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Impact of the COVID-19 Outbreak on Air Pollutants, in 2020 Compared to the Same Period in 2019 in Qom, Iran

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A R T I C L E I N F O

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ABSTRACT

Introduction: The present study aimed to investigate the change of air pollutants in 2020 in Qom compared to the same period in 2019 in five scenarios.

Materials and Methods: The hourly air quality data was obtained from air quality monitoring stations of Qom Environmental Protection Organization (EPO). The meteorological parameters were obtained from Iranian Meteorological Organization website. The data were analyzed using Excel, SPSS, and WRPLOT view.

Results: In the first month of the COVID-19 crisis, NO_2, SO_2, and CO decreased by 26.4, 39, and 0.2 μg/m^3 compared to same period in 2019, respectively; however, $PM_{2.5}$ and O_3 increased by 7.1 and 2.3 μg/m^3, respectively. In Iranian Nowruz holidays, an increase of 2.9 μg/m^3 in O_3 mean concentration and a decrease of 8.1, 23.8, 22.8, and 0.2 μg/m^3 in mean concentration of PM_{10}, NO_2, SO_2, and CO were experienced. The prevailing wind direction during the 2020 in each scenario was from the west of Qom city.

Conclusion: Gaseous pollutants decreased during the crisis, but particulate pollutants increased slightly compared to the same period in 2019. The lockdown may have had the most impact in decreasing pollutants. A slight increase in wind speed from the west could be a factor in increasing particles. This crisis provided an opportunity to assess the role of policies, such as traffic reduction plans or discarding worn-out cars or urban management to improve air quality.

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Introduction

The COVID-19 pandemic has had a huge impact on human health on a global scale [1]. Since the identification of SARS-CoV-2, there has been a swift enhancement in COVID-19 confirmed cases [2]. The first death report in Iran due to the COVID-19 was reported on 19 February 2020 [3]. To control the spread of COVID-19, diverse studies have been conducted to probe significant factors affecting the transmission of SARS-CoV-2 [4] and health policies have been adopted against SARS-CoV-2 among countries worldwide [5]. Given that aggregation has a substantial impact on the COVID-19 pandemic [4], lockdown restrictions have been affirmed to be one of the helpful response measures in plenty of countries [6]. This lockdown applies restrictions which lessen emissions from transportation and industries [7], limitations like dispensable travels in and out of cities, interruption of all transports, and fasten of factories. Due to these traffic and industrial restrictions, air pollution has decreased in many cities and countries [6]; however, following orders and lockdown interventions may cause inconveniences, including the sick building syndrome [5,8].

Air pollution has become a striking problem all over the world, especially in developing countries [7]. Extensive research studies around the world have shown that air pollution threatens young people due to cardiovascular [9] and respiratory diseases [10]. Studies have shown that with the increase in particles as a result of increasing lakes drying around cities, mortality due to air pollution has also increased [11] and in some cities, people are exposed to $PM_{2.5}$ higher than the WHO daily guideline in 58% to 96% of the days of a year [12]. There is inevitable evidence that air pollution is associated with premature mortality [13] and harmful health effects [14]. A study [15] estimated the relationship between higher concentrations of air pollutants and a higher risk of COVID-19. A review study in Spain found that chronic exposure to certain air pollutants complicates the condition of COVID-19 patients and makes recovery more difficult [16]. Scientific evidence highlighted the important contribution of chronic exposure to air pollution on the COVID-19 spread and mortality [17]. The results of a study in Italy, that examined the association between NO_2 levels and COVID-19 cases, showed that there was no definite relationship between NO_2 increase and COVID-19 [18].

There have been remarkable environmental evolutions due to actions taken during the COVID-19 pandemic like reduction in air pollutants [19]. The European Space Agency (ESA) satellite imagery demonstrated a notable deterioration in NO_2 emissions in northern Italy [6]. The Institute of Environmental Science and Meteorology (IESM) estimated a reduction in $PM_{2.5}$ and PM_{10}, as a result of a decline in utilizing machines that crush and grind [20]. Studies have shown that lower temperature may increase the risk of transmitting both MERS and SARS [21,22] and MERS-CoV is more likely to arise in dry conditions [22]. On the other hand, a study in Italy showed that the effectiveness of restrictions appears after about two weeks, and if the restrictions are applied more severely, this interval can be reduced [23].

The changes in this lockdown period may provide a vision into achievement of air quality enhancement [7]; therefore, the changes of four gaseous and two particulate air pollutants in Qom, Iran were investigated and was compared with the same time of 2019. Most COVID-19-based studies have discussed health aspects. Few studies have examined the environmental aspects of the virus. The present study investigated the environmental effects of pandemic, which is the first study in Qom.

Materials and Methods

Study area

This study was conducted in Qom city, which is located at 130 km southwest of Tehran with 218.14 km^2 area. It has a dry and semi-dry climate in the central region of Iran with an annual rainfall of 161 mm [24-28] (Figure 1).

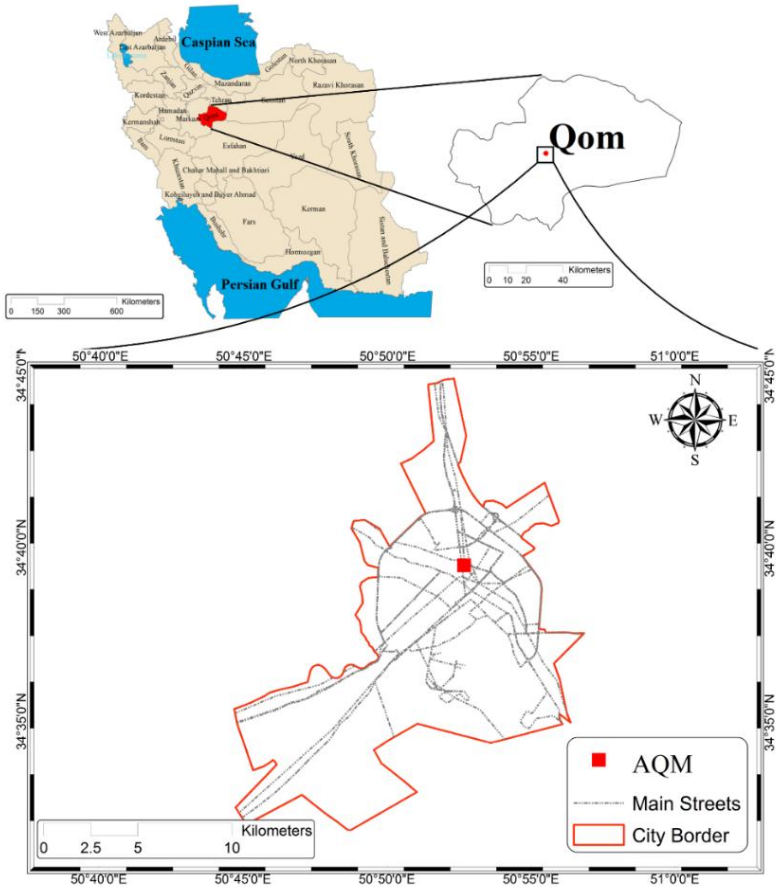

Figure 1: Study area

Data collection and analysis

The hourly air quality data was obtained from air quality monitoring stations of Qom Environmental Protection Organization (EPO) [29]. Qom city has three stations to measure air pollution. Due to the lack of complete information in the past few years, only the information of Emam station was included in the study.

The meteorological parameters were obtained from Iranian Meteorological Organization website [30]. The study period was from 21 January to 20 May 2020 and the same period in 2019.

After air quality processing, such as outlier data cleaning, sheet classification, and time standardization, the data was used to analyze 6 air pollutants during the study. The results were compared in 5 scenarios:

1) From 21 January to 19 February 2020 (one month before the COVID-19 outbreak) compared to the same period in 2019.

2) From 20 February to 19 March 2020 (the first month of the COVID-19 outbreak in Iran) compared to the same period in 2019.

3) From 20 March to 19 April 2020 (Iranian Nowruz holidays) compared to the same period in 2019.

4) From 20 April to 20 May 2020 (one month after Nowruz holidays) compared to the same period in 2019.

5) From 20 February to 20 May 2020 (the whole study period) compared to the same period in 2019.

To validate the results and ensure the impact of the COVID-19 outbreak on the ambient air, the most important meteorological parameters, such as precipitation, wind direction, wind speed, temperature, and number of rainy days in the five mentioned scenarios were investigated to compare with the same period in 2019. The purpose of this comparison was to ensure that adverse weather conditions did not indirectly affect the concentration of pollutants during the outbreak in Qom [31,32]. The data were analyzed using Microsoft Excel 2016, IBM SPSS (version 23) and WRPLOTview (version 8.0.2). WRPLOT View is a fully operational wind rose program for your meteorological data. A wind rose demonstrates the frequency of occurrence of winds in each of the specified wind direction sectors and wind speed classes for a specific location and time [33]. The data comparison between 2020 and 2019 was carried out using the Wilcoxon test and paired t-test.

Ethical issue

The present study was approved by Ethics Committee of Qom University of Medical Sciences (ID: IR.MUQ.REC.1400.051).

Results

Table 1 shows detailed information of air pollutants changes in the 5 defined scenarios. According to Table 1, the mean concentration of $PM_{2.5}$ and NO_2 were significantly different (p-value <0.05) from the same period in previous year. In fact, an increase of 5.6 µg/m^3 (46.3%) in mean concentration of $PM_{2.5}$ and a decrease of 30.9 µg/m^3 (80.4%) in mean concentration of NO_2 were experienced from 21 January to 19 February 2020 (Ozone data for the same period of 2019 was not recorded). In the first month of the COVID-19 crisis, all pollutants except PM_{10} were significantly different from 2019. NO_2, SO_2, and CO decreased by 26.4, 39, and 0.2 µg/m^3 (79.3%, 94.7%, 14.3%) compared to the same period in 2019, respectively. On the other hand, $PM_{2.5}$ and O_3 increased by 7.1 and 2.3 µg/m^3 (70.3%, 22.8%), respectively. From 20 March to 19 April 2020 (Iranian Nowruzholidays), an increase of 2.9 µg/m^3 (27.3%) in mean concentration of O_3 and a decrease of 8.1, 23.8, 22.8, and 0.2 µg/m^3 (20.8%, 83.8%, 66.9%, 20%) in mean concentration of PM_{10}, NO_2, SO_2, and CO were experienced in comparison to the same period in 2019, respectively. The mean concentration of $PM_{2.5}$ had no significant difference from the same period in previous year. NO_2, SO_2, and CO was significantly different from 20 April to 20 May 2020 (scenario 4). The mean concentration of NO_2 and CO decreased by 22.2 and 0.1 µg/m^3 (75.5%, 10%), respectively and the mean concentration of SO_2 increased by 9.6 µg/m^3 (114.2%). In scenario 5, from 20 February to 20 May 2020 (the whole study period), the mean concentration of all pollutants except NO_2 and SO_2 had no significant difference in comparison to the same period in 2019. According to the table, a decrease of 24.1 µg/m^3 (79.5%) and 16.9 µg/m^3 (65.4%) in mean concentration of NO_2 and SO_2 was experienced, respectively. Figures 2 to 6 demonstrate the wind direction in 5 defined scenarios. The prevailing wind direction during the 2020 in each scenario was from the west of Qom city. Detailed information on the meteorological parameters, including temperature (average, maximum, and minimum), wind speed, sum of precipitation and number of rainy days is demonstrated in Table 2. The average temperature during the 5 scenarios of the COVID-19 crisis was 6.2°C, 12.5°C, 14.1°C, 21.9°C, and 13.7°C (for scenarios 1, 2, 3, 4 and 5, respectively), whereas it was 4.1°C, 6.7°C, 11.4°C, 15.3°C and 8.9°C (for scenarios 1, 2, 3, 4, and 5, respectively) during the same period in 2019. The average wind speed during the 5 scenarios of the COVID-19 crisis (3.19, 2.60, 2.87, 3.14, and 2.95 m/s for scenarios 1, 2, 3, 4, and 5, respectively) was almost the same as 2019 (2.21, 2.64, 2.42, 2.38, and 2.41 for scenarios 1, 2, 3, 4, and 5, respectively). According to this table, the percentage changes of average temperature in scenarios 2, 3, and 5 was 85.82, 23.59, and 45.29%, respectively. This indicates that the average temperature in March 2020 increased by 85.82%. The difference in average wind speed in scenarios 2, 3, and 5 was observed as 1.5, 18.6, and 22.4%, respectively. Finally, Figure 7 summarizes the percentage changes of 4 gaseous pollutants (SO_2, NO_2, CO, and O_3) and 2 particulate pollutants (PM_{10}, $PM_{2.5}$) for 5 scenarios.

Table 1: Comparison of scenarios of 2020 with the same period in 2019

Variable	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	2020 Median (24^{th}-75^{th})	2019 Median (24^{th}-75^{th})	2020 Median (24^{th}-75^{th})	2019 Median (24^{th}-75^{th})	2020 Median (24^{th}-75^{th})	2019 Median (24^{th}-75^{th})	2020 Median (24^{th}-75^{th})	2019 Median (24^{th}-75^{th})	2020 Median (24^{th}-75^{th})	2019 Median (24^{th}-75^{th})
$PM_{2.5}$ (µg/m^3)	11.7 (10.3-23.9)	10.5* (7.1-17.8)	15.3 (10.4-20.6)	10.2* (10.2-10.2)	8.7 (6.9-9.9)	8.2 (4.8-10.4)	13.9 (10.2-17.5)	11.2 (8.3-21.5)	11.7 (7.9-16.7)	10.2 (8.0-11.2)
PM_{10} (µg/m^3)	45.3 (32.6-51.4)	48.3 (38.8-64.1)	46.9 (23.9-56.4)	38.6 (29.4-45.5)	28.2 (21.9-32.9)	39.3* (26.6-48.5)	51.0 (35.3-69.8)	42.7 (35.3-61.1)	37.2 (25.9-55.0)	40.1 (29.8-49.5)
NO_2 (ppb)	7.8 (5.9-9.1)	40.7* (31.0-43.7)	7.3 (6.1-8.0)	34.7* (28.8-38.2)	4.5 (3.7-5.2)	27.7* (25.3-30.9)	6.9 (5.5-9.5)	29.2* (26.7-31.9)	6.1 (4.6-7.4)	29.4 (26.8-33.1)
SO_2 (ppb)	29.6 (4.7-60.6)	35.6* (10.5-43.4)	2.2 (2.0-2.4)	41.5* (39.2-42.6)	13.6 (8.1-13.9)	42.8* (29.6-44.0)	20.9 (8.1-23.8)	8.1* (7.9-8.7)	8.1 (2.4-14.1)	38.2 (8.4-42.8)
CO (ppm)	1.5 (1.4-1.6)	1.3 (1.1-1.8)	1.2 (0.0-1.6)	0.9* (0.7-0.9)	0.7 (0.7-0.9)	1.1* (0.9-1.1)	0.9 (0.8-1.0)	1.0* (1.0-1.1)	0.9 (0.8-1.1)	1.0 (0.9-1.1)
O_3 (ppb)	12.3 (11.4-117.3)	-	12.4 (11.8-13.1)	10.1* (10.0-10.1)	13.5 (13.1-14.0)	10.1* (10.0-10.1)	22.0 (13.4-47.3)	10.1 (10.0-23.0)	13.4 (12.6-14.3)	10.1 (10.0-10.1)

*p-value < 0.05

Table 2: Distribution of meteorological parameters by scenario and time period

Variable	Scenario 1		Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	2020 Median (24^{th}-75^{th})	2019 Median (24^{th}-75^{th})	2020 Median (24^{th}-75^{th})	2019 Median (24^{th}-75^{th})	2020 Median (24^{th}-75^{th})	2019 Median (24^{th}-75^{th})	2020 Median (24^{th}-75^{th})	2019 Median (24^{th}-75^{th})	2020 Median (24^{th}-75^{th})	2019 Median (24^{th}-75^{th})
T (^{0}c)	5.6 (4.3-8.1)	4.5 (2.8-5.7)	12.3 (10.4-15.9)	6.3 (5.1-8.9)	14.6 (13.2-16.5)	11.8 (10.1-12.6)	22.1 (20.3-23.9)	16.8 (11.8-19.4)	13.6 (9.0-17.9)	9.0 (5.5-12.5)
T_{max}	12.0 (10.3-17.0)	13.4 (12.4-15.4)	20.0 (17-22)	16.2 (14.7-19.0)	20.0 (19.0-24.0)	22.0 (18.5-24.5)	29.7 (27.2-30.9)	32.0 (25.5-33.0)	20.0 (15.0-25.0)	18.4 (14.7-25.0)
T_{min}	0.0 (-2.0-1.8)	1.1 (-1.4-3.3)	5.0 (3.0-8.0)	3.2 (1.0-4.2)	9.0 (7.0-10.0)	9.0 (5.6-11.0)	14 (11.9-15.9)	14 (10.0-17.3)	7.3 (2.0-11.0)	5.0 (2.0-11.0)
Wind speed (m/s)	2.9 (1.9-3.9)	2.0 (1.7-2.5)	2.1 (1.9-2.8)	2.5 (1.7-3.3)	2.5 (1.9-3.5)	2.4 (1.8-2.9)	2.8 (2.4-3.9)	2.0 (1.8-2.9)	2.6 (1.9-3.6)	2.3 (1.7-3.0)
Precipitation (mm)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0.-1.1)	0 (0-2.3)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Rainy days (d)	2	5	7	6	12	12	5	4	26	27

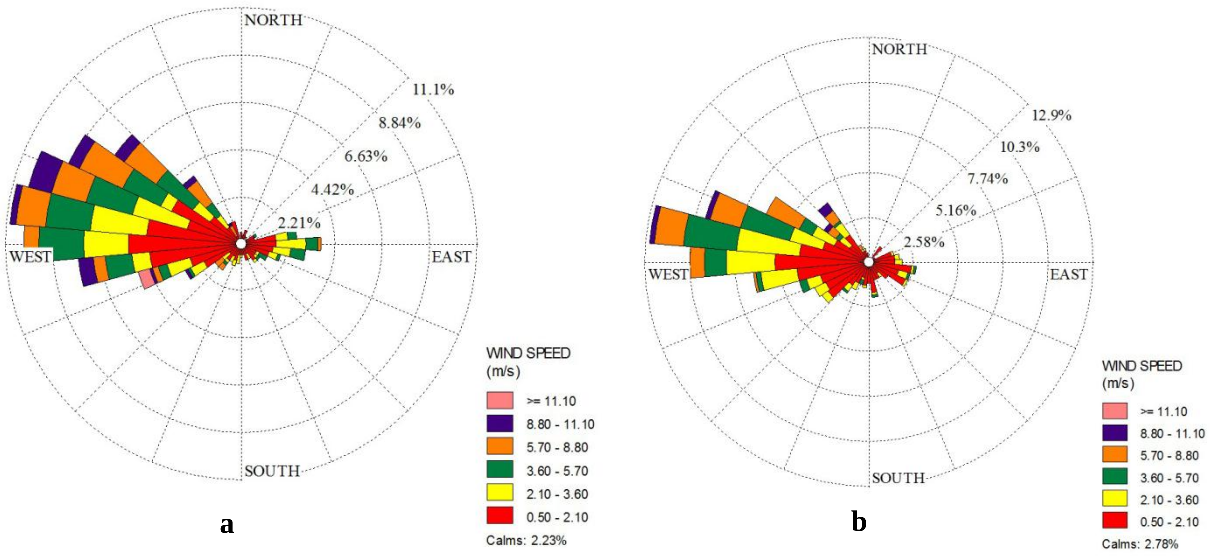

Figure 2: Scenario 1. One month before the COVID-19 outbreak (a) in comparison to the same period in 2019 (b)

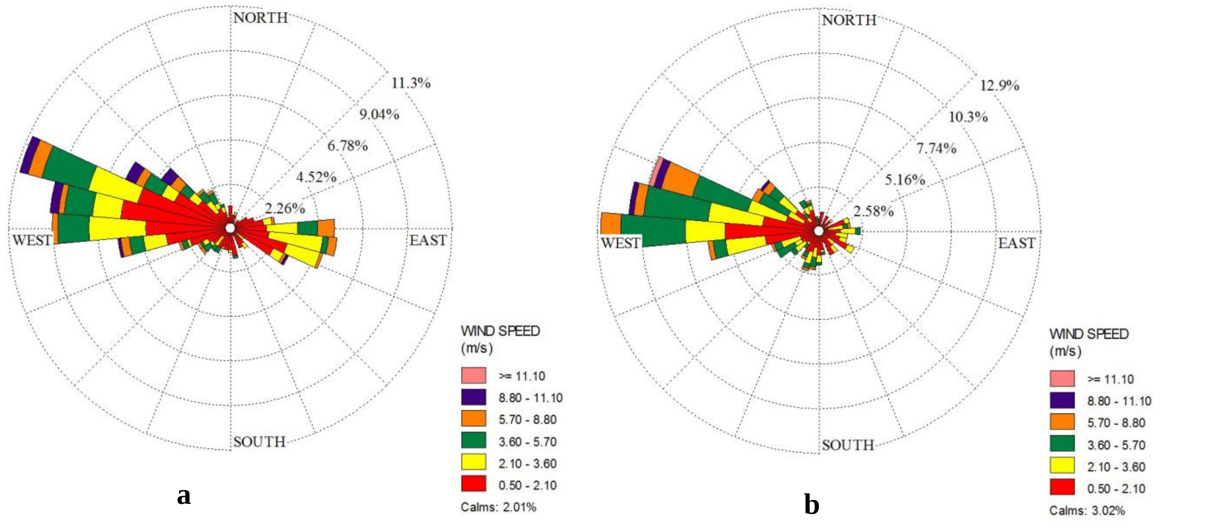

Figure 3: Scenario 2. The first month of the COVID-19 outbreak (a) in comparison to the same period in 2019 (b)

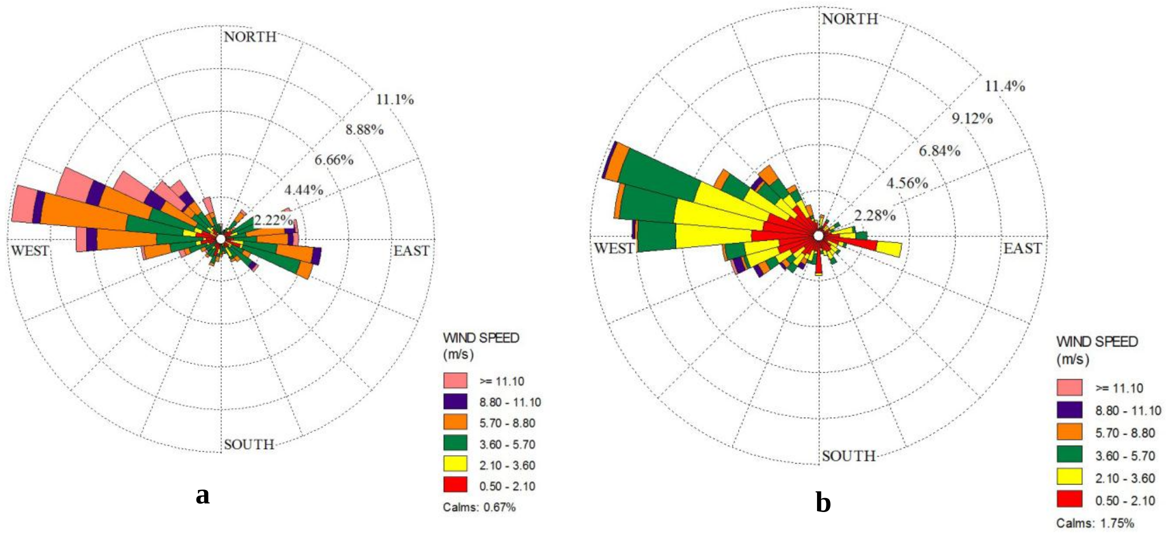

Figure 4: Scenario 3. Iranian New Year Eve holidays (a) in comparison to the same period in 2019 (b)

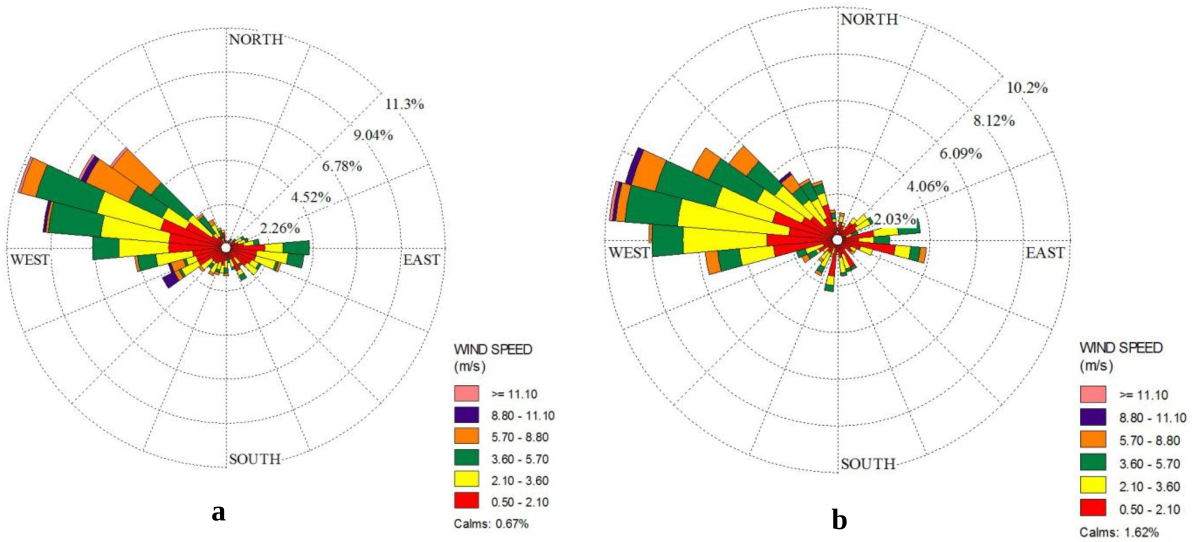

Figure 5: Scenario 4. One month after New Year holidays (a) in comparison to the same period in 2019 (b)

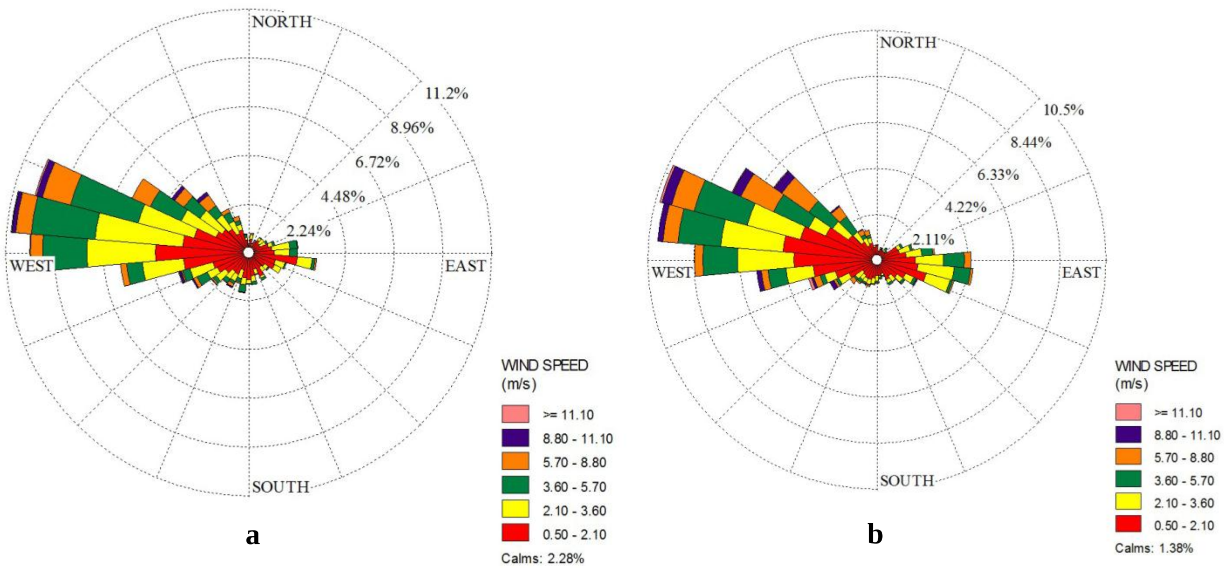

Figure 6: Scenario 5. The whole study period (a) in comparison to the same period in 2019 (b)

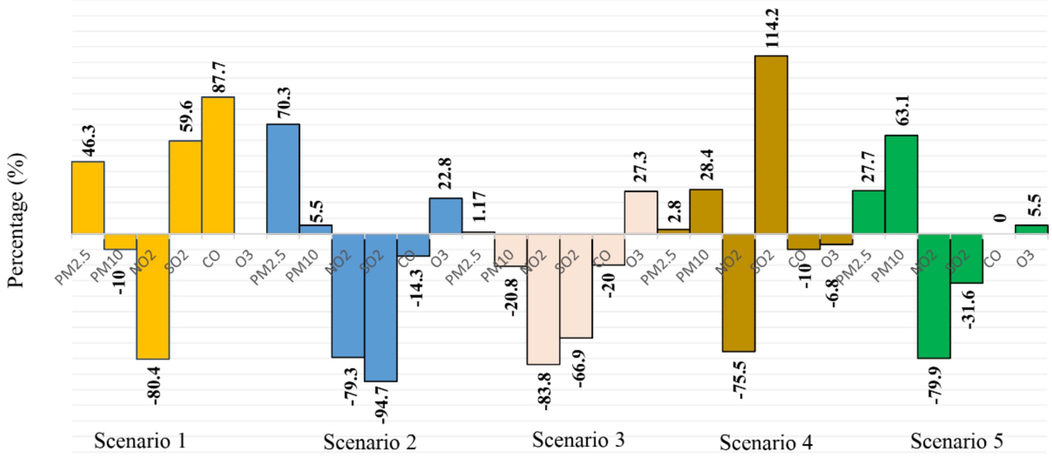

Figure 7: The difference percentage of SO_2, NO_2, CO, O_3, PM_{10}, and $PM_{2.5}$ in 5 scenarios

Discussion

This study was conducted to investigate the changes in concentration of air pollutants in Qom city during the COVID-19 outbreak and to compare them with the same period of last year. To better evaluate, five scenarios were defined, including (1) one month before the COVID-19 outbreak, (2) the first month of the COVID-19 outbreak in Iran, (3) Iranian Nowruz holidays, (4) one month after Nowruz holidays, and (5) the whole study period.

Based on the authors' ecological study, the mean concentration of particles, especially $PM_{2.5}$ has increased compared to the last year. Based on a comparison of $PM_{2.5}$ in February 2020, when there was no quarantine and restriction, an increase in $PM_{2.5}$ was observed in March 2020. An increase in PM_{10} was also observed. The amount of particles in these two months also increased compared to last year. Based on the analysis of meteorological parameters, the average temperature, average wind speed, and sum of precipitation in February increased compared to March 2020 and last year. Therefore, meteorological parameters did not affect the increase of particulate pollutants. Given that southern cities, such as Ahvaz are affected by Mediterranean dust emitted from the west of the country, a slight increase in wind speed at this time from the west of the country may have affected the increase in particles. Therefore, considering that the application of quarantines did not reduce the particles, natural factors, such as wind from the desert areas of the country can be considered the cause of this increase. Moreover, due to the dry climate of Qom and several dust centers around Qom, particles may increase if the traffic decreases [34]. It should be noted that particulate matter has increased compared to last year and particulate pollutants from natural origin are still increasing, solving this problem requires proper management programs. A similar study conducted by Faridi et al. in Tehran, showed a noticeable increase in particles during the COVID-19 outbreak [3]. Another study conducted in Milan found that lockdown due to the COVID-19 outbreak led to a decrease in concentration of PM_{10}, $PM_{2.5}$, BC (Black carbon), CO, Benzene, and NO_X. When the concentration of NO_2 reduced, O_3 concentration increased due to the minor NO concentration [35]. The analysis showed a decrease in concentration of NO_2 and SO_2 during the whole study period in comparison to the same period of last year. This is similar to the results of a study in Spain, which demonstrated that air pollutants reduced due to lockdown of the COVID-19 outbreak [36]. Another study in China, observed a decrease in emission of NO_2 and an increase in emission of O_3 during the lockdown, especially when the restrictions were removed, more emission of O_3 was experienced [37]. However, the results did not show a significant different between concentration of O_3 during the COVID-19 outbreak (the whole study period) and previous year.

According to concentration changes in lockdown time (scenario 2 and 3) in Qom, which movement was restricted in the city, there was an increase in concentration of $PM_{2.5}$ and O_3, a decrease in concentration of CO, NO_2, and SO_2 (scenario 2), a decrease in concentration of PM_{10}, NO_2, SO_2, and CO, and an increase in concentration of O_3 (scenario 3). The reduction of gaseous pollutants can be attributed to the reduction of urban traffic, closure of shops, restaurants and closure of most factories and industries around the city. But restrictions on urban movements have played an important role in reducing emissions. Despite decreasing in concentration of NO_2, the concentration of O_3 increased slightly in both scenarios. It may be concluded due to increasing the average temperature in these scenarios compared to the same period of last year. In these 2 scenarios, similar to the whole study period, the average temperature, average wind speed, and sum of precipitations during the COVID-19 outbreak were higher than the same period of last year.

After removing lockdown, in scenario 4, an increase in concentration of SO_2 was experienced; this may be due to opening of factories and industries and removing lockdown. It should be noted that in Scenario 4, the restriction of intra-city traffic and the closure of jobs were removed, but the closure of schools and universities still reduced the amount of urban traffic.

A study in industrial area in India demonstrated a reduction in air pollutants and Air Quality Index (AQI). NO_2, which is mostly caused by industries and traffic jams, had the highest reduction among pollutants [38]. The results of a study in Western Europe showed a decrease in NO_2 and an increase in fine particles. The authors believe that residential heating emissions and fertilizer spreading in early springtime have increased the fine particles [39]. Lack of recording meteorological data and air quality data in some hours, lack of recording ozone data in one of the scenarios were the limitations of this study.

Conclusions

According to the findings, gaseous pollutants decreased during the COVID-19 outbreak, but particulate pollutants increased slightly compared to the same period in 2019 and the quarantine time. This increase was experienced before applying lockdown, which a slight increase in wind speed compared to the same period in 2019 from the west, could be a factor in increasing particles. The average temperature, wind speed, and sum of precipitation were higher than the same period in 2019. These parameters may have affected air pollutants reduction, but the lockdown and closure of shops, restaurants, most of factories and industries, and decreasing traffic jam may have had the most impact. This crisis provided an opportunity to assess the role of policies, such as traffic reduction plans or discarding worn-out cars or urban management to improve air quality. Furthermore, the role of natural factors and their proper management on reducing or increasing pollutants was identified.

Limitations

One of the limitations of the study is the lack of data for more than one station. Due to the size of the city and approximate uniformity of population in the city, the concentrations of one station can be attributed to the whole city.

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Conflicts of interest

The authors declare that there is no conflict interest**.**

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