Impact of SARS-CoV-2 on Ambient Air Particulate Matter in Tehran

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ABSTRACT

The pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has indirectly produced both positive and negative effects on the environment, particularly in terms of air quality. Our study aimed to determine these effects in the city of Tehran by comparing the ambient PM_{2.5} and PM₁₀ levels recorded at 22 air quality monitoring stations during the outbreak (20 February–2 April 2020) with those from the corresponding period last year (20 February–3 April 2019). Contrary to expectation, the average concentrations of both the PM_{2.5} and the PM₁₀ were markedly higher during the former, increasing by 20.5% and 15.7%, respectively, for the first month of the outbreak (20 February–19 March 2020) and by 23.5% and 20.0% for the subsequent Nowruz New Year holidays (from late March till early April), which resulted in overall increases of 20.5% and 16.5% for the entire period. The non-integrated responses to the pandemic, including the failure to close administrative centers and, in particular, the recommendation to maintain social distancing by reducing public transportation use (prompting citizens to travel by private vehicle), have worsened the ambient air quality in Tehran, providing an exceptional opportunity to evaluate the direct/indirect influence of air quality policies and emission control measures on PM_{2.5} and PM₁₀. Because of the significant association between the lethality of coronavirus disease 2019 (COVID-19) and exposure to ambient air pollution, the rise in airborne PM_{2.5} during this outbreak may increase the mortality rate of SARS-CoV-2.

Keywords: SARS-CoV-2; COVID-19; Ambient air quality; PM_{2.5}; PM₁₀; Tehran.

INTRODUCTION

The first official announcement of death in Iran due to the coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was reported on 19 February 2020 (Faridi *et al.*, 2020; Takian *et al.*, 2020). As of 20 February, restricting social contact, reducing public transportation, closing down administrative centers, universities, schools, businesses and religion public places were recommended by the Iran Ministry of Health and Medical Education, but we observed two or three weeks' time lag to implement the aforementioned recommendations (not lockdown) in Iran, specifically in Tehran megacity.

Compared to other megacities around the world, particularly in China, Italy, Spain, France, Germany, England and USA (Frontera *et al.*, 2020; Tobías *et al.*, 2020; Zambrano-Monserrate *et al.*, 2020), lockdown measures were not adopted during the SARS-CoV-2 outbreak in Tehran. As a result, Tehran with the highest confirmed COVID-19 cases and associated deaths experienced an emergency situation during this outbreak and ranked the first place among all cities in Iran (Faridi *et al.*, 2020). Tehran, with the daytime population of more than 12 million people and about 9 million residents, is the capital and most populous city of Iran. The city has faced high levels of ambient air PM₁₀ and PM_{2.5} during the past few decades due to transportation of more than 4 million vehicles in the megacity, as well as its proximity to a large number of industrial sources (Heger and Sarraf, 2018; Shamsipour *et al.*, 2019; Yousefian *et al.*, 2020). During the SARS-CoV-2 outbreak in Tehran in particular over the first month, the reduction of using the public transportation recommended by public health bodies at the national and subnational levels to minimize the close contact led to a remarkable increases of private transportation. The aim of this study was to

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compare the concentrations of ambient air PM_{10} and $PM_{2.5}$ in Tehran during the SARS-CoV-2 outbreak and over the same period of last year.

METHODS

We obtained hourly air quality data of PM_{10} and $PM_{2.5}$, as the most common ambient air pollutants in Tehran, from 22 active ambient air quality monitoring stations (AQMSs; Fig. 1) belonging to the Tehran Air Quality Control Company for the period of 20 February–2 April 2020 as the SARS-CoV-2 outbreak and 20 February–3 April 2019 as the same period of last year. The air quality data processing was conducted based on our previous publications elsewhere (Faridi et al., 2018, 2019; Yousefian et al., 2020). After air quality data processing, 15 and 16 eligible AQMSs were used to calculate the averages of ambient $PM_{2.5}$ and PM_{10} in Tehran at the city level, respectively. The results were compared in three defined scenarios as follows: 1) the period between 20 February 2020 and 19 March 2020 (the first month of SARS-CoV-2 outbreak in Iran) in comparison to the same period of last year (20 February–20 March 2019); 2) Nowruz Iranian New Year holidays from 20 March 2020 to 2 April 2020 compared to 21 March–3 April 2019 and 3) during the whole study period, 20 February–2 April 2020, in comparison to 20 February–3 April 2019. In addition to the comparing of the results at the city level, we investigated the aforementioned scenarios at two stations with the highest (Shad abad) and lowest (Zone 2) ambient air particulate matter concentrations (Faridi et al., 2019). To validate the results of the impact of SARS-CoV-2 on ambient air $PM_{2.5}$ and PM_{10} in Tehran, the most important meteorological parameters, including wind speed, wind direction, temperature, precipitation and the number of rainy days, were investigated at three mentioned scenarios during the SARS-CoV-2

outbreak in comparison to the same period of last year. In fact, meteorological parameters were used for qualitative interpretation of the effect of SARS-CoV-2 on the ambient $PM_{2.5}$ and PM_{10} level. The purpose of this comparison was to make sure the unfavorable or stagnant meteorological conditions did not indirectly increase the ambient air $PM_{2.5}$ and PM_{10} concentrations during the outbreak in the city (Dantas et al., 2020; Kerimray et al., 2020).

RESULTS AND DISCUSSION

Tables 1–3 compare the ambient air $PM_{2.5}$ and PM_{10} concentrations at three different scenarios. As shown in Table 1, the average concentration of $PM_{2.5}$ and PM_{10} increased from 24.0 and 57.5 $\mu g m^{-3}$ during the same period of last year to 28.9 and 66.5 $\mu g m^{-3}$ over the first month of SARS-CoV-2 outbreak in Tehran, respectively. In fact, an increase of 5.0 $\mu g m^{-3}$ (20.4%) and 9.0 $\mu g m^{-3}$ (15.7%) in average concentrations of ambient $PM_{2.5}$ and PM_{10} was experienced during the first month of SARS-CoV-2 outbreak in comparison to the same period of last year in Tehran. As the most polluted AQMS in Tehran according to our previous study (Faridi et al., 2019), Shad abad ambient air monitoring station recorded the average concentrations of ambient $PM_{2.5}$ and PM_{10} equal to 37.6 and 89.5 $\mu g m^{-3}$ in the first month of SARS-CoV-2 outbreak, whereas these figures for ambient $PM_{2.5}$ and PM_{10} were 28.4 and 70.1 $\mu g m^{-3}$ in the same period of last year, respectively. Zone 2 AQMS in north of the city which normally recorded the lowest amount of pollutants (Faridi et al., 2019) experienced a noticeable increase of nearly 75.5% and 49.0% in the average concentrations for ambient $PM_{2.5}$ and PM_{10} over the first month of SARS-CoV-2 outbreak compared to the same period of last year. SARS-CoV-2 outbreak caused a significant increase equal to 3.0 and 5.0 $\mu g m^{-3}$ in ambient $PM_{2.5}$ and PM_{10} average concentrations

Fig. 1. Spatial distribution of air quality monitoring stations throughout Tehran.

Table 1. Ambient PM_{2.5} and PM₁₀ concentrations in Tehran during the SARS-CoV-2 outbreak (20 February–19 March 2020) in comparison to their concentrations in the same period of last year (20 February–20 March 2019) as the first scenario (the first month of SARS-CoV-2 outbreak in Iran).

AQMS	PM _{2.5}	PM _{2.5}	PM ₁₀	PM ₁₀	Variation for PM _{2.5}		Variation for PM ₁₀	
	SARS-CoV-2 outbreak	The same period of last year	SARS-CoV-2 outbreak	The same period of last year	µg m ⁻³	(%)	µg m ⁻³	(%)
Shad abad								
25 th percentile	22.0	17.0	58.0	46.0	+5.0	+29.41	+12.0	+26.09
Average	37.6	28.4	89.5	70.1	+9.2	+32.39	+19.4	+27.67
50 th percentile	32.0	25.0	82.0	64.0	+7.0	+28.00	+18.0	+28.13
75 th percentile	48.0	37.0	115.0	88.0	+11.0	+29.73	+27.0	+30.68
Zone 2								
25 th percentile	14.0	9.0	45.0	30.0	+5.0	+55.56	+15.0	+50.00
Average	27.0	15.4	60.9	40.9	+11.6	+75.32	+20.0	+48.90
50 th percentile	22.0	14.0	58.0	39.0	+8.0	+57.14	+19.0	+48.72
75 th percentile	35.0	19.0	77.0	49.0	+16.0	+84.21	+28.0	+57.14
Tehran								
25 th percentile	18.0	16.9	47.7	43.2	+1.1	+6.51	+4.5	+10.42
Average	28.9	24.0	66.5	57.5	+4.9	+20.42	+9.0	+15.65
50 th percentile	25.5	22.9	63.6	55.3	+2.6	+11.35	+8.3	+15.01
75 th percentile	36.6	29.6	82.0	69.4	+7.0	+23.65	+12.6	+18.16

Table 2. Ambient PM_{2.5} and PM₁₀ concentrations in Tehran during the SARS-CoV-2 outbreak (20 March–2 April 2020) in comparison to their concentrations in the same period of last year (21 March–3 April 2019) as the second scenario (Nowruz Persian New Year holidays).

AQMS	PM _{2.5}	PM _{2.5}	PM ₁₀	PM ₁₀	Variation for PM _{2.5}		Variation for PM ₁₀	
	SARS-CoV-2 outbreak	The same period of last year	SARS-CoV-2 outbreak	The same period of last year	µg m ⁻³	(%)	µg m ⁻³	(%)
Shad abad								
25 th percentile	10.0	9.0	24.0	23.0	+1.0	+11.11	+1.0	+4.35
Average	16.7	13.8	37.5	32.7	+2.9	+21.01	+4.8	+14.68
50 th percentile	14.0	12.0	34.0	30.0	+2.0	+16.67	+4.0	+13.33
75 th percentile	21.0	17.0	47.0	39.0	+4.0	+23.53	+8.0	+20.51
Zone 2								
25 th percentile	7.0	5.0	22.0	13.0	+2.0	+40.00	+9.0	+69.23
Average	13.3	8.1	32.5	21.5	+5.2	+64.20	+11.0	+51.16
50 th percentile	11.0	7.0	30.0	19.0	+4.0	+57.14	+11.0	+57.89
75 th percentile	17.0	11.0	39.0	26.0	+6.0	+54.55	+13.0	+50.00
Tehran								
25 th percentile	9.1	8.0	19.5	18.7	+1.1	+13.75	+0.8	+4.28
Average	14.2	11.5	30.1	25.1	+2.7	+23.48	+5.0	+19.92
50 th percentile	12.2	11.0	28.9	23.6	+1.2	+10.91	+5.3	+22.46
75 th percentile	18.4	13.7	36.3	29.0	+4.7	+34.31	+7.3	+25.17

in Nowruz New Year holidays compared to Nowruz time of last year (Table 2). In fact, the SARS-CoV-2 outbreak led to a rise of about 23.5% and 20.0% in the ambient air PM_{2.5} and PM₁₀ concentrations in comparison to the last two Nowruz New Year holidays. Moreover, the SARS-CoV-2 caused a growth of 3.0 and 5.0 µg m⁻³ in the ambient air PM_{2.5} and PM₁₀ concentrations at Shad abad AQMS, whereas the average concentrations of ambient PM_{2.5} and PM₁₀ increased from 8.1 and 21.5 µg m⁻³ to 13.3 and 32.5 µg m⁻³ at Zone 2 AQMS, respectively (Table 2). As can be seen in Table 3, the average concentrations of ambient PM_{2.5} at Shad

abad and Zone 2 AQMSs increased by 4.1 (20.5%), 7.1 (30.1%) and 9.5 (72.5%) µg m⁻³ during the SARS-CoV-2 outbreak in the third scenario (the whole study period) in comparison to the same period of last year. In general, over the SARS-CoV-2 outbreak in Tehran, the ambient PM₁₀ concentrations increased from 46.9, 34.2 and 57.9 µg m⁻³ to 54.6, 51.9 and 72.6 µg m⁻³ for Tehran city, Zone 2 and Shad abad AQMSs, a considerable rise equal to 16.4%, 51.7% and 25.4%, respectively. Detailed information (25th, 50th and 75th percentiles) regarding the ambient PM_{2.5} and PM₁₀ concentrations in Tehran during the SARS-CoV-2 outbreak

days is presented in Tables 1–3. Detailed information on the meteorological parameters (wind speed, wind direction, temperature (minimum, average, maximum), precipitation and the number of rainy days) during the investigated scenarios is summarized in Table 4. As shown in Table 4, the average temperature during the three scenarios of SARS-CoV-2 outbreak was 12.3°C, 12.2°C and 12.2°C, while it was 9.4°C, 11.4°C and 10.1°C during the same period of last year, respectively. Additionally, the average of wind speed during the three scenarios of SARS-CoV-2 (3.0, 4.0 and 3.2 m s⁻¹ for Scenario I, II and III, respectively) was approximately similar to those figures over the same period of last year (3.0, 3.3 and 3.4 m s⁻¹). The number of rainy days during the three

scenarios of SARS-CoV-2 outbreak was 8.0, 8.0 and 16.0 days, while it was 5.0, 6.0 and 11.0 days at the same period of last year. Lastly, the prevailing wind direction during the periods under investigation was from the west of Tehran city (Fig. 2).

This study critically highlights the negative indirect effect of SARS-CoV-2 outbreak on the average concentration of ambient air PM_{2.5} and PM₁₀ as the most notable air pollutants in Tehran. We investigated the changes in ambient air PM_{2.5} and PM₁₀ concentrations due to the SARS-CoV-2 outbreak compared to the same period of last year through three different time period scenarios. The first scenario of investigation was across the first month of SARS-CoV-2 outbreak from

Table 3. Ambient PM_{2.5} and PM₁₀ concentrations in Tehran during the SARS-CoV-2 outbreak (20 February–2 April 2020) in comparison to their concentrations in the same period of last year (20 February–3 April 2019) as the third scenario (the whole study period).

AQMS	PM _{2.5}	PM _{2.5}	PM ₁₀	PM ₁₀	Variation for PM _{2.5}		Variation for PM ₁₀	
	SARS-CoV-2 outbreak	The same period of last year	SARS-CoV-2 outbreak	The same period of last year	µg m ⁻³	(%)	µg m ⁻³	(%)
Shad abad								
25 th percentile	16.0	12.0	38.8	32.0	+4.0	+33.33	+6.8	+21.25
Average	30.7	23.6	72.6	57.9	+7.1	+30.08	+14.7	+25.39
50 th percentile	25.0	20.0	63.0	50.0	+5.0	+25.00	+13.0	+26.00
75 th percentile	36.0	31.0	99.2	75.0	+5.0	+16.13	+24.2	+32.27
Zone 2								
25 th percentile	10.0	7.0	32.0	20.0	+3.0	+42.86	+12.0	+60.00
Average	22.6	13.1	51.9	34.2	+9.5	+72.52	+17.7	+51.75
50 th percentile	18.0	12.0	48.0	32.0	+6.0	+50.00	+16.0	+50.00
75 th percentile	29.0	17.0	67.0	44.0	+12.0	+70.59	+23.0	+52.27
Tehran								
25 th percentile	13.3	11.7	31.6	27.3	+1.6	+13.68	+4.3	+15.75
Average	24.1	20.0	54.6	46.9	+4.1	+20.50	+7.7	+16.42
50 th percentile	20.6	17.9	49.9	44.6	+2.7	+15.08	+5.3	+11.88
75 th percentile	31.4	26.6	74.6	62.2	+4.8	+18.05	+12.4	+19.94

Table 4. Meteorological parameters during the SARS-CoV-2 and the same period of last year at three scenarios.

Statistic	SARS-CoV-2 outbreak						The same period of last year (Scenario I)					
	WS	T	T-min	T-max	Precipitation	Rainy days	WS	T	T-min	T-max	Precipitation	Rainy days
25 th percentile	2.0	9.0	5.5	14.5	0.0	8.0	2.0	6.7	3.5	12.4	0.0	5.0
Average	3.0	12.3	7.6	16.7	3.1		3.0	9.4	5.2	14.0	0.8	
50 th percentile	3.0	12.3	7.2	16.9	0.0		3.0	9.4	5.0	14.4	0.0	
75 th percentile	4.0	15.9	10.9	19.6	0.3		5.0	11.9	7.0	14.8	0.01	
S	SARS-CoV-2 outbreak						The same period of last year (Scenario II)					
	WS	T	T-min	T-max	Precipitation	Rainy days	WS	T	T-min	T-max	Precipitation	Rainy days
25 th percentile	2.0	9.8	7.0	15.4	0.0	8.0	2.0	9.4	6.8	12.4	0.0	6.0
Average	4.0	12.2	7.8	16.5	4.5		3.3	11.4	7.9	15.3	5.5	
50 th percentile	3.7	12.5	7.3	16.4	0.3		3.0	11.2	8.3	15.6	0.01	
75 th percentile	4.0	14.7	9.6	18.3	9.0		4.0	13.8	9.4	17.4	13.4	
S	SARS-CoV-2 outbreak						The same period of last year (Scenario III)					
	WS	T	T-min	T-max	Precipitation	Rainy days	WS	T	T-min	T-max	Precipitation	Rainy days
25 th percentile	2.0	9.2	5.6	14.6	0.0	16.0	2.0	7.6	4.0	12.4	0.0	11.0
Average	3.2	12.2	7.6	16.6	3.6		3.4	10.1	6.1	14.5	2.5	
50 th percentile	3.0	12.3	7.2	16.6	0.0		3.0	10.2	6.2	14.6	0.0	
75 th percentile	4.0	15.6	9.6	19.2	1.2		4.0	12.7	8.6	15.8	0.2	

S: wind speed (m s⁻¹); T: temperature (°C); T-min: minimum temperature (°C); T-max: maximum temperature (°C).

Fig. 2. Wind rose plot for Tehran during the SARS-CoV-2 and the same period of last year at three scenarios.

20 February 2020 to 19 March 2020. Second and third scenarios were over the Nowruz New Year holidays as the longest holiday in Iran (two weeks from late March to early April each year) and the whole study period (20 February–2 April 2020), respectively. In addition to studying the average

concentrations of ambient air $PM_{2.5}$ and PM_{10} in Tehran at the city level, their concentrations also were compared at two AQMSs (Zone 2 and Shad abad) located at the highest and lowest socioeconomic regions of the city (Rohani-Rasaf et al., 2018). Based on our analysis, the average of ambient

air $PM_{2.5}$ and PM_{10} concentrations noticeably increased at the city level during the three scenarios of SARS-CoV-2 outbreak in comparison to the same periods of last year. Furthermore, we observed that the increase of ambient air $PM_{2.5}$ and PM_{10} concentrations at Zone 2 AQMS was higher than those of Shad abad station. Nevertheless, Zone 2 station was ranked as the least polluted location throughout Tehran based on our previous publication (Faridi *et al.*, 2019). In fact, the growth of ambient air $PM_{2.5}$ and PM_{10} concentrations at Shad abad AQMS (as the most polluted location in Tehran; Faridi *et al.*, 2019) during the SARS-CoV-2 outbreak was much lower than the Zone 2 station. The average temperature during the three scenarios of SARS-CoV-2 outbreak was higher than those figures during the same period of last year (Table 4). Additionally, the average of wind speed during the three scenarios of SARS-CoV-2 was approximately similar to its figure over the same period of last year. The number of rainy days during the three scenarios of SARS-CoV-2 outbreak was higher than the same periods of last year. Lastly, the prevailing wind direction during the periods under investigation was exactly the same. These results show that the meteorological conditions did not affect the ambient $PM_{2.5}$ and PM_{10} concentrations during the SARS-CoV-2 outbreak in Tehran compared to the same period of last year. In fact, the increase of ambient $PM_{2.5}$ and PM_{10} concentrations during the SARS-CoV-2 outbreak can be attributed to the numerous potential socioeconomic factors and governmental recommendations. For example, some countries recommended and immediately implemented lockdown measures to reduce or prevent the SARS-CoV-2 outbreak (Dutheil *et al.*, 2020; Frontera *et al.*, 2020; Tobías *et al.*, 2020; Zambrano-Monserrate *et al.*, 2020); however, Iran faced two or three weeks' time lag to implement the restricting precautions (not lockdown measures) recommended by public health bodies at national and subnational levels. It was also endorsed by authorities/policy-makers to avoid public transportation (specifically metro lines and Bus Rapid Transit system with daily usage of between four and five million passengers as the most crowded public transportation sectors in Tehran; Heger and Sarraf, 2018) and the use of private cars might potentially lead to worse ambient air quality status during the SARS-CoV-2 outbreak in Tehran. Previously conducted studies have reported that there is a strong association between short- and long-term exposures to ambient air pollution, particularly $PM_{2.5}$, and high lethality of SARS-CoV-2 (Conticini *et al.*, 2020; Dutheil *et al.*, 2020; Frontera *et al.*, 2020; Yongjian *et al.*, 2020). Consequently, we worry that the observed rise in the ambient air $PM_{2.5}$ and PM_{10} concentrations might increase the lethality of SARS-CoV-2 outbreak in Tehran. We did not evaluate the increase in the number of private cars directly, but the potential reason for such increase in $PM_{2.5}$ and PM_{10} level could be attributed to the usage of private cars. In agreement with the mentioned reason, previously conducted studies in Tehran have reported that mobile sources and associated secondary aerosols as the most notable sources of ambient $PM_{2.5}$ air pollution are responsible for approximately 75–80% of $PM_{2.5}$ emissions in Tehran (Taghvaei *et al.*, 2018a, b). Compared to our results, Zambrano-Monserrate *et al.* (2020) and Tobías

et al. (2020) have reported that ambient air pollution markedly reduced in 368 cities in China and Barcelona (Spain) during the SARS-CoV-2 outbreak because of immediate adoption of lockdown and quarantine measures. Compared to the outbreak of COVID-19 during February 2020, the average concentrations of ambient air $PM_{2.5}$, PM_{10} , SO_2 , CO, and NO_2 in the three cities of Wuhan, Jingmen, and Enshi in central China were 30.1%, 40.5%, 33.4%, 27.9%, and 61.4% lower than those levels in February 2017–2019, respectively (Xu *et al.*, 2020a). In fact, the adopted and immediately implemented appropriate policies led to reduced ambient air pollutants in central China during the SARS-CoV-2 outbreak. Jain and Sharma (2020) showed that the implementation of social and travel lockdown directed to a decline in the ambient air pollutants ($PM_{2.5}$, PM_{10} , NO_2 and CO) in megacities of India. Xu *et al.* (2020b) showed that lockdown related to COVID-19 pandemic in Anqing, Hefei, and Suzhou (China) declined the ambient air pollutants of $PM_{2.5}$, PM_{10} , SO_2 , CO and NO_2 equal to 46.5%, 48.9%, 52.5%, 36.2%, and 52.8% compared to the same period of last three years. Similar to our study, Mohd Nadzir *et al.* (2020) stated the increase of ambient $PM_{2.5}$ and PM_{10} concentrations during the Movement Control Orders (MCOs) as a lockdown measure in Kota Damansara, Malaysia. They reported that the ambient $PM_{2.5}$ and PM_{10} concentrations increased up to 60% and 9.7%, respectively (Mohd Nadzir *et al.*, 2020).

CONCLUSIONS

Contrary to expectation, the levels of ambient $PM_{2.5}$ and PM_{10} in Tehran did not decrease during the SARS-CoV-2 outbreak. As we did not assess the change in concentration for gaseous air pollutants, further studies are necessary to determine the overall status of ambient air quality in this city. Crises such as this pandemic offer the opportunity to evaluate the direct/indirect effects of environmental policies and socioeconomic factors on emissions and air quality.

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