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The Positive Impact of the Lockdown on the Atmosphere and Climate in Downtown, Amman, Jordan Using Geographic Information Systems and Remote Sensing

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Abstract

Coronavirus is a pandemic threatening global stability. Many countries imposed the lockdown to limit the spread of this virus, and to reduce the infection among individuals. Jordan was one of these countries that adopted strict decisions to limit the spread of the Coronavirus, as the Jordanian government imposed on March 21 the decision to completely lockdown. This study aims to find out the extent of the impact of the lockdown on the atmosphere and climate in Downtown, Amman, Jordan by using geographic information systems and remote sensing. Daily air pollutants concentration (PM10, NO2, SO2, O3, and CO), temperature, humidity, and wind speed and direction were obtained from the Environment Ministry of Jordan. The results indicated that the lockdown reduced the concentration of NO2, CO, and PM10, and did not affect the concentration of O3, and SO2. Also, there were no significate changes in the temperature, relative humidity, and wind speed, and direction during the lockdown period, compared with previous years. Therefore, lockdown may have a positive impact on the environment, but this apparent decrease in air pollutants may be a temporary decrease, as these values are expected to rise again after passing the Corona pandemic and the end of the lockdown.

Keywords: Coronavirus, Pandemic, Lockdown, Remote Sensing, Pollutants, Atmosphere, Climate.

1. INTRODUCTION

The analysis of remote sensing and geographic information systems (GIF) depends on the use of technology mainly to collect data and analyze it to understand many phenomena (1).This is in line with the great expansion of available opportunities, and the great availability of vital tools, which can be used to provide the correct development in various fields (2). Usually, remote sensing systems and geographic information systems are used together, where data is collected by remote sensing systems through specific devices, and this data is analyzed using geographic information systems where this data is displayed in the form of geographical information and then it is stored on computers, this helps to monitor the change in natural resources and various environmental factors (1, 2). Remote sensing and geographic information systems have been used effectively in environmental monitoring in many types of research.

The world recently witnessed a catastrophe called COVID-19, which is an infectious virus that is infecting the respiratory system. Statistics around the world indicate the seriousness of this virus, as the whole world suffering from the Coronavirus pandemic (3). The virus appeared for the first time on 12/2019 in China.On January 30, 2019, the Coronavirus became the sixth health emergency in the world, the global virus spread began in February 2020, as studies indicated that it is transmitted through human interaction (4) and spread very quickly, as within five months it moved to 210 countries and many people were infected and are still infecting with it until now (5). Based on the extent of Corona's impact on the countries and the diff of its capabilities, the government of each country has adopted some preventive measures to limit Corona's spread, and reduce the number of daily cases and deaths, the interventions are including enforcing quarantines, banning the assembly, restricting transportation, urging social distancing, and lockdown (6). The Corona pandemic has affected directly or indirectly the whole world, such as environmental, social, economic, health, and other impacts (7). The Coronavirus has caused many negative changes in the path of life on the planet. There are many negative direct and indirect effects of the Coronavirus, especially on those countries that have suffered greatly such as China, the United States of America, Italy, and Spain (8), But some environmental changes were seen during the Corona pandemic, as after a long absence it was seen the return of fish in the waters of Venice or seen a clear blue sky in China (9). So the COVID-19 may have indirect ways to improve the environment. Coronavirus indirectly contributed to improving the atmosphere by raising the air quality in many countries around the world through the lockdown (10). Most countries were under a partial or complete lockdown for a period ranging from weeks to months. Studies have indicated air quality improvement in those countries as a result of the decrease in pollutants caused by human activities such as road and air transport, industries, construction activities, burning, residential activities (11). Furthermore it the

lockdown included a curfew for all except for those who perform basic services, in addition to the closure of restaurants, cinemas, schools, markets, and universities (12). These activities affect the concentration of some gases in the air, where transportation contributes to 23% of the world's carbon emissions, and driving and air transport contributes 83% of the greenhouse gas emissions from the transportation sector (13), so restricting these activities may help to reduce the percentage of pollutants in the air,but the lockdown helped to reduce these pollutants in the short term (14).The sources of these pollutants can stationary, like emissions from factories, or mobile like emissions from cars (15).Several studies indicated that the significant decline in industrial and transport activity during the lockdown period led to a reduction in the percentage of one of the main air pollutants in the atmosphere, which is nitrogen dioxide,as the concentration of nitrogen dioxide (NO2) decreased by half in some parts of the European continent compared to the previous reading.In addition to reducing the concentration of carbon dioxide (CO2) in the world by up to 25% (13).

Jordan is distinguished by its strategic location as it borders Syria, Palestine, Saudi Arabia, and Iraq. Jordan is the eleventh country in the Middle East in terms of population, where the population of Jordan in 2020 reached about 10.6 million people. The total area of Jordan is 89,342 square kilometers. In line with the Corona pandemic, the Jordanian government imposed a complete lockdown in all governorates Kingdom for two and a half months (16).

Jordan was one of the first countries to imposed preventive measures to limit the spread of the Coronavirus. At the beginning of March 2020, the Jordanian government announced the first case of Coronavirus in Jordan and began making decisions to limit the spread of this virus. On March 17th, the borders were closed, and air and land travel between Jordan and other countries was prohibited (17,18). On March 21th, the National Defense Law has announced imposed complete lockdown, which included curfews, prevented gatherings, and closed schools, universities, cafes, restaurants, cinemas, and other places that allow the gathering of more than 10 people. Also suspended work of public and private sectors, and imposed measures to restrict travel, movement, education, religious events. In addition to many strict measures that were intended to seek to limit the spread of the Coronavirus as much as possible and imposed sanctions for violators of these measures (16). The lockdown has affected Jordan significantly in terms of economic, social, health, environmental, and other sectors (17,18).

2. MATERIAL AND METHOD

2.1 Selection study area

Amman was chosen in this research based on several factors, which is the capital of Jordan, and it is one of the largest cities with industrial activity in Jordan. Therefore, the level of air pollution in it is higher than in other cities. In addition to being the largest city in Jordan in terms of population, where the population of the capital, Amman, in 2019 was nearly four and a half million (19).Also, the Jordanian Ministry of Environment provides daily data on the concentration of air pollutants, temperatures, humidity, and wind speed and direction (Table 1) (20). Where the daily meteorological and air pollution data are collected in Jordan for more than 143 different points, in addition to the use of geographic information systems and geographical statistics to determine the climate variables and evaluate them based on location (21). So, we choose the Downtown region in Amman as the specific area for this research (Figure 1)

Table 1: Daily Averages of PM10, NO2, SO2, CO, O3, temperature, humidity, wind direction, and wind speed in downtown (20).

The Date	PM10	NO2	SO2	CO	O3	Temperature	Humidity	Wind Direction	Wind Speed
	120 µg/m3	80 ppb	140 ppb	9000 ppb	80 ppb				
	24 HR AVG	24 HR AVG	24 HR AVG	8 HR AVG MAX/2 4 HRS	8 HR AVG MAX/ 24 HRS	[°C]	[%]	[°]	[km/h]
1/3/2020	15.3	13.6	8.2	1872	11.3	5.05	92.3	227	29.3
2/3/2020	24.5	4.38	3.38	2209	8.9	6.21	93.4	42.3	42.9
3/3/2020	33.4	13.6	4.94	1868	15.9	9.78	74.3	65.5	5.62

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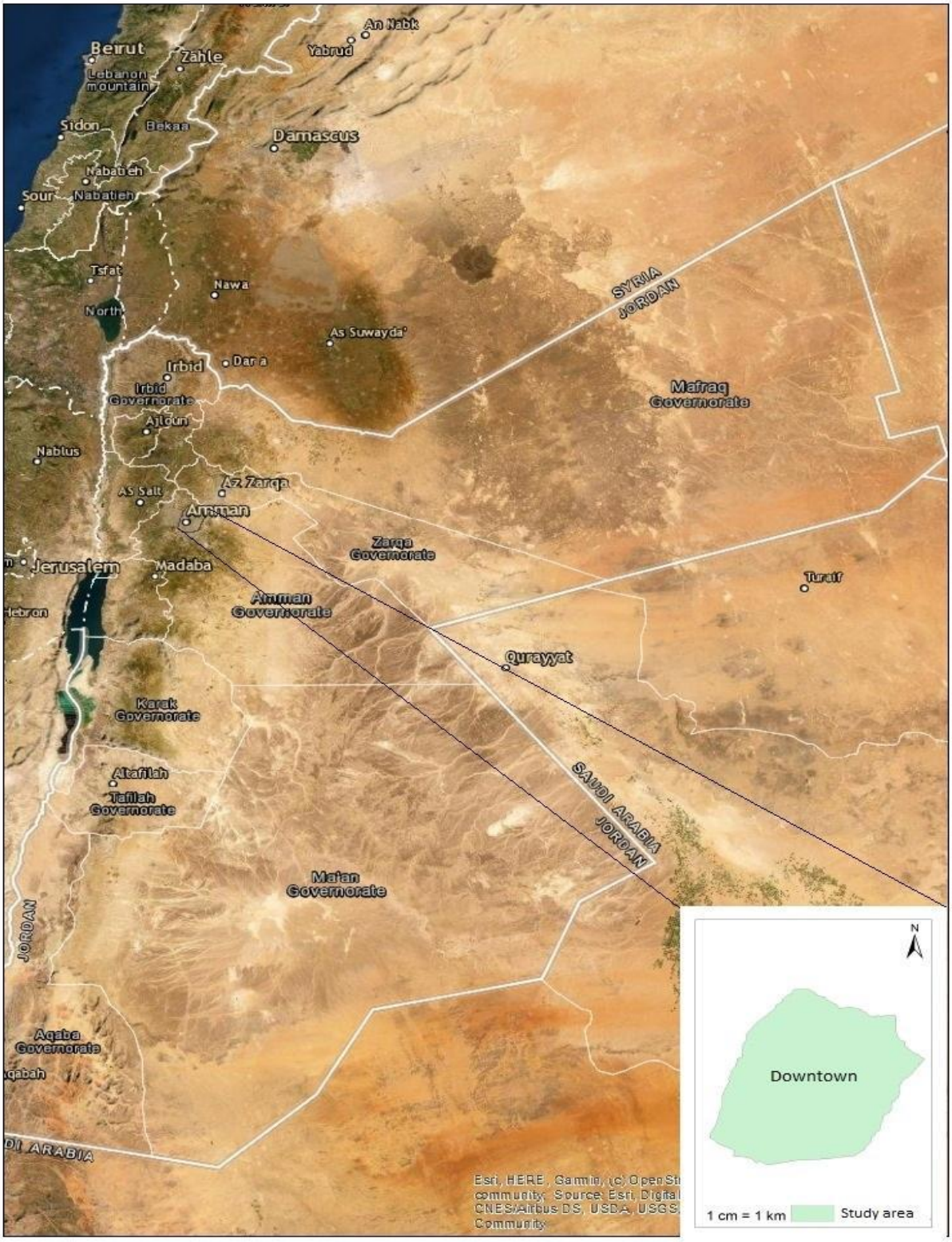

Figure 1: Location map of the study area.

2.2 Selection of air pollutants

Air quality is determined by measuring the percentage of pollutants in it. The concentration of fine particles matter (PM2.5), coarse particulate matter (PM10), carbon monoxide (CO), ground-level ozone (O3), sulfur dioxide (SO2), and nitrogen dioxide (NO2) are often measured to evaluate the air quality. Daily values for each of these pollutants were obtained,

except for fine particles matter from the Jordanian Ministry of Environment. Where the Ministry of Environment did not provide values for PM2.5. Except forthe ground-level ozone, all pollutants are caused by various human activities such as fires, gases emitted from transportation, and industrial activities. In this study, we chose PM10, CO, O3, SO2, and NO2 to investigate air quality during the lockdown period and before that.

Also in this study, the daily values of temperatures, humidity, and wind speed and direction were obtained to evaluate the effect of the lockdown on climate factors by comparing the values of these parameters in March, April, May, and June in 2020 with the same months in 2018 and 2019.

The data of all parameters in 2020 represented the effect of lockdown, while 2019, and 2018 data represented the pre-lockdown phases.

2.3 Application of RS and GIS techniques

The monthly average of PM10, NO2, SO2, O3, CO, temperature, relative humidity, wind speed, and wind direction have been calculated for downtown in Amman in March, April, May, and June in 2020, 2019, and 2018 with the same months. The results were prepared based on the daily average of these parameters. The maps have been prepared on Arcmap 10.4.

2.4 Data and analysis

Data on air pollutant ratios, temperature, humidity, and wind speed and direction during March, April, May, and June for the years 2020, 2019, and 2018collected to study the role of the lockdown on air quality and climate factors, noting that the lockdown period was From March 21 until the beginning of June on Jordan. The comparison is based on the mean monthly concentration of the air pollutants, and climate factors of four months in 2018, 2019, and 2020 using a welch two-sample t-test.

3. LITERATURE REVIEW

Guojun et.al (2020) indicated that the lockdown in China cities has a positive effect on the air quality, where the PM2.5 declined by 14.07 μg m−3, compared with last years (5).

Shresthaet.al (2020) showed the effect of lockdown on air pollution of 40 major cities around the world. Where the lockdown reduced the proportions of pollutants in the air between the cities like PM2.5, PM10, NO2, and CO (6).

Cheval et.al (2020) reached that Coronavirus has a positive effect on the environment; the lockdown reduced human activity which improved the air and water quality (7).

Bera et.al (2020) pointed to that the lockdown in Kolkata, India improved the environment in it by declined the percentage of PM2.5, PM10, NO2, SO2, and CO in the air during the lockdown period (4).

Monserrate et.al (2020) indicated the indirect benefits of coronavirus in improving the environment in the most affected countries such as China, Italy, and others. The complete lockdown in these countries has raised their air quality, reduced the environmental noise, and also helped with beach cleaning (8).

Kumari and Toshniwal (2020) showed the positive impact of the lockdown in three cities in India on the air quality of it, as the results indicated that the lockdown helped to reduce the concentration of four air pollutants in Delhi and Mumbai, which were PM2.5, PM10, NO2, and SO2 (12).

Noor (2020) pointed out that the lockdown in most countries of the world helped to improve the air quality, as it strengthened the restriction of various activities that were the main reason for the release of pollutant gases into the atmosphere to improve the environment, and she also indicated that the percentage of CO2 emissions decreased to 25% in the world (13).

Isaifan (2020) showed that lockdown in China has a positive effect on improved air quality, where the NO2 proportion in the air dropped by 30%, and carbon emissions also decreased by 25% (22).

4. RESULTS

An obvious decrease in the PM10 proportion in the air in Downtown, Amman was shown during the months of lockdown in 2020, compared to the PM10 proportion in 2018 and 2019 for the same months.Analytical statistics indicated a significant decrease in PM10 proportion in the air in the Downtown region in Amman during April and May in 2020, which is the same period for the complete lockdown that Jordan was witnessed. Thelevel of PM10 decreased to 19.11μg/m^3 in April 2020, compared to 40.1μg/m^3 in April 2019, and 42.12μg/m^3 in April 2018. The concentration of PM10 declined to 23.25μg/m^3 in May 2020, compared to 84.28μg/m^3 in May 2019, and 80.1μg/m^3 in May 2018. In March and June in 2020, the statistical analysis did not show an obvious decreased in the PM10 proportion in the air, compared to March and June in 2019 and 2018. (Figure 2). Where the PM10 concentration was 39.93 μg/m^3 in March 2020, 36.52 μg/m^3 in March 2019, and 46.7 μg/m^3 in March 2018. In June PM10 concentration was 49.49 μg/m^3 in 2020, 36.77 μg/m^3 in 2019, and 50.2 μg/m^3 in 2018.

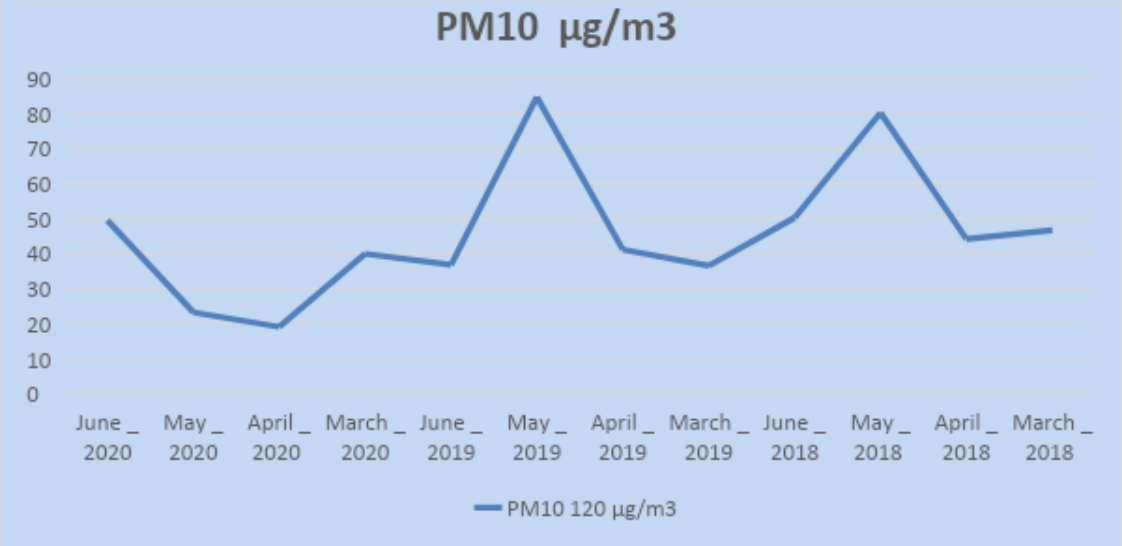

Figure 2: PM10 percentage in the air in Downtown, Amman in March, April, May, and June in 2018, 2019, and 2020.

A significantly declined was seen in NO2 concentration in the air in Downtown, Amman, during the lockdown period. Where NO2 concentration decreased by 5.07ppb in March 2020, compared with 13.3 ppb in March 2019, and 19.04 ppb in March 2018. Also, the monthly average NO2 concentration decreased to 1.75 ppb in April 2020, compared with 12.29 ppb in April 2019, and 13.53 ppb in April 2018. In May 2020 the NO2 concentration decreased to 2.03 ppb, compared with 44.5 ppb in May 2019, and 9.9 ppb in May 2018. There was no decreased inNO2 percentageinJune 2020, even NO2 concentration was increased, compared with NO2 concentration in June 2019, and 2018, this may be due to the unlock phase in June 2020(Figure 3).

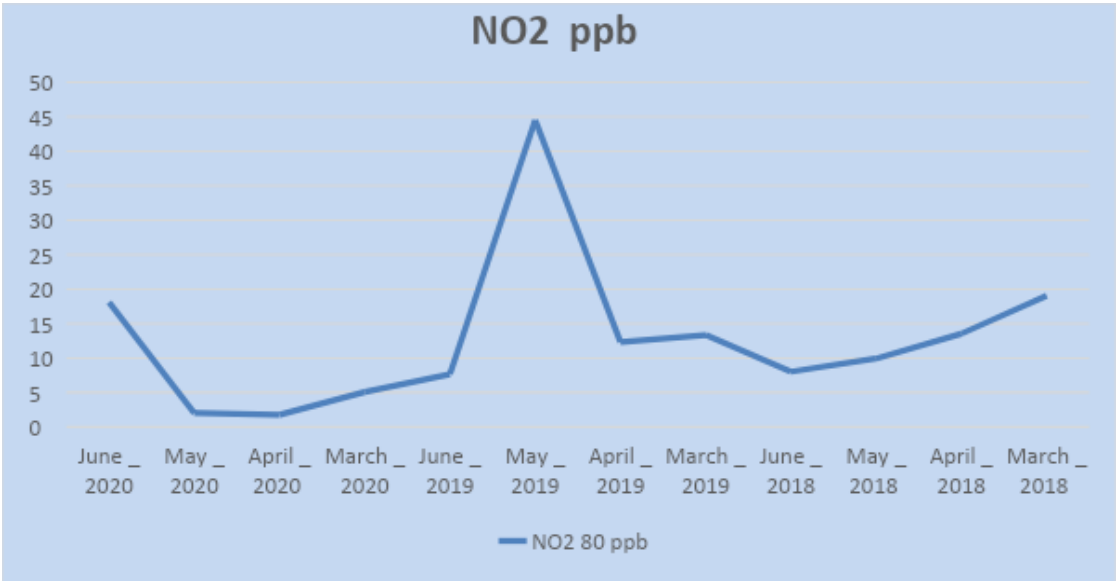

Figure 3: The NO2 percentage in the air in Downtown, Amman in March, April, May, and June in 2018, 2019, and 2020.

No significant decline was inmean monthly SO2 concentration in the air during the lockdown period in Downtown, Amman. Where the values of SO2 in 2020 were similar to 2019, and 2018. Except for the concentration of SO2 in May 2019, which was high compared to other values. SO2 concentration was 4.17ppb in March 2020, compared with 6.78 ppb in March 2019, and 2.37 ppb in March 2018. In April 2020 the monthly average SO2 concentration declined to 3.08 ppb, compared with 5.8 ppb in April 2019, and in April 2018 was 2.61 ppb. In May 2020 the SO2 concentration was 3.08 ppb, compared with 16.61 ppb in May 2019, and 2.66 ppb in May 2018. The data showed 6.54 ppb of SO2 percentage in June 2020, compared with 5.45 ppb in June 2019, and 2.39 ppb in June 2018 (Figure 4).

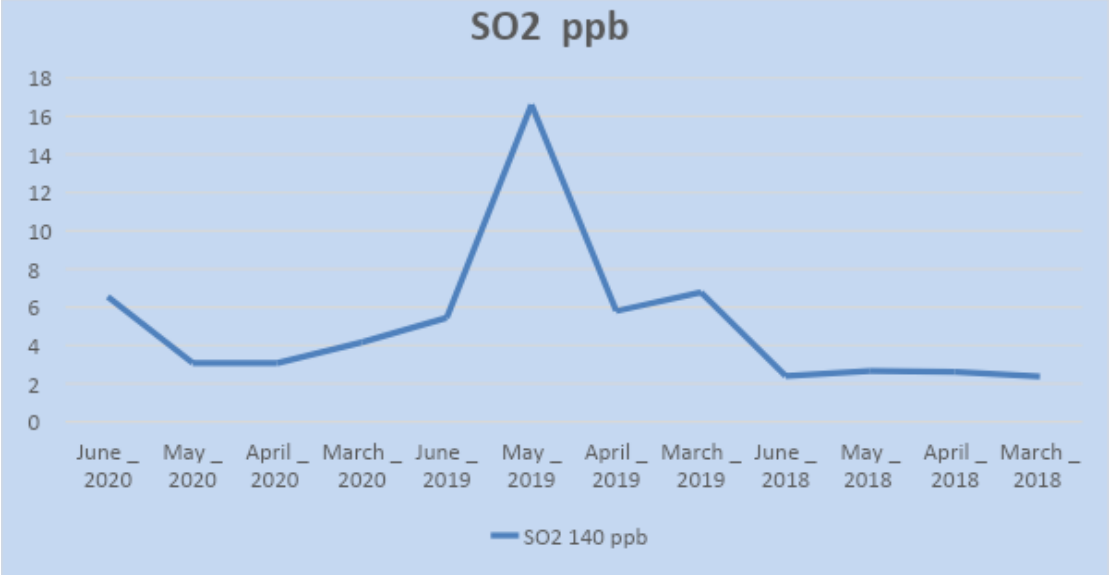

Figure 4: The So2 percentage in the air in Downtown, Amman in March, April, May, and June in 2018, 2019, and 2020.

Analytical statistics indicated that there is no change in O3 values in the air during the four months in the three years. The O3 is a secondary air pollutant that is affected by the proportions of major pollutants in the air, in addition to that, it is affected by various weather factors such as temperature (6). The concentration of O3 in the air was 31.8ppb in March 2020, 38.37 ppb in March 2019, and 34.54 ppb in March 2018. The average of O3 concentration in April 2020 was 39ppb, compared with 43.8 ppb in April 2019, and 33.9 ppb in April 2018. In May 2020 the O3 percentage was 36.9 ppb, compared with 45.65 ppb in May 2019, and 32.7 ppb in May 2018. O3 value in June 2020 was 35.5 ppb, compared with 35.9 ppb in June 2019, and 37.8 ppb in June 2018 (Figure 5).

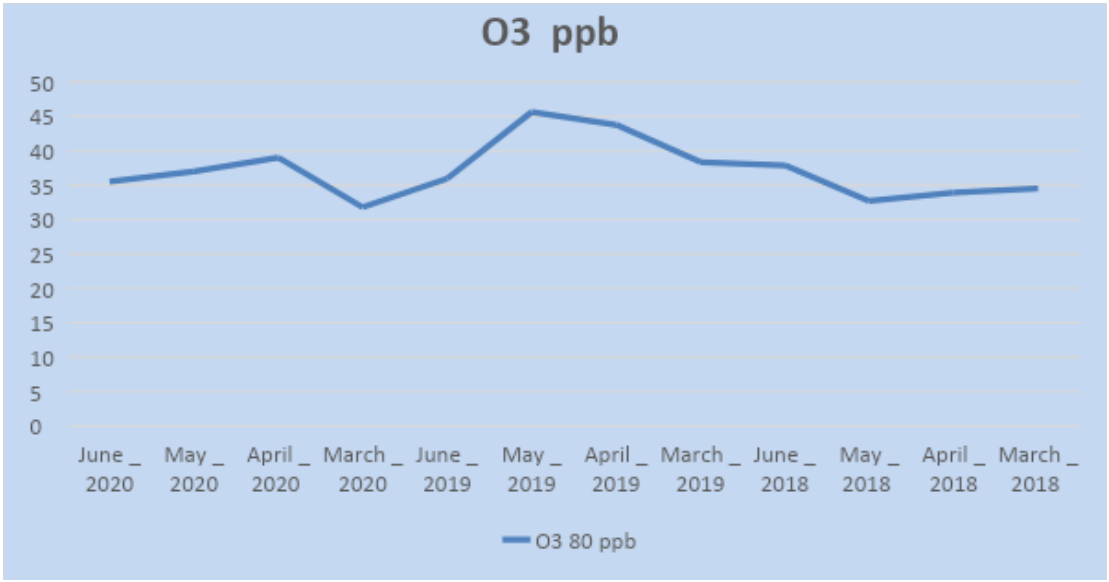

Figure 5: The O3 percentage in the air in Downtown, Amman in March, April, May, and June in 2018, 2019, and 2020.

The concentration of CO in the air was 1398.5 ppm in April 2020, which was a significant decrease compared with 2675.5 ppm in April 2019, and 2820.4 ppm in April 2018. In May 2020 the mean monthly CO concentration was 1321.25 ppm, compared with 2577.66 ppm in May 2019, and 2143 ppm in May 2018. In March, and June 2020 the CO concentration was not significantly declined, due to low numbers of lockdown days in these months, where the CO proportion in the air in March 2020 was 1758 ppm, compared with 2514.4 ppm in March 2019, and 2809 ppm in March 2018. In June 2020 the CO concentration was 1712.33 ppm, 2327.8 ppm in June 2019, and 2043.8ppm in June 2018 (Figure 6).

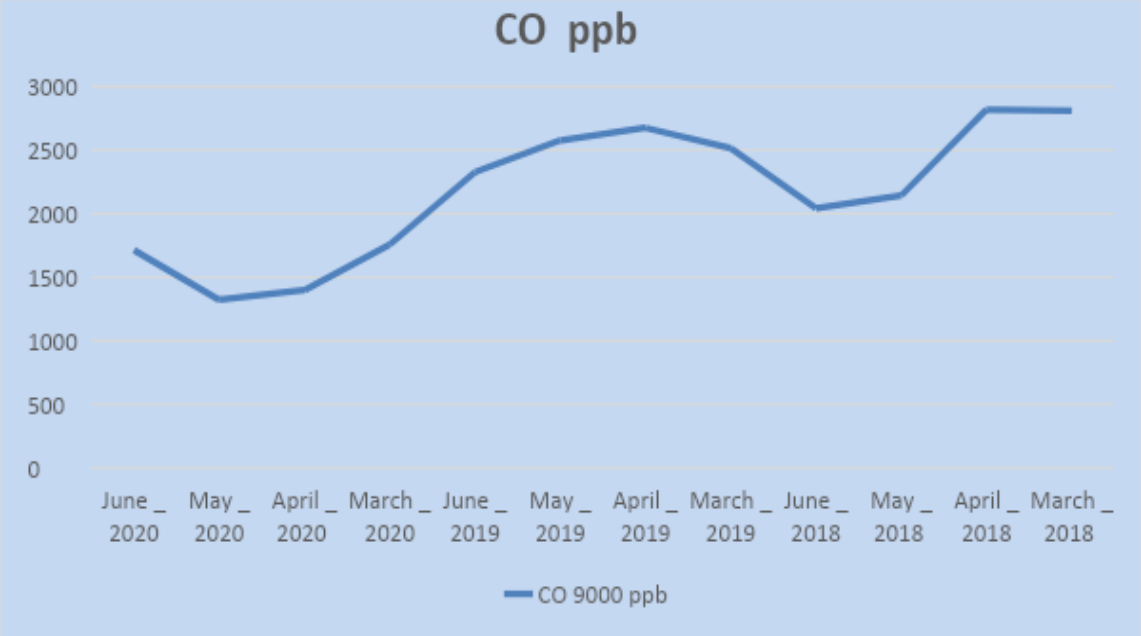

Figure 6: The CO percentage in the air in Downtown, Amman in March, April, May, and June in 2018, 2019, and 2020.

Table (2) showed the average concentrations of PM10, NO2, SO2, CO, and O3 in 2020, 2019, and 2018. Where each data point represented the mean of air pollutants concentration in March, April, May, and June.

Table 2: The concentration of PM10, NO2, SO2, CO, and O3 in 2020, 2019, and 2018.

Years	**PM10**	**NO2**	**SO2**	**CO**	**O3**
	120 µg/m3	80 ppb	140 ppb	9000 ppb	80 ppb
	24 HR AVG	24 HR AVG	24 HR AVG	8 HR AVG MAX/2 4 HRS	8 HR AVG MAX/ 24 HRS
2020	32.945	6.74	4.21925	1547.52	35.834
2019	49.7425	19.45	8.66075	2523.84	40.9445
2018	55.28	12.62725	2.50975	2379.05	34.7625

The statistical analyzes showed that there were no significant differences in temperature, relative humidity, wind speed, and wind direction between the months of lockdown compared to the pre-lockdown months in 2019 and 2018 (Figure 7). Where the temperature was in March 2020 9.77 °C, compared with 9.97°C in March 2019, and 12.47°C in March 2018. In April 2020 the ambient temperature was 13.4 °C, 11.7 °C in April 2019, and 16.08°C in April 2018. Ambient temperature in May 2020, 2019, and 2018 was 18.6 °C, 22.4 °C, and 20.3 °C respectively. In June 2020, 2019, and 2018 the ambient temperature was 20.73°C, 22.8°C, and 21.3 °C respectively (Figure 8).

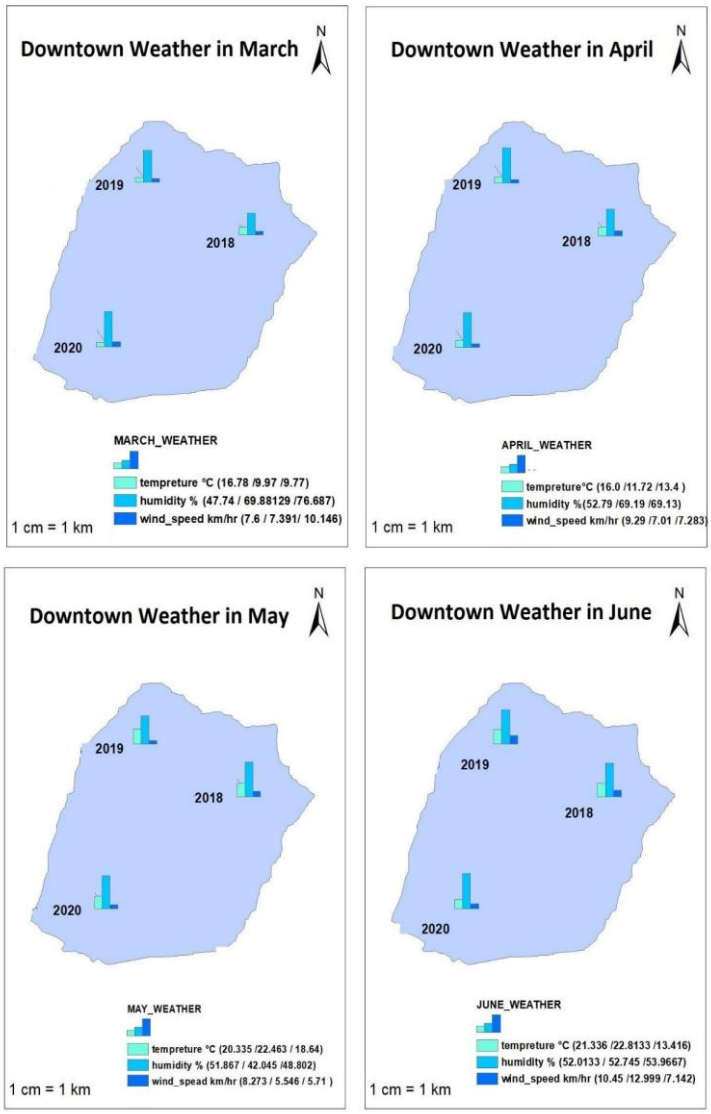

Figure 7: The temperature, humidity, and wind speed in Downtown, Amman in March, April, May, and June in 2020, 2019, and 2018.

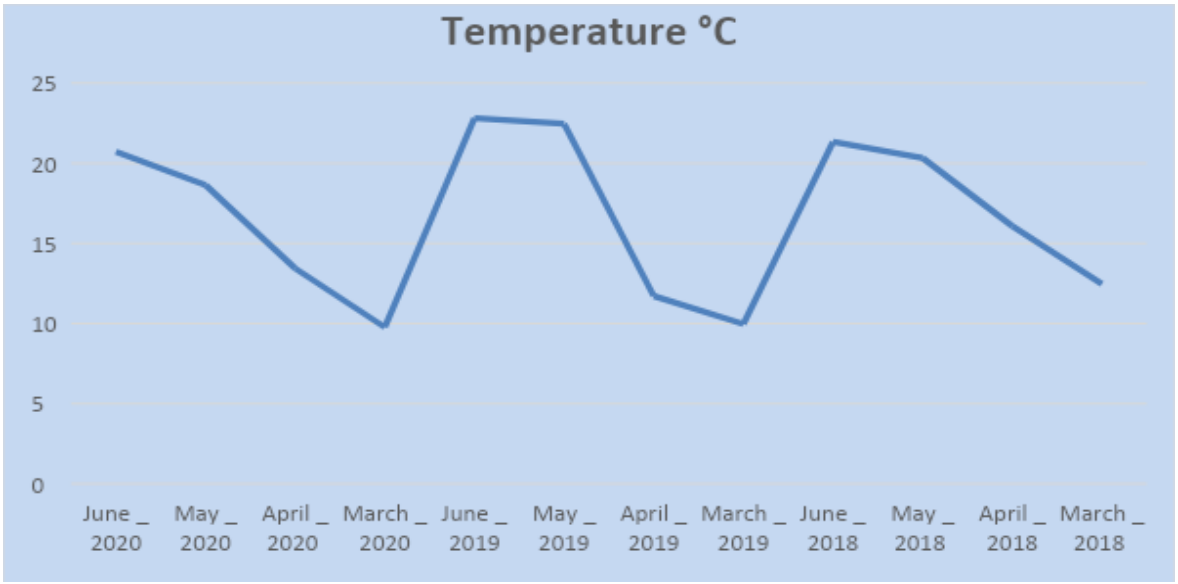

Figure 8: The temperature in Downtown, Amman in March, April, May, and June in 2018, 2019, and 2020.

Relative humidity was in March 2020 76.6%, compared with 69.8% in March 2019, and 47.7% in March 2018. In April 2020 the relative humidity was 69%, 69% c in April 2019, and 51.8% in April 2018. Relative humidity in May 2020, 2019, and 2018 was 48.8%, 42%, and 51.8% respectively. In June 2020, 2019, and 2018 the relative humidity was 53.9%, 52.7%, and 52% respectively (Figure 9).

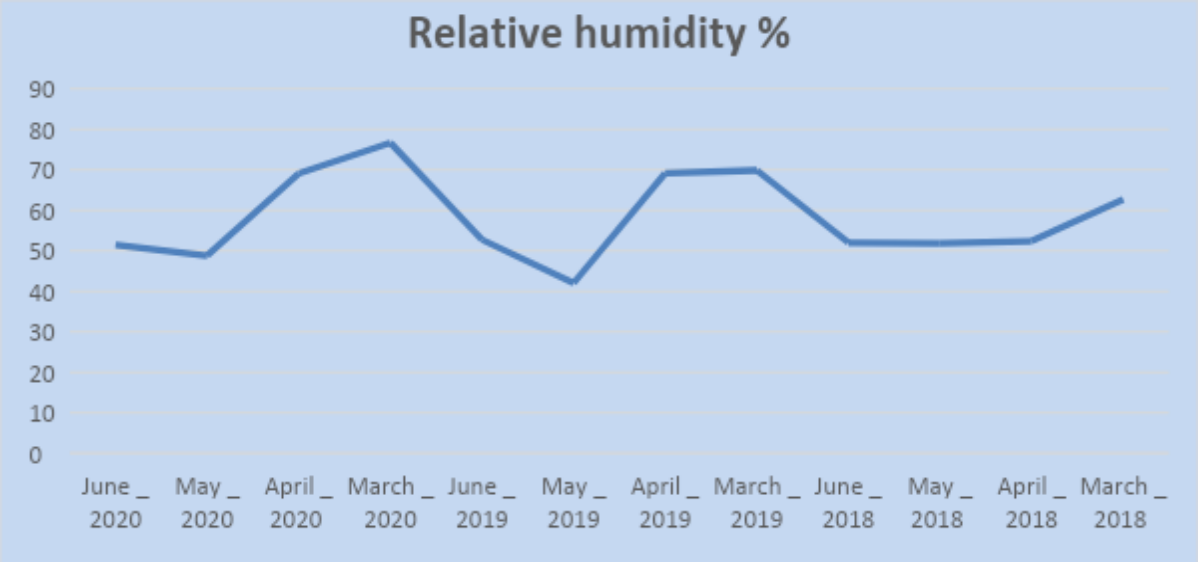

Figure 9: The relative humidity in Downtown, Amman in March, April, May, and June in 2018, 2019, and 2020.

In March 2020, 2019, and 2018 the wind speed was 10.1 km/h, 7.3 km/h, and 9.2 km/h respectively. In April 2020 the wind speed was 7.2 km/h, 7 km/h in April 2019, and 9.2 km/h in April 2018. Wind speed in May 2020, 2019, and 2018 was 5.7 km/h, 5.5 km/h, and 8.2 km/h respectively. Wind speed was in June 2020 7.1 km/h, compared with 12.9 km/h in June 2019, and 10.4 km/h in June 2018 (Figure 10).

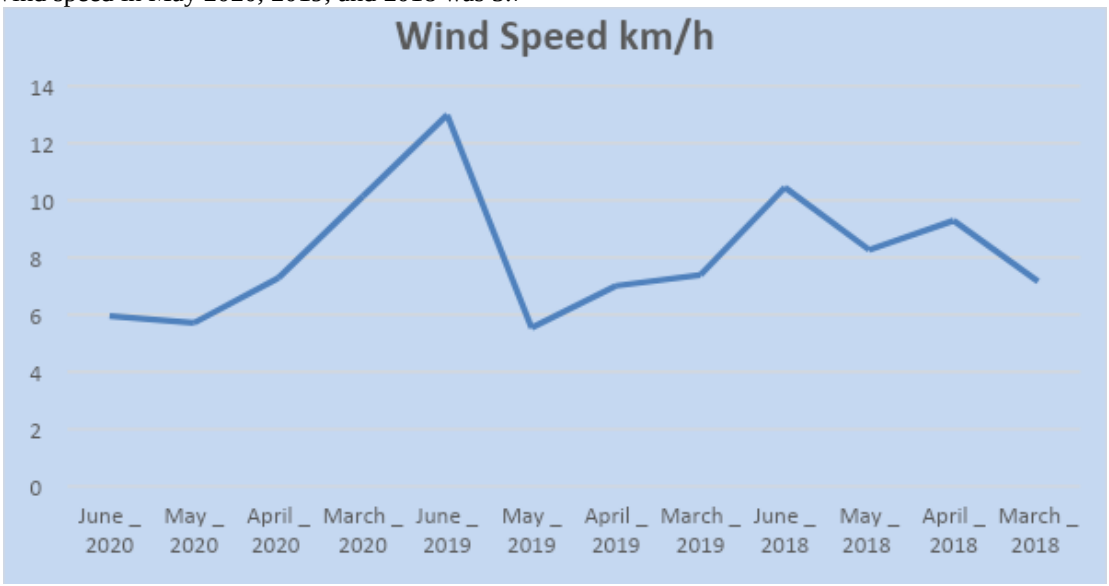

Figure 10: The wind speed in Downtown, Amman in March, April, May, and June in 2018, 2019, and 2020.

The wind direction in March 2020, 2019, and 2018 was 182.8°, 208.5°, and 211° respectively. In April 2020 the wind direction was 222°, 203° in April 2019, and 244° in April 2018. The wind direction in May 2020, 2019, and 2018 was 235°, 216°, and 225° respectively. In June 2020 the wind direction was 208.7°, 240° in June 2019, and 257.4° in June 2018 (Figure 11).

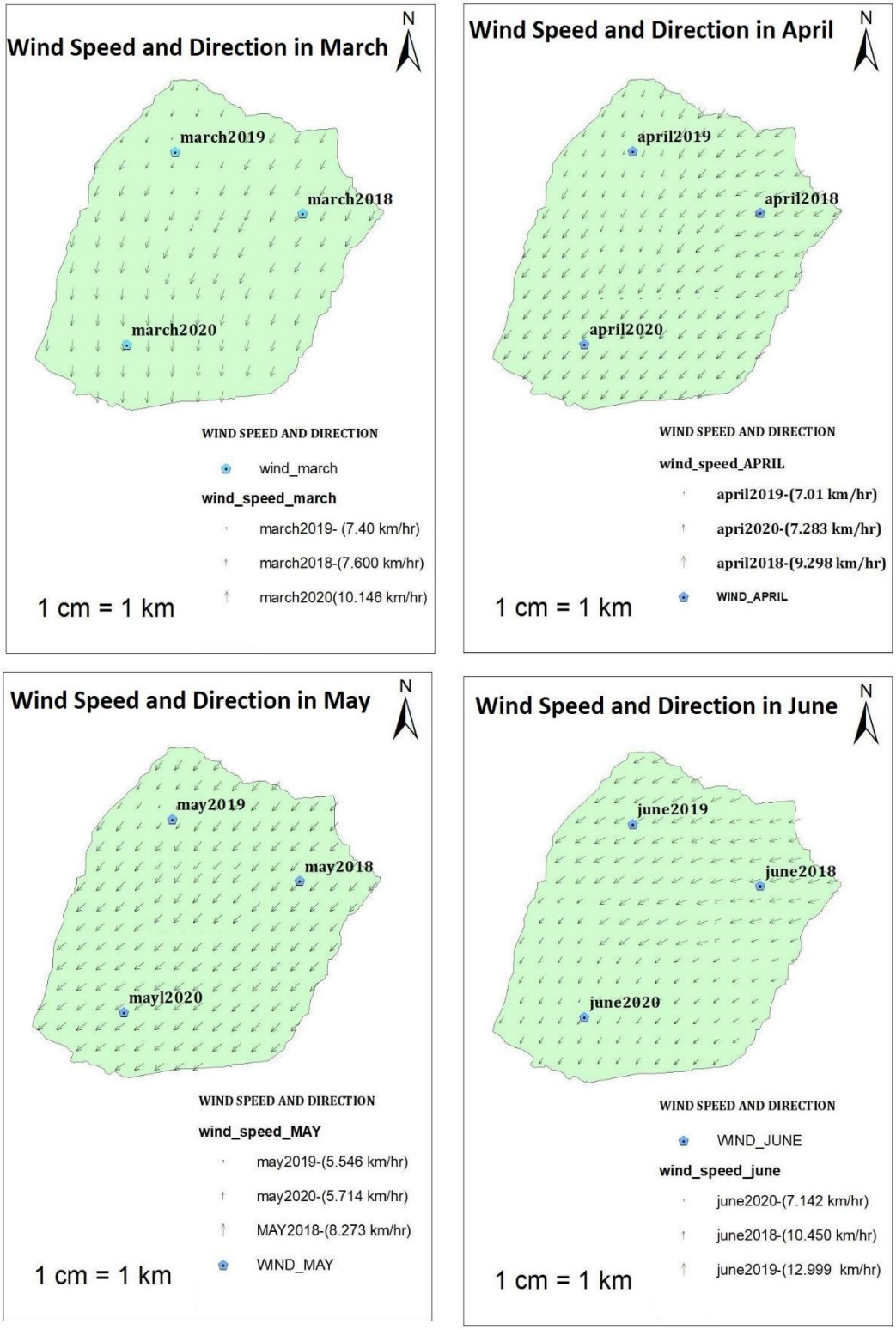

Figure 11: The wind direction in Downtown, Amman in March, April, May, and June in 2018, 2019, and 2020.

5. DISCUSSIONS

The Corona pandemic affected the whole world, as many countries have adopted different policies to limit the spread of this virus (23). Jordanian government was one of the countries that imposed the lockdown to reduce infection with the Coronavirus, as it issued firm decisions to limit any activities that contribute to the transmission of infection among citizens. Many studies indicated that the lockdown contributed positively to improving air quality, as the levels of some pollutants decreased during the lockdown in that cities that

adopted a lockdown policy to limit the spread of the Coronavirus (5, 6, 7).

The findings of this research showed that the decrease in air pollutants during the lockdown period was more obvious in April and May because the lockdown in Jordan began in late March and ended in early June.The data obtained from the Jordanian Ministry of Environment showed that O3 and SO2 have not decreased during the lockdown. This is because Jordan is not a country with a large industrial activity. Where the huge big coal-fired power plants are one of the most important sources of sulfur dioxide. Besides that Jordan does not suffer from the huge seasonal fires that affect the rates of these gases, so the decrease in human activities during the period of lockdown may not be sufficient reason to reduce the concentrations of these gases in the air in Jordan.Also, the concentration of O3 in the atmosphere is affected by the concentration of nitrogen dioxide and the rate of its accumulation (4), it is also affected by weather factors such as temperature (6). The proportion of O3 in the air of India increased during the lockdown due to the reduction of NO2 and volatile organic compounds (12). But in this study, the level of O3 was unchanged at the time of lockdown despite the reduction in nitrogen dioxide. This may be due to the higher concentration of NO2 in the air in India compared to Jordan.

Air quality was positively affected during the lockdown period in many countries, by reducing the level of four main pollutants, namely: PM2.5, PM10, NO2, and CO (6). In this research, the pollutants that significantly declined were PM10, NO2, and CO. This makes sense because these pollutants are generated mainly by daily human activities like road transportation. This is in line with the reduction in dust, transportation operations, industrial activities, etc. during the lockdown, which in turn reduced the levels of PM10, CO, and NO2 in the atmosphere (4).

The lockdown may has a role in influencing the ambient temperature, relative humidity, and wind speed and direction by reducing the air pollutants (24). Where the high temperatures and wind speed are associated with an increase in the level of O3, CO, and PM10. And that high humidity has a role in raising CO and NO2 and reducing O3, PM10, and SO2 (25). But the period of lockdown was not long enough in Jordan to witness these changes. The results of this research showed that the lockdown did not affect significantly these factors. So we need more researches to investigate that.

6. CONCLUSION

Coronavirus is one of the most important risks that the whole world is currently facing, as infections and deaths increase daily, but many types of research have shown that this virus indirectly helped to improve air quality through the lockdown that most countries imposed it.

Coronavirus may be of benefit to humanity as well as was a pandemic.The results of this study showed that the lockdown that took place in Jordan helped to improve air quality by reducing the level of some pollutants, such as PM10, NO2, and CO. This improvement in air quality may help reduce many health problems. But this change is temporary, where the levels of these pollutants in the air will rise again when the normal life will come back. Also, this research indicated that the lockdown didn't make obvious changes in weather factors, which were temperature, humidity, and wind speed and direction during the lockdown months, which is considered a short period to generalize this result.

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