COVID19: Impact on Environmental Parameters During the Lockdown Period in India

V. Balaji Venkateswaran and Devender K. Saini

Abstract The coronavirus pandemic has entirely changed the current situation and has led people to realize the living scenario is no longer similar to before. The present-day situation is majorly subjugated with studies on developing strategies that can defer the spread of this virus, and to invent the vaccination. One of the prominent solution followed by many countries is to apply regional or country-level lockdown. This has affected the lives of many industries and become a challenge for its economic development. In this paper, we examine the correlation between the air pollutants (such as $PM_{2.5}$, PM_{10}, Ozone, CO, SO_X and NO_X) and weather parameters (such as temperature, humidity and dew point) with the coronavirus disease 2019 (COVID-19) by considering the six major red-zone hotspots identified in India. The effect of these parameters on major hotspots is examined based on Spearman's correlation coefficients for the lockdown period announced by the Government of India. From the results, it is evident that the highest correlation is obtained for different parameters for different red-zone districts. The study results may guide the authorities to develop a decentralized approach for effective implementation of lockdown and take appropriate measures in these red-zone hotspots.

Keywords Coronavirus · Air pollutants · Temperature · Humidity · Dew point · Sustainable development goals

1 Introduction

COVID-19 is a highly infectious and communicable disease that was initially found in December 2019 in Wuhan, China. Later, this virus was spread to many countries across the globe and therefore, the World Health Organization (WHO) has declared

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this as a pandemic. As of May 3rd, 2020, there were about 3,272,202 confirmed cases, 230,104 deaths, worldwide [1]. In a country like India, where the population is more than 1.32 billion, handling this situation is very challenging [2]. Even though the first case reported in India was on 31st January 2020, the significant spread of this virus was noticed on 14th March 2020. As of 2nd May 2020, the total number of tests carried was 11,529,433, and it is identified that the confirmed cases were 26,535 and the number of deaths recorded was 1223 (https://www.mygov.in/covid-19). From these data, it is clear that the ratios of confirmed cases are 0.2% and the death rate is very low. However, the number of cases recorded in major cities like Mumbai, Chennai, Hyderabad, Bengaluru, Kolkata, and New Delhi is high and therefore these are identified under red-zone hotspot region [3] The ratio of confirmed cased in these cities (or district) to the total number of cases in the state is Fig. 1. There are about 3761 confirmed cases in Delhi, where the district wise numbers are under reconciliation.

Initially, many researchers were developing a growth model for prediction of the effect of COVID-19. In [4] a simple growth model is proposed based on cumulative distribution function (CDF) to predict the spread of this virus. Meanwhile, many researchers confirmed that this virus can be transferred from human-to-human through droplets and direct contact of the materials used by the affected ones. Concerning this, many articles were found in recent times, where the correlations between the entire number of cases and weather conditions are identified to model the spread of this virus. In [5], a study is conducted in major cities of Turkey and was found that the temperature is highly correlated with the total number of cases. Conversely, a study conducted in New York City reveals that there is no significant scientific evidence found to conclude that, the warmer conditions will suppress

Fig. 1 Ratio of confirmed cases in major red-zone hotspot to the total number of cases in that State of India

the effect of COVID19 [6]. In [7], a study was performed to evaluate the effect of climatic parameters such as average temperature, precipitation, humidity, wind speed, and solar radiation on COVID-19. Here, the Partial correlation coefficient (PCC) and Sobol'-Jansen methods are used to analyze the spreading rate. From the analysis, it was identified that the population density and intra-state movement are the direct cause for the outbreak of infection. In [8], the positive and negative effects on the environment due to COVID-19 were identified for countries like China, France, Germany, Spain, and Italy. A similar kind of research based on suspended particle matter (SPM) was performed in Vembanad Lake, in India with the help of satellite images [9]. It is identified that during the lockdown period, the SPM level has decreased on an average by 15.9% compared to pre-lockdown conditions.

Similar to other countries, in containing the spread of this infection, the Government of India has announced a nationwide lockdown that started on 24th March 2020. However, considering the spread of this virus, the lockdown was extended for the third time for two weeks starting from 4th May 2020. To improve and enhance the financial situation of the country, the government has classified the COVID-19 affected districts into red, orange, and green zones and has provided the guidelines to be followed in these regions [3]. According to these guidelines, most of the activities are not permitted in red-zones. Nonetheless, few relaxations are provided to orange and green zones. Even after taking various steps to contain the infection, the confirmed cases are in the increasing trend, especially in some red-zone districts.

The major objective of this paper is to analyze the correlation between the climatic parameters and the COVID-19 confirmed cases in major red-zone hotspot districts in India. This study has been carried for the entire duration of the lockdown period. Thus, from this study, corrective measures can be derived for the identified red-zone districts to convert them into orange and then green.

2 Methodology

India is a highly populated country and has less per capita land space, especially in major cities. For example, Delhi and Mumbai are the second and the fifth highly populated city in the world [10]. Therefore, it is essential to identify unique ways in which the virus can be contained.

2.1 Dataset

The dataset for $PM_{2.5}$, PM_{10}, Ozone, CO, SO_X, NO_X, temperature, humidity and dew point are taken from the archives of U.S. Embassy and Consulates' Air Quality Monitor in India, National Air Monitoring Programme (NAMP) of Central Pollution Control Board and World Air Quality Index Project (NAMP; "U.S. Embassy and Consulates' Air Quality Monitor in India,"; WAQI Project.). Figure 2 shows the

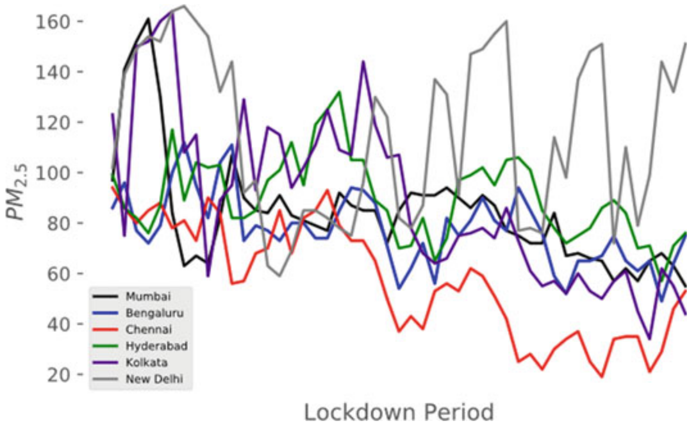

Fig. 2 Variation of $PM_{2.5}$ in identified red-zones of India

dissimilarity of $PM_{2.5}$ during the lockdown period (from 24th March till 4th May 2020) in the identified major red-zone districts of India. It refers to particulate matter in the atmosphere which has a diameter of less than 2.5 μm.

Figure 3 shows the variation of PM_{10} during the lockdown period in the identified major red-zone districts of India. It refers to particulate matter in the atmosphere which has a diameter of less than 10 μm. The variations of air pollutants such as O3, CO, NO_X, and SO_X during the lockdown period are shown from Figs. 4, 5, 6 and 7 respectively.

Figures 8, 9 and 10 shows the temperature, humidity, and dew point variations during the lockdown period in the identified major red-zone districts of India. Table 1 shows the total confirmed cases in major states such as Maharashtra, Karnataka,

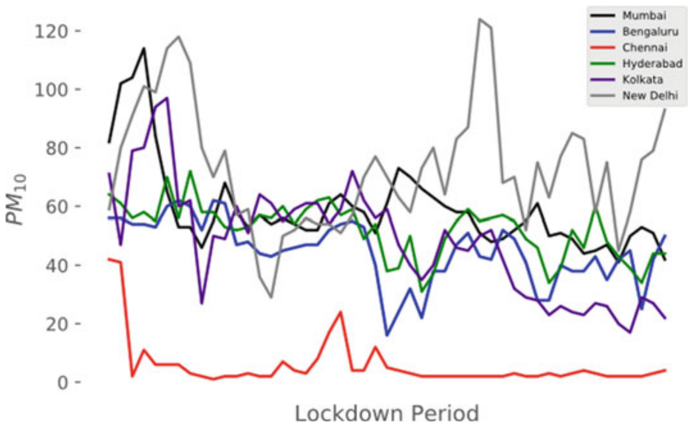

Fig. 3 Variation of PM_{10} in identified red-zones of India

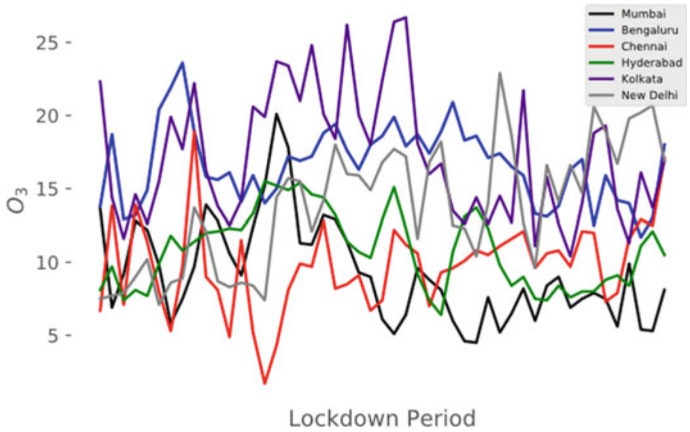

Fig. 4 Variation of O_3 in identified red-zones of India

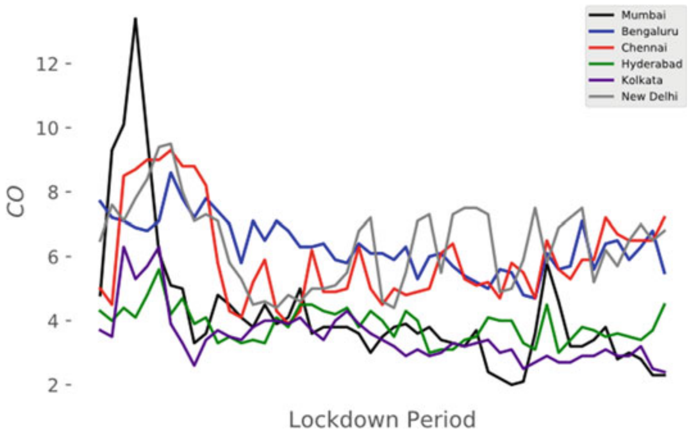

Fig. 5 Variation of CO in identified red-zones of India

Tamil Nadu, Telangana, West Bengal, and Delhi till 4th May, and Fig. 11 shows the trend of the number of confirmed cases between 14th March 2020 to 4th May 2020 in these states. Figure 12 shows the population density (in per km^2 scaled by 100) of identified red-zone districts and corresponding means sea level (MSL) in meters.

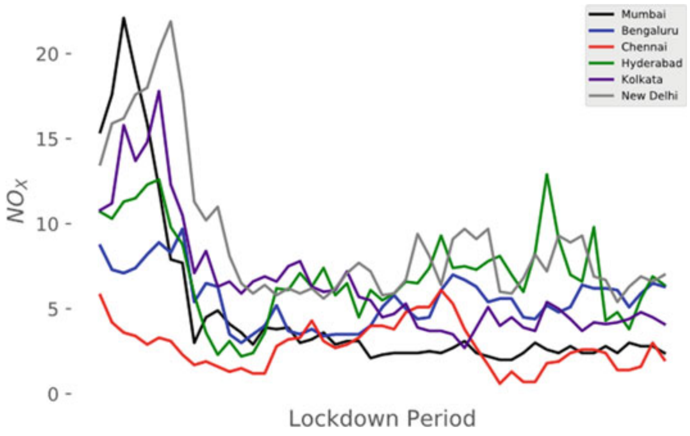

Fig. 6 Variation of NO_X in identified red-zones of India

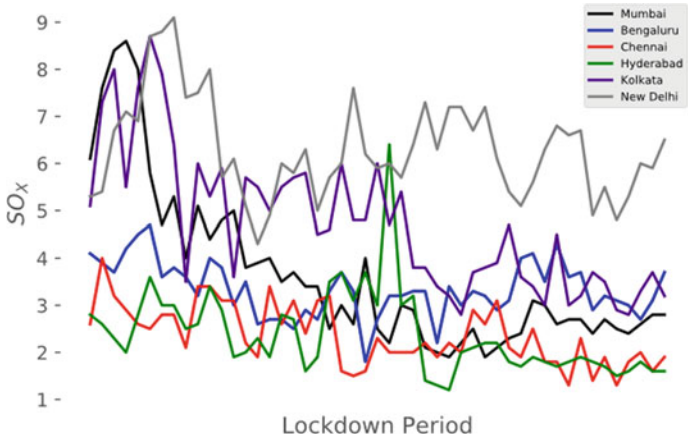

Fig. 7 Variation of SO_X in identified red-zones of India

2.2 Spearman's Correlation Analysis

The Spearman's correlation is a non-parametric analysis from which the correlation rank is derived. This rank provides a measure of strength and direction of relationship between the chosen two variables. Here, the correlation coefficients are derived between the two datasets x and y, if the coefficient is greater than zero, it implies that x increases with an increase in y and if the coefficient is less than zero, it implies that x increases with decrease in y. The Spearman's coefficient can be calculated using the Eq. (1).

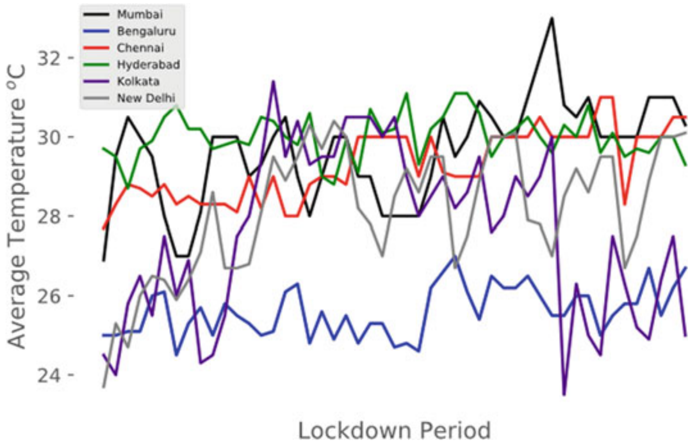

Fig. 8 Variation of average temperature (°C) in identified red-zones of India

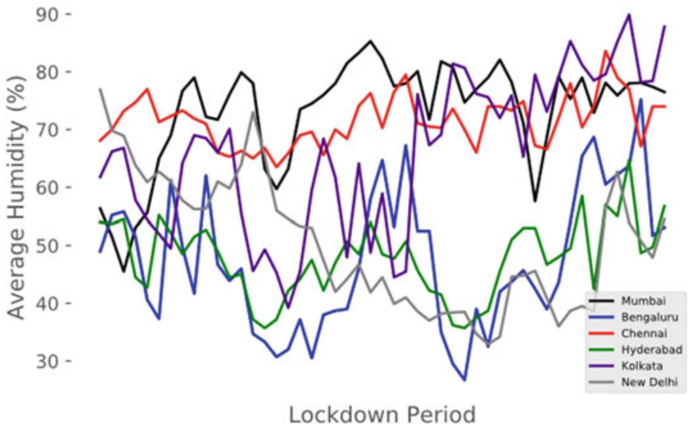

Fig. 9 Variation of average humidity (%) in identified red-zones of India

$$r_s = 1 - 6 \times \frac{\sum {d_r}^2}{n\left(n^2 - 1\right)} \tag{1}$$

where d_r denotes the change in rank between the variables, n is the total quantity of cases. Therefore, in this study, the Spearman rank coefficient test is used to observe the correlation between the air pollutants, weather parameters with the confirmed cased of COVID-19 in six major red-zone hotspot regions of India.

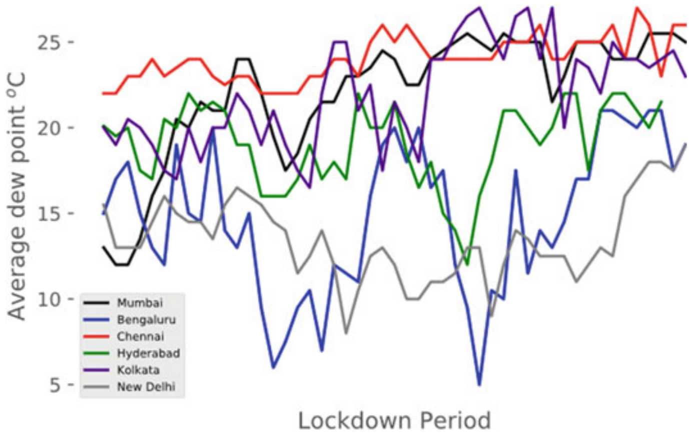

Fig. 10 Variation of average dew point (°C) in identified red-zones of India

Table 1 Total confirmed COVID cases in the Major States of India

State	Total confirmed cases
Maharashtra	12,974
Karnataka	642
Tamil Nadu	3023
Telangana	1082
West Bengal	963
Delhi	4549

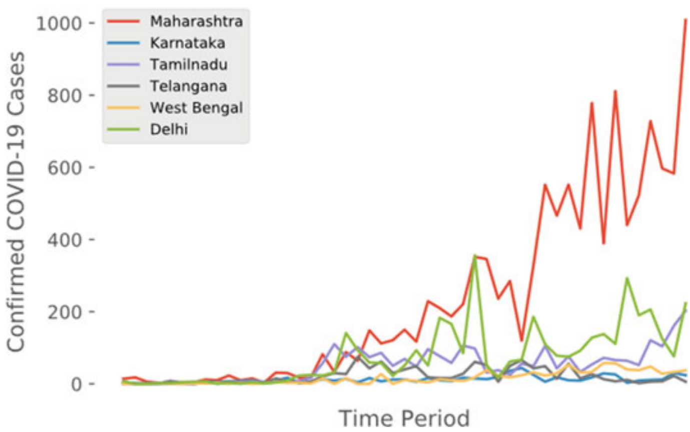

Fig. 11 Number of confirmed cased in the Major States of India

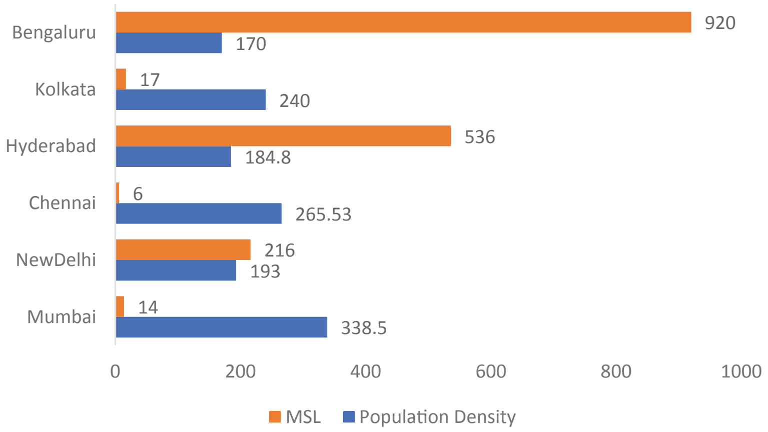

Fig. 12 Population density and MSL of identified red-zone districts in India

3 Results and Discussion

Table 2 represents the result of Spearman's correlation analysis. As mentioned earlier, air pollutants such as $PM_{2.5}$, PM_{10}, Ozone, CO, $SO_{X,}$ and NO_X and weather parameters such as average temperature, average humidity, and dew point are considered for this study. All these parameters are evaluated for the duration of lockdown between 24th March till 4th May 2020.

In Table 2, the positive correlation coefficients are in italic and the negative correlation coefficients are in bold. By comparing the Fig. 12 and Table 2, expect Kolkata, all the other red-zone districts are having positive temperature correlation with COVID-19 cases. From the results, it is evident that for the Mumbai district, all the air pollutants are having negative correlation coefficient with a maximum for SO_X which is – 0.73162. The maximum value of the positive coefficient is for the dew point which is

Table 2 Results from Spearman's Correlation Analysis

	Mumbai	Bengaluru	Chennai	Hyderabad	Kolkata	New Delhi
$PM_{2.5}$	**– 0.53081**	**– 0.30462**	**– 0.52129**	*0.139179*	**– 0.78619**	**– 0.23106**
PM_{10}	**– 0.5335**	**– 0.41196**	**– 0.07703**	**– 0.21973**	**– 0.78224**	**– 0.14839**
O_3	**– 0.53388**	**– 0.05906**	*0.274844*	*0.111364*	**– 0.28197**	*0.694413*
CO	**– 0.69787**	**– 0.55868**	**– 0.07287**	**– 0.11002**	**– 0.72236**	**– 0.19363**
NO_X	**– 0.71124**	**– 0.17373**	0.064664	**– 0.05174**	**– 0.74995**	**– 0.4349**
SO_X	**– 0.73162**	**– 0.3357**	**– 0.53746**	**– 0.0486**	**– 0.78756**	**– 0.27337**
Avg. temperature	*0.587189*	*0.231033*	*0.630225*	*0.382372*	**– 0.13478**	*0.479886*
Avg. humidity	*0.320102*	**– 0.03885**	*0.187166*	**– 0.28948**	*0.713122*	**– 0.57176**
Dew point	*0.775292*	**– 0.00647**	*0.537491*	**– 0.13348**	*0.578741*	**– 0.17347**

0.775292. In other words, in Mumbai, as the dew point increases the confirmed cases are also increasing and the SO_X is decreasing with an increase in confirmed cases. For the Bengaluru district, all the air pollutants are having negative correlation coefficient along with humidity and dew point. Here the maximum negative correlation coefficient is obtained for PM_{10} which is − 0.41196. In other words, in Bengaluru, as the confirmed cases increase the level of PM_{10} is decreasing, and as the temperature increases the number of COVID-19 cases increases. For the Chennai district, air pollutants such as $PM_{2.5}$, PM_{10}, CO, and SO_X are having negative correlation coefficient out of which the maximum is for SO_X (− 0.53746). The other parameters such as O_3, NO_X, average temperature, average humidity, and dew point are having positive correlation coefficients out of which the maximum is for temperature. For the Hyderabad district, except for parameters such as $PM_{2.5}$, O_3, and average temperature, all the other parameters are having negative correlation coefficient out of which the maximum is for humidity which is − 0.28948. For the Kolkata district, all the parameters are having a negative correlation coefficient except for humidity and dew point. The maximum value of negative correlation is for $PM_{2.5}$. For New Delhi district, expect O_3 and average temperature all the other values are having negative correlation coefficient out of which humidity is having maximum value (− 0.57176).

The average temperature was found to be highly correlated with COVID-19 cases in Turkey [8]. Whereas from this study, it is clear that, there is no single parameter which is having a negative correlation coefficient for all the districts. A comparison of correlation results for temperature between [8] and the current study is shown Fig. 13. From Fig. 13, it is clear that the temperature is not having negative correlation in majority of the major cities of India. From this study, it is clear that, the guidelines to be formulated must be regional-specific rather than a nationwide framework under the current situation to convert these red-zones to orange and then to green.

This study may have a few limitations. The study results may not reflect the actual situation in the selected red-zones. In recent reports, it was found that people are traveling between districts due to various reasons. One among those is intra-state

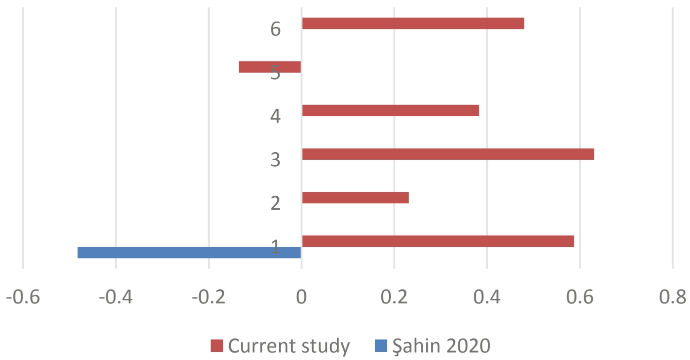

Fig. 13 Comparison of temperature correlation coefficient of major cities of Turkey and India

transportation to carry the essentials goods to maintain the supply chain. Therefore, without the knowledge of people traveling between these major cities, converting the red-zone to orange and then green is challenging.

4 Conclusion

Compared to other developed and developing countries, India, having the largest population has controlled the spread of the virus more effectively. However, it is still challenging for those red-zone districts which have a positive trend in confirmed cases in the current scenario which provides an alarming sign. In this study, the impact of air pollutants (such as $PM_{2.5}$, PM_{10}, Ozone, CO, SO_X and NO_X) and weather parameters (such as average temperature, average humidity, and dew point) from 14th March 2020 to 4th May 2020 on confirmed COVID-19 cased using data in India is presented. The results obtained show that the correlation coefficient is diverse for all the regions of India. Therefore, in the current situation, it is essential to have a decentralized control and guideline mechanism among the red-zone districts identified in India to convert those into orange and then green.

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