 2020, and in Zaragoza, Spain, note a significant decline of 50% in PM$_{2.5}$ during March 2020.

The results obtained confirm that air pollutants exhibit a clear seasonal pattern. Average daily PM$_{2.5}$ and PM$_{10}$ concentration levels tend to be higher during the cold season. This is confirmed by the data analyzed from the last three weeks of the study. The relative humidity increased considerably in this period, which had an impact on the increase of the concentration values of PM$_{2.5}$ and PM$_{10}$. This is observed even when the
inhabitants are in confinement and most of the city’s activities are suspended. Also, it was identified that when presenting a constant decrease in temperature (for several continuous days), the concentration of PM$_{2.5}$, PM$_{10}$, and CO suffer small increases in their concentration levels. Likewise, similar conditions have been reported in related literature. Kerimray et al. (2020) report that the average PM$_{2.5}$ concentration tends to be lower during periods with warmer temperatures combined with wind direction changes and the presence of rainfall.

On the other hand, Pearson correlation analysis was used to decipher the relationships between confirmed COVID-19 cases, concentrations of three ambient air pollutants, and three meteorological variables (Table 2). In the first scenario, the estimates of the associations of PM$_{2.5}$, PM$_{10}$, CO, relative humidity, temperature, absolute humidity with COVID-19 confirmed cases in Ciudad Victoria, Mexico are described. In this scenario, only data from the last four weeks (May 10 to June 06) during a partial lockdown period are used, collected through the six air quality monitoring stations. This analysis aims to identify the behavior and association between the study variables considering the growth in

Table 1

| STATION    | Mean of the four-week before partial lockdown | Mean of the twelve-week before partial lockdown | Relative change |
|------------|-----------------------------------------------|------------------------------------------------|-----------------|
|            | PM$_{2.5}$ (µg/m$^3$) | PM$_{10}$ (µg/m$^3$) | CO (ppm) | PM$_{2.5}$ (µg/m$^3$) | PM$_{10}$ (µg/m$^3$) | CO (ppm) | PM$_{2.5}$ % | PM$_{10}$ % | CO % |
| Average    | 25.63 ± 5.84       | 28.21 ± 6.01       | 1.45 ± 0.15       | 14.22 ± 4.26     | 15.64 ± 4.59       | 0.78 ± 0.12       | −44.52       | −44.56       | −46.20 |
| AQ-IoT-1   | 30.50 ± 1.29       | 33.00 ± 1.41       | 1.68 ± 0.14       | 18.83 ± 3.13     | 20.83 ± 3.43       | 0.85 ± 0.18       | −38.26       | −36.87       | −49.40 |
| AQ-IoT-2   | 19.25 ± 1.26       | 22.25 ± 0.96       | 1.35 ± 0.08       | 9.92 ± 1.56      | 11.08 ± 1.98       | 0.75 ± 0.16       | −48.46       | −50.20       | −44.44 |
| AQ-IoT-3   | 23.00 ± 2.16       | 25.75 ± 2.22       | 1.37 ± 0.05       | 11.58 ± 2.19     | 12.67 ± 2.50       | 0.70 ± 0.08       | −49.65       | −50.79       | −48.90 |
| AQ-IoT-4   | 19.00 ± 0.82       | 20.75 ± 1.50       | 1.34 ± 0.09       | 11.00 ± 1.28     | 12.17 ± 1.75       | 0.76 ± 0.07       | −42.10       | −41.34       | −43.28 |
| AQ-IoT-5   | 33.00 ± 2.16       | 35.75 ± 1.71       | 1.39 ± 0.05       | 18.42 ± 3.45     | 19.50 ± 3.37       | 0.81 ± 0.10       | −44.18       | −45.45       | −41.72 |
| AQ-IoT-6   | 29.00 ± 2.58       | 31.75 ± 3.40       | 1.57 ± 0.06       | 15.58 ± 1.68     | 17.58 ± 2.02       | 0.78 ± 0.07       | −46.27       | −44.62       | −50.31 |

Fig. 3. Confirmed positive COVID-19 cases up to June 06, 2020, in the study.

Fig. 4. Average PM$_{2.5}$ concentration before and during partial lockdown.

Fig. 5. Average PM$_{10}$ concentration before and during partial lockdown.
positive cases for COVID-19 in these four weeks.

All PM factions showed very strong positive correlation with each other, \( r \) of 0.99 (\( p\text{-value} < 0.001 \)). Statistically moderate positive correlations between both CO and PM\(_{2.5}\) and CO and PM\(_{10}\) were found, with statistically significant at 5\% level. We found that PM\(_{2.5}\) and PM\(_{10}\) have a significant correlation for confirmed cases of COVID-19, with a coefficient value of 0.77 \( p\text{-value} < 0.05 \) and 0.79 \( p\text{-value} < 0.05 \), respectively. The magnitude of the correlation coefficient of CO and confirmed COVID-19 cases \( r = 0.80, p\text{-value} < 0.05 \) is the value higher in the correlation matrix test, confirming a very strong correlation between these variables.

Furthermore, meteorological variables included in our study are relative humidity (RH), temperature (T) and absolute humidity (AH) (Table 2). The statistical analysis reveals a negative coefficient of correlation between the number of infected individuals and temperature \( r = -0.77, p\text{-value} < 0.05 \). We observe that temperature exhibit a consistently moderate to very strong negative relationship \( -0.92 \geq r \geq -0.45 \) with all the air pollution variables. The association between temperature and CO with a very high statistical significance \( p\text{-value} < 0.01 \), and the relationship with absolute temperature with a correlation coefficient of \( r = 0.78 \). Results also show a negative correlation coefficient of absolute humidity and CO was \( -0.63, p\text{-value} < 0.05 \). This relationship is moderate to strong correlation, as well as the association with relative humidity was just 0.60 with the same p-value. Positive correlations between relative humidity and all other studied parameters with the range of 0.13 \( \geq r \geq 0.61 \) were also observed, except for the temperature variable.

Our findings show that environmental pollutants are significantly correlated with COVID-19 cases in Victoria City, as described in the correlation matrix shown in Fig. 7. This figure shows a correlogram of the correlation between the variables, which allows us to perceive these relationships more clearly.

According to the correlation matrix analysis above (Table 2), an association is apparent between CO, PM\(_{10}\), PM\(_{2.5}\) levels, temperature, and COVID-19 outbreak distribution during the last four weeks of partial lockdown. In this sense, to corroborate the observations found in the correlation between the air pollutants, meteorological factors, and the confirmed cases of COVID-19 studied, a second correlation analysis was performed (Table 3). In this second scenario, the concentration of pollutants for the twelve contingency weeks (from March 15 to June 06) and the number of infections of COVID-19 from March 23 (first confirmed case of COVID-19 in the City) to June 06 is used. Of the confirmed cases, those with a location close to the air quality monitoring stations were selected.

Table 3 shows the association between the variable of confirmed COVID-19 cases and other variables: a correlation higher than 0.75 (\( p\text{-value} < 0.05 \)) is between CO, and infected individuals of COVID-19, a lower coefficient of correlation is between relative humidity and confirmed cases \( r = -0.58, p\text{-value} < 0.05 \). The correlation coefficient of CO and COVID-19 was remarkably higher than those of PM\(_{2.5}\) and COVID-19 \( r = 0.64, p\text{-value} < 0.05 \), although all the variables displayed extremely significant relativity (Table 3). In the same manner, the association between PM\(_{10}\) and COVID-19 presents a strong correlation of \( r = 0.69 \).

Like the first correlation scenario, the results show similar behavior in the correlations, with associations between variables that present a moderate to very strong significance between the three pollutants and relative humidity (Table 3). The correlation was observed between PM\(_{2.5}\) and PM\(_{10}\) with a significant level of \( p < 0.001 \) and \( r = 0.99 \). The pollutant CO presents an almost equal correlation coefficient with PM\(_{2.5}\) and PM\(_{10}\), \( r = 0.84 (p < 0.03) \) and \( r = 0.85 (p < 0.03) \), respectively. In relative humidity, a moderate positive relationship with PM\(_{2.5}\) and PM\(_{10}\) is observed with a coefficient of \( r = 0.60, \) with each particulate matter.

Recently, several studies demonstrate significant relationships between COVID-19 spread with temperature, humidity, rainfall, wind speed, PM\(_{2.5}\), PM\(_{10}\) and CO. In Bolaño-Ortiz et al. (2020) analyzed climate and air pollution indicators and their relationship with the spread of SARS-CoV-2 in the Latin American region. The data analyzed from Mexico City found a significant negative correlation between relative humidity and the total number of positive COVID-19 cases, with \( r = -0.464 \) and a negative correlation \( r = -0.444, p < 0.01 \) between total cases of COVID-19 and PM\(_{10}\). Tosepu et al. (2020) provides evidence of a significant correlation between average temperature and confirmed cases of COVID-19, with a coefficient of \( r = 0.92 \) and a significance level of \( p < 0.001 \). Similarly, Kumar (2020) found a positive association between daily COVID-19 cases and temperature and a mixed association with relative and absolute humidity over India. Chen et al. (2020) reports relatively small changes in PM\(_{2.5}\) concentration due to the lockdown in 28 cities of USA, as well as a correlation between PM\(_{2.5}\) and PM\(_{10}\) with \( r = 0.78 \, p< 0.05 \). Recently, Dogan et al. (2020) have carried out an analysis of meteorological parameters on COVID-19 and found a significant positive correlation between the numbers of confirmed COVID-19 cases and PM\(_{2.5}\) (\( r = 0.1797, p< 0.05 \)), and the temperature and confirmed COVID-19 cases with a weak negative correlation.

The results presented in the previous studies are consistent in most cases with the results obtained in our work. Our findings suggest a

| Table 2   | Pearson correlation coefficient matrix for main variables using a dataset of the last four weeks of the partial lockdown. |
|-----------|---------------------------------------------------------------|
|           | PM\(_{2.5}\)  | PM\(_{10}\)  | CO       | RH       | T         | AH       | COVID-19  |
| PM\(_{2.5}\) | 1.00     | 0.99\(a\)  | 0.59\(a\) | 0.61\(a\) | -0.45     | 0.04     | 0.77\(a\) |
| PM\(_{10}\)  | 0.99\(a\) | 1.00       | 0.56\(a\) | 0.59\(a\) | -0.45     | 0.03     | 0.79\(a\) |
| CO         | 0.59\(a\) | 0.56\(a\)  | 1.00     | 0.13     | -0.92\(a\) | -0.63\(a\) | 0.80\(a\) |
| RH         | 0.61\(a\) | 0.59\(a\)  | 0.13     | 1.00     | -0.009    | 0.009    | 0.60\(a\) |
| T          | -0.45     | -0.45      | -0.92\(a\) | 1.00     | 0.009     | 0.78\(a\) | -0.77\(a\) |
| AH         | 0.04      | 0.03       | -0.63\(a\) | 0.60\(a\) | 0.78\(a\) | 1.00     | -0.45     |
| COVID-19   | 0.77\(a\) | 0.79\(a\)  | 0.80\(a\) | 0.23     | -0.77\(a\) | -0.45    | 1.00      |

\(a\) p-value < 0.05.
significant statistical relationship between the air pollutants studied and the total confirmed cases of COVID-19. Therefore, it is important to consider a more in-depth study considering prolonged exposure to atmospheric pollutants considering data from previous years to ratify our findings. On the other hand, the identified associations of average temperature and relative humidity with confirmed COVID-19 cases are not constant in the two scenarios presented.

### 4. Conclusions

The reduction of specific pollutants due to the containment measures implemented by the COVID-19 pandemic was very significant. The most significant variation was observed in the concentration of CO, with an average concentration of 0.78 ± 0.12 (ppm) during the partial lockdown, where the combustion processes as the main emitters, in our case, the road traffic in urban areas, specifically by diesel and gasoline vehicles.

There was a reduction in the PM$_{2.5}$ concentration by −44.52% in the partial lockdown compared to the four weeks before lockdown.

Coincidentally, the monitoring station with low vehicular traffic during the partial lockdown was recorded the most significant reduction in the concentration of PM$_{2.5}$ and PM$_{10}$ by −49.65% and −50.79%, respectively. Concerning the concentration of PM$_{10}$ during the partial lockdown, an average concentration in the city of 15.64 ± 4.59 μg/m$^3$ was captured, which does not exceed the reference value (50 μg/m$^3$). The restriction measures helped in improving the air quality, which is directly reflected by the decline in air pollutants.

On the other hand, the results of the correlation analysis between confirmed cases of COVID-19 and air pollutants, as well as the meteorological variables at a micro level, allow us to consider that there is a possible influence of air quality on the spread of COVID-19. This was observed in the two correlation studies carried out, where the three pollutants (PM$_{2.5}$, PM$_{10}$, and CO) analyzed in which a significant correlation is identified with the confirmed cases of COVID-19. In conclusion, we found that PM$_{2.5}$, PM$_{10}$, CO, and temperature are four variables that could potentially promote the sustained transmission of COVID-19.

Finally, current research has some limitations. The study period is relatively short compared to other epidemiological studies, which could result in a deviation of the results from the exact effect of environmental pollution and meteorological parameters on the transmission of SARS-CoV-2. In a future study, we will record data for more weeks, including the number of new confirmed daily cases and the number of deaths caused by COVID-19.

### Credit author statement

Edgar Tello-Leal: Conceptualization, Methodology, Visualization, Writing - original draft, Writing - review & editing. Bárbara Azucena Macías Hernández: Data curation, Investigation, Writing - original draft.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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