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Temporal variation of air pollution variables in different regions of Turkey during the Covid-19 restrictions

Covid-19 pandemisi kısıtlamaları sırasında Türkiye'deki farklı bölgelerdeki hava kirliliği değişkenlerinin zamansal değişimi

Zinnur Yılmaz[1,*], Mustafa Bünyamin Karagözoğlu[2]

[1,2] *Sivas Cumhuriyet University, Environmental Engineering Department, 58140, Sivas, Turkey*

Abstract

The main source of air pollution is harmful gases and particulate matter released into the atmosphere as a result of burning fossil fuels. The emergence of the new coronavirus has caused a pandemic respiratory disease (COVID-19) in which vaccines and targeted therapeutics for treatment are unavailable. For this reason, the concentration levels of PM10 and SO_2 measured with the help of data from 78 measurement stations in Turkey, primarily in Ankara, Istanbul and Izmir, were evaluated within the scope of the "National Air Quality Monitoring Network". According to the average values calculated depending on some measures taken during the quarantine period, there has been a significant decrease in air pollutant concentrations such as PM10 and SO_2, albeit in a short time. Depending on the population density of the 78 provinces represented, the ratio of the population in the regions positively affected by the decrease in PM10 and SO_2 parameters to the population of Turkey is 87.6% and 70.2%, respectively. The rates for the regions negatively affected by the concentration increase were calculated as 11.8% and 29.8% for both pollutants.

Keywords: Air pollution, COVID-19, PM10, SO_2, Turkey

Öz

Hava kirliliğinin ana kaynağı, fosil yakıtların yakılması sonucu atmosfere salınan zararlı gazlar ve partikül maddelerdir. Yeni koronavirüsün ortaya çıkması, tedavi için aşıların ve hedefli terapötiklerin bulunmadığı pandemik bir solunum hastalığına (COVID-19) neden olmuştur. Bu nedenle Türkiye'de Ankara, İstanbul ve İzmir başta olmak üzere 78 ölçüm istasyonundan alınan veriler yardımıyla ölçülen PM10 ve SO_2 konsantrasyon seviyeleri "Ulusal Hava Kalitesi İzleme Ağı" kapsamında değerlendirilmiştir. Karantina döneminde alınan bazı önlemlere bağlı olarak hesaplanan ortalama değerlere göre PM10 ve SO_2 gibi hava kirletici konsantrasyonlarında kısa sürede de olsa önemli bir azalma olmuştur. Temsil edilen 78 ilin nüfus yoğunluğuna bağlı olarak PM10 ve SO_2 parametrelerindeki düşüşten olumlu etkilenen bölgelerdeki nüfusun Türkiye nüfusuna oranı sırasıyla %87.6 ve %70.2'dir. Konsantrasyon artışından olumsuz etkilenen bölgeler için oranlar her iki kirletici için %11.8 ve %29.8 olarak hesaplanmıştır.

Anahtar kelimeler: Hava kirliliği, COVID-19, PM10, SO_2, Türkiye

1 Introduction

The Novel Coronavirus Disease (COVID-19) was first reported in Wuhan City of the People's Republic of China in December 2019, with a virus identified on January 13, 2020, as a result of research conducted in a group of patients, who presented with respiratory symptoms. The recent coronavirus disease called COVID-19 has raised global concerns and led to thorough restrictions in many countries [1–4]. The disease is induced by severe acute respiratory syndrome arising from coronavirus 2 (SARS-CoV-2) [5]. The disease was first detected in people who visited seafood and animal markets located in the specified region. It soon spread from person to person, reaching Wuhan and other cities in China, as well as the other countries of the world [6]. The deadly and novel coronavirus spreads rapidly among people in close contact with those infected [3,7]. It's possible to contain the spread of the virus by maintaining appropriate social distance, practicing proper personal hygiene, avoiding gatherings and activities with high infection risk such as visiting hospitals, attending meetings, and using public transportation [6,8,9].

On January 31, 2020, the World Health Organization (WHO) declared the "Public Health Emergency of International Concern (PHEIC)" regarding the novel coronavirus (COVID-19) outbreak that originated in China [10]. The pandemic affected 196 countries in the world, including Turkey.

In Turkey, the first known case of COVID-19 pandemic caused by the globally spreading coronavirus was reported on March 11, 2020, by the Ministry of Health of the Republic of Turkey. The first death in Turkey due to the virus occurred on March 16, 2020. The number of cases in Turkey has been continually increasing since March 2020. According to the latest data from the WHO, the COVID-19 virus has infected approximately 587 million people and more than 6.43 million people have died from the virus as of today.

* Corresponding author e-mail: zinnuryilmaz@cumhuriyet.edu.tr (Z. Yılmaz)
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The uncertainty about the long-term effects of the COVID-19 pandemic and the duration of the pandemic is likely to continue for a while [11]. Various factors such as climate conditions (e.g. temperature and humidity), population density, and quality of medical care all affect the transmission of viruses [4]. Therefore, understanding the relationship between the geographic characteristics of a country and the transmission of COVID-19 is the key to making the best decision to control and prevent a pandemic. Therefore, the geography and the spatial organization of a city can be very helpful in tracking the spread of the disease [4,12].

Previous studies show that air pollutants in the environment constitute risk factors for respiratory tract infection by transmitting microorganisms and affecting immunity, thus making people less resistant to pathogens [13–17].

2 Air pollution and the Covid-19 pandemic

The main sources of air pollution are the harmful gasses and particulate matter released into the atmosphere as a result of burning fossil fuels to generate energy. The current air pollutants are the primary pollutants released directly from the source to the atmosphere, and the secondary pollutants are generated during certain physical and chemical reactions resulting from the interactions of primary pollutants in the atmospheric environment [18,19].

Today, air pollution poses a serious environmental risk regarding many diseases and deaths in the world [20]. Figure 1 shows a world map exhibiting the death rate related to air pollution according to 2017 data [21]. According to the data, 9 out of 10 people have to breathe in air containing high levels of pollutants, which emphasizes the negative effect of air pollution on human health [1]. According to a report by WHO, exposure to air pollution causes 7 million deaths every year, mostly from non-contagious diseases, including acute respiratory infections such as pneumonia [22].

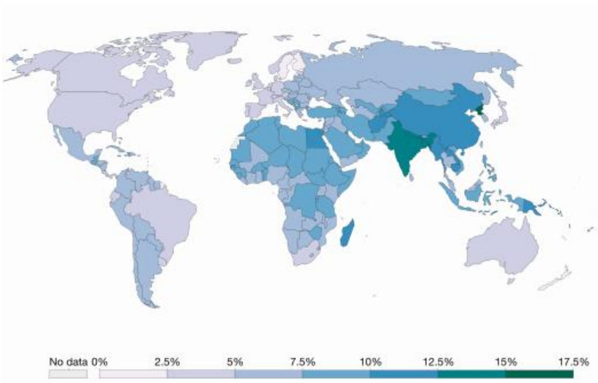

Figure 1. World map displaying the death rate from air pollution in 2017 [21].

Air pollutants, formed as a result of chemical reactions or physical events in the atmosphere, act as a carrier and negatively affect the immune system [13,14]. Several studies have revealed an association between short and long-term exposure to ambient air pollutants and multiple adverse health effects (such as higher mortality rates, increased number of hospitalizations, and outpatient clinic visits) [23].

Globally, 9% of deaths are caused by air pollution, and this rate varies among countries (2% to 15%). Researchers have argued that high air pollution and especially smoking have made people more vulnerable to diseases caused by air pollution in the current course of COVID-19 [18,19]. Scientists believe that air pollution is a common denominator in countries with severe cases of COVID-19, particularly in the northern regions of China, South Korea, Iran, and Italy [24]. Cities with more air pollution, in particular, carry a higher risk of COVID-19 [18]. Changing volumes of air pollution have been associated with increased respiratory infections and lung diseases [15,21,22,25,26]. These adverse conditions suffered by individuals due to air pollution may reduce the chances of survival from COVID-19 [27].

Studies conducted in China have concluded that the risk factors associated with the development of COVID-19 are advanced age, smoking history, hypertension, and heart disease [28–30].

The restriction of routine life activities in large geographic areas due to quarantine measures prompted by COVID-19 has led to a significant reduction in air pollution in many parts of the world, including China, Italy, and California (USA) [31,32]. In addition to pollution, greenhouse gas emissions have also decreased across continents [33]. The amounts of nitrogen monoxide (NO) and nitrogen dioxide (NO_2), which are significant air pollutants in China, vary in the atmosphere depending on the season and the hour of the day. Findings show that the rates of these pollutants decreased by 36% in 2020 compared to 2019 [34].

Particularly in Italy, the release of NO_2, an important source of PM generated by diesel vehicles, significantly decreased [27]. The PM10 levels in Lombardy significantly decreased after the implementation of 10-day social distancing mandates pertaining to the COVID-19 pandemic (Figure 2 A-B). Also, the concentration of NOx, one of the major air pollutants, significantly decreased in France due to a decrease in economic activity and transport caused by COVID-19 (Figure 3) [35].

Weather monitoring studies conducted in New York (USA) have revealed extremely high levels of CO over the past year and a half [36]. However, after the spread of COVID-19 in New York, traffic levels decreased by 35% from the previous year. CO and CO_2 emissions (5-10%) and methane concentrations also showed a significant reduction. In addition, officials have reported a decrease in NO_2 levels as the COVID-19 pandemic has led to a decline in business activity, resulting in less traffic in certain areas of the US [37].

In Brazil (Rio de Janeiro), carbon monoxide (CO) levels dropped significantly (30.3–48.5%) during the partial lockdown that began in mid-March. NO_2 decreased at a lower rate due to industrial and diesel engine vehicle inputs, and ozone level increased due to the decrease in nitrogen oxide level with a volatile organic compound (VOC) controlled scenario [38].

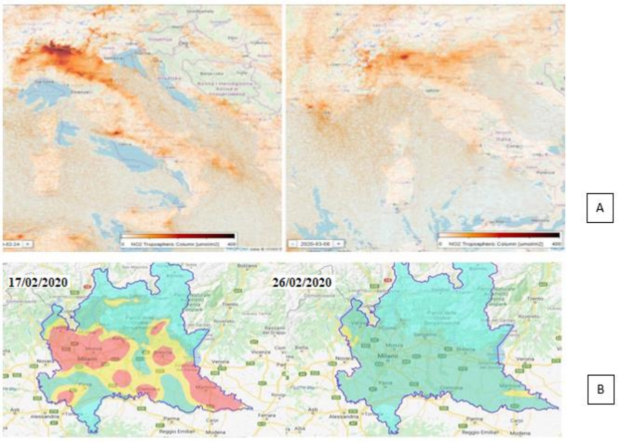

Figure 2. Image (A) shows the decrease in particulate matter levels of 10 micrometers (PM10) in Lombardy (Italy), and Image (B) shows the change in the NO_2 concentration in major Italian cities after 10 days of social distancing measures implemented due to the COVID-19 [27].

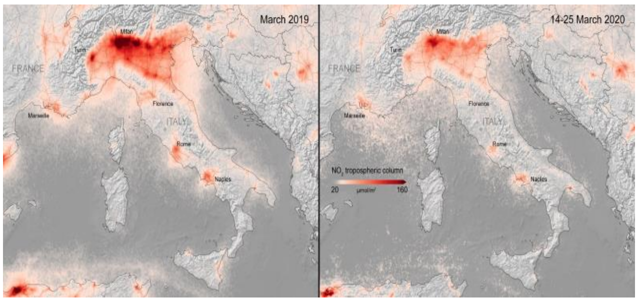

Figure 3. Image shows the decrease in NO_2 concentration in major French cities during the COVID-19 quarantine measures [35].

In another study conducted in Brazil, in order to understand the effects of partial quarantine on air quality in the state of São Paulo due to COVID-19, a study was conducted in which the five-year monthly average and four weeks before the quarantine data from four air quality stations were analyzed. As a result of the study, a decrease of up to 64.8% in CO concentrations (ppm) in the city center, and a decrease of up to 77.3% and 54.3% in the concentrations of NO and NO_2 on the city highways were observed, respectively. The partial quarantine has contributed to a positive effect on air quality [39].

In the study conducted in Beijing, Shanghai, Guangzhou and Wuhan cities of China, the effect of decreasing anthropogenic activities on air quality when COVID-19 started was investigated. PM2.5 decline rates in Beijing, Shanghai, Guangzhou and Wuhan were found to be 9.23, 6.37, 5.35 and 30.79 μg/m^3, respectively. It has been understood that the decrease in anthropogenic activities, especially in transportation and industry, contributes to the reduction of $PM_{2.5}$ concentrations. The decrease in $PM_{2.5}$ also indirectly demonstrates the adoption of “social distancing” [40,41].

Çelik and Arıcı (2021) air quality forecasting during the covid-19 outbreak: the example of Zonguldak, in his works; historical air quality data and PM10, SO_2, CO, O_3 and NO_2 pollutant concentrations measured on days during the Covid-19 epidemic process were analyzed with machine learning models for a successful prediction of air quality. A significant decrease was observed in the measured values of CO and SO_2 pollutants. When the data set consisting of pollutant concentrations measured daily for 2019-2020 is examined, it has been found that the relationship between PM10 and Air Quality Index is in parallel with the PM10 increase-decrease curve and the air quality curve at many points [42]. Topuz and Karabulut (2021), in their study to examine the effect of the measures taken within the scope of Covid-19 on the air quality in the Eastern Mediterranean, daily measurement of 9 measurement stations in Adana, Mersin, Hatay, Kahramanmaraş and Osmaniye between 01.01.2019-01.06.2020. data were taken and analyzed. When the results are examined; Especially from March 2020 until 01.06.2020, a significant decrease was observed in all measured pollutant values, especially PM 10 and SO_2, of almost all stations compared to the same period of the previous year (March-June 2019).According to the results of the statistical analysis; It has been determined that there are significant differences in the 99% confidence interval between the March-June periods of 2019 and 2020 in the average of the pollutant values of all stations, excluding PM 10 pollutants of Kahramanmaraş Central, Hatay İskenderun and Adana stations [43].

Kaplan et al., (2021), in their study, the effects of the COVID-19 quarantine implemented in Turkey on air quality were examined using remote sensing data. In this context, air quality was determined by measuring the amount of NO_2, CO, O_3, SO_2 molecules in the air obtained by the Sentinel-5P TROPOMI satellite before and after the shutdown, and comparisons were made. The results revealed how the closures implemented during the COVID-19 pandemic affect air quality. The results revealed how the closures implemented during the COVID-19 pandemic affect air quality [44]. Kaplan et al., (2021), in their study on Predicting PM10 and SO_2 air pollutants using Artificial Neural Network and Calculating the Error Rate, PM10 and SO_2 estimation was made using Sulfur Dioxide (SO_2) and Particulate Matter (PM10) data. In addition, Levenberg - Marquardt learning algorithm was used in Artificial Neural Networks (ANN) feedback network structure as a method. The obtained results were compared with the actual values and the root mean square error (OKH) was found. The OKH values found were < 0.04 [45]. Kara et al., (2020) investigated the effect of pollutants (PM10, PM2.5, SO_2, NO_2 and O_3) caused by the COVID-19 epidemic on air quality in semi-rural areas in Trabzon during the COVID-19 Measures. The measures implemented in Turkey were taken into account as three periods before (1 January-15 March), during (16 March-31 May) and after (1 June-30 June) and analysis of 6 different pollutants was carried out. It has been determined that air pollution in Trabzon decreased by 20% in general during the curfew period, and the pollutant concentrations increased by 30% during the normalization period [46].

The studies conducted above on COVID-19 show the effects and reflections of closure decisions and restrictions on air quality in the world and in Turkey.

According to scientific studies, meteorological data revealed that air pollution resulting from a combination of factors such as the level of industrialization and regional topography may be a vector of infection and a damage factor in the health-related consequences of the COVID-19 pandemic [47–49].

Air quality varies depending on natural (forest fires, volcanic eruption) and anthropogenic (traffic, industrial and domestic heating) sources, meteorological parameters and atmospheric and topographic factors in a particular region, and directly or indirectly affects human health negatively.

Given the fact that Turkey has implemented similar measures to those in various other countries; The main objective of this study is to determine the distribution of hourly PM10 and SO_2 concentration values obtained from 78 measuring stations throughout Turkey between 16 March and 11 May 2020 and to compare them with the limit values in national and international regulations.

3 Method

In this study examining the distribution of PM10 and SO_2 concentrations in terms of air pollution in 78 cities of Turkey, the concentration values of the aforementioned air pollutants were obtained from the air quality monitoring stations of the Ministry of Environment and Urbanization of the Republic of Turkey. Data regarding the hourly PM10 and SO_2 values between 00.00 on March 16, 2020, and 23.59 on May 11, 2020, were obtained from the air quality monitoring stations [48].

PM10 and SO_2 concentration values were evaluated within the scope of the study for a total of 336 measurement stations where air quality measurements were carried out in Turkey. The grouping of stations in industry, traffic and urban areas were not included in the study because they showed the same increase and decrease values for all groups in terms of the parameters examined. In addition, air pollution measurement stations in Mersin, Uşak and Ardahan provinces were not included in the study because there was no necessary data.

The mean values of the concentrations of these pollutants between March 16 - May 11, 2020, when strict measures were taken in Turkey regarding the coronavirus, and the same periods covering the years 2015-2019, when there was no virus epidemic, were calculated and compared with the countries in the world in order to monitor the current possible changes.

These dates were selected as they indicate the days when the restrictions were first implemented following the first death in Turkey due to COVID-19, and when the restrictions were eased. This period can be described as Phase I in Turkey.

In the study, one air quality station was selected from each city, and the related station data were evaluated with the Excel 2010 program, and then the calculated average and change rates were processed on the Turkey map with the ArcMap 10.8 program.

Accordingly, arithmetic mean values of the pollutants were calculated using the equation given below.

$$\overline{X} = \frac{\sum_{i=1}^{n} x_i}{n} = \frac{x_1 + x_2 + \cdots + x_n}{n} \tag{1}$$

In this equation (1),
$\bar{x}$ = mean PM10 or SO_2 values
x = hourly PM10 or SO_2 values
n = total PM10 or SO_2 counts

4 Results and discussion

This study examined the effects of reduced emission on air pollution due to decreased human activity during the COVID-19 outbreak in For this purpose, 78 provinces with current data for 2020 in air pollution monitoring stations from 81 provinces in Turkey were selected.

Table 1 shows the cities with trends of increase and decrease in PM10 and Table 2 shows the cities with trends of increase and decrease in SO_2 concentrations. These tables also show the mean values of these parameters from the same periods between the years of 2015 and 2019. The mean distribution of the concentrations of the pollutants among the provinces is presented in Figure 4-5.

PM10 generally contains earth crust materials, and the dust released into the atmosphere from roads and industrial facilities. Various natural sources such as the burning of fuels, diesel engines, construction and industrial activities, secondary aerosols (reaction of ammonia, sulfur, and nitrogen oxides in the air), plant pollen, and dust from the ground can generate particulate matter [49]. Calculations around the dates referred to as Phase I, indicating the implementation of measures in Turkey due to COVID-19 (March 16 - May 11, 2020) and the same periods between 2015 and 2019 showed that Hakkari (76%), Mardin (76%), Niğde (62%), Şanlıurfa (62%), and Afyonkarahisar (59%) were the cities where mean PM10 values decreased the most. A comparison between the dates in Phase I and the corresponding periods from 2015-2019 revealed that the mean PM10 values increased in 2020 in Tunceli (61%), Kilis (54%), Şırnak (31%), Malatya (28%), and Çanakkale (23%).

SO_2 is released through the burning of sulfur compounds found in fossil fuels, coal, and fuel oil. SO_2 concentrations are generally high in central areas of cities with the widespread use of coal for domestic heating, as well as industrial zones and their surroundings [50]. In this context, the maximum decrease and maximum increase rates of SO_2 concentrations on the basis of provinces were calculated for the dates we call phase I and the relevant periods between 2015-2019. The cities with the maximum decrease in mean SO_2 concentrations were Afyonkarahisar (79%), Kars (77%), Denizli (71%), Bartın (70%), and Osmaniye (68%); and Hakkari (393%), Ordu (369%), Tunceli (296%), Kocaeli (226%), and Şanlıurfa (186%) showed the most increased mean values.

Table 1. The changes in PM10 concentrations in cities with trends of increase and decrease in the specified periods (%).

NO	Station	Maximum Trend of Increase in PM10 ($\mu g/m^3$) Parameters			Station	Maximum Trend of Decrease in PM10 ($\mu g/m^3$) Parameters		
		2020	2015-2019 (Mean)	Change (%)		2020	2015-2019 (Mean)	Change (%)
1	Tunceli	25.82	16.02	61.17	Hakkari	11.1	46.42	76.09
2	Kilis	48.53	31.46	54.27	Mardin	13.65	57.07	76.08
3	Şırnak	48.16	36.79	30.91	Niğde	26.29	69.19	62.01
4	Malatya	46.08	36.03	27.9	Şanlıurfa	13.41	35.26	61.97
5	Çanakkale	39.83	32.41	22.89	Afyonkarahisar	23.54	57.73	59.23
					Mean Value for Turkey	32.66	45.45	28.15

Table 2. The changes in SO_2 concentrations in cities with a trend of increase and decrease during the specified periods (%).

NO	Station	Maximum Trend of Increase in SO_2 ($\mu g/m^3$) Parameter			Station	Maximum Trend of Decrease in SO_2 ($\mu g/m^3$) Parameter		
		2020	2015-2019 (Mean)	Change (%)		2020	2015-2019 (Mean)	Change (%)
1	Hakkari	169.94	34.46	393.12	Afyonkarahisar	4.06	19.55	79.24
2	Ordu	24.05	5.13	369.04	Kars	3.54	15.39	77
3	Tunceli	20.3	5.13	295.87	Denizli	4.86	16.71	70.91
4	Kocaeli	15.51	4.76	225.84	Bartın	3.31	10.94	69.76
5	Şanlıurfa	25.9	9.05	186.31	Osmaniye	3.36	10.36	67.58
Mean Value for Turkey		11.89	10.50	13.16				

(a)

(b)

Figure 4. Mean PM10 values in Turkey between March 16 - May 11, (a- 2020, b- Between 2015-2019)

(a)

(b)

Figure 5. Mean SO2 values in Turkey between March 16 - May 11 (a- 2020, b- Between 2015-2019)

According to Turkish Statistical Institute (TurkStat) data, the 78 cities, where the air pollutants such as PM10 and SO_2 were evaluated, represent 97.2% of the population of Turkey. Based on the population density of the 78 cities represented, the ratio of the population in the regions positively affected by the decrease in the PM10 parameters to the population of Turkey was 87.6%. The population ratio in the regions that were adversely affected by the increase in PM10 parameters was 11.8%. The population ratio in regions with no change in PM10 concentrations was 0.6%. The ratio of the population in the regions positively affected by the decrease in concentration in the SO_2 parameter to the population of Turkey was 70.2%, while for the regions negatively affected by the increase in concentration, this figure was 29.8%.

These calculations were made with the view that the PM10 and SO_2 parameters had the same impact on the population of the entire city in the regions where the measurements were taken.

Comparison between the mean values of the data belonging to the period with COVID-19 restrictions and the data belonging to the period between 2015 and 2019 in Turkey, revealed an increase in both PM10 and SO_2 parameters in Artvin (PM10 5%, SO_2 20%), Kastamonu (PM10 5%, SO_2 38%), Bingöl (PM10 12%, SO2 33%), Amasya (PM10 18%, SO_2 79%), Şırnak (PM10 31%, SO_2 12%), Kilis (PM10 54%, SO_2 19%), and Tunceli (PM10 61%, SO_2 296%).

A study conducted in Salé City (Morocco) evaluated the changes in the concentrations of certain air pollutants (PM10, SO_2) during the restriction period. The results indicated that the difference between the concentrations recorded before and during the restriction period was 75% - 49% for PM10 and SO_2, respectively [51].

Another study examining the potential effects of COVID-19 restrictions on the air quality in Tehran, the capital of Iran, based on the data obtained from 12 air quality monitoring stations, revealed that SO_2, PM10 concentrations had decreased by 5–28% and 1.4–30%, respectively [52].

A similar study conducted in China showed that the SO_2 and PM10 concentrations measured in 44 cities between January 1 and 21, 2020, had decreased by 6.76% and 13.66%, respectively and that the mean air quality index (AQI) had decreased by 7.8% [53].

Another study in Korea showed that the concentration of PM10 associated with industrial activities and traffic decreased in periods when COVID-19 restrictions were put in place. In March 2020, following the quarantine, the average level of PM10 concentration across the country decreased by 35.56% compared to the average level of the previous year and researchers reported that the aforementioned decrease was not associated with a decrease in SO_2 concentration [54]. A comparison between PM10 concentration values from the period with COVID-19 restrictions in Turkey and the mean values between 2015 and 2019 (45.45 µg/m^3), showed a 28% decrease based on the mean 2020 data (32.66 µg/m^3). On the other hand, there was a 13% increase in the mean SO_2 concentration values (2020: 11.89 µg/m^3; mean value between 2015 and 2019: 10.50 µg/m^3).

5 Conclusıon

It has been concluded that PM10 concentration, which is related to industrial activities and traffic, decreased during the quarantine period, with the COVID-19 virus epidemic measures being taken in Turkey. Furthermore, the distributions of SO_2 concentrations in Turkey, showed that COVID-19 quarantine periods imposed during the cold season in the country led to high SO_2 concentration levels in regions where the use of solid fuel is common.

Findings showed that even though SO_2 concentrations presented a trend of increase, based on the mean values for the concentrations of air pollutants, air pollution significantly decreased as a result of certain measures such as curfews on weekends and weekdays, restriction of industrial activities and intercity transportation, albeit for short periods.

Taking into consideration the mortality rate associated with air pollution, it is important for people living in cities with higher air pollution levels to be more cautious and take steps to strengthen their immune systems. Additionally, the use of masks can reduce coronavirus exposure, as the transmitting aerosols are in the 1-5 µm range. Mask use is therefore imperative to reduce the impact of air pollution in highly-polluted cities, which could, in turn, lower the risk associated with COVID-19.

With the implementation of safety measures and restrictions, emissions from exhausts of vehicles and industrial production showed a significant decrease, which contributed to a decline in the concentrations of the pollutants examined in the study.

In conclusion, the decrease in the PM10 and SO_2 concentrations observed in the cities examined in the study could essentially be associated with the strict measures implemented during the COVID-19 pandemic, which restricted mobility and industrial activities, leading to a significant decrease in the emissions caused by exhausts of vehicles and industrial production.

Conflict of interest: The authors declare that they have no conflict of interest.

Similarity (iThenticate): 13%

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