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Time variation of atmospheric pollutants in first weeks of COVID-19 lockdown in the Metropolitan Region of Rio de Janeiro

Variação temporal dos poluentes atmosféricos nas primeiras semanas de encerramento da COVID-19 na Região Metropolitana do Rio de Janeiro

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ABSTRACT
This study aims to assess the COVID-19 partial lockdown influence on air quality in the Metropolitan Region Rio de Janeiro (MRRJ). Criteria pollutants (CO, SO_2, O_3, and NO_2) sampled at four sites under vehicular and industrial influences were investigated, between March 1st to April 12th, 2019 and 2020. Results showed that the partial lockdown affected pollutant levels through emission sources reduction. High decreased concentrations were observed for SO_2, NO_2, and CO; while an increase in the ozone concentration was recorded. Pollutant time variation evaluations helped to understand the trend and sources in the different periods.

Keywords: quarantine, air quality, criteria pollutants, ozone, coronavirus

RESUMO
Este estudo tem como objetivo avaliar a influência do lockdown parcial da COVID-19 na qualidade do ar na Região Metropolitana do Rio de Janeiro (RMRJ). Poluentes de critérios (CO, SO_2, O_3 e NO_2) amostrados em quatro locais sob influências veiculares e industriais foram investigados, entre 1º de março e 12 de abril de 2019 e 2020. Os resultados mostraram que o bloqueio parcial afetou os níveis de poluentes por meio da redução das fontes de emissão. Reduções nas concentrações de SO_2, NO_2 e CO foram registradas; enquanto um aumento na concentração de ozônio foi observado. As avaliações da variação temporal dos poluentes ajudaram a entender a tendência e as fontes nos diferentes períodos.

Palavras-chave: quarentena, qualidade do ar, critérios poluentes, ozônio, coronavírus

1 INTRODUCTION

The new coronavirus has been causing the greatest pandemic of the 21st century. The impacts vary from improvements on air quality to unparalleled losses in economic systems. COVID-19 spread across the world quickly. In Brazil, the first official case was registered on February 26, 2020. Since then, many containment measures have been taken, varying from one region to another, as the virus has spread heterogeneously throughout the country[1,2].

The Rio de Janeiro city was one of the first to detect the virus in Brazil and one of the most affected by losses and overload of the health system. As a result, the government has adopted the partial lockdown to minimize the spread of the virus. The partial lockdown period started on March 16th, 2020. Until June, only essential services were allowed to work. The population was instructed to stay at home, leaving only to perform physical activities, medical services, or basic purchases. The metropolitan region of Rio de Janeiro (MRRJ) has undergone many structural changes to host the 2016 Olympic Games and the FIFA 2014 World Cup, two mega-events. The works include the construction of new streets and tunnels, closing off some avenues, new BRT, and VLT lines, among others. All of these changes have affected air quality in the region as reported in some studies [3–10].

After partial lockdown has been implemented by Rio de Janeiro government, the urban routine changed significantly, especially the traffic[11]. In this context, the present study aims to assess the time variation of air pollutants in the first weeks of the partial lockdown, and compare with weeks before the partial lockdown and with the same period in 2019. The levels of criteria pollutants (CO, O_3, NO_2, and SO_2) were monitored from March 1st to April 12th, 2019 and 2020. Four MRRJ sites under industrial influence and close to major roads were selected to assess the influence of these emission sources on air pollutant levels during the beginning of the partial lockdown. It is important to note that the first month of the partial lockdown registered the highest percentages of social isolation. Thus, the evaluation of the impacts of the change in urban routine in this period is useful, mainly to signal the contribution of vehicle emissions.

2 MATERIALS AND METHODS

The Metropolitan Region of Rio de Janeiro (MRRJ) spans up 21 counties, and three of them were assessed in this study: Itaguaí, Duque de Caxias, and Rio de Janeiro. In Rio de Janeiro, two districts were selected, Manguinhos (in the north zone) and Santa Cruz (in the west zone). The characteristics and location of the sampling sites are show in Figure 1 and Table 1.

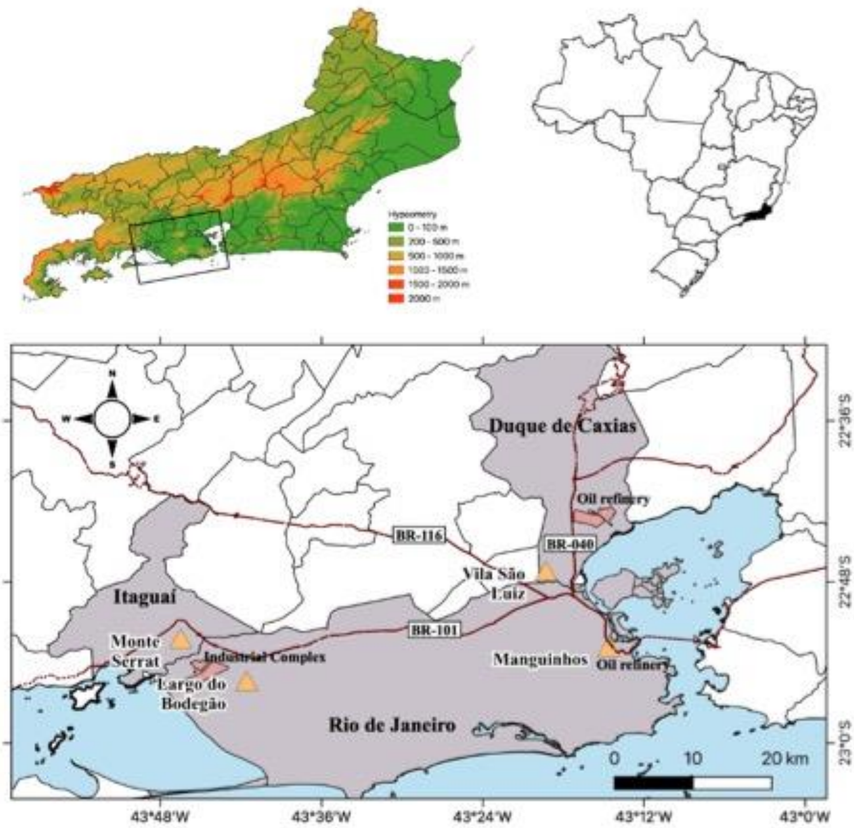

Figure 1. Locations of air quality monitoring station and emission sources (industrial district and roads). Itaguaí (Monte Serrat station, MS), Duque de Caxias (São Luiz station, SL), and Rio de Janeiro (Manguinhos station (MG) and Santa Cruz, (Largo do Bodegão station, LB).

To evaluate the impact of the partial lockdown on the air quality in the MRRJ, four regulated pollutants (CO, O_3, NO_2, and SO_2) concentrations obtained between

March 1st and April 12nd, 2019 and 2020 were evaluated. To verify changes caused by quarantine, the 2020 period was divided in two: 1) March 1st to 15th, 2020 classified as “before lockdown” and 2) March 16th to April 12th, 2020.

Sulfur dioxide (SO_2) was monitored by the ultraviolet (UV) fluorescence methods, nitrogen dioxide (NO_2) was measured by the chemiluminescence method, carbon monoxide (CO) was measured by infrared method and tropospheric ozone (O_3) was measured by the infrared method absorption of ultraviolet light. Data were obtained each 15-minute interval by the automatic monitoring stations using standard methods and types of equipment (Horiba, Japan and Ecotech, Australia), according to the Brazilian Technical Guide for Air Quality Monitoring (MMA, 2020). The automatic stations were calibrated monthly.

Sampling site	**Characteristics**	**Air Quality Parameters**	
São Luiz (SL) – Duque de Caxias	Located at 500 m away from a road with intense flow of light and heavy vehicles and near to unpaved roads, 10 km away from Duque de Caxias Petrochemical Complex.	SO_2, NO_2, O_3, and CO	-22,784550°, -43,286388°
Manguinhos (MG) – Rio de Janeiro	Located at 500 m from two roads with intense flow of light and heavy vehicles, an oil refinery, FIOCRUZ research center, and a community.	SO_2, NO_2, O_3, and CO	-22.884198°, -43.242592°
Santa Cruz – Largo do Bodegão (LB) – Rio de Janeiro	Intense flow of light and heavy vehicles, 5 km from the Santa Cruz Industrial District, Sepetiba Bay, and Itaguaí Port Complex.	SO_2 and NO_2	-22,927140°, -43,694727°
Monte Serrat (MS) - Itaguaí	Moderate flow of light and heavy vehicles, 6 km from the Industrial District of Santa Cruz and the Itaguaí Port Complex.	SO_2, NO_2, and O_3	-22,874843°, -43,770067°

Data were analyzed using the R language and environment for statistical computing (R Core Team, 2020). The package Openair was applied to make Time Variation plots, considering weekly and diurnal cycles.

3 RESULTS AND DISCUSSION

Weekly pollutants variation is presented in Figure 2. Comparing both years, NO_2 and O_3 presented lower concentration in 2020 in all sites. Besides of that, these pollutants presented little variation during week days in 2020, which is a consequence of the mobility reduction during the lockdown weeks. In the partial lockdown, pollutants levels during the week were similar to weekend levels as a consequence of adopting remote study and home office in those critical weeks of social isolation. SO_2 levels in 2020 were higher in all sites, mainly at LB, although weekly variation was similar to the previous year. CO concentration at MG was higher in 2020 than in 2019, nevertheless the same weekly variation was observed: an increase in the middle of the week and a decrease on the weekend.

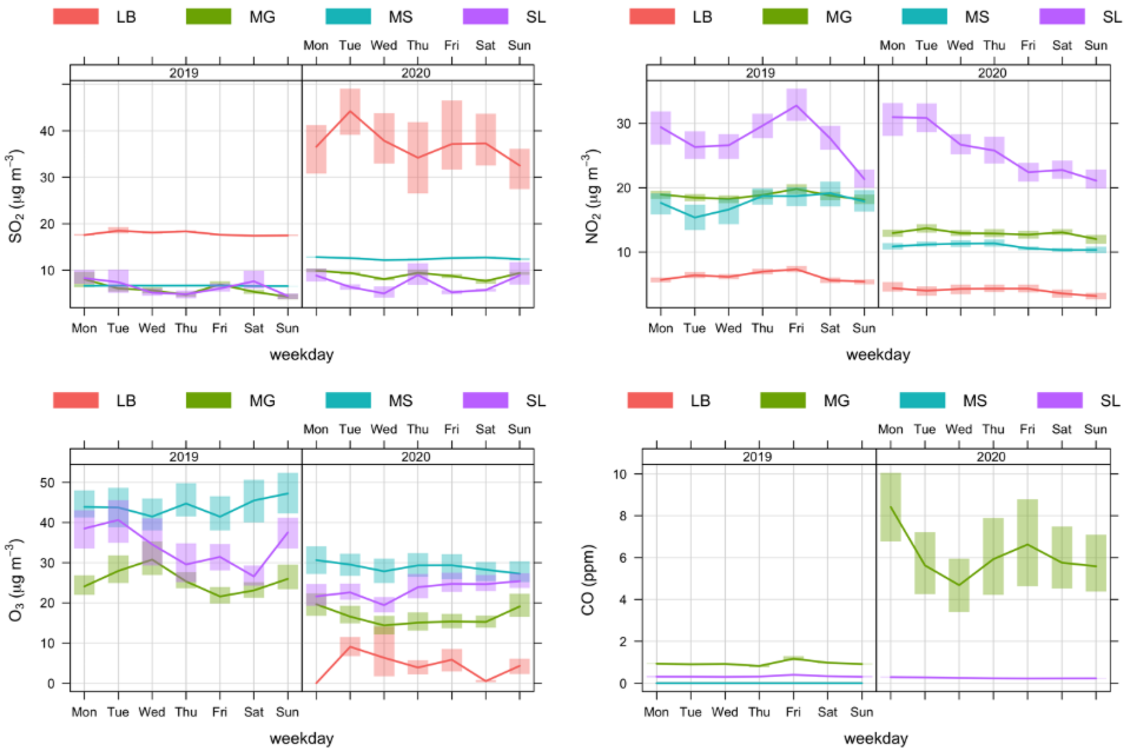

Figure 2. Weekly concentrations for SO_2, NO, O_3 and CO between March 1^{st} and April 12^{th} 2019 and 2020 in all monitoring sites. Itaguaí (Monte Serrat station, MS), Duque de Caxias (São Luiz station, SL), and Rio de Janeiro (Manguinhos station (MG) and Santa Cruz, (Largo do Bodegão station, LB).

Considering difference on routine scenarios, as a consequence of lockdown decree, weekly pollutant variation for data from 2020 (before and during lockdown) is presented in Figure 3.

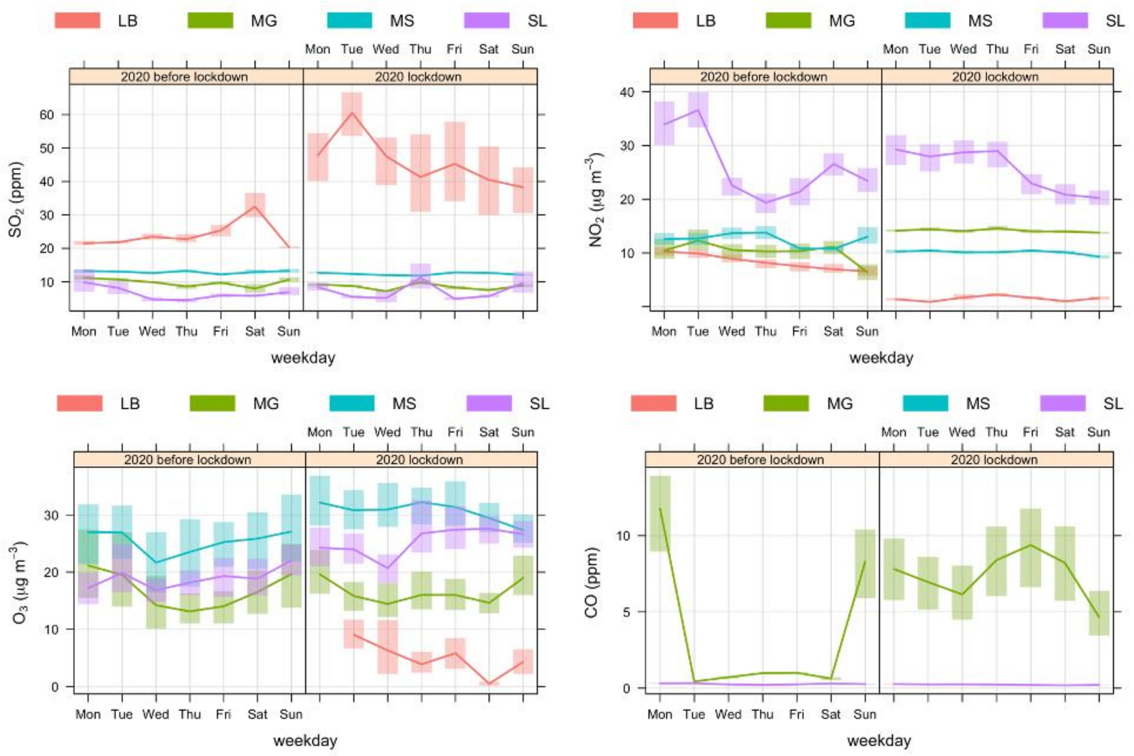

Figure 3. Weekly concentrations for SO_2, NO, O_3 and CO between March 1st and April 12th 2020 split according to lockdown decree. Itaguaí (Monte Serrat station, MS), Duque de Caxias (São Luiz station, SL), and Rio de Janeiro (Manguinhos station (MG) and Santa Cruz, (Largo do Bodegão station, LB).

Evaluating 2020 as a whole data frame, lower concentrations are observed compared to 2019, however, when the lockdown decree (March 16th) is considered. A clear change can be associated with this new urban routine. Particularly, O_3 concentration shows a different behavior. While SO_2, NO_2 and CO decreased during lockdown, O_3 increased, which was also observed in different cities around the world and attributed to the decrease in primary pollutants, that are related with ozone formation. According to Geraldino et al.[12], in Rio de Janeiro low NO_2 concentration leads to high O_3 concentration, once NO participates on O_3 depletion. The traffic reduction contributed to NO_2 decrease, and therefore, to O_3 increase.

Pollutant hourly variations for all sites is presented in Figure 4. SO_2 hourly profile in LB and CO hourly profile in MG did not present peak concentrations, which is characteristic of industrial emission, corroborating the hypothesis that industries from Santa Cruz and Manguinhos are accountable for SO_2 and CO emission, respectively.

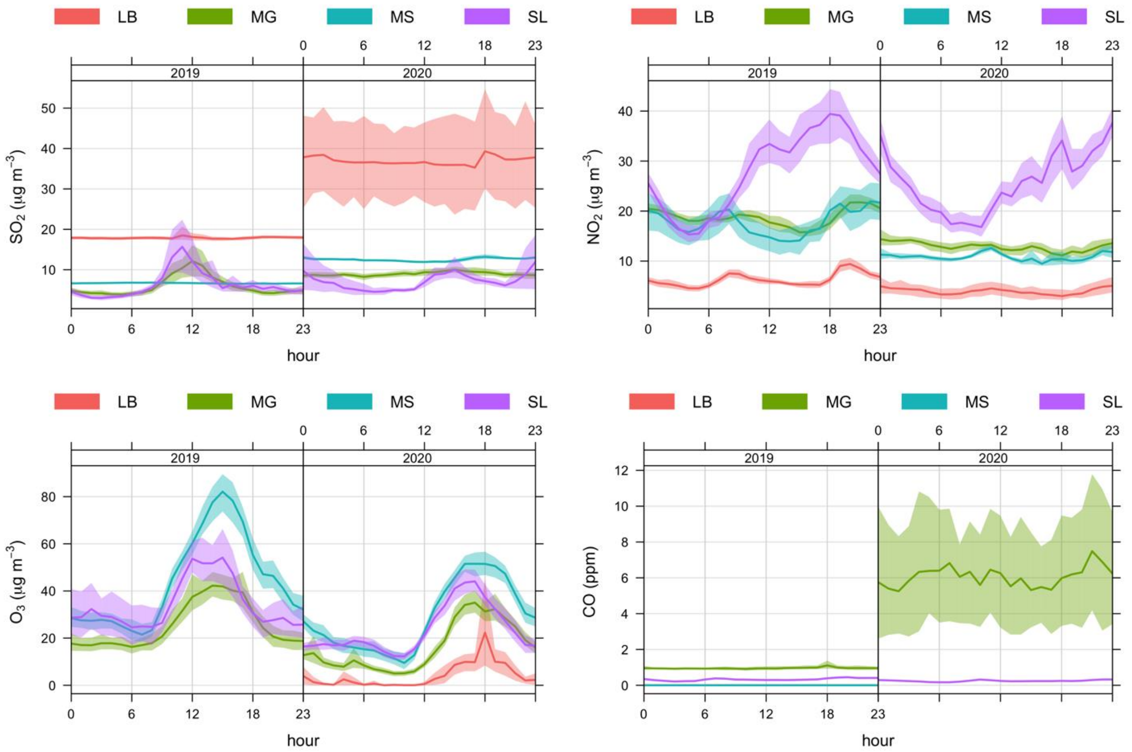

Figure 4. Hourly concentrations for SO_2, NO, O_3 and CO between March 1st and April 12th 2019 and 2020 in all monitoring sites. Itaguaí (Monte Serrat station, MS), Duque de Caxias (São Luiz station, SL), and Rio de Janeiro (Manguinhos station (MG) and Santa Cruz, (Largo do Bodegão station, LB).

The main source of NO_2 and SO_2 in the urban centers are vehicles, because of that, they generally present two peaks of concentration, which correspond to intense traffic times. This behavior may be observed for NO_2 in 2019, but in 2020 no peak of concentration is observed, which reflect the decrease in traffic during the partial lockdown. For SO_2 in 2019 a huge peak may be observed in the final morning, followed by random variation in the afternoon. However, in 2020, this pollutant presented little variation, once traffic decreased.

An interesting change in diurnal pollutants cycles may be observed for O_3. Comparing both years, all sites presented peak of concentrations at different times. In 2019, the O_3 peak concentration occurs about noon, when solar radiation is more intense, favoring photochemical processes. In 2020, O_3 peak of concentration occurred in the late afternoon. While in 2019, NO_2 emission contributed to O_3 depletion throughout the afternoon, the decrease in NO_2 concentration recorded in 2020 contributed to O_3 accumulation, leading to higher concentration in the evening. After that, the absence of solar radiation implies that O_3 formation stops, thus, the concentration decrease.

Sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) are generated from the combustion processes in vehicle and industries. NO_2 compound is a precursor for O_3, which is a secondary atmospheric pollutant that is formed in the troposphere by different mechanisms that depend mainly on volatile organic compounds (VOCs) and nitrogen oxides (NOx). Carbon monoxide (CO) is derived from incomplete combustion.[13,14] All of them are directly or indirectly related to vehicle emissions. Thus, the reduction in mobility caused by social isolation has led to considerable variations in their concentrations.

According to State Environmental Institute (Instituto Estadual do Ambiente, INEA/RJ), reductions of up to 80 % NO_2 and 75 % CO were recorded in the first two weeks of the partial lockdown [15]. In addition, reductions of up to 65 % SO_2 and increases of up to 25 % of O_3 were also registered. Rio de Janeiro recorded a higher SO_2, NO_2 and CO reduction comparing to Spain and some regions of Chine [13,16,17].

Studies carried out in São Paulo and Rio de Janeiro also recorded lower SO_2 and NO_2 reductions than this study[1,2]. Although the percentages of reduction obtained for the monitoring stations in this study are higher, the variation profile is similar to that observed by other studies already conducted in Rio de Janeiro and São Paulo[1,2,11]. Satellite data also show significant reduction of pollutants such as CO and NO_2 around the world [18,19]. Despite recording high reductions in primary pollutants, the increase in O_3 was not as large as in other cities around the world and some other neighborhoods in Rio de Janeiro. This behavior is related to the complex formation of ozone which in the state of Rio de Janeiro varies according to the topography of the region.

4 CONCLUSIONS

In summary, our findings indicated that control actions to prevent the spread of the pandemic had impact on the air quality levels for the four sites studied. The reduction in pollutant concentrations was related to the decrease in vehicle traffic caused by the closure of schools, industries, and commercial establishments, as well as the interruption of the activity of some transport lines. The increase in the concentration of O_3 was related to the decrease in NO_2 concentration, since the negative correlations between these pollutants indicate that NO_2 is involved in the consumption mechanism of tropospheric ozone. The importance of social isolation measures on air quality changes was certified by the comparison of the beginning of March with the period after the lockdown decree.

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