The Hashemite Kingdom of Jordan

Ministry of Environment

Ambient Air Quality Monitoring Report

In Amman – Irbid – Zarqa

2021

Ministry of Environment

National Ambient Air Quality Monitoring Network

Amman – Irbid – Zarqa

Yearly Report

2021

Abstract

The Ministry of Environment monitors ambient air quality as required by the Environmental Protection Law No. 6 of 2017 and the Air Protection bylaw No. 28-2005. In the interest of safeguarding public health, the ministry is guided by ambient air quality limits as stipulated in Jordanian Standard No. 1140/2006 for ambient air quality.

In addition to continuously recording and reporting measured data, the ministry also takes necessary measures in the event of limit exceedances of the standard.

The process of monitoring ambient air quality in Jordan aims to determine the levels of gaseous pollutants and inhaled particulate matters suspended in ambient air. These levels are then compared with the limits stipulated in the Jordanian Standard for Ambient Air Quality law No. (1140/2006).

The process also aims to evaluate changes recorded in the ambient air quality over the years in observed areas, comparing the quality of the ambient air in different regions of Jordan.

The ministry then provides findings and recommendations to decision makers in order for them to take the proper course of action based on given information and data.

The appropriate strategies and policies are then adopted in order to improve air quality in the region and to provide better lives for the people of Jordan. In addition to this, decision makers will also be able to activate emergency control procedures accordingly to prevent or reduce accidents that lead to further air pollution accidents.

In 2014, the ministry established a national ambient air quality monitoring network consisting of 12 ambient air quality monitoring stations. These stations were spread out across industrial areas, areas with high traffic, and residential areas based on scientific findings and research. They were 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 ≤ 2.5 microns (PM2.5)
- 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 the centre of the ministry where they are stored, audited, analysed and issuing reports on a daily, monthly and annual bases. The monitoring results are analysed 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 the cities of Amman, Zarqa, and Irbid during 2021. The stations also compared their observational results to those recorded between 2015 and 2021. Exceedance limits were determined by comparing observational results within limits set in the Jordanian Standard No. 1140/2006.

In this year, a switch was made from PM10 measuring instruments with an effective diameter of ≤10 microns (PM10) to PM2.5 measurements with an effective diameter of ≤2.5 microns (PM2.5) based on recommendations from the World Health Organization (WHO). The readings of previous years were converted by multiplying by 0.41 factor which is approved by the (WHO).

The results of monitoring ambient air quality for the year 2021 in different locations showed that the air quality was moderate and within the permissible limits in the Jordanian Standard No.1140/2006 with the exception of Particulate matter with aerodynamic diameter ≤ 2.5 microns (PM2.5), Excesses were observed in the annual averages of the limit stipulated in the Jordanian specification of 15 µg/m3 in all monitoring stations, in addition to that, daily averages exceeded the limit stipulated in the Jordanian standard of 65 µg/m3 in most monitoring stations. Excesses in (PM2.5) are attributed to emissions from sources of air pollution as a result of human activities, especially from the sectors of transportation, industry and energy, in which fossil fuels are burned, in addition to dust storms and airborne pollutants.

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INTRODUCTION

In recent decades, Jordan experienced a significant population growth as a result of forced migration and natural increase, which placed additional pressure on several sectors – including the industrial, agricultural, construction, service, health, transport, and energy sectors - and led to higher ambient-air pollution.

The rise in emissions of various gaseous pollutants as well as fine particulate matter (PM), stemmed from multiple sources of which there are three main categories: mobile sources, specifically the increase in land transport vehicles that produced traffic growth in urban areas, stationary sources such as factories, power plants, landfills, and wastewater treatment plants, and lastly, natural sources such as sandstorms, wind-blown dust, wildfires, and pollination.

In line with the UN sustainable development goals (SDG), the Ministry of Environment established a national network to monitor the levels of concentrations of gaseous air pollutants and particulate matter suspended in the most polluted areas and through which developed a set of effective and efficient policies and procedures to reduce air pollution.

The air monitoring network - established on 1/5/2014 - consists of twenty-six monitoring stations distributed over seven governorates, twelve of which are fixed in the three major cities with the highest population concentration - seven are located in the capital Amman, three in Zarqa, and two in Irbid. In addition, a mobile laboratory was set up to monitor the ambient air quality in other areas as needed.

A fundamental electronic system was also developed to allow citizens and interested parties alike to monitor the real-time ambient air quality index online on national and international websites, and to view historical monitoring reports and results on the Ministry's website.

Monitoring Areas

- **Amman Governorate**

Amman is the most-populous governorate in Jordan with an estimated population of 4,642,000 people as of 2021. It is the third largest in area following the governorates of Ma'an and Mafraq and is the most crucial for the national identity of Jordan.

The capital, Amman, is considered the largest city in the Kingdom and one of the most-populous Arab cities. Amman is considered the hub for all governmental departments, commercial, administrative, economic and educational institutions.

Hence, seven stations have been established to monitor the ambient air quality, distributed in the following districts:

- Amman District: Four monitoring stations in the Greater Amman Municipality, King Hussein Gardens, Tabarbour, and Yarmouk.
- Marka District: One monitoring station in Mahatta.
- University District: One monitoring station in Jordan University Street.
- Sahab District: One monitoring station in King Abdullah II Industrial City.

- **Zarqa Governorate**

Zarqa Governorate is located about 20 km north-east of Amman, and is the third most-populous Jordanian governorate, with an estimated 1,581,000 people in the year 2021.

Zarqa has a competitive advantage, especially in the industrial sector, as it comprises more than half of the national industry in terms of invested capital, labour, and production volume, in addition to the Qualified Industrial Zone in Al Dhlail, which includes many factories, and is an important corridor to several border posts.

Three ambient air quality monitoring stations have been established here, distributed in the Kasbah al-Zarqa district, in the Wadi Al-Hajar health centre, the Municipal Slaughterhouse in the Masane' area, and The Hashemite Hall.

- **Irbid Governorate**

Irbid is located in the far north of Jordan, stretching to the Jordanian Syrian border near the Yarmouk River, and is the second most-populous Jordanian governorate with an estimated 2,050,300 people in 2021.

The importance of the governorate is highlighted by its strategic location, as well as its historical and archaeological value. Moreover, Irbid is considered the principal agricultural region in Jordan, especially in the production of citrus fruits, olives, grains, and honey. It is characterised by the availability of social, youth, and cultural services in its urban centre.

The two ambient air quality monitoring stations are distributed in Kasbah Irbid District in Al Hassan Sports City and Al Barha Street.

Table (1.0) shows the population number, percentage, and density and the land area they occupy in the major cities of the Kingdom, as well as the Kingdom as a whole.

Governorate	Population (people)	Percentage of population in the Kingdom (%)	Area (km^2)	Area percentage in the Kingdom (%)	Population density (people/km^2)
Amman	4,642,000	41.98%	7,579.2	8.49%	612.47
Zarqa	1,581,000	14.30%	4,761	5.33%	332.07
Irbid	2,050,300	18.54%	1,571.7	1.76%	1,304.51
Total	8,273,300	74.82%	13,911.9	15.58%	594.69
The Kingdom	11,057,000	100.00%	89,318	100.00%	123.79

Table 1.0: Population percentages and areas of monitoring areas in the Kingdom.

It is clear from this table that the electronic system for monitoring air quality in the three cities, covers about 75% of the population of the Kingdom, although the total area constitutes only about 16% of the area of the Kingdom, with the average population density of the three cities is about 595 people / km^2.

1.1 Monitoring Sites

The ministry's Ambient Air Quality Monitoring Network consists of 12 fixed continuous-monitoring stations distributed in Amman, Irbid, and Zarqa.

The locations were chosen after an initial survey of gas and particle concentrations was conducted using test tubes and special devices approved for that purpose, distributed in the three cities. The results were analysed and mapped to show the areas of highest gases and particles concentrations. The sites were also carefully chosen in a manner that includes the different activities in industrial, commercial, and residential areas as well as areas with high traffic densities.

Table (1.1) shows the names and locations of the stations in Jordan.

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

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

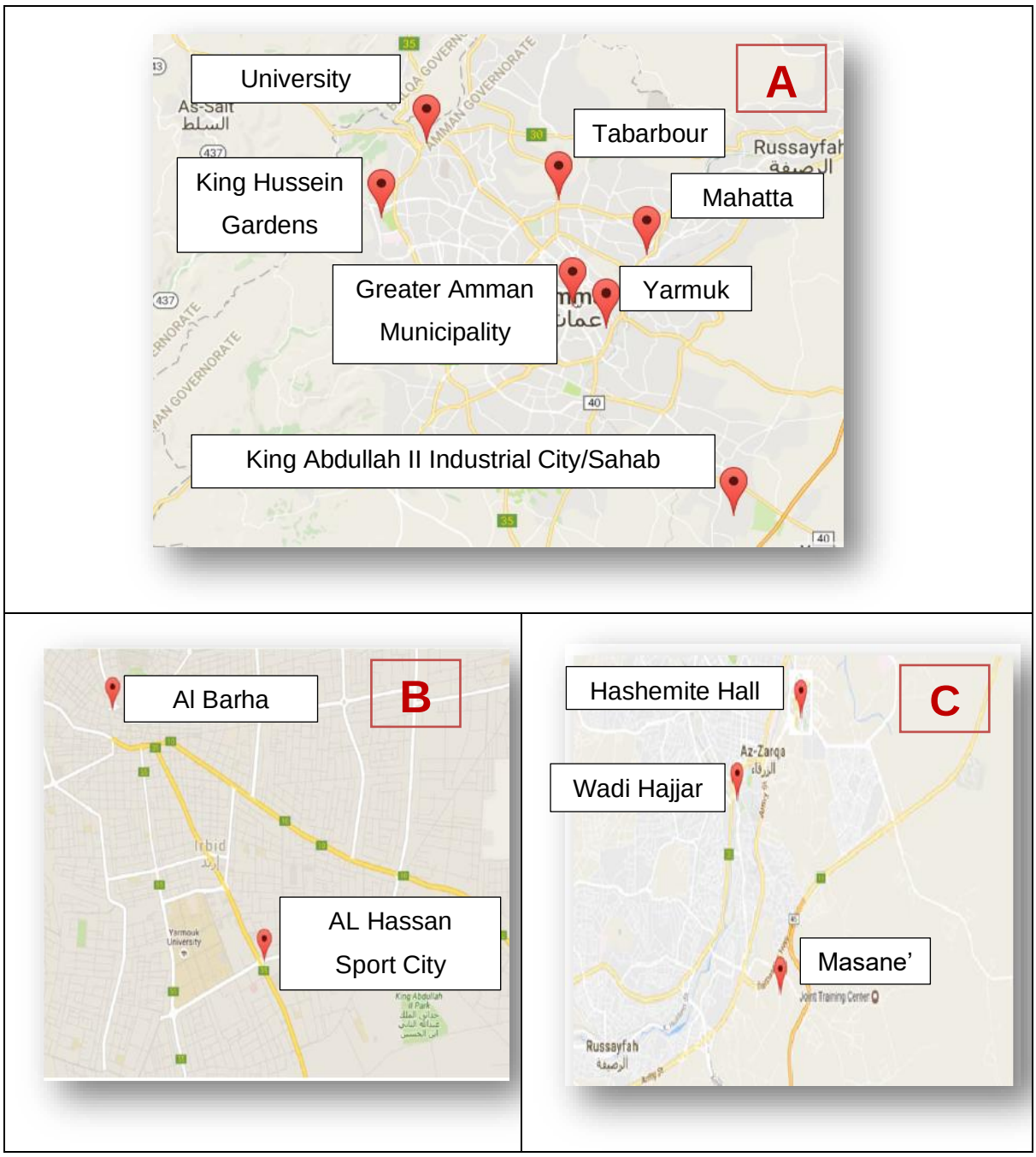


Figure 1.1: A) Distributed Stations in Amman, B) Distributed Stations in Irbid, C) Distributed Stations in Zarqa.

1.2 Jordanian Standard for Ambient Air Quality Monitoring

Table (1.2) shows the permissible limits for emissions of gases and particulate matter to the ambient air as outlined in Jordanian Standard No. 1140/2006 for the quality of the ambient air. The results of the monitoring were compared with the limits allowed in this technical rule.

Pollutant	Sample Duration	Maximum Allowable Limit	Number of Allowable Exceeded Events
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 parts per million (ppm)	3 times in any 12-month period per year
	8 Hours	9 parts 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)	-

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

1.3 Pollutants

Pollutants monitored include particulate matter with aerodynamic diameter ≤ 2.5 microns (PM2.5), 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.

Type of station	Station Name	Short name	CO	NO_2	SO_2	O_3	PM2.5	MET
Amman								
Background	King Hussein Gardens	KHG		✓	✓	✓	✓	✓
Urban	Greater Amman Municipality	GAM	✓	✓	✓		✓	
Traffic	Northern Bus Station Tabarbour	TAB	✓	✓			✓	
Urban	Marka / Mahata	MAH		✓	✓		✓	
Traffic	University street /Sweileh	UNI		✓			✓	
Industrial	King Abdullah II Industrial City / Sahab	KAC		✓	✓	✓	✓	
Industrial	Yarmuk	YAR		✓	✓		✓	
Zarqa								
Traffic	Wadi Hajjar Health Center	HAJ	✓	✓	✓		✓	✓
Industrial	Massane’	MAS		✓	✓		✓	
Traffic	Hashemite Hall	ABK/HH		✓	✓		✓	
Irbid								
Traffic	Al Hassan Sport City	HSC	✓	✓			✓	
Urban	Al Barha Street	BAR		✓	✓	✓	✓	✓

Table 1.3: Pollutants monitored in each station.

1.4 Measuring devices

All devices used to monitor gases and particulate matter are calibrated for measuring ambient air pollutants. They are in compliance with the Jordanian standard 1140/2006 and approved by the American Environmental Protection Agency (EPA), in addition to European and other International environmental authorities.

Table (1.4) shows the types of instruments used for each pollutant.

Pollutant	Model	Examination certificate	Principle of Operation
Particulate Matter (PM2.5)	Thermo 5014i	U.S. EPA Approved PM-2.5 (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

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 them.

1.5 Calibration

All gas analysers were 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 (weather elements measurement)

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

1.7 Communication and Telemetry

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

1.8 Operation and site Performance

The United Technology Establishment (UniTec), under the direct supervision of the Environmental Monitoring and Evaluation Directorate in the Ministry of Environment, manages and maintains all monitoring stations - including securing spare parts, calibrating devices, and the upkeep of metal rooms, cameras, alarms, communication, and air conditioning - as well as validates data and issues daily, monthly, and yearly reports.

Monitoring stations are operated according to the manufacturer's instructions, in accordance with international quality assurance procedures to monitor ambient air quality.

Multiple measures have been taken to reduce data loss ensure data security, and to promptly dispatch maintenance teams to monitoring stations as soon as any warning or defect signals in the monitoring devices appear in an effort to acquire the largest possible percentage of data completion.

1.9 Air Quality Index

The Ministry of Environment has made great efforts to monitor ambient air quality, and since 2018 began the direct broadcast of the National Network for Ambient Air Quality Monitoring data to the Ministry's website as an indicator of air quality (Air Quality Index). The Ministry has made electronic connections to global monitoring networks and has created a website available to all citizens and researchers https://www.jordanenv.com/ that broadcasts the results of ambient air quality indicators on the internet directly and is linked to a global website https://aqicn.org.

This is part of the Ministry's duties to participate in national, regional, and global monitoring efforts, initiatives and programs. The site continuously and directly shows the air quality index for each of the ministry's air quality monitoring stations in Amman, Zarqa and Irbid. All concerned parties and citizens can follow the ambient air quality index around the clock on this site to take appropriate measures, especially for sensitive groups in the event that air quality changes according to the degrees approved internationally.

The website simulates the global website of the air quality index 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 colour index linked to numerical values that are used by government institutions and agencies concerned with the protection of the environment in addition to those interested in the environment and citizens to know air quality in a specific location. Each group is indicated with a description and colour symbolized by it. So that green indicates that the air quality is good, yellow indicates that the quality is moderate, while orange indicates that the air may adversely affect sensitive groups. Red indicates that the air is unhealthy, while violet indicates that is very unhealthy, and brown indicates that it is hazardous.

1.10 Stations

Figure 1.2: Station from inside

Figure 1.3: Station from outside

2

RESULTS

Table (2.1) shows the annual averages of air pollutants that were monitored in all stations during the period from 1/1/2021 to 31/12/2021.

#	Station	Short Name	PM2.5 µg/m^3	NO_2 ppb	SO_2 ppb	CO ppb	O_3 ppb
			Average as in Jordanian Limits 1140/2006				
			15 µg/m3	50 ppb	40 ppb	Not Found	Not Found
Amman							
1	King Hussein Gardens	KHG	25.7	6.9	5.28	-	35.9
2	Greater Amman Municipality	GAM	26.5	26.3	14.2	3889	-
3	Northern Bus Station Tabarbour	TAB	25.4	34.4	-	1022	-
4	Marka / Mahata	MAH	24.3	24	16.2	-	-
5	University street Sweileh	UNI	33.6	22.5	-	-	-
6	King Abdullah II Industrial City / Sahab	KAC	20.1	17.5	7.35	-	21.3
7	Yarmuk	YAR	45.7	23.3	6.5	-	-
Zarqa							
8	Health Center Wadi Hajar	HAJ	27.5	13.5	8.23	3493	-
9	Main slaughterhouse Masane' Zone	MAS	30.8	26.1	4.44	-	-
10	Hashemite Hall	ABK/HH	32	12.9	6.79	-	-
Irbid							
11	AL Hassan Sport City	HSC	22.8	15.8	-	1032	-
12	Al Barha street	BAR	20.6	18.6	10.8	-	43.5

Table 2.1: Yearly Averages of pollutants in all stations.

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.

Station			PM2.5	NO_2	NO_2	SO_2	SO_2	CO	CO	O_3	O_3
			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			65 $\mu g/m^3$	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	1	-	-	-	-	-	-	-	-
2	Greater Amman Municipality	GAM	5	-	-	-	-	-	-	-	-
3	Northern Bus Station Tabarbour	TAB	1	-	-	-	-	-	-	-	-
4	Marka / Mahata	MAH	4	-	-	-	-	-	-	-	-
5	University street Sweileh	UNI	2	-	-	-	-	-	-	-	-
6	King Abdullah II Industrial City / Sahab	KAC	-	-	-	-	-	-	-	-	-
7	Yarmuk	YAR	28	-	-	-	-	-	-	-	-
Zarqa											
8	Health Center Wadi Hajar	HAJ	6	-	-	-	-	-	-	-	-
9	Main slaughterhouse Masane' Zone	MAS	11	-	-	-	-	-	-	-	-
10	Hashemite Hall	ABK /HH	3	-	-	-	-	-	-	-	-
Irbid											
11	AL Hassan Sport City	HSC	2	-	-	-	-	-	-	-	-
12	Al Barha street	BAR	2	-	-	-	-	-	-	-	-

Table 2.2: Number of exceedances in all stations.

Table (2.3) shows the percentages of exceeding and the percentages of conformity with the Jordanian specification for pollutants in all stations.

Pollutants	Monitoring Sites	The number of hourly rates exceedances above the specification limit	Exceeding the hourly rates of the specification limit (Percentage)	The rate of conformity with the hourly rates of the specification	The number of daily rate exceedances above the specification limit	Exceeding the daily rates of the specification limit (Percentage)	The rate of conformity with the daily rates of the specification
PM2.5	GAM	There is no limit in the specification			5	1.40%	98.60%
	KAC				-	-	100%
	KHG				1	0.30%	99.70%
	MAH				4	1.10%	98.90%
	TAB				1	0.30%	99.70%
	UNI				2	0.60%	99.40%
	YAR				28	8.10%	91.90%
	BAR				2	0.60%	99.40%
	HSC				2	0.60%	99.40%
	HAJ				6	1.80%	98.20%
	ABK/HH				3	0.90%	99.10%
	MAS				11	3.30%	96.70%
	Average in all Stations				5.4	1.60%	98.40%
NO_2	GAM	-	-	100%	-	-	100%
	KAC	-	-	100%	-	-	100%
	KHG	-	-	100%	-	-	100%
	MAH	-	-	100%	-	-	100%
	TAB	-	-	100%	-	-	100%
	UNI	-	-	100%	-	-	100%
	YAR	-	-	100%	-	-	100%
	BAR	-	-	100%	-	-	100%

Pollutants	Monitoring Sites	The number of hourly rates exceedances above the specification limit	Exceeding the hourly rates of the specification limit (Percentage)	The rate of conformity with the hourly rates of the specification	The number of daily rate exceedances above the specification limit	Exceeding the daily rates of the specification limit (Percentage)	The rate of conformity with the daily rates of the specification
	HSC	-	-	100%	-	-	100%
	HAJ	-	-	100%	-	-	100%
	ABK/HH	-	-	100%	-	-	100%
	MAS	-	-	100%	-	-	100%
SO_2	GAM	-	-	100%	-	-	100%
	KAC	-	-	100%	-	-	100%
	KHG	-	-	100%	-	-	100%
	MAH	-	-	100%	-	-	100%
	YAR	-	-	100%	-	-	100%
	BAR	-	-	100%	-	-	100%
	HAJ	-	-	100%	-	-	100%
	ABK/HH	-	-	100%	-	-	100%
	MAS	-	-	100%	-	-	100%
CO	GAM	-	-	100%	-	-	100%
	TAB	-	-	100%	-	-	100%
	HSC	-	-	100%	-	-	100%
	HAJ	-	-	100%	-	-	100%
O_3	KAC	-	-	100%	-	-	100%
	KHG	-	-	100%	-	-	100%
	BAR	-	-	100%	-	-	100%

Table 2.3: Percentages of Exceeding and Conforming to the Jordanian Standard.

2.1 Particulate Matters (PM2.5)

Particulate Matter with aerodynamic diameter ≤ 2.5 microns (PM2.5) They are coarse suspended particles and are less than or equal to 2.5 µg/m3 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 ≤2.5 micron (PM2.5) in Jordanian Technical Rule No. 1140 of 2006:

- Annual average is 15 µg/m3
- **The daily average (24 hours) is 65 (µg/m3),** which is not to be exceeded for more than three times in a 12-month period.

The reason for the high level of **PM2.5** readings and the annual average is mainly due to emissions from air pollution sources as a result of human activities, especially from the transportation, industry and energy sectors in which fossil fuels are burned, in addition to dust storms and airborne pollutants.

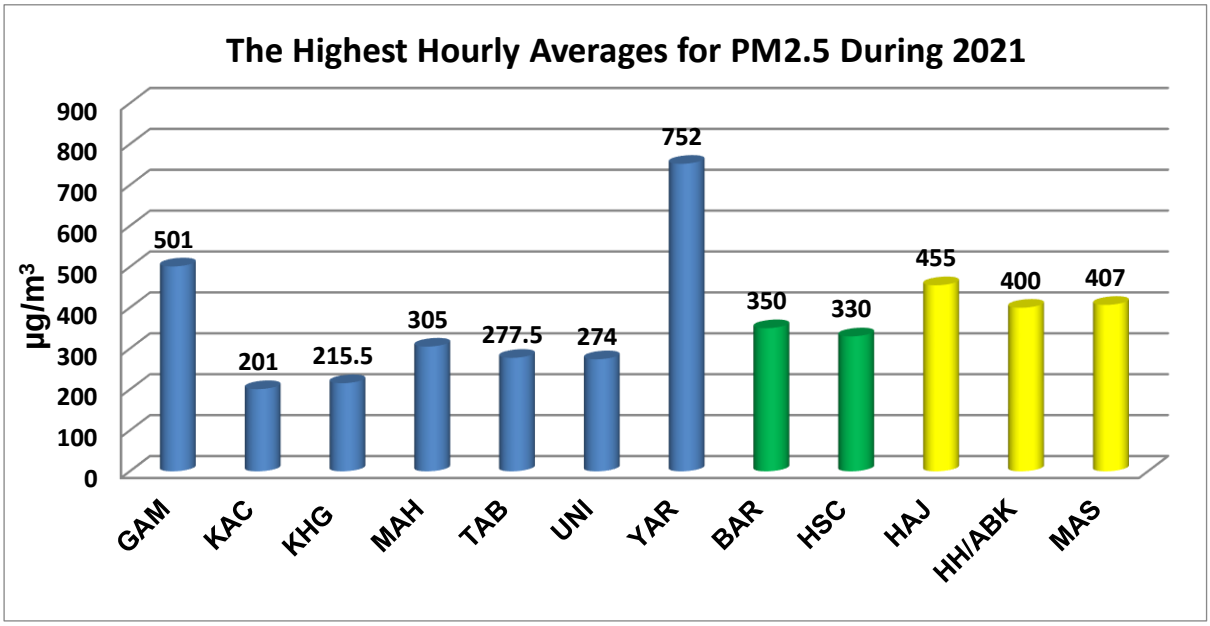


Figure 2.1: The highest hourly averages for (PM2.5) during 2021 in all stations

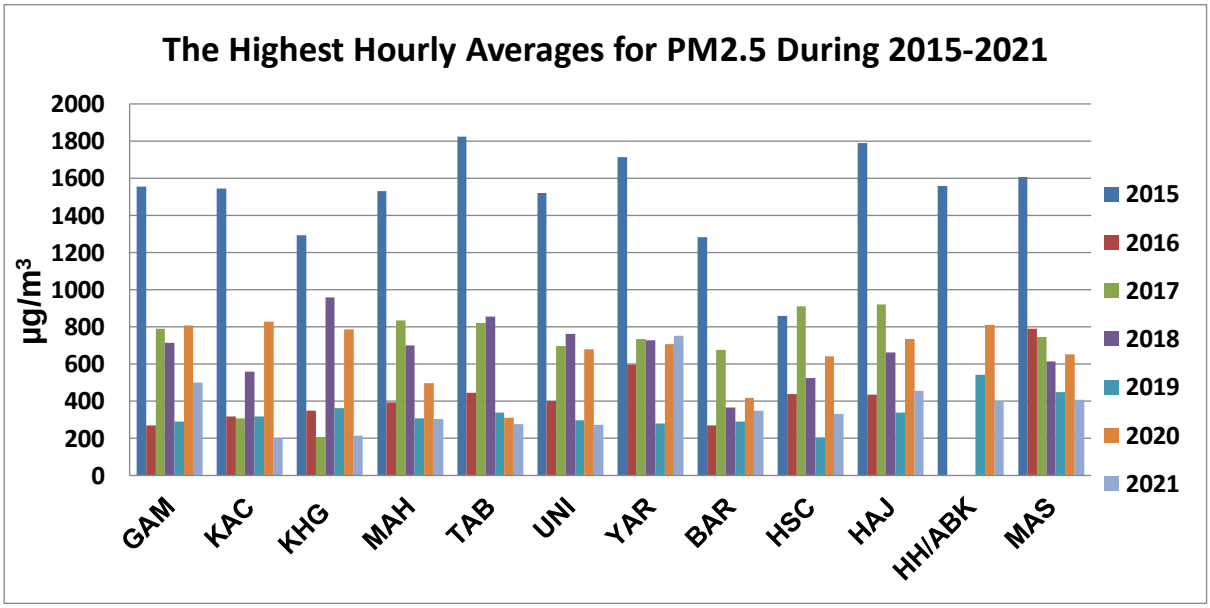


Figure 2.2: The highest hourly averages for (PM2.5) during 2015-2021 in all stations

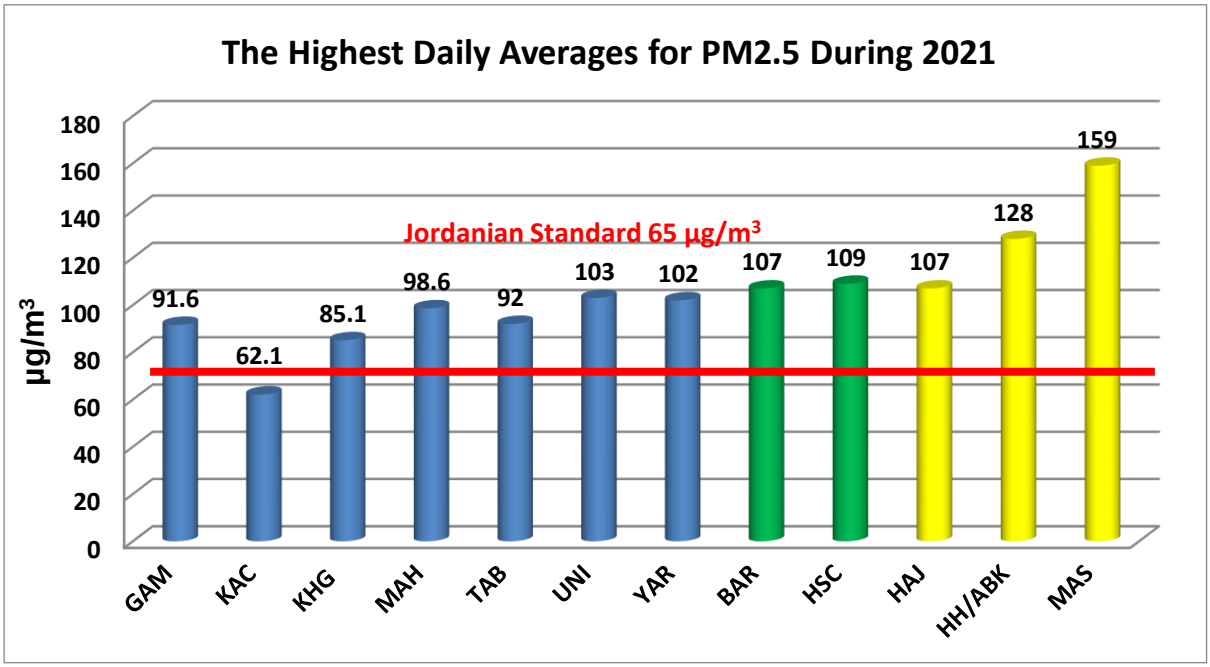


Figure 2.3: The highest daily averages for (PM2.5) during 2021 in all stations

The results of ambient air quality monitoring showed that there were excesses in the daily averages of PM2.5 in most of the monitoring stations, where the highest daily average reached 159 µg/m3 at “MAS” station in Zarqa.

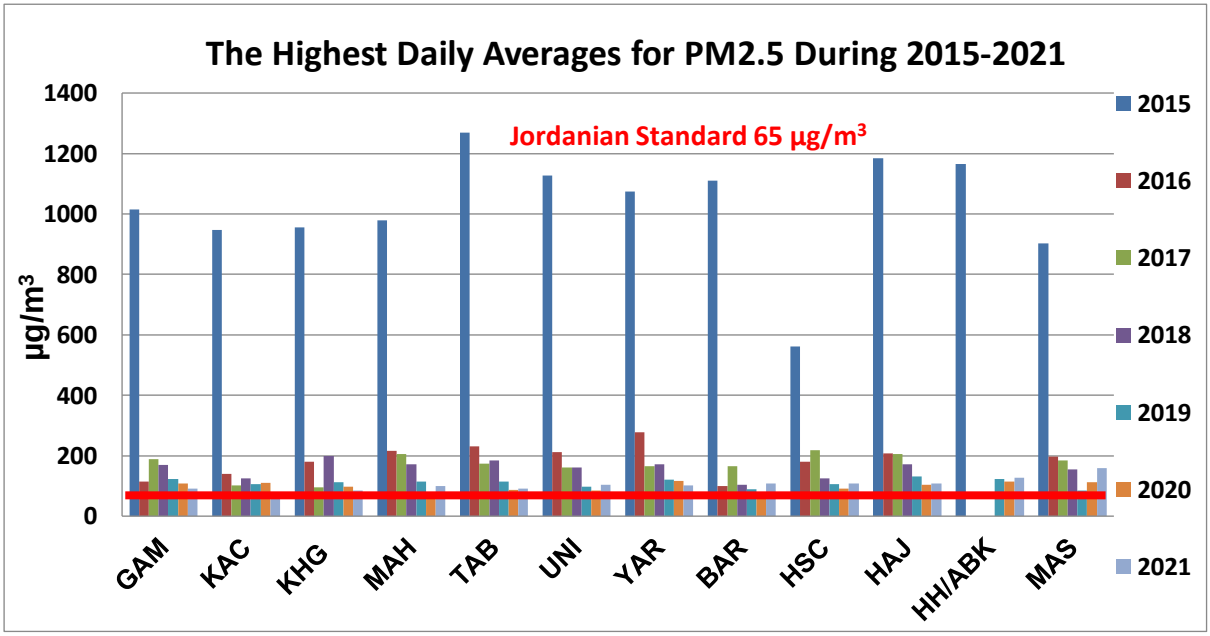


Figure 2.4: The highest daily averages for (PM2.5) during 2015-2021 in all stations

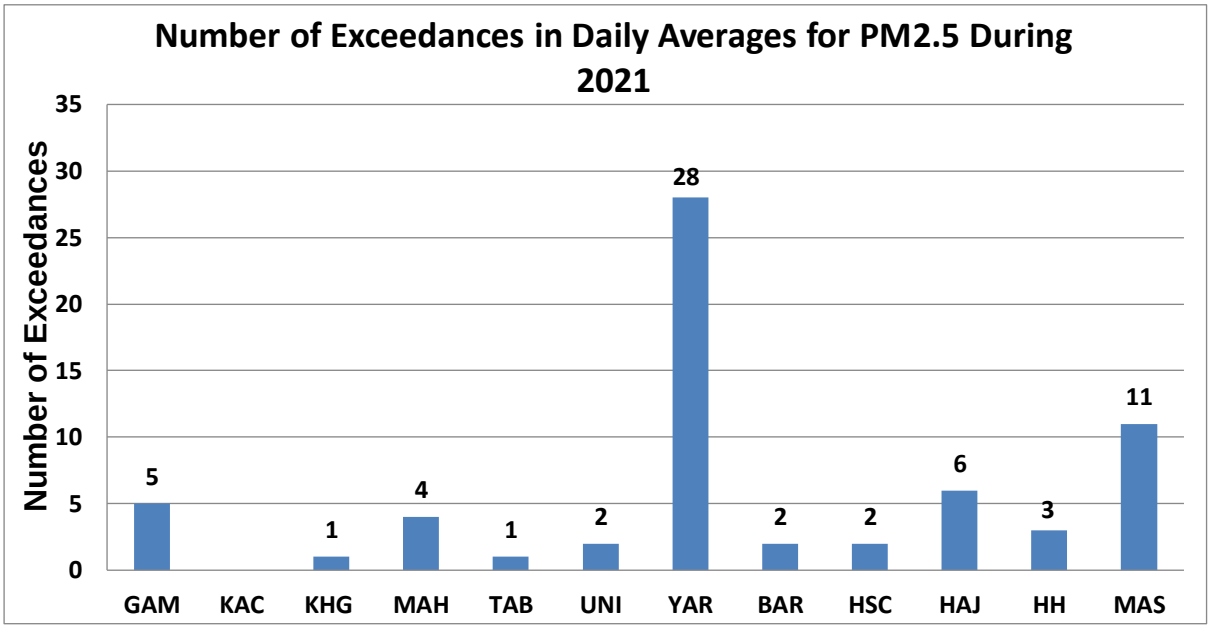


Figure 2.5: Number of exceedances in daily averages for (PM2.5) during 2021 in all stations.

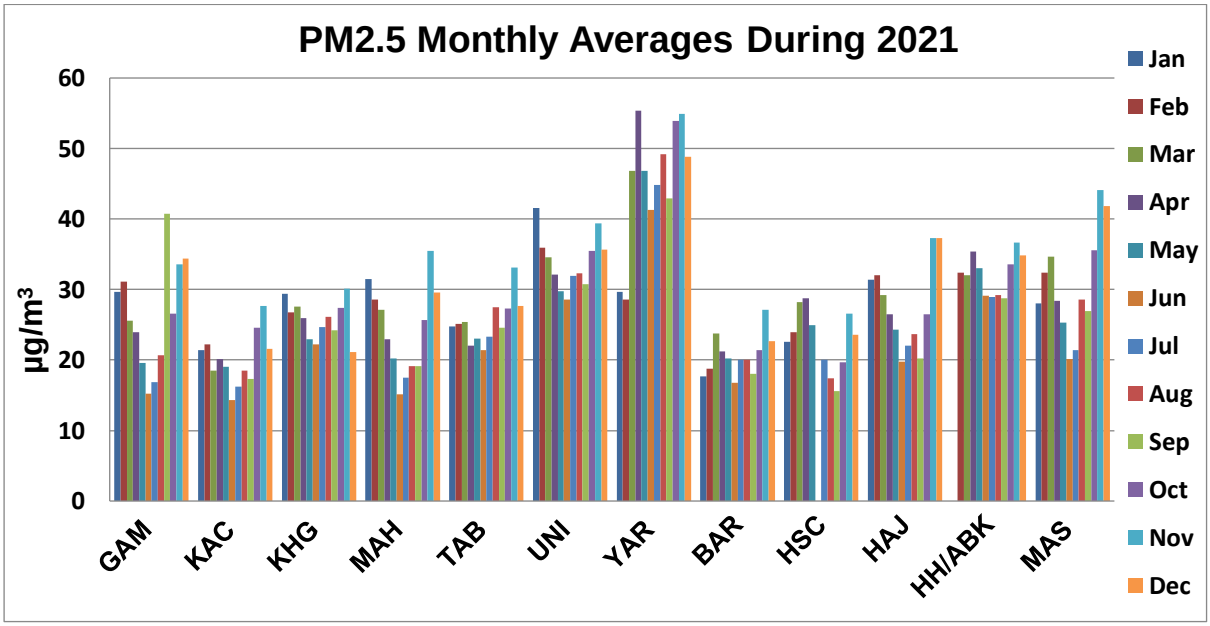


Figure 2.6: (PM2.5) monthly averages during 2021 in all stations.

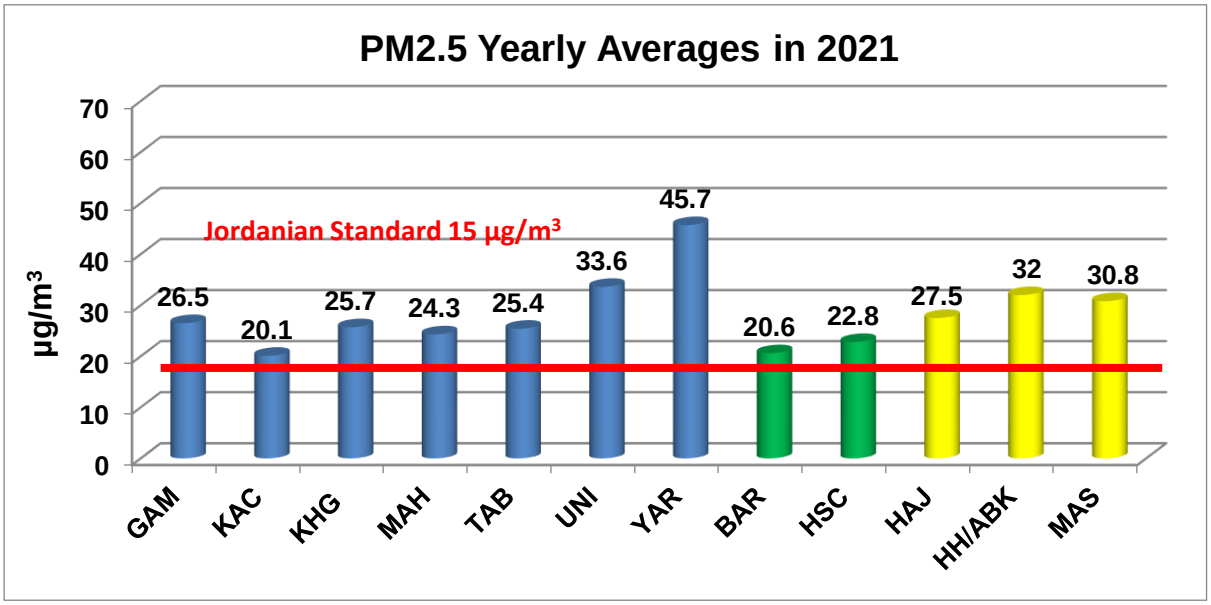


Figure 2.7: (PM2.5) yearly averages in 2021 in all stations.

The results of the ambient air quality monitoring showed that there were excesses in the annual averages of PM2.5 in all the monitoring stations as shown in the figure (2.7).

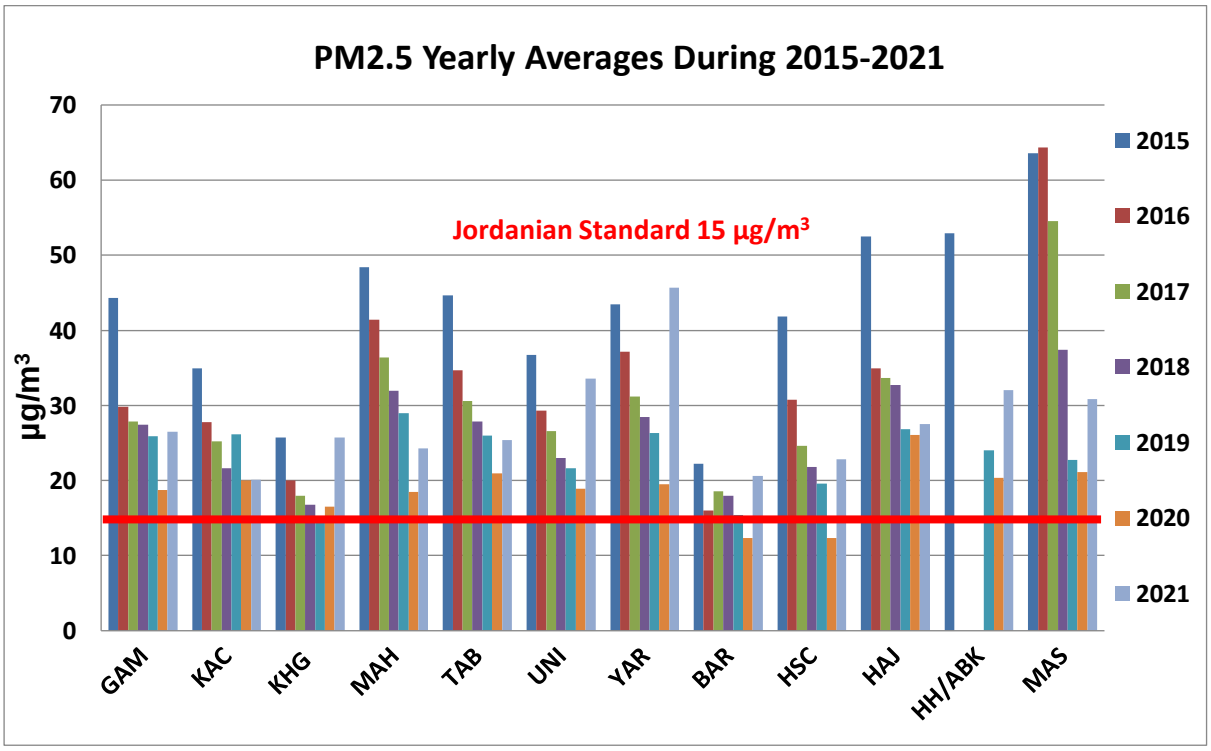


Figure 2.8: (PM2.5) yearly averages during 2015-2021 in all stations.

- **Note: In the years from 2015 to 2020, particulate matter with an effective diameter of ≤10 microns (PM10) was measured. For the purpose of comparison with the measurements of the current year 2021, which was started with the measurement of the particulate matter with an effective diameter of ≤2.5 microns (PM2.5), the measurements of (PM10) were converted to (PM2.5), based on the equation approved by the World Health Organization (WHO) where PM2.5=PM10*0.41.**

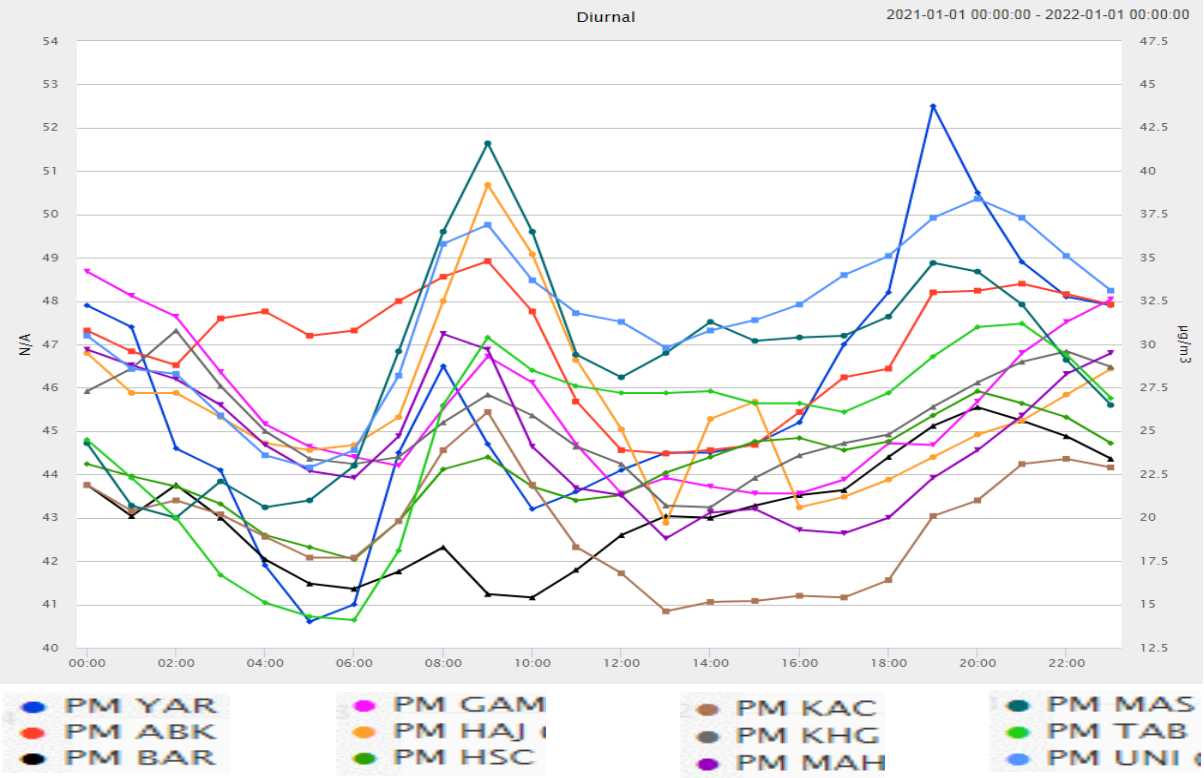


Figure 2.9: The average value of the Particulate Matter (PM2.5) in each hour of the day in all stations during 2021

The results indicate, as shown in Figure (2.9), that the highest daily readings of PM2.5 occur in the peak traffic period, between the hours (8-11 am), (3-5 pm) and (7-9 pm). 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.

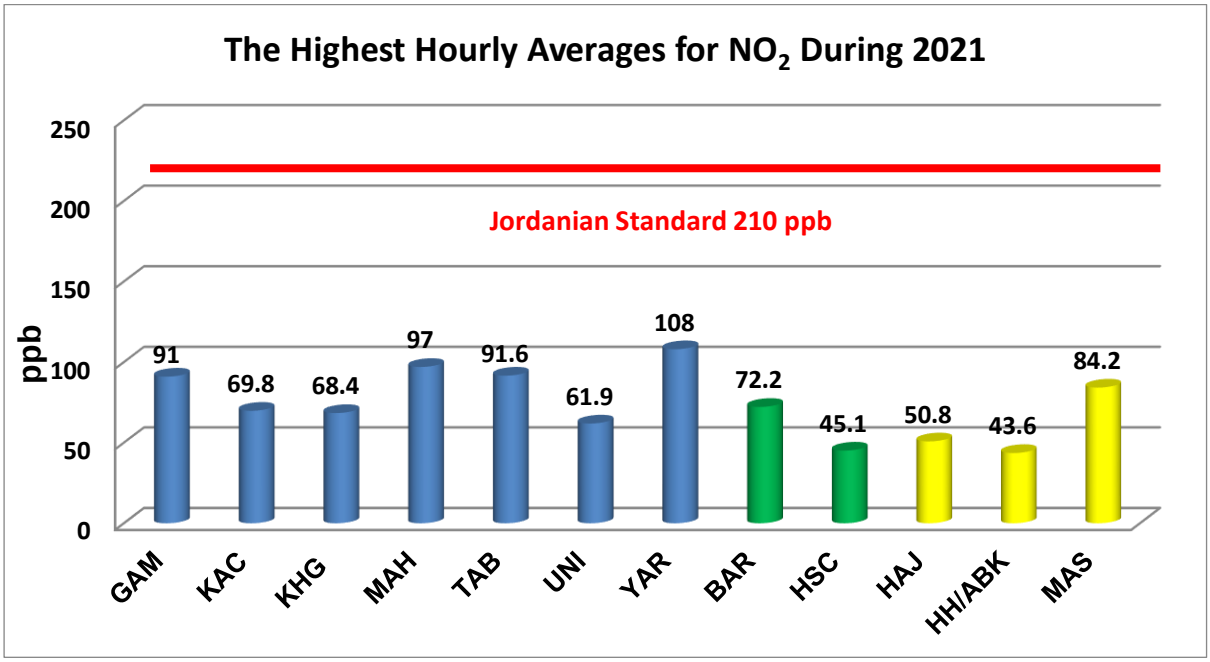


Figure 2.10: The highest hourly averages for (NO_2) during 2021 in all stations

The results of ambient air quality monitoring showed that the hourly averages of NO_2 were within the permissible limits in the Jordanian Standard (1140/2006) in all monitoring stations, where no excess was detected. Where the highest hourly average reached 108 ppb as shown in the figure above (2.10).

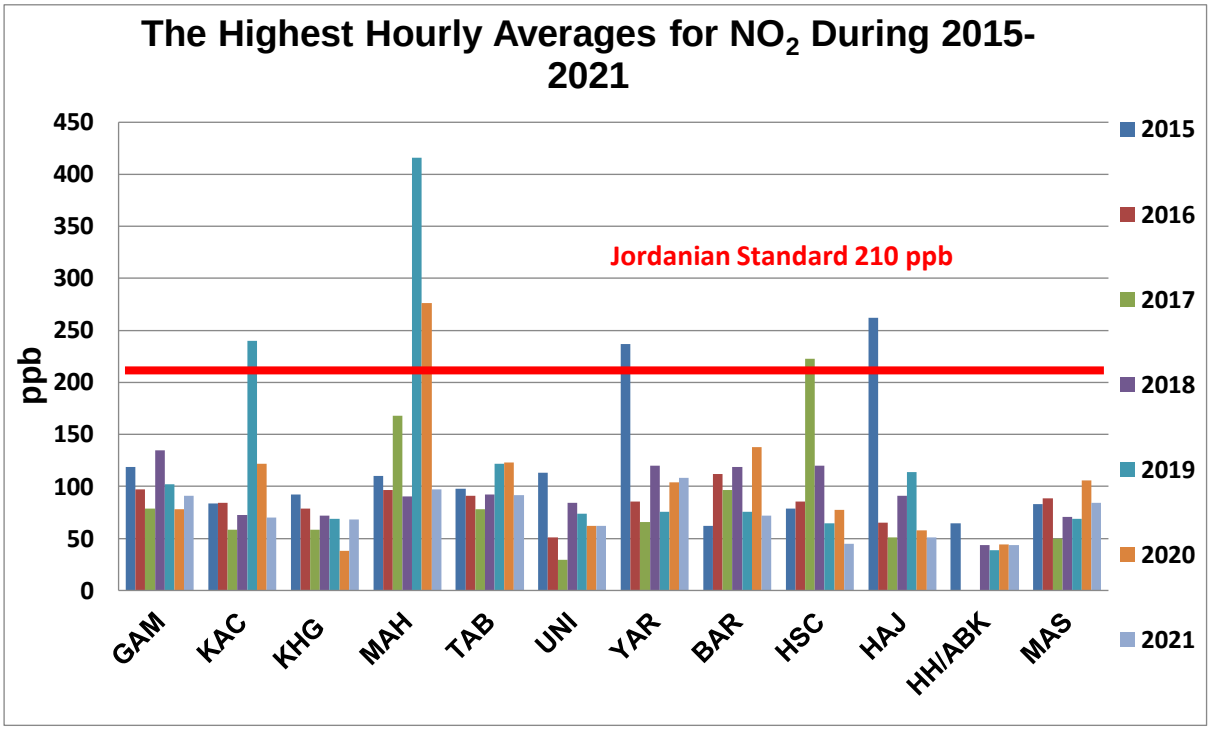


Figure 2.11: The highest hourly averages for (NO_2) during 2015-2021 in all stations

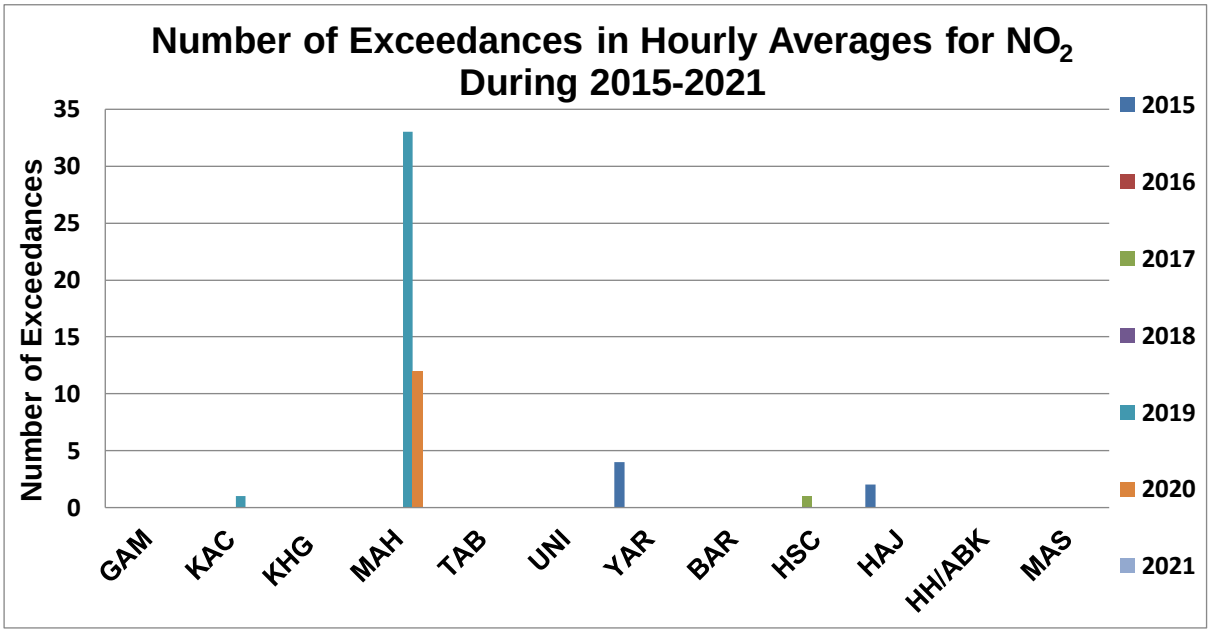


Figure 2.12: Number of exceedances in hourly averages for (NO_2) during 2015-2021 in all stations

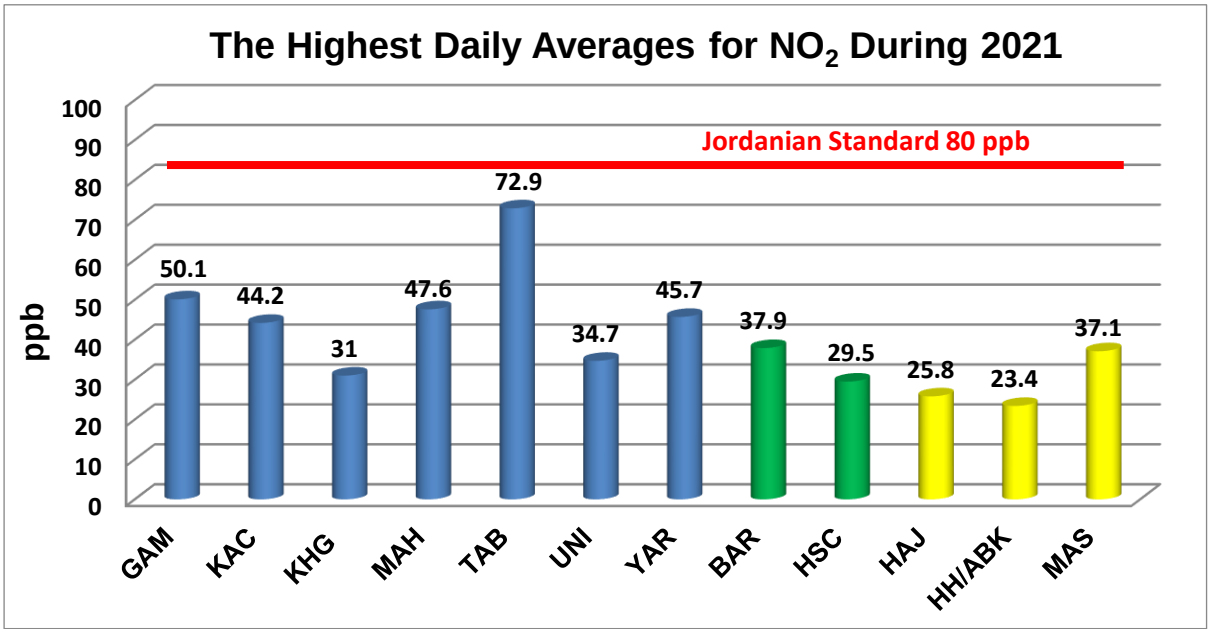


Figure 2.13: The highest daily averages for (NO_2) during 2021 in all stations

The results of ambient air quality monitoring showed that there were no excesses in the daily averages of NO_2 gas beyond the permissible limits in the Jordanian standard specification (1140/2006) in all monitoring stations as shown in the figure (2.13). Where the highest daily average of NO_2 gas was 72.9 ppb at "TAB" station in Amman.

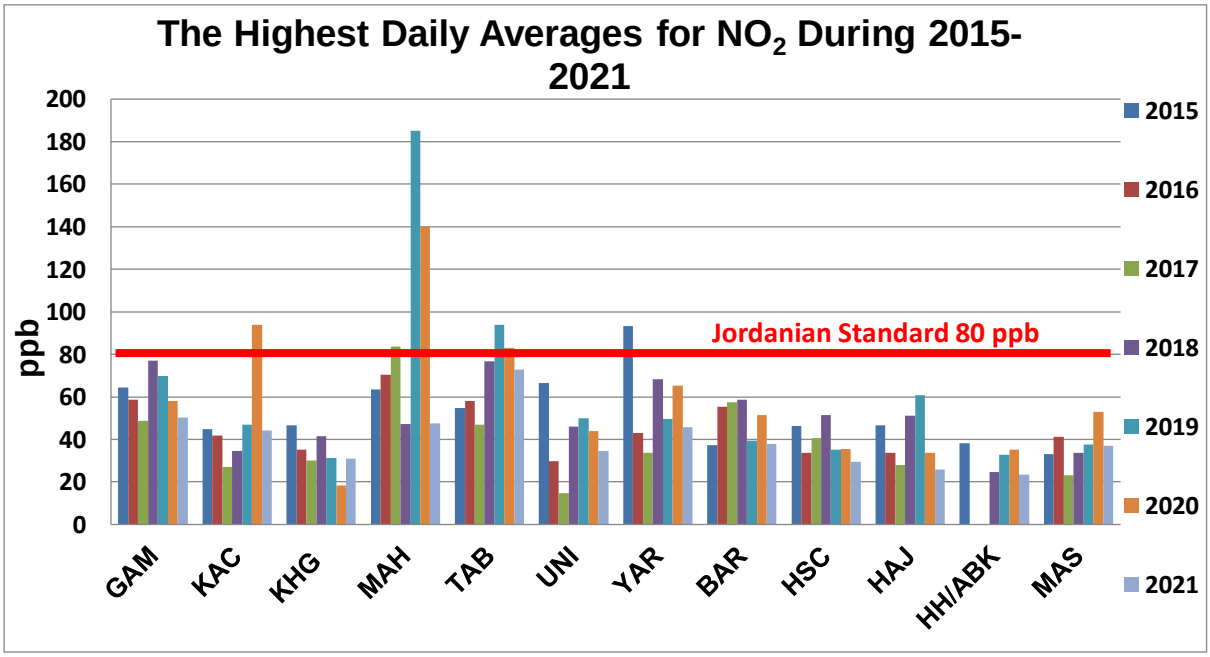


Figure 2.14: The highest daily averages for (NO_2) during 2015-2021 in all stations

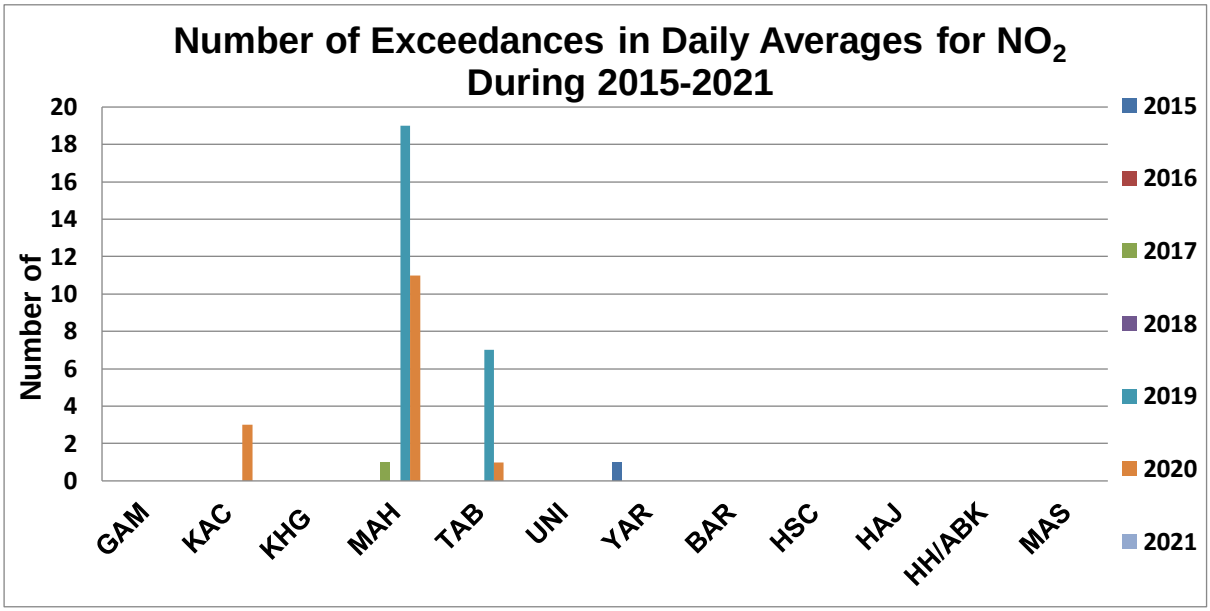


Figure 2.15: Number of exceedances in daily averages for (NO_2) during 2015-2021 in all stations.

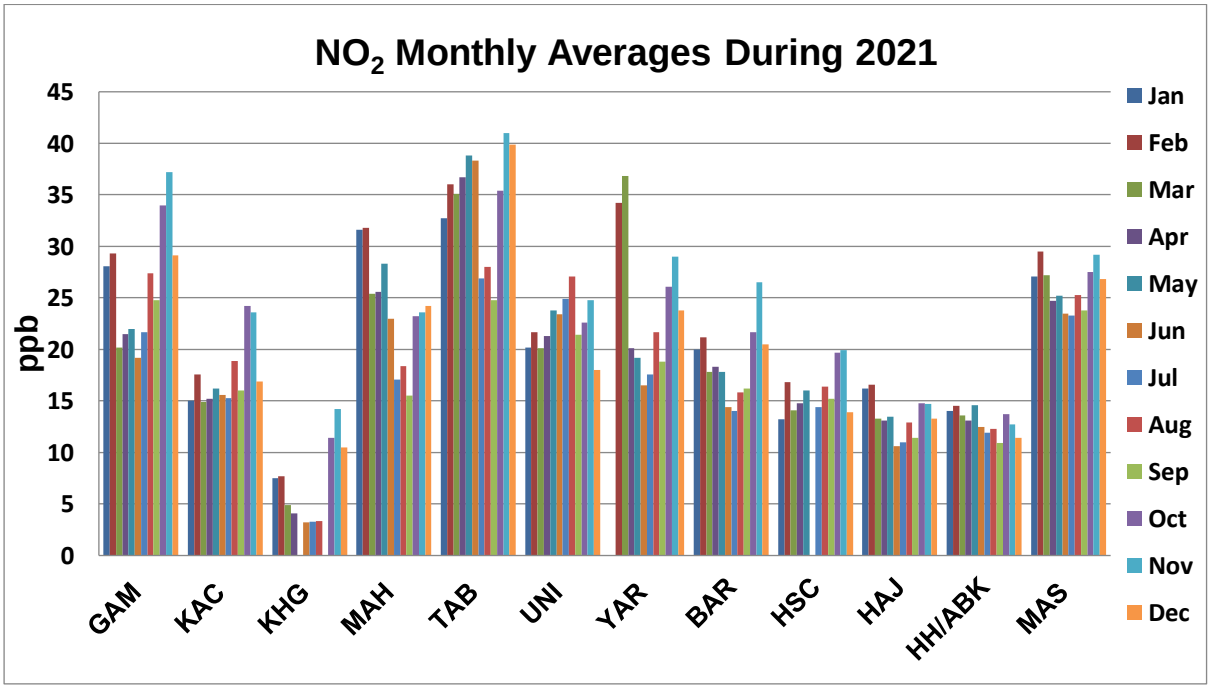


Figure 2.16: (NO_2) monthly averages during 2021 in all stations.

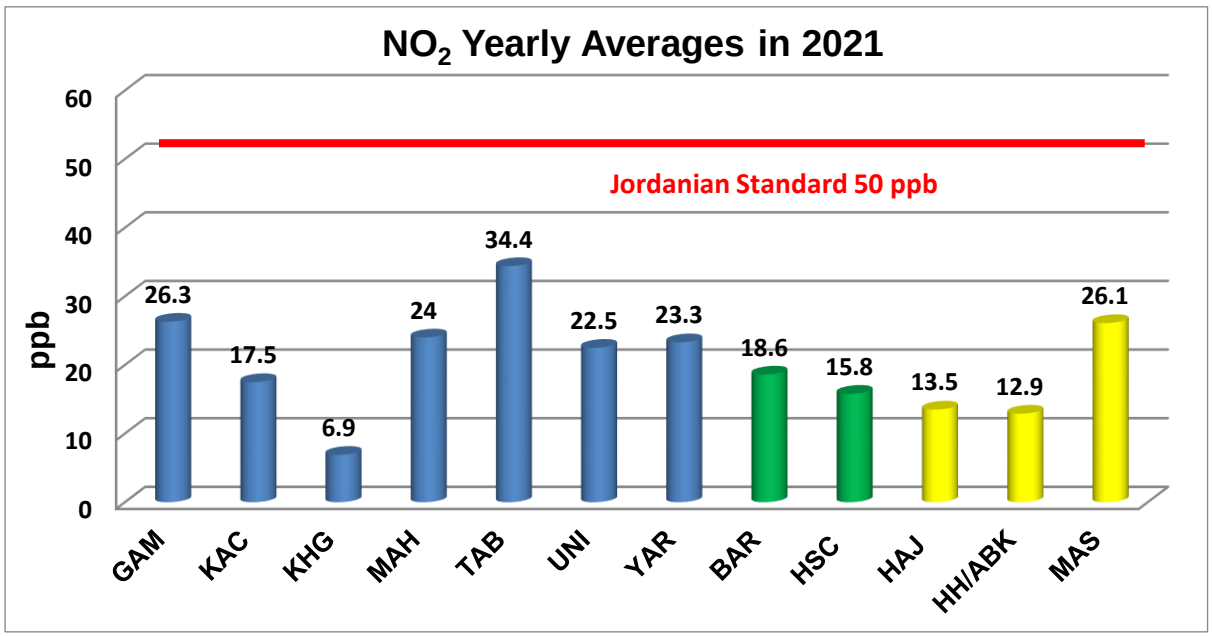


Figure 2.17: (NO_2) yearly averages in 2021 in all stations.

The results of ambient air quality monitoring showed that the annual averages of NO_2 were within the permissible limits in the Jordanian Standard (1140/2006) in all monitoring stations, where no exceedances were detected as shown in the figure (2.17).

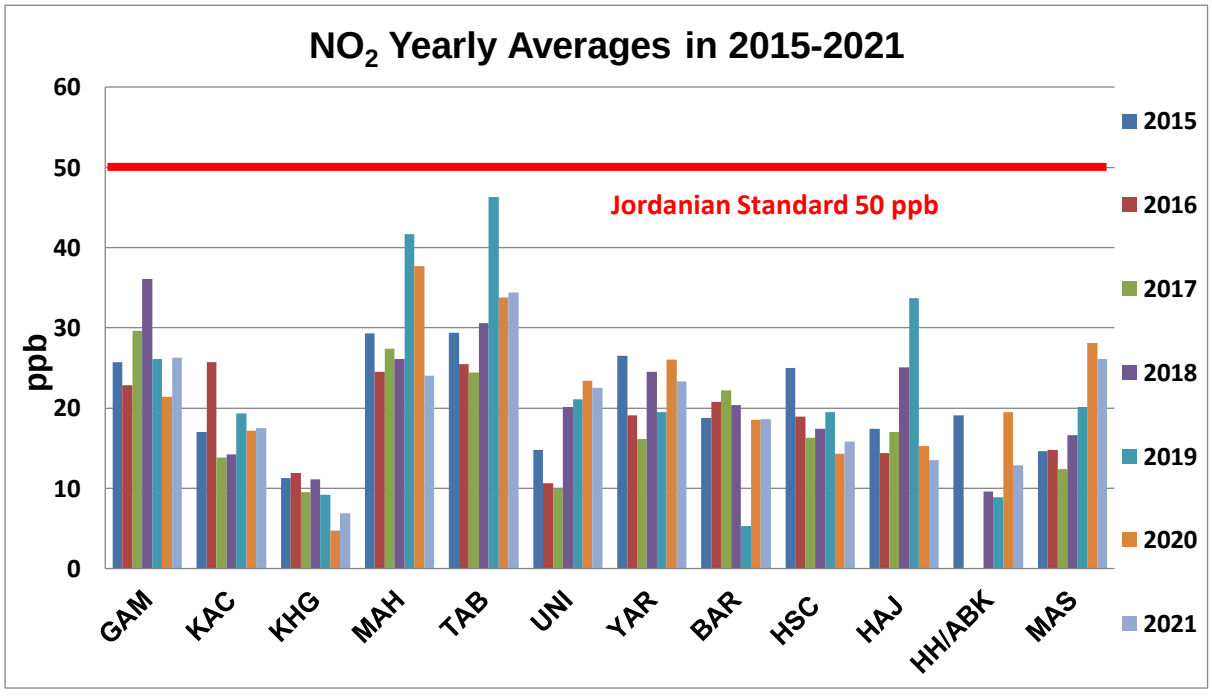


Figure 2.18: (NO_2) yearly averages during 2015-2021 in all stations.

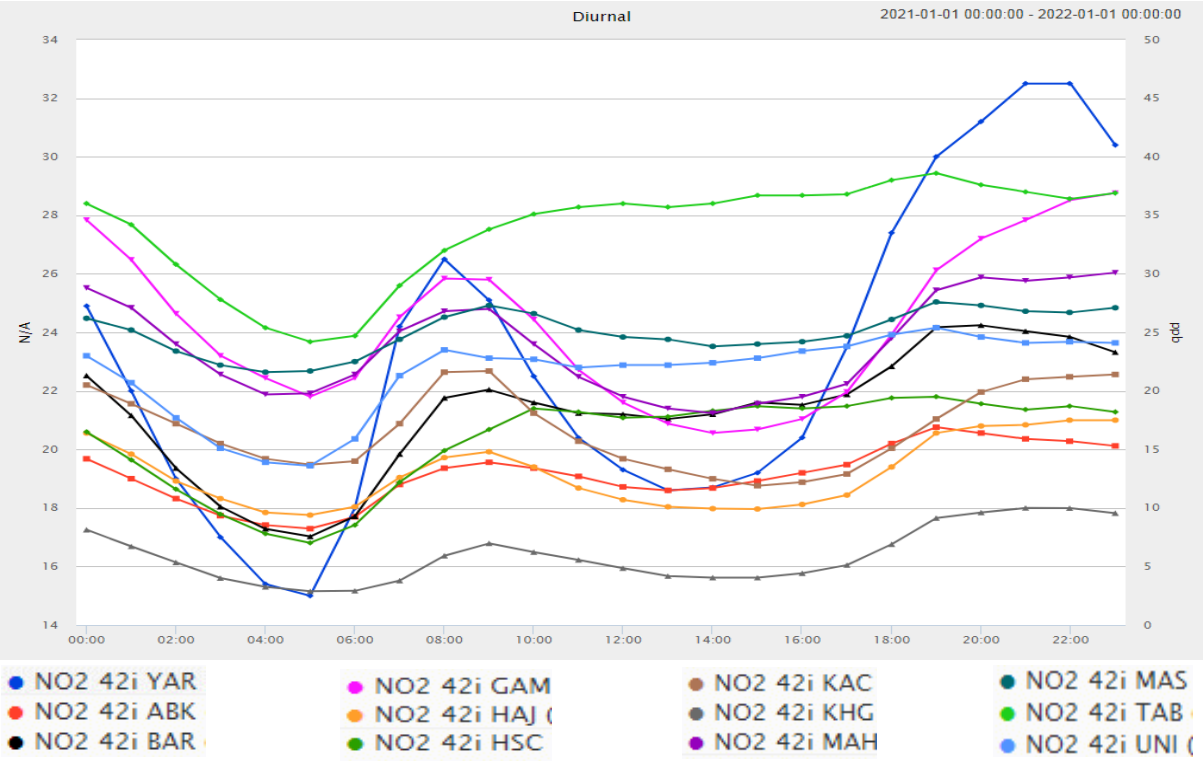


Figure 2.19: The average value of Nitrogen Dioxide (NO_2) in each hour of the day in all stations during 2021.

Monitoring results in all stations indicate that the concentrations are within the limits of technical rule No. 1140/2006 and that the highest readings of NO_2 occur during the peak period in traffic, between the hours (7-10 am) and (6-9 pm), and here we notice the difference in Concentration 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.

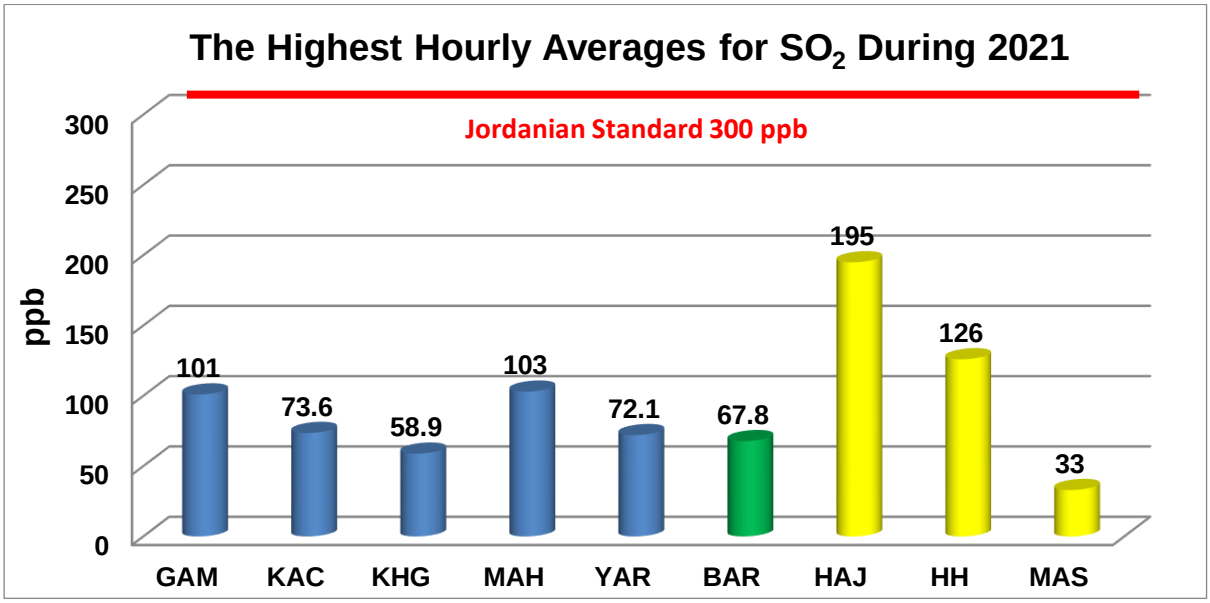


Figure 2.20: The highest hourly averages for (SO_2) during 2021

The results of ambient air quality monitoring showed that the hourly averages of SO_2 were within the permissible limits in the Jordanian Standard (1140/2006) in all monitoring stations, as no excess was detected as shown in the figure (2.20), where the highest hourly average of SO_2 was 195 ppb at Wadi Al Hajar in Zarqa.

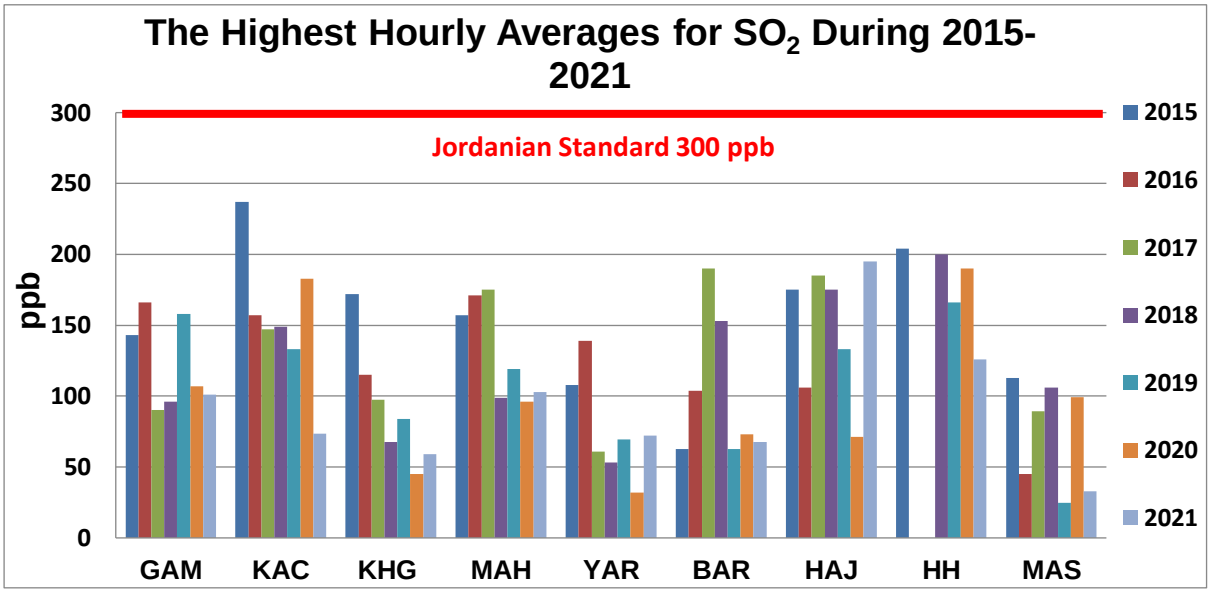


Figure 2.21: The highest hourly averages for (SO_2) during 2015-2021

The results of ambient air quality monitoring showed that the level of sulfur dioxide concentration for the hourly averages was within the permissible limit in the Jordanian Standard Specification (1140/2006), where no exceedances have been detected since the beginning of the monitoring process so far.

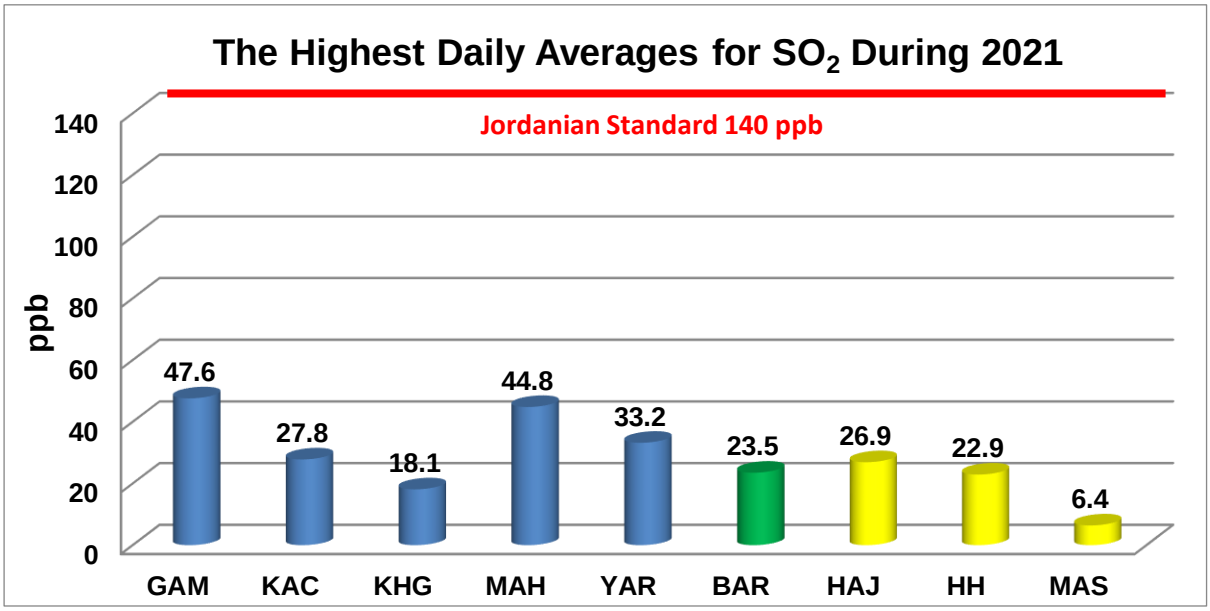


Figure 2.22: The highest daily averages for (SO_2) during 2021.

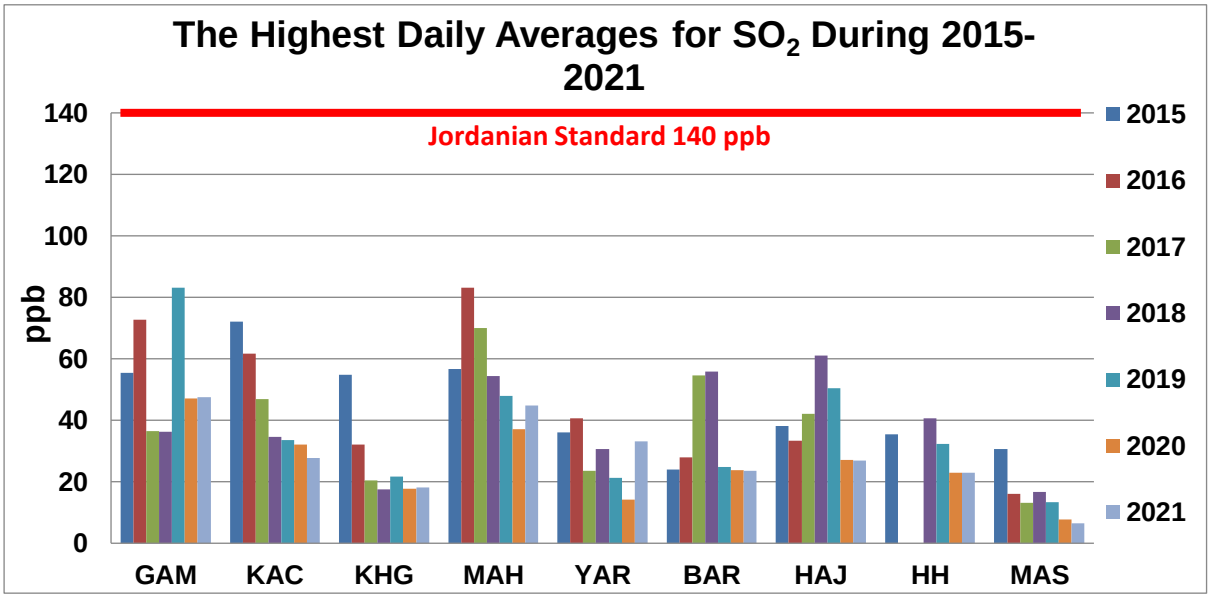


Figure 2.23: The highest daily averages for (SO_2) during 2015-2021

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

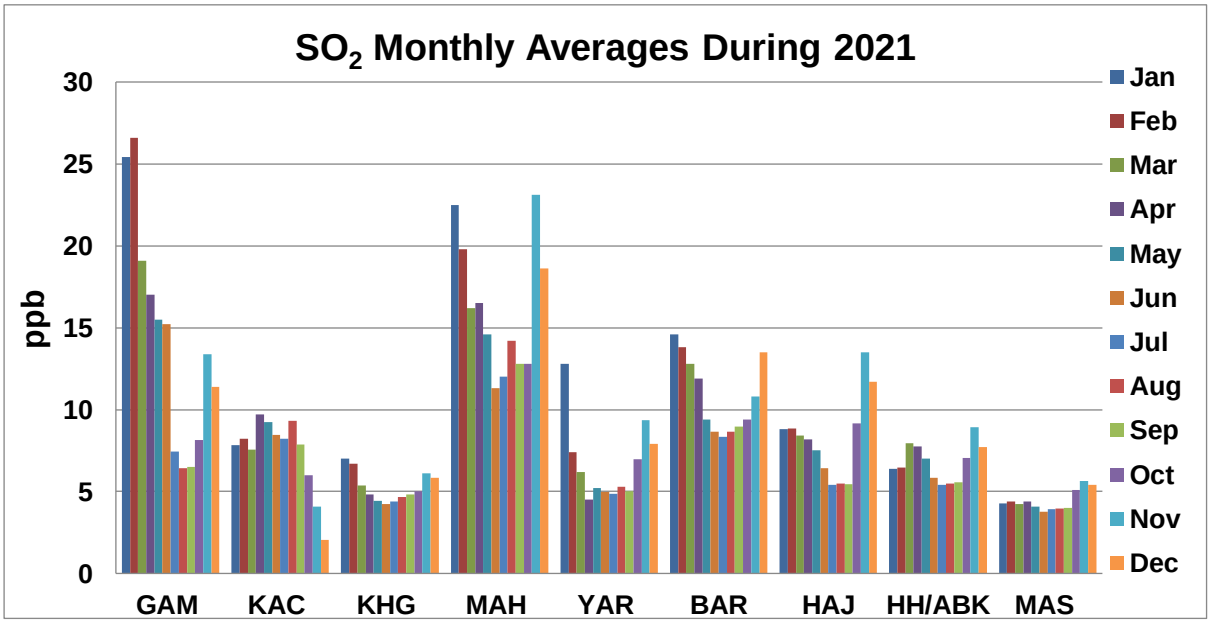


Figure 2.24: (SO_2) monthly averages during 2021

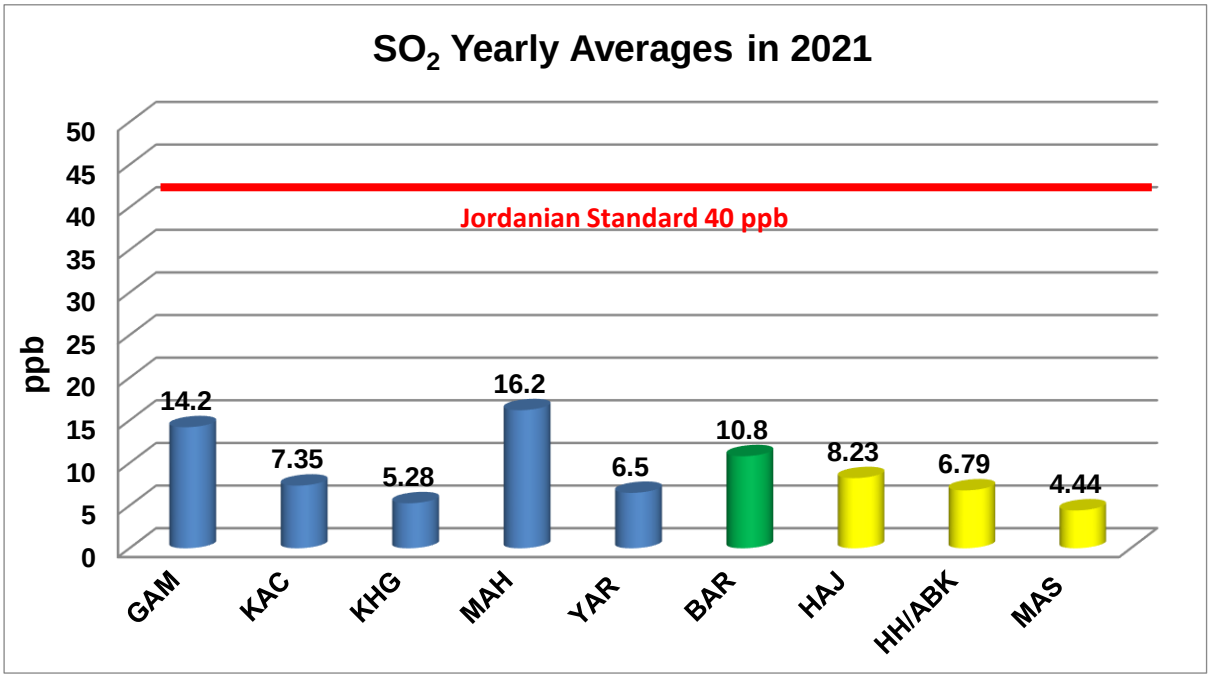


Figure 2.25: (SO_2) yearly averages during 2021.

The results of ambient air quality monitoring showed that the annual averages of SO_2 were within the permissible limits in the Jordanian Standard (1140/2006) in all monitoring stations, where no excess was detected as shown in the figure (2.25), where the highest annual average was 16.2 ppb at Al Mahatta in Amman.

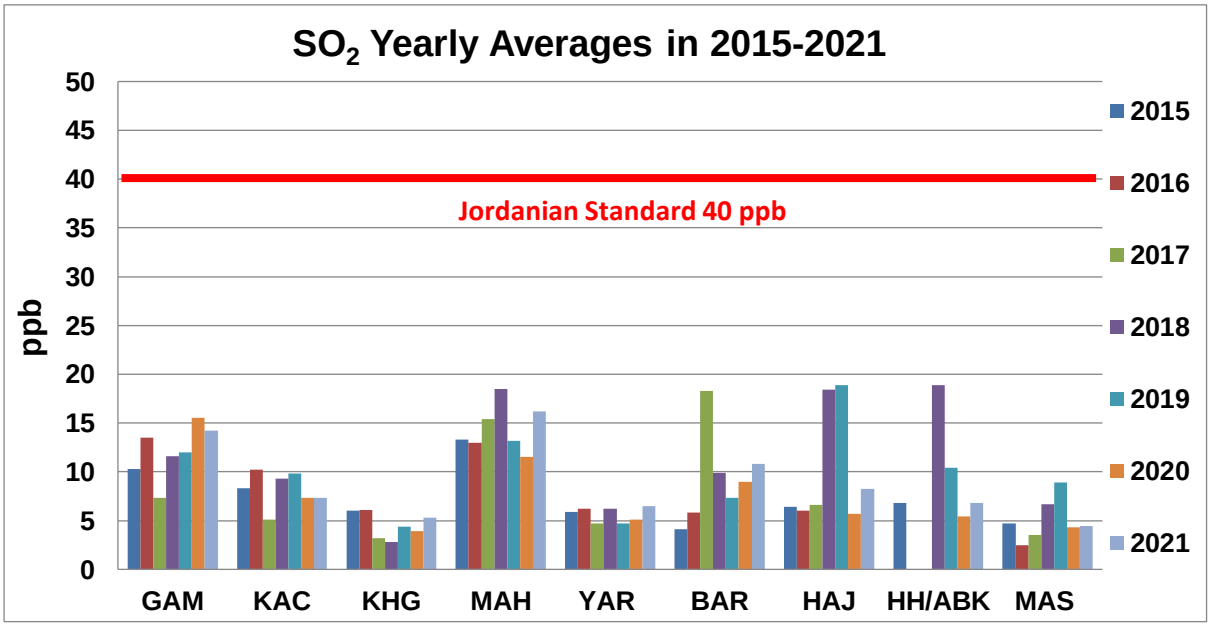


Figure 2.26: (SO_2) yearly averages during 2015-2021.

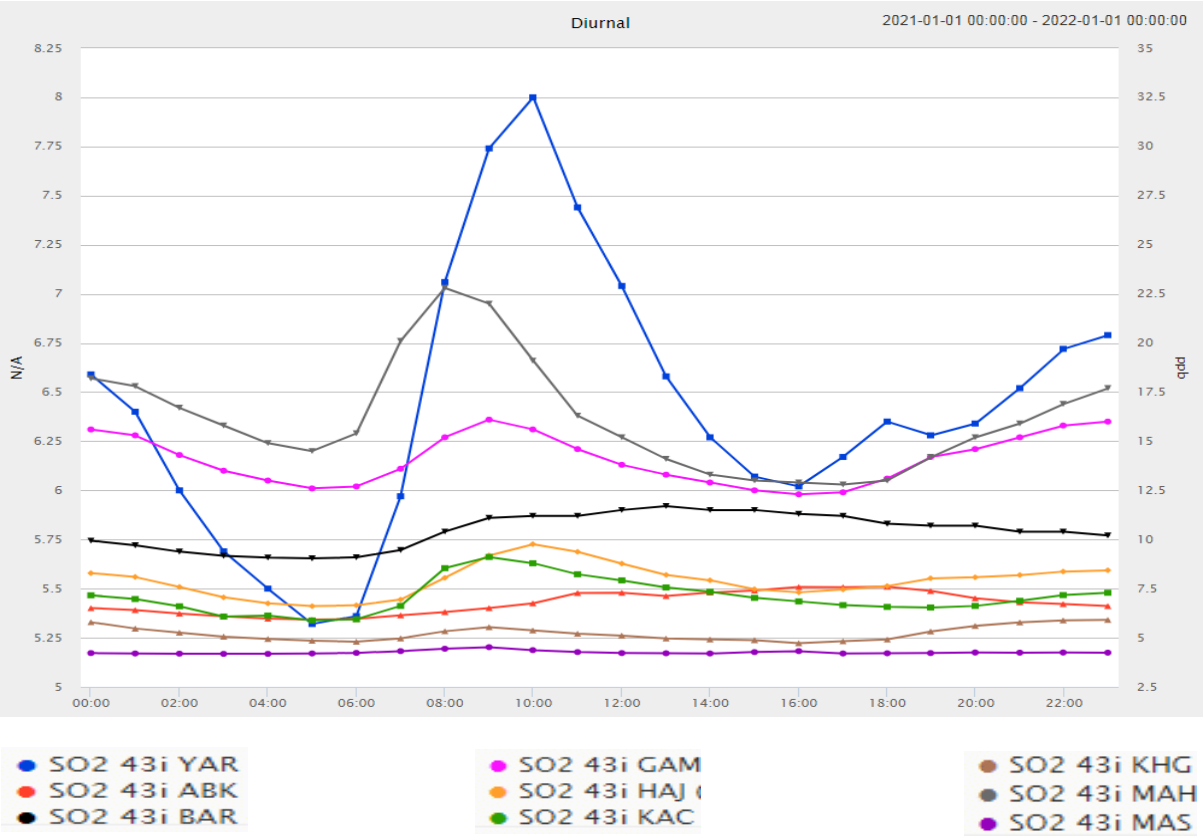


Figure 2.27: The average value of Sulfur Dioxide (SO_2) in each hour of the day in all stations during 2021.

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, colourless 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.

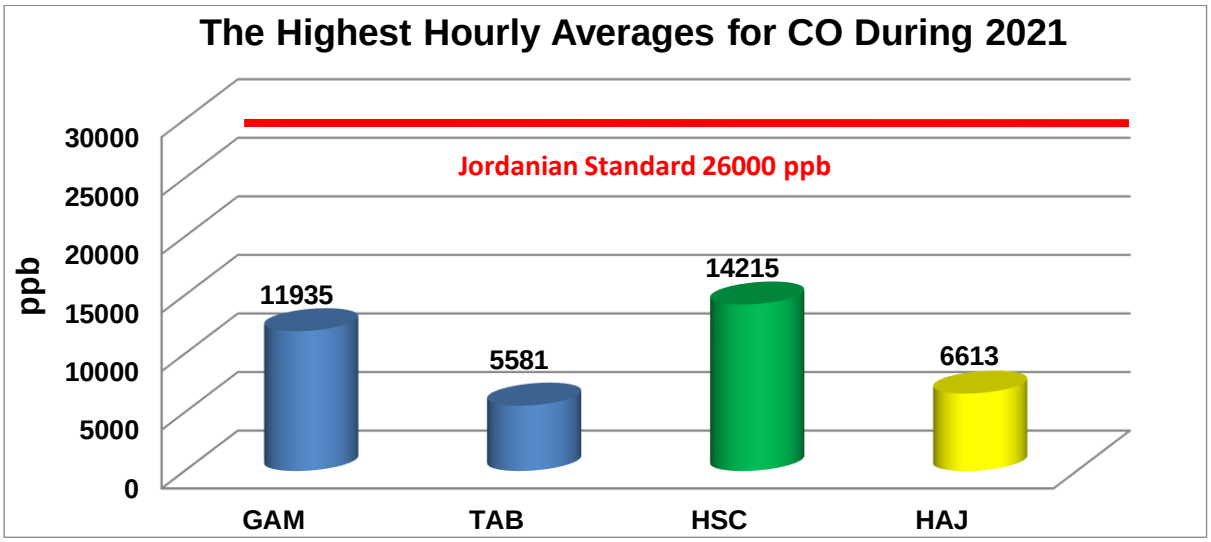


Figure 2.28: The highest hourly averages for (CO) during 2021

The results of ambient air quality monitoring showed that the hourly averages of CO gas were within the permissible limits in the Jordanian Standard (1140/2006) in all monitoring stations, where no excess was detected as shown in the figure (2.28), where the highest hourly average of CO gas was 14215 ppb at Al Hassan Sport City in Irbid.

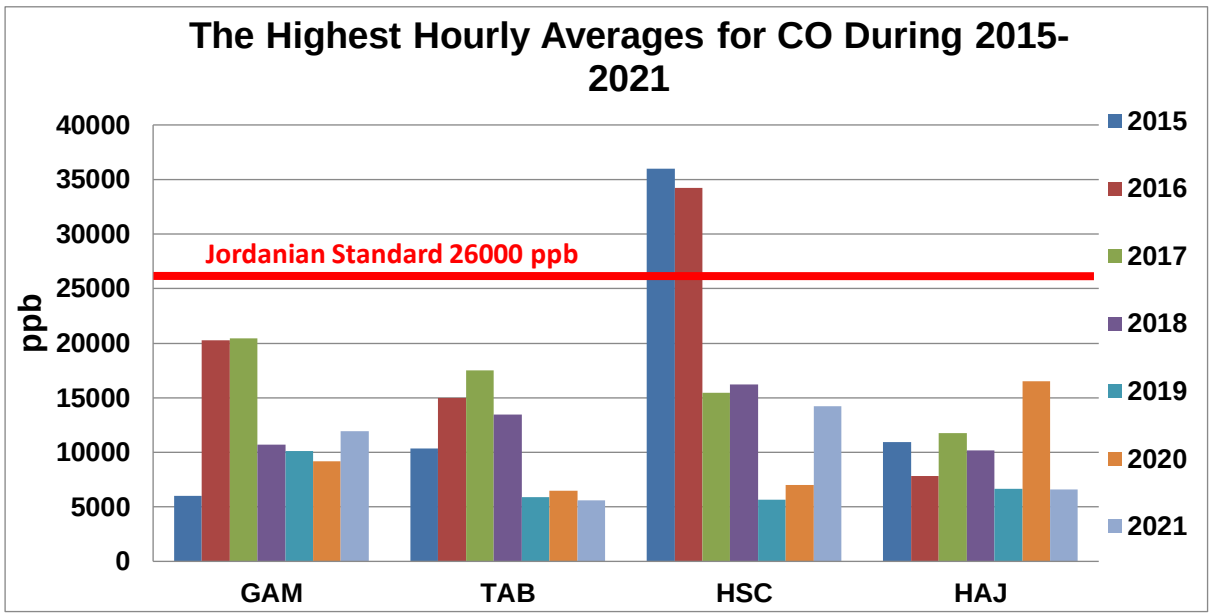


Figure 2.29: The highest hourly averages for (CO) during 2015-2021

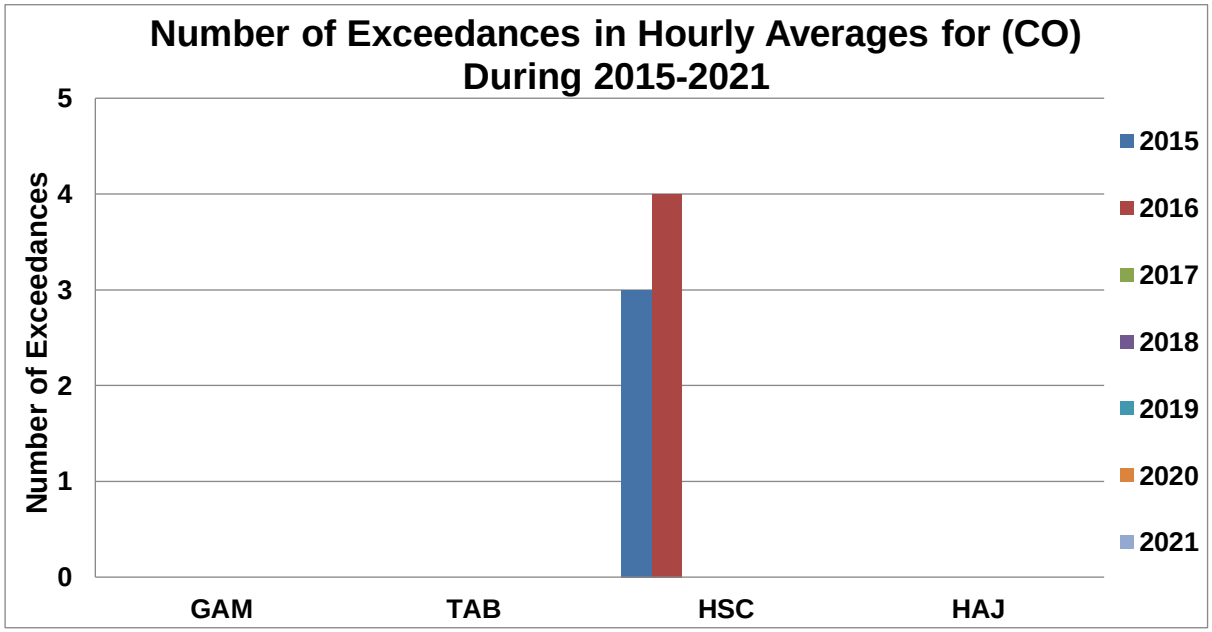


Figure 2.30: Number of exceedances in hourly averages for (CO) during 2015-2021

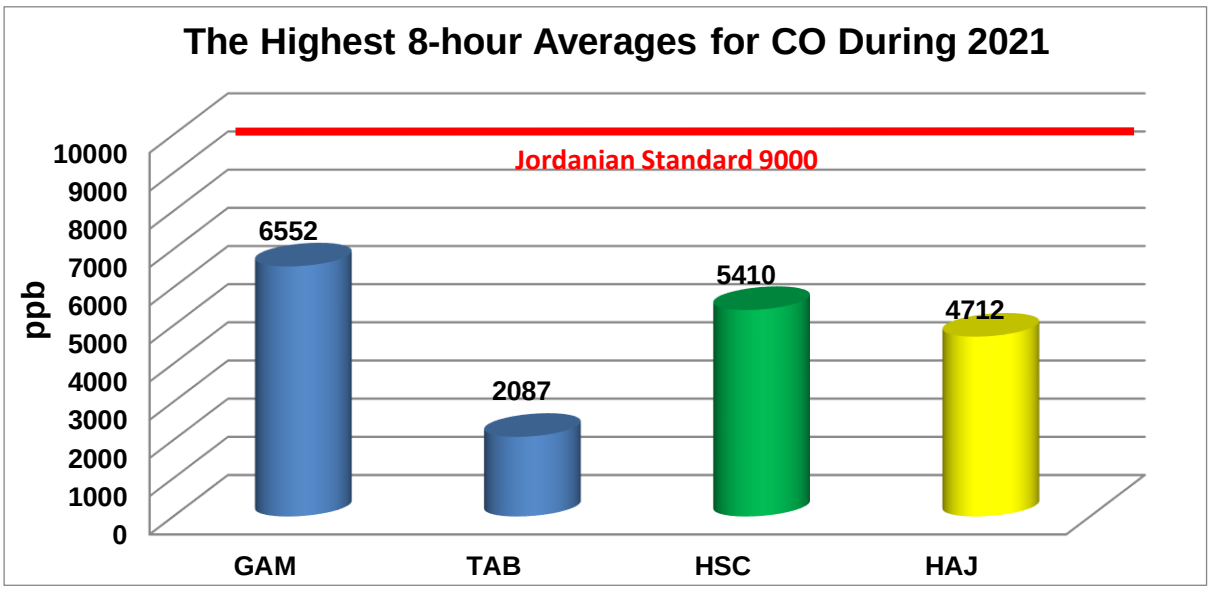


Figure 2.31: The highest 8-hour averages of (CO) during 2021

The results of ambient air quality monitoring showed that the daily averages (the 8-hour averages) of CO gas were within the permissible limits in the Jordanian Standard (1140/2006) in all monitoring stations, where no excess was detected as shown in the figure (2.31), Where the highest daily average of CO gas reached 6552 ppb at the Greater Amman Municipality station in Amman.

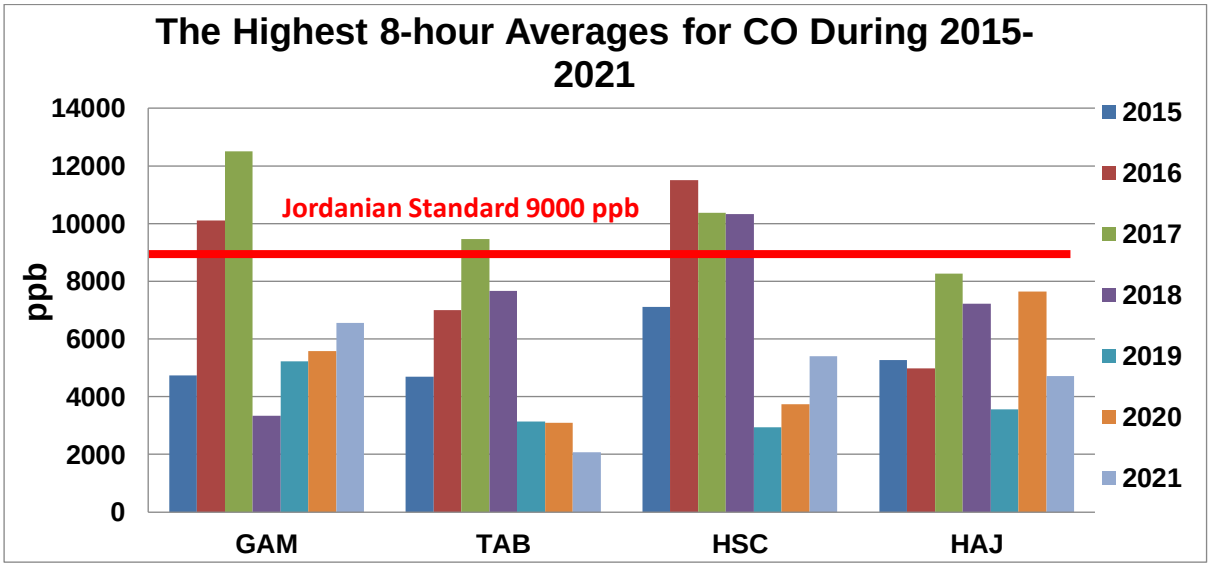


Figure 2.32: The highest 8-hour averages of (CO) during 2015-2021

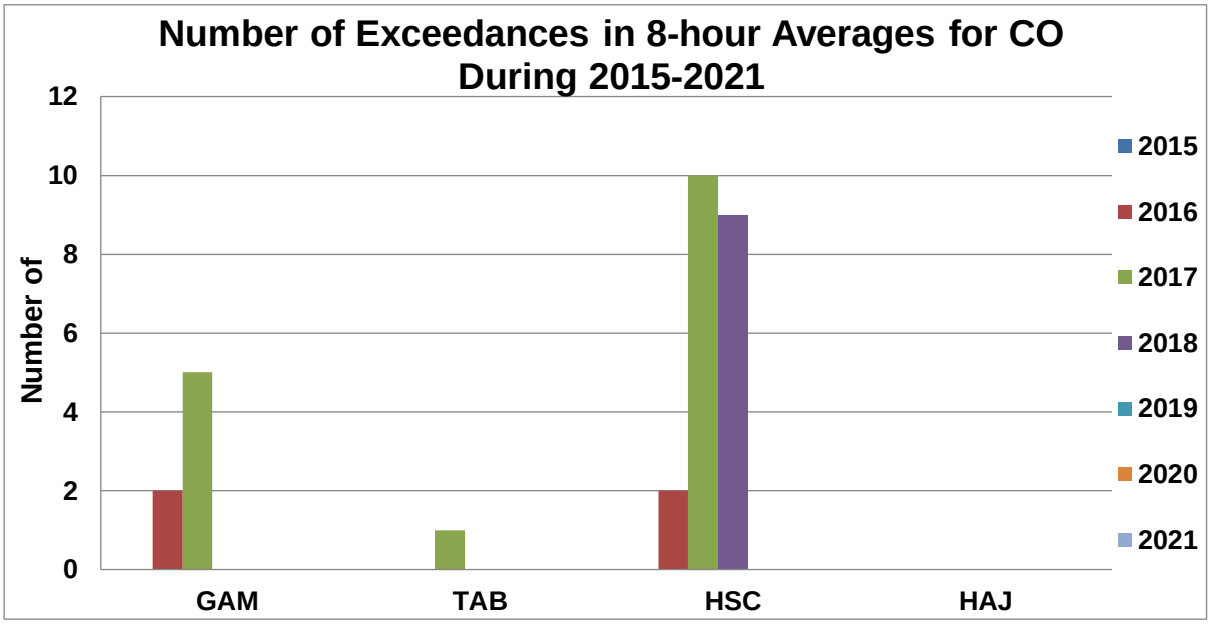


Figure 2.33: Number of exceedances in 8-hour averages for (CO) during 2015-2021

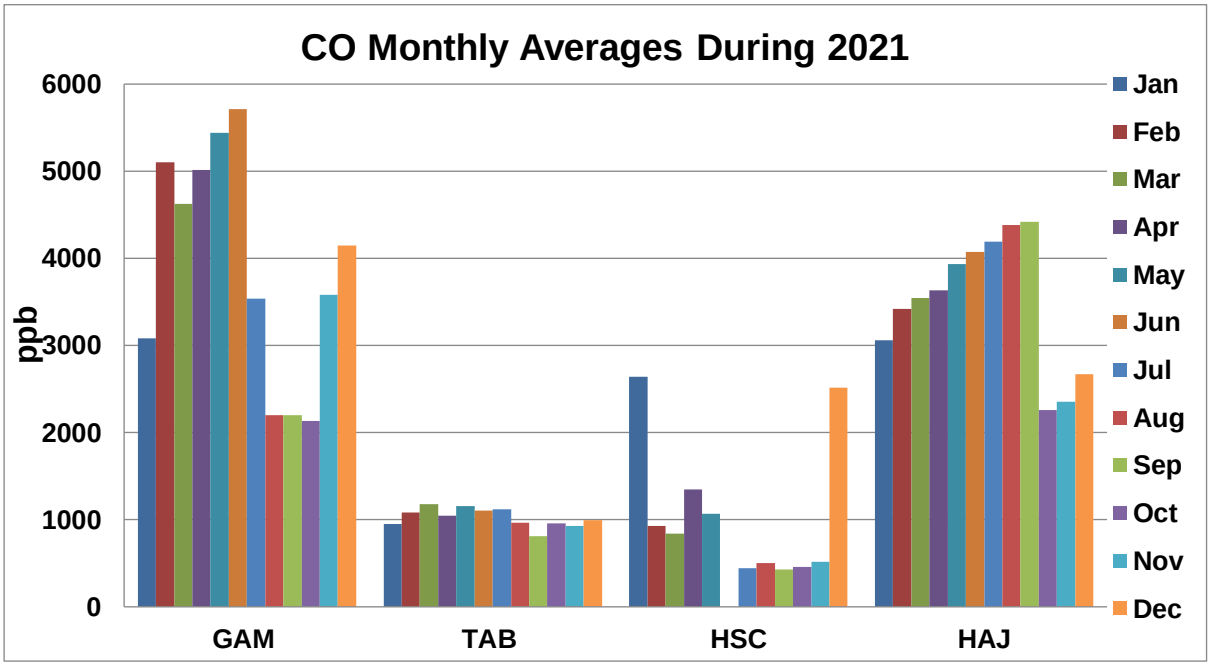


Figure 2.34: (CO) monthly averages during 2021

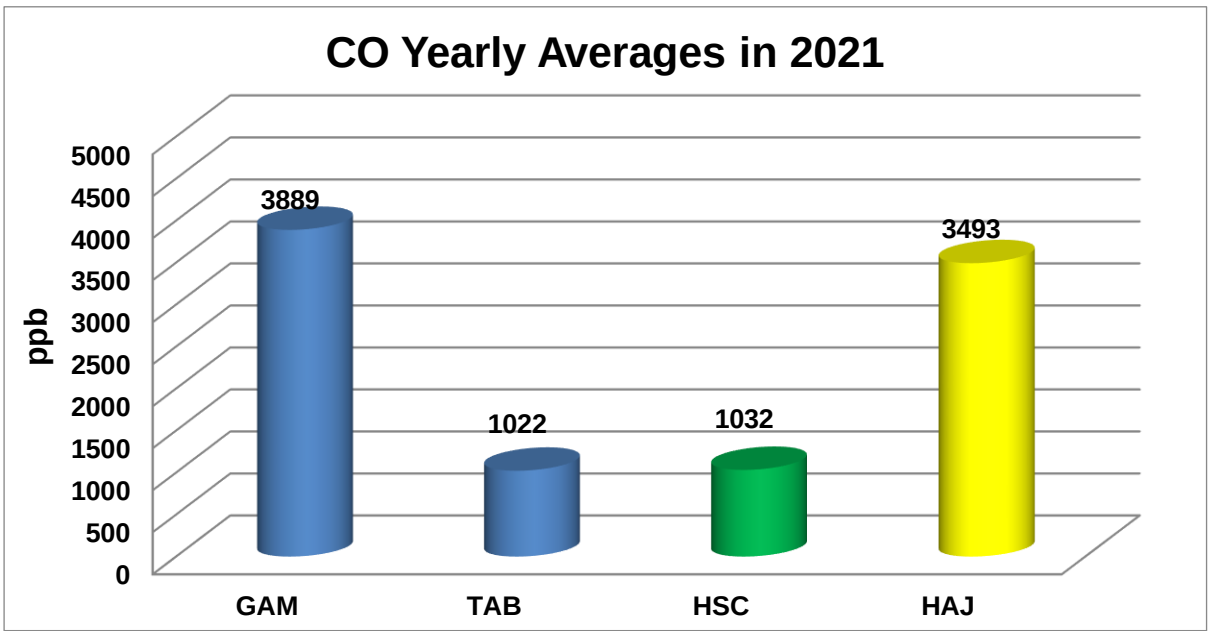


Figure 2.35: (CO) yearly averages during 2021

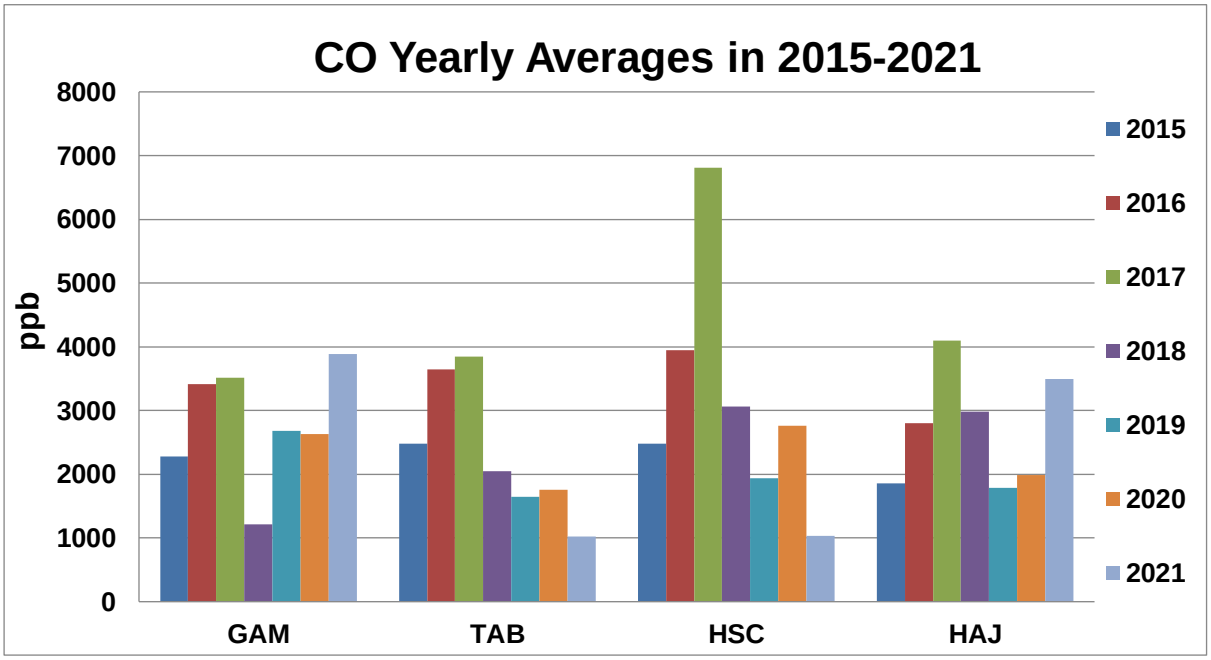


Figure 2.36: (CO) yearly averages during 2015-2021

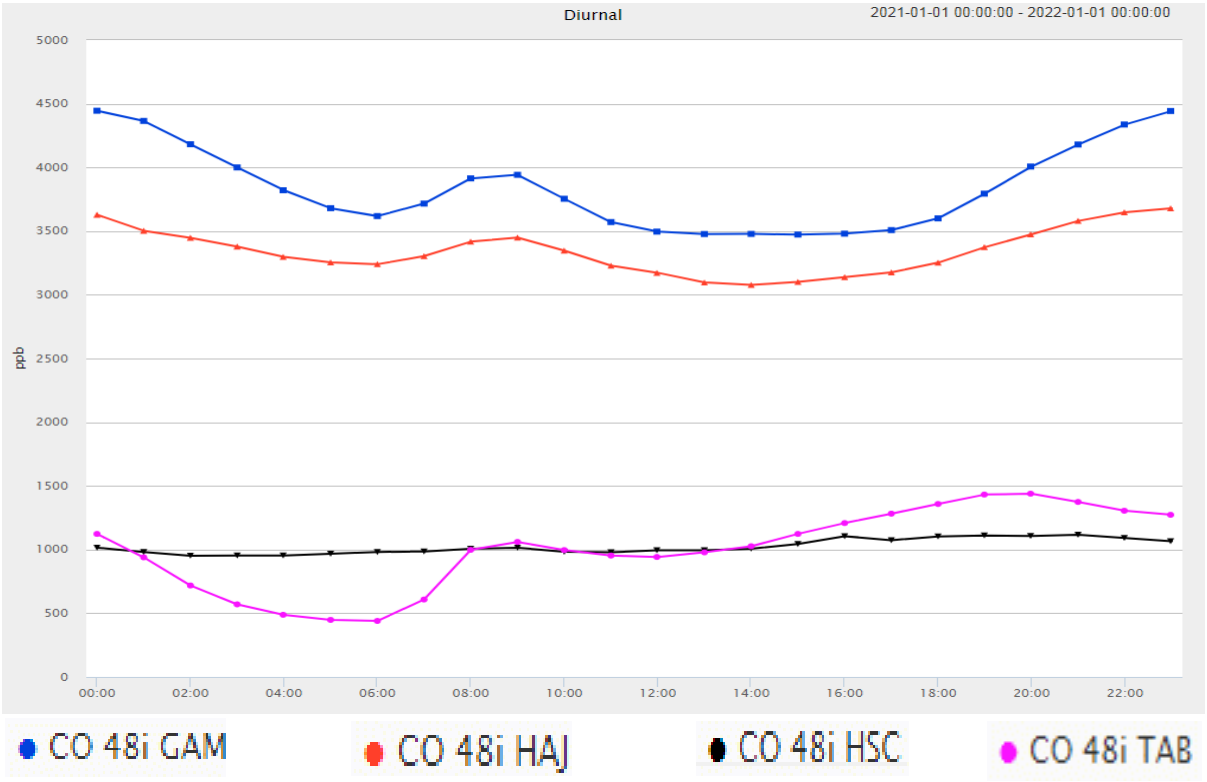


Figure 2.37: The average value of Carbon monoxide (CO) in each hour of the day in all stations during 2021.

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 O2), 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 (VOCs), undergo photochemical reactions in air in the presence of sunlight. Thus NO_2, CO, and VOCs 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 kilometres, 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.

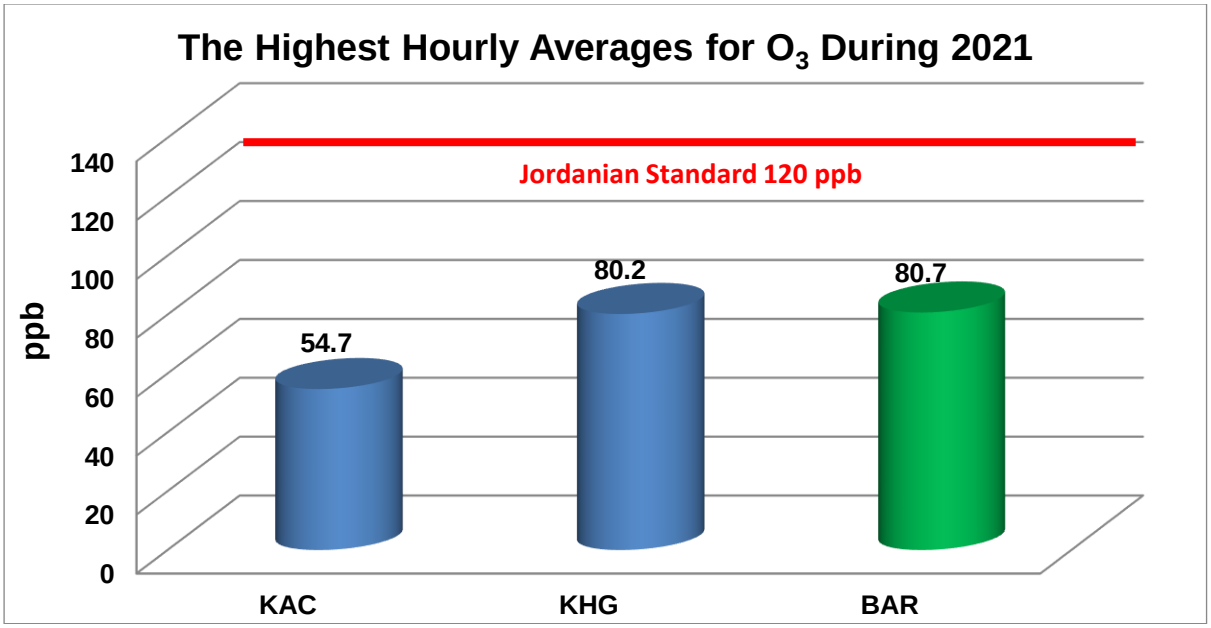


Figure 2.38 The highest hourly averages for (O_3) during 2021.

The results of ambient air quality monitoring showed that the hourly averages of O_3 were within the permissible limit in the Jordanian Standard (1140/2006) where no excess was detected as shown in the figure (2.38).

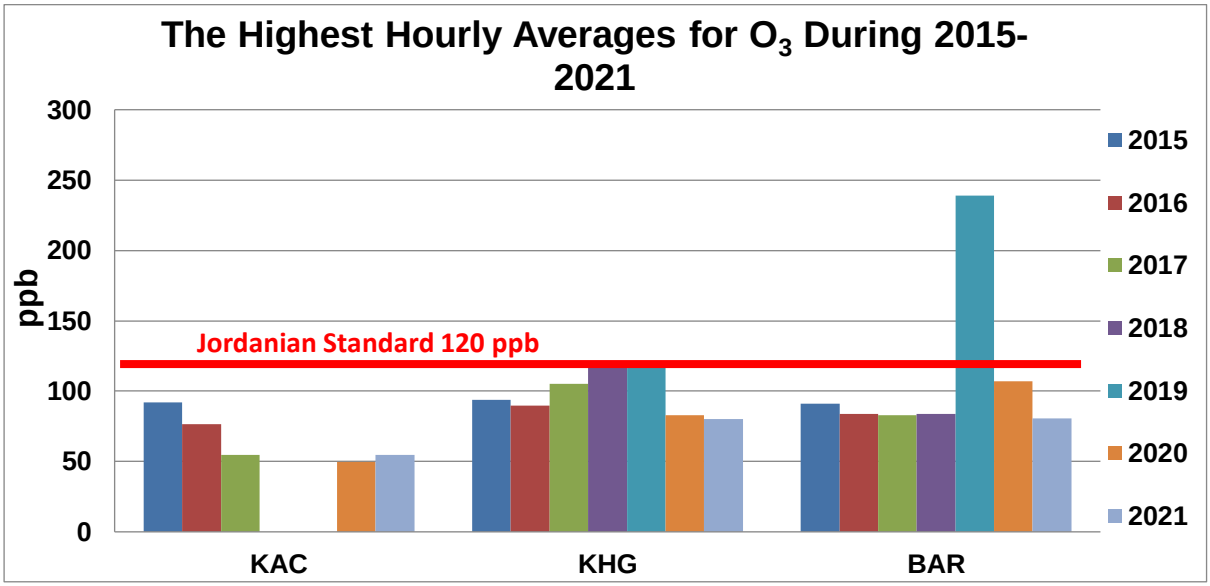


Figure 2.39: The highest hourly averages for (O_3) during 2015-2021.

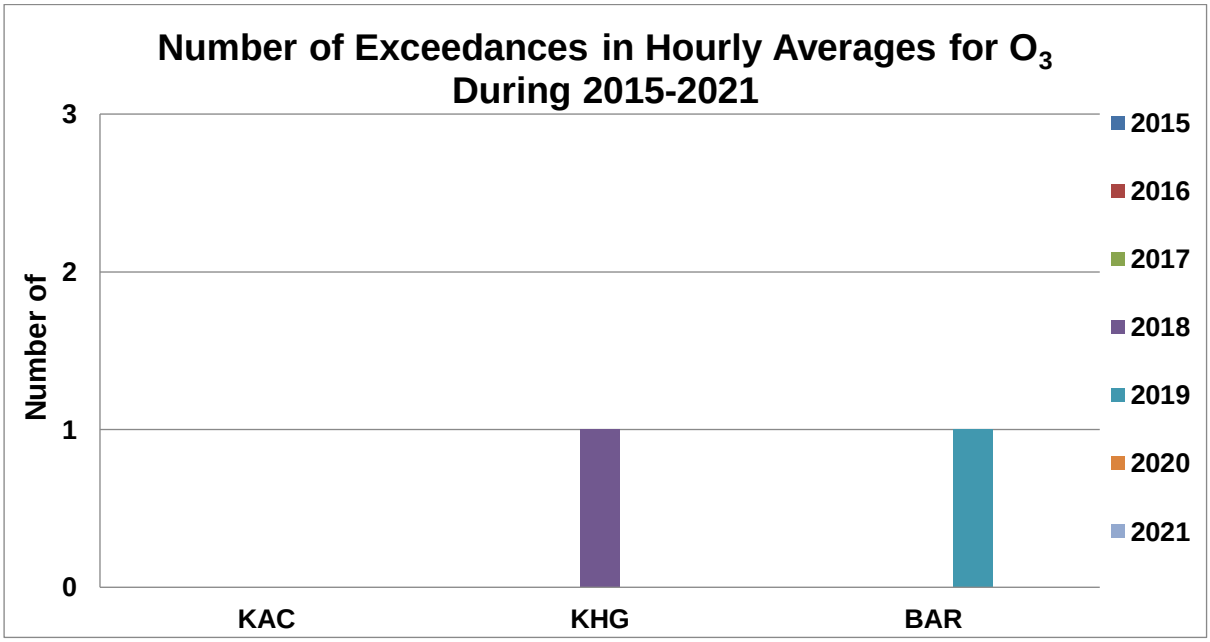


Figure 2.40: Number of exceedances in hourly averages for (O_3) during 2015-2021

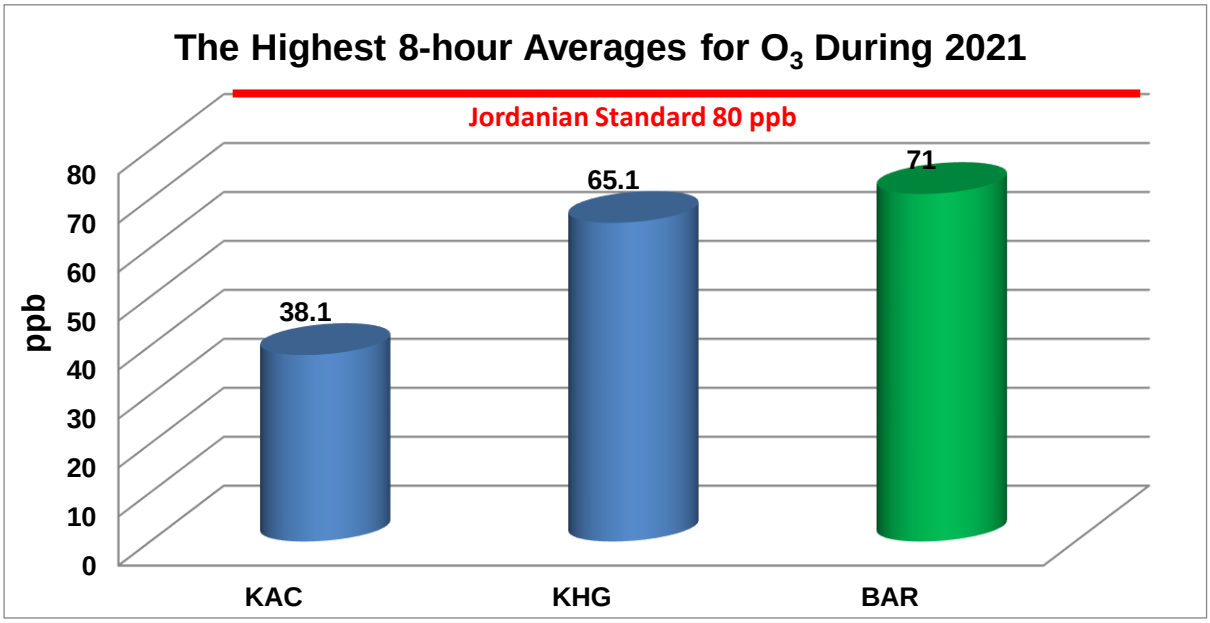


Figure 2.41: The highest 8-hour averages of (O_3) during 2021

The results of ambient air quality monitoring showed that the daily averages (the 8-hour averages) of O_3 were within the permissible limits in the Jordanian Standard Specification (1140/2006), where no excess was detected as shown in the figure (2.41), where the highest daily average (highest 8-hour average) of O_3 gas was 71 ppb at Al Barha Street station in Irbid.

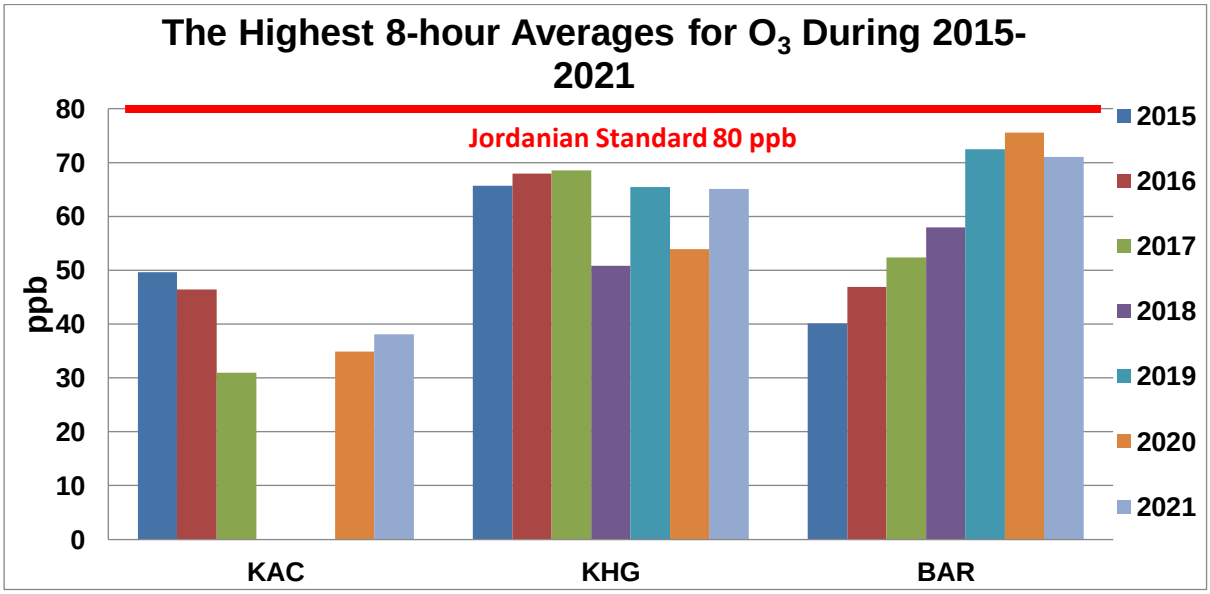


Figure 2.42: The highest 8-hour averages of (O_3) during 2015-2021

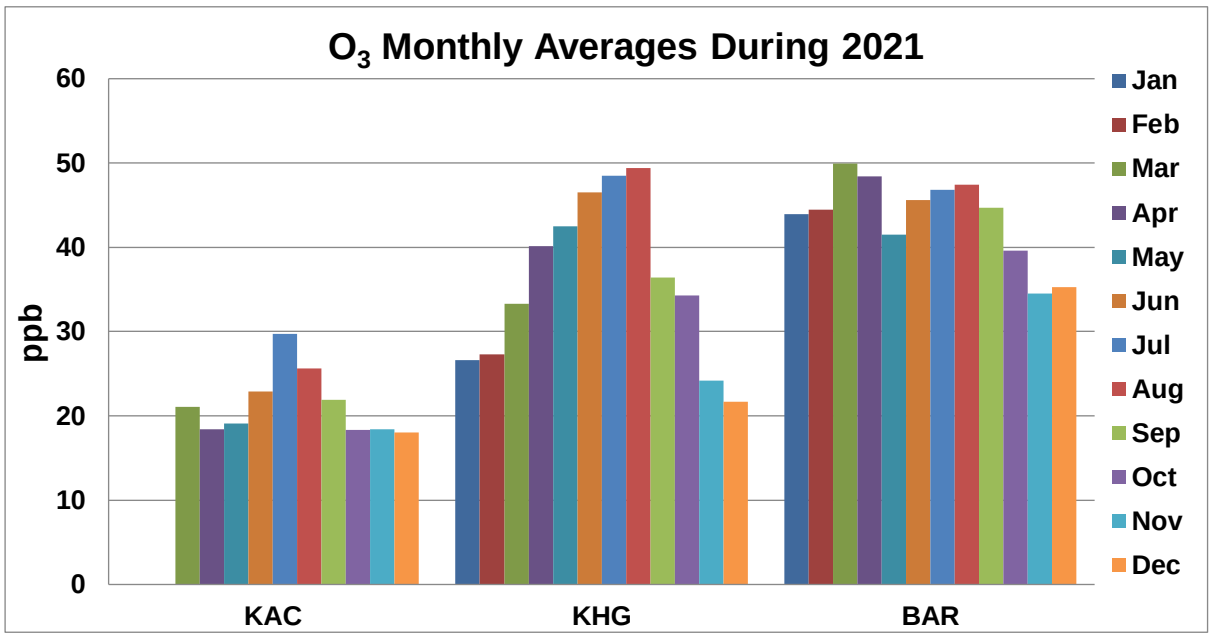


Figure 2.43: (O_3) monthly averages during 2021.

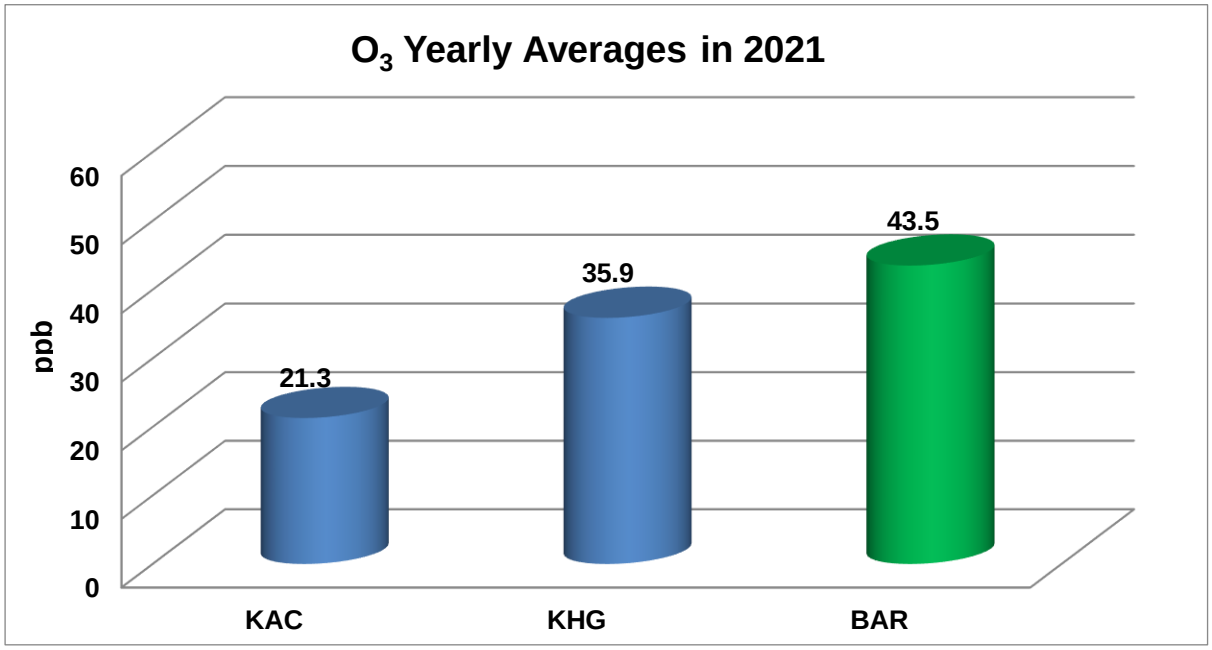


Figure 2.44: (O_3) yearly averages during 2021

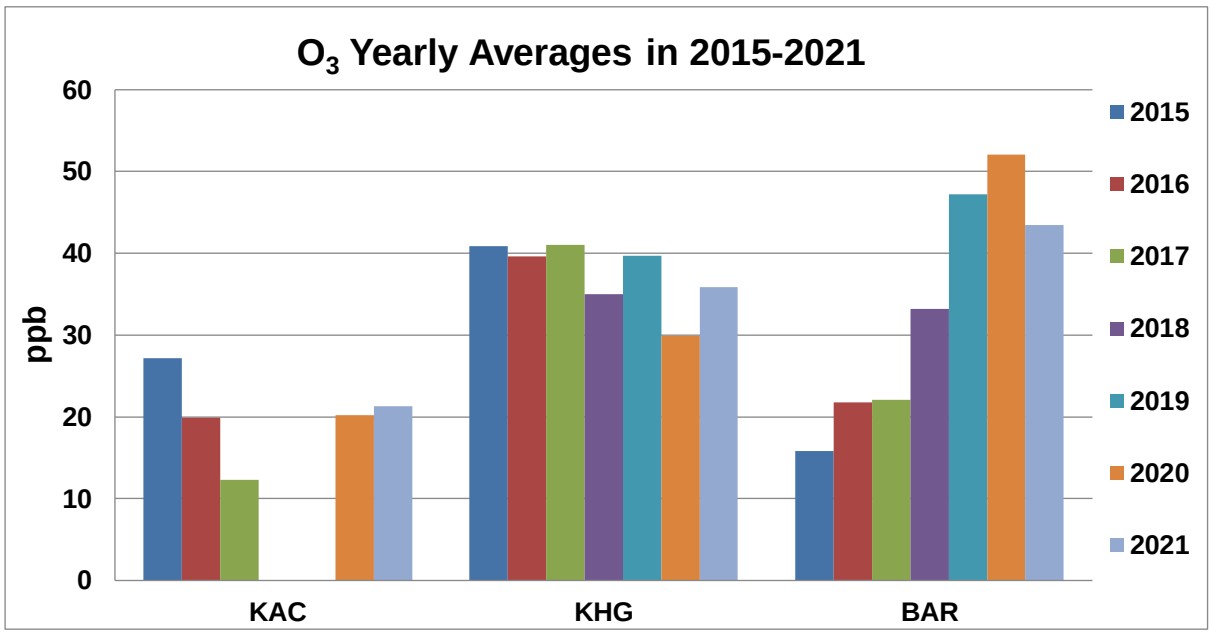


Figure 2.45: (O_3) yearly averages during 2015-2021

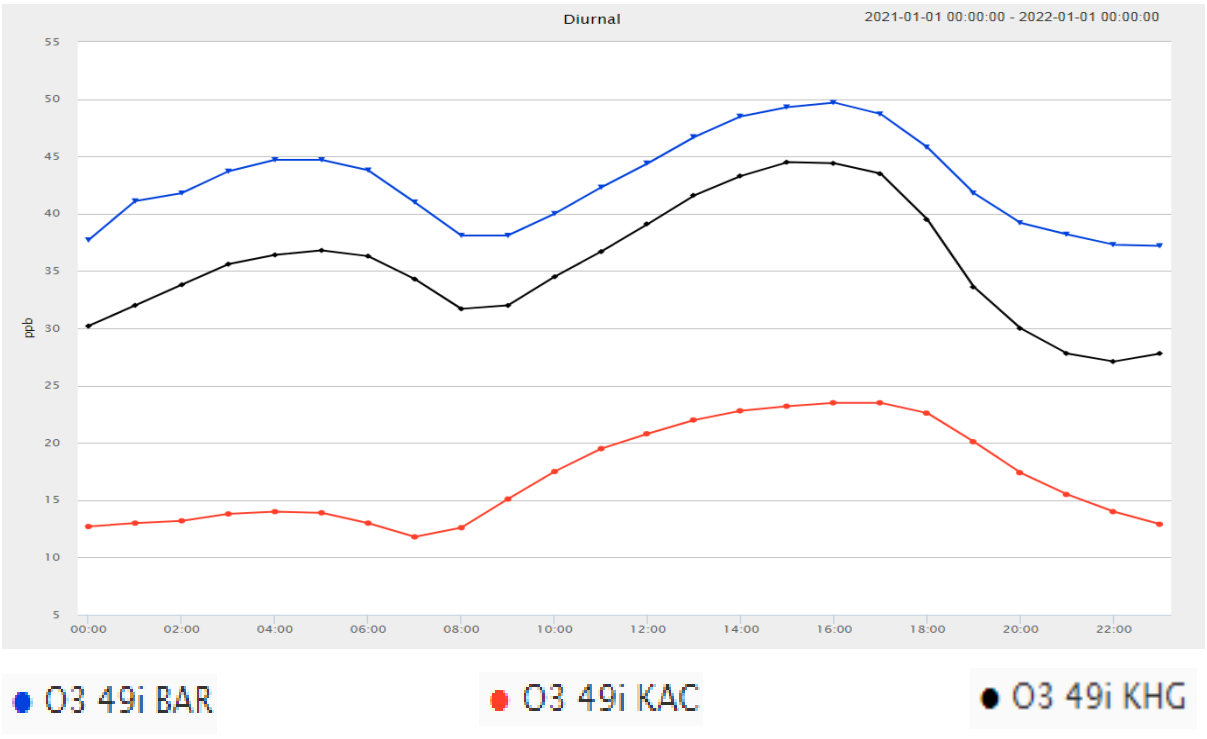


Figure 2.46: The average value of Ozone (O_3) in each hour of the day in all stations during 2021

2.6 Meteorology: Wind Speed and Direction, Temperature and Humidity

As shown in figure (2.47), wind direction at the King Hussein Gardens (Reference station) in Amman is mainly from the south/south west, where the annual average wind direction was 241°. Wind direction at the Barha street station in Irbid figure (2.48) is almost south east, where the average wind direction is 126°. And in Zarqa – Wadi Al-Hajjar station figure (2.49) the wind is mainly from the north west, where the direction of the wind is 251°.

King Hussein Gardens (Amman) station

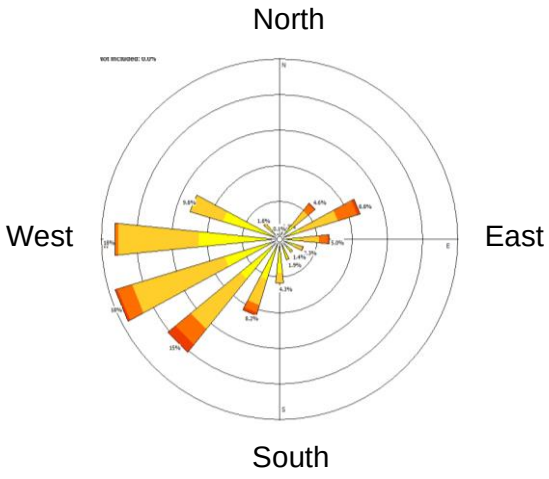
Temperature

- Minimum daily temperature: -0.39 °C
- Maximum daily temperature: 28.3 °C
- Minimum hourly temperature: -2.31 °C
- Maximum hourly temperature: 35 °C
- Average yearly temperature: 16.3 °C

Humidity

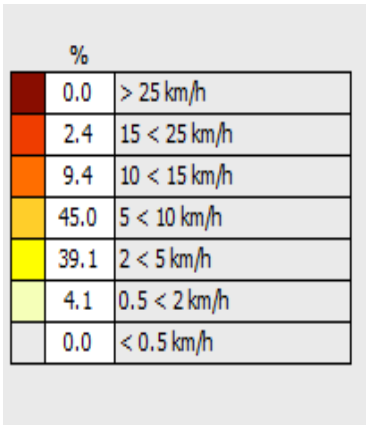
- Minimum daily humidity: 24.7 %
- Maximum daily humidity: 100 %
- Minimum hourly humidity: 19 %
- Maximum hourly humidity: 100 %
- Average yearly humidity: 60.5 %

Wind direction



Average: 241°

Wind Speed



Average: 6.1 km/h

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

Al Barha Street (Irbid)

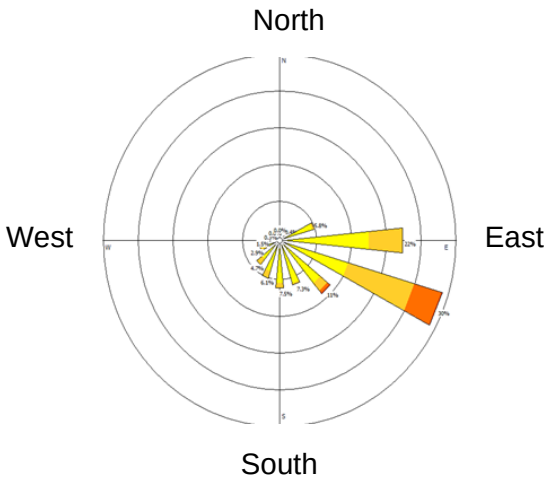
Temperature

- Minimum daily temperature: 3.19 °C
- Maximum daily temperature: 31.1 °C
- Minimum hourly temperature: 0.45 °C
- Maximum hourly temperature: 37.9 °C
- Average yearly temperature: 19.5 °C

Humidity

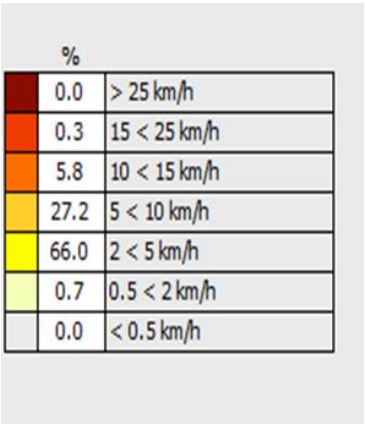
- Minimum daily humidity: 12.7 %
- Maximum daily humidity: 92.3 %
- Minimum hourly humidity: 11 %
- Maximum hourly humidity: 99 %
- Average yearly humidity: 53.7 %

Wind direction



Average: 126°

Wind Speed



Average: 4.9 km/h

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

Wadi Al-Hajjar (Zarqa)

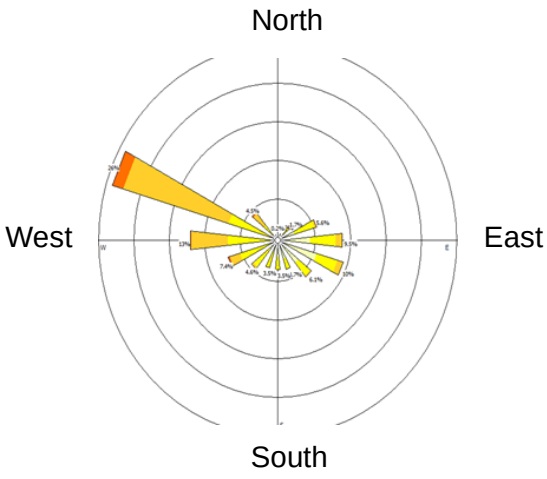
Temperature

- Minimum daily temperature: 7.34 °C
- Maximum daily temperature: 34.9 °C
- Minimum hourly temperature: 3.06 °C
- Maximum hourly temperature: 43.3 °C
- Average yearly temperature: 22.3 °C

Humidity

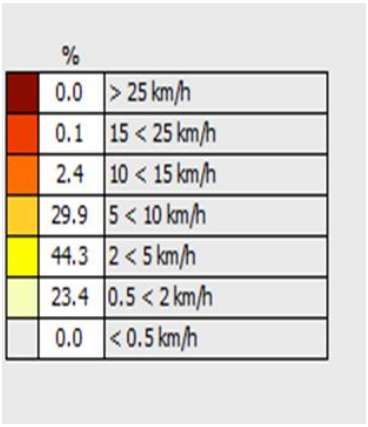
- Minimum daily humidity: 22.25 %
- Maximum daily humidity: 91.75 %
- Minimum hourly humidity: 13 %
- Maximum hourly humidity: 100 %
- Average yearly humidity: 51.1 %

Wind direction



Average: 251°

Wind Speed



Average: 4.1 km/h

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

2.7 Air Quality Index

The Air Quality Index (AQI) is a colourised scale of air pollution that gives an indication of how clean the air is and recommends changes to outdoor activity if pollution levels are high.

The AQI is calculated from air quality data relating to the monitored pollutants, a lower value indicates better air quality, and a higher value indicates poorer air quality that may cause adverse health effects.

There are six categories ranging from 'Good' to 'Hazardous', each shown in a different colour.

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 unconditionally do different daily activities naturally in the open air
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	Hazardous	Health alert: everyone may experience more serious health effects	Everyone should never go out

Table 2.4: Air Quality Index

Table (2.5) below 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 2021.

January/2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	12.2%	19.4%	2.2%	11.3%
Percentage of days when the AQI was moderate	55.3%	75.8%	64.4%	65.2%
Percentage of days when the AQI was unhealthy for sensitive groups	27.2%	4.9%	30%	20.6%
Percentage of days when the AQI was unhealthy	5.3%	-	3.4%	2.9%

February/2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	4.3%	9.1%	2.7%	5.4%
Percentage of days when the AQI was moderate	74.3%	87.1%	67.3%	76.2%
Percentage of days when the AQI was unhealthy for sensitive groups	19.5%	3.9%	20.1%	16.5%
Percentage of days when the AQI was unhealthy	1.9%	-	3.9%	1.9%

March/2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	7.6%	1.7%	-	3.1%
Percentage of days when the AQI was moderate	67.7%	86.4%	73.3%	75.8%
Percentage of days when the AQI was unhealthy for sensitive groups	9.9%	5.1%	17.4%	10.8%
Percentage of days when the AQI was unhealthy	14.7%	6.8%	9.3%	10.3%

April/2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	4.8%	5%	-	3.3%
Percentage of days when the AQI was moderate	68.5%	80%	65.1%	71.2%
Percentage of days when the AQI was unhealthy for sensitive groups	18.2%	15%	29.8%	21%
Percentage of days when the AQI was unhealthy	8.6%	-	5.1%	4.5%

May/2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	1.4%	-	2.8%	1.3%
Percentage of days when the AQI was moderate	81.4%	92%	79.4%	84.2%
Percentage of days when the AQI was unhealthy for sensitive groups	15.1%	8%	16.4%	13.1%
Percentage of days when the AQI was unhealthy	2.9%	-	1.4%	1.4%

June/2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	4%	1.9%	2.7%	2.8%
Percentage of days when the AQI was moderate	81.7%	98.1%	90.4%	90.1%
Percentage of days when the AQI was unhealthy for sensitive groups	14.3%	-	6.9%	7.1%

July/2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	1.4%	3.3%	1.2%	2%
Percentage of days when the AQI was moderate	81.5%	93.6%	93.3%	89.5%
Percentage of days when the AQI was unhealthy for sensitive groups	16.1%	3.3%	5.5%	8.2%
Percentage of days when the AQI was unhealthy	0.9%	-	-	0.3%

August/2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	1%	-	-	0.3%
Percentage of days when the AQI was moderate	81.5%	100%	92.9%	91.3%
Percentage of days when the AQI was unhealthy for sensitive groups	15.5%	-	5.4%	7%
Percentage of days when the AQI was unhealthy	2%	-	2.1%	1.4%

September/2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	2.2%	3.4%	2.6%	2.7%
Percentage of days when the AQI was moderate	82.8%	96.7%	86.6%	88.7%
Percentage of days when the AQI was unhealthy for sensitive groups	15%	-	10.8%	8.6%

October/2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	2.3%	1.6%	1.1%	1.7%
Percentage of days when the AQI was moderate	68.3%	96.8%	66.5%	77.2%
Percentage of days when the AQI was unhealthy for sensitive groups	22.5%	1.6%	26.2%	16.8%
Percentage of days when the AQI was unhealthy	7%	-	6.2%	4.4%

November/2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	1%	-	-	0.3%
Percentage of days when the AQI was moderate	52.7%	80%	41.4%	58%
Percentage of days when the AQI was unhealthy for sensitive groups	36.8%	18.4%	45.6%	33.6%
Percentage of days when the AQI was unhealthy	9.5%	1.6%	13.3%	8.1%

December/2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	5.4%	16.2%	2.2%	7.9%
Percentage of days when the AQI was moderate	63.1%	67.8%	49.5%	60.1%
Percentage of days when the AQI was unhealthy for sensitive groups	21.2%	12.9%	33.8%	22.6%
Percentage of days when the AQI was unhealthy	10.3%	3.2%	13.4%	9%
Percentage of days when the AQI was very unhealthy	-	-	1.1%	0.4%

Average for all Months during 2021	Amman	Irbid	Zarqa	Average in the three cities
Percentage of days when the AQI was good	4%	5.2%	1.5%	3.6%
Percentage of days when the AQI was moderate	71.6%	87.9%	72.6%	77.4%
Percentage of days when the AQI was unhealthy for sensitive groups	19.3%	6.1%	20.8%	15.4%
Percentage of days when the AQI was unhealthy	5.3%	1%	3.8%	3.4%
Percentage of days when the AQI was very unhealthy	-	-	0.1%	0.03%

Table 2.5: Ambient air quality monitoring results based on ambient air quality index

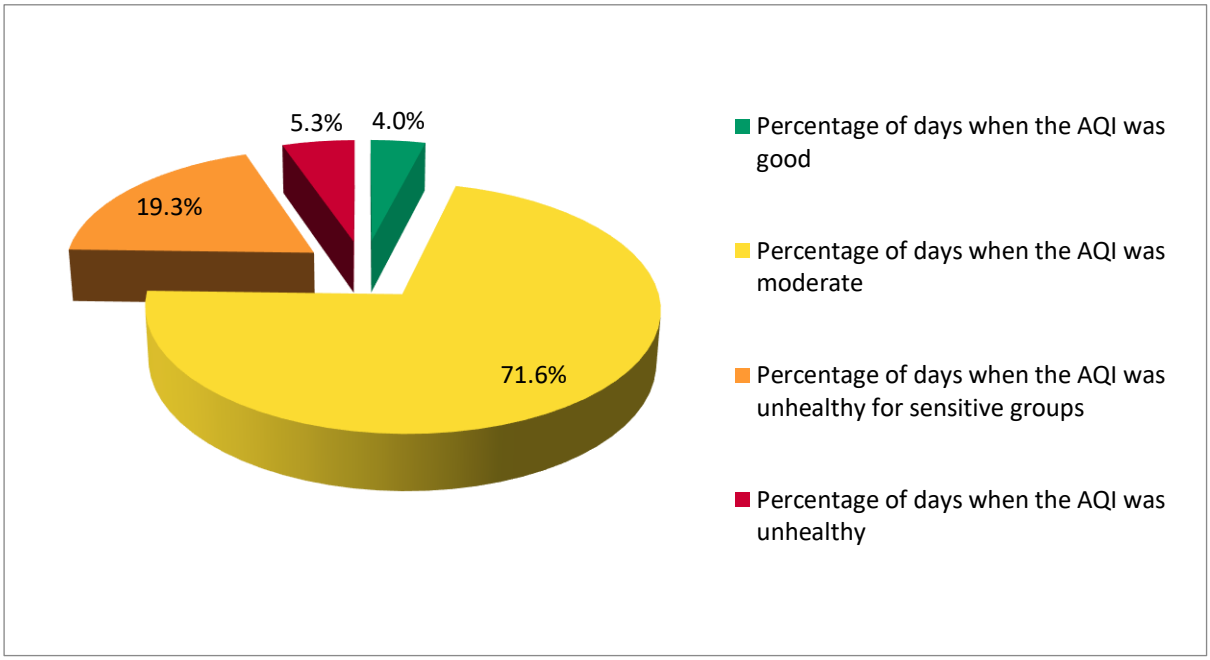


Figure 2.50: Results of ambient air quality monitoring based on the air quality index in Amman

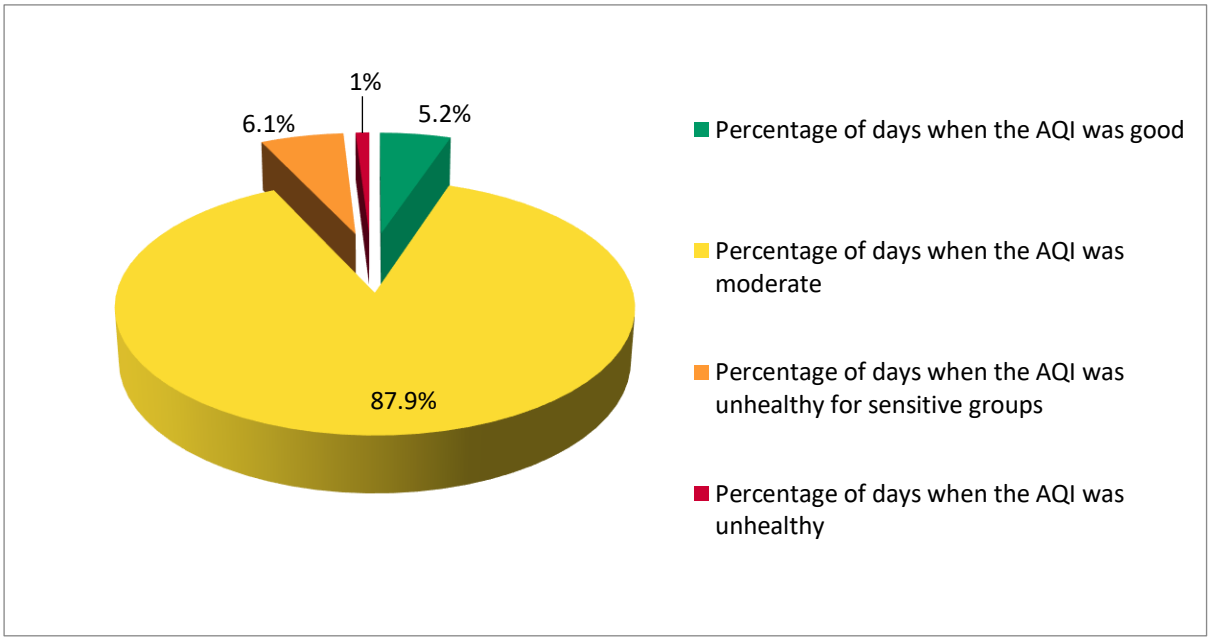


Figure 2.51: Results of ambient air quality monitoring based on the air quality index in Irbid

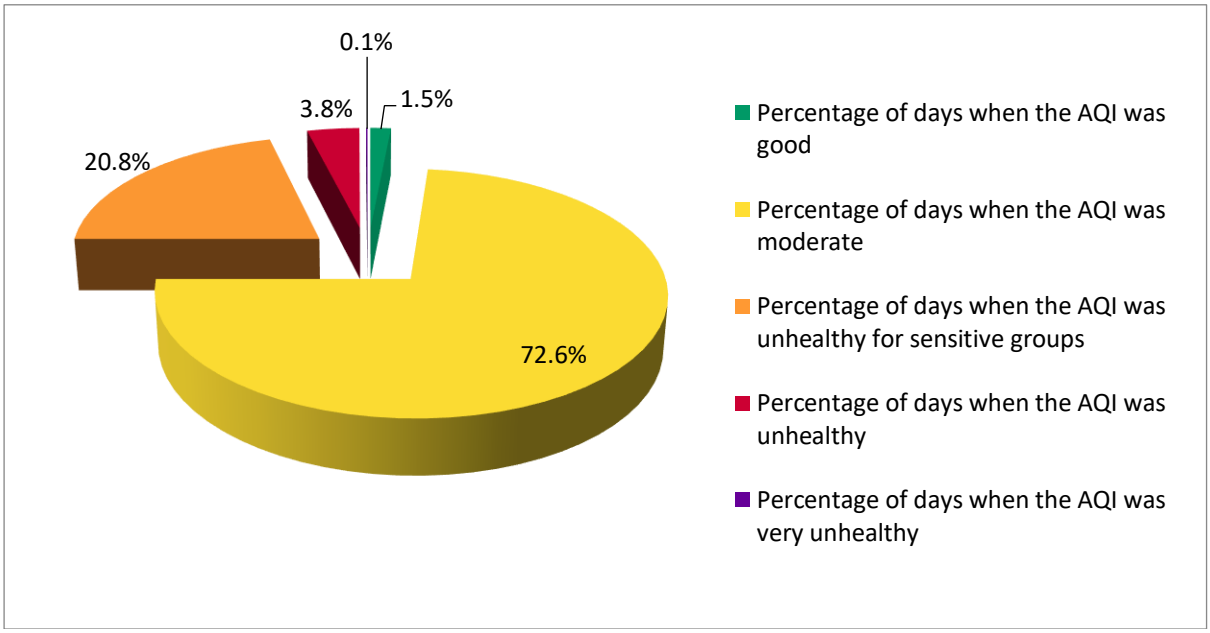


Figure 2.52: Results of ambient air quality monitoring based on the air quality index in Zarqa

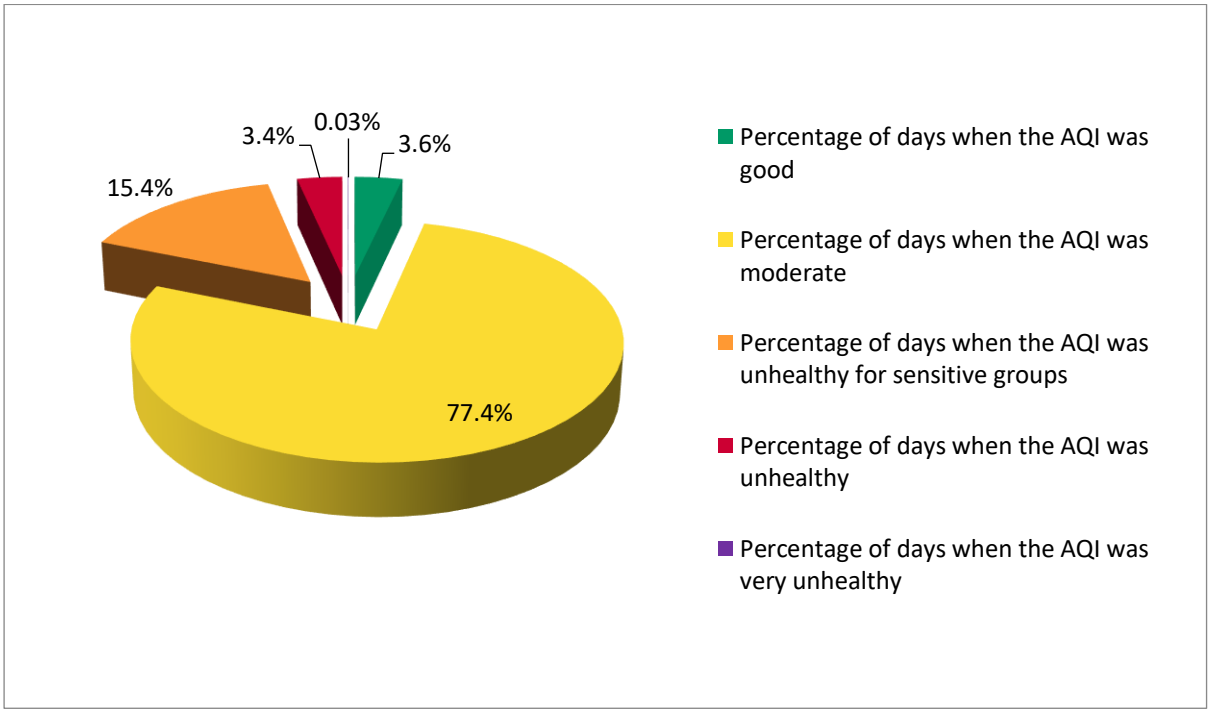


Figure 2.53: Results of ambient air quality monitoring based on the air quality index

3

CONCLUSION

- **The results indicate that the ambient air quality in Amman, Irbid, and Zarqa is moderate for most days of the year based on the Jordanian technical standard for ambient air quality 1140/2006 (Table 1.2 on page 7 above).**

- **Excesses in the annual averages of particulate matter (PM2.5) were recorded in all stations during the period from 1/1/2021 to 31/12/2021 within the limits allowed in Jordanian Standard JS1140/2006 (technical rule).**

- **The pollutants (carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3)) in all stations were within the permissible limits in the Jordanian technical rule of ambient air quality No. 1140/2006 for hourly, daily, and annual averages.**

- **Emissions from air pollution sources as a result of human activities, especially from the transportation, industry, and energy sectors in which fossil fuels are burnt, in addition to dust storms and airborne pollutants, have contributed to raising the level of particle concentrations with an effective diameter less than or equal to ≤ 2.5 microns (PM2.5). This has led to violations of the daily averages of the limits set out in the technical rule No. 1140/2006 for the quality of ambient air in most of the sites (Table 2.2 on page 15 above).**

- **The wind direction in Amman during the measurement period was south-west/west, at a speed of 6.1 km/h, while in Zarqa, the prevailing wind direction was in the north west direction, at an average speed of 4.1 km/h, and in Irbid, the prevailing wind direction was south east, at a rate of 4.9 km/h.**

- **The results of ambient air quality monitoring 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 3.6% and moderate at 77.4%. The average percentage of days when the air was unhealthy for sensitive groups was 15.4%, and the percentage of days when the air was unhealthy was 3.4%, while it was very unhealthy by 0.03%.**

4

RECOMMENDATIONS

1) **The necessity of working on preparing a national strategy to combat air pollution and monitor the quality of ambient air in the Kingdom or 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 not covered by continuous monitoring, and their inclusion in the national monitoring network, in order to identify areas prone to pollution, and implement the procedures (Air Quality Control) that control the air quality within the national specifications and maintain its quality from deterioration in the corresponding areas.**

3) **Complete the installations to measure the concentrations of gaseous pollutants in the stations as needed.**

4) **Measurement of meteorological elements, wind speed and direction in all stations, as they were only monitored in three stations.**

5) **Review and update Jordanian legislation and standards related to air quality.**

6) **Encouraging and supporting universities and scientific research centres to conduct research related to air pollution and reducing negative impacts on the environment.**