Significant Association of COVID-19 with Ozone and PM2.5: A Case of Tehran, Iran

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Abstract

Introduction: Air pollution is one of the prime public health concerns influencing infectious diseases. From May 13 to July 29, 2020(77 days), Tehran experienced unhealthy conditions caused by high levels of O_3 and PM2.5, whereas other pollutants remained at safe levels. This study, for the first time, sought to investigate the linkage between not only PM pollutants, but also O_3 and the number of daily confirmed new cases of COVID-19 in Tehran, Iran.
Materials and Methods: In this experimental study, the data on air pollution were obtained from an average of 23 air quality monitoring stations scattered in 20 districts of Tehran municipality during the 77days. Pearson's correlation and log-linear generalized additive model (GAM) were used to examine the association of the daily numbers of confirmed cases of COVID-19 and levels of O_3 and PM2.5. Also, effective degrees of freedom (edf) used to determine the structural relationship between independent and dependent variables. GAM was performed by R software (version 3.5.3) with the "mgcv" package (version 1.8-27).
Results: The results show a significant relationship betweenO_3, PM2.5, and COVID-19 ($P < 0.001$), while other pollutants such as NO_2, PM10, CO, and SO_2 remain at healthy levels during the study period. Besides, O_3 and PM2.5 with edfs greater than 1 had significant nonlinear effects on the daily number of COVID-19 cases ($P < 0.001$).
Conclusion: Considering the results of this study, there is a positive nonlinear association between O_3, PM2.5, and daily confirmed cases of COVID-19. These findings suggest that O_3 and PM2.5 levels should be considered as influential factors that can aggravate coronavirus infection.

Keywords: COVID-19, Air pollution, GAM, Tehran

Introduction

The novel coronavirus disease known as COVID-19 is essentially a respiratory disease; thus, the study of the interactions of this virus concerning environmental and climatic factors has become of vital importance for global organizations, governments, and researchers (1). As a result of actions taken by governments to constrain the normal activities of the people, considerable changes in climatic and environmental conditions have been observed (2). COVID-19, initially recognized in the Hubei province of China with an unknown etiology of pneumonia, at last, became a pandemic outbreak all over the world (3). Iran was one of the first countries after China to be infected with the virus. On February 19, 2020, Iran's government officially announced the COVID-19 outbreak by reporting 2 infected cases in the city of Qom. Soon thereafter, Tehran became involved with the disease. In a few weeks, most provinces of Iran were in a state of emergency, and newly infected cases reached numbers higher than 3000 per day in March (4). To date, several studies have investigated the causes and consequences of COVID-19, particularly concerning environmental factors. The study showed drastic decreases in NO, NO_2, and CO concentrations but an increase of approximately 30% in O_3 concentrations over the urban area of Sao Paulo during a partial lockdown (5). Some epicenters of COVID-19, such as Wuhan, Italy, Spain, and the USA, have reported a 30% reduction in NO_2 (6). In addition, a higher rate of infection occurs among individuals who had been exposed to urban air pollution more than 100 days per year (7). The study reported that long-term exposure to air pollution could lead to higher mortality risk (8). Similarly, there were the positive correlations between PM pollution and COVID-19 inside and outside the cities of Hubei Province (9). Using Sentinel-5P, the research suggests an association between the high Covid-19 death rates in northern Italy and central Spain with the highest concentrations of NO_2(10). The influences of other environmental factors such as temperature and humidity on the COVID-19 spread rate were also examined by (11), who indicated an intense negative relationship between temperature as well as humidity and COVID-19 transmission rate. Nevertheless, one of the main phenomena of the hot season is the increase in O_3 level and its relationship with COVID-19, which has not yet been studied. Accordingly, the purpose of this study was to analyze the associations between O_3 and PM2.5 with the daily number of confirmed COVID-19 cases from May 13 to July 29, 2020, which coincided with the second wave of COVID-19 in Tehran, Iran.

Tehran is located at 35° 45´ N and 51° 30´ E and is characterized by ahigh-density population (>8.5 million [Statistical Centre of Iran, 2017]); interminable traffic jams and environmental problems such as air and noise pollution (12); intra-provincial movement (13); and high daily travel activity from its environs. The sources of air pollution in Tehran are motorized traffic, dust, and a broad range of heavy and light industries across the city (14). The annual average temperature in Tehran is 18.5 °C, and maximum and minimum temperatures reach 40 °C and -10 °C in July and January, respectively (15). Due to the presence of subtropical high pressure, Tehran's weather gets warm and dry in the summer; nonetheless, the Alborz Mountains moderate the dryness in part (16).

Like the U.S, Spain, Peru, Japan, Australia, the Netherlands, and several other countries, Iran has experienced a second wave of COVID-19. The first peak in Iran occurred on March 30, 2020, with 3186 new cases, while the second peak came on June 4, 2020, and involved an even higher number of 3574 new cases (4). This rate was mirrored in the daily number of newly infected individuals in Tehran; as seen in Figure 1, the highest peak was on March 21 with 379 new cases, and the second peak occurred on July 14 with 293 new cases. The focus of this paper is on the second peak of COVID-19 in Tehran, which occurred from June 11 to July4, 2020.

Data on air pollution was obtained from an average of 23 air quality monitoring stations scattered in 20 districts of Tehran municipality with samples recorded daily at 11 a.m. During the 77-day study period, the air quality index (AQI) showed 28 days of unhealthy conditions for sensitive groups and two days of unhealthy conditions for all individuals. High levels of the pollutant O_3 caused the unhealthy conditions during this period according to the AQI, and for 6 days, O_3 and PM2.5were at unhealthy levels simultaneously. No other pollutant reached unhealthy levels during this period.

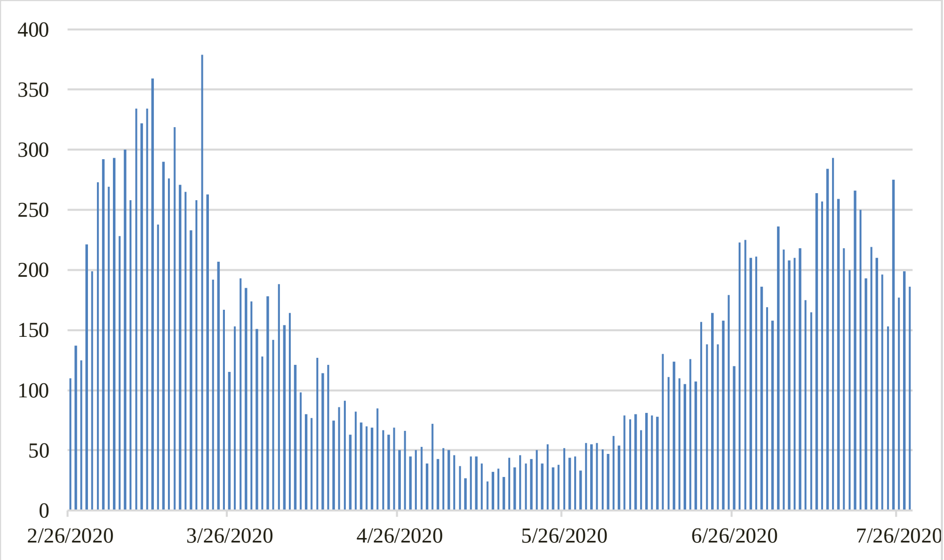

Figure 1. The number of daily confirmed cases of COVID-19 in Tehran during this study from May 13 to July 29, 2020.

Statistical Analysis

A log-linear generalized additive model (GAM) was used to analyze the associations between air pollutants ($O_3$and PM2.5) and cases of COVID-19. The GAM is indeed a semi-parametric flexible form of the generalized linear model (GLM) that handles linear and nonlinear relationships between dependent and independent variables (17, 18). In GAM, the non-linear relationships are treated using smooth functions. GAM allows a broad range of distributions for the response variable to be adopted and link functions for measuring the effects of the predictor. The link function is selected based on the distribution of the response variable (19). In this paper, the response i.e., the daily confirmed cases of COVID-19 were counted. Thus, Poisson distribution with the log link function was used to fit the data. The basic form of the GAM equation used herein was:

$$log\ (Y_t) = \alpha + s(O_3) + s(PM2.5)$$

WhereY_t, is the daily number of confirmed cases of Covid-19;s and α denote the smooth function and intercept, respectively; and O_3 and PM2.5 are the studied air pollutants. GAM was implemented using R software (version3.5.3) with the "mgcv" package (version 1.8-27). A P value less than 0.05 was considered significant.

Results

During the study period (May 13 to July 29, 2020), Tehran reported 10,393 confirmed cases of COVID-19. Statistics revealed the highest daily rate of infection on July 14, when 293 new cases were seen.

Pearson's correlation test indicated that the correlation between O_3 and PM2.5 was 0.55. The Spearman test revealed that $O_3$and PM2.5 were positively associated with daily incidences of COVID-19 (r= 0.55 and 0.36, respectively).

The results of GAM demonstrated a positive relationship between the relevant air pollutants and the daily number of confirmed cases of COVID-19. Table 1 shows the approximate significance of smooth terms, revealing that $O_3$and PM2.5 had statistically significant correlations with COVID-19. One of the most important issues in GAM is to recognize the structural relationship between independent and dependent variables. In Table 1,the effective degree of freedom (edf) shows the complexity of the smooth, where an edf of 1 indicates a straight line and higher edfs describe more wiggly curves.Thus, it can beconcluded that O_3 and PM2.5 with edfs greater than 1 have significant nonlinear effects on the daily number of COVID-19 cases (P <0.001). Figure 2 shows the smoothing components plots of predictors along with a 95% confidence interval. This figure depicts and justifies the use of the nonlinear effects of predictors to explore the effect of air pollutants on the number of COVID-19 cases. As shown in Figure 2, there is an increasingly positive correlation between O_3 and COVID-19 in which changes in the response curve are accompanied by the trend of COVID-19 incidence. Such trend is also seen withPM2.5and for both pollutants is wiggly and non-linear.

Table1. Parametric coefficients of air pollutants concerning the daily confirmed cases of COVID-19 during this study.

Air pollutant factors	Effective degree of freedom (edf)	Reference degrees of freedom (Ref.df)	Chi. sq	P value
s(O_3)	8.595	8.952	679	<0.001
s(PM2.5)	8.408	8.882	365.2	<0.001

s: Smooth Function.

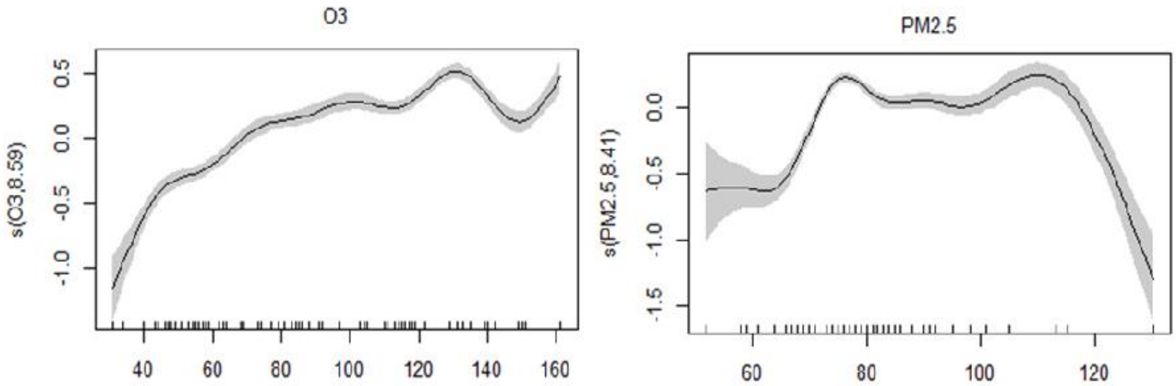

Figure 2. Response curves obtained from the log-linear generalized additive model. The edfs forO_3 and PM2.5 are 8.059 and 8.41, respectively. This fact shows there is a positive nonlinear correlation between O_3, PM2.5, and COVID-19 in which changes in the response curve are accompanied using the trend of COVID-19 incidence.

Discussion

In the first wave of COVID-19, severe restrictions were imposed across the country that limited intra-provincial movement and transportation and suspended a large number of jobs and industrial activities (4). After the first wave subsided, quarantine conditions were largely adjusted, leading to the emergence of the second wave in Iran (3). The governments have been forced to enact restrictive rules due to the high impact of COVID-19 on the health condition of people (4). In addition to the relaxation of quarantine conditions, failure to comply with preventive measures such as the role of various factors such as social distance, the use of masks, attention to health principles, quarantine of patients, and increasing patients' access to medical facilities and medical counseling should not be overlooked (23).

Despite extensive efforts to control the spread of COVID-19, official statistics show an increasing trend in confirmed cases globally (10). Air quality has been regarded as a factor that may influence the spread pattern of COVID-19 (13). O_3 and PM2.5 are two rather independent and most consistent predictors of the health effects of ambient air pollution (20). Exposure to pollutants such as airborne PM2.5 and O_3 has deleterious effects on respiratory and cardiovascular diseases and increases mortality rates. Remarkably, these effects have also been reported in daily and long-term studies at very low levels of exposure (21). O_3 is a pollutant of the warmer months of the year that is formed in the presence of sunlight by the reaction of volatile organic compounds (VOCs) and nitrogen oxides (NOx) (22). It is known as a secondary pollutant detrimental to vegetation and like any other pollutant has adverse effects on human health (23).

This study was the first to investigate the linkage between PM pollutants, $O_3$with the number of daily confirmed new cases of COVID-19 in Tehran, Iran. The findings of our study showed the relationship between O_3, PM2.5, and COVID-19, while other pollutants such as NO_2, PM10, CO, and SO_2 remained at healthy levels during the study period. Some studies were in line with the results of this paper. For example, O_3effects on COVID-19 over the urban area of Sao Paulo during a partial lockdown (5). Also, a positive correlation observed between PM pollution and COVID-19 in Hubei Province (9).

According to our results and published literature, air pollution could lead to a higher mortality risk (8, 24). Besides the aforementioned studies, we examined nonlinear correlation between PM2.5, O_3, and the number of daily confirmed cases of COVID-19. The results of this study are essential for considering the effects of PM2.5 and most especially, O_3 on the incidence of COVID-19 and will aid in determining the necessary measures to be taken.

Conclusion

Our findings showed that there is a positive relationship between O3, PM2.5 levels and the daily number of confirmed cases of COVID-19. Accordingly, the number of daily confirmed cases of COVID-19 can be reduced by controlling the relevant air pollutants. Given the importance of the impact of the virus on the other environmental problems, it is necessary the governments pay more attention to such studies to manage this condition.

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