The Hashemite Kingdom of Jordan

Ministry of Environment

Ambient Air Quality Monitoring Report

In (Amman-Irbid-Zarqa)

2020

Ministry of Environment

National Ambient Air Quality Monitoring Network

Amman - Irbid - Zarqa

Yearly Report

2020

Abstract

The Ministry of Environment monitors ambient air quality as obligated by Environmental Protection Law No. 6 of 2017 and the Air Protection bylaw No. 28 of 2005, which include the obligation to monitor air pollution in the interest of public health.

Criteria air quality pollutants (PM, NO2, SO2, CO, Ozone) are continuously measured on an hourly basis and measurements are evaluated against limits set in Jordanian Standard No. 1140/2006 for ambient air quality. Exceedances as stipulated in the standard are reported.

Measurement of ambient air quality over several years within the various AQ stations and various regions in Jordan provides necessary data needed to formulate recommendations to decision makers in order to develop mitigation strategies to improve air quality in each region. Improved air quality helps to promote better health for Jordanian citizens thus contributing to the achievement of the sustainable development goals. In addition, continuous measurement is necessary to activate emergency control procedures to prevent or reduce air pollution accidents.

In order to achieve the monitoring goals, a national ambient air quality monitoring network was established in 2014 consisting of 12 ambient air quality monitoring stations. Locations of the monitoring stations were chosen based on a scientific study, and cover industrial ,traffic and residential areas within Amman, Irbid and Zarqa, distributed as follows:

- 7 stations located in Amman (GAM, KAC, KHG, MAH, TAB, UNI, and YAR).
- 3 stations in Zarqa (HAJ, MAS, and ABK/HH).
- 2 stations in Irbid (HSC, and BAR).

The stations monitor the following pollutants:

- Particulate matter with aerodynamic diameter ≤ 10 microns (PM10)
- Carbon monoxide (CO)

- Sulfur dioxide (SO_2)
- Nitrogen dioxide (NO_2)
- Ozone (O_3)

Monitoring is carried out continuously and around the clock, and the results are transmitted electronically to a central server where they are stored, audited, analyzed and reports issued on a daily, monthly and yearly basis. The monitoring results are analyzed continuously, and the results are compared with the limits stipulated in Jordanian Standard No. 1140/2006.

This report represents the annual results of air pollutants that were measured through the ambient air quality monitoring stations distributed in Amman, Zarqa, and Irbid cities during 2019. In addition, a comparison to previous results during the period 2015 to 2019 is included. The excedances were determined by comparing the observational results with the limits set out in the Jordanian Standard No. 1140/2006.

The results of ambient air quality monitoring for the year 2020 in different locations showed that the air quality was good and within the permissible limits in the Jordanian Standard No. 1140/2006 with the exception of fine inhaled particles suspended in the air, whose particle diameter is 10 microns and less **(PM10).** Exceedances in the daily averages of the limit stipulated in the Jordanian specification of 120 µg/m^3 were observed in all stations. These exceedances are attributed to natural factors, traffic and industrial activities.

Hourly averages of nitrogen dioxide **(NO_2)** were exceeded 12 times above the limit stipulated in the Jordanian standard, which is equal to 210 parts per billion at Marka/ Mahatta station. In addition, daily averages were exceeded 11 times above the daily limit of 80 ppb at Marka / Mahatta station, and one exceedance at Tabarbour station in Amman.

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INTRODUCTION

1.1 Monitoring Sites

The ministry's Ambient Air Quality Network consists of 12 fixed continuous monitoring stations distributed in Amman, Irbid and Zarqa.Table (1.1) shows the names of the stations and the pollutants they monitor. The locations of the monitoring stations were chosen after conducting a survey of gas concentrations by using permeation gas test tubes and dust analyzers distributed in the three cities. Results from these measurements were analyzed and mapped. The monitoring stations were consequently permanently placed in areas showing the highest mapped concentrations. To cover all types of areas, station sites were chosen to cover Urban, residential, industrial areas and locations with high traffic frequency.

Table (1.1): Names of ambient air quality monitoring stations in Jordan.

Short Name	Name in Arabic	Type of Station	Name in English
Amman			
KHG	حدائق الملك حسين	Background	King Hussein Gardens
GAM	أمانة عمان الكبرى	Urban	Greater Amman Municipality
TAB	مجمع الشمال/ طبربور	Traffic	Tabarbour
MAH	ماركا / المحطة	Urban	Marka – Mahata
UNI	شارع الجامعة / صويلح	Traffic	University street Sweile
KAC	مدينة الملك عبدالله الثاني الصناعة / سحاب	Industrial	King Abdullah II Industrial City / Sahab
YAR	اليرموك	Industrial	Yarmuk
Irbid			
HAJ	مركز صحي وادي الحجر	Traffic	Health Center Wadi Hajjar
MAS	المسلخ البلدي منطقة المصانع	Industrial	Main slaughter house Masane' Zone
ABK/HH	القاعة الهاشمية	Urban	Hashemite Hall
Zarqa'a			
HSC	مدينة الحسن الرياضية	Traffic	AL Hassan Sport City
BAR	شارع البارحة	Urban	Al Barha Street

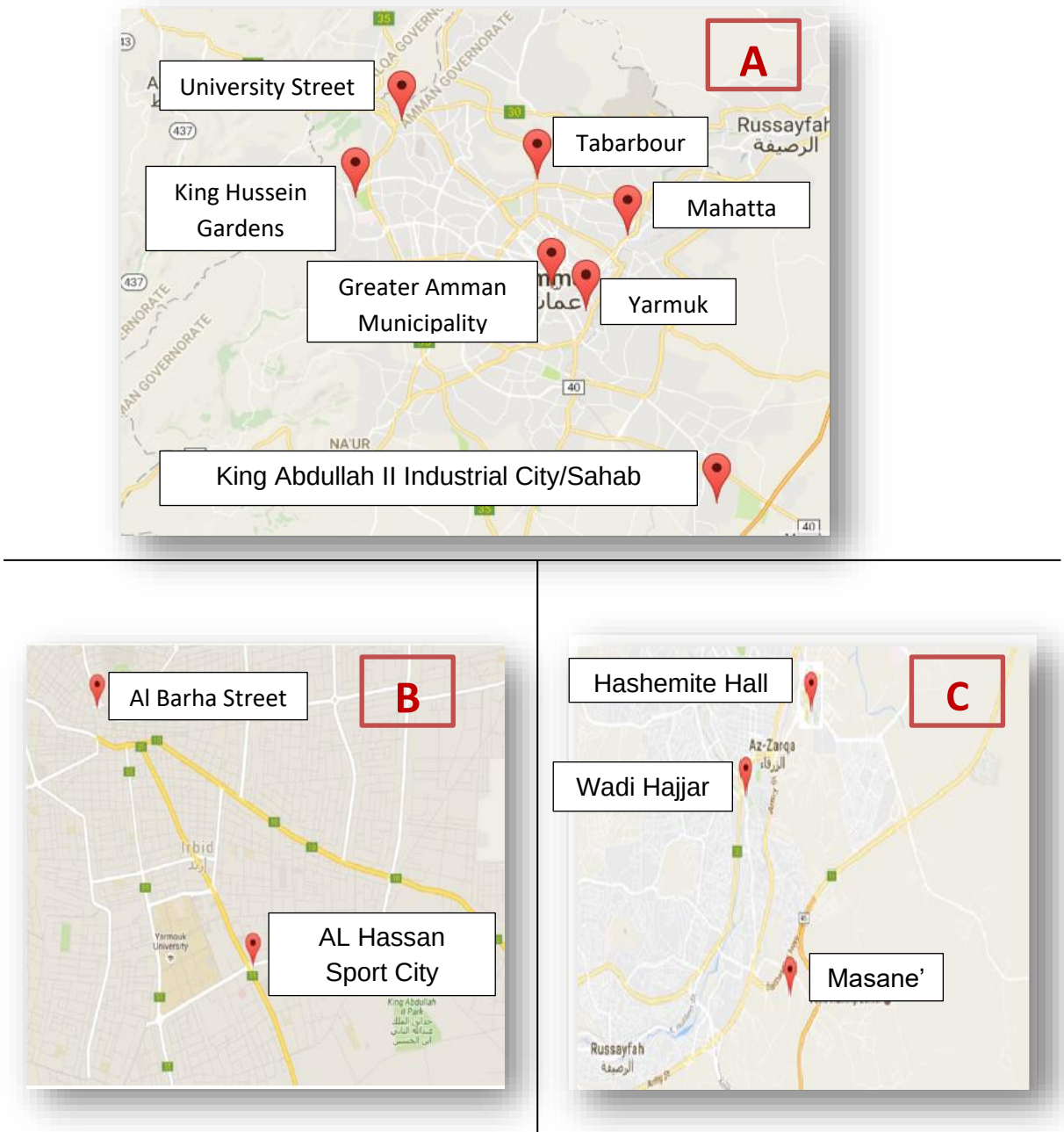

Figure (1.1): A) Distributed Stations in Amman, B) Distributed Stations in Irbid , C) Distributed Stations in Zarqa.

1.2 Jordanian Standard for Ambient Air Quality Monitoring

Table No. (1.2) shows the permissible limits for emissions of gases and particulate matter to the ambient air as shown in Jordanian Standard No. 1140/2006. Analysis of results in this report are done in comparison with the limits in this standard.

Table (1.2) Jordanian Standard for Ambient Air Quality No. 1140/2006

Sulfur dioxide (SO_2)	One Hour	0.3 part per million (ppm)	3 times in any 12-month period per year
	24 Hours	0.14 part per million (ppm)	Once per Year
	Yearly	0.04 part per million (ppm)	-
Carbon monoxide (CO)	One Hour	26 part per million (ppm)	3 times in any 12-month period per year
	8 Hours	9 part per million (ppm)	3 times in any 12-month period per year
Nitrogen dioxide (NO_2)	One Hour	0.21 part per million (ppm)	3 times in any 12-month period per year
	24 Hours	0.08 part per million (ppm)	3 times in any 12-month period per year
	Yearly	0.05 part per million (ppm)	-
Ozone (O_3)	One Hour	0.12 part per million (ppm)	-
	8 Hours	0.08 part per million (ppm)	-
Particulate Matter (PM10)	24 Hours	120 Microgram (µg/m3)	3 times in any 12-month period per year
	Yearly	70 Microgram (µg/m3)	-

1.3 Pollutants

Pollutants Monitored included: Particulate matter with aerodynamic diameter ≤ 10 microns (PM10), Carbon monoxide (CO), Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2) and Ozone (O_3). Table (1.3) shows the pollutants that are monitored in each station.

Table (1.3): Pollutants monitored in each station.

Type of station	Station Name	Short name	CO	NO_2	SO_2	O_3	PM10	MET
Amman								
Background	King Hussein Gardens	KHG		1	1	1	1	1
Urban	Greater Amman Municipality	GAM	1	1	1		1	
Traffic	Northern Bus Station Tabarbour	TAB	1	1			1	
Urban	Marka / Mahata	MAH		1	1		1	
Traffic	University street /Sweileh	UNI		1			1	
Industrial	King Abdullah II Industrial City / Sahab	KAC		1	1	1	1	
Industrial	Yarmuk	YAR		1	1		1	
Zarqa'a								
Traffic	Wadi Hajjar Health Center	HAJ	1	1	1		1	1
Industrial	Massane'	MAS		1	1		1	
Urban	Hashemite Hall	ABK/HH		1	1		1	
Irbid								
Traffic	Al Hassan Sport City	HSC	1	1			1	
Urban	Al Barha Street	BAR		1	1	1	1	1

1.4 Measuring devices

All devices used to monitor gases and particulate matter in all stations are in compliance with the Jordanian standard 1140/2006 and the American Environmental Protection Agency **(EPA)**, in addition to European and other International environmental authorities.

Table (1.4): The type of devices used to measure concentrations of gases and particulate matter at monitoring stations and the approved examination certificates that belong to

Pollutant	Model	Examination certificate	Principle of Operation
Particulate Matter **(PM10)**	Thermo 5014i	U.S. EPA Approved PM-10 (EQPM1102-150	Using Beta attenuation
Nitrogen dioxide **(NO_2)**	Thermo 42i	U.S. EPA Reference Method: RFNA-1289-074; MCerts Certified: MC070093/00; EN14211: 936/21203248/C Report; NF Certificate: 05/01	Using Chemiluminescence
Sulfur dioxide **(SO_2)**	Thermo 43i	US EPA Equivalent Method: EQSA-0486-060, MCERTS Certified Sira MC070094/00, EN14212: TÜV 936/21203248/D Report	Using UV-Fluorescence
Carbon monoxide **(CO)**	Thermo 48i.	US EPA Reference Method: RFCA-0981-054, MCERTS Certified Sira MC070095/00, EN14626: TÜV 936/21203248/A Report	Using Infrared
Ozone **(O_3)**	Thermo 49i	US EPA Equivalent Method: EQOA-0880-047, MCerts Certified MC070096/00, EN14626: 936/21203248/13 Report, NF Certificate: 05/01	Using Ultra-Violet Photometry

1.5 Calibration

All gas analyzers are regularly calibrated using the Thermo Scientific Dynamic Gas Calibrator model 146i with Gas Phase Titration, the Zero Air generator model 111 and calibration Gas bottles. The calibrator produces precise gas levels of nitric oxide, nitrogen dioxide, carbon monoxide, sulfur dioxide and ozone to calibrate the instruments for span and multipoint calibrations. The zero air generator is used to perform zero calibration.

1.6 Meteorology (measure weather elements)

Weather elements (wind speed and direction in addition to temperature and relative humidity) are measured using sensors in only three monitoring stations distributed over Amman, Irbid and Zarqa. The sensors are mounted at about 10 meters above the ground using retractable mast.

1.7 Communication and Telemetry

All measurements are automatically transmitted to the ministry of environment central server through internet connection.

1.8 Operation and site Performance

United Technology Establishment (UniTec), under direction of the Environmental Monitoring and Evaluation Directorate at the Ministry of Environment, manages the operation of the network and performs all required maintenance and supply of spare parts for the instruments as well as the shelters, communication network, central servers, and IT software. Furthermore, UniTec performs routine validation of the data and issues daily, monthly, and yearly reports for all pollutants and all stations. Monitoring stations are operated according to the manufacturer's guidelines and in compliance with international quality assurance standards for monitoring ambient air quality.

These guidelines and multiple other measures aim to reduce data loss and ensure data security. To increase the percentage of data collected and ensure accuracy, UniTec has a Maintenance team dedicated to resolving any issues on site, as soon as any warning signal or defect in the monitoring devices arises.

1.9 Air Quality Index

The Ministry of Environment has made great efforts to monitor ambient air quality in Jordan, culminating, since 2018, in the direct data broadcast of the National Network for Ambient Air Quality Monitoring on a dedicated website https://www.jordanenv.com/. Data is shown in the form of an air quality indicator (Air Quality Index). This is due to the Ministry's duties to participate in national, regional and global monitoring efforts, initiatives and programs. The website continuously shows the air quality index for each of the air quality monitoring stations in the major cities of Amman, Zarqa and Irbid. All concerned parties and citizens can track the ambient air quality index around the clock to take appropriate measures, especially for sensitive groups in the event that Jordan's air quality index exceeds the approved international guidelines. The website emulates the global website of the air quality index https://aqicn.org that includes more than 130 countries where the air quality index is calculated in real time for more than 30,000 stations in 2000 cities in the world and the readings are updated to calculate the indicators every hour periodically.

The Air Quality Index (AQI) is a color index linked to numerical values, which is mostly utilized by government institutions and agencies concerned with the protection of the environment, parties interested in the environment as well as citizens interested in knowing the air quality in a specific location. Changes in AQI means different concentrations of ambient air pollutants where each group is distinguished with a color and description. The green color indicates that the air quality is good, yellow indicates that the air quality is moderate while the orange color indicates that the air may affect sensitive groups and the red color indicates that the air is not healthy. As for the violet color, it indicates that the air is very unhealthy, and finally the highest indication is brown which means that the air quality is dangerous.

The results of observing Jordan's Ministry of Environment website shows that the air quality index in all 12 monitoring stations of the Kingdom ranges between green (good) and yellow (moderate). Whereas, during heavy traffic or dessert dust storms, the AQI changes to darker colors.

1.10 Stations

All twelve stations are uniform in external architecture and were designed to provide both functionality as well as nice exterior aesthetics. The shelters are made from sheet steel which are fully insulated and protected from external heat. Monitoring devices and Analyzers were mounted internally in 19" racks and the shelter was fitted with two air conditioning units to ensure an optimum temperature of 25 degrees is maintained. Finally, a six pillar sandstone block fence encloses the steel shelter for maximum security. A standard station is shown in (Figures 1.2 and 1.3).

Figure (1.2) Station from inside

Figure (1.3) Station from outside

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RESULTS

Table (2.1) shows the annual averages of air pollutants that were monitored in all stations during the period from 1/1/2020 to 31/12/2020, Note that no exceedances were recorded.

Table (2.1): Yearly Averages of pollutants in all stations.

#	Station	Short Name	PM10 µg/m^3	NO_2 ppb	SO_2 ppb	CO ppb	O_3 ppb
		Average as in Jordanian Limits 1140/2006					
			70 µg/m^3	50 ppb	40 ppb	Not Found	Not Found
Amman							
1	King Hussein Gardens	KHG	40.2	4.7	3.9	-	29.9
2	Greater Amman Municipality	GAM	45.6	21.4	15.5	2630	
3	Northern Bus Station Tabarbour	TAB	51	33.8	-	1756	-
4	Marka / Mahata	MAH	45	37.7	11.5	-	-
5	University street Sweileh	UNI	46.1	23.4	-	-	-
6	King Abdullah II Industrial City / Sahab	KAC	48.8	17.2	7.3	-	20.2
7	Yarmuk	YAR	47.5	26	5.1	-	-
Zarqa							
8	Health Center Wadi Hajjar	HAJ	63.6	15.3	5.7	1987	-
9	Main slaughter house Masane' Zone	MAS	51.6	28.1	4.3	-	-
10	Hashemite Hall	ABK/HH	49.7	19.5	5.4	-	-
Irbid							
11	AL Hassan Sport City	HSC	30.1	14.3	-	2756	-
12	Al Barha street	BAR	30.2	18.5	9	-	52.1

Table (2.2) shows the number of exceedances each according to what is required in technical specification number JS1140 for the year 2006 regarding the ambient air quality.

Table (2.2): Number of exceedances in all stations.

			PM10	NO_2	NO_2	SO_2	SO_2	CO	CO	O_3	O_3
Station			24hr AVG	24hr AVG	1hr MAX/ 24hr	24hr AVG	1hr MAX/ 24hr	8hr AVG MAX/ 24hr	1hr MAX/ 24hr	8hr AVG MAX/ 24hr	1hr MAX/ 24hr
Limits			120 $\mu g/m^3$	80 ppb	210 ppb	140 ppb	300 ppb	9000 ppb	26 ppm	80 ppb	120 ppb
Number of allowed exceedances			3	3	3	3	3	3	3	-	-
Amman											
1	King Hussein Gardens	KHG	3	-	-	-	-	-	-	-	-
2	Greater Amman Municipality	GAM	9	-	-	-	-	-	-	-	-
3	Northern Bus Station Tabarbour	TAB	6	1	-	-	-	-	-	-	-
4	Marka – Mahata	MAH	3	11	12	-	-	-	-	-	-
5	University street Sweile	UNI	4	-	-	-	-	-	-	-	-
6	King Abdullah II Industrial City/Sahab	KAC	10	3	-	-	-	-	-	-	-
7	Yarmuk	YAR	18	-	-	-	-	-	-	-	-
Zarqa											
8	Health Center Wadi Hajjar	HAJ	29	-	-	-	-	-	-	-	-
9	Main slaughter house Masane' Zone	MAS	15	-	-	-	-	-	-	-	-
10	Hashemite Hall	ABK/HH	5	-	-	-	-	-	-	-	-
Irbid											
11	AL Hassan Sport City	HSC	3	-	-	-	-	9	-	-	-
12	Al Barha street	BAR	3	-	-	-	-	-	-	-	-

2.1 Particulate Matters (PM10)

Particulate Matter with aerodynamic diameter ≤ 10 microns (PM10) They are coarse suspended particles and are less than or equal to 10 μg/m^3 in diameter. The smaller the particles, the more they can reach the lungs and can cause several health problems, especially for people who already suffer from respiratory diseases such as asthma and bronchitis. Particles can also affect the immune system, thereby reducing the body's ability to fight infection. Epidemiological research recently indicated that inhaled particles may lead to high blood pressure, strokes, and lung cancer, thus increasing annual death rates.

Allowable limits for particle emissions with an effective diameter of ≤10 micron (PM10) in Jordanian Technical Rule No. 1140 of 2006:

- **Annual average is 70 μg/m^3**
- **The daily average (24 hours) is 120 (μg/m3), which is not to be exceeded for more than three times in a 12-month period.**

Sandstorms and atmospheric instabilities cause high concentrations of particulate matters with an effective diameter ≥10 micron (**PM10**). Also, Emissions from domestic sources including vehicles, light industries and household heating contribute to the high level of PM10 readings.

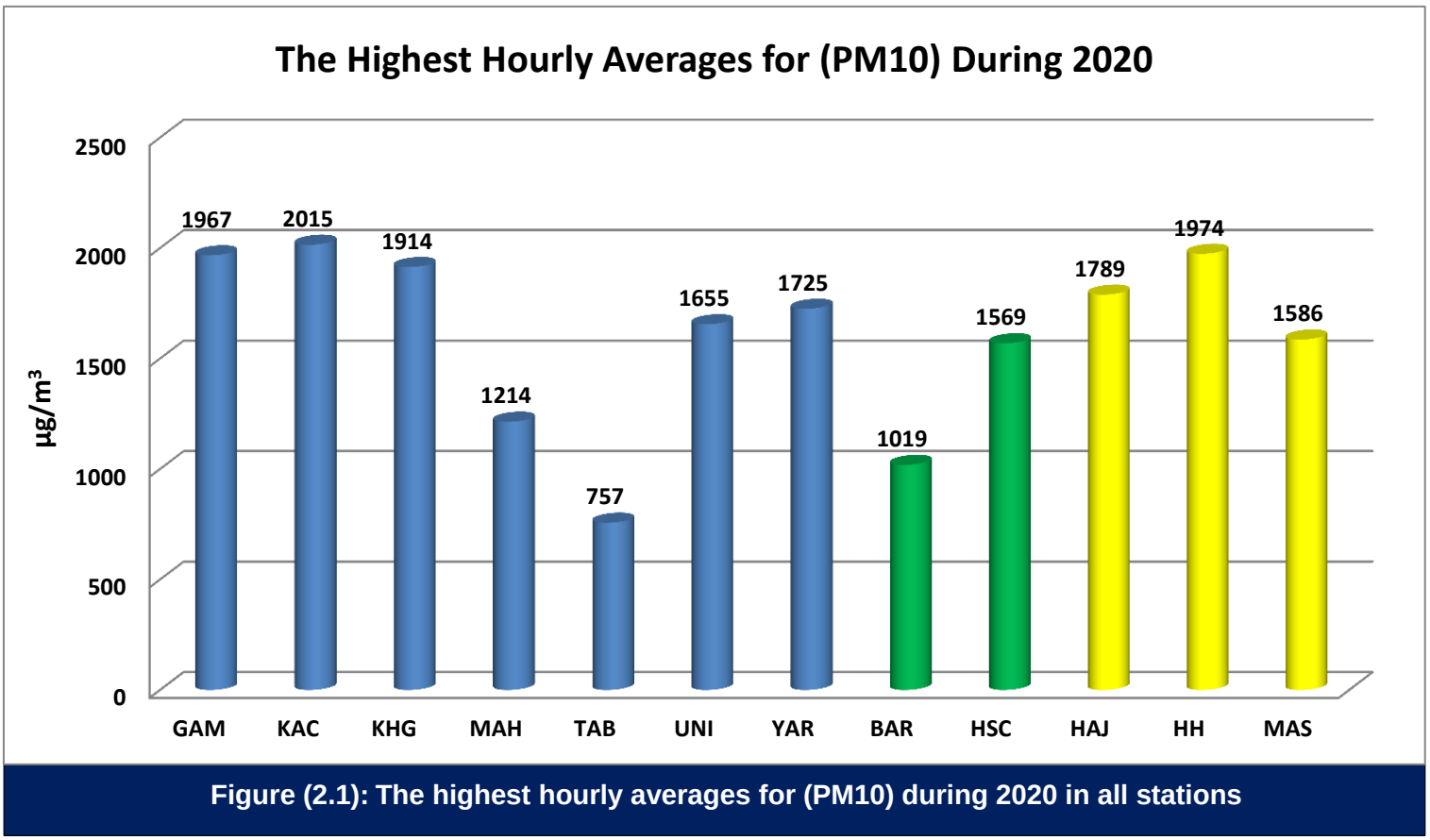


Figure (2.1): The highest hourly averages for (PM10) during 2020 in all stations

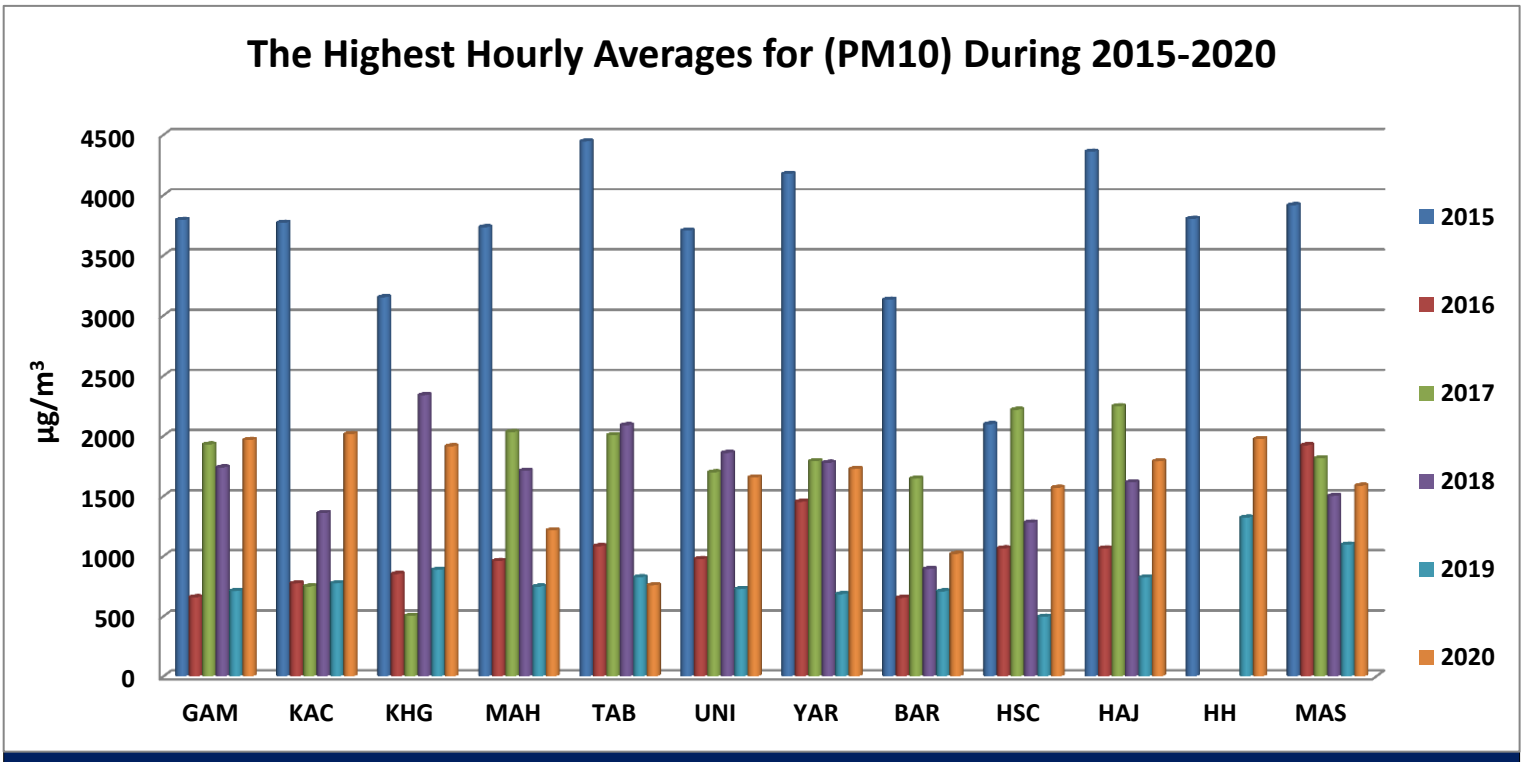


Figure (2.2): The highest hourly averages for (PM10) during 2015-2020 in all stations

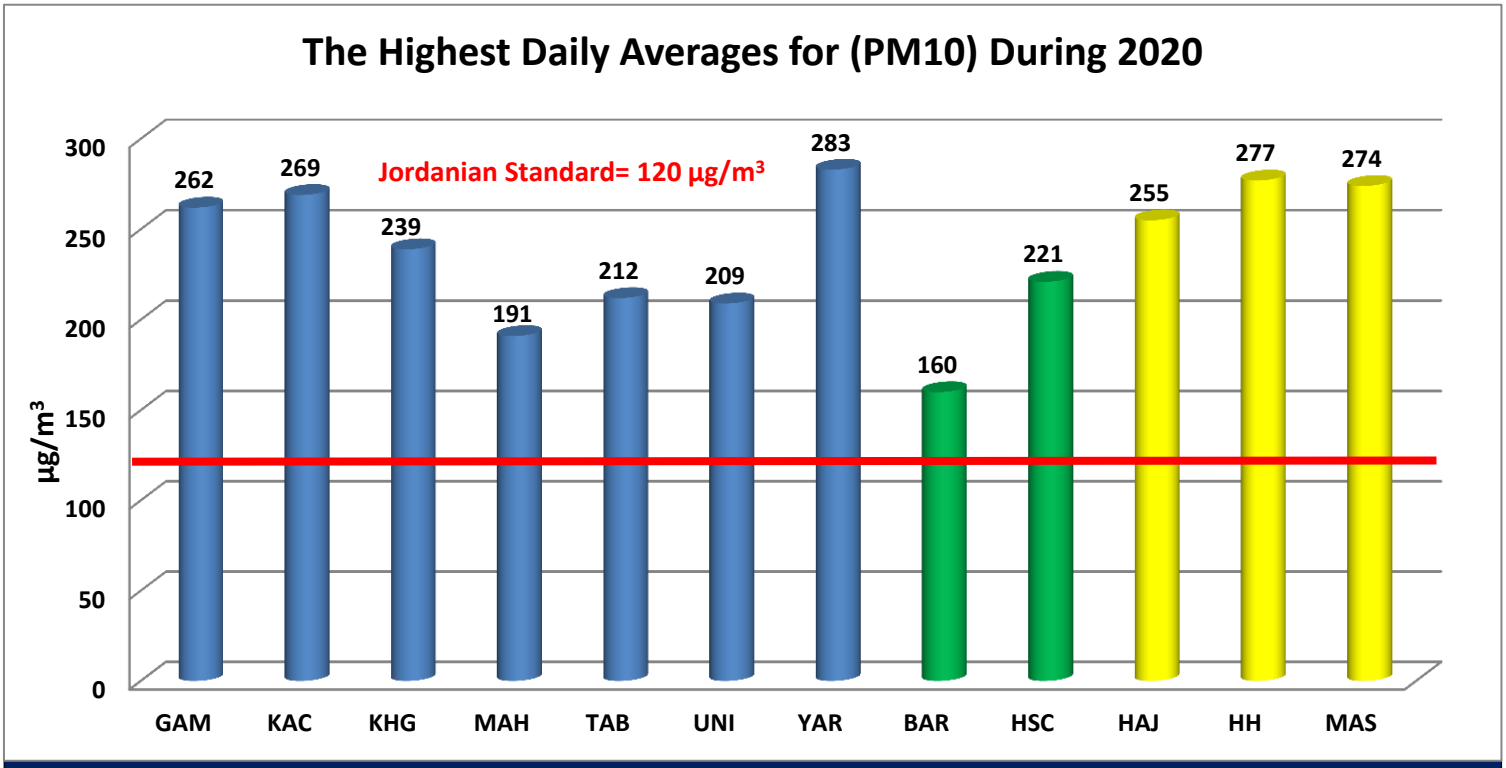


Figure (2.3): The highest daily averages for (PM10) during 2020 in all stations

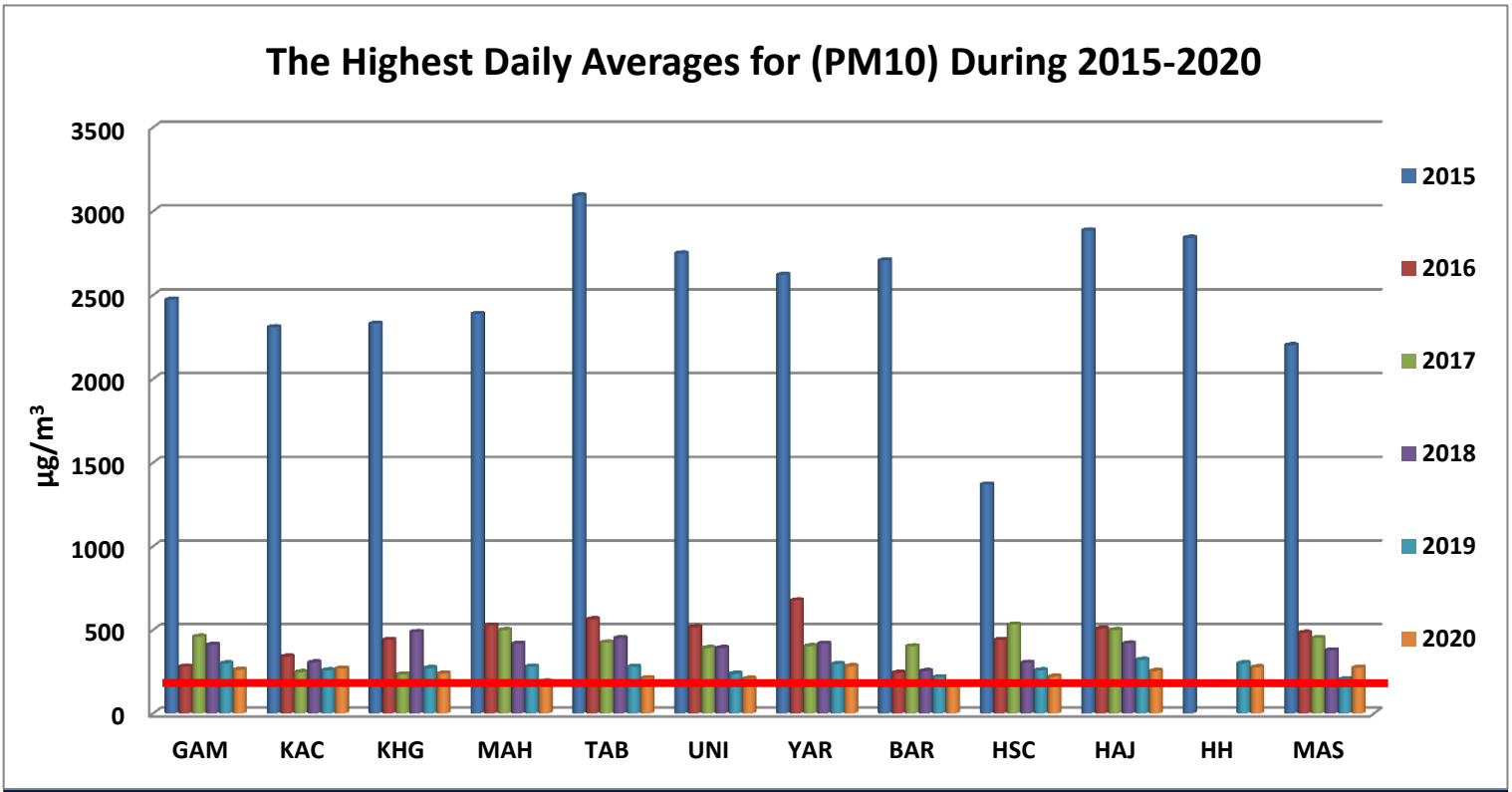


Figure (2.4): The highest daily averages for (PM10) during 2015-2020 in all stations

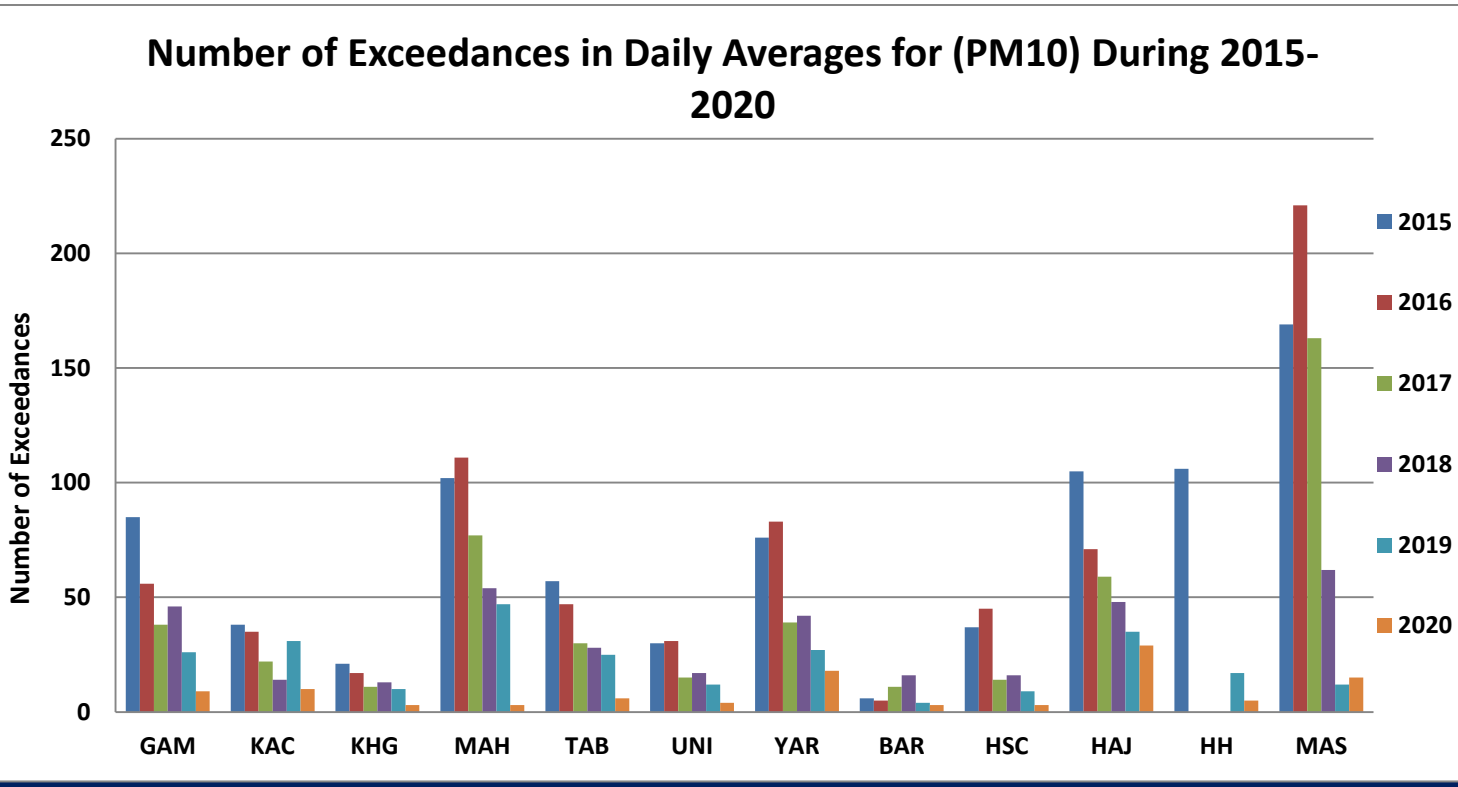


Figure (2.5): Number of exceedances in daily averages for PM10 during 2015-2020 in all stations.

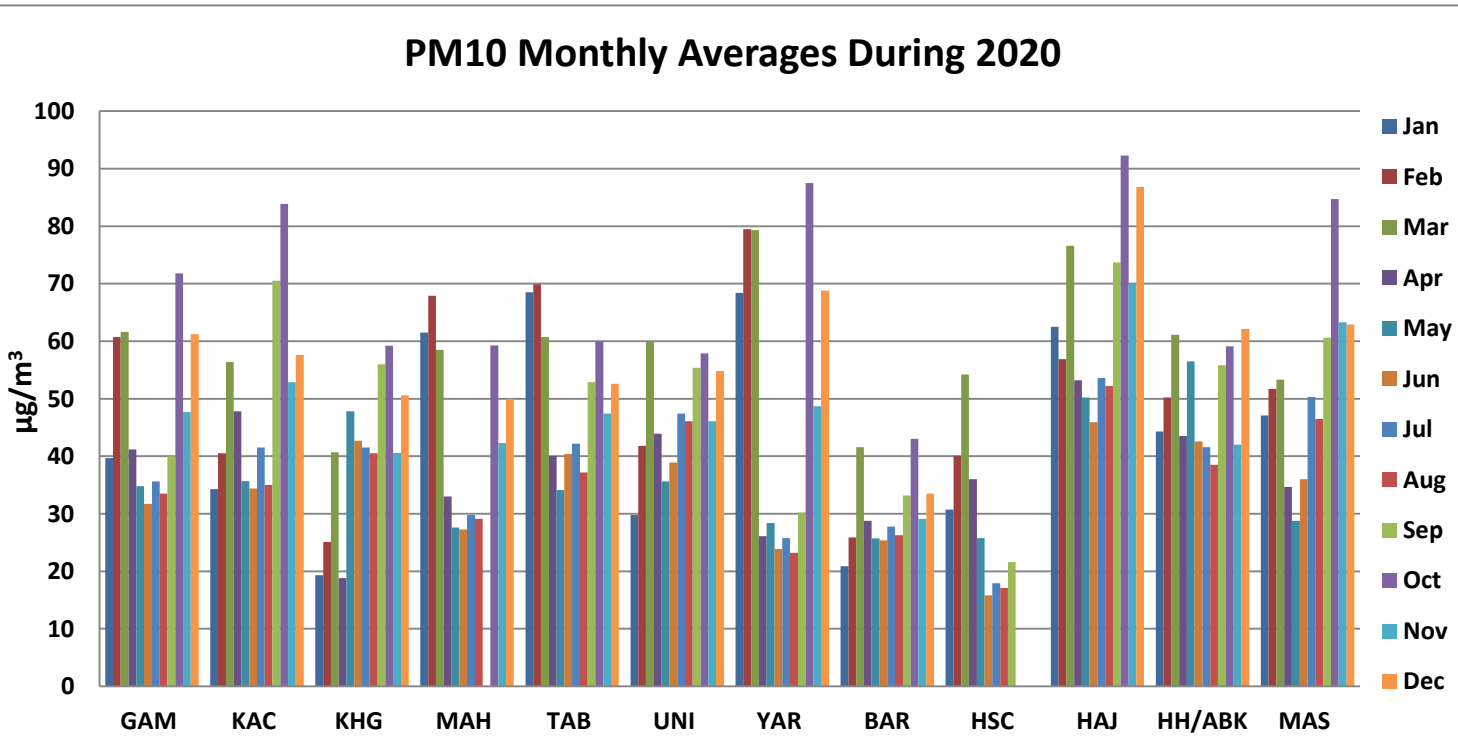


Figure (2.6): PM10 monthly averages during 2020 in all stations.

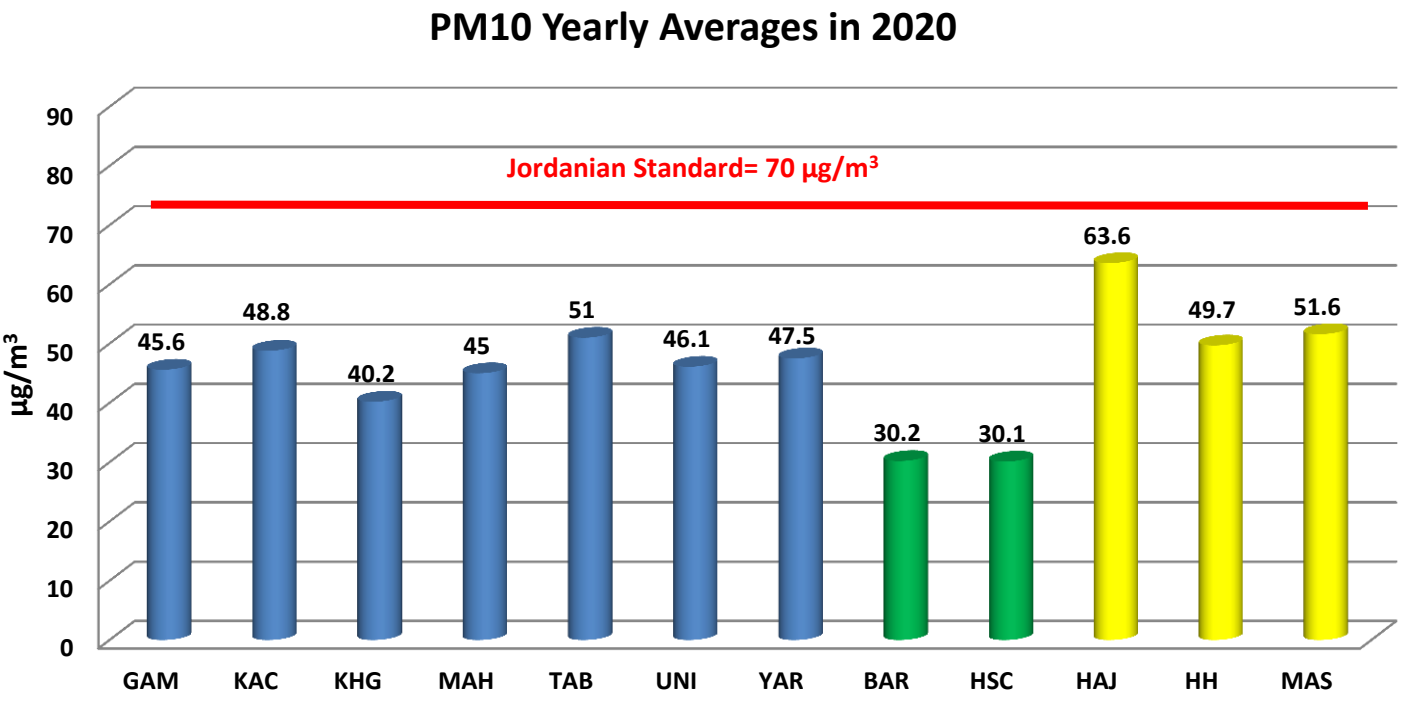


Figure (2.7): PM10 yearly averages in 2020 in all stations.

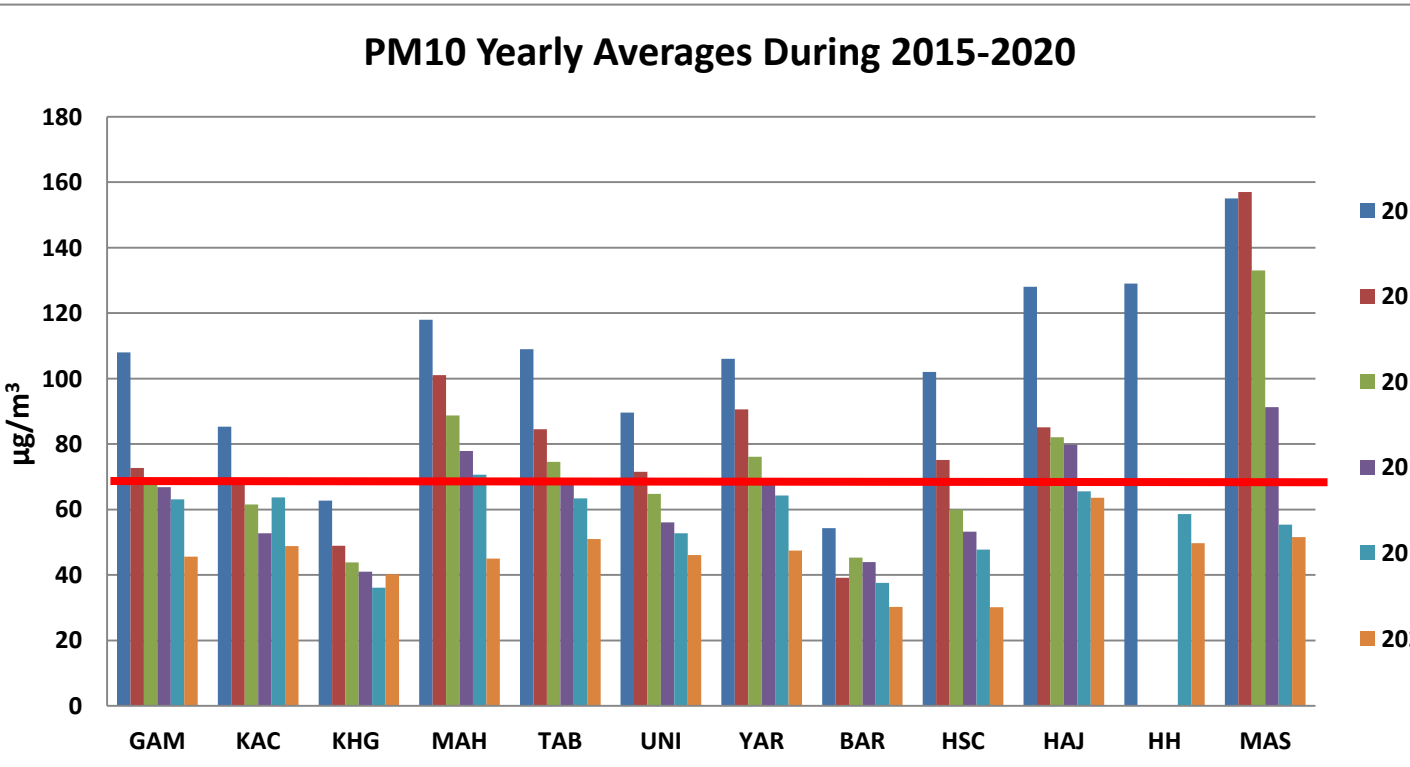


Figure (2.8): PM10 yearly averages during 2015-2020 in all stations.

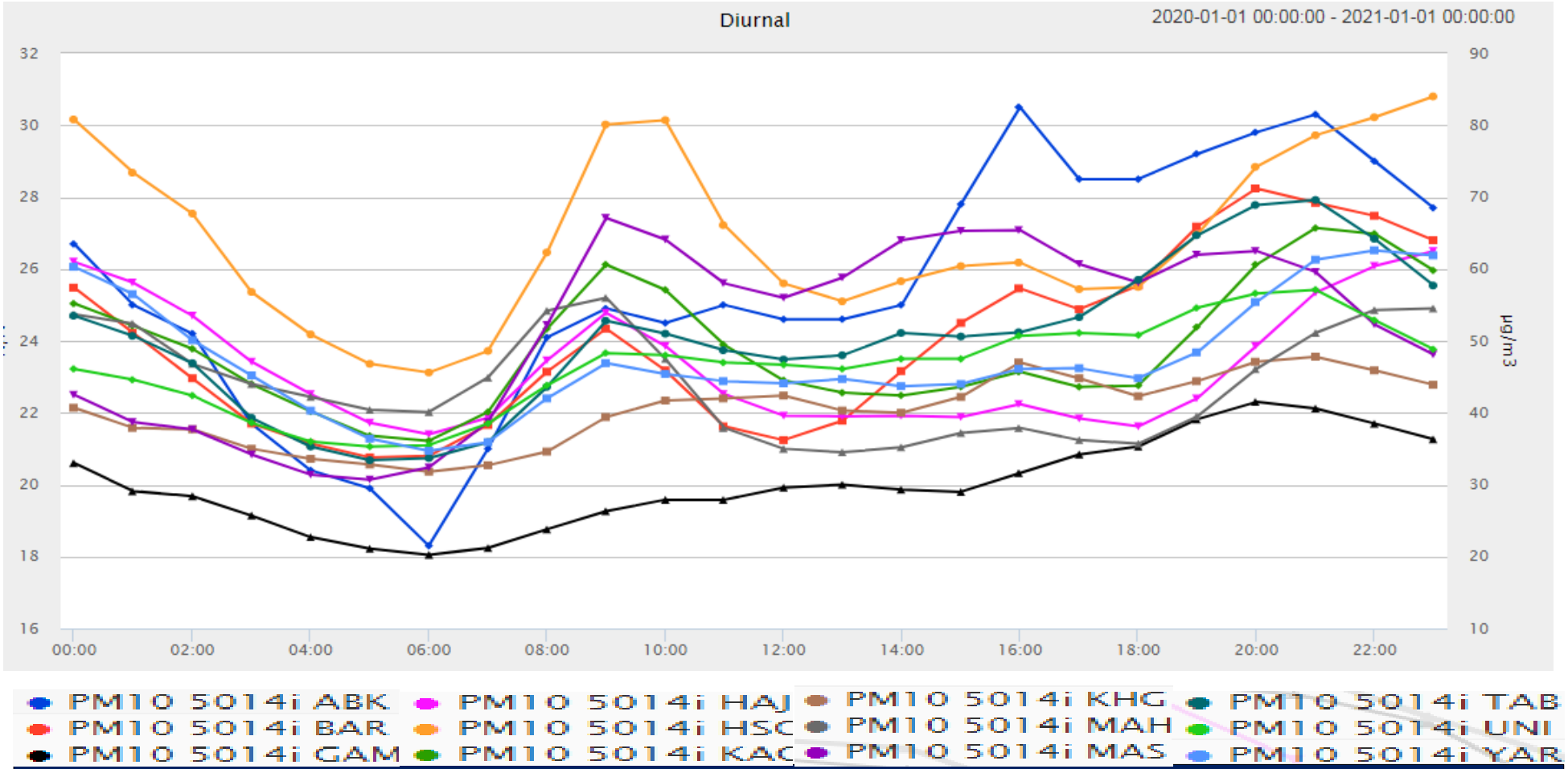


Figure (2.9): The average value in each hour of the day in all stations of the Particulate Matter (PM10)

The results indicate, as shown in Figure (2.9), that the highest daily readings of PM10 occur in the peak traffic period, between (8-11 am), (3-5 pm) and (7-9 pm), and here we note The difference in concentrations between working hours and rest times.

2.2 Nitrogen Dioxide (NO_2)

Nitrogen dioxide (NO_2) is a gas that adversely affects the respiratory system. The Jordanian Standard allows three 1-hour average concentrations greater than 210 ppb a 12-month period. The 24-hour average Jordanian Standard for ambient air quality is 80 ppb while the yearly average is 50 ppb.

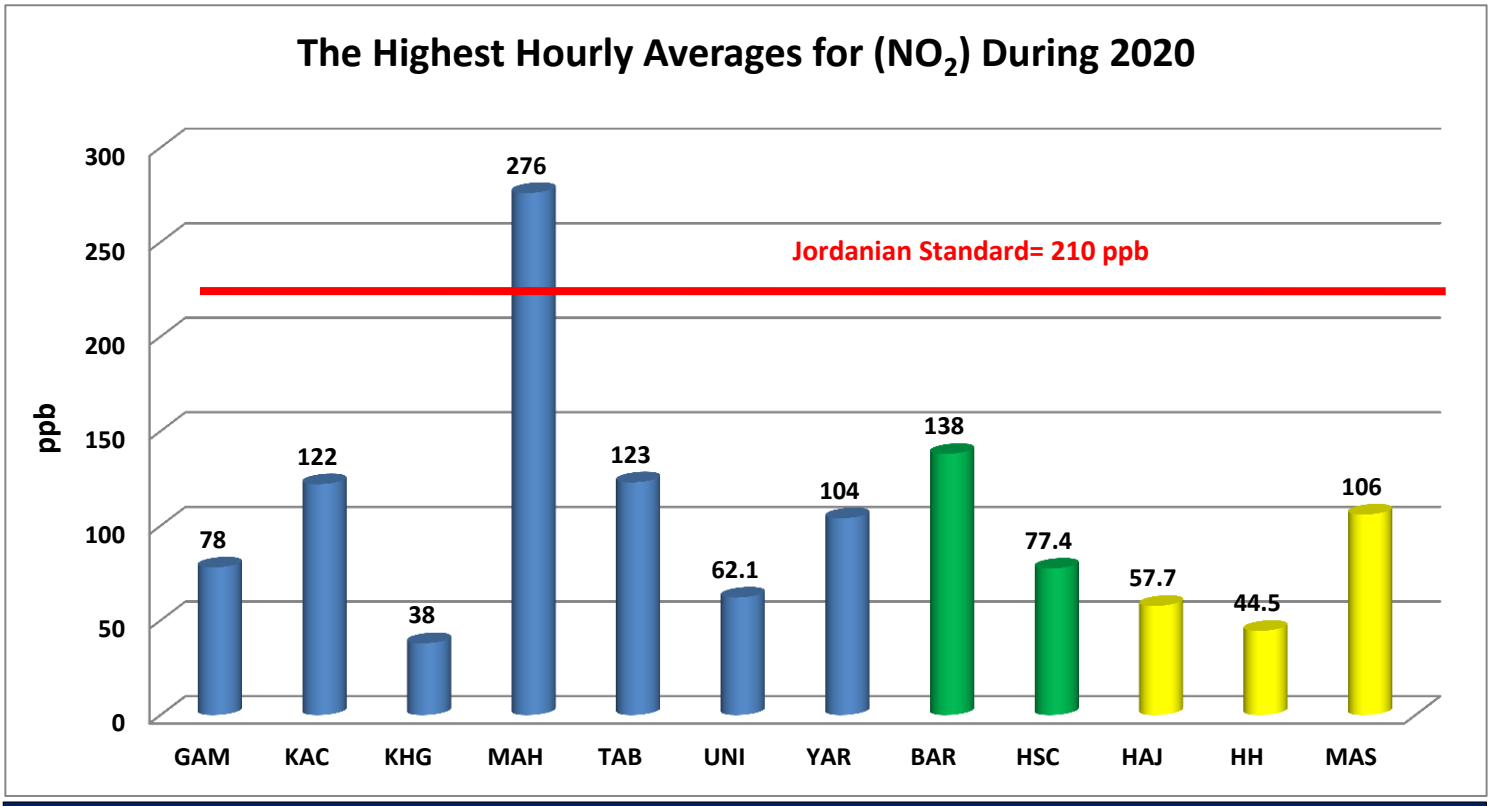


Figure (2.10): The highest hourly averages for (NO_2) during 2020 in all stations

The results of monitoring the ambient air quality showed that the hourly averages of **NO_2** gas were within the limits allowed in the Jordanian standard (1140/2006) in most of the monitoring stations, where only One exceed were detected in Mahatta Station in Amman as shown in figure (2.10) above.

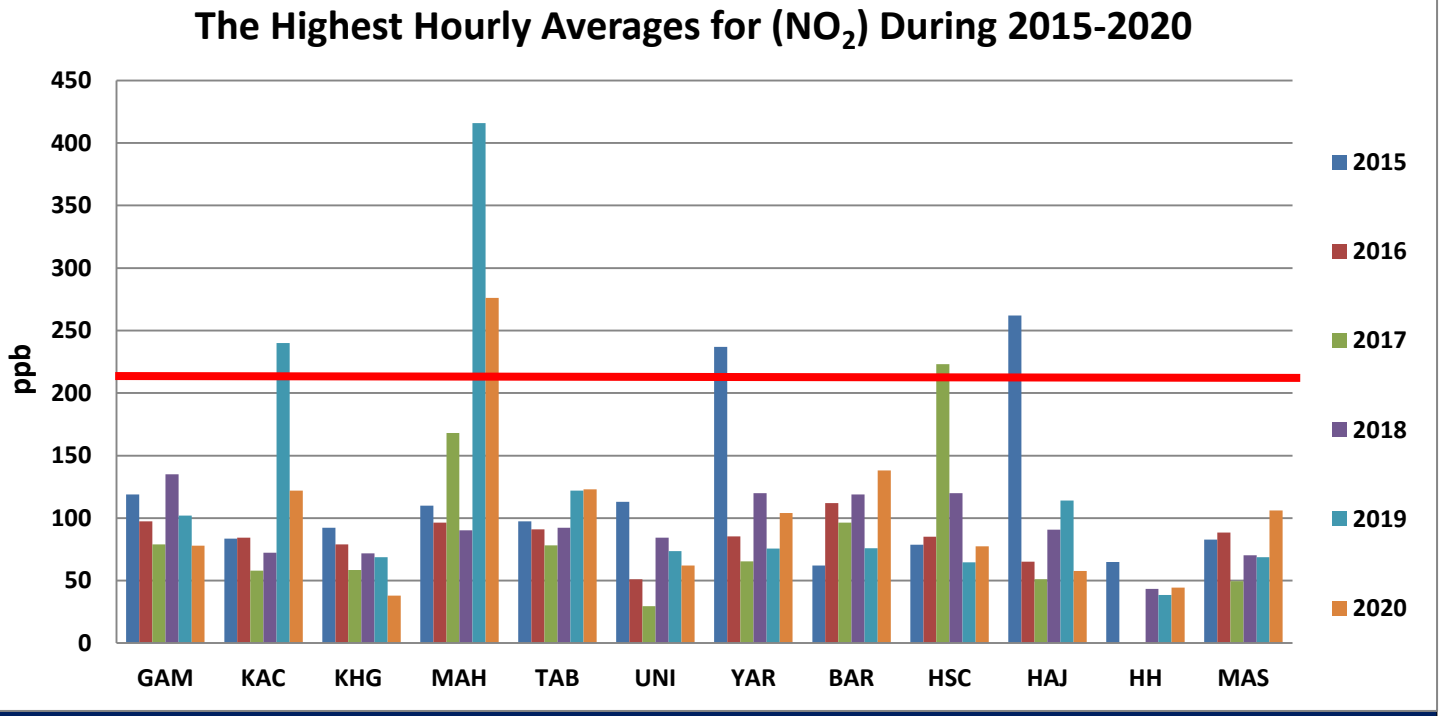


Figure (2.11): The highest hourly averages for (NO_2) during 2015-2020 in all stations

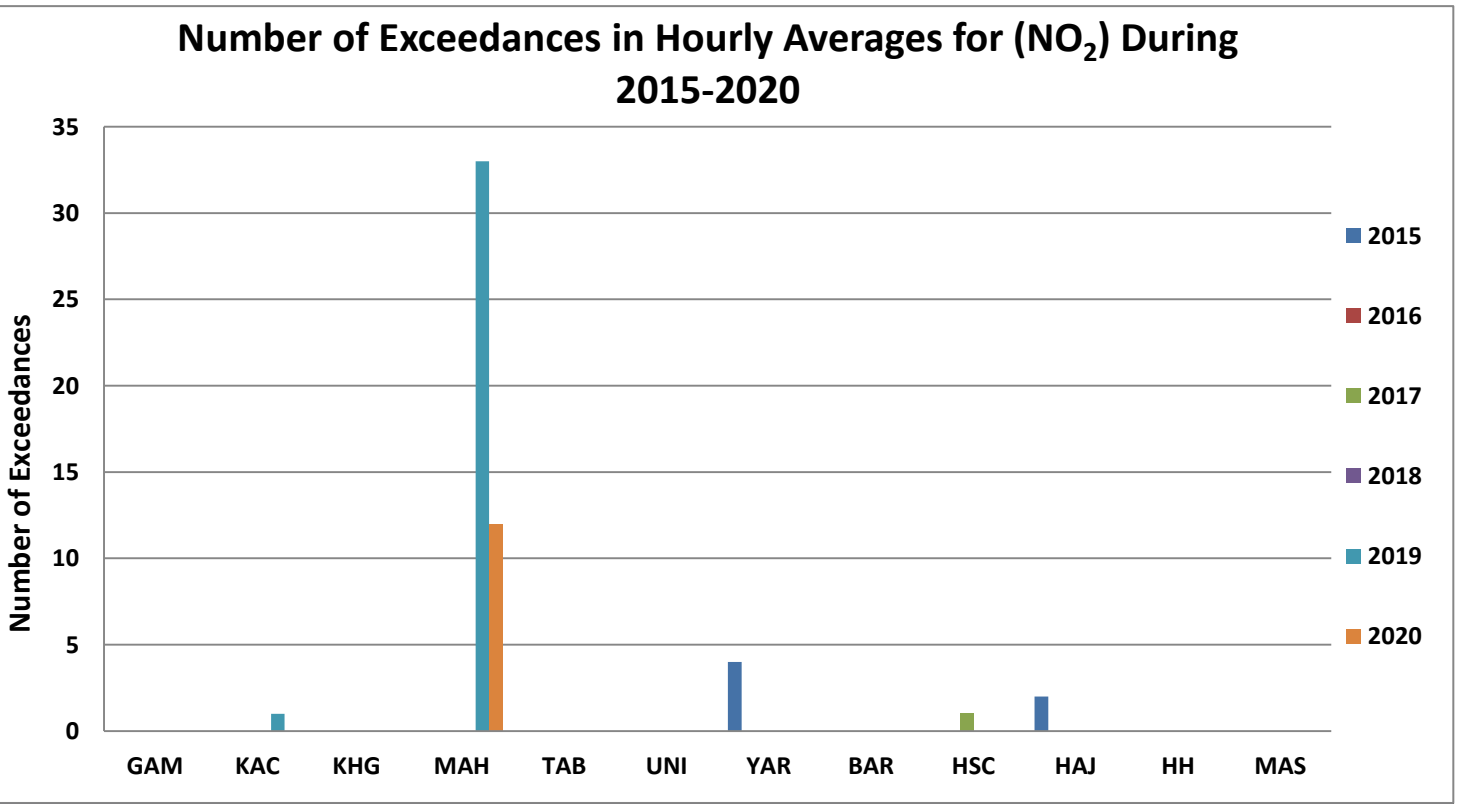


Figure (2.12): Number of exceedances in hourly averages for NO_2 during 2015-2020 in all stations

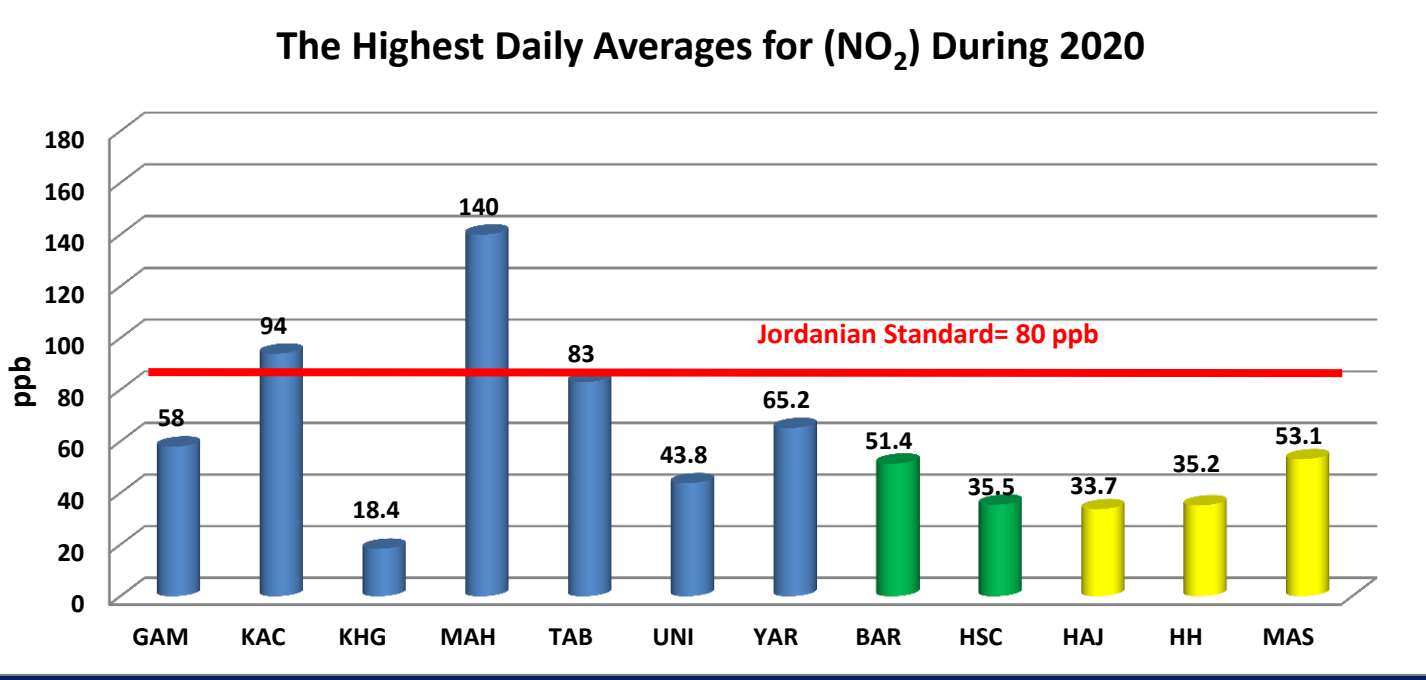


Figure (2.13): The highest daily averages for (NO_2) during 2020 in all stations

The results of monitoring the ambient air quality showed that the daily averages of **NO_2** gas were within the limits allowed in the Jordanian standard (1140/2006) in the majority of monitoring stations, where only three exceeds were observed in Tabarbour, King Abdulla II Industrial City, and Mahatta stations in Amman as shown in the figure (2.13). The highest daily **NO_2** gas average was 140 ppb at Mahatta Station.

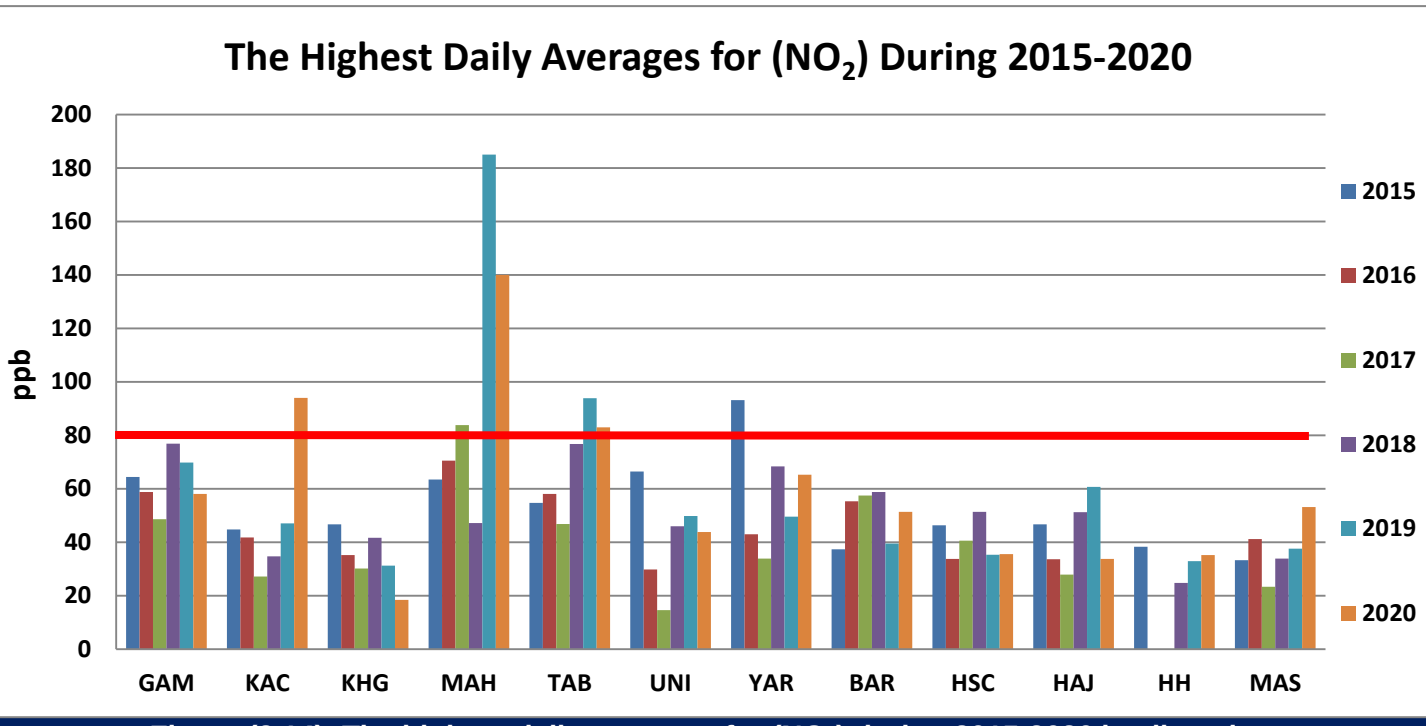


Figure (2.14): The highest daily averages for (NO_2) during 2015-2020 in all stations

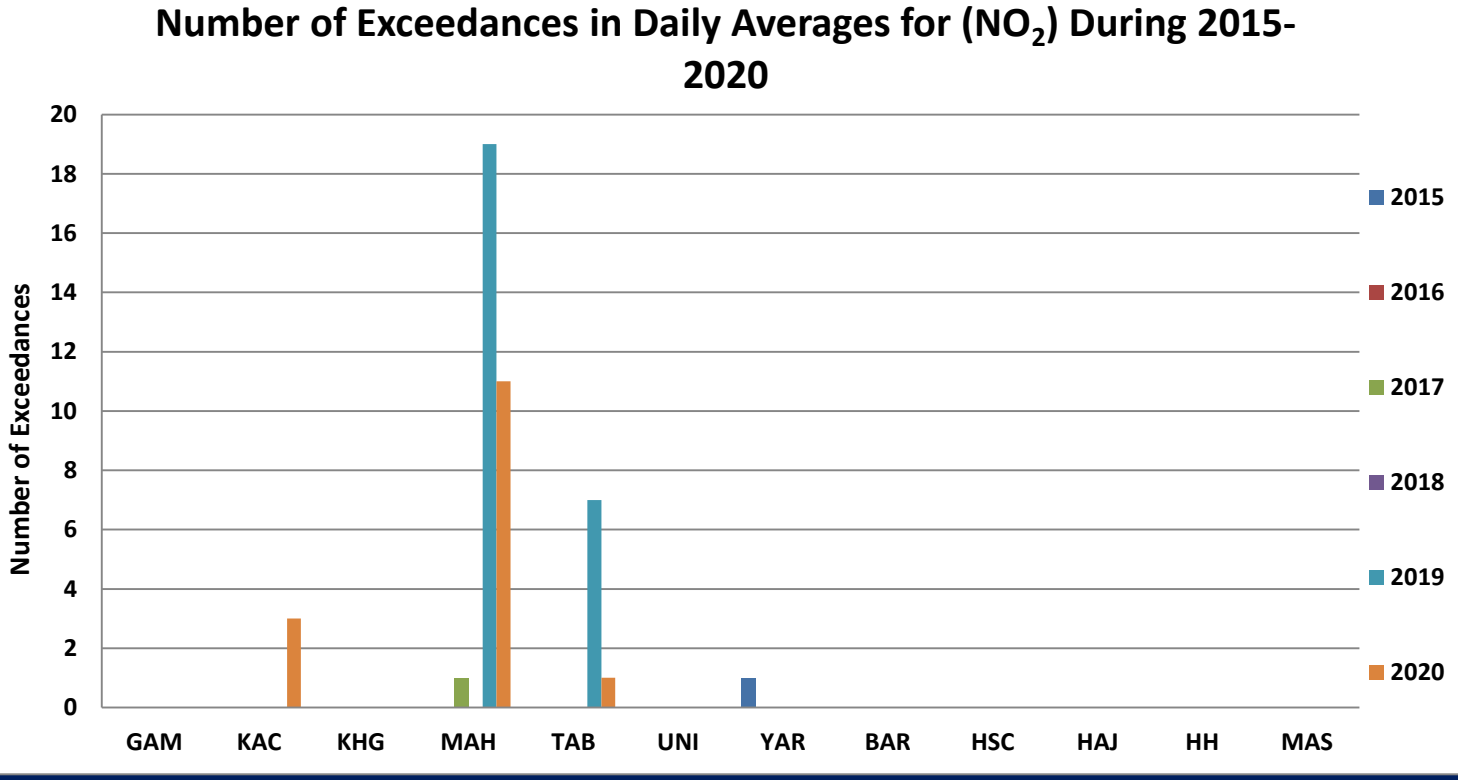


Figure (2.15): Number of exceedances in daily averages for NO_2 during 2015-2020 in all stations.

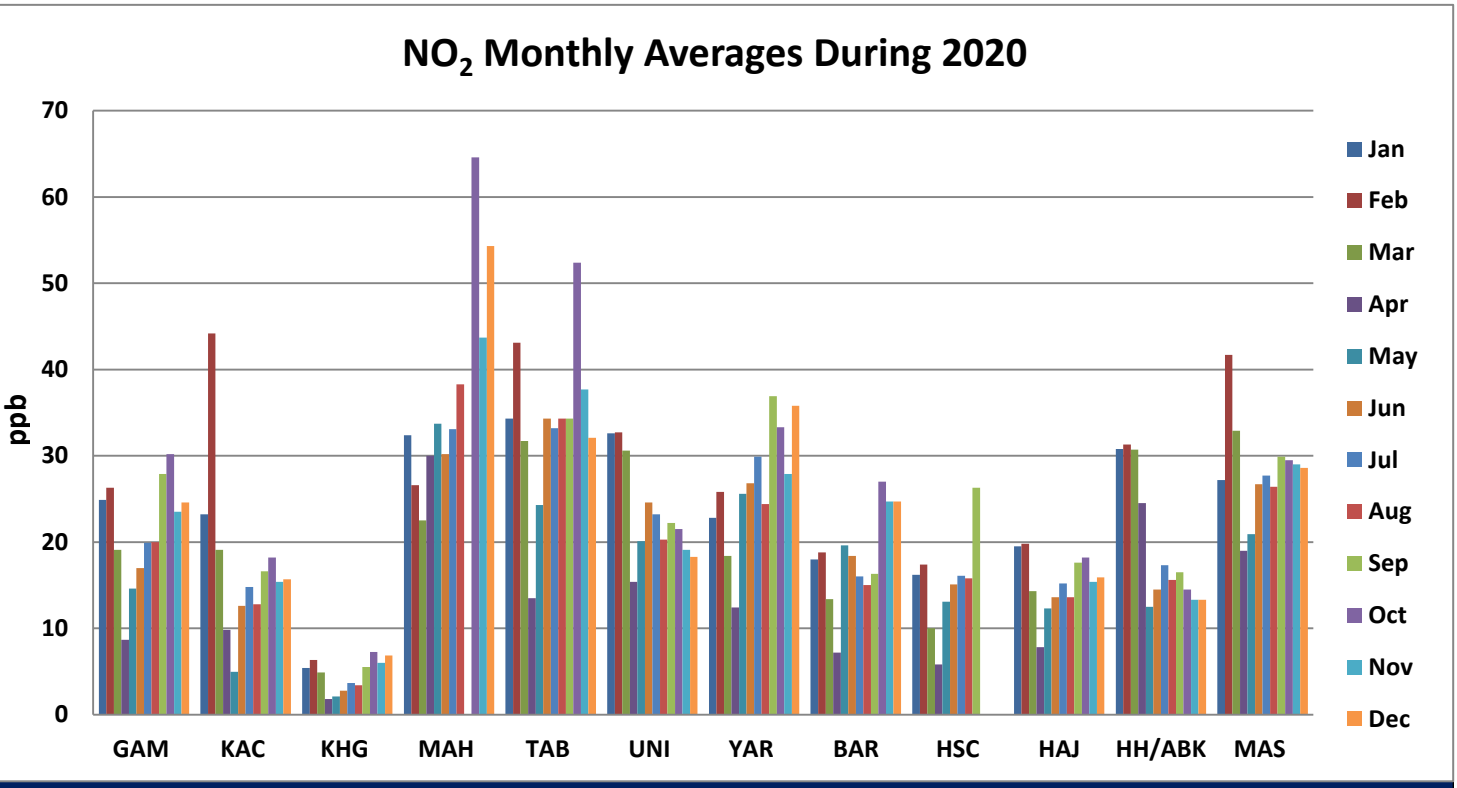


Figure (2.16): NO_2 monthly averages during 2020 in all stations.

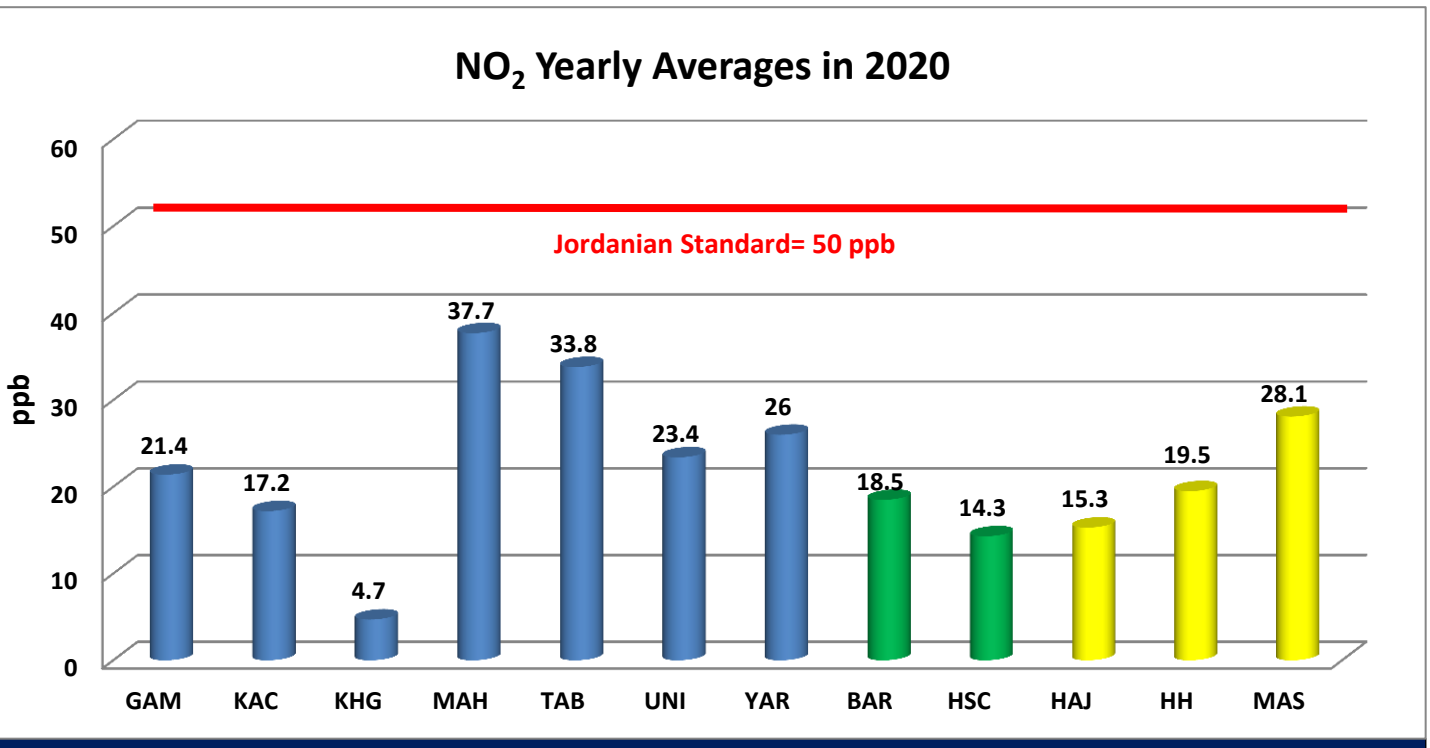


Figure (2.17): NO_2 yearly averages in 2020 in all stations.

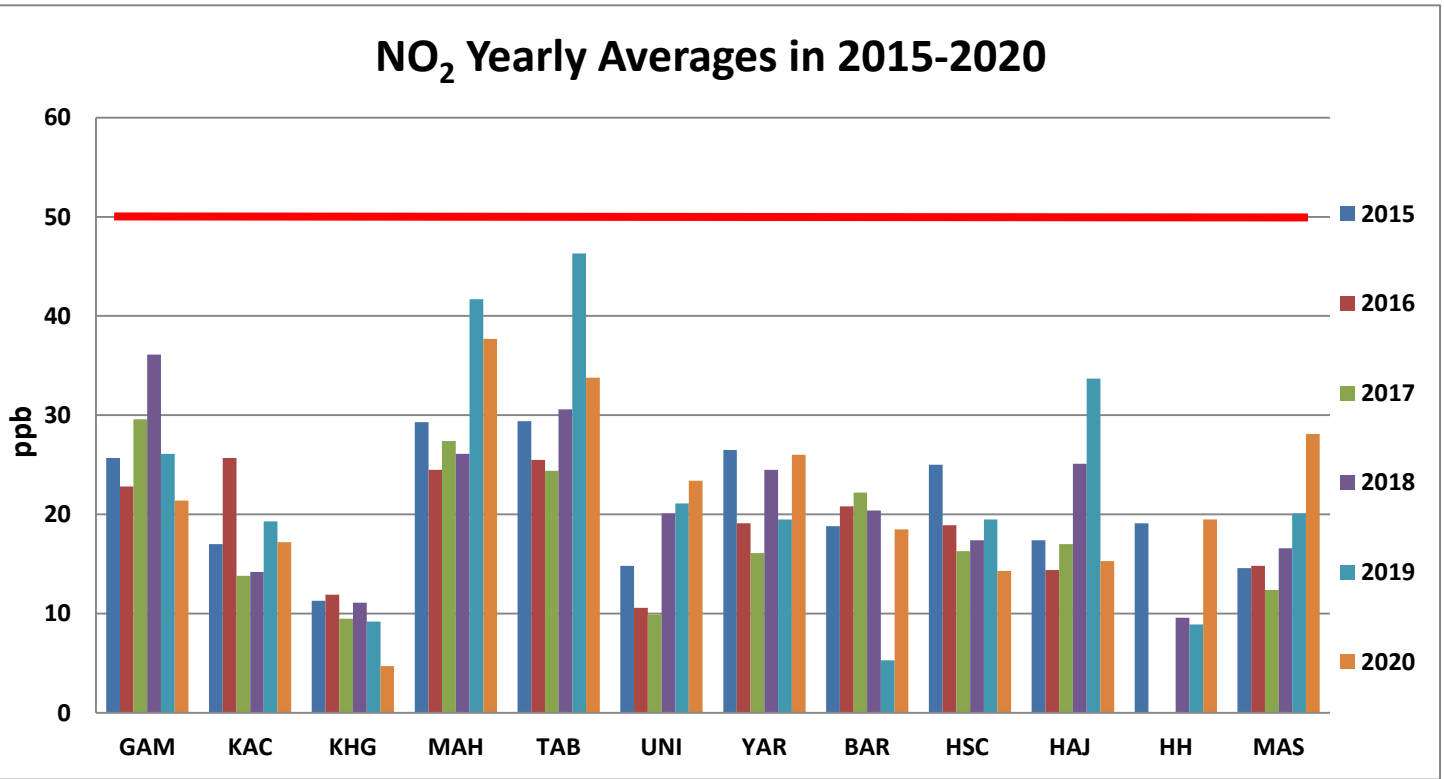


Figure (2.18): NO_2 yearly averages during 2015-2020 in all stations.

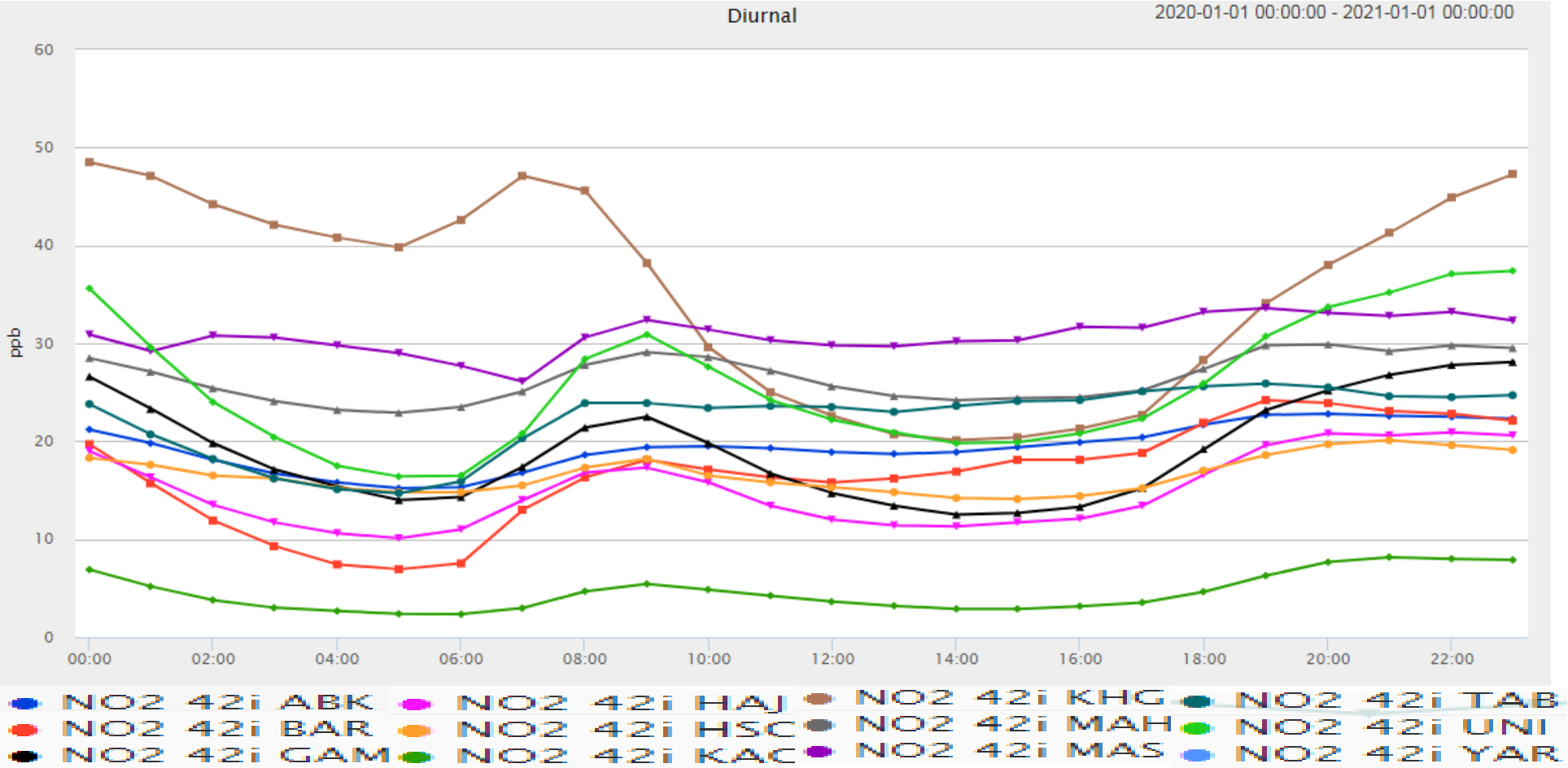


Figure (2.19): The average value in each hour of the day in all stations of Nitrogen Dioxide (NO_2).

Monitoring results in all stations indicate that the concentrations are within the limits of technical rule No. 1140/2006 and that the highest daily readings of NO2 occur during the peak period in traffic, between the hours (7-10 am) and (6-9 pm), and here we note The difference in concentrations between working hours and rest times. As shown in Figure (2.19).

2.3 Sulfur Dioxide (SO_2)

Sulphur dioxide (SO_2) is a toxic gas known to have adverse impacts on the respiratory system. It irritates the nose, throat and lungs and it could cause bronchitis.

- The Jordanian Standard allows three 1-hour average concentrations greater than 300 ppb in a 12-month period.
- The 24-hour average Jordanian Standard for ambient air quality is 140 ppb while the yearly average is 40 ppb.

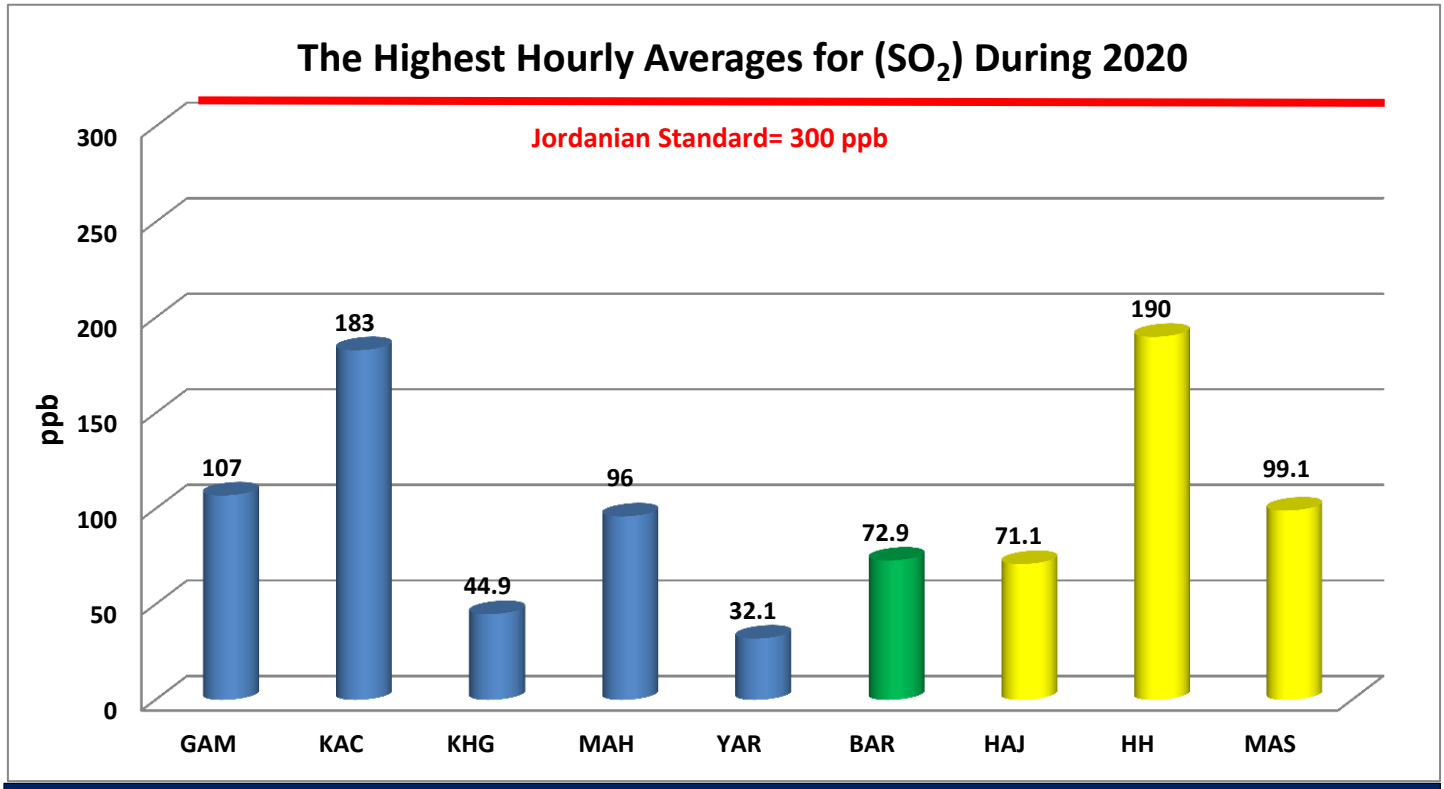


Figure (2.20): The highest hourly averages for SO_2 during 2020

The results of monitoring the ambient air quality showed that the hourly averages of SO_2 were within the limits allowed in the Jordanian standard (1140/2006) in all monitoring stations, Where no excess was observed as shown in the figure (2.20). The highest hourly average of SO_2 gas reached 190 ppb at the Hashemite Hall Station, Zarqa.

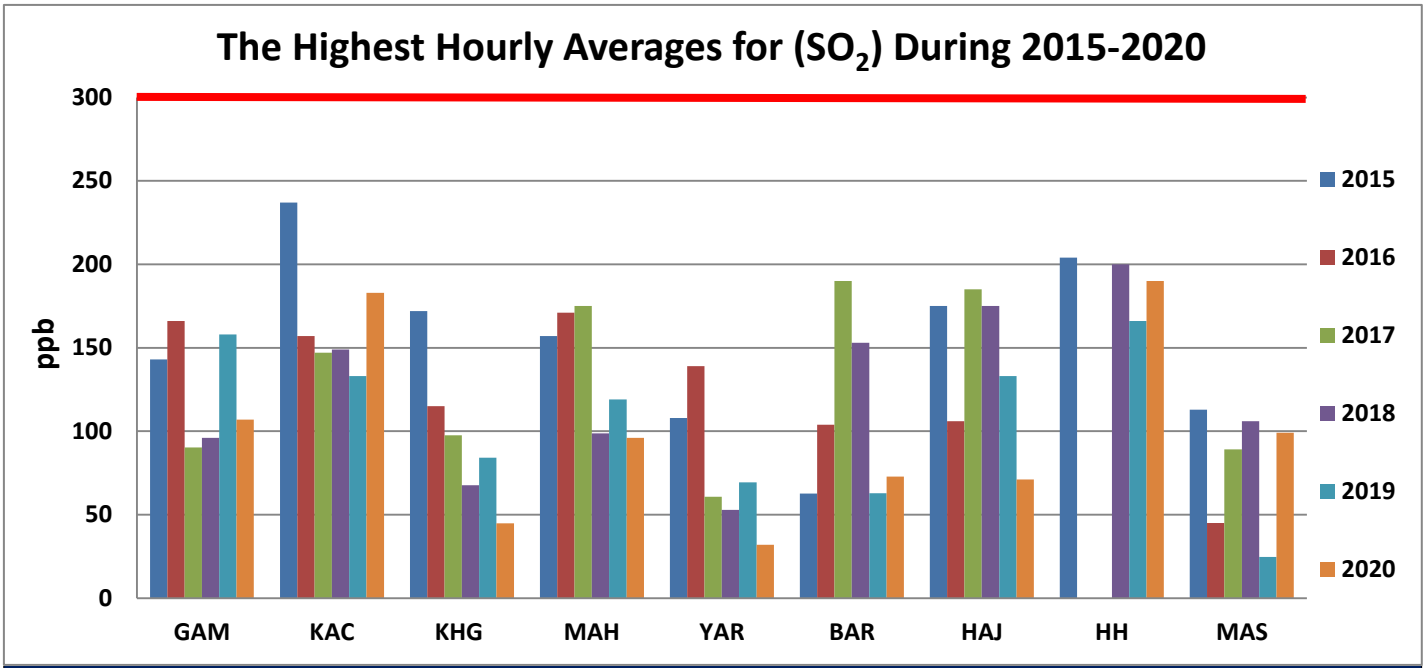


Figure (2.21): The highest hourly averages for SO_2 during 2015-2020

The results of monitoring the ambient air quality showed that the level of sulfur dioxide gas for the hourly averages was within the allowable limit in the Jordanian standard (1140/2006), as no excess was observed since the beginning of the monitoring process until now.

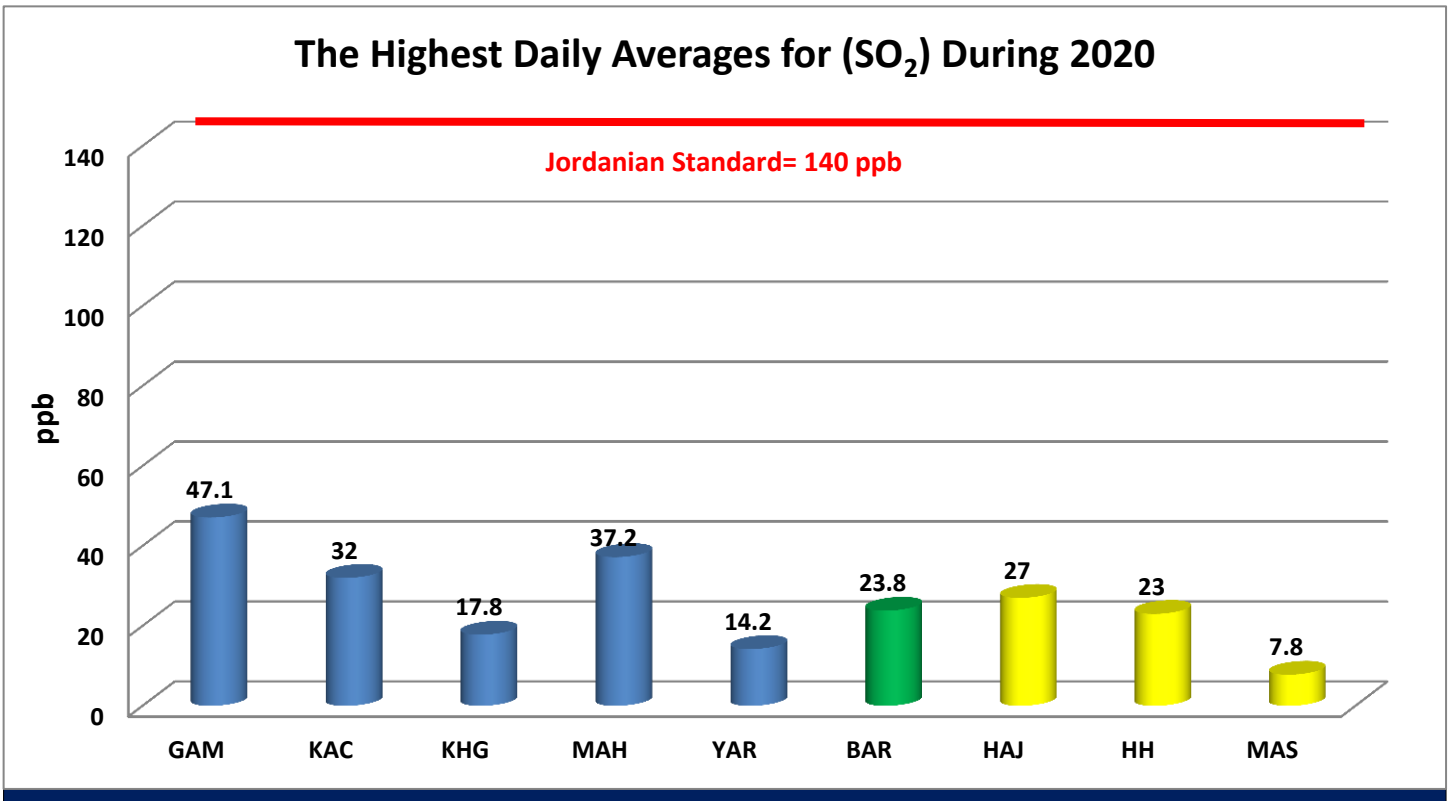


Figure (2.22): The highest daily averages for SO_2 during 2020.

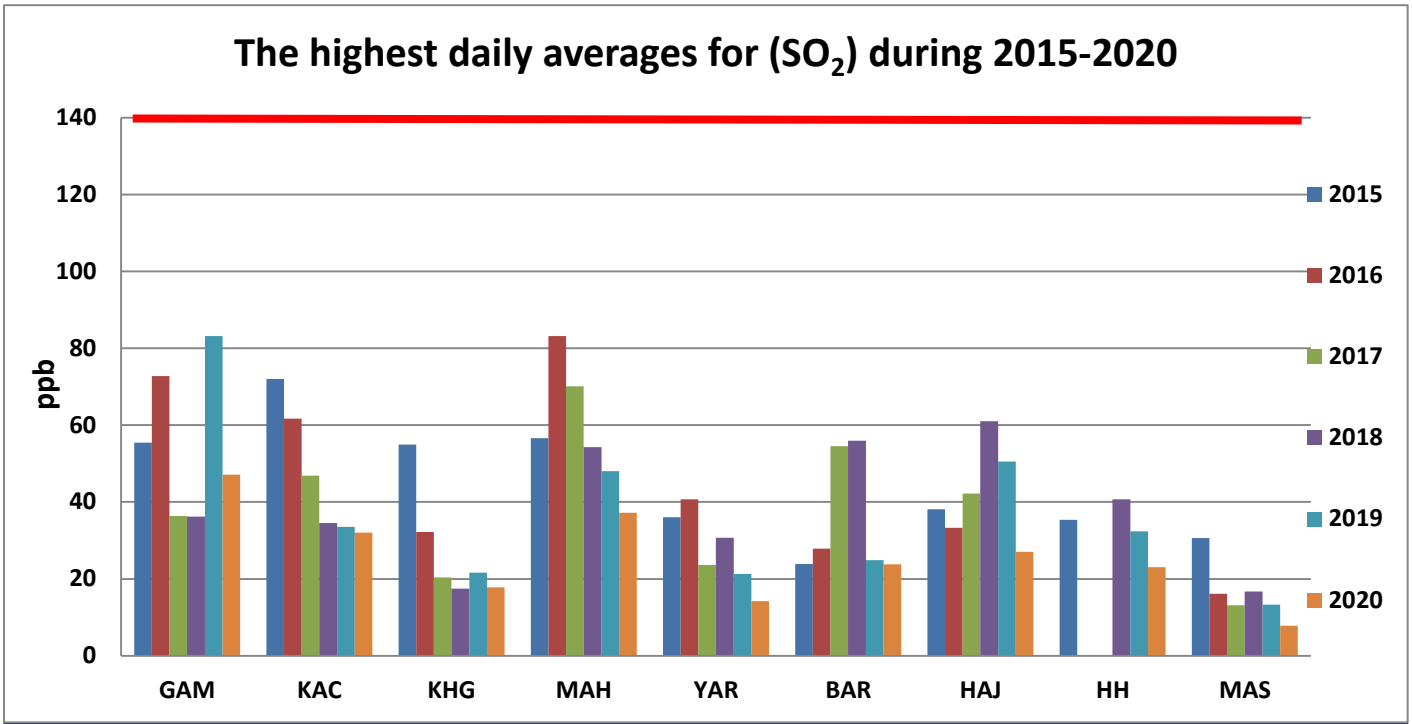


Figure (2.23): The highest daily averages for SO_2 during 2015-2020

The results of monitoring the ambient air quality showed that the level of sulfur dioxide concentration for daily rates was within the allowable limit in the Jordanian standard (1140/2006) which is equal to 140 ppb, as no excess has been monitored since the beginning of the monitoring process until now.

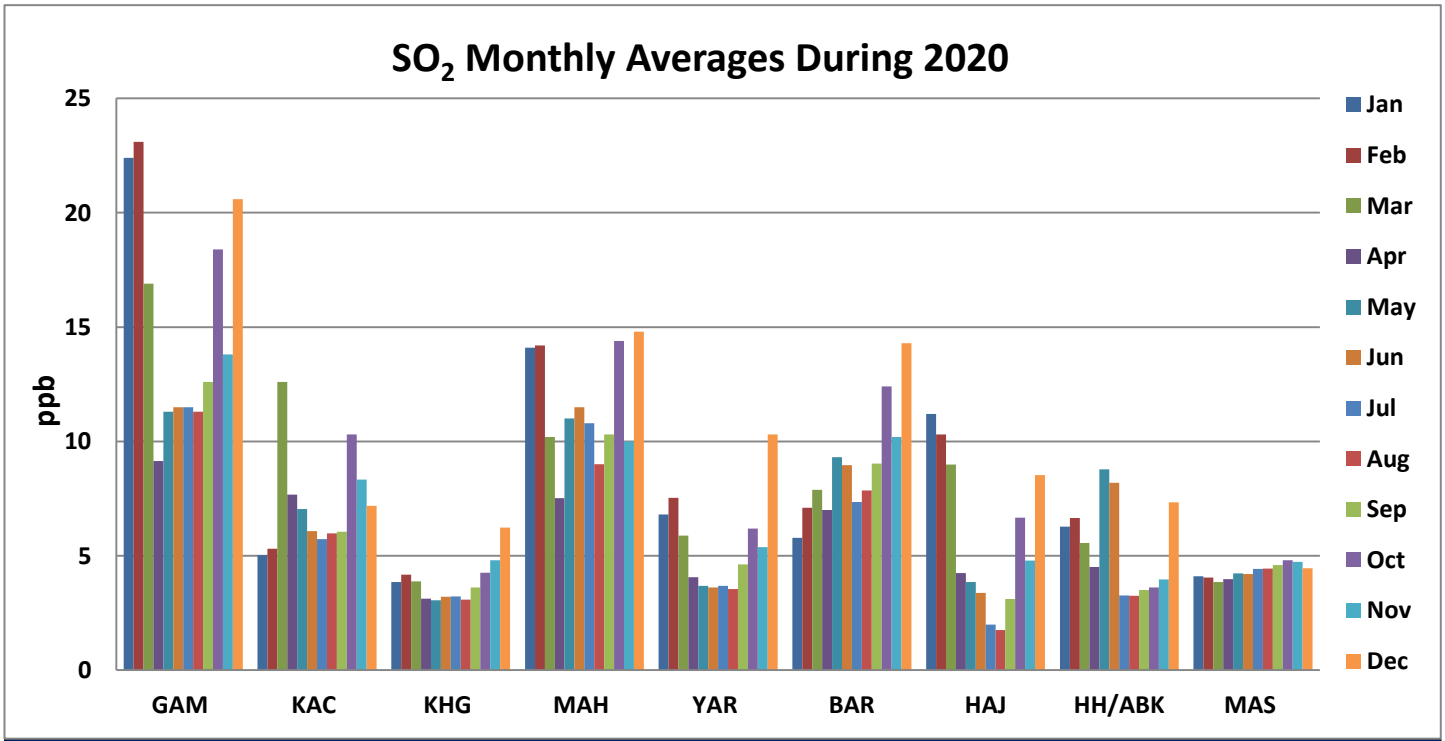


Figure (2.24):SO_2 monthly averages during 2020

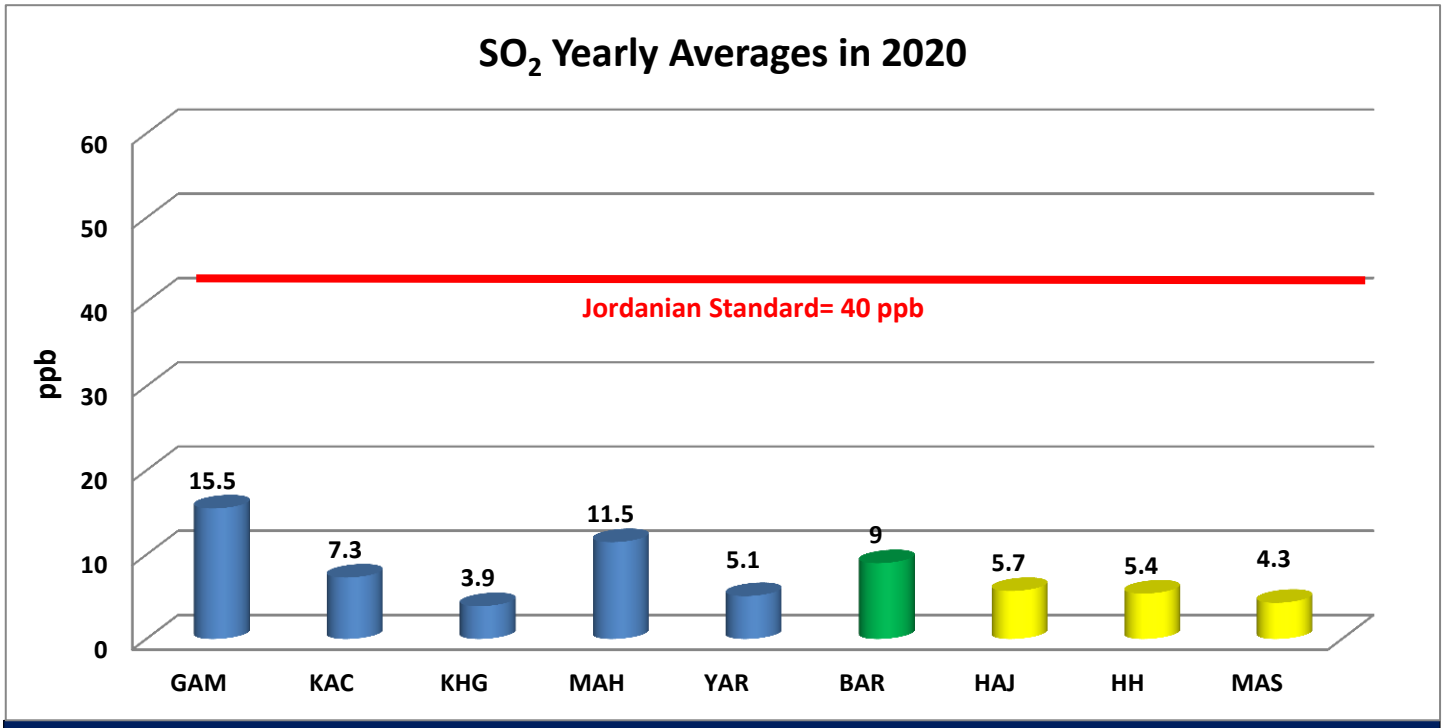


Figure (2.25): SO_2 yearly averages during 2020.

The results of monitoring the ambient air quality showed that the annual averages of SO_2 were within the limits allowed in the Jordanian standard (1140/2006) in all monitoring stations, where no excess was observed as shown in the figure (2.25), Where the highest annual average of SO_2 15.5 ppb at Greater Amman Municipality Station in Amman.

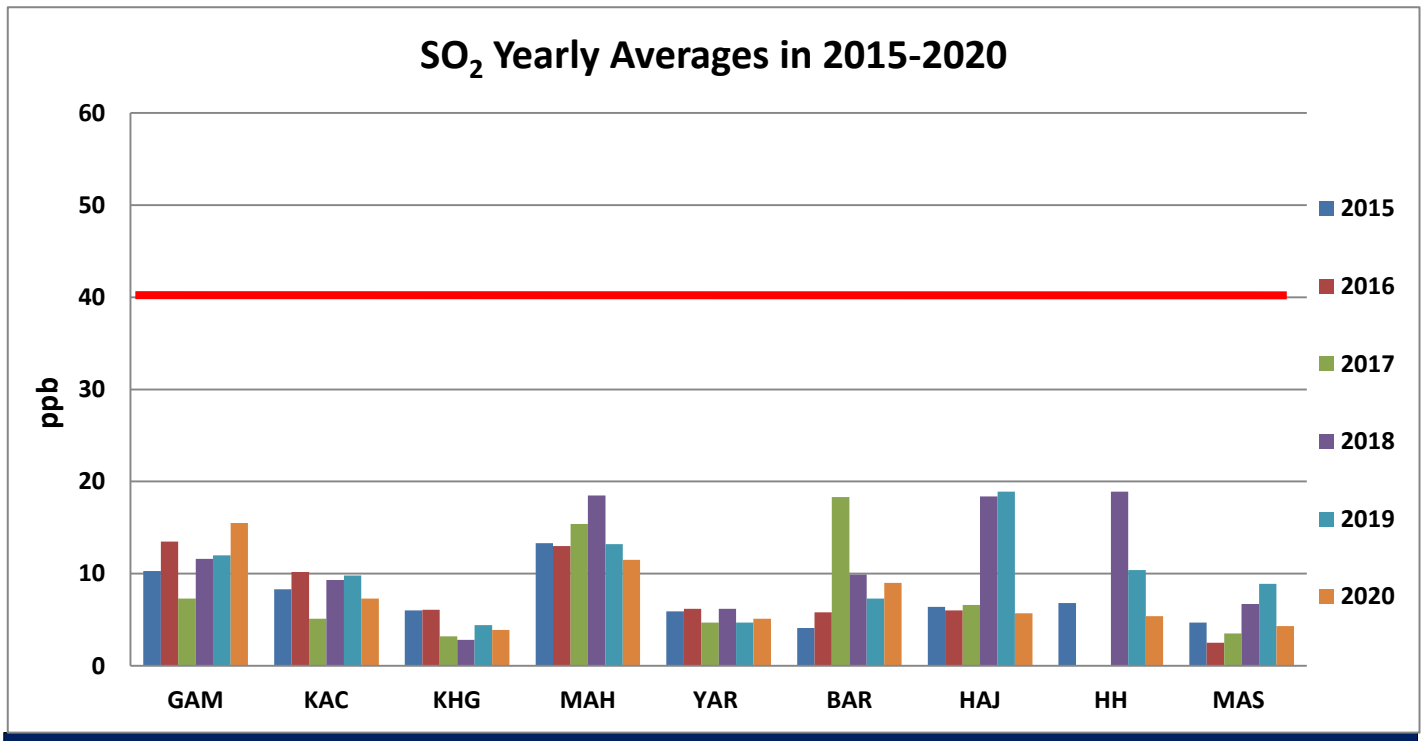


Figure (2.26): SO_2 yearly averages during 2015-2020.

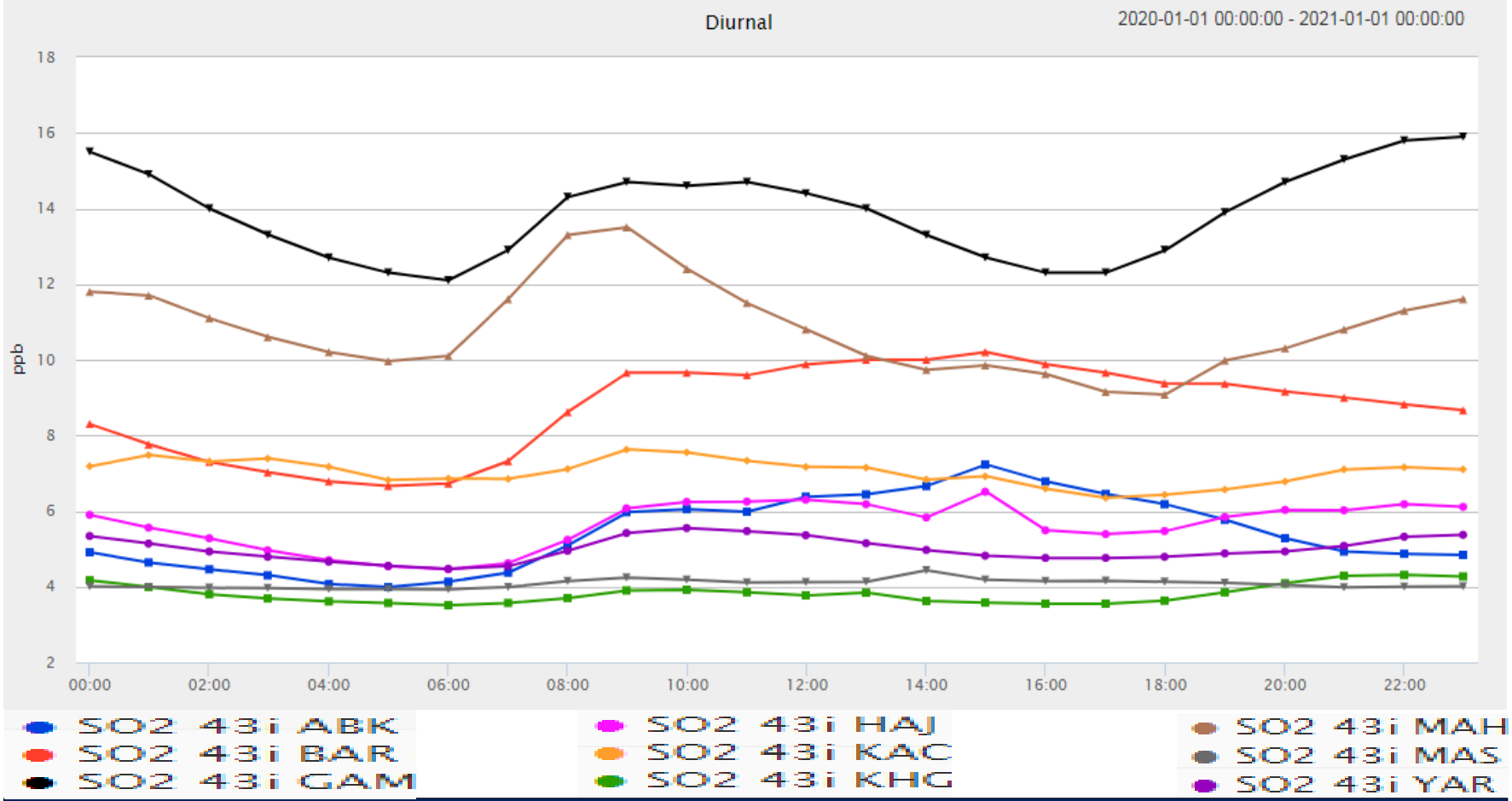


Figure (2.27): The average value in each hour of the day in all stations of Sulfur Dioxide (SO_2).

The results indicate that the highest daily readings of SO_2 gas were recorded during the peak period in traffic between (7-10 am), as shown in Figure (2.27).

2.4 Carbon Monoxide (CO)

- Carbon monoxide (CO) is a toxic, colorless gas that limits the blood's ability to transport oxygen to cells and organs, resulting in suffocation at higher doses.
- .The Jordanian Standard allows three 1-hour average concentrations greater than 26 ppm in a 12-month period.
- The 8-hour average guideline is 9 ppm and there is no yearly average in the Jordanian Standard for ambient air quality.

Note that this gas is monitored only in 4 stations.

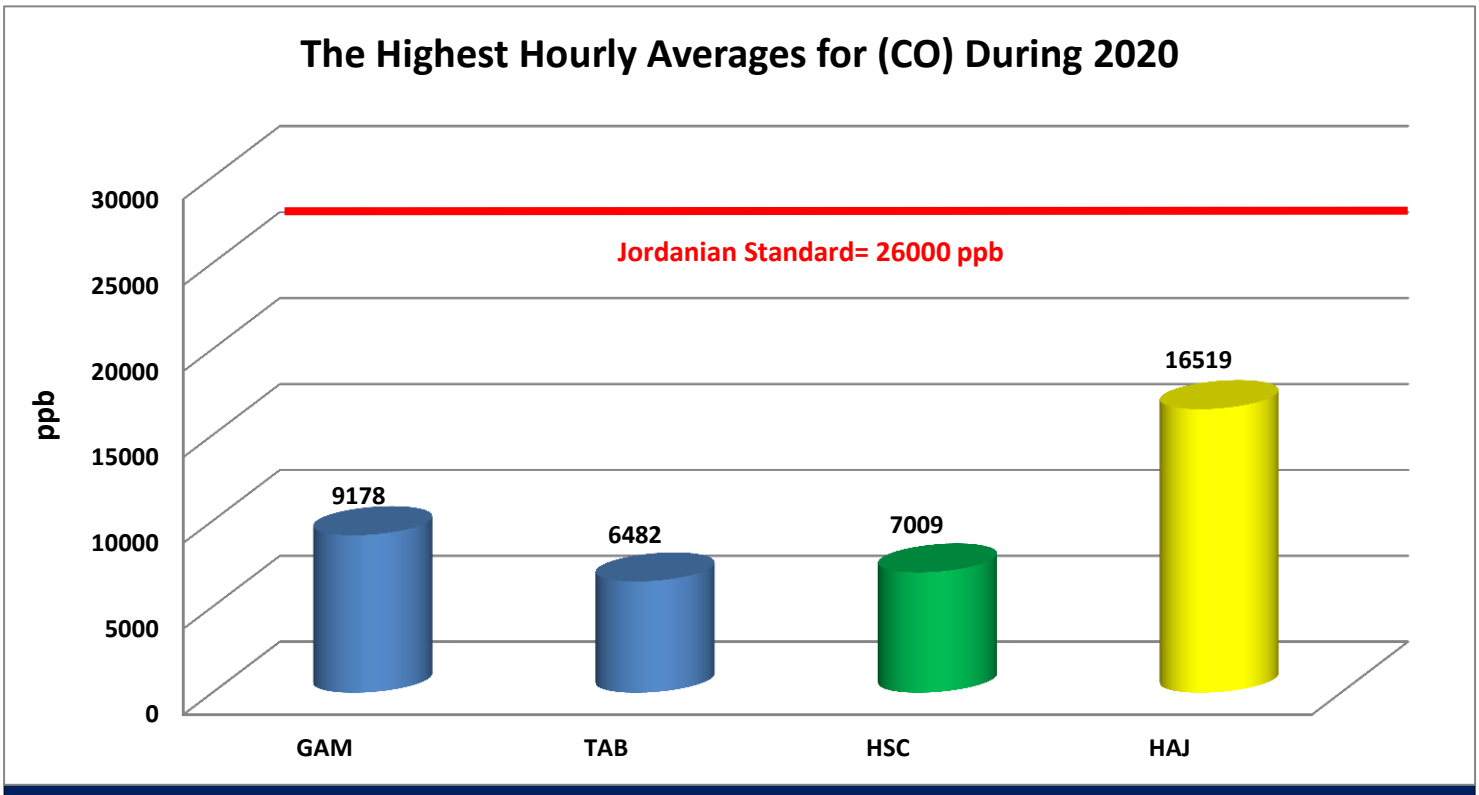


Figure (2.28): The highest hourly averages for CO during 2020

The results of monitoring the ambient air quality showed that the hourly averages of CO gas were within the limits allowed in the Jordanian standard (1140/2006) in all monitoring stations where no excess was observed as shown in the figure (2.28) where the highest hourly average of CO gas reached 16519 ppb at Wadi Al Hajjar station in Zarqa'.

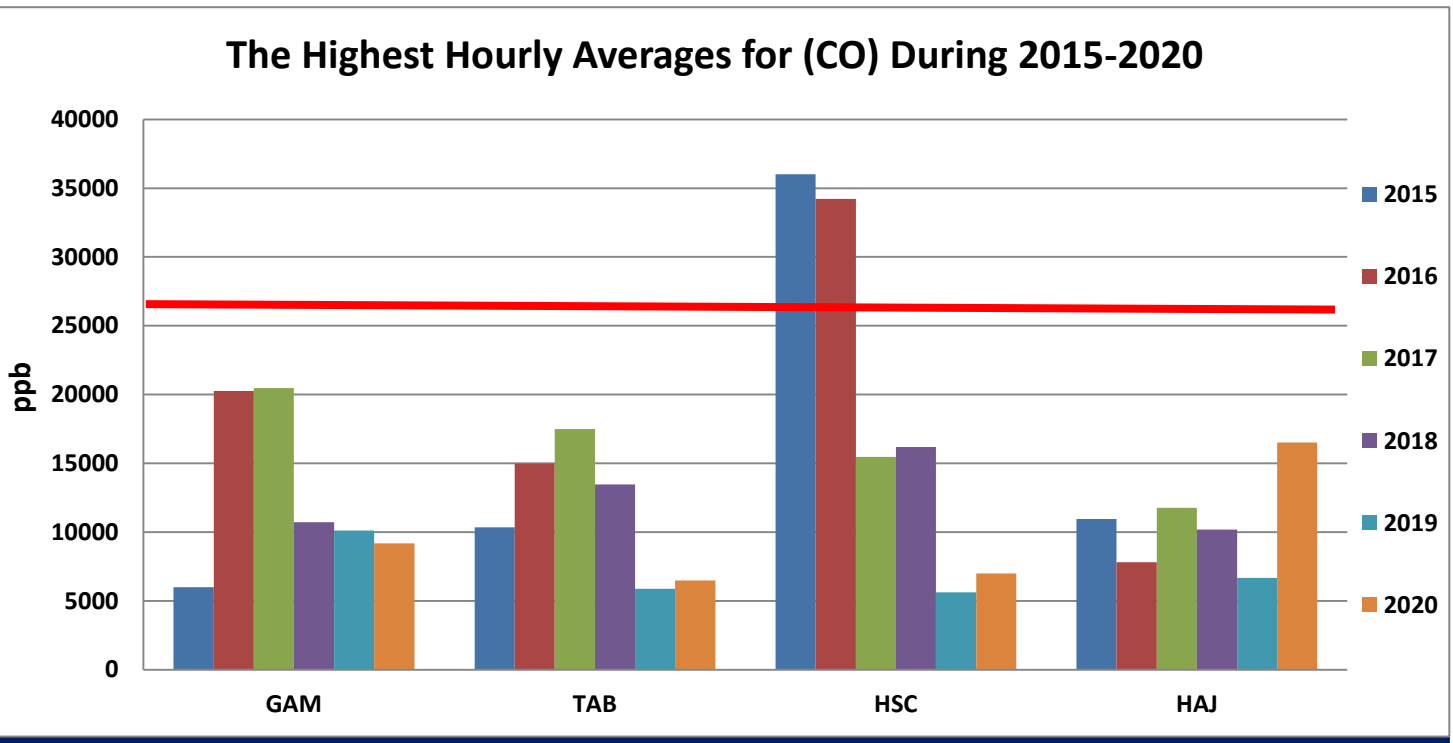


Figure (2.29): The highest hourly averages for CO during 2015-2020

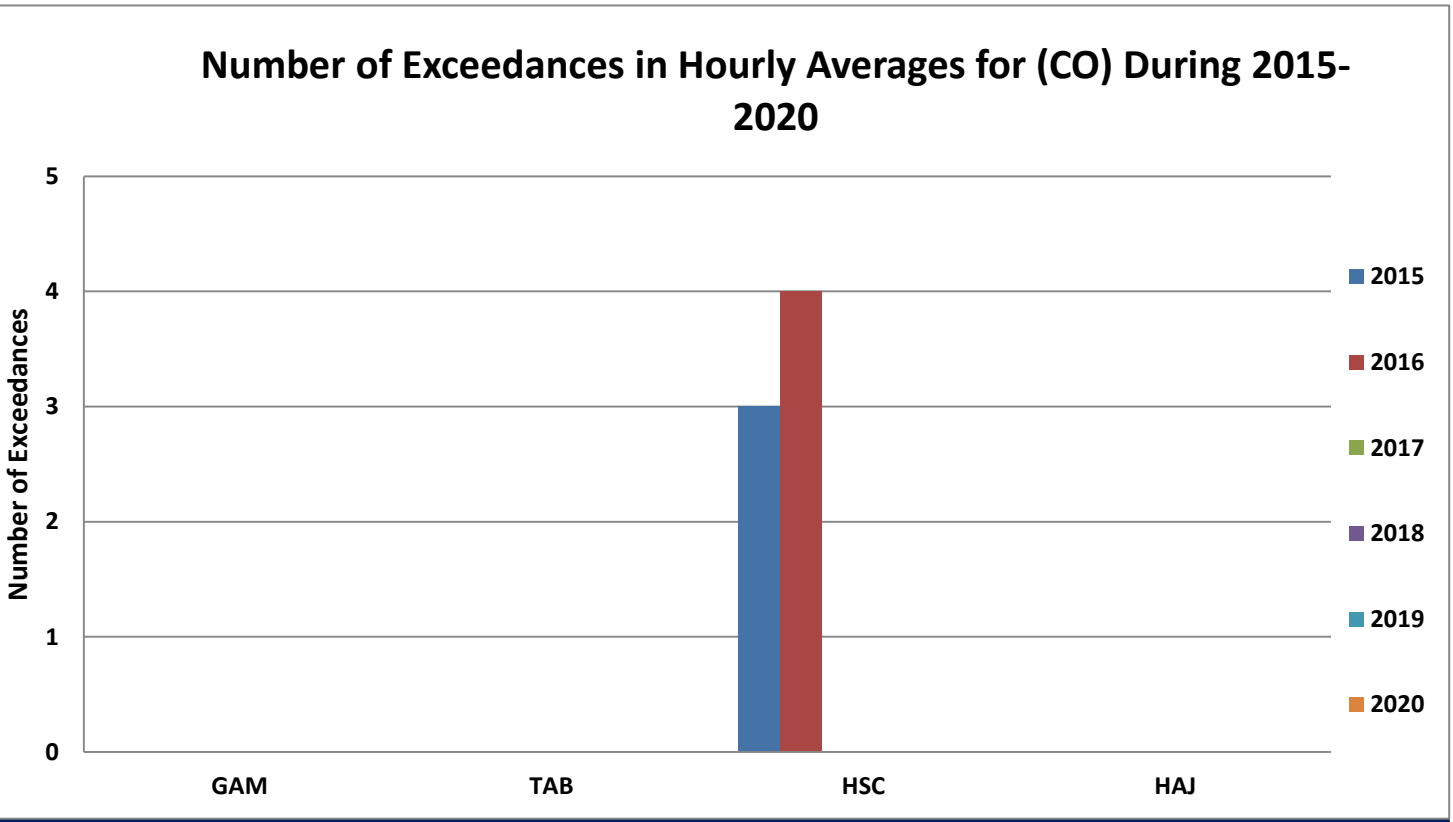


Figure (2.30): Number of exceedances in hourly averages for CO during 2015-2020

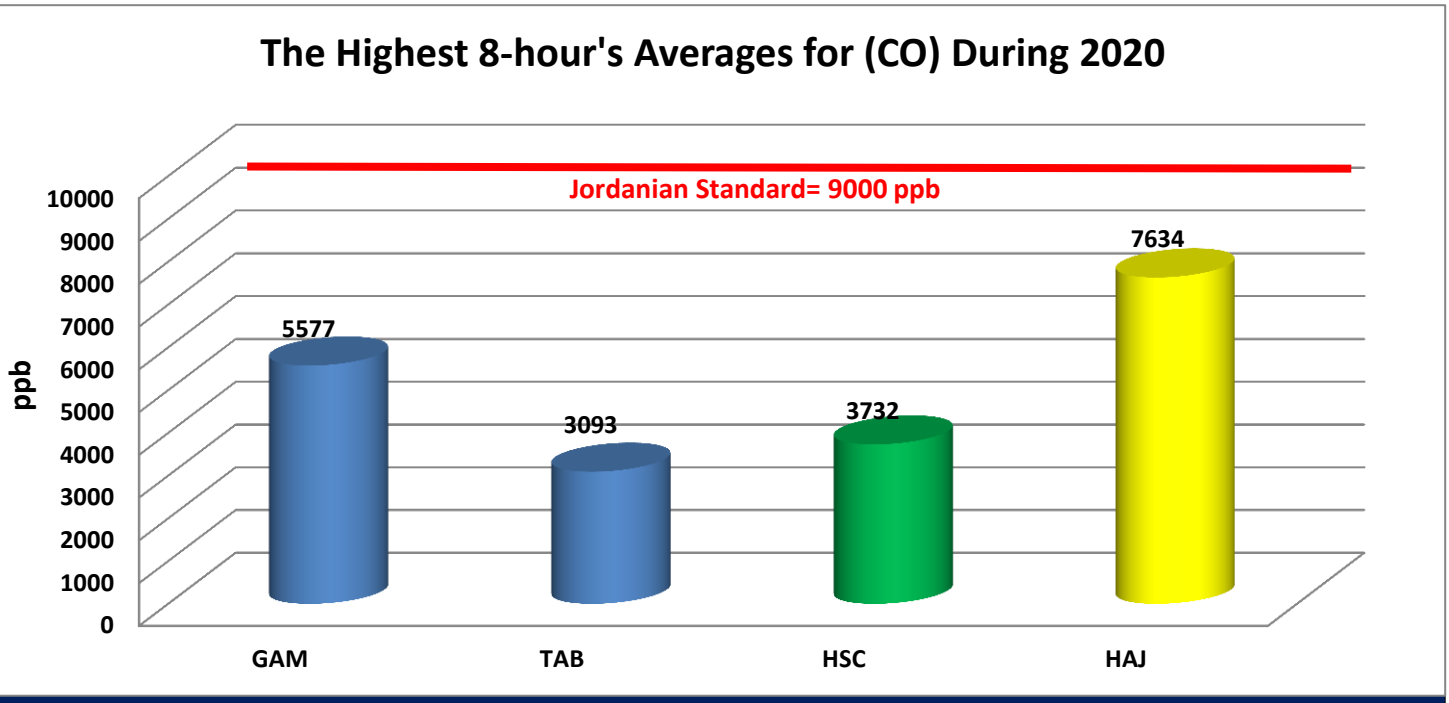


Figure (2.31): The highest 8-hour's averages of CO during 2020

The results of monitoring the ambient air quality showed that the daily averages of CO gas were within the limits allowed in the Jordanian standard (1140/2006) in all monitoring stations where no excess was observed as shown in the figure (2.31) where the highest daily average was 7634 ppb at Wadi Al Hajjar station in Zarqa'.

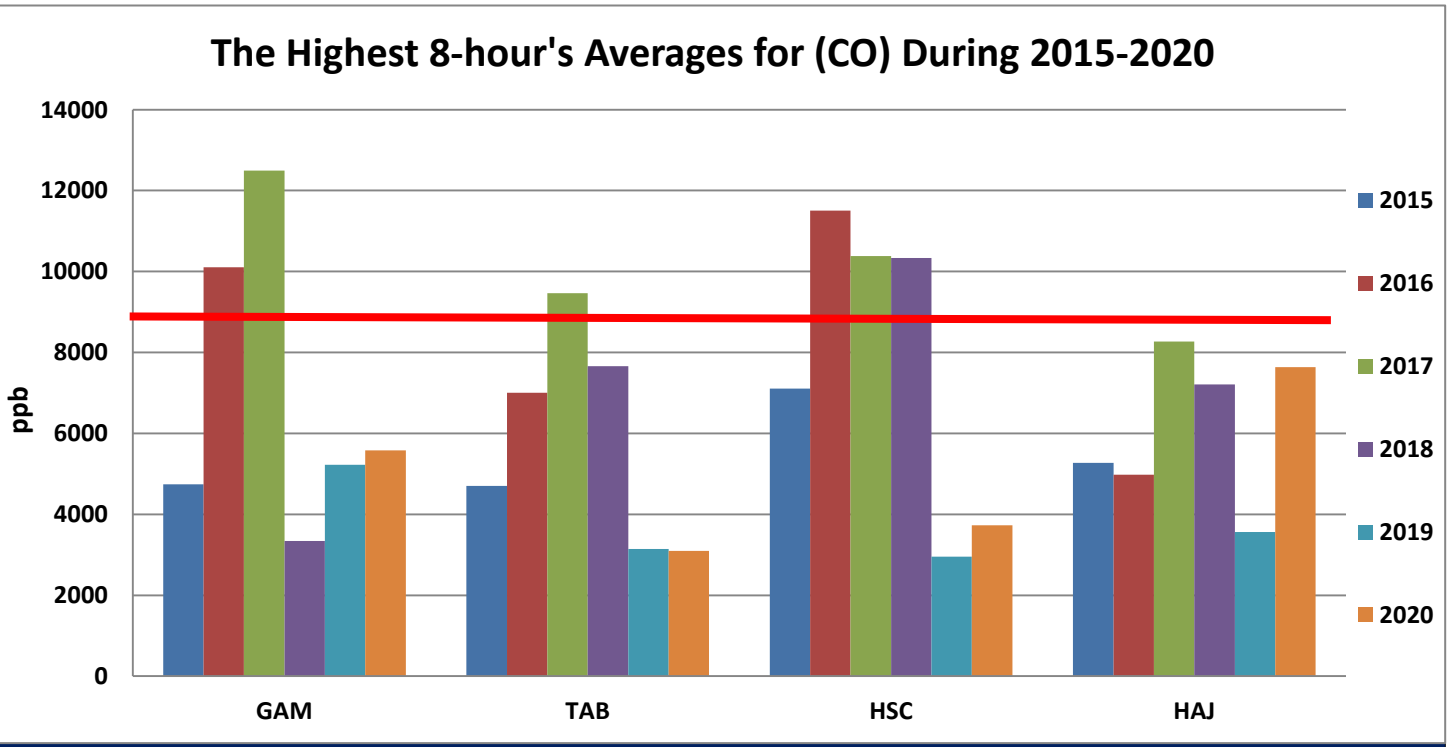


Figure (2.32): The highest 8-hour's averages of CO during 2015-2020

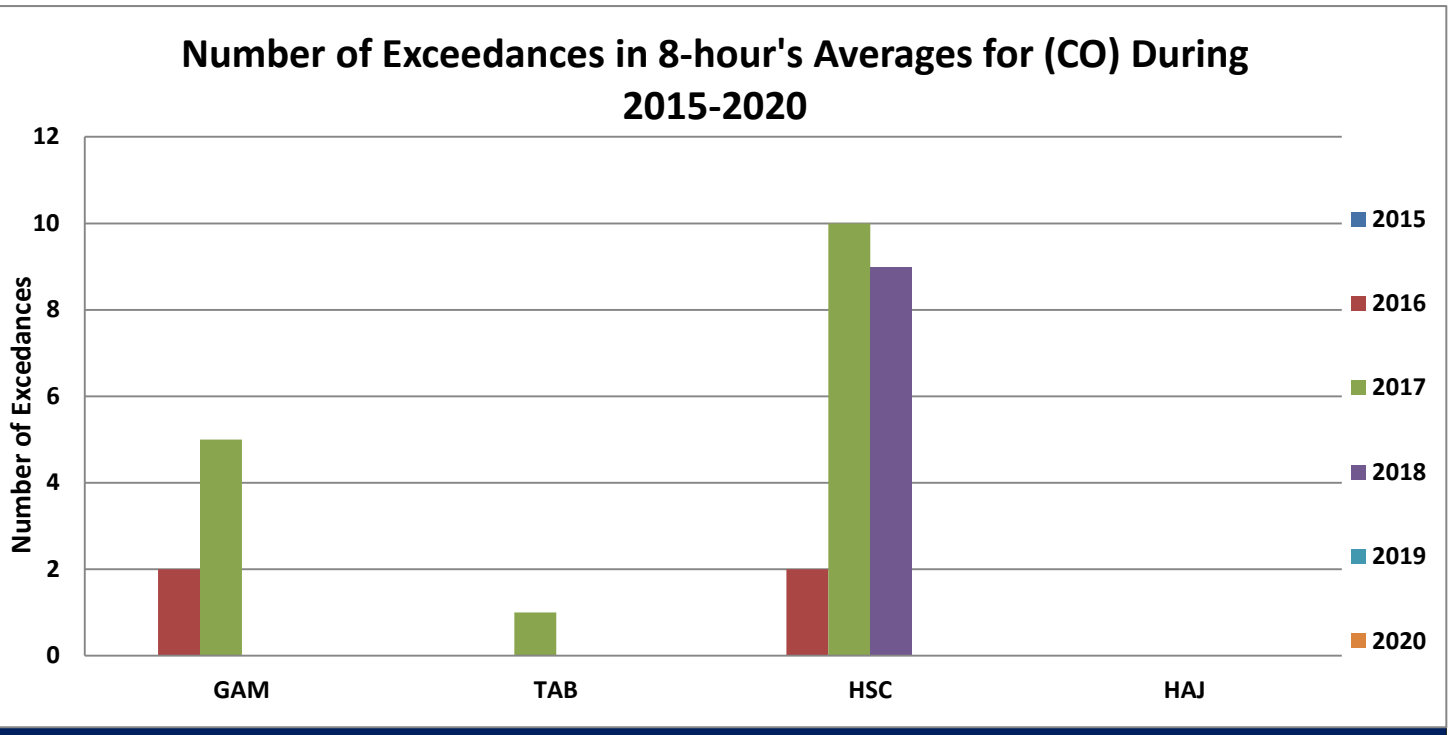


Figure (2.33): Number of exceedances in 8-hour's averages for CO during 2015-2020

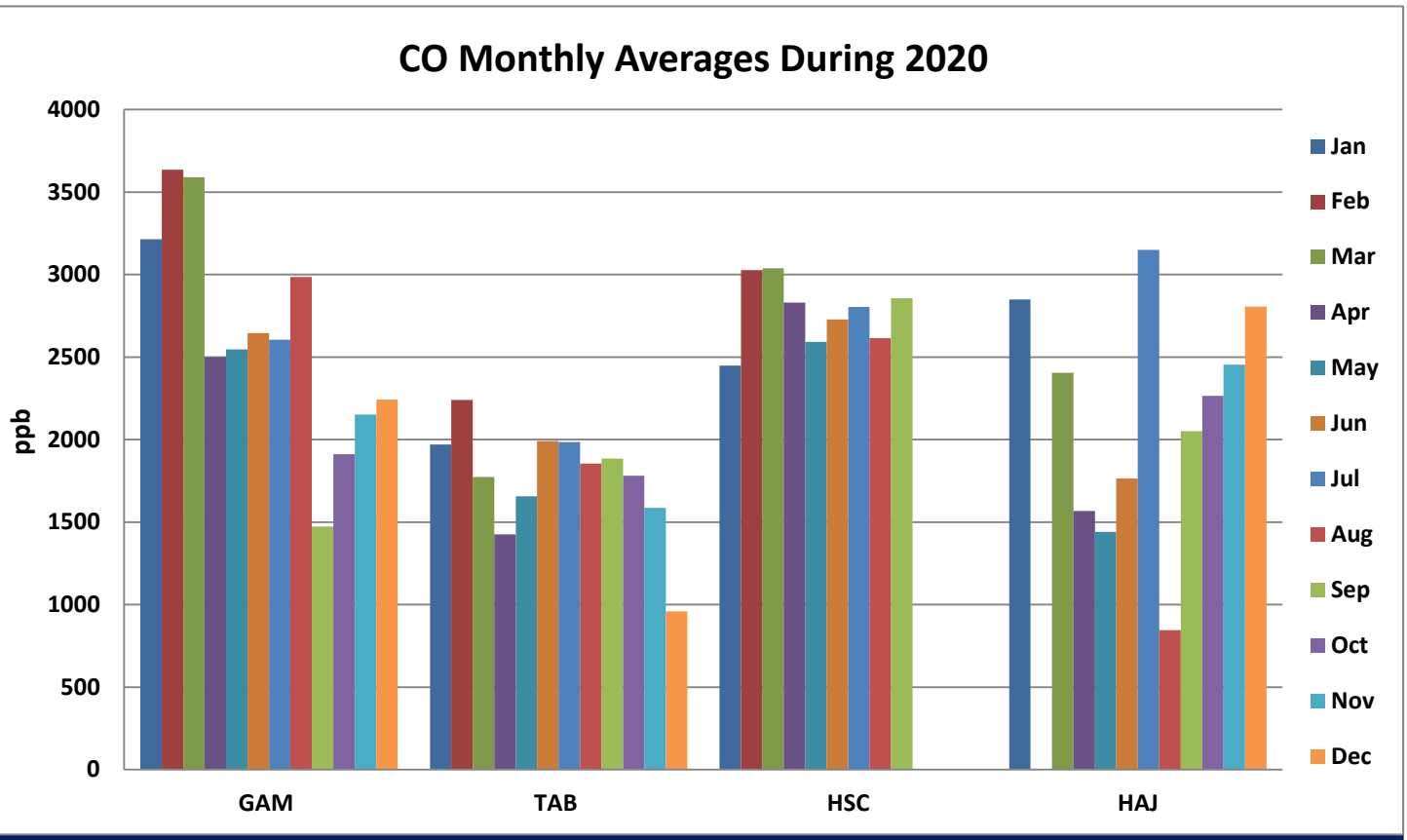


Figure (2.34): CO monthly averages during 2020

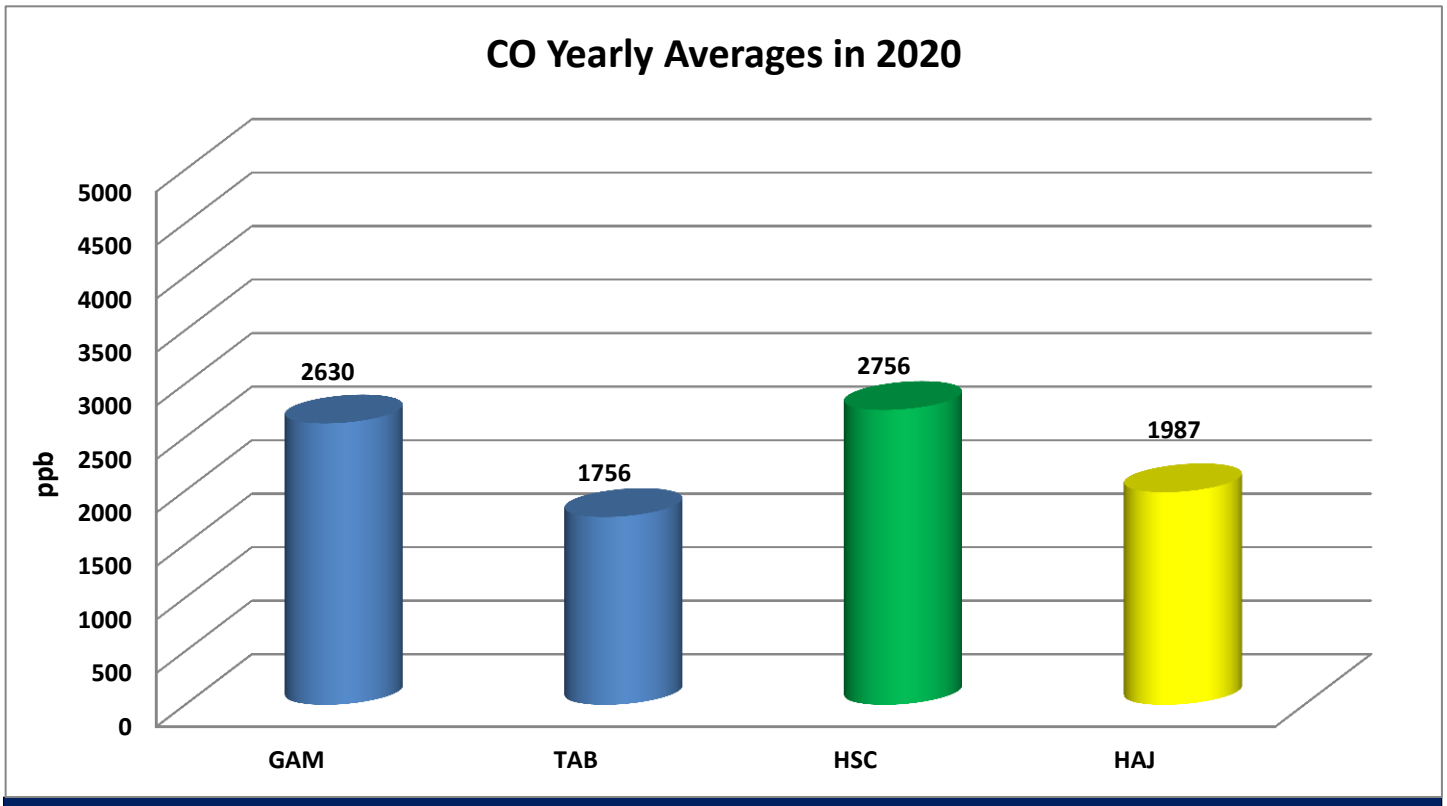


Figure (2.35): CO yearly averages during 2020

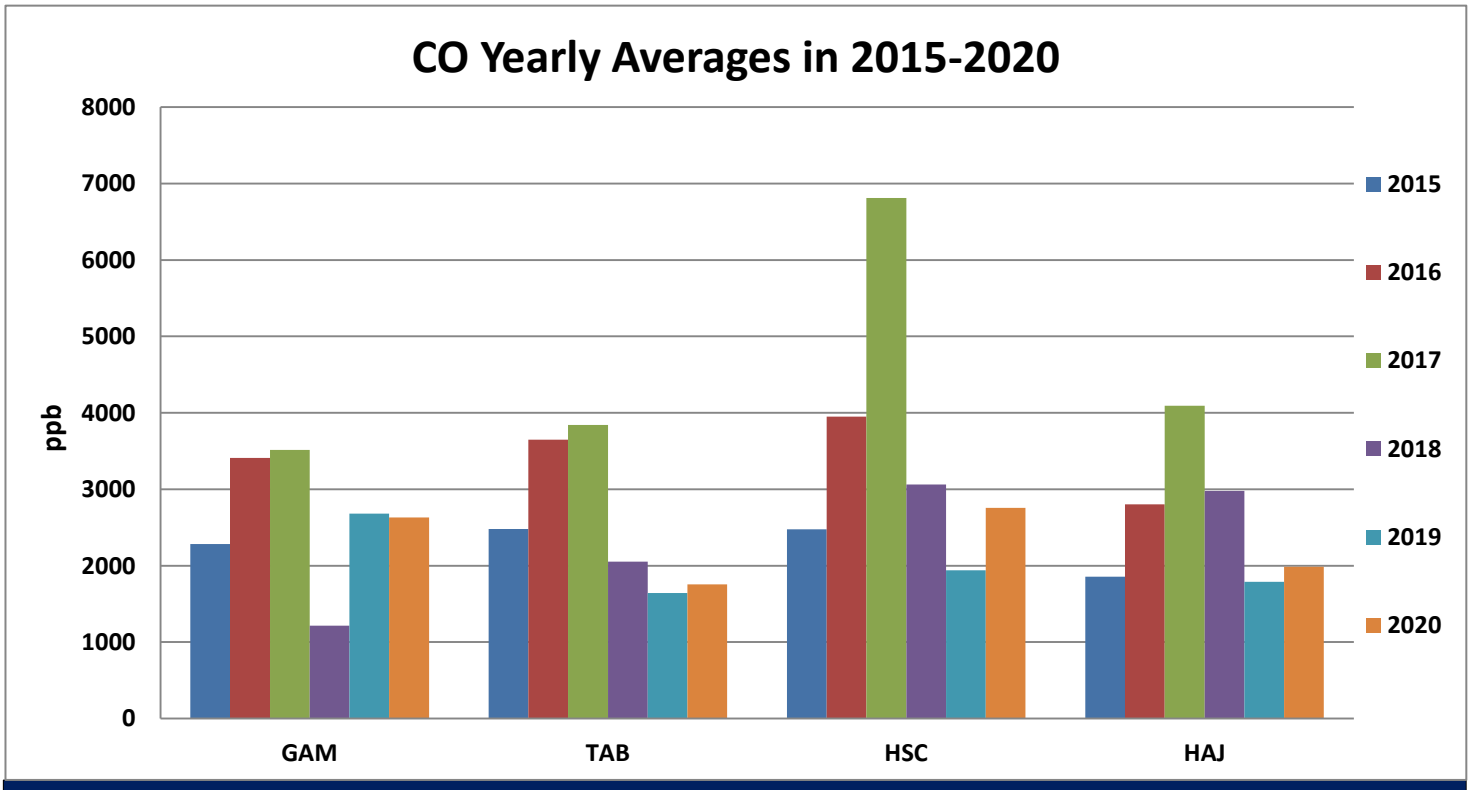


Figure (2.36): CO yearly averages during 2015-2020

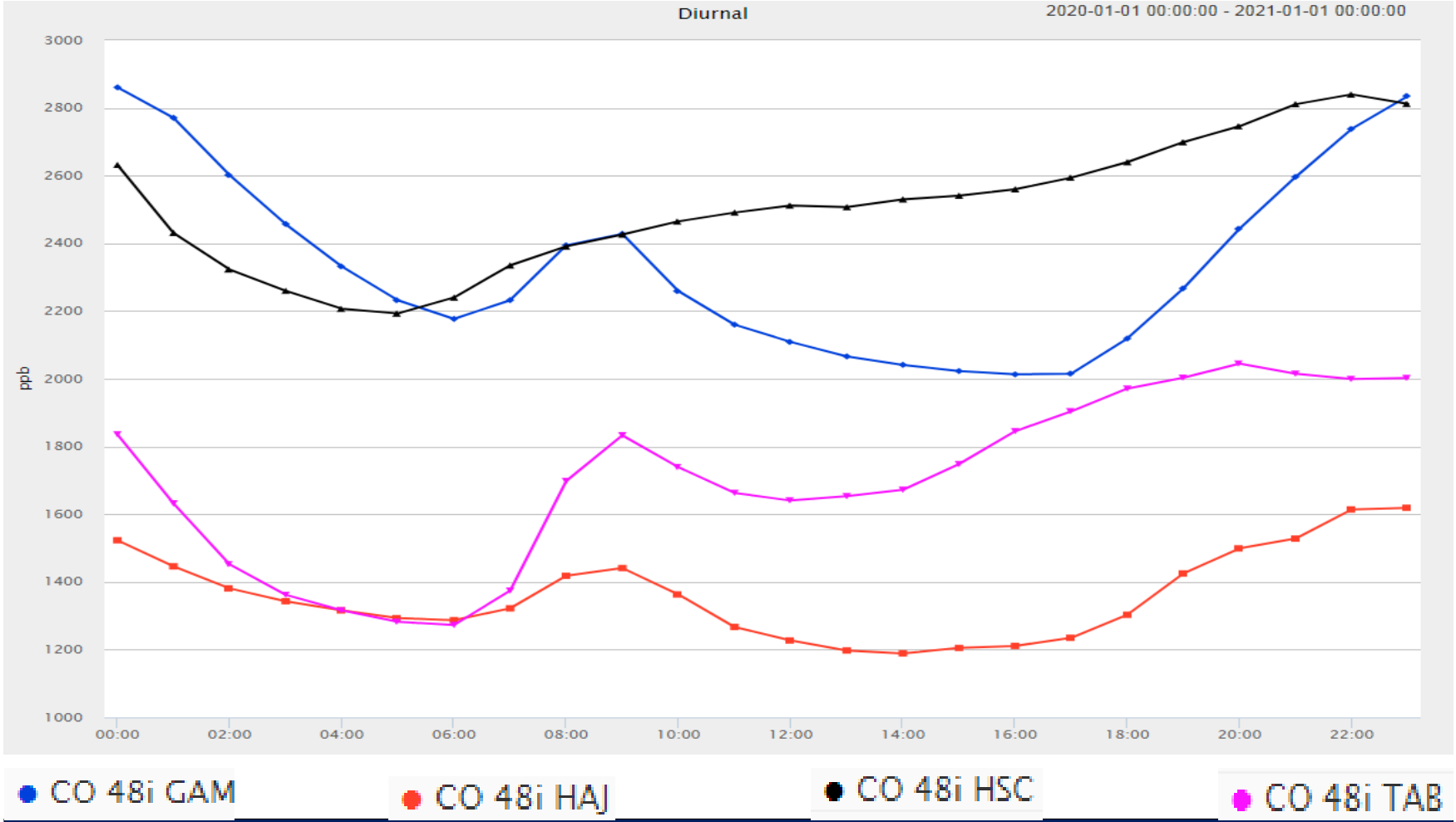


Figure (2.37): The average value in each hour of the day in all stations of Carbon monoxide (CO).

2.5 Ozone (O_3)

The ozone molecule consists of three oxygen atoms that are bounded together (triatomic oxygen, or O_3). Unlike the form of oxygen that is a major constituent of air (diatomic oxygen, or O_2), Ozone is a powerful oxidizing agent. Ozone reacts with biological membranes, such as those present in the linings of the human lungs and plant leaves, which can damage living cells. Exposure to Ozone has been associated with several adverse health effects, such as aggravation of asthma and decreased lung function.

The majority of tropospheric Ozone is formed when nitrogen dioxide (NO_2), carbon monoxide (CO) and volatile organic compounds (VOC_s), undergo photochemical reactions in air in the presence of sunlight. Thus NO_2, CO, and VOC_s are called Ozone precursors. Motor vehicle exhaust, industrial emissions, and chemical solvents are the major anthropogenic sources of ozone precursors. Although these precursors often originate in urban areas, winds can carry NO_2 hundreds of kilometers, causing ozone formation to occur in less populated regions as well.

The Jordanian Standard guidelines for Ozone are 120 ppb for 1-hour average concentrations and 80 ppb for 8-hour average concentrations and there is no yearly average guideline.

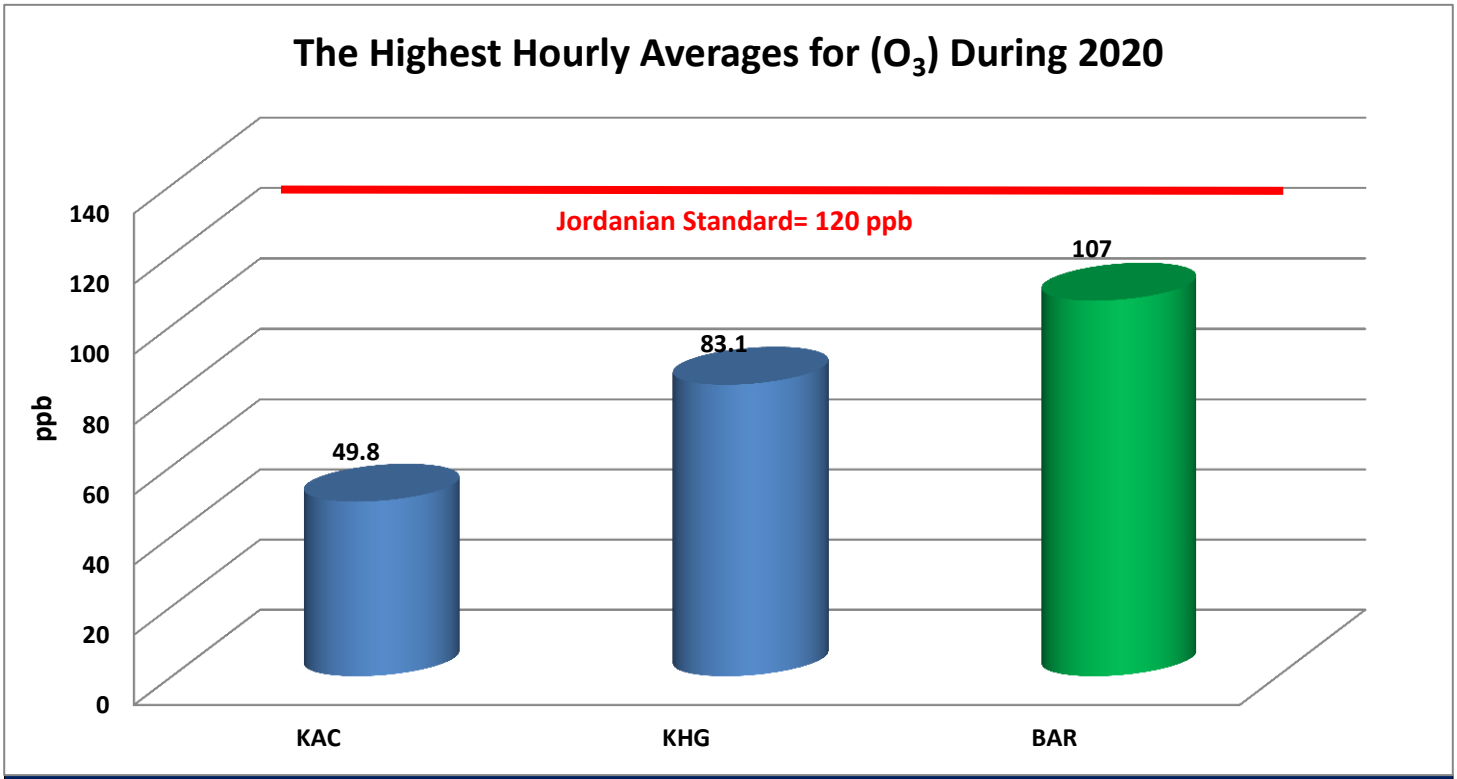


Figure (2.38): The highest hourly averages for O_3 during 2020.

The results of monitoring the ambient air quality showed that there was no exceedances in the hourly averages of O_3 gas than the allowable limit in the Jordanian standard (1140/2006) as shown in the figure (2.38).

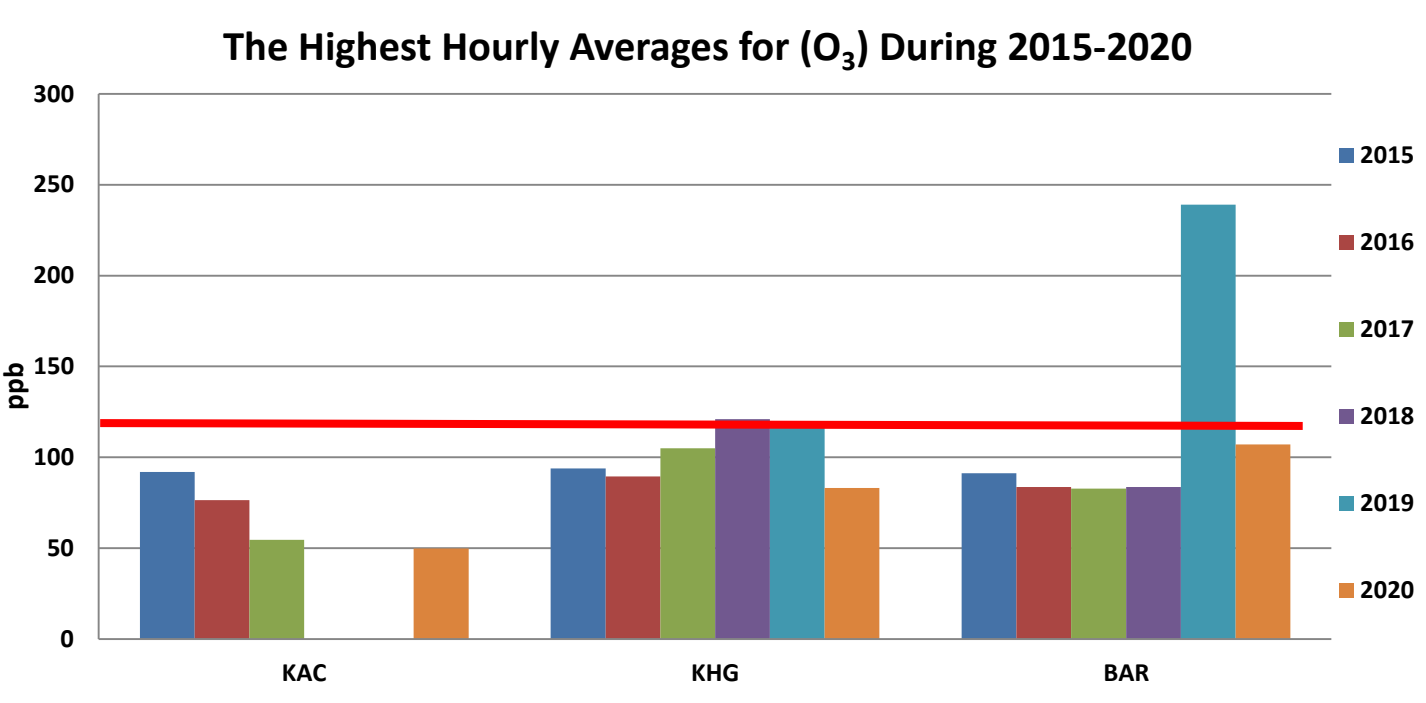


Figure (2.39): The highest hourly averages for O_3 during 2015-2020.

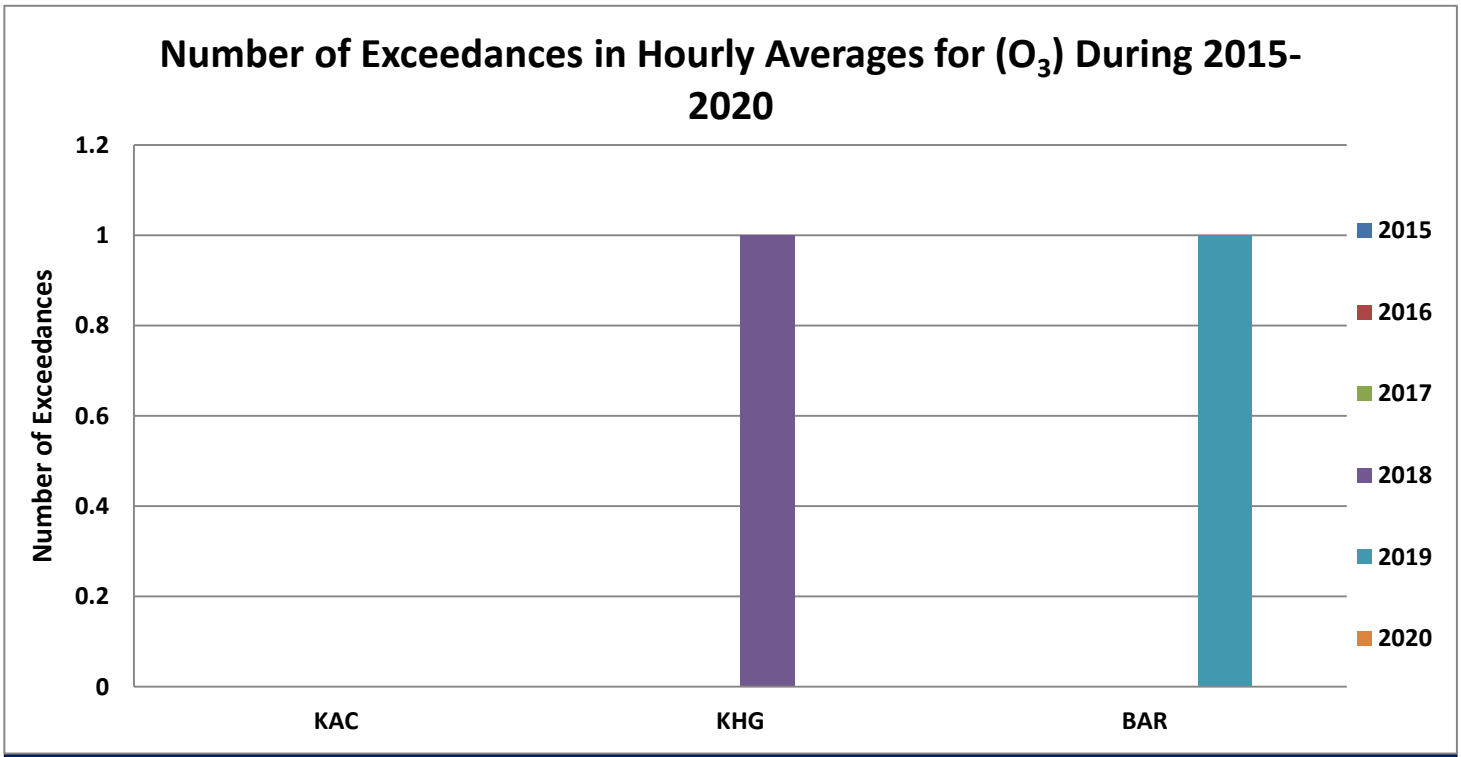


Figure (2.40): Number of exceedances in hourly averages for O_3 during 2015-2020

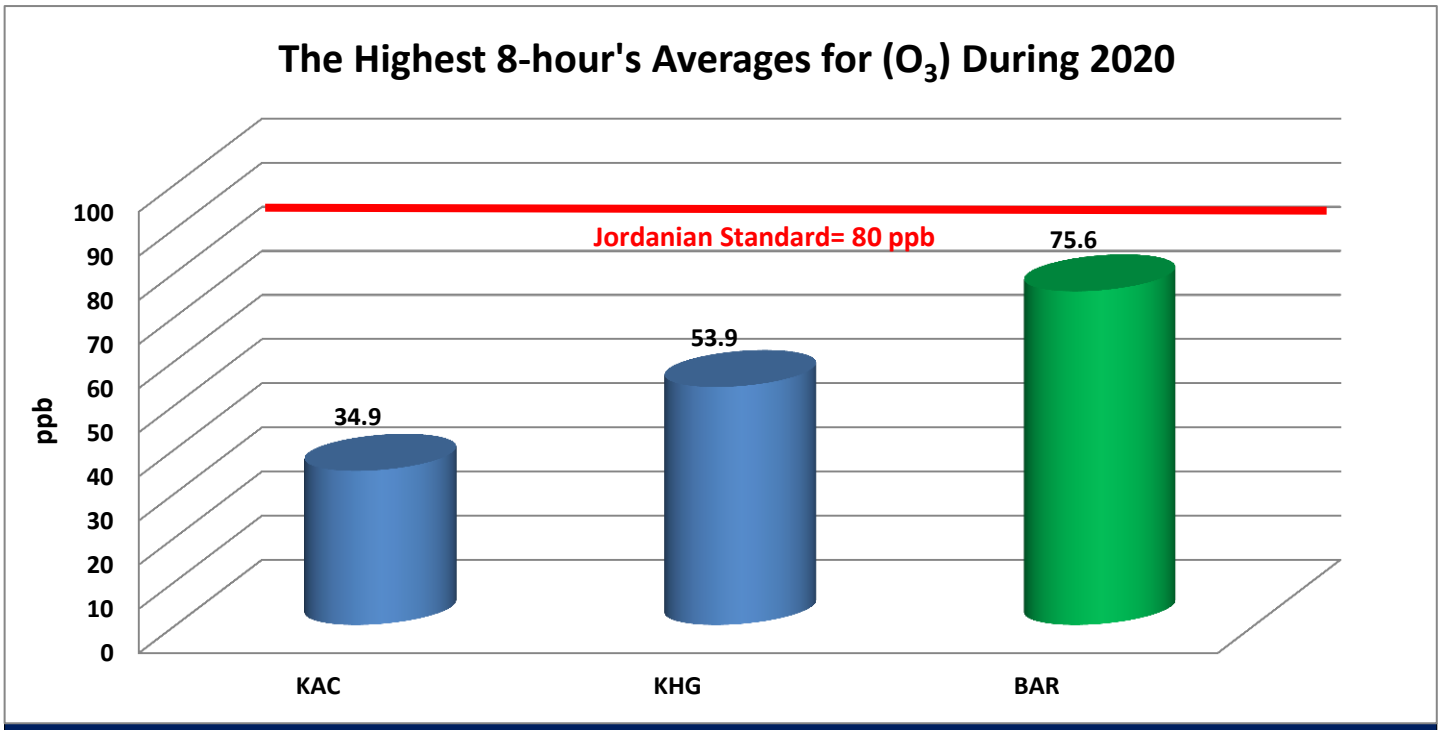


Figure (2.41): The highest 8-hour's averages of O_3 during 2020

The results of monitoring the ambient air quality showed that the daily averages of O_3 gas were within the limits allowed in the Jordanian standard (1140/2006) where no exceedances were monitored as shown in the figure (2.41), where the highest daily average of O_3 gas 75.6 ppb at Barha Street station in Irbid.

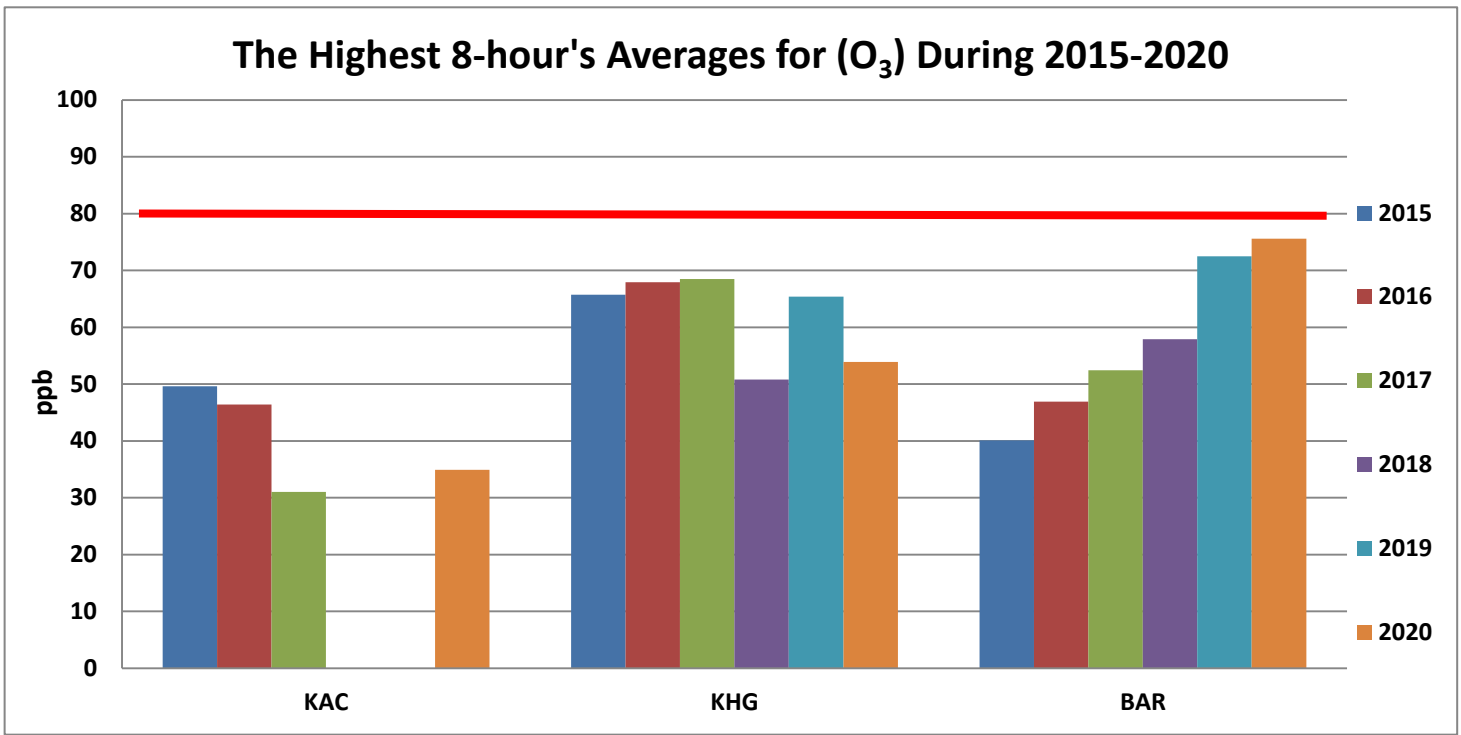


Figure (2.42): The highest 8-hour's averages of O_3 during 2015-2020

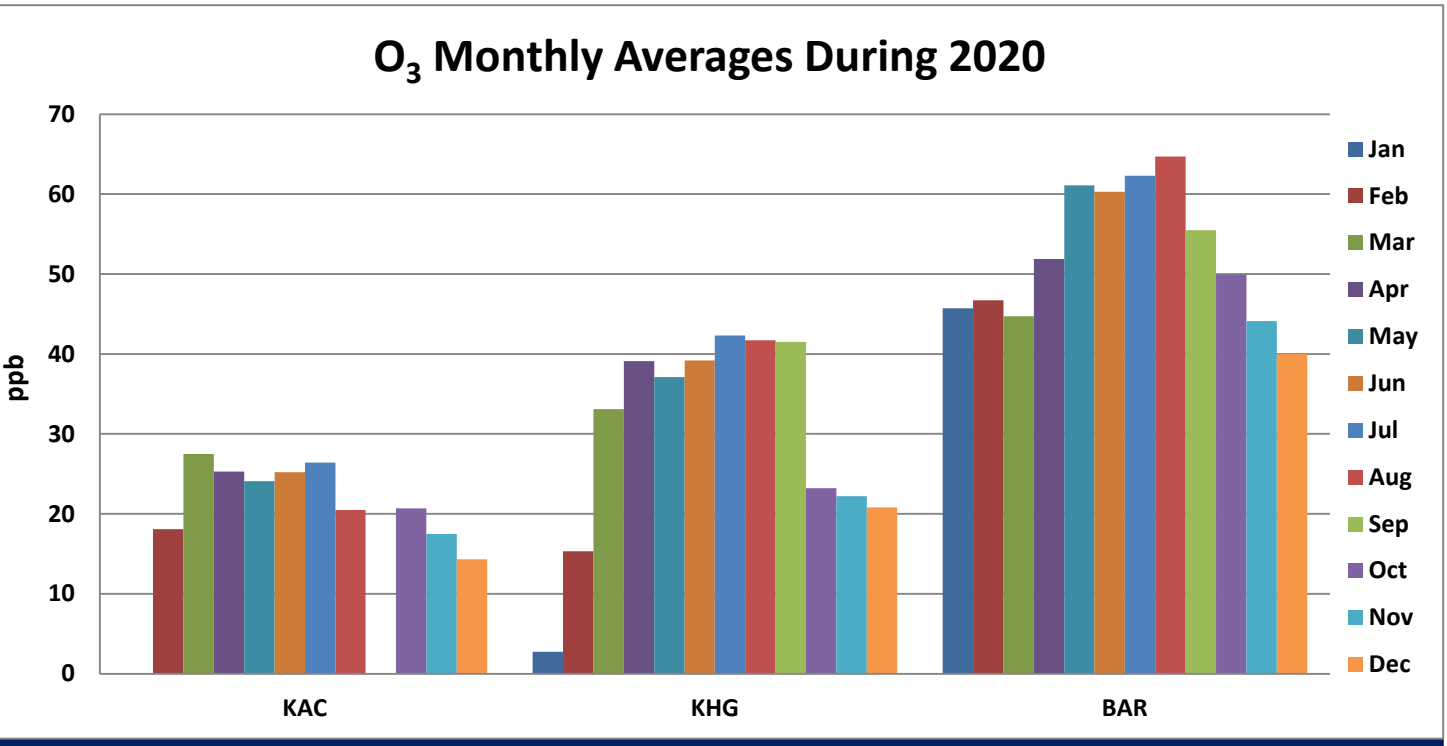


Figure (2.43): O_3 monthly averages during 2020.

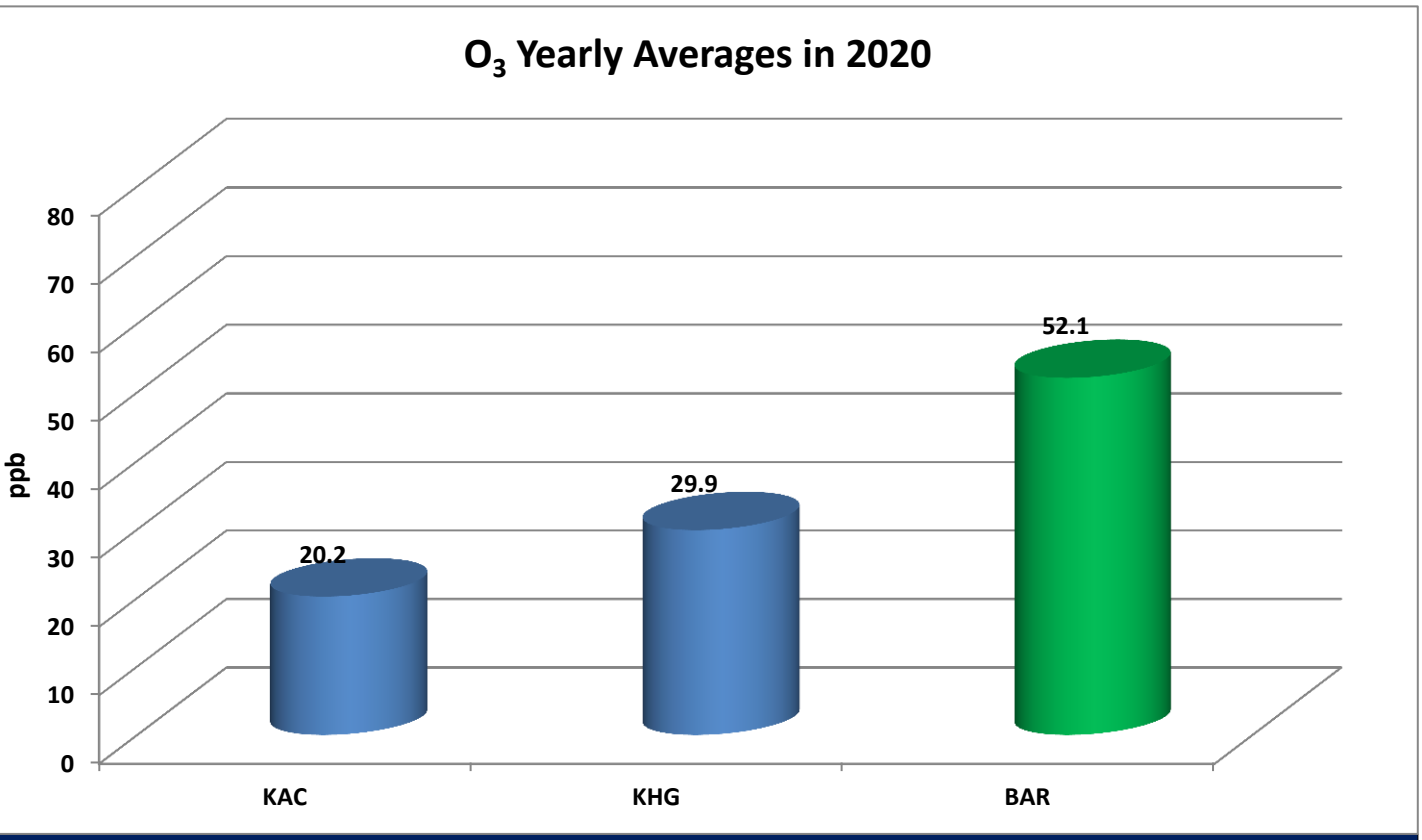


Figure (2.44):O_3 yearly averages during 2020

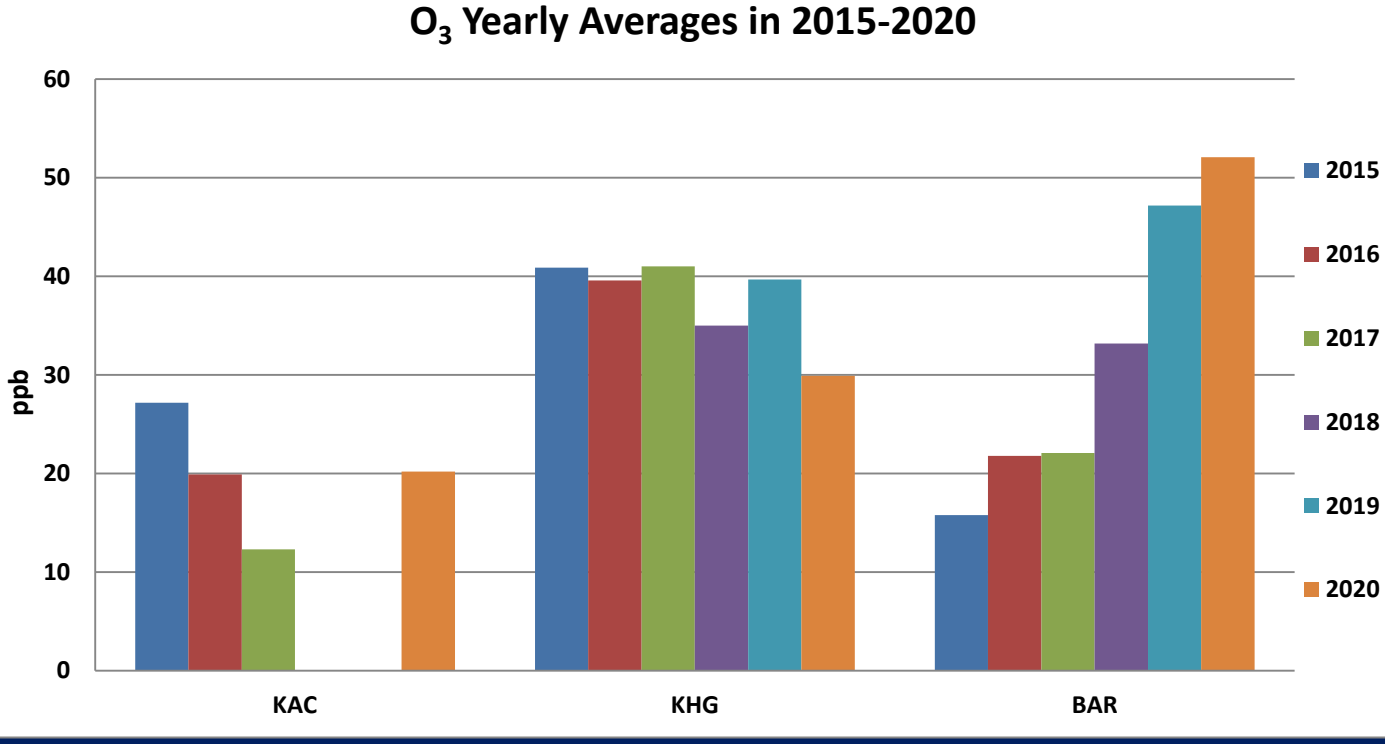


Figure (2.45):O_3 yearly averages during 2015-2020

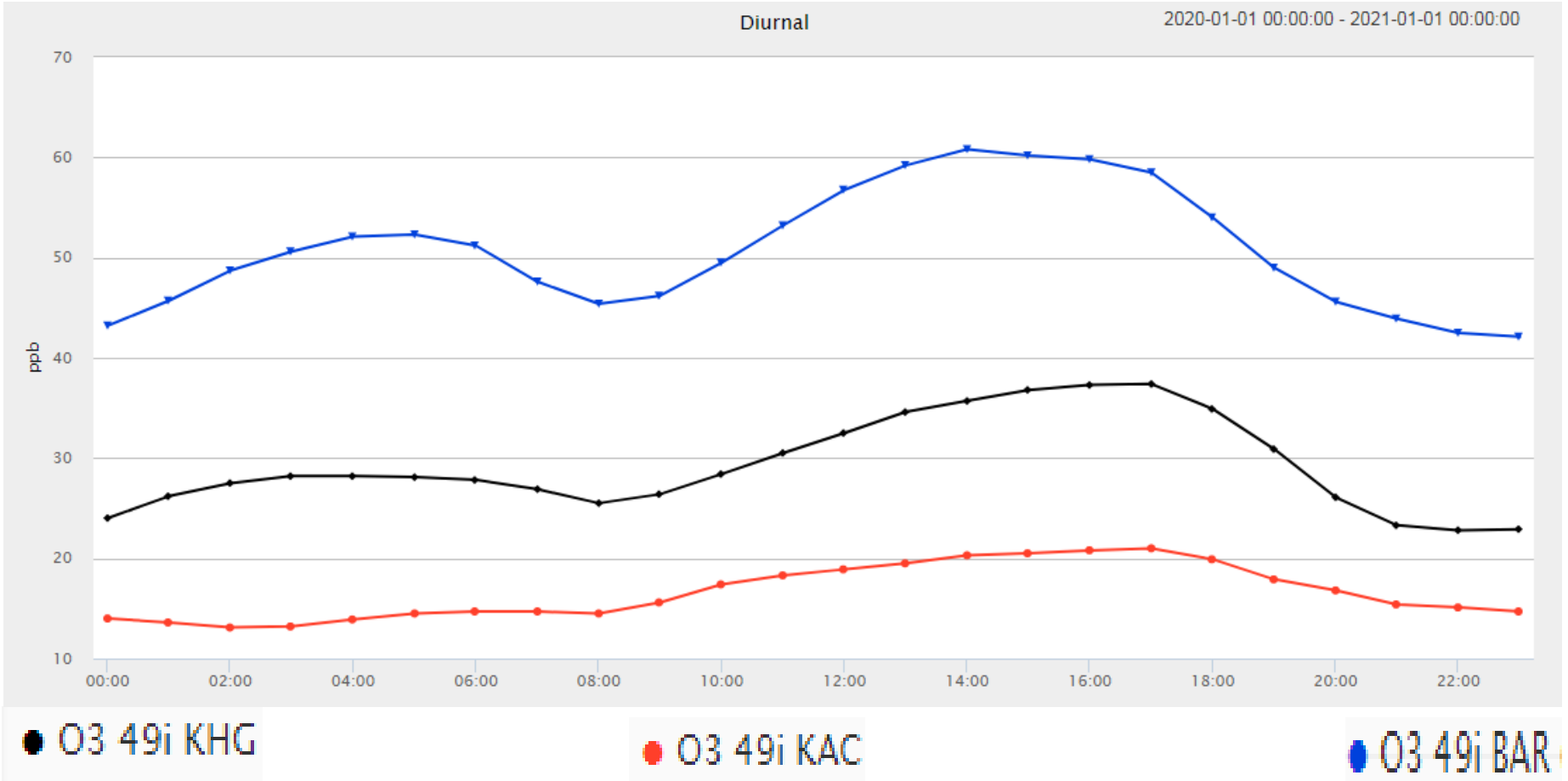


Figure (2.46): The average value in each hour of the day in all stations of Ozone (O_3)

2.6 Meteorology: Wind Speed and Direction, Temperature and Humidity

King Hussein Gardens (Amman)

- As shown in figure (2.47), wind direction at the King Hussein Gardens (Reference station) in Amman is mainly from south – west, where the annual average wind direction was 234◦. Wind direction at the Barha street station in Irbid figure (2.48) is almost south-east, where the average wind direction is 147◦. And in Zarqa – Wadi Al-Hajjar station figure (2.49) the wind is mainly from the south – west, where the direction of the wind is 206◦.

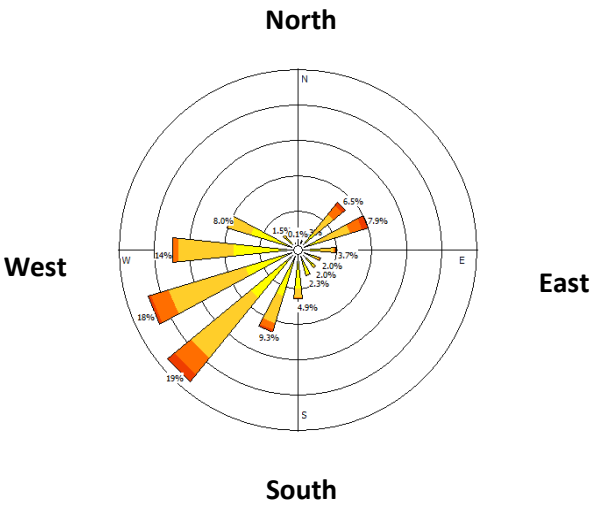
Temperature

- Minimum daily temperature: -1.12 °C
- Maximum daily temperature: 32 °C
- Minimum hourly temperature: -2.6 °C
- Maximum hourly temperature: 38.2 °C
- Average yearly temperature: 16 °C

Humidity

- Minimum daily humidity: 23.2 %
- Maximum daily humidity: 100 %
- Minimum hourly humidity: 16 %
- Maximum hourly humidity: 100 %
- Average yearly humidity: 65.6 %

Wind Direction



Average: 234 °

Wind Speed

%	
0.0	> 25 km/h
2.9	15 < 25 km/h
9.6	10 < 15 km/h
42.6	5 < 10 km/h
38.1	2 < 5 km/h
6.6	0.5 < 2 km/h
0.2	< 0.5 km/h

Average: 6.1 km/h

Figure (2.47): Meteorological Data for King Hussein Gardens Station (Amman)

Al Barha Street (Irbid)

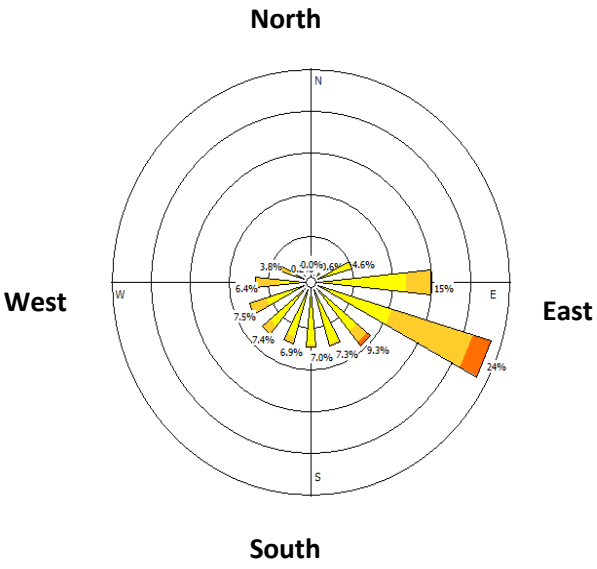
Temperature

- Minimum daily temperature: 4.4 °C
- Maximum daily temperature: 34.5 °C
- Minimum hourly temperature: -1.18 °C
- Maximum hourly temperature: 44.2 °C
- Average yearly temperature: 19.4 °C

Humidity

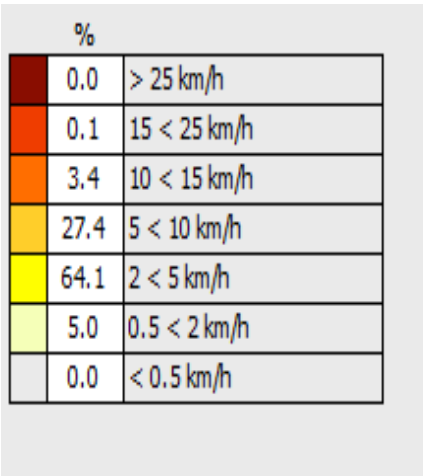
- Minimum daily humidity: 15.4 %
- Maximum daily humidity: 90%
- Minimum hourly humidity: 8 %
- Maximum hourly humidity: 97 %
- Average yearly humidity: 59.6 %

Wind Direction



Average: 147 °

Wind Speed



%	
0.0	> 25 km/h
0.1	15 < 25 km/h
3.4	10 < 15 km/h
27.4	5 < 10 km/h
64.1	2 < 5 km/h
5.0	0.5 < 2 km/h
0.0	< 0.5 km/h

Average: 4.5 km/h

Figure (2.48): Meteorological Data for Al-Barha Street Station (Irbid)

Wadi Al-Hajjar (Zarqa)

Temperature

- Minimum daily temperature: 6.1 °C
- Maximum daily temperature: 36.4 °C
- Minimum hourly temperature: 2.7 °C
- Maximum hourly temperature: 46.5 °C
- Average yearly temperature: 22.1 °C

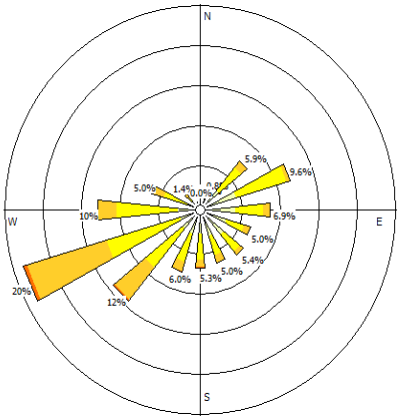
Humidity

- Minimum daily humidity: 19 %
- Maximum daily humidity: 96.8 %
- Minimum hourly humidity: 11 %
- Maximum hourly humidity: 100 %
- Average yearly humidity: 55.5 %

Wind Direction

North

West



East

Average: 206 °

Wind Speed

%	
0.0	> 25 km/h
0.0	15 < 25 km/h
0.8	10 < 15 km/h
23.6	5 < 10 km/h
49.1	2 < 5 km/h
24.3	0.5 < 2 km/h
2.2	< 0.5 km/h

Average: 3.65 km/h

Figure (2.49): Meteorological Data for Wadi Al-Hajjar Station (Zarqa')

2.7 Air Quality Index

Air Quality Index (AQI) It is a color indicator linked to numerical values used by government institutions and agencies concerned with environmental protection, as well as those interested in the environment to know the air quality in a particular place.

The higher the value of this indicator and the change in its color with the change in pollutant concentrations, the more likely it will result in adverse health effects on the population. Each group is indicated by a description and a color code for it.

The green color indicates that the air quality is good, the yellow color is moderate, the orange color indicates that the air may affect sensitive groups, and the red color indicates that the air is unhealthy. As for the purple color, the air is very unhealthy, and the highest signal is the brown color, which indicates that the air quality is dangerous

Table (2.3): Air Quality Index.

Air Quality Index	Health Effects	cautionary statement	Actions to be taken
0-50	Good	Air quality is good, and air pollution poses little risk	Everyone can do different daily activities naturally in the open air without conditions
51-100	Moderate	Air quality is acceptable, however for some pollutants there may be a mild health concern for a very small number of people who are unusually sensitive to air pollution	It is preferable to limit various daily activities in the outdoors, especially those that require effort for long periods
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience negative health effects	Everyone should significantly reduce daily activities in the open air, and it is required to wear protective masks when going out for necessity, especially for sensitive .groups

151-200	Unhealthy	Most people may suffer from side effects that affect health. Individuals with sensitive health status may suffer from serious health problems	Everyone should never go out and do any of the daily activities outdoors
201-300	Very Unhealthy	Health Warnings For emergency conditions, all residents are likely to be affected	Children, active adults, and people with respiratory illnesses should avoid all outdoor exertion
+300	Dangerous	Health alert: everyone may experience more serious health effects	Everyone should never go out

Table (2.4) shows the results of ambient air quality monitoring based on the ambient air quality index in Amman, Irbid, and Zarqa during all months of the year 2020.

Table (2.4): Ambient air quality monitoring results based on ambient air quality index

January/2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%60.1	%100	%66.9	%75.7
Percentage of days when the AQI was moderate	%39.9	-	%32.1	%24.3

February/2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%59.9	%92.6	%53	%68.5
Percentage of days when the AQI was moderate	%40.1	%7.4	%46.4	%31.3
Percentage of days when the AQI was unhealthy for sensitive groups	-	-	%0.5	%0.2

March/2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%55.4	%67.7	%52.2	%58.4
Percentage of days when the AQI was moderate	%41.2	%28.4	%42.9	%37.5
Percentage of days when the AQI was unhealthy for sensitive groups	%1.1	%4	%1.9	%2.3
Percentage of days when the AQI was unhealthy	%2.3	-	%1.5	%1.3

April/2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%76.2	%90.3	%83.9	%83.5
Percentage of days when the AQI was moderate	%21.6	%10	%15.6	%15.7
Percentage of days when the AQI was unhealthy for sensitive groups	%2.2	-	%0.5	%0.9

May/2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%74	%92.7	%86.3	%84.3
Percentage of days when the AQI was moderate	%26	%7.3	%13.7	%15.7

June/2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%81.1	%100	%93.6	%91.6
Percentage of days when the AQI was moderate	%18.9	-	%6.4	%8.4

July/2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%78.6	%100	%95.4	%91.3
Percentage of days when the AQI was moderate	%21.4	-	%4.6	%8.7

August/2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%85.5	%100	%93.1	%92.9
Percentage of days when the AQI was moderate	%14.5	-	%6.9	%7.1

September/2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%37.4	%98.2	%57.6	%64.4
Percentage of days when the AQI was moderate	%62.6	%1.8	%42.4	%35.6

October/2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%29.6	%71	%38.3	%46.3
Percentage of days when the AQI was moderate	%65.9	%29	%60.3	%51.7
Percentage of days when the AQI was unhealthy for sensitive groups	%4.5	-	%1.4	%2

November/2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%62	%100	%71.7	%77.9
Percentage of days when the AQI was moderate	%36.8	-	%28.3	%21.7
Percentage of days when the AQI was unhealthy for sensitive groups	%1.2	-	-	%0.4

December/2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%43.5	%90.3	%65	%66.3
Percentage of days when the AQI was moderate	%48.9	%9.7	%32.9	%30.5
Percentage of days when the AQI was unhealthy for sensitive groups	%6.5	-	%2.1	%2.9
Percentage of days when the AQI was unhealthy	%1.1	-	-	%0.4

Average for all months during 2020

	Zarqa	Irbid	Amman	Average
Percentage of days when the AQI was good	%61.9	%91.9	%71.4	%75.1
Percentage of days when the AQI was moderate	%36.5	%7.8	%27.7	%24
Percentage of days when the AQI was unhealthy for sensitive groups	%1.3	%0.3	%0.5	%0.7
Percentage of days when the AQI was unhealthy	%0.3	-	%0.13	%0.14

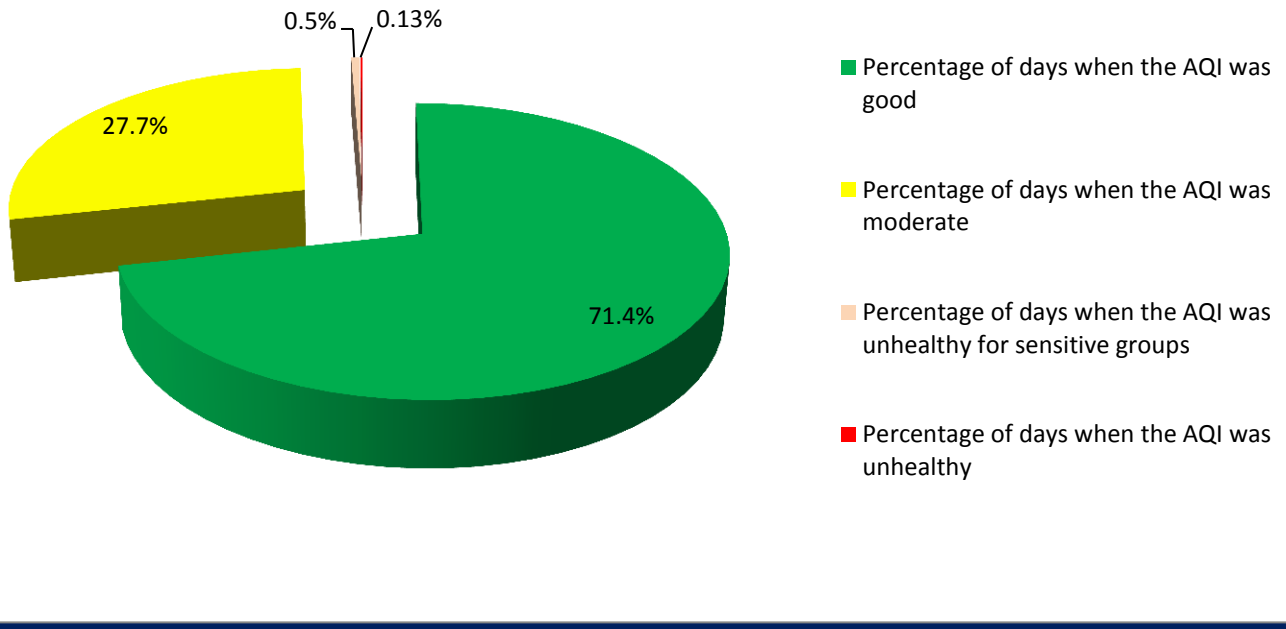


Figure (2.50): Results of ambient air quality monitoring based on the air quality index in Amman

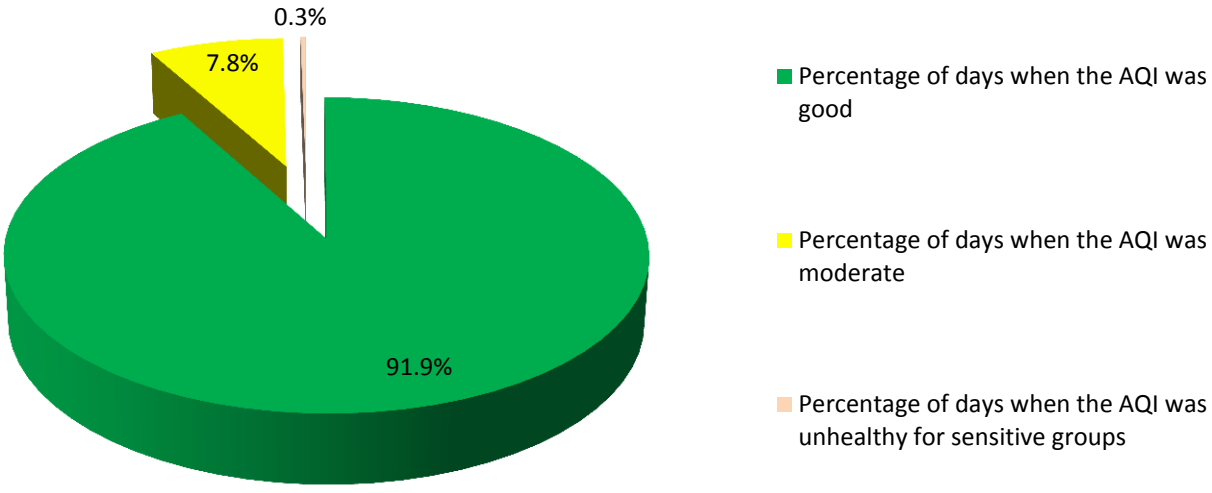


Figure (2.51): Results of ambient air quality monitoring based on the air quality index in Irbid

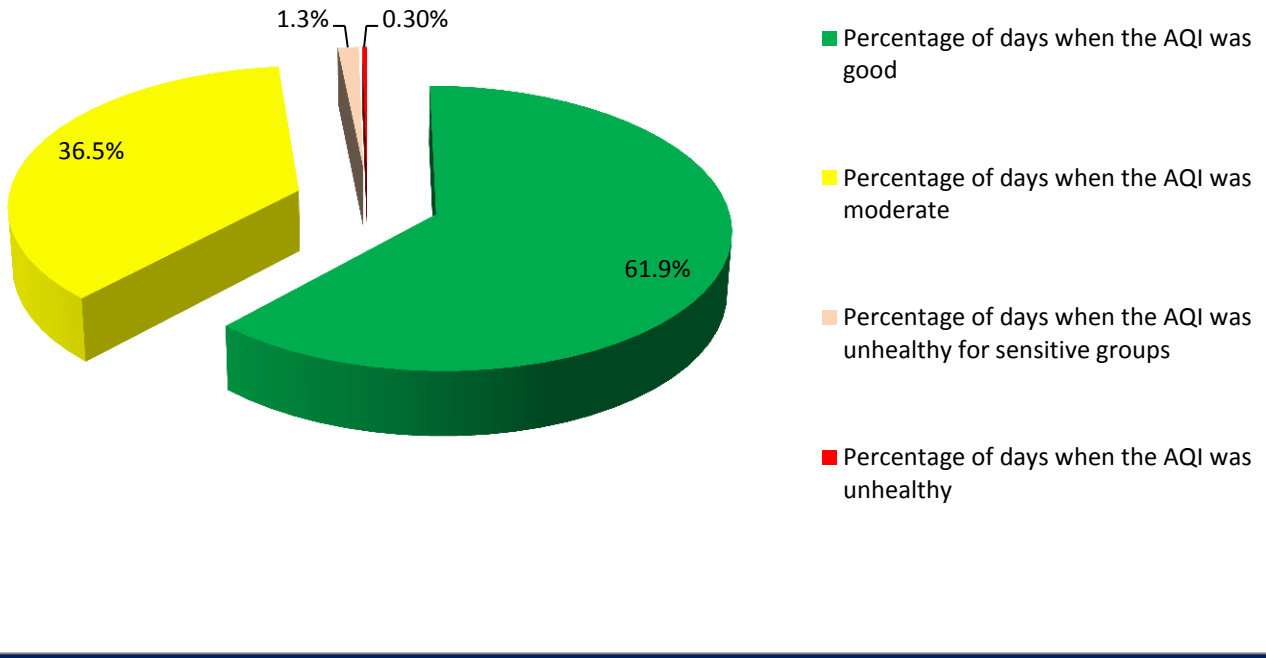


Figure (2.52): Results of ambient air quality monitoring based on the air quality index in Zarqa

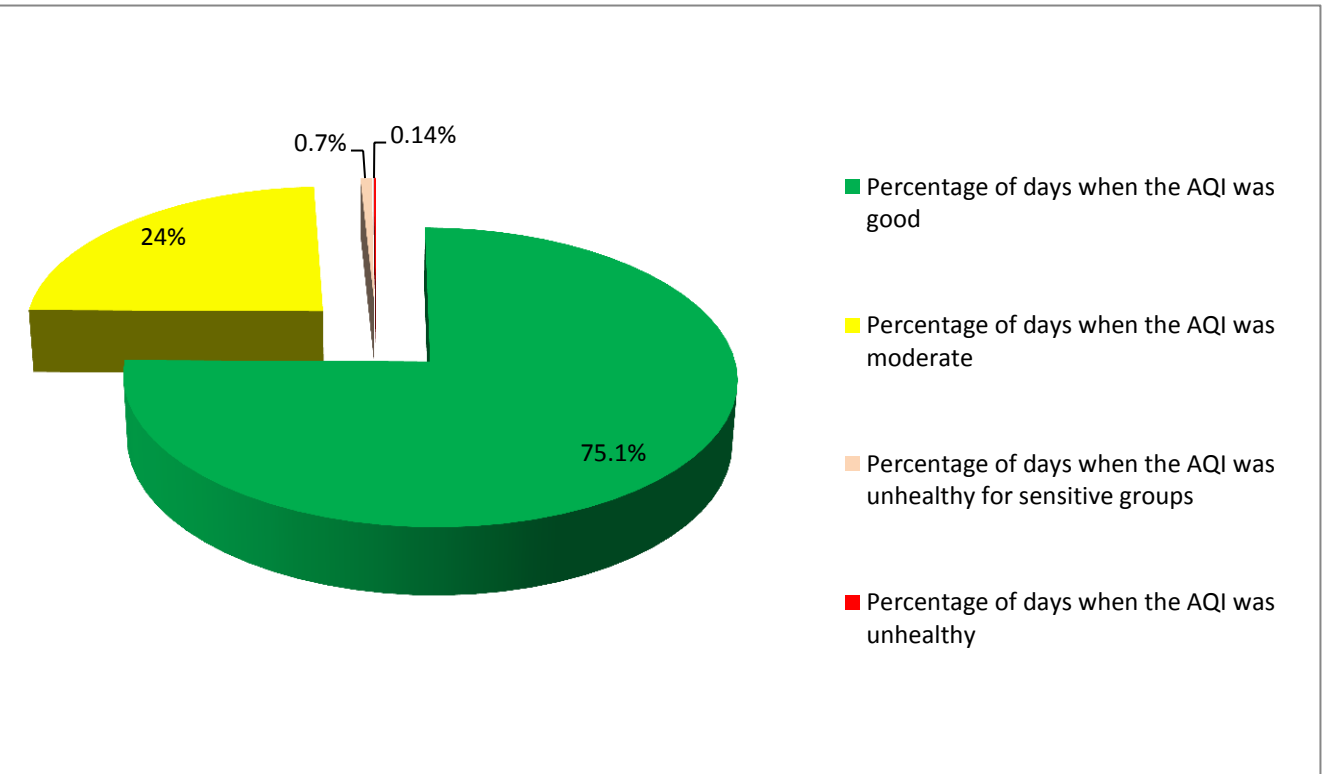


Figure (2.53): Results of ambient air quality monitoring based on the air quality index

3

A study of the rates of change in the concentrations of pollutants in the ambient air in Amman, Irbid, and Zarqa as a result of government measures taken during the period from March 15, 2020 to April 15, 2020 to confront the coronavirus pandemic

3.1 Study Scope

The period from 15/3/2020 to 15/4/2020 was studied, which is the period during which government measures were strict, which included a partial and comprehensive ban to confront the emerging coronavirus pandemic, COVID-19. The data was compared with the same period last year and also with a month before Crisis (14/2/2020 to 3/14/2020).

3.2 Summary of government actions in the face of the Corona virus pandemic

The Jordanian government has taken several measures and decisions aimed at controlling the spread of the new Corona virus, which first appeared in the beginning of March 2020, Including the imposition of a comprehensive or partial ban, the disruption of government and private institutions, the closure of borders, and the prohibition of vehicle movement in some periods or the work of the double and single system for the movement of vehicles and other measures taken according to the epidemiological situation.

Summary of government decisions that included implementing the defense law and issuing defense orders, including declaring a partial or complete curfew:

Table (3.1): Government measures to confront the coronavirus pandemic.

Date	Actions taken by the Jordanian government
March 15, 2020	• Suspending all operations of educational institutions in schools, universities, kindergartens and nurseries. • Ceasing all national events, and not gathering in social events (weddings and funerals). • Emphasizing the citizens' commitment to stay at home as much as possible, and not to leave unless necessary. • A fatwa was issued by Dar Al-Ifta and the Council of Churches in Jordan prohibiting prayer in all mosques and churches of the Kingdom as a precautionary measure, and tourist sites were closed in order to implement purification campaigns in these sites. • Canceling musical and cultural events, closing cinemas, swimming facilities, sports clubs and youth centers, banning hookah and smoking in cafes and restaurants, stopping visits to hospitals and prisons. Sports events in the Kingdom have also been cancelled.

March 16, 2020	• **The government announced that all arrivals to Jordan through airports and border crossings will be subject to mandatory 14-day quarantine in designated hotel facilities specified by the government, during which they are subject to the health procedures approved by the Ministry of Health.**
March 17, 2020	**A Royal Decree was issued approving the decision of the Council of Ministers, announcing the implementation of Defense Law No. 13 of 1992, in all parts of the Hashemite Kingdom of Jordan, as of March 17, 2020** • **Disable all official institutions and departments, except for the vital sectors specified by the Prime Minister.** • **Suspension of all flights to and from Jordan, until further notice, with the exception of commercial cargo traffic. All land and sea border crossings and airports were closed to passenger traffic, with the exception of commercial cargo traffic.** • **Preventing citizens from leaving the house except in cases of extreme necessity.** • **Disabling the private sector, with the exception of the health sector and vital sectors determined by the Prime Minister.** • **The government prevented gatherings of more than 10 people, and prevented movement between governorates, and suspended operations, medical reviews, and visits to patients except in cases of emergency and emergency operations.** • **Stopping the printing of paper newspapers, because they contribute to the transmission of infection, and suspending the work of mass and transportation means.** • **Maintaining the work of pharmacies, supply centers, bakeries, food, medicine, water, fuel, electricity and supply chains.** • **Closing malls and commercial centers and allowing only the opening of supply centers and pharmacies in them.** • **The Jordanian government has established quarantine camps for those coming from the land border crossing.**
March 19, 2020	**Defense Order No. (1) Was issued suspending the provisions of Social Security Law No. (1) Of 2014 and its amendments, and the regulations and instructions.**
March 20, 2020	**Activating Defense Order No. (2), which imposes a ban on the movement of citizens and stops the use of public transportation in all regions of the Kingdom, starting from the morning of Saturday, March 21, 2020 until further notice. The law also included the following provisions:** • **Closing all shops in all regions of the Kingdom, provided that specific times will be announced later that allows citizens to fulfill their necessary needs.** • **Persons authorized to move by the Prime Minister and the Minister of Defense are excluded from the ban.** • **Citizens must inform the Public Security / Civil Defense regarding emergency medical cases so that they can take the necessary measures.**
March 21, 2020	**The entry into force of the decision to impose a curfew in all regions, after**

	the announcement of Defense Order No. (2), which stipulates the imposition of a curfew in all regions, until further notice.
March 24, 2020	**The process of distributing water and bread began through Amman Municipality vehicles in the capital, water trucks, and in the governorates via buses.**
March 25, 2020	**Opening of small shops that include basic food stores, shops selling vegetables and fruits, bakeries, pharmacies, and water stores in neighborhoods, and the start of large markets with delivery services between 10 am and 6 pm.**
March 26, 2020	**Defense Order No. (3) Was issued imposing financial fines and penalties for violators of Defense Order No. (2) up to imprisonment, in addition to seizing vehicles, closing shops for violators, and increasing penalties in the event of a repeat violation.** **The government decided to isolate Irbid governorate completely from the rest of the governorates, and not allow anyone to leave or enter it.**
March 31, 2020	**Defense Order No. (4) Was issued, which establishes a fund to support the national effort to combat the Corona virus epidemic, and confront its effects.**
April 3, 2020	**Jordan entered a comprehensive 24-hour curfew, in an effort by the government to contain the emerging corona virus.**
April 8, 2020	**Defense Order No. 6 was issued, which aims to protect the rights of workers in various economic sectors, in light of the government's tendency to gradually operate some commercial and industrial sectors, while continuing the curfew until further notice.**
April 10, 2020	**Jordan entered a comprehensive 48-hour curfew; With the aim of enabling the epidemiological investigation teams to resume their work efficiently and effectively.**
April 15, 2020	**Defense Order No. 7 was issued, which is concerned with regulating school and university education, distance vocational training, and student evaluation mechanisms.** **Defense Order No. 8 was issued, which is concerned with limiting the spread of the Corona virus, as this law punishes with imprisonment up to three years or a fine of three thousand dinars, or with both penalties for anyone who commits one of the violations set forth in the defense order.**
April 16, 2020	**The gradual start-up of some economic sectors based on specific criteria represented in ensuring the continuity of providing services and products to citizens and the sustainability of work for the various economic sectors and supply chains for the sectors authorized to operate.** **Whereas, the rest of the industrial sectors were allowed to start working in their factories at a rate of 40%, (in two shifts, each shift is 20%).**

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3.3 Summary of a study of the rates of change in the concentrations of pollutants in the surrounding air in Amman, Irbid, and Zarqa as a result of government measures taken during the period from March 15, 2020 to April 15, 2020 to confront the coronavirus pandemic

A. Particulate Matter with aerodynamic diameter ≤ 10 microns (PM10)

The study showed that the average decrease in the daily averages of PM10 concentrations, with the calculation of the effect of dust storms monitored by the ambient air quality monitoring stations in Amman, was about 38%, in Irbid about 15%, and in Zarqa about 30%, and the average decrease in all stations Monitoring in the three governorates is about 28%.

The study also showed that the average percentage decrease in the daily averages of PM10 concentrations without calculating the effect of dust storms to show the extent of the impact of stopping most human activities from transportation, industry and services, which were monitored by ambient air quality monitoring stations in Amman was about 47% and in Irbid about 32%, In Zarqa about 36%, and the average drop in all monitoring stations in the three governorates is about 38%.

Table (3.2): The percentage of decrease in the daily averages of PM10 concentrations in the three cities

Particulate Matter with aerodynamic diameter ≤ 10 microns	City	The percentage of decrease in daily averages for the period 15/3-15/4/2020 compared to that in the period 14/2-14/3/2020	The percentage of decrease in the daily averages for the period 15/3-15/4/2020 compared to that in the same period of the year 2019	Average
PM10 (with calculating dust storm)	Amman	%43.3	%32.7	%38
	Irbid	%16.2	%13.5	%14.8
	Zarqa’	%30.7	%29.5	%30.1
	All monitoring stations	%30.1	%25.2	%27.6
PM10 (without calculating dust storm)	Amman	%48.2	46.1%	47.1%
	Irbid	%26.7	36.8%	31.8%
	Zarqa’	%32.8	39%	35.9%
	All monitoring stations	%35.9	40.6%	38.3%

Table (3.3): Comparison of the monthly averages of PM10 concentrations in the three cities

	City	PM10 (with calculating dust storm)			PM10 (without calculating dust storm)		
		Crisis Month 15/3-15/4/2020	A Month Before the 14/2- Crisis 14/3/2020	15/3 - 15/4/2019	Crisis Month 15/3-15/4/2020	A Month Before the Crisis 14/2-14/3/2020	15/3 - 15/4/2019
GAM	Amman	36.6	66.3	60.1	26	47.9	54
KAC		40.4	58	65.3	28.4	39.3	60.9
KHG		20.7	42.3	37	17.7	25.8	29.6
MAH		33	73.5	65.5	23.8	66	59.6
TAB		46.2	73.7	59.4	29.5	64.7	52.2
UNI		45.4	59.7	51.6	34.3	46.4	45.6
YAR		43.3	94.8	55.7	30.6	77.1	51
Averages		37.9	66.9	56.4	27.2	52.5	50.4
BAR	Irbid	31.8	36	37.8	21.1	28.4	35.3
HSC		44.5	55.1	50.4	30	41.3	45.6
Averages		38.2	45.6	44.1	25.6	34.9	40.5
HAJ	Zarqa’	48.4	72.1	71.2	39.4	55.6	63.8
HH/ABK		42.7	59.3	58	31.2	49.5	52
MAS		34.7	57.5	-	24.6	40.4	-
Averages		41.9	63	64.6	31.7	48.5	57.9

B. Nitrogen dioxide (NO_2)

The study showed that the average decrease in the daily rates of NO_2 concentrations due to the cessation of most human activities from transportation, industry and services, which were monitored by ambient air quality monitoring stations in Amman, was about 50%, in Irbid about 71% and in Zarqa about 56% The average drop in all monitoring stations in the three governorates is about 59%.

Table (3.4): The percentage of decrease in the daily averages of NO_2 concentrations in the three cities

Nitrogen dioxide	City	The percentage of decrease in daily averages for the period 15/3-15/4/2020 compared to that in the period 14/2-14/3/2020	The percentage of decrease in the daily averages for the period 15/3-15/4/2020 compared to that in the same period of the year 2019	Average
NO_2	Amman	51.8%	48%	49.9%
	Irbid	66.7%	75.8%	71.2%
	Zarqa'	43.6%	68.4%	56%
	All monitoring stations	54%	64.1%	59%

Table (3.5): Comparison of the monthly averages of NO_2 concentrations in the three cities

	City	Crisis Month 15/3-15/4/2020	A Month Before 14/2- the Crisis 14/3/2020	15/3 - 15/4/2019
GAM	Amman	10.3	26.5	24.8
KAC		15.8	43	18.5
KHG		2	7.3	13.6
MAH		22.1	29.5	32.3
TAB		18.1	42.9	46.2
UNI		20.2	34.7	34.3
YAR		12.6	25.8	24.7
Averages		14.4	30	27.8
BAR	Irbid	6.2	19	28.1
HSC		5.6	16.5	20.8
Averages		5.9	17.8	24.5
HAJ	Zarqa'	8.9	19.6	39.4
HH/ABK		5.5	6	6.2
MAS		23.3	39.9	21.5
Averages		12.6	21.8	22.4

C. Sulfur dioxide (SO_2)

The study showed that the average decrease in the daily rates of SO_2 concentrations due to the cessation of most human activities from transportation, industry and services, which were monitored by ambient air quality monitoring stations in the city of Amman was about 18%, in the city of Irbid about 47% and in the city of Zarqa about 44% The average drop in all monitoring stations in the three governorates is about 37%.

Table (3.6): The percentage of decrease in the daily averages of SO_2 concentrations in the three cities

Sulfur dioxide	City	The percentage of decrease in daily averages for the period 15/3-15/4/2020 compared to that in the period 14/2-14/3/2020	The percentage of decrease in the daily averages for the period 15/3-15/4/2020 compared to that in the same period of the year 2019	Average
SO_2	Amman	%24.4	%11.6	%18
	Irbid	%34.6	%60.2	%47.4
	Zarqa'	%28.5	%59.5	%44
	All monitoring stations	%29.2	%43.8	%36.5

Table (3.7): Comparison of the monthly averages of SO_2 concentrations in the three cities

	City	Crisis Month 15/3-15/4/2020	A Month Before 14/2- the Crisis 14/3/2020	15/3 - 15/4/2019
GAM	Amman	9.8	23.8	7.4
KAC		9.9	9.5	11.3
KHG		3.3	4.5	5.4
MAH		7.1	13.7	11.4
YAR		4.9	7.7	4.1
Averages		7	11.8	7.9
BAR	Irbid	5.7	8.7	6.9

HAJ	Zarqa’	6.9	10.6	24.9
HH/ABK		4	7.1	9.8
MAS		3.9	4	9.7
Averages		4.9	7.2	14.8

D. Carbon monoxide (CO)

The study showed a discrepancy in the percentage of decrease or increase in the daily rates of carbon monoxide (CO) gas, as it showed that the average decrease in the daily rates for the period 3/15-15/4/2020 compared to it in the period 2/14-14/3/2020 in the city of Amman 26%, Irbid 8%, and Zarqa 48%, and the general average rate of decline for all monitoring stations is 27.3%. When comparing the daily rates for the period 3/15-15/4/2020 with the same period in 2019, the results showed that the percentage decrease in Amman is 9%, and there is an increase of 55% in Irbid and 35% in Zarqa.

This discrepancy may be attributed to the small number of stations that measure carbon monoxide or to other factors that need to be studied more than the sources of pollutants and the possibility of some cross-border pollutants entering, bearing in mind that the daily rates were within the permissible limits in the Jordanian standard specification No. (2006/1140).Where no exceedances of the daily rates were detected in all monitoring stations.

Table (3.8): The percentage change of the daily averages of carbon monoxide (CO) gas concentrations in the three cities

Carbon monoxide	City	The percentage of decrease in daily averages for the period 15/3-15/4/2020 compared to that in the period 14/2-14/3/2020	The percentage of decrease in the daily averages for the period 15/3-15/4/2020 compared to that in the same period of the year 2019	Average
CO	Amman	%26	%9	%17.5
	Irbid	%8	55-%	-
	Zarqa’	%48	35-%	-
	All monitoring stations	%27.3	-	-

Table (3.9): Comparison of the monthly averages of carbon monoxide (CO) gas concentrations in the three cities				
	City	Crisis Month 15/3-15/4/2020	A Month Before 14/2- the Crisis 14/3/2020	15/3 - 15/4/2019
GAM	Amman	3013	3776	3049
TAB		1515	2075	1746
Averages		2264	2926	2398
HSC	Irbid	2963	3150	1856
HAJ	Zarqa'	2265	-	1432

E. Ozone (O_3)

The study showed that the average drop in the daily rates of ozone gas O_3 concentrations due to the cessation of most human activities from transportation, industry and services, which were monitored by the two ambient air quality monitoring stations in Amman, was about 24% and in Irbid about 21%, and the average drop in Amman and Irbid was about 22 %.

Table (3.10): The percentage of decrease in the daily averages of ozone (O_3) gas concentrations				
Ozone	City	The percentage of decrease in daily averages for the period 15/3-15/4/2020 compared to that in the period 14/2-14/3/2020	The percentage of decrease in the daily averages for the period 15/3-15/4/2020 compared to that in the same period of the year 2019	Average
O_3	Amman	%41	%6	%23.5
	Irbid	%17	%25	%21
	All monitoring stations	%29	%15.5	%22.3

Table (3.11): Comparison of the monthly averages of ozone gas concentrations				
	City	Crisis Month 15/3-15/4/2020	A Month Before 14/2- the Crisis 14/3/2020	15/3 - 15/4/2019
KHG	Amman	37.7	26.8	40.2
BAR	اربد	39.6	47.9	53.1

Conformity of the results of ambient air quality monitoring to the permissible limits in the Jordanian Standard No. (2006/1140) during the period from 15/3/2020 to 15/4/2020

The study also showed that the results of ambient air quality monitoring of inhaled fine particles suspended in the air whose particles diameter is less than or equal to 10 microns PM10 (with the exception of dust storms) as well as all gaseous pollutants were within the permissible limits in the Jordanian Standard Specification No. (2006/1140). Where no exceedances of the daily rates were detected in all monitoring stations.

Table (3.12): Percentage change in pollutant concentration averages in the three major cities				
Pollutants	City	The percentage of decrease in daily averages for the period 15/3-15/4/2020 compared to that in the period 14/2-14/3/2020	The percentage of decrease in the daily averages for the period 15/3-15/4/2020 compared to that in the same period of the year 2019	Average
PM10 (with calculating dust storm)	Amman	%43.3	%32.7	%38
	Irbid	%16.2	%13.5	%14.8
	Zarqa’	%30.7	%29.5	%30.1

PM10 (without calculating dust storm)	Amman	%48.2	%46.1	%47.1
	Irbid	%26.7	%36.8	%31.8
	Zarqa’	%32.8	%39	%35.9
NO_2	Amman	%51.8	%48	%49.9
	Irbid	%66.7	%75.8	%71.2
	Zarqa’	%43.6	%68.4	%56
SO_2	Amman	%24.4	%11.6	%18
	Irbid	%34.6	%60.2	%47.4
	Zarqa’	%28.5	%59.5	%44
CO	Amman	%26	%9	%17.5
	Irbid	%8	%55-	-
	Zarqa’	%48	%35-	-
O_3	Amman	%41	%6	%23.5
	Irbid	%17	%25	%21

4

CONCLUSION

- Air pollution measurement results indicate that the ambient air quality in Amman, Irbid, and Zarqa' is good for most days of the year based on the Jordanian technical standard for ambient air quality 1140/2006 **(Table 1.2).**

- No exceedances were recorded in the annual averages of air pollutants that were monitored in all stations during the period from 1/1/2020 to 31/12/2020. Results were within the permissible limits in the Jordanian Standard JS1140/2006 (technical base).

- Pollutants (Carbon monoxide (CO), Sulfur dioxide (SO_2), Nitrogen dioxide (NO_2) and Ozone (O_3) in most stations were within the limits of the Jordanian technical standard for ambient air No. 1140/2006.

- Sandstorms and quintet winds contributed to raising the concentrations of particulate matters with an effective diameter less than or equal to ≤ 10 microns (PM10), which led to their exceeding in most locations for daily averages **(Table 2.2).**

- The wind direction in Amman during the measurement period was southwest, with a speed equal to 6.1 km/h, and in Zarqa the wind direction was southwest with a speed of 3.65 km/h, and in Irbid the wind direction was southeast with a speed of 4.5 km/h.

- The results of monitoring the ambient air quality in the three governorates, based on the ambient air quality index, showed that the average percentage of days in which the air quality was good was 75.1%, and it was moderate for 24% of the year. The average percentage of days when the air was unhealthy for sensitive groups was 0.7%, and the percentage of days when the air was unhealthy was 0.14%.

- Based on the study of the rates of change of pollutants in the ambient air in Amman, Irbid, and Zarqa as a result of government lockdown measures during the period from March 15, 2020 to April 15, 2020 to confront the Corona virus pandemic, an overall percentage decrease of 28% in the daily averages of PM10 concentrations was found. When subtracting the effect of dust storms, the percentage decreases by 38%. The study also showed a decrease in the daily rates of nitrogen dioxide NO_2 concentrations by 59% in all monitoring stations in the three governorates. As for sulfur dioxide, the percentage of decrease in the daily rates was 37%. The decrease in the daily rates of concentrations of these pollutants occurred due to the cessation of most human activities such as transportation, industry and services.

5

RECOMMENDATIONS

1) The necessity of working on preparing a national strategy to combat air pollution and prepare a sectorial strategy for the environment that includes air pollution control and ambient air quality control issues.

2) Continue to monitor the ambient air quality in the current monitoring sites and increase the number of stations to cover all areas in the kingdom not covered by continuous monitoring and include them in the national monitoring network database.

3) Add devices to measure PM2.5 in line with WHO recommendations due to their harmful health effects.

4) Add continuous analyzers to measure black carbon concentrations in areas that suffer from heavy traffic.

5) Add measurement analyzers to the existing twelve AQ stations to cover other criteria pollutants as required since currently not all pollutants are measured in all stations.

6) Measurement of meteorological elements, wind speed and direction in all stations as they are monitored in only three stations.
7) Review and update Jordanian legislation and standards related to air quality.
8) Encourage universities and scientific research centers to conduct research related to air pollution.