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IMPACT OF COVID-19 LOCKDOWN PRECAUTIONS ON AIR POLLUTANTS IN TURKEY

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Abstract: Due to the COVID-19 pandemic, the precautions taken in the early period of the pandemic have had a significant impact on the reduction of air pollutants. In this research, the changes in the concentrations of some air pollutants (PM_{10}, NO_2, SO_2, CO, O_3) concentrations have been investigated and evaluated between March 15 - May 31, 2019 and March 15 - May 31, 2020 in Turkey. According to the results, PM_{10}, NO_2 and SO_2 concentrations decreased by up to 75%, 80% and 77% respectively. However, there has been an increase in CO and O_3 concentrations in many cities. Pearson's correlation analysis showed that there is a strong relevance between NO_2 - CO and O_3 - CO concentrations in the lockdown period. In addition, with the precautions, the positive correlation between PM_{10} and NO_2 and between SO_2 and CO increased, and the negative correlation between PM_{10} and O_3 decreased.

Keywords: Air pollution, COVID-19, nitrogen dioxide, ozone, PM10

Covid-19 Kapanma Önlemlerinin Türkiye'deki Hava Kirleticilerine Etkisi

Öz: COVID-19 nedeniyle pandeminin erken döneminde alınan önlemler, hava kirleticilerinin azaltılmasında önemli bir etki yaratmıştır. Bu araştırmada, Türkiye'de 15 Mart-31 Mayıs 2019 ve 15 Mart-31 Mayıs 2020 tarihleri arasında bazı hava kirletici (PM_{10}, NO_2, SO_2, CO, O_3) konsantrasyonlarındaki değişimler araştırılmış ve değerlendirilmiştir. Sonuçlara göre PM_{10}, NO_2 ve SO_2 konsantrasyonları sırasıyla %75, %80 ve %77'ye kadar düşmüştür. Ancak birçok şehirde CO ve O_3 konsantrasyonlarında artış tespit edilmiştir. Pearson korelasyon analizi, kapanma döneminde NO_2-CO ve O_3-CO konsantrasyonları arasında güçlü bir ilişki olduğunu göstermiştir. Ayrıca alınan önlemlerle PM_{10} ile NO_2 ve SO_2 ile CO arasındaki pozitif korelasyon artmış, PM_{10} ile O_3 arasındaki negatif korelasyon azalmıştır.

Anahtar Kelimeler: COVID-19, hava kirliliği, azot dioksit, ozon, PM_{10}

1. INTRODUCTION

In December 2019, a disease called COVID-19, which was determined to be transmitted from person to person through airborne droplets, emerged in China-Wuhan (WHO, 2019). Later in the same month, it was found that the virus was not only found in Wuhan but also caused a pandemic that spread rapidly all over the world (Muhammad et al., 2020). Because of the COVID-19 pandemic, thousands of people are dying in just one day in the world. As of 3 January 2022, 281.808.270 positive cases have been confirmed and 5.411.759 deaths were reported (WHO, 2022). The most important precaution to be taken to prevent the pandemic is that people isolate themselves in their homes and stay away from social areas unless they have to.

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By the COVID-19 pandemic, each individual has changed their lifestyle by following the precautions determined by the scientific boards and governments. Therefore, important changes have occurred in living spaces where people are frequently present. According to the researches, mobility has decreased by up to 95% in some countries (Google, 2020; Muhammad et al., 2020).

As countries apply to stay within the framework of lockdown precautions, some industrial activities have ended globally, road and air transport have decreased considerably and even stopped in some countries (Muhammad et al., 2020). Air pollution has been significantly reduced due to reasons such as people not going out unless necessary, a decrease in the use of motor vehicles, and having to stop production in large industrial facilities (Islam et al., 2021). As the world came to a halt, the sudden disruption of most industrial activities significantly reduced air pollution levels. Satellite images revealed a significant decrease in global nitrogen dioxide (NO_2) levels emitted from automobile engines and commercial production facilities and responsible for bad air quality in many major cities. According to NASA's NO_2 measurements, air pollution in the US reached its lowest level since 2005, when measurements with satellites began (Blumberg, 2020).

The main pollutants that cause air pollution are particulate matter, nitrogen dioxide, sulfur dioxide, carbon monoxide and ozone. Particulate matter is formed anthropogenically and naturally, by the dispersion of solid and liquid particles in the suspended form in the air (WHO, 2006). Nitrogen dioxide is a highly reactive substance produced by burning fossil fuels. It occurs from industrial activities and emissions from vehicles. NO_2 is a key to atmospheric chemistry and is an important precursor for both ozone generation and secondary aerosol generation (Seinfeld & Pandis, 2016). Sulfur dioxide arises from industrial activities such as thermal power generation, mineral ores, industrial activities burning fossil fuels, motor vehicle emissions (Chen et al., 2012; Islam et al., 2021). Anthropogenic carbon monoxide emissions originate from unburned carbonaceous materials. Exhausts of internal combustion engines and gasoline vehicles constitute carbon emissions. Coal-using power plants and waste incineration plants are among the other carbon emission factors (WHO, 2000). Ground-level ozone is a harmful air pollutant. It is formed by the chemical reaction of nitrogen oxides and volatile organic compounds but is not emitted directly into the air. Ozone emitted from vehicles, power plants, refineries, and chemical factories react chemically in the presence of sunlight and is transported long distances by wind, even in rural areas (Nuvolone et al., 2018).

In this study, five air pollutants (PM_{10}, NO_2, SO_2, CO and O_3) concentrations were investigated between March 15 - May 31, 2019 and March 15 - May 31, 2020. The study aims to determine the effect of lockdown precautions on air pollutants in some cities in Turkey.

2. MATERIALS AND METHOD

To determine the effect of the COVID-19 precautions on concentrations of air pollutants, five different air pollutants (PM_{10}, NO_2, SO_2, CO, and O_3) data were collected for some provinces (Edirne, Trabzon, Erzurum, Ankara, Izmir, Antalya, Istanbul, Zonguldak, Kocaeli, Denizli, Kayseri and Adana) that have different specific features in Turkey during the period of March 15-May 31, 2019 and March 15-May 31, 2020 using Continuous Monitoring Center (CMC). The CMC is affiliated with the TR Ministry of Environment and Urbanization, and air pollutants are constantly measured through stations located in different places by CMC. There are many different measuring stations in a city, although not the same number. The average of the measuring stations in each city was taken. The stations make measurements every hour and every day according to the type of pollutant and location. In PM10 measurement, Environnement SA MP101M (France) (works with the principle of obtaining a reference value with the diaphragm placed between the filter and beta rays reflector), Thermo 5014i (USA) (measures mass concentration by beta diffraction method) and Met One Bam 1020 (USA) (measures with constant beta radiation) devices were used. For NO_2 measurement, Environnement SA AC32M-AC32e

(France) (uses the chemical luminescence characteristic of nitrogen dioxide in the presence of ozone molecules with high oxidation capacity), Thermo 42i (USA) (works with the principle of chemical radiation technique) and Teledyne T200 (USA) (works with adaptive filtering technique) devices were used. In SO_2 measurement, Environnement SA AF22M-AF22e (France) (works with the fluorescence measurement principle in ultraviolet rays), Thermo 43i (USA) (measures with UV fluorescence technique, it is more selective in wavelength isolation) and Teledyne T100 (USA) (Used for low-level SO_2 concentration measurement with UV fluorescence principle) devices were used. In CO measurement, Environnement SA CO12M-CO12e (France) (used to measure carbon monoxide at low concentrations according to the infrared beam principle), Thermo 48i (USA) (measures carbon monoxide using gas filter correlation technology) and Teledyne T300 (USA) (Absorbed infrared energy is calculated according to the Beer-Lambert law. It measures by comparing it with that absorbed by a reference gas) devices were used. In O_3 measurement, the Environnement O341M-O342M-O342e (France) (works according to the ultraviolet absorption principle), Thermo 49i (USA) (works according to UV photometric technology) and Teledyne T400 (USA) (detection of UV light signal and absorbed ozone concentration according to Beer-Lambert law) devices were used. While determining the concentration of pollutants, the averages of the daily changes between the specified months of 2019 and 2020 were taken. The analysis was carried out in March-April-May, and the average air temperature measured for the sampling stations in the spring season for 2019 was 12.6±4.8 °C and for 2020 the average was 12.5±4.4 °C (Weather Spark, 2022).

Since air pollutant concentrations are also affected by factors such as industrial activities, vehicle traffic, etc., the Google Mobility Report was evaluated first. Percentage change in places where people spend their time in Turkey according to the Google Mobility Report within the COVID-19 precautions is given in Fig. 1 (Google, 2020). According to the report, the time spent in residences increased by 25%, while the time spent on transportation decreased by up to 82%. Time spent in entertainment centers has also decreased significantly with a value of 79%.

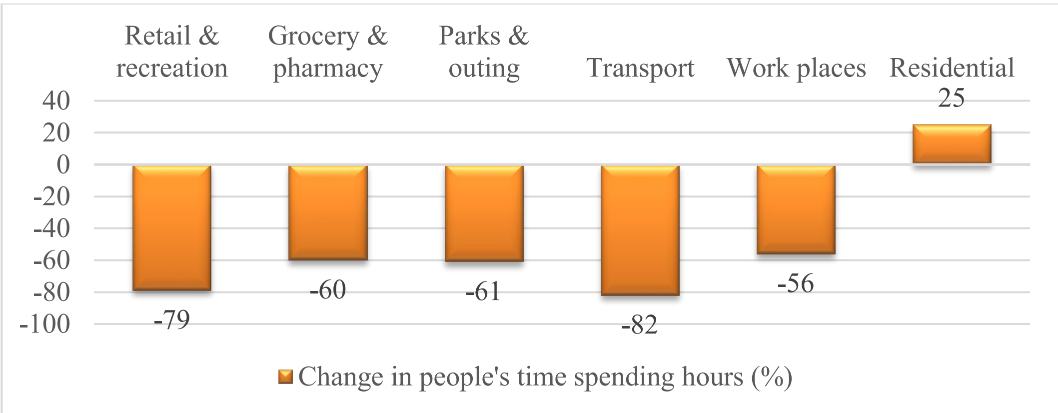

Figure 1:
Percentage change in places where people spend their time after the COVID-19 precautions in Turkey

While selecting the cities to evaluate, the cities which are able to represent the region where they are located in terms of industrial facilities and for whom the data provided by the Continuous Monitoring Center is possible has been selected. The reasons for choosing the cities are as follows: Edirne, Trabzon, Erzurum, Ankara, Izmir and Antalya represent their geographical regions, Istanbul is the most populous city in Turkey in terms of population density, Zonguldak has a Thermal Power Plant and Kocaeli, Denizli, Kayseri and Adana are big industrial cities. The average data is shown on the map using the paintmaps.com application.

The average of air pollutant concentrations from March 15-May 31, 2019 from the Continuous Monitoring Center, compared with the average values of pollutant concentrations between March 15, 2020 and May 31, 2020.

3. RESULTS

There are no published results for all pollutant parameters by the Continuous Monitoring Center for all stations where measurements were made. Therefore, the number of pollutant parameters varied for each station.

3.1. Particulate Matter (PM_{10})

The average PM_{10} concentration changes in Turkey are given in Fig. 2. When the figure is analyzed, the values were at a concentration range of 105-120 µg/m^3 in 2019 in Ankara and Zonguldak and has decreased to range of 85-105 µg/m^3 in 2020. The PM_{10} concentration was between 85-105 µg/m^3 in Adana in 2019 and it has decreased significantly to the range of 30-40 µg/m^3. In addition, PM_{10} concentrations in Erzurum, Kayseri and Kocaeli have significantly decreased by up to 87%, depending on the precautions taken in 2020. PM_{10} concentrations have decreased in all other provinces in Turkey (CMC, 2020).

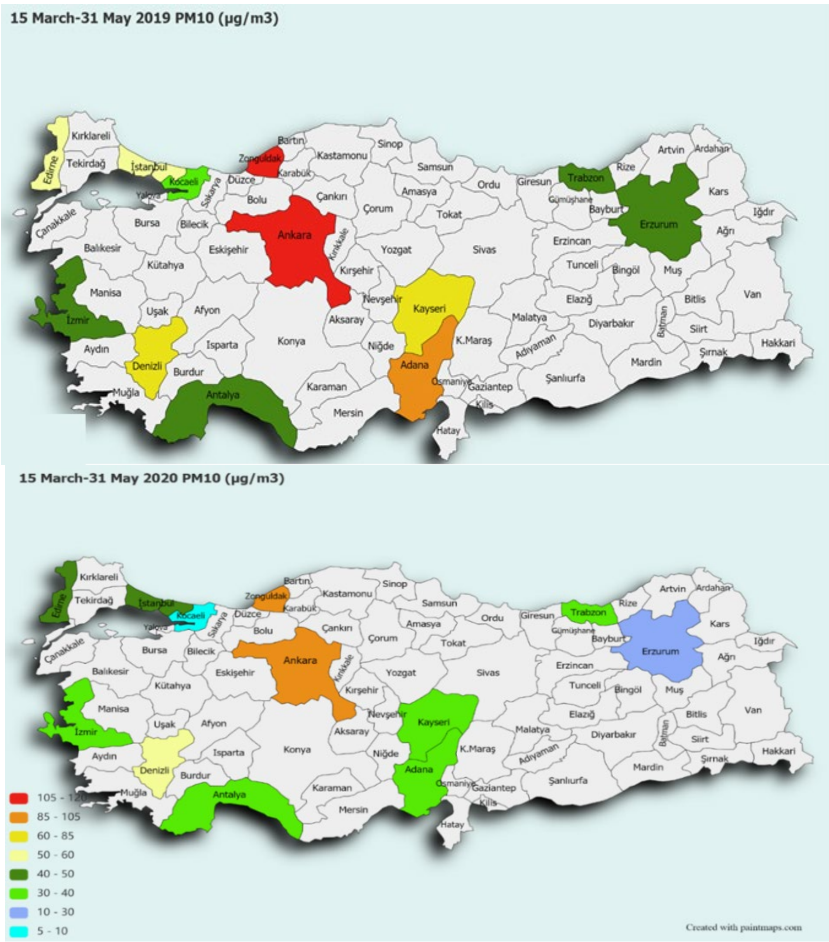

Figure 2:
Average PM_{10} concentration changes after the COVID-19 precautions

3.2. Nitrogen Dioxide (NO_2)

In Fig. 3, average NO_2 concentration changes in Turkey are given. NO_2 concentration is varying between 80 and 90 µg/m^3 in Istanbul and Kayseri between March and May 2019, significantly decreasing to 50-70 µg/m^3 in Istanbul and 20-30 µg/m^3 in Kayseri in the same months of 2020. There was a 77% decrease in NO_2 concentration. NO_2 concentration in Zonguldak remained stable on average but decreased in other provinces by up to 20 µg/m^3 (CMC, 2020). Sentinel-5 P Nitrogen Dioxide Tropospheric column in Turkey between March-May 2019 and 2020 is shown in Fig. 4 (Google Earth Engine, 2021). When Fig. 4 is examined, there is a high concentration of NO_2 especially in the Marmara region between March-May 2019, while there is a decrease in NO_2 concentration in the same months of 2020. Regions, where large decreases are observed, are places where population and industrial facilities are concentrated.

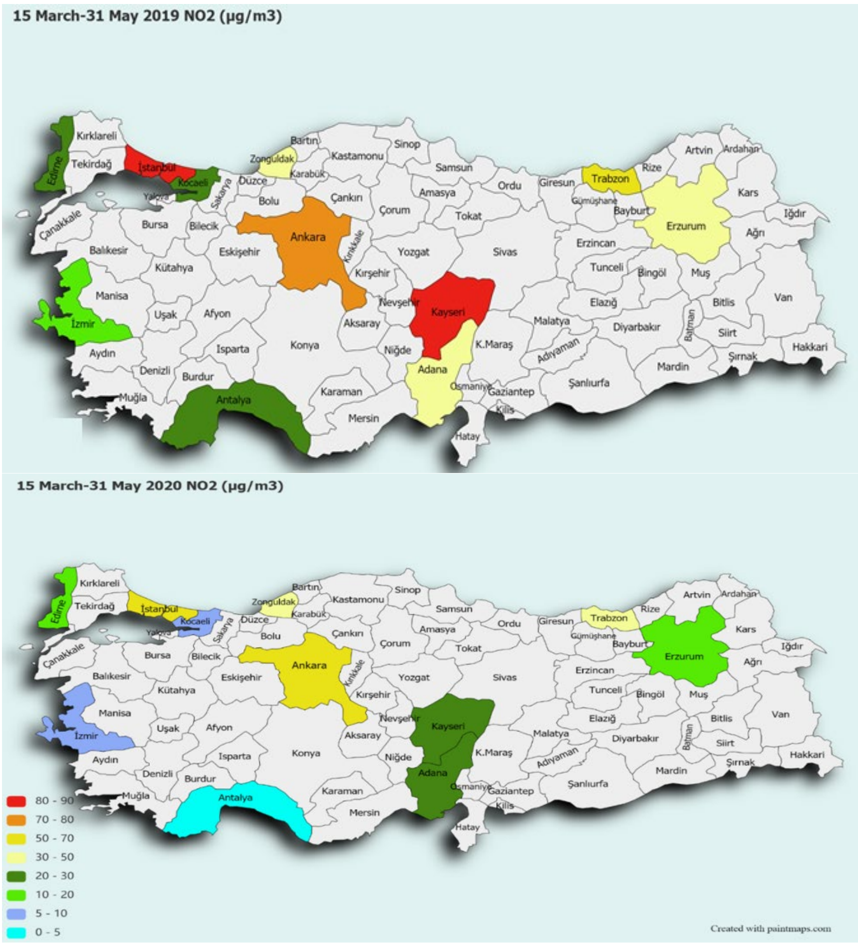

Figure 3:
Average NO_2 concentration changes after the COVID-19 precautions

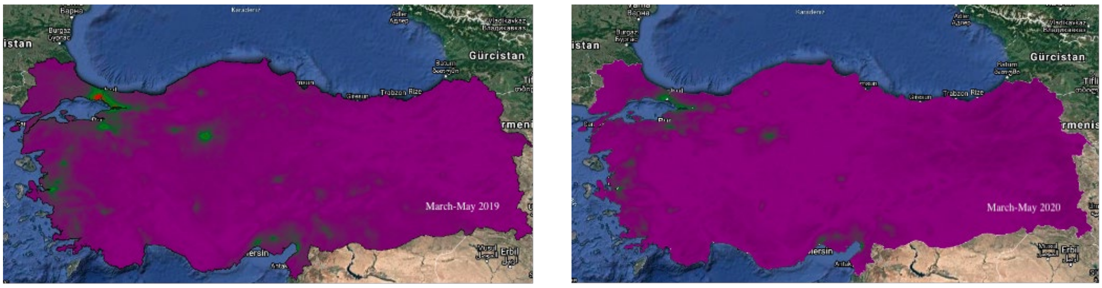

Figure 4:

Average NO_2 concentration changes in Turkey (Google Earth Engine, 2021)

3.3. Sulfur Dioxide (SO_2)

Fig. 5 shows the changes of SO_2 after the COVID-19 precautions in some provinces in Turkey. While the SO_2 concentration in Edirne ranged between 60-110 µg/m^3, it decreased to the range of 25-60 µg/m^3. SO_2 concentrations are not at high levels in Turkey in general. There has been a significant decrease in SO_2 concentration from 20-25 µg/m^3 to 0-5 µg/m^3, 98% in Denizli. In Istanbul and Trabzon an increase of 5 µg/m^3 occurred in 2020 compared to 2019 in SO_2 concentration (CMC, 2020).

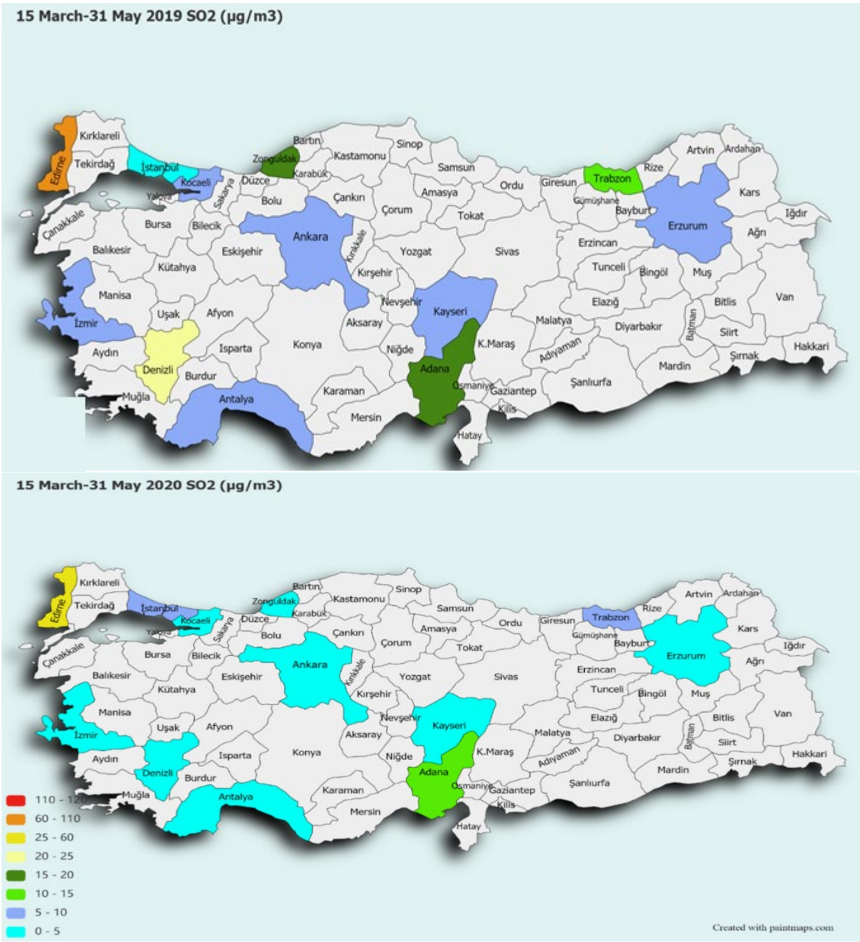

Figure 5:

Average SO_2 concentration changes after the COVID-19 precautions

3.4. Carbon Monoxide (CO)

In Fig. 6, CO concentration value changes are given in Turkey. In all provinces given, there was an increase in CO concentration after the COVID-19 precautions. Erzurum and Zonguldak follow Istanbul with high CO concentrations. İzmir has been determined as the province with the lowest CO concentration value (CMC, 2020).

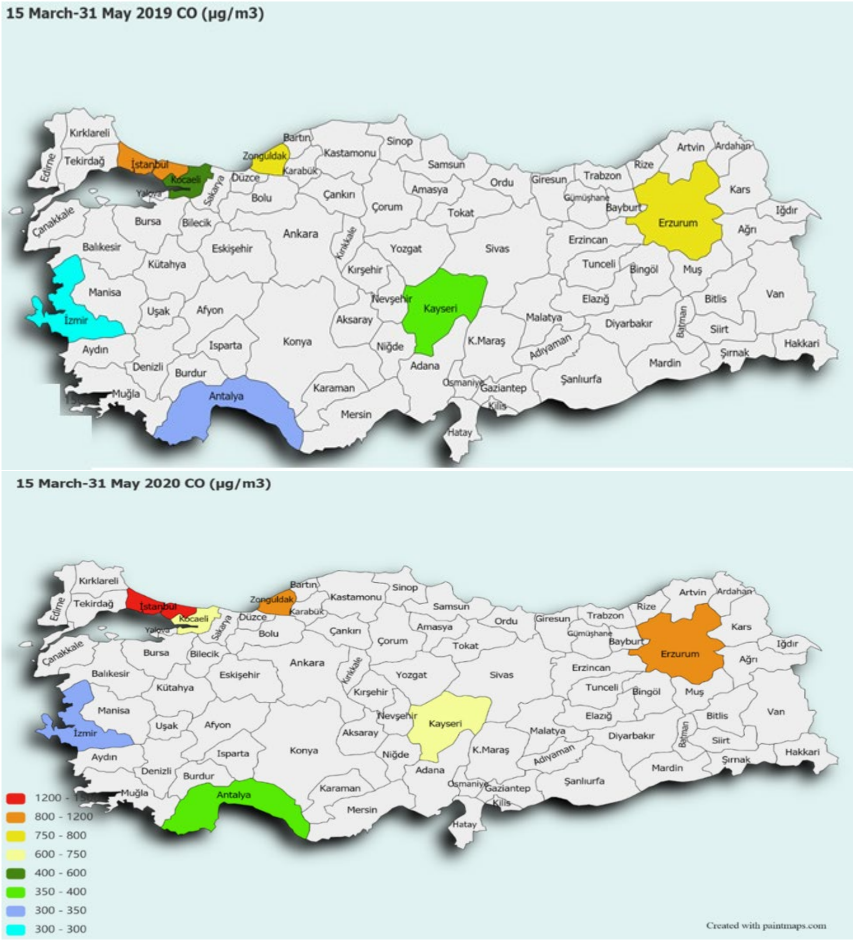

Figure 6:
Average CO concentration changes after the COVID-19 precautions

3.5. Ozone (O_3)

In Fig. 7, O_3 concentrations that change with the COVID-19 precautions in Turkey are given. In Adana and Antalya, after the COVID-19 precautions, an increase was observed in the O_3 concentration. While the average O_3 concentrations remained the same in Erzurum and Edirne, there is a decrease in O_3 concentration in Kocaeli. By the way, the highest ozone concentration among the provinces provided was recorded in Erzurum.

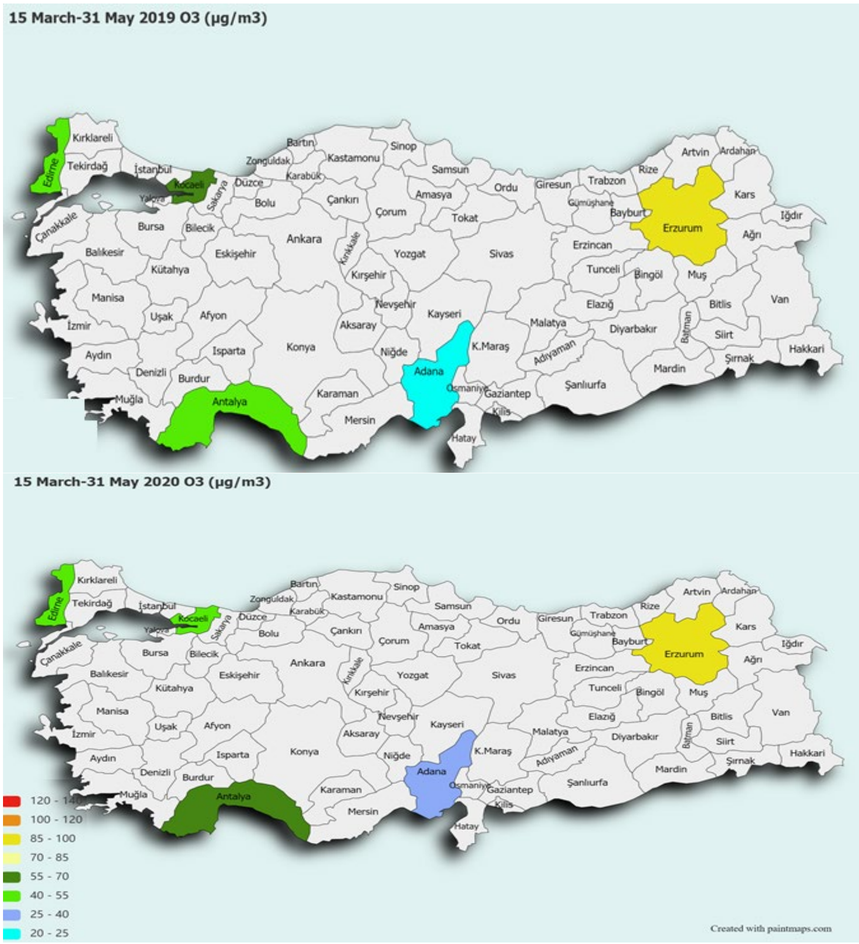

Figure 7:
Average O_3 concentration changes after the COVID-19 precautions

3.6. Pearson's Coefficients of Air Pollutants

The correlation between the detected air pollutant concentrations of 2019 and 2020 was investigated. In 2019, the highest correlation in the same direction was found between CO and O_3 (r=1). The highest reverse correlation was determined between PM_{10} and O_3 (r=–0.73). While there is a moderate positive correlation between PM_{10} and NO_2, there is a low positive correlation between CO and PM_{10}. A moderate negative correlation was found between NO_2 and SO_2, while a moderate positive correlation was found between NO_2 and CO. There is a low positive correlation between NO_2 and O_3. However, there is no linear correlation between SO_2 and PM_{10}. There was a low positive correlation between SO_2 and CO, and a low negative correlation between SO_2 and O_3 (Table 1).

When the year 2020 is evaluated, the highest positive correlation was determined between NO_2 and CO (r=0.86). The lowest correlation was found between PM_{10} and SO_2 with a negative direction (r=–0.03). There is a high positive correlation between PM_{10} and NO_2 - PM_{10} and CO, and a low negative correlation between PM_{10} and O_3. There is a low negative correlation between NO_2 and SO_2 and O_3. While there is a positive correlation between SO_2 and CO, there is a moderate negative correlation between SO_2 and O_3. As of 2019, there is a strong positive correlation between CO and O_3 (r=0.71) (Table 1).

Table 1. Pearson correlation coefficients of air pollutants after lockdown.

	2019					2020				
Pearson Correlation Coefficient	PM_{10}	NO_2	SO_2	CO	O_3	PM_{10}	NO_2	SO_2	CO	O_3
PM_{10}	1	0.35	0	0.28	-0.73	1	0.66	-0.03	0.30	-0.28
NO_2	0.35	1	-0.32	0.46	0.09	0.66	1	-0.13	0.86	-0.27
SO_2	0	-0.32	1	0.04	-0.26	-0.03	-0.13	1	0.69	-0.34
CO	0.28	0.46	0.04	1	1	0.30	0.86	0.69	1	0.71
O_3	-0.73	0.09	-0.26	1	1	-0.28	-0.27	-0.34	0.71	1

4. DISCUSSION

When the PM_{10} concentrations regarding the effect of the precautions taken in Turkey on air pollutants are examined, it has been observed that from 2019 to 2020, it has decreased from 85-105 µg/m^3 to 30-40 µg/m^3, while there are upward decreases in some provinces to 87%. A similar decrease occurred in PM2.5 and PM_{10} concentrations in other countries (IQAir, 2019; Shrestha et al., 2020; TUİK, 2019; Wang et al., 2020). $PM_{2.5}$ concentration levels in many countries around the world fell to an unprecedented level as a result of compliance with lockdown precautions. $PM_{2.5}$ levels decreased by 44% in Wuhan, 54% in Seoul, 60% in New Delhi and 31% in Los Angeles (IQAir, 2019. It has been determined that anthropogenic emission, primarily originating from transportation and industry, has decreased and contributed to the reduction of $PM_{2.5}$ concentrations. The reduction concentrations of $PM_{2.5}$ in Beijing, Shanghai, Guangzhou, and Wuhan were determined as 9.23, 6.37, 5.35, and 30.79 µg/m^3 respectively (Wang et al., 2020). In a study conducted in Turkey, it was determined that the provinces with the highest decrease in PM_{10} value were Kahramanmaras with 60% (the reason for the highest PM_{10} decrease in Kahramanmaras is the temporary closure of the thermal power plant located here for legal reasons). In Istanbul, which has a dense population, the reduction value was determined as 11% (TUİK, 2020). In another study, with the precautions taken after the pandemic, PM_{10} concentration decreased by 60.7% in Vienna, 53.3% in Bern, 52.7% in Paris, 45.9% in Warsaw, and 44.3% in Dublin (Shrestha et al., 2020).

A decrease was observed in NO_2 concentration measurements in 2020 compared to 2019 in Turkey. This is observed when the satellite images of both years are compared. Similarly, with the COVID-19 precautions, compared to the same days of 2019, the decrease rate in NO_2 concentrations in some countries, regions, and cities after the lockdown is 30% for Wuhan, 25% for China, Europe, Italy, France, Spain, 30% for the USA, 40% for Mumbai, 50% for New Delhi (Muhammad et al., 2020), and 54.3% São Paulo state, Brazil (Nakada & Urban, 2020). According to data from Sentinel-5P Nitrogen Dioxide tropospheric column, NO_2 concentration decreased by 40-50% from 2019 January to 2020 April in industrial areas in India (Balamadeswaran et al., 2021; ESA, 2021b). In a study conducted in the UK, it was stated that the NO_2 pollution on the roadsides decreased slightly with the COVID-19 precautions by comparing the same months of 2019 and 2020 (EEA, 2021; ESA, 2021a).

When SO_2 concentrations between 2019 and 2020 are examined, a decrease of up to 98% was found in some cities in Turkey, and an increase of 5 µg/m^3 in Istanbul and Trabzon. Similar results were obtained in studies examining both Istanbul and other world cities. In studies on the effect of COVID-19 precautions on SO_2 concentrations, a decrease of 75.2% in Lima, 38.9% in Nanjing, 36.8% in Beijing, and 64.8% in Bogota was observed. SO_2 concentrations increased in cities such as Buenos Aires, London, Toronto, and Istanbul (Shrestha et al., 2020). In a study conducted in

China, SO_2 concentration decreased by 15.9% (Zhang et al., 2021), but in another study conducted in Canada, no significant correlation was found between SO_2 and COVID-19 precautions (Tian et al., 2021).

When the CO concentrations of 2019 and 2020 are examined, it has been determined that the CO concentrations have increased in every city in Turkey. In world cities, there is both an increase and a decrease. Therefore, it is not possible to say that the precautions taken significantly affect the CO concentration. In a study investigating the relationship between CO concentration and COVID-19 precautions, CO concentration decreased by 35.1% in Amsterdam, 48.3% in London, and 27.3% in Lima. However, it increased by 171% in Istanbul, 465.2% in Jerusalem, 15.8% in Bogota, 22.6% in San Francisco, 28.1% in Warsaw, and 24.3% in Taipei (Shrestha et al., 2020). While the percentage of reduction in CO concentration in China was detected as 10.8% (Zhang et al., 2021), and in Brazil (São Paulo) was detected as 64.8% (Nakada & Urban, 2020). The reasons for the increase in the CO concentration during the lockdown may be the population density of the cities where the measurement is made, the continuation of activities in some industries without taking strict measures, changing temperature, precipitation, and climatic-social factors (Barua & Nath, 2021; Ray et al., 2022).

When the O_3 concentrations in Turkey in 2019 and 2020 are compared, a decrease was observed in some cities and an increase was observed in some cities, as in the case of SO_2 concentrations. The fact that Erzurum is the city with the highest O_3 concentration can be explained by the terrestrial climate conditions of Erzurum and the propagation behavior of air pollutant emissions accordingly. When the relationship between COVID-19 precautions and O_3 concentrations was investigated in the world, an increase in O_3 concentration was found in most studies. For example, there has been an increase of 32.9% in China (Zhang et al., 2021) and up to 30% in Brazil (São Paulo) (Nakada & Urban, 2020). There are even studies in which the O_3 concentration has been determined to be 525% periodically (Hashim et al., 2021). The reason for the ozone increase may be related to the decrease in NO, NO_2, and PM concentrations (Liu et al., 2020; Nakada & Urban, 2020).

While the correlation between CO and O_3 was high in 2019, it is observed that the correlation between CO and O_3 decreased in 2020. Instead, there was a significant increase in the correlation between CO and NO_2. It can be said that there is no correlation between PM_{10} and SO_2 for both years. With lockdown precautions, the positive correlation between PM_{10} and NO_2 increased and the negative correlation between PM_{10} and O_3 decreased. It was determined that the positive low correlation between SO_2 and CO turned into a positive high correlation in 2020.

5. CONCLUSIONS

As a result of the literature review, it was seen that in some countries, after the COVID-19 precautions, air pollution decreased by up to 46% and concentrations of $PM_{2.5}$, CO_2 and NO_2 from air pollutants decreased by 60%, 25% and 90%, respectively.

The study we have done is about air pollutant concentrations in some cities in Turkey, and it was carried out by obtaining data from the Continuous Monitoring Center between 15 March-31 May 2019 and 15 March-31 May 2020. The results showed a decrease of up to 75%, 80% and 77% in PM_{10}, NO_2 and SO_2 concentrations in Turkey, respectively. However, there has been an increase in CO concentration and O_3 concentration in many cities. It is thought that this situation is caused by meteorological factors affecting secondary air pollutants formed as a result of oxidation from primary pollutants. The positive correlation between CO and NO_2 and, CO and O_3 reveals the importance of taking measures to reduce the CO concentration.

When the change of all air pollutants during quarantine is examined in Turkey, it is possible to say that there has been a significant improvement in air quality, especially in big cities, due to the suspension of industrial activities and the decrease in transportation due to the pandemic. It has also been determined that anthropogenic effects change the interaction between air pollutants and air pollutant concentrations. Therefore, a sustainable reorganization of living conditions during closure measures can be recommended so that people are not exposed to environmental pollution.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

SGD: Conceptualization, Methodology, Data curation, Writing-Original draft preparation, Visualization, Investigation, Supervision**,** Writing-Reviewing and Editing.

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