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The effects of COVID-19 pandemic on the air pollutants concentration during the lockdown in Tehran, Iran

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ARTICLE INFO

Keywords:
Air quality
COVID19
Lockdown
O3
PM10

ABSTRACT

In this study, 24-h average concentration of major pollutants, including PM2.5, PM10, NO2, SO2, O3 and CO in the period 1 January to 30 July 2016 to 2020 were investigated to show how partial lockdown affects the behavior of pollutants' concentrations in an urban region. For this purpose, three sites of Aghdasieh, Setad-e Bohran and Shahr-e-Rey, which are located in various parts of Tehran considered. Results showed that PM10 had maximum reduction especially for Aghdasieh and Setad-e Bohran stations (20–30%) compared to the 5-year monthly average. Furthermore, the highest reduction in the Shahr-e-Rey station was related to NO2 (27.6%). The trend of AQI decreased considerably in 2020 compared to its pre-lockdown values. The relative reduction of AQI in March compared to February was about 12.8%, 27.6%, and 2.27% for Shahr-e-Rey, Aghdasieh, and Setad-e Bohran, respectively. The concentration of pollutants was expected to fall after the lockdown, but it was noted that compared to their average during the 5-year period, the concentrations of all pollutants especially O3 increased to some extent. A major reason for this trend is the removal of the traffic control plan and the increasing use of private vehicles in an effort to implement social distancing.

1. Introduction

Toward the end of December 2019, the first patients with pneumonia-like symptoms were diagnosed in Wuhan, China. This viral disease, caused by an unknown microbial agent, was called 2019 novel coronavirus (SARS-CoV-2 /COVID-19). It is a contagious disease that spread rapidly all over the world (Huang et al., 2020; Dutheil et al., 2020; Chen et al., 2020; Lu et al., 2020; Xu et al., 2020, He et al., 2020). Up to July 15, the virus had hit 213 countries and territories, leading to the death of over 579,724 people and the infection of 13,420,863 people (WHO, 2020).

In Iran, the first confirmed case of COVID-19 was reported on February 18, 2020 in Qom. The rapid growth of this severe acute respiratory syndrome resulted in lockdown in many countries affected by the disease. On February 21, 2020, Iran's status changed from white to yellow, such that by March 4, 2020 the disease had spread rapidly throughout the country. Based on the proposal of the Iran's Ministry of Health, the region is in a white (low risk) situation if the number of definite new cases per 100,000 people is maximum equal to one and the average number of daily hospitalizations is maximum equal to 14 during two weeks (including suspicious and definite cases). Yellow situation means that one or more cases of positive PCR test (polymerase chain reaction) have been seen in the area and the number of definite new cases per 100,000 people is 1 to 9.

According to the Iranian Ministry of Health report, by noon of March 4, 2020 the total number of people infected with the COVID-
19 reached 2922 and the number of deaths reached 92. Due to the high rate of the outbreak, partial lockdown and minor restrictions were imposed across the country on February 20. These gradual restrictions included lockdown of kindergartens, schools, universities, restaurants, shopping malls, centers of social and economic activities, and beauty salons. Also, many people cancelled their New Year (Nowrouz) travel plans, and intercity trains, planes, and buses stopped working.

Recent studies show a link between reduced vehicles uses, restriction of social activities, social distancing measures, and air pollutants' concentration (Tobías et al., 2020; Sicard et al., 2020). Therefore, it is expected that emissions from sources such as transportation and industries should decrease during the lockdown. In this regard, Sharma et al. (2020) assessed the levels of particulate matter (PM2.5, PM10), CO, NO\textsubscript{2}, and SO\textsubscript{2} in a number of Indian cities. The results showed that PM2.5, PM10, CO, and NO\textsubscript{2} respectively decreased by 43%, 31%, 10%, and 18% after lockdown. Moreover, O\textsubscript{3} increased by 17% and SO\textsubscript{2} changed slightly. Mahato et al. (2020) studied 34 monitoring stations spread over a megacity and found that air quality was notably better during lockdown as the concentrations of PM10 and PM2.5 dropped by 50% compared to their values in the pre-lockdown period. Besides, the concentrations of NO\textsubscript{2} and CO decreased −52.86% and 30.35%, respectively. Using the data of Copernicus Atmosphere Monitoring Service, Zambrano-Monserrate et al. (2020) reported a 30% reduction in PM2.5 during lockdown (February 2020). (Tobías et al., 2020) investigated air quality variations during the lockdown in Barcelona and observed that PM10 and NO\textsubscript{2} fell 31% and 51%, respectively. Mahato et al. (2020) showed that the COVID-19 lockdown in Milan led to a significant increase of surface daily average of O\textsubscript{3} concentrations by a factor of 2.25. Moreover, the concentrations of daily average of NO\textsubscript{2}, PM10 and PM2.5 were significantly reduced by 64.7%, 45% and 47% respectively in comparison with pre-lockdown period. AQI was also improved by 30% in comparison to pre-lockdown values. They also showed that the COVID-19 viral infections are positively correlated with values of Ozone, PM and AQI and inversely correlated with nitrogen dioxide ground levels. Furthermore, they demonstrated that warm season will not stop COVID-19 spreading and even dry air, low winds and precipitation rates supports the virus transmission. In addition to the above, other researchers have shown improvement in air quality due to lockdown in their research (Lian et al., 2020; Zangari et al., 2020; Berman and Ebisu, 2020; Kerimray et al., 2020; Ahmadi et al., 2020; Menut et al., 2020; Shehzad et al., 2020).

In this paper, air quality variations were analyzed to investigate the impact of gradual partial lockdown imposed on people by COVID-19. First, targeting three stations across Tehran, we gathered air quality data related to the last five years (2016–2020) and the period between February 15 and July 30, 2020. This paper also explored and analyzed short-term changes of a number of pollutants (NO\textsubscript{2}, PM2.5, PM10, CO, SO\textsubscript{2}, and O\textsubscript{3}) to identify the effect of lockdown on their concentration. For this purpose, pollutants' levels during the lockdown (March 4 to April 18, 2020) were compared to their 5-year average in the same period to detect how the lockdown effect air quality in this region. Section 3 presents and discusses the results. Finally, Section 4 draws some conclusions.

![Fig. 1. Location of the selected air quality monitoring stations of Tehran (Aghdasieh, Setad-Bohran District7, Shahr-e-Rey).](image-url)
Table 1

Monthly mean concentration ($\mu g.m^{-3}$) and relative changes (%) of main pollutants including PM2.5, PM10, NO$_2$, SO$_2$, O$_3$, and CO in comparison with the 5-year average between January 1 to July 30 in Tehran.

| MONTH   | AQI   | CO    | O$_3$ | NO$_2$ | SO$_2$ | PM10 | PM2.5 | AQI% | CO% | O$_3$% | NO$_2$% | SO$_2$% | PM10% | PM2.5% |
|---------|-------|-------|-------|--------|--------|------|-------|------|-----|--------|---------|---------|-------|--------|
| Shahr-e-Rey |       |       |       |        |        |      |       |      |     |        |         |         |       |        |
| Jan-20  | 123.32| 23.07 | 12.64 | 57.86  | 11.42  | 66.11| 123.32| 4.62 | -23.73| -12.72 | -13.59  | -26.67 | -0.27 | 4.62   |
| Feb-20  | 91.03 | 18.05 | 66.17 | 10.62  | 59.79  | 95.50| -13.78| -16.98| -14.06| 21.49 | -9.12  | -9.89  |        |        |
| Mar-20  | 79.34 | 25.20 | 10.31 | 52.64  | 79.17  | -4.57| -7.19 | -19.26| -7.24 |       |        |        |        |        |
| Apr-20  | 69.96 | 22.22 | 12.48 | 47.09  | 68.61  | -5.88| -24.81| -17.99| -13.10| -6.21 |        |        |        |        |
| May-20  | 79.87 | 35.68 | 14.35 | 63.74  | 76.74  | -0.29| 0.67 | 8.15  | 2.76 | -2.76 | -2.96  |        |        |        |
| Jun-20  | 93.77 | 19.43 | 50.38 | 73.58  | 91.13  | 8.52 | -37.90| 24.98 | 5.70 | -0.16 | 2.82   |        |        |        |
| Jul-20  | 93.29 | 15.06 | 47.83 | 76.42  | 67.38  | 8.62 | -52.02| 8.61 | 7.90 | -9.60 | 0.38   |        |        |        |
| Aghdasieh |       |       |       |        |        |      |       |      |     |        |         |         |       |        |
| Jan-20  | 77.20 | 23.80 | 9.77 | 74.57  | 5.67  | 49.79| 77.20 | 5.01 | -39.44| -25.74 | 8.69   | -56.89 | 1.77  | 5.49   |
| Feb-20  | 56.93 | 30.07 | 20.13 | 74.76  | 5.67  | 44.10| 55.52 | -9.83| -17.61| 15.61  | -0.21  | -57.91 | -10.88| -11.62 |
| Mar-20  | 44.62 | 20.14 | 33.76 | 60.86  | 5.45  | 33.41| -11.00| -26.91| 15.76 | 2.76  | -18.13 |        |        |        |
| Apr-20  | 53.71 | 16.55 | 42.06 | 47.97  | 5.63  | 23.41| 52.00 | 12.37| -30.49| 7.52  | -12.95 | -30.77 | 8.40  |        |
| May-20  | 80.35 | 13.16 | 61.47 | 60.06  | 7.00  | 44.43| 59.93 | 23.99| -35.28| 4.44  | -10.00 | 6.76  | -7.77 |        |
| Jun-20  | 111.10| 20.00 | 118.58| 74.13  | 7.63  | 51.13| 72.41 | 38.55| -7.42 | 53.73 | 4.10   | 21.82 | 2.70  |        |
| Jul-20  | 151.75| 23.57 | 150.91| 85.26  | 14.43 | 56.47| 78.33 | 50.45| -9.85 | 49.81 | 7.57   | 8.71  | 7.71  |        |
| Setad-e-Bohran |       |       |       |        |        |      |       |      |     |        |         |         |       |        |
| Jan-20  | 70.59 | 25.15 | 5.59 | 81.83  | 7.07  | 51.74| 71.19 | -18.40| -26.33| -71.37 | -2.02 | 2.36  | -5.62 | -20.98 |
| Feb-20  | 58.93 | 27.69 | 14.68 | 75.24  | 6.03  | 46.14| 57.85 | -28.06| -13.44| -50.35 | -5.82 | -3.05 | -3.47 | -30.16 |
| Mar-20  | 57.62 | 21.28 | 33.45 | 63.79  | 6.28  | 35.31| 53.97 | -10.89| -1.68 | -8.65 | -10.14 | 7.75  | -21.54| -20.53 |
| Apr-20  | 65.97 | 27.83 | 27.00 | 62.40  | 6.90  | 28.83| 54.63 | 10.50| 16.09 | -31.95| -14.15 | 28.52 | -20.07| -10.24 |
| May-20  | 79.03 | 23.90 | 44.00 | 68.74  | 7.69  | 45.23| 71.81 | -0.87 | -5.21 | -18.48| -7.11 | 33.84 | -6.99 | -9.95  |
| Jun-20  | 106.97| 28.07 | 91.71 | 81.65  | 11.79 | 53.16| 70.81 | 7.30 | -28.66| 6.83  | -1.76 | 69.46 | -2.37 | -14.03 |
| Jul-20  | 139.64| 22.76 | 139.44| 83.20  | 11.28 | 49.44| 65.64 | 26.67| -37.36| 32.23 | -6.03 | 45.42 | -14.69| -15.56 |
2. Materials and methods

In this study, the variation of air quality before, during, and after the lockdown period investigated. In order to evaluate these changes, the long-term concentrations of air pollutants and AQI (Air Quality Index) data were received from the Tehran Air Quality Control Company. This company is one of the organs under the supervision of the national Environmental Protection Organization and is a subset of Iran’s air pollution monitoring system. The data obtained from this national organization are completely controlled in terms of quality and are one of the main reference data cited in valid scientific and academic researches in this field of investigations.

For this purpose, three sites of Aghdasieh, Setad-e Bohran-District 7, and Shahr-e-Rey, situated in various parts of Tehran, were considered. Tehran as a sample of urban microclimate has a high level of air pollution and the largest gradients of air pollutants. Urban microclimate is defined as any set of observed local climate conditions in an area that notably different from neighbor rural areas (Toparlar et al., 2018; AMS, 2017). This type of climate is affected by urban features such as thermo-physical properties, layout and geometrical characteristics, air quality, buildings, population density and their activities, pavement type and heat sources existing in the area. This type of microclimate affects meteorological variables such as precipitation, air temperature, air pressure, wind direction and speed (Santamouris, 2013; Dimoudi et al., 2013).

The selected sites had an almost complete dataset for the selected dates. The study stations are located between 35°30' to 36° north and 51°30' to 52°00' east. Fig. 1 displays the geographical distribution and properties of the stations under study. The dataset period ranges from January 10 to July 10, 2020.

Located in the south of Tehran, Shahr-e-Rey is known as the air pollution hotspot of this city. The existence of hundreds of small and large industrial units, including cement factory and oil refinery, and the traffic of thousands of heavy vehicles are the main causes of the accumulation of pollutants in this region. Furthermore, due to the western prevailing winds in Tehran and the situation of a large part of industries and factories in the west of the city, most of the pollution is driven to the city center (Setade Bohran District 7). The mountains in the north and northeast of Tehran prevent air pollution from leaving the capital; consequently, the northeastern part of Tehran (i.e. Aghdasieh) is highly polluted.

For each site, 24-h mean concentrations of the main pollutants including PM2.5, PM10, NO2, SO2, O3, and CO between January 1 to July 30, 2016–2020 were used to calculate the five-year mean levels of each pollutant for each day before, during, and after the lockdown. The data were classified into three groups: pre-COVID-19 period (January 1th-February 18th), COVID-19 lockdown period (February 19–April 18st), and the first enacted state-wide social distancing order (April 19–July 30). The abovementioned pollutants in the selected stations were subjected to statistical analysis in the three periods. To indicate the pollutants’ time series variations and detect the effect of lockdown on air pollutants’ concentrations, we calculated the monthly mean bias between the monthly average of each pollutant and its monthly five-year average.

![Aghdasieh (2020)](image-url)

Fig. 2. The pollutant’s percentage Relative deviation in comparison with five-year monthly average (Aghdasieh).
The aim of this study was to show how partial lockdown affects pollutants’ concentrations in the lower atmosphere. It is hypothesized that pollutants significantly decline due to reduced traffic and temporary business closures.

3. Results and discussions

In Iran, the first cases of COVID-19 were reported on days with severe air pollution. In Tehran, the level of pollution in autumn and winter of 2020 was such that schools and universities were closed frequently. It is expected that lockdown and the imposition of traffic restrictions in dense and high-traffic urban areas such as Tehran will reduce the concentration of pollutants. Considering the statistical analysis, it is evident that the pollutants behave differently in the three study stations (Table 1 and Figs. 2–4).

In this study, pollutants’ concentrations at each station were monitored at three time intervals: before lockdown, during lockdown, and after lockdown. According to Fig. 2, it can be seen that in Aghdasieh station (northeast of Tehran) during the pre-lockdown period, the highest reduction in pollutants in comparison with the 5-year average is related to SO$_2$, which showed a relative percentage deviation (RPD) of $-56.89\%$ in January and $-57.91\%$ in February. The other pollutant that decreased significantly is CO with an RPD equal to $-39.77\%$ and $-17.61\%$ in January and February, respectively. The concentration of PM2.5 and PM10 increased slightly in January ($5.49\%$ and $1.77\%$, respectively) but decreased by $-10.88\%$ and $-11.62\%$ in February. The RPD of NO$_2$ increased by $8.69\%$ in January and decreased by $-0.21\%$ in February. Additionally, O$_3$ decreased by $-25.74\%$ in January and increased by $15.61\%$ in February. The overall air quality during the pre-lockdown was $5.01\%$ in January, which decreased by $-9.83\%$ in February.

During the partial lockdown period, which coincided with the Nowruz holiday, the highest amount of pollutant reduction was related to CO by $-26.91\%$ in March and $-30.49\%$ in April. As well, the RPD of PM10 dropped by about $-18.13\%$ and $-30.77\%$ in March and April, respectively. Moreover, O$_3$ increased by $15.76\%$ in March and $7.52\%$ in April. The overall air quality for the lockdown period decreased by $-11.0\%$ in March and increased by $12.37\%$ in April. Based on Fig. 2, it can be understood that the RPD of AQI increased over time because of the special circumstances arising from the implementation of the social distancing plan in order to counter COVID-19. Traffic control plan is one of the most important programs to deal with air pollution in metropolitan cities, especially Tehran. Accordingly, the use of private cars will diminish and people will be directed to using public transport. With the implementation of the social distancing policy, the traffic control plan was cancelled, resulting in increased pollution caused by the use of private cars.

Due to the sustained cancellation of the traffic plan in June and July, the rate of AQI increased sharply. Thus, during the post-lockdown period, the RPD of AQI increased by about $38.55\%$ in June and $50.45\%$ in July. In this period, the highest amount of pollutant increase was related to O$_3$, which was $53.73\%$ in June and $49.81\%$ in July. In addition, during the implementation of social distancing, PM pollutants, especially PM10, increased at a higher rate than in previous periods ($21.82\%$ in June and $8.71\%$ in July).

In Fig. 3, it can be seen that in Setad-e-Bohran station (central part of Tehran) during pre-lockdown period, the RPD of pollutants is negative or, in other words, pollutants’ concentration is reduced. This is because of the frequent lockdown due to severe air pollution in Tehran in this period. Setad-e-Bohran station is located in the central part of Tehran, which is a hotspot for businesses, universities, shopping malls, etc. Therefore, the concentration of pollutants is higher and their changes are more evident in this area. The highest reduction in pollutants compared to the 5-year average is related to O$_3$, with an RPD of $-71.37\%$ in January and $-50.35\%$ in February. The other pollutant that decreased significantly is PM2.5 that show reduction rate throughout the entire of time period. The

![Setad-e-Bohran (2020)](image-url)

Fig. 3. The pollutant's percentage Relative deviation in comparison with five-year monthly average (Setad-e-Bohran).
RPD of this pollutant was −20.98% and −30.16% in January and February, respectively. PM10 decreased slightly in January and February (−5.62% and −3.47%, respectively). Moreover, the RPD of NO\textsubscript{2}, SO\textsubscript{2}, CO, and AQI in the pre-lockdown period decreased in January and February.

During the partial lockdown period, the highest amount of pollutant reduction occurred in the case of O\textsubscript{3} by −8.65% in March and −31.95% in April. As well, the RPD of PM10 declined by 21.54% and −20.07% in March and April, respectively. Other pollutants which increased or decreased just slightly were CO and SO\textsubscript{2}. According to Fig. 3, it can be inferred that the RPD of SO\textsubscript{2} rose over time. Thus, the RPD of this gas soared from 7.75% in March to 28.52% in April. As well, the RPD of PM10 declined by 21.54% and −20.07% in March and April, respectively. Other pollutants which increased or decreased just slightly were CO and SO\textsubscript{2}.

According to Fig. 3, it can be inferred that the RPD of SO\textsubscript{2} rose over time. Thus, the RPD of this gas soared from 7.75% in March to 28.52% in April. This rising trend continued until the post-lockdown period, when SO\textsubscript{2} reached its maximum of 69.46% in June. Besides, AQI increased with continuing cancellation of the traffic control plan in June and July. Specifically, during the post-lockdown period, the RPD of AQI rose by 7.30% in June and 26.67% in July. In this period, the highest rate of pollutant increase was associated with SO\textsubscript{2} by about 69.46% in June and 45.42% in July. In addition, during the implementation of social distancing, the amount of PM pollutants decreased at the same rate as in the previous periods.

Fig. 4 shows that in Shahr-e-Ray station (southeast of Tehran) during the pre-lockdown period, the highest reduction in pollutants compared to the 5-year average was related to SO\textsubscript{2} with an RPD of −26.67% in January. The other pollutant that decreased significantly is CO, with an RPD of −23.73% in January. PM2.5 increased slightly in January by 4.62% and decreased by 9.89% in February. The RPD of NO\textsubscript{2} decreased by 13.59% in January and by 17.99% in February. Also, O\textsubscript{3} decreased by −12.72% in January and by −16.98% in February. The overall air quality in the pre-lockdown period was 4.62% in January and decreased by −9.83% in February.

The amount of CO was not recorded during the partial lockdown period. Hence, based on the available data, the highest pollutant growth rate was related to O\textsubscript{3} in April (−24.81%). As well, the RPD of NO\textsubscript{2} reduced about −14.06% and −19.26% in March and April respectively. PM10 decreased by −7.24% in March and by −13.10% in April. The overall air quality in the lockdown period decreased by −4.57% in March and −5.88% in April. According to Fig. 4, it can be seen that the Percentage Relative Deviation of AQI increased over time. This increase, as in other stations, is brought about by the special conditions resulting from both the implementation of social distancing policy in order to counter COVID-19 and the use of private cars instead of public transport. Thus, during the post-lockdown period, the RPD of AQI increased about 8.52% in June and 6.62% in July. In this period, the highest rate of pollutant increase was related to O\textsubscript{3}, with an RPD by 24.98% in June and 8.61% in July. In addition, during the implementation of social distancing, the rate of PM2.5 increased but the rate of PM10 declined.

Figs. 5 to 7 and Table 1 show the variations in AQI and other pollutants during the study period (January 1 to July 18) in three air pollution assessment stations of Tehran. Among the studied stations, Setad-e-Bohran and Shahr-e-Ray have the densest population. Table 1 reveals that the AQI in these two stations improved significantly during lockdown compared to the five-year monthly average (2016–2020). For example, in Shahr-e-Ray station AQI was reduced by −4.57% and −5.88% in March and April (partial lockdown
Fig. 5. Trend of daily average concentrations of air pollutants between 1st January and 30th July in Aghdasieh, Tehran.
Fig. 6. Trend of daily average concentrations of air pollutants between 1st January and 30th July in Shahr-e-Ray, Tehran.
Fig. 7. Trend of daily average concentrations of air pollutants between 1st January and 30th July in Setad-e-Bohran, Tehran.
period) in comparison to the five-year monthly average, respectively. This reduction could be seen in Figs. 5 and 6. In densely populated urban areas, the improvement in air quality is largely due to the reduction of traffic load, which was realized during partial lockdown period compared to the five-year monthly averages. Moreover, as shown in Fig. 6, the average monthly concentrations of other pollutants such as ozone, sulfur dioxide, PM2.5, and especially PM10 decreased during the lockdown in comparison to their 5-year monthly average.

The concentration trend of pollutants in Setad-e-Bohran station is presented in Fig. 7. As shown in this figure and Table 1, the greatest reduction of pollutants occurred in the case of O3 (31.95% in April) and PMs, especially PM10, which decreased by 21.54% and 20.07% in April and March, respectively, in comparison to its five-year average. The increase in SO2 during the lockdown period was 7.75% and 28.52% in April and March, respectively. The maximum reduction of NO2 levels during the lockdown was 14.15% in April.

Aghdasieh, another study station, behaved differently in response to the imposed conditions. According to Fig. 5, all pollutants increased to varying degrees during the lockdown compared to their 5-year average, but AQI and PM10 concentration decreased during the lockdown (Table 1).

After the lockdown, the AQI was expected to decrease at all three stations. The results showed that the average AQI in Shahr-e-Rey station was 79.8 μg.m\(^{-3}\) in the post-lockdown period, which is a – 0.29% reduction compared to its rate during the corresponding period from 2016 to 2019. This is because this area is far from the city’s main highways and densely populated areas. Aghdasieh station had the highest AQI (50.45%). As well, the average AQI in Setad-e-Bohran was 139.64 μg.m\(^{-3}\), which equals a 26.67% increase in July in comparison to its 5-year average of the study period. The concentration of pollutants was expected to fall after the lockdown period. Nevertheless, according to Figs. 5-7 and Table 1, compared with their 5-year average, the concentrations of all pollutants including CO, SO2, NO2, PM2.5, PM10, and O3 heightened to some extent after the lockdown ended. One of the most important reasons for this trend could be the elimination of the traffic control plan and the increasing use of private cars instead of public transport so as to practice social distancing.

Between January 1 and July 30, 2020, the highest O3 concentration occurred in Aghdasieh (150 μg.m\(^{-3}\)), while the lowest mean concentration of O3 (5.59 μg.m\(^{-3}\)) was observed in Setad-e-Bohran (Table 1). Ozone is a secondary pollutant whose concentration is affected by changes in NO concentrations and meteorological conditions. The highest NO2 concentration (85.26 μg.m\(^{-3}\)) was observed in Aghdasieh. NO2 ranged from 7.0 μg.m\(^{-3}\) in Aghdasieh to 19.1 μg.m\(^{-3}\) in Shahr-e-Rey (Table 1, Figs. 5 and 6). CO was another measured pollutant and its average concentration was 13.16 μg.m\(^{-3}\) in Aghdasieh. The highest rate of PM2.5 was 92.13 μg.m\(^{-3}\) in Shahr-e-Rey, and its lowest rate was recorded in Aghdasieh (52 μg.m\(^{-3}\)). Furthermore, the lowest and highest PM10 concentrations were 44.43 μg.m\(^{-3}\) in Aghdasieh and 71.03 μg.m\(^{-3}\) in Shahr-e-Rey. It could be suggested that the most important pollutant determining the value of AQI after the lockdown is PM2.5 in Shahr-e-Rey and O3 in Aghdasieh and Setad-e-Bohran. This is because Shahr-e-Rey is located in the south of Tehran, where the oil refinery is situated. Consequently, the type of pollutant affecting this area is different from the other two stations, which are mostly affected by pollutants caused by vehicles. Comparing average concentrations after the lockdown with their counterparts during the equivalent time period between 2016 and 2020, we found that higher O3 concentrations occurred after the lockdown. This was especially the case in Aghdasieh (53.73%) in June. The rise of O3 led to polluted days in June and July in Tehran and made it the major pollutant of the capital in the summer of 2020.

4. Conclusion

In this study, the effect of partial lockdown and the reduction of human activities on air pollutants’ concentration and air quality in Tehran was investigated. To this end, we analyzed the mean daily concentrations of seven pollutants including CO, O3, NO2, PM2.5, PM10, SO2 and AQI between January 1 and July 30, 2016–2020 in three stations in Tehran. (One of the most important advantages of our study is the use of measured data.) The results revealed that each year the air pollution in Tehran decreased gradually from February to April because of seasonal variations in the weather. As spring approaches and fossil fuel consumption declines, the air quality gets better. Therefore, when examining how the concentration of pollutants changes over time, one should consider meteorological and environmental conditions. In this study, to eliminate the effect of meteorological conditions, we compared the concentrations of pollutants to their 5-year average in the same time period. Another factor that affected the results of this study compared to other studies is the early reopening of businesses due to economic problems in society. Our results show that the air quality in three pollution stations of Tehran significantly improved during the COVID-19 lockdown. Besides, the concentrations of all pollutants except O3 decreased. The considerable increase in the O3 concentration could be due to the fall in PM, NO2, and VOCs.

Results showed that PM10 had maximum reduction among all pollutants, especially in Aghdasieh and Setad-e-Bohran stations (20–30%). Furthermore, the highest reduction in Shahr-e-Rey station is related to NO2, which may be related to the decrease in vehicular traffic as the rate of people with remote jobs increased and private travel was restricted. Also, O3 concentration increased significantly in Aghdasieh station, and AQI followed a considerably decreasing trend in 2020 compared to the pre-lockdown period. With the implementation of the social distancing policy, the traffic control plan was abandoned, resulting in increased pollution from the use of private cars. As the cancellation of the traffic plan continued in June and July, AQI increased sharply. During the implementation of social distancing, the amount of PM pollutants, especially PM10, rose at a higher rate than in previous periods except in Shahr-e-Rey, which could be due to the location of the oil refinery in the area and the presence of high concentration of PM2.5.

The results indicated the complicated status of air quality in Tehran. The lockdown imposed by COVID-19 served as an opportunity to find out the degree to which lowering urban transport parameters can enhance air quality. The results of this study exhibited that as long as there are other primary emission sources which dominate a city, pollution levels cannot be significantly reduced even during traffic-free periods.
Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Competing Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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