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Analyzing relationships between air pollutants and Covid-19 cases during lockdowns in Iran using Sentinel-5 data

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ABSTRACT

Introduction: Air quality improvement was an unparalleled environmental consequence of the Covid-19 global crisis in many regions. Numerous researches have been conducted on the influence of national quarantines on air pollution and the relationship between the abundance of infected cases and mortality caused by this pandemic with air pollutants; however, these investigations are limited in Iran. The present study aims to investigate the correlation between Covid-19 cases and air pollution from a statistical viewpoint in order to evaluate the performance of multiple national lockdowns from February 2020 to August 2021 through measuring changes in air pollutants in the 31 provinces of Iran.
Materials and methods: We applied a remote sensing method by employing Sentinel-5P satellite data to analyze changes in $PM_{2.5}$, CO, and O_3 during the three public quarantine periods and their two months earlier.
Results: We recognized a considerable positive correlation between $PM_{2.5}$ and the infected cases (r=0.63, p=0.001) and victims (r=0.41, p=0.001). Moreover, we compared the efficiency of lockdowns and supposed lockdown 2 (November-December 2020) as an only effective quarantine due to a dramatic reduction in $PM_{2.5}$ (21.2%), CO (0.8%), the infected cases (48.7%), and victims (66.9%) in comparison to the average of its next two months.
Conclusion: Governments should handle the outbreak of Covid-19 by implementing efficient quarantines, as well as environmental conservation strategies.

Introduction

The emergence of a new viral epidemic in 2020 was the most significant challenge which humanity has fronted since World War II [1]. Covid-19 is an intensive transmissible disease that was detected in December 2019 and was verified as a dangerous pandemic on March 13, 2020, by WHO [2, 3]. Most countries implemented social distancing and national quarantine policies in order to prevent the outbreak of Covid-19, which led to a remarkable decline in industrial, commercial, and transportation activities [4]; thereby, it imposed considerable global socio-economic challenges [1], as well as unprecedented environmental consequences [3]. One of the environmental outcomes of lockdowns was an extraordinary decrease in air pollutants emission [5]. Global quarantines reduced NO_2 and $PM_{2.5}$ levels by 5

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and 4% [6], furthermore improved air quality in numerous polluted capitals, including Beijing, Delhi, Madrid, Paris, Seoul, Sydney, and Tokyo [7]. An air pollution data assessment in 597 megacities of the world from January to July 2020 indicated that NO_2, PM_{10}, SO_2, $PM_{2.5}$, and CO decreased by 20-14%, 2-20%, 7-16 %, 7-11%, and 23-37%, respectively; however, O_3 increased by 10-27% [8]. The $PM_{2.5}$ level in the 50 most polluted cities reduced by 12% during the quarantine days [1]. A study revealed that industrial and mobility, NO_2, $PM_{2.5}$, and PM_{10} levels decreased by 20-40% during quarantines in comparison to 2018 and 2019 in Spain, Sweden, France, and the United Kingdom [4]. Moreover, the global NO_2 level declined by 9.19-9.57% in March-April 2020, and most monitoring stations in Europe, United States, China, and India recorded a significant drop in air pollutants emission and an increase in O_3 concentration [9].

In addition to global air pollution studies, many researchers have explored the effects of the Covid-19 outbreak on air pollution on a national scale. It was reported that NO_2 emissions in the United States decreased by approximately 25.5% in January-April 2020 compared to 2017-2019 [10]. Another investigation revealed that social distancing due to the outbreak of Covid-19 in South Korea reduced NO_2, PM_{10}, $PM_{2.5}$, and CO levels by 45.45%, 35.56%, 20.41%, and 17.33% in comparison to 2019 [11]. The traffic was reduced upper 80% during the quarantine season in Spain; however, some pollutants such as secondary aerosol or O_3 were increased in some cities [12]. A study in Kolkata (India) demonstrated that NO_2, CO, and SO_2 levels were significantly decreased, although O_3 was slightly enhanced due to transportation and industrial activity suspension during the quarantine period [13]. Moreover, NO_2 levels decreased by 40-50% in Mumbai and Delhi compared to 2019 [14].

Several investigations also have been carried out on the relationship between the abundance of infected cases and mortality of Covid-19 and different air pollutants. An investigation in several areas of the United Kingdom recognized that a 1μ/m^3 increase in $PM_{2.5}$ led to a 12% growth in the Covid-19 mortality rate [15]. Air pollution might affect the outbreak of the Covid-19 pandemic [16]. A positive correlation was detected between NO_2, PM_{10}, $PM_{2.5}$, and O_3 with daily infected cases of Covid-19 in China [17]. Exposure to high levels of $PM_{2.5}$ was correlated with mortality ($p<0.05$) in nine Asian cities; however, its correlation with PM_{10} was not significant ($p=0.118$) [18].

As an Asian country, Iran was one of the first countries that faced the Covid-19 pandemic in February 2020 [19]. At the time of this writing, Covid-19 has infected more than 5.4 million people and led to the death of more than 117,000 victims [20], which imposed severe economic, social, and environmental consequences in Iran [21, 22]. Although the metropolises of Iran, especially Tehran, are among the most polluted centers worldwide, few studies have been conducted on the influences of Covid-19 on air pollution in Iran. The levels of CO, NO_2, PM_{10}, and $PM_{2.5}$ pollutants declined by 11%, 15%, 10%, and 6%, respectively; however, the concentrations of SO_2 and O_3 increased by 15 and 12% between March 1 and April 9, 2020 [23]. According to another research, the NO_2 and CO levels in 2020 were 5% lower than in 2019; however, they rose by 5% in 2021 compared to 2020 due to high traffic and irregular lockdown in Iran [24]. Three national lockdowns have been implemented in Iran since the Covid-19 outbreak; nevertheless, most studies have assessed just the first lockdown (March to April 2020). Hence, the present study aims to evaluate changes in $PM_{2.5}$, CO, and O_3 pollutants during three lockdowns (i): February 29 to April 10, 2020 (ii): November 21 to December 4, 2020, and (iii): August 15 to 29, 2021, and analyze the performance of lockdowns according to changes in the abundance of infected cases and mortality rate of Covid-19. Moreover, the correlation between infection cases and mortality and air pollutants has been investigated.

Materials and methods

Case study

The Islamic Republic of Iran, as a West Asian broad mountainous region, is located on the 250 3' to 390 47' N and 440 5' to 630 18' E, linked to Azerbaijan, Armenia, Turkey, Iraq, Turkmenistan, Afghanistan, and Pakistan. It comprises 1,648,195 square kilometers, though a considerable share of its lands is uninhabitable, and population density is estimated at 49.29 people/m^2. Iran has the fourth-largest oil reserves and the most abundant natural gas resources. The population of Iran was less than 10 million people between 1880 and 1920, but it unwaveringly grew to 20 million by 1955. The population dramatically rose to 70 million in 2005, and presently, it is estimated at more than 85 million [25]. This country has 31 provinces and 1154 cities [26] (Fig. 1), which are challenged by hazardous urban air pollution due to extensive industrial activities, particular topographic positions, unrestricted combustion of fossil fuels, and high exhaustion of the transportation system.

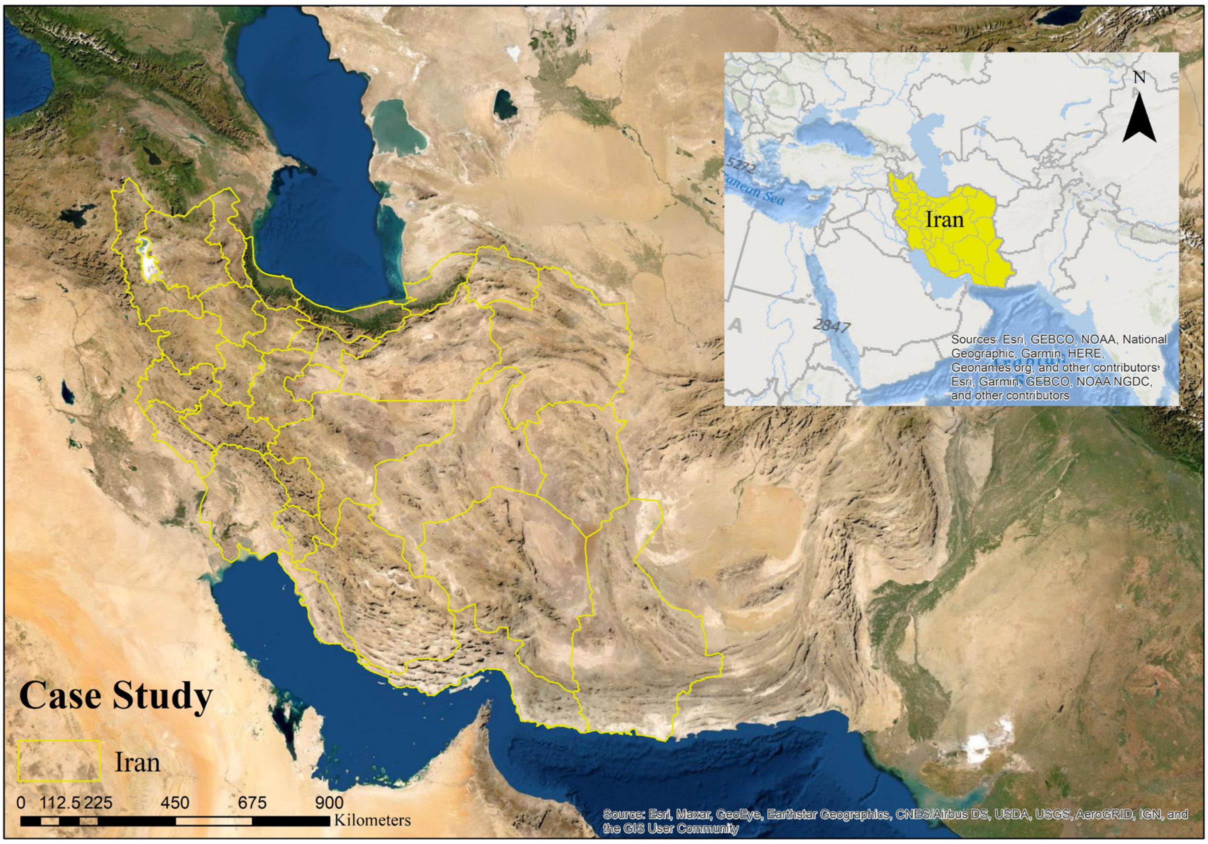


Fig. 1. Map of the provinces of Iran (1=East Azerbaijan, 2=West Azerbaijan, 3=Ardabil, 4=Isfahan, 5=Alborz, 6=Ilam, 7=Bushehr, 8=Tehran, 9=Chahar-Mahal and Bakhtiari, 10=South Khorasan, 11=Razavi Khorasan, 12=North Khorasan, 13=Khuzestan, 14=Zanjan, 15=Semnan, 16=Sistan and Baluchestan, 17=Fars, 18=Qazvin, 19=Qom, 20=Kurdistan, 21=Kerman, 22=Kermanshah, 23=Kohgiluyeh and Boyer-Ahmad, 24=Golestan, 25=Gilan, 26=Lorestan, 27=Mazandaran, 28=Markazi, 29=Hormozgan, 30=Hamedan, 31=Yazd)

Data

Data on the statistics of infected cases and victims of Covid-19 in Iran were downloaded from a research [27], and report on the date of public lockdowns implementation acquired from Iranian news agencies. Data of particular matter ($PM_{2.5}$, index=-1 to 5 (340-380 nm)), carbon monoxide (CO, index=0 to 0.1 mol/m^2), and ozone (O_3, index=0 to 0.36 mol/m^2) were measured through a remote sensing method by the Sentinel satellite from 2020 to 2021. Positive values for $PM_{2.5}$ indicate the presence of aerosol particles. Sentinel-5P is one of the most novel satellites of the European Space Agency (ESA), that facilitates remote sensing of various air pollutants such as aerosols, CH_4, NO_2, CO, HCHO, SO_2, and O_3 [28].

Separate polygons were drawn in Google Earth Pro (version 7.3.3.7721) and uploaded to the Sentinel-Hub system in order to collect accurate data for each province. After calculating indexes, the data of every pollutant were downloaded separately to investigate changes in lockdown 1 (February 29 to April 10, 2020), lockdown 2 (November 21 to December 4, 2020), and lockdown 3 (15 to 29 August 2021). Average data of lockdowns have been compared with the average of two months before lockdown, and the percentage of difference has been reported for measuring alterations in pollutant emissions before and during quarantine. Data were analyzed through employing SPSS (version 18), and descriptive statistics of the mean and standard deviation of variables and Pearson correlation coefficient were applied in analytical statistics. The significance level of the Pearson correlation coefficient between the two variables was considered less than 0.05.

The geographic information system (GIS) was utilized for mapping air pollutants situation in provinces of Iran. This system is a digital-based data processing engine for assembling, banking, and analyzing geographic information. GIS is intended explicitly for spatial vector data [29], and this study employed the latest version of ArcGIS PRO. Determining the accurate coordinate system for geometric data is crucial; hence, the geometric data used in this software was vector class and polygon structure. Quantitative data was characterized using SYMBOLOGY after inserting the data into ArcGIS via Excel file; thus, the variables of three quarantine periods were compared.

Results and discussion

Relationships between air pollution, infection, and mortality

Descriptive data on air pollution variables, infected cases, and mortality caused by Covid-19 in Iran is shown in Table 1. The results revealed a direct and obvious connection between $PM_{2.5}$ and Covid-19 infection cases (r=0.63) and mortality (r=0.41). This relationship was significant from a statistical perspective at the significance level of 0.05 (p=0.001). Similarly, the association of CO with infection and O_3 with mortality was also significant. The correlation between CO and daily mortality cases (p=0.112) and O_3 with the number of infected people was statistically insignificant (p=0.482) (Table 2). Fig. 2a explicates that when the number of Covid-19 patients exceeds 30,000, the $PM_{2.5}$ range is from 0 to 1.5. Furthermore, the infected cases are zero whenever the indexes of CO and O_3 are less than 0.025 and 0.1 (Fig. 2b and Fig. 2c). Fig. 3a further reveals the positive correlation between $PM_{2.5}$ and the abundance of victims. When the abundance of victims increases to more than 500 per day, the $PM_{2.5}$ index is higher than 0.4. Additionally, when the CO and O_3 reduce to less than 0.025 and 0.1, the cases of victims are zero (Fig. 3b and Fig. 3c).

Table 1. Descriptive information on air pollution variables and the abundance of infected cases and victims in the period of Covid-19 outbreak (n=557)

Variable	M±SD
$PM_{2.5}$	-1.13±0.74
CO	0.03±0.00
O_3	0.13±0.01
New death	201.51±151.22
New cases	9337.51±9522.46

M: Mean; SD: Standard Deviation

Table 2. The correlation between the investigated variables

Variable		New cases	New death
$PM_{2.5}$	correlations	0.63	0.41
	p	0.001	0.001
CO	correlations	0.27	0.07
	p	0.001	0.112
O_3	correlations	0.03	0.76
	p	0.482	0.001

Correlations: Pearson's correlation coefficient; significance level of 0.05 was considered

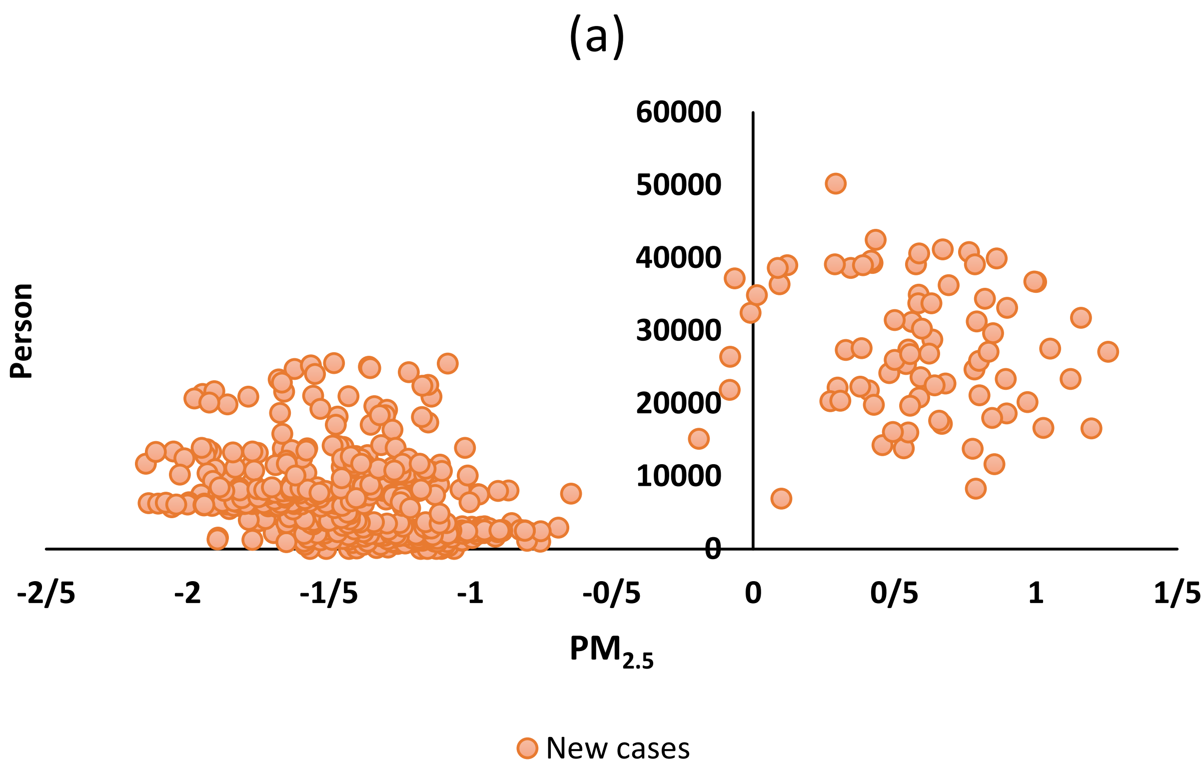
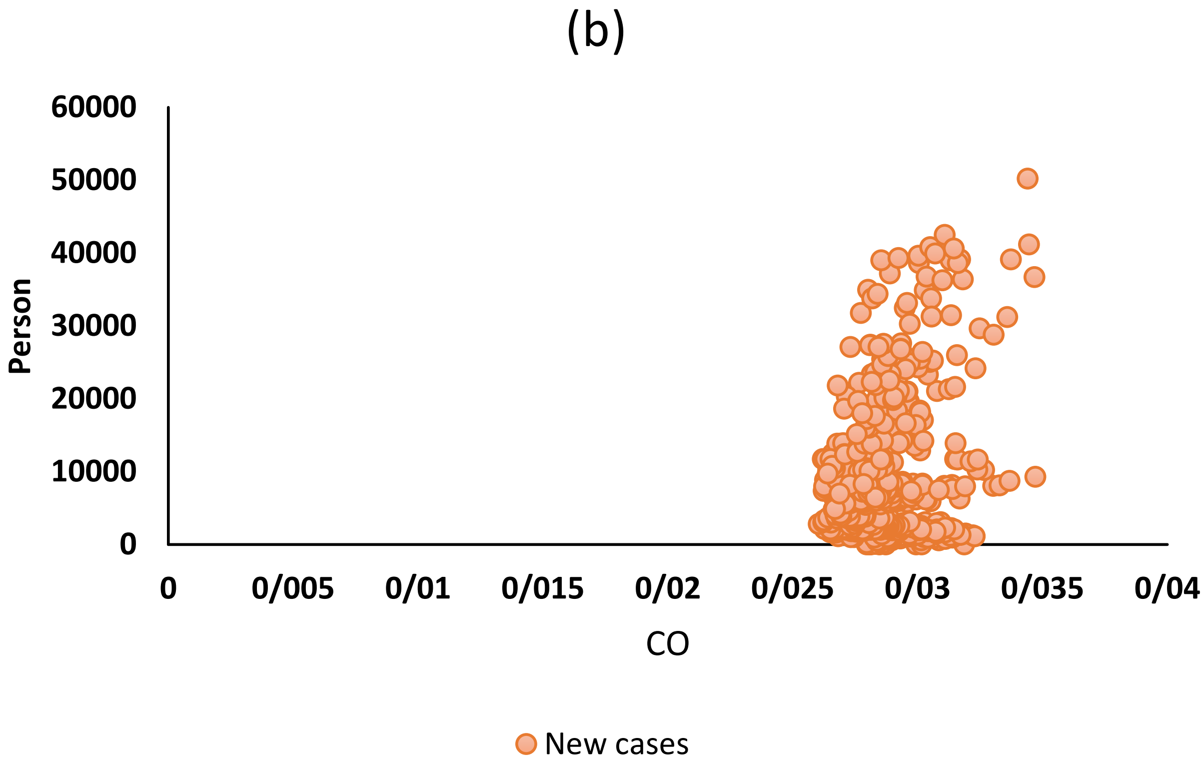
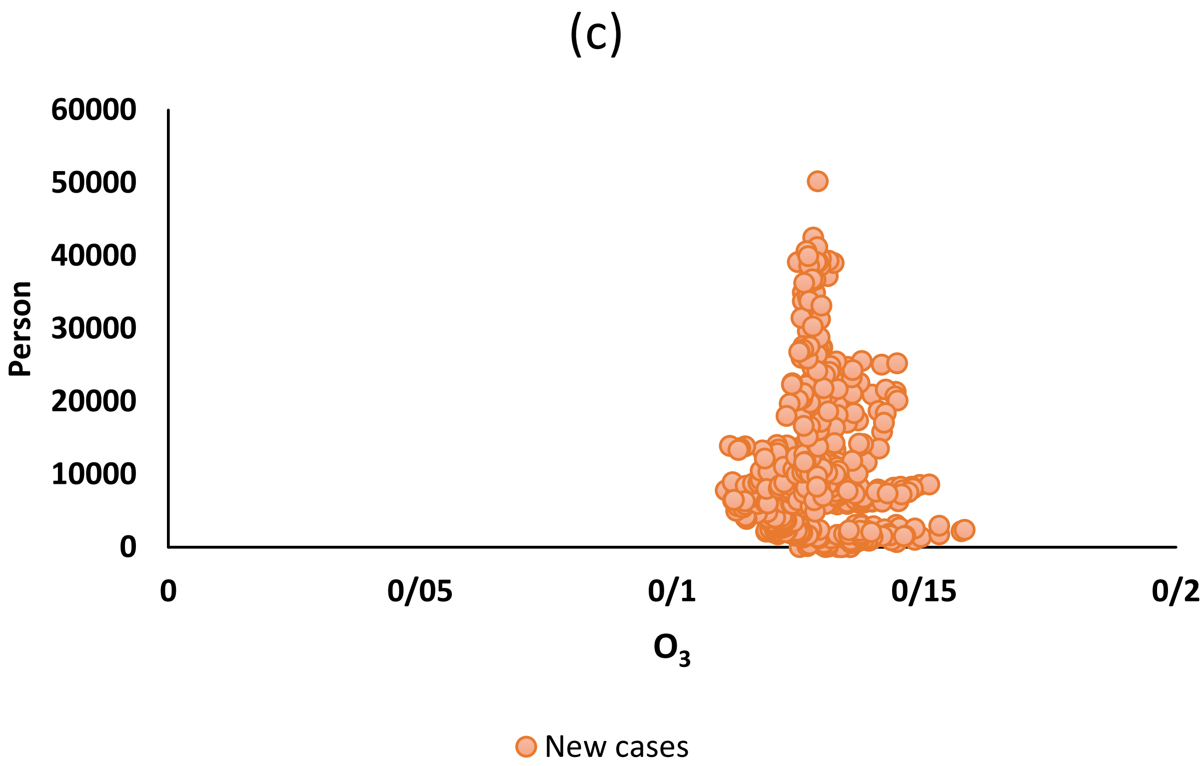


Fig. 2. The connection between air pollutants and the number of Covid-19 infected in Iran from February 2020 to September 2021; $PM_{2.5}$=index between -2.5 to 2, CO (0-0.04), O_3 (0-0.18), and New case (person)





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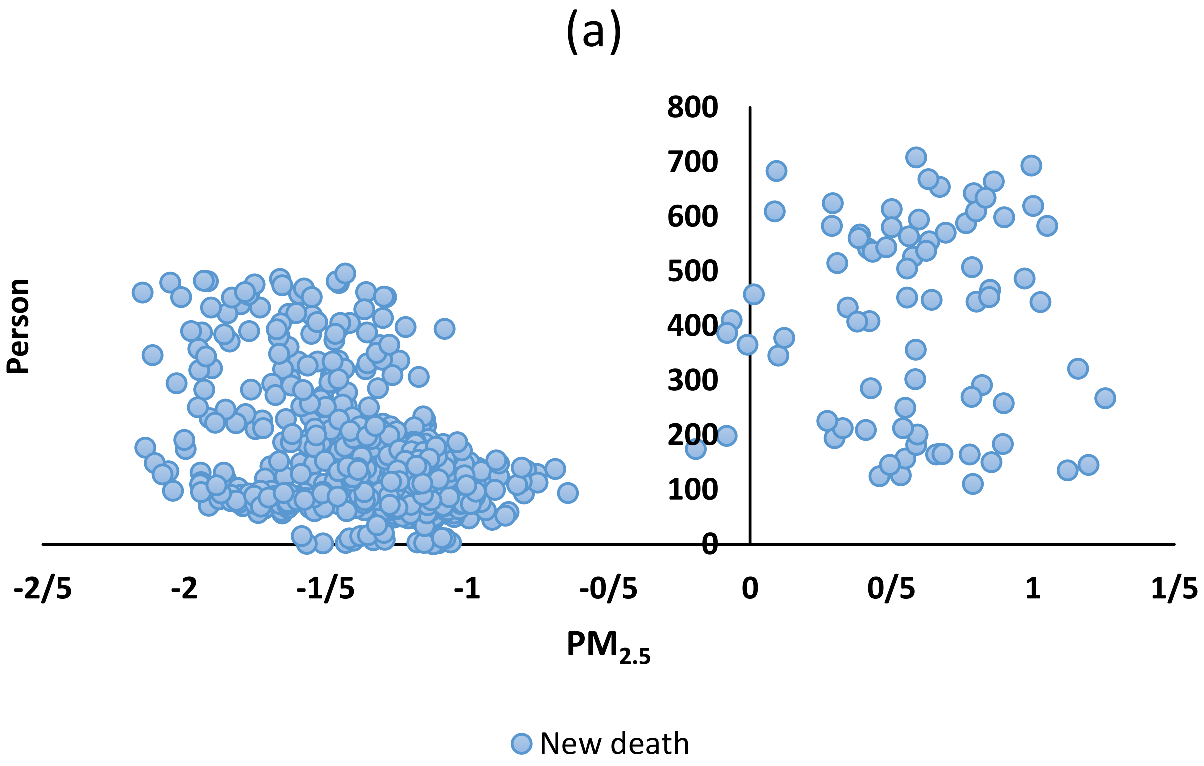

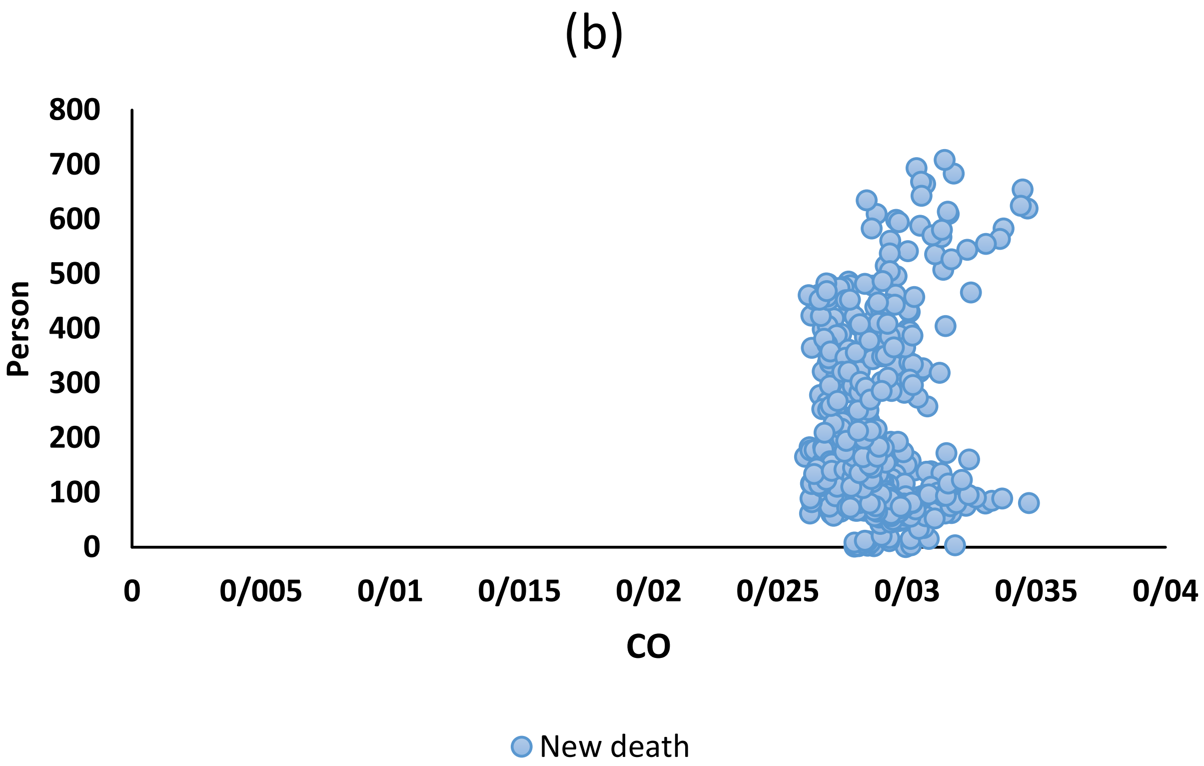

Fig. 3. The connection between air pollutants and the number of deaths caused by Covid-19 in Iran from February 2020 to September 2021; index for $PM_{2.5}$ (-2.5 to 2), CO (0-0.04), O_3 (0-0.18), and New death (person)

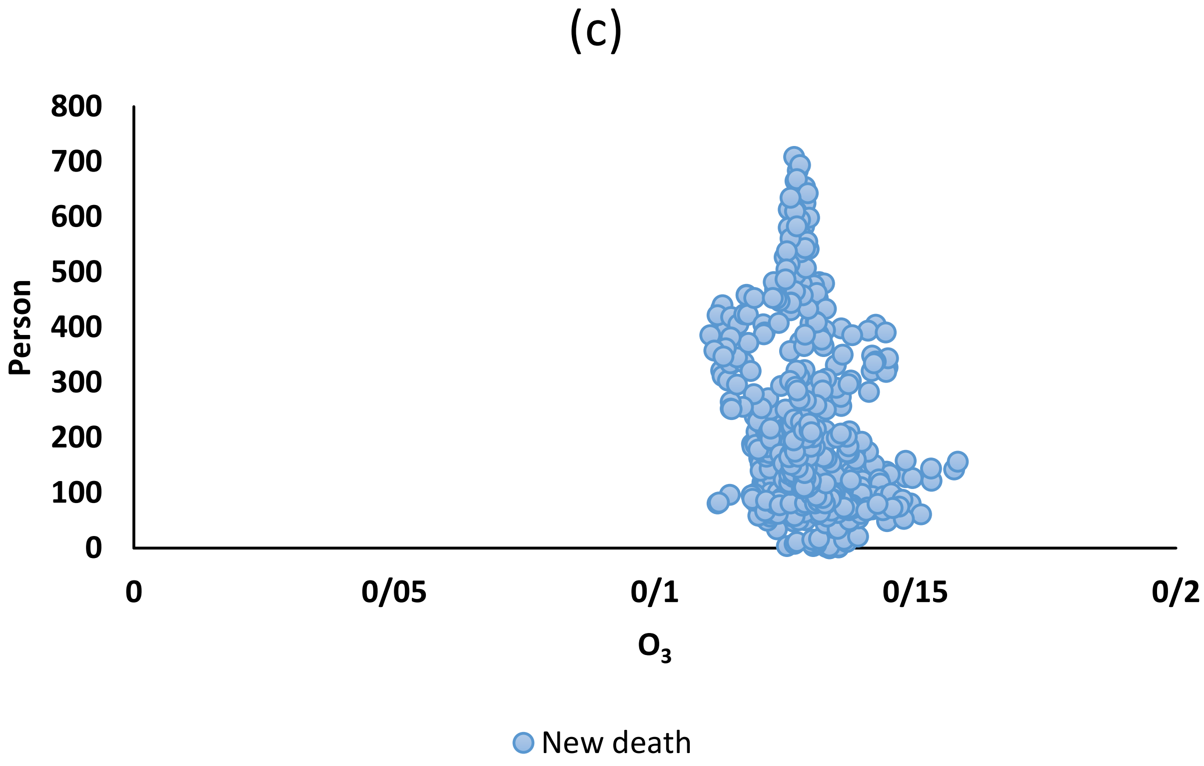

Fig. 3. The connection between air pollutants and the number of deaths caused by Covid-19 in Iran from February 2020 to September 2021; index for $PM_{2.5}$ (-2.5 to 2), CO (0-0.04), O_3 (0-0.18), and New death (person)

Through analyzing the relationship between daily mortality cases caused by Covid-19 and air pollutants in 12 cities of Iran, it was identified that for an increase of 1 μg/m^3 in the NO_2 level, mortality grows by 2.7 units (95% confidence interval) [30]. Accordingly, there is a considerable correlation between Covid-19 mortality and NO_2 in Iran and other countries [30, 31]. An increase of 1 μg/m^3 in the $PM_{2.5}$ level was connected with an 8% increase in Covid-19 mortality in the United States [32]. It was recognized that air pollutants were positively associated with infected cases of Covid-19 in China [33]. A similar research also concluded that rising levels of particulate matter enhanced mortality [34]. Additionally, infected cases of Covid-19 were positively linked with gaseous pollutants. Therefore, air pollution effectively raises the risk of mortality caused by Covid-19 [35].

Changes in air pollutants during lockdowns

Lockdown 1

The highest increase in $PM_{2.5}$ level was recorded in Markazi (+86.3%), and the most significant decrease in $PM_{2.5}$ was reported in East Azerbaijan (-9%). The maximum CO increase was also shown in Fars (+5.7%), and the most notable drop was recorded in Kermanshah (-2.5%), as well as a slight drop in O_3 level in Khorasan Razavi (-2.6%) and a considerable increase in Sistan and Baluchestan (+4.5%), compared to the average of the previous two months (Table 3). Accordingly, lockdown 1 has not been appropriately implemented in 23 provinces due to the rising level of $PM_{2.5}$ and CO, which are a reflection of industrial and traffic activities. The average of $PM_{2.5}$, CO, and O_3 in Iran increased by 22%, 3.1%, and 0.5% during lockdown 1 in comparison to the previous two months; thereby, the average infected cases grew by 10.7% two months after lockdown due to inefficient quarantine. Nevertheless, the average abundance of victims two months after lockdown 1 decreased by approximately 29.8%, which indicates that the quarantine has been slightly effective in diminishing the Covid-19 mortality rate.

Table 3. Changes in air pollutants during the lockdown 1 in comparison to its two months ago

Row	Province	$PM_{2.5}$ changes (%)	CO changes (%)	O_3 changes (%)
1	East Azerbaijan	-9	+0.9	-2.5
2	West Azerbaijan	-6	+1.2	-2.4
3	Ardabil	+4.9	+1.1	-2.1
4	Isfahan	+9.5	+3.6	-0.7
5	Alborz	+8.3	+3.3	-1.5
6	Ilam	-6.6	+2.4	-2.1
7	Bushehr	+36	+3.9	+2.1
8	Tehran	+8.8	-0.9	-2.2
9	Chahar-Mahal and Bakhtiari	+19.3	+5.4	-0.8
10	South Khorasan	+9.6	+3.5	+1.6
11	Razavi Khorasan	+8.5	+1.3	-2.6
12	North Khorasan	+10.7	+1.7	-1.9
13	Khuzestan	+17.8	+2.1	-0.1
14	Zanjan	-2.9	+2	-2.4
15	Semnan	+9.4	+1	-1.3
16	Sistan and Baluchestan	+22.6	+2.1	+4.5
17	Fars	+17.7	+5.7	+2.1
18	Qazvin	+29	+2.6	-2
19	Qom	+7.2	+3.5	-1.6
20	Kurdistan	-2.6	+1.1	+1.1
21	Kerman	+15.7	+4.1	+2.9
22	Kermanshah	+6.3	-2.5	-1.8
23	Kohgiluyeh and Boyer-Ahmad	+20.8	+3.5	+0.5
24	Golestan	+15.8	-0.5	-1.5
25	Gilan	+19.8	+1.8	-2.1
26	Lorestan	+7.2	+3.4	+1.8
27	Mazandaran	+19.7	+2.1	-1.1
28	Markazi	+86.3	+5.2	-2.2
29	Hormozgan	+28.2	+4.5	+4.4
30	Hamedan	+1.6	+3.2	-2.3
31	Yazd	+8.6	+3.3	+0.9

Lockdown 2

The average of $PM_{2.5}$, CO, and O_3 during lockdown 2 changed by -21.2%, +0.8%, and +1.8% compared to the average of the prior two months. The highest rise in $PM_{2.5}$ was recorded in Alborz (+9.3%), and the most significant reduction was related to $PM_{2.5}$ in Qom (-20%), compared to the average of the previous two months (Table 4). Decreasing trends of CO and $PM_{2.5}$ were recognized in 18 and 29 provinces during lockdown 2; consequently, lockdown 2 has a more significant influence on air pollutants emission than lockdown 1 owing to the fact that infected cases after lockdown 2 decreased by 48.7%. The average abundance of victims after lockdown 2 similarly declined by approximately 66.9%, indicating that the quarantine was considerably efficient in controlling Covid-19 mortality.

Table 4. Changes in air pollutants during the lockdown 2 in comparison to its two months ago

Row	Province	$PM_{2.5}$ changes (%)	CO changes (%)	O_3 changes (%)
1	East Azerbaijan	-10	-0.3	+5.1
2	West Azerbaijan	-6.3	-0.7	+4.9
3	Ardabil	-4.1	+2.5	+4.5
4	Isfahan	-15.7	-3.1	+1.3
5	Alborz	+9.3	-9.4	+2.5
6	Ilam	-11	-2.9	+2.3
7	Bushehr	-10.7	+0.8	+0.9
8	Tehran	-0.2	-5	+2.1
9	Chahar-Mahal and Bakhtiari	-10	-3.8	+1.6
10	South Khorasan	-14.1	+2.4	+1.2
11	Razavi Khorasan	-13.5	+2	+0.7
12	North Khorasan	-9.6	+0.4	+0.9
13	Khuzestan	-16.8	+4	+1.6
14	Zanjan	-8.3	-0.9	+3.6
15	Semnan	-14.2	+1.4	+1.6
16	Sistan and Baluchestan	-13.6	+2.8	+1.3
17	Fars	-9.4	+1.2	+1.3
18	Qazvin	-3.4	-4	+2.9
19	Qom	-20	-1.9	+2.3
20	Kurdistan	+1	+1.1	+3.8
21	Kerman	-7	+2.2	+1.6
22	Kermanshah	-5.4	-2.2	+3.3
23	Kohgiluyeh and Boyer-Ahmad	-8.9	-3.9	+1.7
24	Golestan	-9.5	+1	+1.4
25	Gilan	-19.3	-1.4	+3.4
26	Lorestan	-5.5	-2.9	+2.1
27	Mazandaran	-2	-3.5	+2.3
28	Markazi	-19.3	-4.3	+2.5
29	Hormozgan	-12.8	+2.9	+0.7
30	Hamedan	-4.6	-2.5	+3.1
31	Yazd	-14	+1.8	+1.3

Lockdown 3

The highest rise in pollutants is relevant to $PM_{2.5}$ in Gilan (+91.2%), and the most significant drop in pollutants is associated to O_3 in Kerman (-1.2%), compared to the average of the previous two months (Table 5). $PM_{2.5}$ and CO levels grew in all provinces during Lockdown 3, indicating that quarantine policy was not implemented efficiently. O_3 level changes were changeable in the provinces during all lockdowns, and satellite investigations further validated that changes of O_3 have various complex patterns in different cities [36]. The average of $PM_{2.5}$, CO, and O_3 in Iran during lockdown 3 changed by +92.8%, +12.3%, and -0.5% in comparison to the average of its previous two months. Measurement of the average infected cases showed that patients lowered by 32.9% after lockdown 3. The average abundance of victims two months after lockdown 3 decreased by approximately 13.9%, indicating that the quarantine had a slight influence in controlling Covid-19 mortality. Notwithstanding the remarkable growth in air pollution during lockdown 3, high-speed vaccination in August-September 2021 appears to have prevented infection cases extension. Figures 4 and 5 obviously verify that $PM_{2.5}$ and CO declined significantly in lockdown 2, afterward, dramatically increased during lockdown 3. However, changes in O_3 are low in all lockdowns (Fig. 6).

Table 5. Changes in air pollutants during the lockdown 3 in comparison to its two months ago

Row	Province	$PM_{2.5}$ changes (%)	CO changes (%)	O_3 changes (%)
1	East Azerbaijan	+55.7	+12.5	-0.7
2	West Azerbaijan	+50.2	+11.6	-0.9
3	Ardabil	+68.4	+15	-0.5
4	Isfahan	+38.6	+11.2	-0.5
5	Alborz	+50.9	+10.3	-0.1
6	Ilam	+77	+8.3	-0.5
7	Bushehr	+58	+5.4	-0.5
8	Tehran	+41.3	+12	-0.1
9	Chahar-Mahal and Bakhtiari	+56.8	+6.5	-0.5
10	South Khorasan	+63	+15.8	-0.5
11	Razavi Khorasan	+88.5	+18	+0.3
12	North Khorasan	+44.3	+19	+0.7
13	Khuzestan	+51.6	+8.9	-0.3
14	Zanjan	+51.6	+12.2	-0.4
15	Semnan	+83.7	+12.7	+0.2
16	Sistan and Baluchestan	+42	+14.7	-0.9
17	Fars	+39.2	+4.8	-0.6
18	Qazvin	+51.2	+12.3	-0.3
19	Qom	+67.1	+14.1	-0.4
20	Kurdistan	+52.7	+9.6	-0.6
21	Kerman	+83.2	+12.9	-1.2
22	Kermanshah	+41.8	+7.8	-0.6
23	Kohgiluyeh and Boyer-Ahmad	+39.7	+4.3	-0.4
24	Golestan	+54.3	+19.2	+0.7
25	Gilan	+91.2	+16.4	-0.1
26	Lorestan	+43.2	+8.3	-0.5
27	Mazandaran	+64.4	+15.9	+0.3
28	Markazi	+47	+10.7	-0.4
29	Hormozgan	+49.1	+8.6	-0.9
30	Hamedan	+49.9	+9.8	-0.5
31	Yazd	+33	+10.6	-0.8

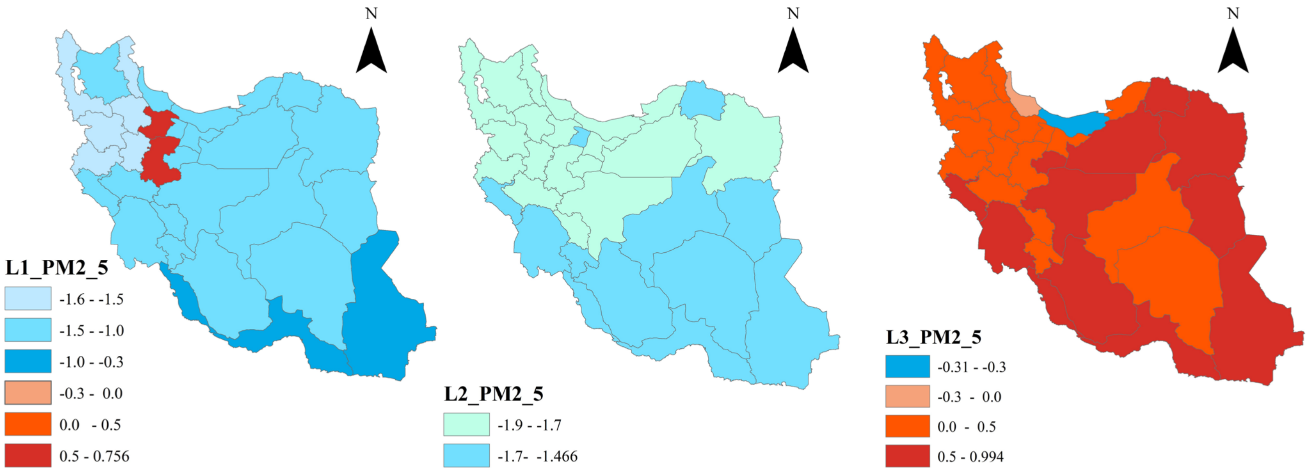

Fig. 4. Changes in $PM_{2.5}$ index in the provinces of Iran during lockdown 1-3

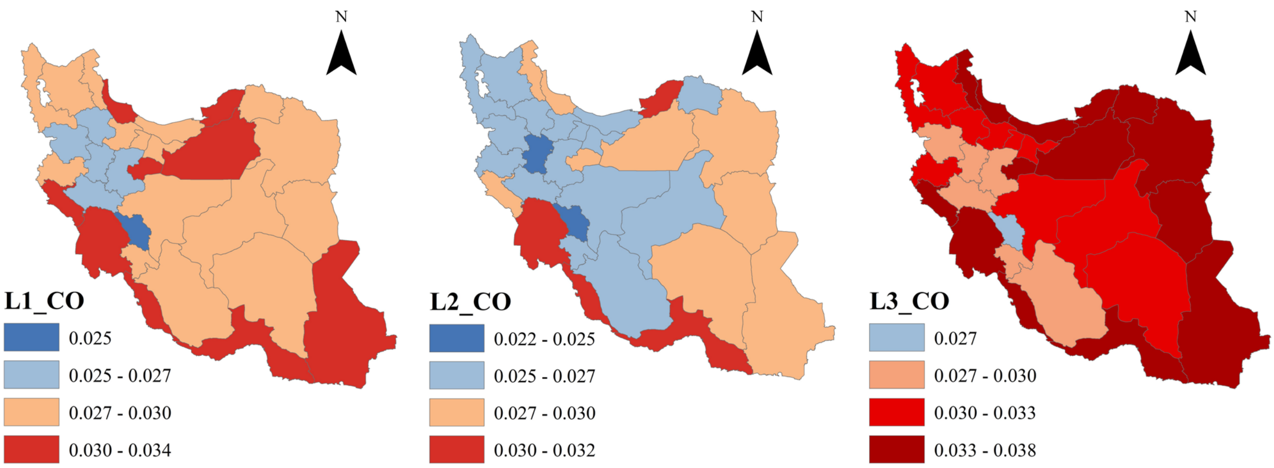

Fig. 5. Changes in CO index in the provinces of Iran during lockdown 1-3

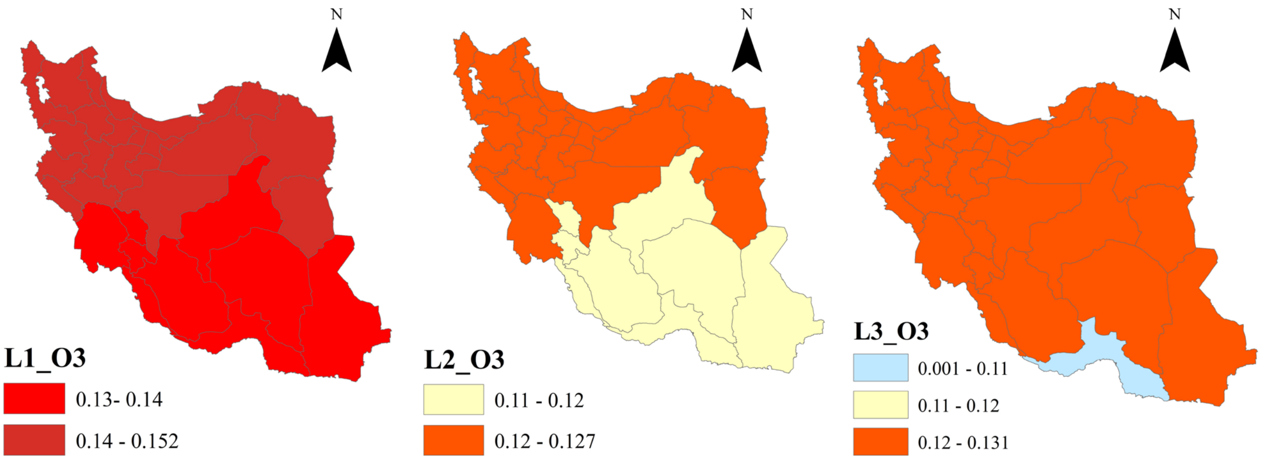

Fig. 6. Changes in O_3 index in the provinces of Iran during lockdown 1-3

Obtained results by this study are consistent with previous investigations. NO_2 and $PM_{2.5}$ levels declined by 60 and 31%, respectively; however, O_3 increased by 4% during quarantines in 34 countries [37]. The levels of PM_{10}, $PM_{2.5}$, and NO_2 in twelve cities during lockdowns decreased by 20-34%, 24-47%, and 32-64%, respectively; nevertheless, O_3 concentration increased due to reduction of NO emission [38]. Additionally, NO_2, SO_2, CO, and PM_{10} levels declined in some Spanish cities from March 15 to April 12, 2020; however, O_3 levels were increased [39]. Consequently, metropolitan lockdowns have led to dramatic air quality improvements that assist in managing the Covid-19 outbreak [40]. Although the Covid-19 pandemic is a substantial global health challenge that led to a dramatic alteration in environmental issues such as global warming and climate change in the 21st century and has influenced more than 210 countries, potentially it can create a novel lifestyle for sustainable environmental health [41, 42].

Conclusion

The emergence of the Covid-19 pandemic in 2020 was a health challenge that impacted more than 210 countries with unparalleled global economic and environmental consequences. Ecological outcomes of Covid-19 have been investigated as a remarkable absorbing research subject in numerous studies. Air quality improvement was one of these actual results in many regions, predominantly metropolitan and industrialized zones. Iran faced the Covid-19 pandemic and its critical consequences after China in February 2020. Three national quarantines were implemented in Iran to prevent fatalities and control the infection cases frequency between February 2020 and August 2021. Since air pollution reflects traffic and industrial activity, this ecological indicator was applied as the lockdown performance. The average changes of $PM_{2.5}$, CO, and O_3 and the infected cases and victims two months before and after each lockdown revealed that along with rising air pollution in lockdown 1, infected cases enhanced by 10.7%, and victims reduced by 29.8%. With decreasing air pollution in lockdown 2, infected cases and victims declined by 48.7% and 66.9%, respectively. Despite a significant increase in pollutants during lockdown 3, the infected cases and victims similarly decreased by 32.9% and 13.9%, respectively. Consequently, lockdown 2 (November-December 2020) was the most efficient quarantine, which significantly diminished air pollution plus Covid-19 cases. By considering the changes in air pollutants, the performance of lockdowns was not equal in all provinces of Iran.

The present study additionally demonstrated a statistically positive correlation between air pollutants and the abundance of infected cases and victims. $PM_{2.5}$ was more correlated with both abundances of cases and victims, among other pollutants. Despite the connection between Covid-19 cases and ecological factors such as air pollution, governments should handle the outbreak of Covid-19 by implementing accurate and effective quarantines, as well as environmental conservation strategies. This study did not examine interactions between air pollutants and meteorological determinants such as temperature, humidity, and wind speed; accordingly, it is recommended that next investigations concentrate on various effects of weather conditions on the prevalence of Covid-19. Furthermore, it is proposed that future investigations focus on diverse impacts of air pollution on the Covid-19 outbreak at a local or residential scale.

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Competing interests

The authors declare that no conflict of interest would influence this work.

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Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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