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Statistical Analysis of Ambient Air Quality in Residential Communities in Jordan

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Sulphur (SO_2), nitrogen oxides (NO, NO_2 and NOx), H_2S, PM_{10} and PM $_{2.5}$ have been tracked in: AB / Al-Balqa, MU / Amman, AG / Amman, RU / Zarqa and KH / Al-Mafraqa, to determine the ambient air quality in these areas. Data was obtained from the report taken from Jordan ministry of environment. The primary objective was to classify the rates of contaminants in the above-mentioned five areas in the period December 2015 to November 2016 and to compare the concentrations of different air pollutants reported hourly, monthly, and annually with Jordanian standards (JS 1140/2006). The study also aims to assist policy makers in evaluating and improving the application of effective interventions that could enhance the conditions in the research areas and thus improve the quality of public health in Jordanian life. The principal findings of the study show that the reported rates of SO_2 and NO_2 were within the Jordanian norm for environmental quality at all five monitoring sites. The PM_{10} levels in AG station were high at this site when compared to the other sites, the higher PM_{10} levels were reported and the average permissible limit for the Jordanian test standards was exceeded in 96 days during the course of the study period. In addition, PM_{10} levels were high and in 81 days during the study period the daily permissible limit in Jordan was exceeded. KH's PM_{10} levels were high, but in comparison with the other sites, the lower PM_{10} levels were reported and the average allowable Jordanian requirements in twenty-seven months in the course of the study were exceeded. During the study period, 1 hour and 1 day total for H_2S was reported. In addition, in 18 days during the course of the analysis, the $PM_{2.5}$ values in Jordan reached the daily permissible cap. Some of the recommended steps suggested by this study are the continued monitoring of existing areas of ambient air quality, increased monitoring of most kingdom areas in the region and expansion of polluter monitoring, especially black carbon and ozone levels.

Keywords: *Residential Communities; Meteorological Parameter; PM_{10}; SO_2; NO_2; H_2S; $PM_{2.5}$*

1. Introduction

There are many industries and activities that may lead to ambient air pollution in the Hashemite Kingdom of Jordan. The increase in the population and economic growth has led to an increase in pressure on service activities accompanied by expansion in the industrial sector and an increase in the number of vehicles, which has led to traffic intensity on the internal and external roads especially in populated areas near industrial and service activities and heavy traffic, (M.Tayank ,1999). The concentration of SO_2 and nitrogen oxides (NO, NO_2, NOx) has been monitored at all monitoring sites as it is produced by burning fuels in light and heavy industries and vehicles, (Amman Chamber of Industry, 2017).

It should be noted that the percentage of sulphur is relatively high in diesel and heavy fuel used in Jordan. Particle concentration ($PM_{2.5}$) was also monitored in the spot for its proximity to movement. There is heavy circulation between Amman and the northern region of the Kingdom and monitoring of particulate concentration (PM_{10}) in three locations in KH, RU and AG takes place since it is close to industrial operations and main highways, alongside all the areas of the Kingdom vulnerable to natural pollution. The levels of hydrogen sulphide (H_2S) in AB were monitored for their proximity to the wastewater treatment plant (O. Sana'a, 2015).

This study aims to determine the levels of gaseous pollutants and suspended particles in the surrounding air of the study areas and compare them with the limits of the Jordanian standards for ambient air quality No. (1140/2006). It aims also to evaluate the annual impact on ambient air quality in the observed areas, comparing the condition of surrounding air quality in different regions of Jordan according to different conditions such as location, climate, number of people, size of industries, etc and submit findings and suggestions to decision makers to help them take actions and decisions based on monitoring information .(O. Sana'a., et al., 2017).

2. Methodology

2.1 Air Monitoring Sites

2.1.1 AB Station

AB station is one of six camps established in 1968 and inhabited by about 94,000 people. It is the largest in Jordan and is located in the Ain al-Basha Brigade / Balqa Governorate, 6.5 km north of Amman. One of the main sources of air pollution in this camp is a wastewater treatment plant, and industrial activities such as mining, lime and gypsum manufacturing, in addition to traffic congestion, as it is located on the main road between Amman and Irbid and other areas of the northern governorates, also occur.

2.1.2 AG Station

AG station is located in Amman Governorate, to the south of Queen Alia International Airport. This region is considered one of the inhabited areas, with the population of AG District estimated at 54,750 people. The city of AG is located on the desert road that links the capital with other southern governorates. One of the main sources of air pollution in this region is mainly industrial activities, iron and carbonate industries in addition to the high traffic at the airport, which affects the air quality of this site, taking into account the nature and location of the site that can be affected by natural dust.

2.1.3. KH

KH station is located in Al-Mafraq Governorate, to the northeast of the city of Amman, and it is inhabited by about 26,340 people. The main sources of air pollution in this region are industrial facilities such as cement and crushers, in addition to cows, poultry, natural dust, and traffic on the highway between Zarqa and Mafraq.

2.1.4. RU

RU station is the second largest city in Zarqa governorate, which is located to the northeast of the city of Amman. The RU Brigade has about 341,290 people. One of the main sources of air pollution in this region is industrial activities such as foodstuffs, plastic industries, tanning, detergents and cosmetic products in addition to traffic.

2.1.5. MU

MU station is located in the Amman governorate, to the southeast of Amman. MU Brigade has about 39,080 people. The main sources of air pollution in this region are industrial activities such as iron, chlorine and soap industries, bearing in mind that this area is adjacent to a group of factories.

2.2 Monitoring Procedures

Five monitoring sites were selected in AB, KH, MU, RU and AG to monitor levels of gaseous pollutants and particulate emissions from different air pollution sources surrounding these areas, as shown in Figure 1.

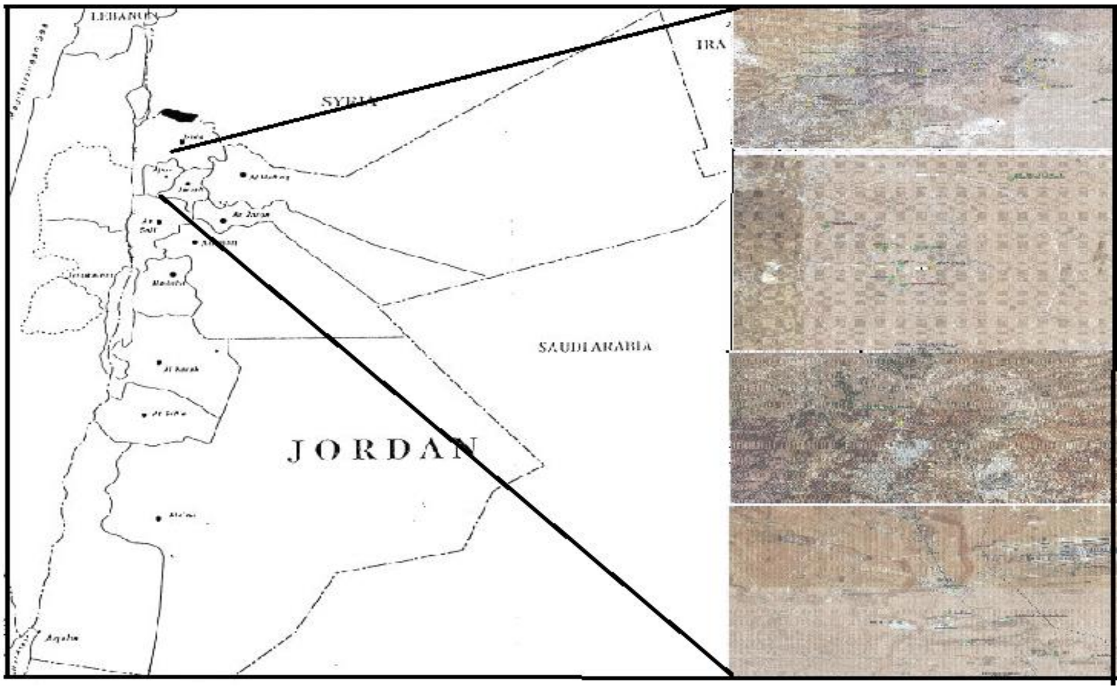


Fig. 1. Location map of the study area.

Table 1 shows the monitoring sites in addition to pollution sources in an area and the kind of pollutants measure in each station. Equipped stations have been established to monitor all pollutants as well as stations to monitor wind speed direction, relative humidity and temperature (Environment Ministry Reports 2010 -2016).

Table 1: Air Pollutants that are monitored at each site.

Sources of pollution	Station Name	H_2S	$PM_{2.5}$	SO_2	NO_x	PM_{10}
Wastewater treatment plant, quarries, lime factory and lime brick, medicine factory	AB	1	1	1	1	1
Amman International Airport, quarries, iron factory, lime factory and lime brick, aluminium factory, paint factories, tobacco and vegetable Oils, wastewater treatment plant, For Amman International Airport and another, Close to the Giza camp and its, large capacity	AG			1	1	1
Cowsfarm, white cement factory	KH			1	1	1
Phosphate laboratories, detergent factory, multiple industries like battery factory, plastic factory, light industries such as crafts and workshops, Pepsi factory, yeast Factory, Biogas plant, iron factory, tanning factory, alcohol factory	RU			1	1	1
Chlorine plant, soap factory, iron factory, air conditioning factory, industries as light as crafts, And concerns.	MU			1	1	

3. Results & Discussion

3.1 Statistics:

Statistics including, minimum, maximum, standard deviation (SD) and mean were carried out. Results are depicted in Table 2.

Table 2: The maximum hourly, daily, monthly and yearly average concentrations for the air pollutants in each station.

Station Name	Pollutants	The Max. Hourly Average	The Max. daily Average	The Max. monthly Average	The Max. yearly Average
AB	H_2S ppm	0.034	0.012	0.008	0.005
	$PM_{2.5}$ µg/m^3	-----	400	117	31
	SO_2 ppm	0.114	0.042	0.015	0.009
	NO_2 ppm	0.077	0.044	0.026	0.017
AG	SO_2 ppm	0.183	0.060	0.026	0.012
	NO_2 ppm	0.064	0.039	0.031	0.018
	PM_{10} µg/m^3	-----	750	149	115
KH	SO_2 ppm	0.214	0.037	0.015	0.006
	NO_2 ppm	0.099	0.038	0.020	0.009
	PM_{10} µg/m^3	-----	430	91	73
RU	SO_2 ppm	0.146	0.036	0.016	0.008
	NO_2 ppm	0.090	0.054	0.031	0.018
	PM_{10} µg/m^3	-----	450	195	101
MU	SO_2 ppm	0.323	0.126	0.017	0.009
	NO_2 ppm	0.155	0.049	0.014	0.009

3.2 Variation of Pollutant Levels for Data

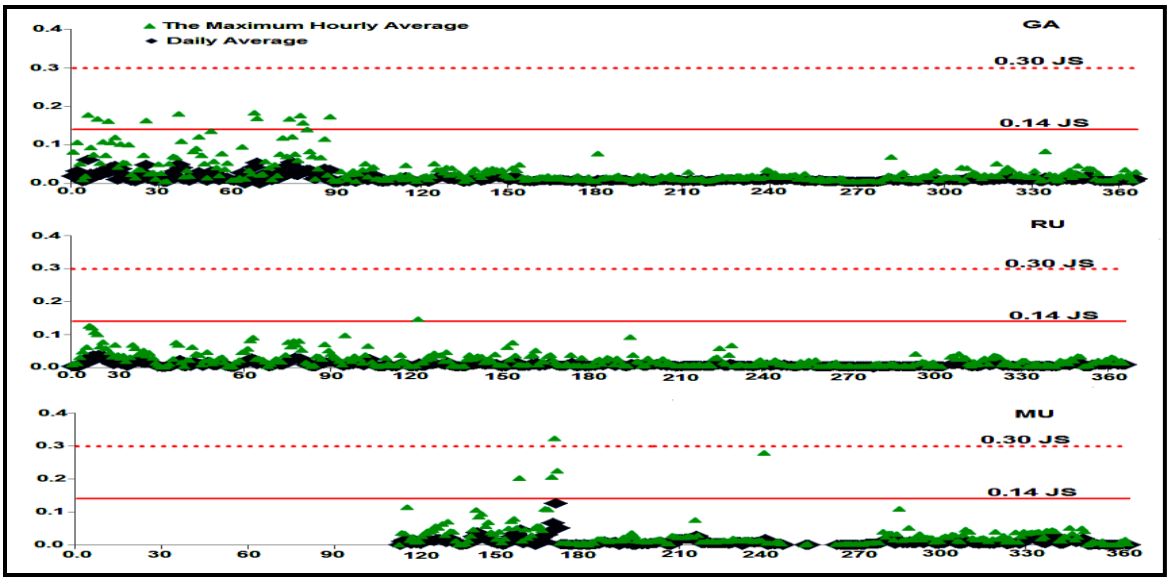
3.2.1 Sulphur dioxide (SO_2) Trend

A colourless gas with a pungent odour is sulphur dioxide (SO_2). The main sources of emissions are power plants, metallic sulphur smelting facilities, oil refineries and other industries and activities in which fossil fuels containing high sulphur levels are burned.

This gas is also produced from natural sources such as volcanoes and the decomposition of organic matter. Exposure to this gas causes irritation in the eye and respiratory membranes in varying degrees depending on its concentration in the inhaled air and the duration of exposure, as well as the sensitivity of the exposed person and its presence with other pollutants such as particles and ozone. It can cause chronic diseases such as asthma and bronchitis. It also creates acid rain (sulphuric acid) that may kill wildlife and trees and damage buildings, materials and property. The Jordanian Standard for SO_2 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.

Five testing sites were tracked to monitor the level of sulphur dioxide at BA, RU, AG and KH levels, and the result showed that they were within the limits of Jordanian ambient air quality standards No. 1140/2006.

Figure 2 shows that the highest daily rate recorded in each observing station was 042.0 ppm in AB, 060.0 in GA, 037.0 ppm in KH, 036.0 in RU, and 126.0 ppm in MU. It appears that the highest daily rates were recorded at AB station, and that is without recording any exceeding the daily average of the Jordanian standard limit of 140.0 ppm at any monitoring site. It should be noted that the standard does not allow exceeding the daily limit of sulphur dioxide gas more than once a year.



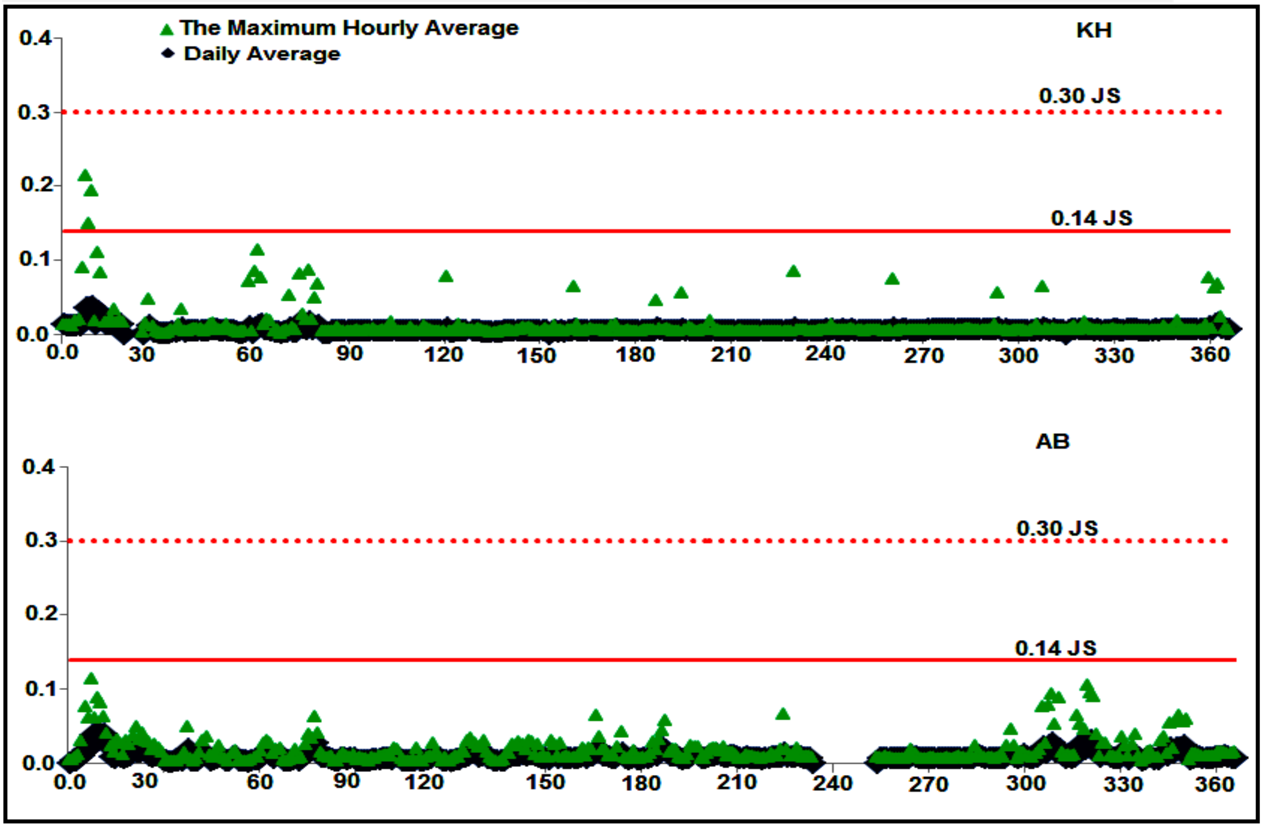


Figure 2: The averages and maximums per day. Average SO2 level reported at all stations per hour.

3.2.2 Particles Matter Less Than 2.5 µm ($PM_{2.5}$) Trend

There are many sources of particles $PM_{2.5}$ in the ambient soil. In addition to the natural sources, these particles are produced by means of transport especially on diesel fuel, smoke from various combustion sources, fires, mineral extraction, construction, etc. (Kong et al., 2016)

The particle size is one of the major characteristics that governs the atmospheric activity of these particles, as well as their environmental and health impacts. Particles of smaller or equivalent diameter of 10 microns (PM_{10}) may remain trapped in the air for many days, while particles of less than or greater than 2.5 microns of diameter ($PM_{2.5}$) can remain stuck in the air for a very long time and spread over large areas or long distances from the source of the origin. The effects of exposure to these particles usually appear through the coughing and excitation of the bronchi and eyes, and since $PM_{2.5}$ are small enough to penetrate into the bronchi and lungs, they are considered more dangerous to the lungs. The health effects resulting from exposure to these particles depends not only on their size but also on their concentration in the inhaled air, the duration of exposure to them, and their chemical composition in addition to the factor that people who suffer from certain chronic respiratory diseases such as asthma are considered more sensitive to exposure to these particles (Benamet at., 2016).

Particle rates of less than or equal to 2.5 micron diameter ($PM_{2.5}$) in the AB station were monitored. Figure 3 shows the daily averages of the particle concentrations recorded at the monitoring sites during the observation period where many exceedances were recorded for the daily limit set in the Jordanian standards of 65 µg / m^3, where 18 days exceeded, or 6.02% of the monitoring period were recorded.

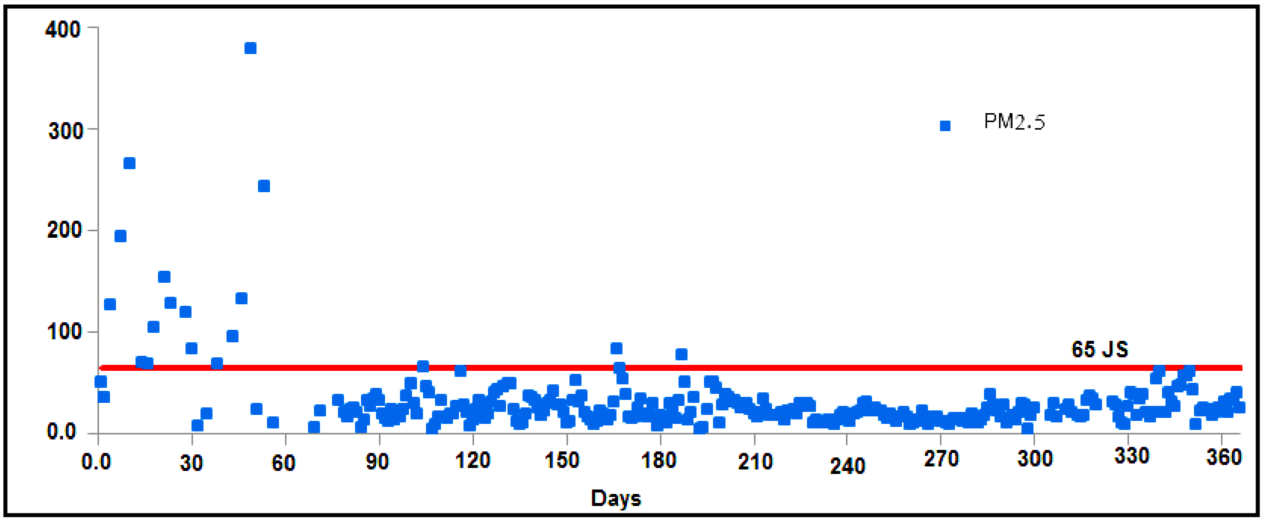


Figure 3: The daily averages of $PM_{2.5}$ concentrations recorded at AB station.

3.2.3 (PM_{10}) Trend

The smaller the particle, the more it is able to reach into the lungs, causing many health problems, in particular for people who have chronic respiratory conditions such as asthma and bronchitis. The more inhaled the aerosols are of less than 10µm of diameter (Gauderman et al., 2002).

Particles can also alter immune systems and thus reduce the body's ability to resist and fight infection. Recent epidemiological research has also pointed out that inhalable particulates could lead to high blood pressure, strokes and lung cancer, and thereby increase annual mortality rates. The average Jordanian PM_{10} standard is 70mg / m^3 annually. The Jordanian 24-hour average PM_{10} standard is 120 µg / m3 which must be no longer than three times in a 12-month period. Regional dust events and erosion cause high PM_{10} readings and during regional dust storms all stations report high dust measurements (Calderón-Garciduеñas et al., 2008).

Other lighter pollution storms as well as local pollutants, including motor cars, light industry and domestic heating, resulted in high PM_{10} readings. Events of unstable atmospheric conditions may also lead to elevated PM_{10} levels .

Figure 4 shows the daily excesses at three sites of monitoring. It shows the rise in the daily average excesses to the Jordanian standard limits of 120 µg / m^3 where 96 days exceeded the limit in GA with 58.31% , 27 days exceeded in KH with 21.8% and 81 days exceeded in RU with 03.29% .

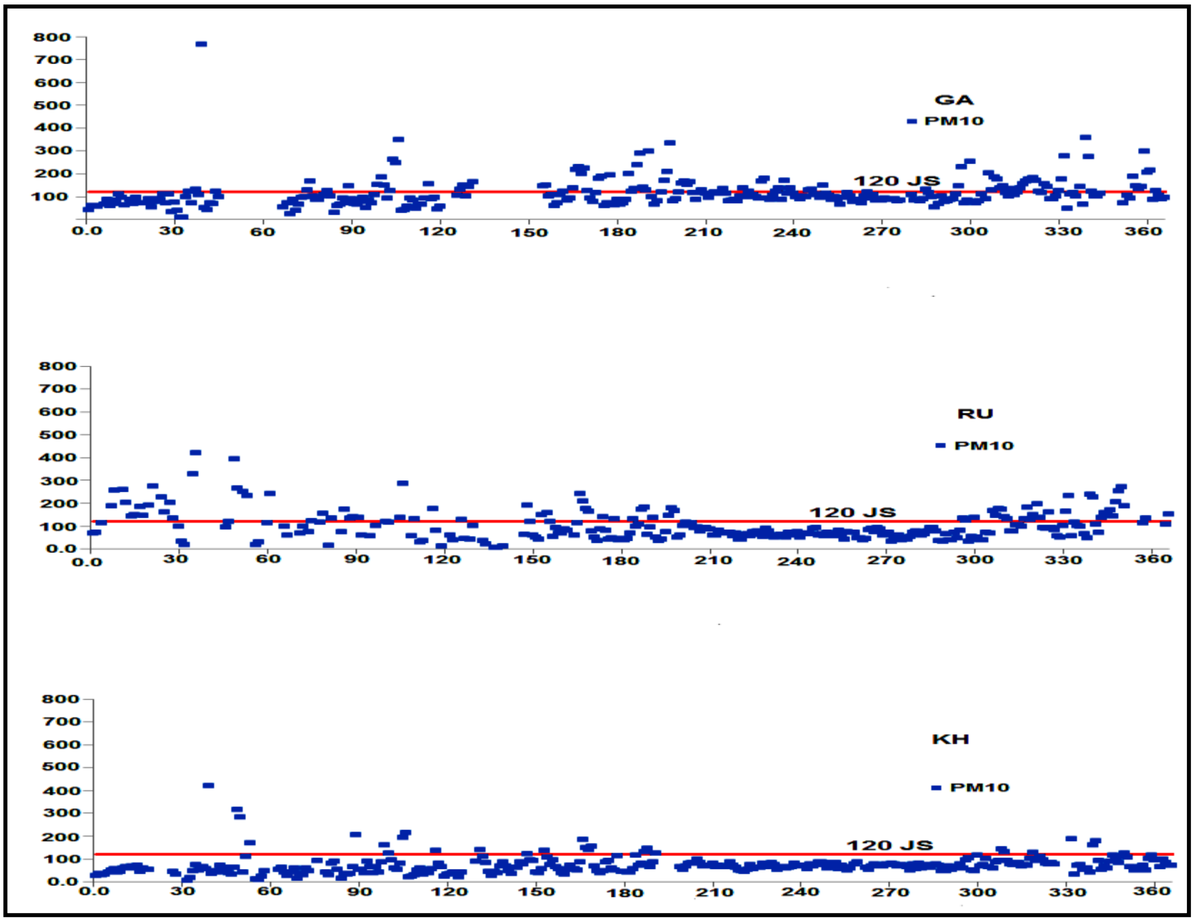


Figure 4: The daily averages of PM_{10} concentrations recorded at all stations.

3.2.4 Nitrogen Dioxide (NO_X) Trend

Nitrogen oxides (NOx) are known as the total sum of both nitrogen dioxide (NO_2 and N) . These oxides are formed as a product of all combustion processes in which air enters, especially at high temperatures due to oxidation of atmospheric nitrogen. Although NO is the main product, it is not considered to have a negative impact on human health. NO_2 is an odorless brown gas. Part of the NO_2 is released as a result of combustion while most of its concentrations are in the surrounding air as a result of oxidation of NO through various processes, for example by means of ozone, as it can continue to oxidize to obtain more oxidizing products such as nitric acid (HNO_3) and in addition to sulphuric acid leads to the phenomenon of acid rain (Ainslie and Steyn, 2007).

Exposure to NO_2 gas leads to attacking the tissues of the lungs and respiratory tracts in living organisms. At low concentrations it reduces the body's resistance to germs, which leads to irritation of the lungs and eyes. This gas thus reduces body tolerance to respiratory conditions such as pneumonia through exposure to high concentrations. Research indicates that children are the most susceptible to NO_2 gas as they appear to record more various respiratory disorders than others. Asthma patients are a particularly sensitive group of this gas (Guttikunda and Gurjar, 2011).

Figure 5 shows the daily average of NO, NO_2 and NO_X concentrations recorded at all stations were 63 days exceeded the limit in GA with 33.4% , 16 exceeded in RU with 13.4%, 47 exceeded in AB with 24.1% and no days exceeded the limit of Jordanian standard in MU and KH.

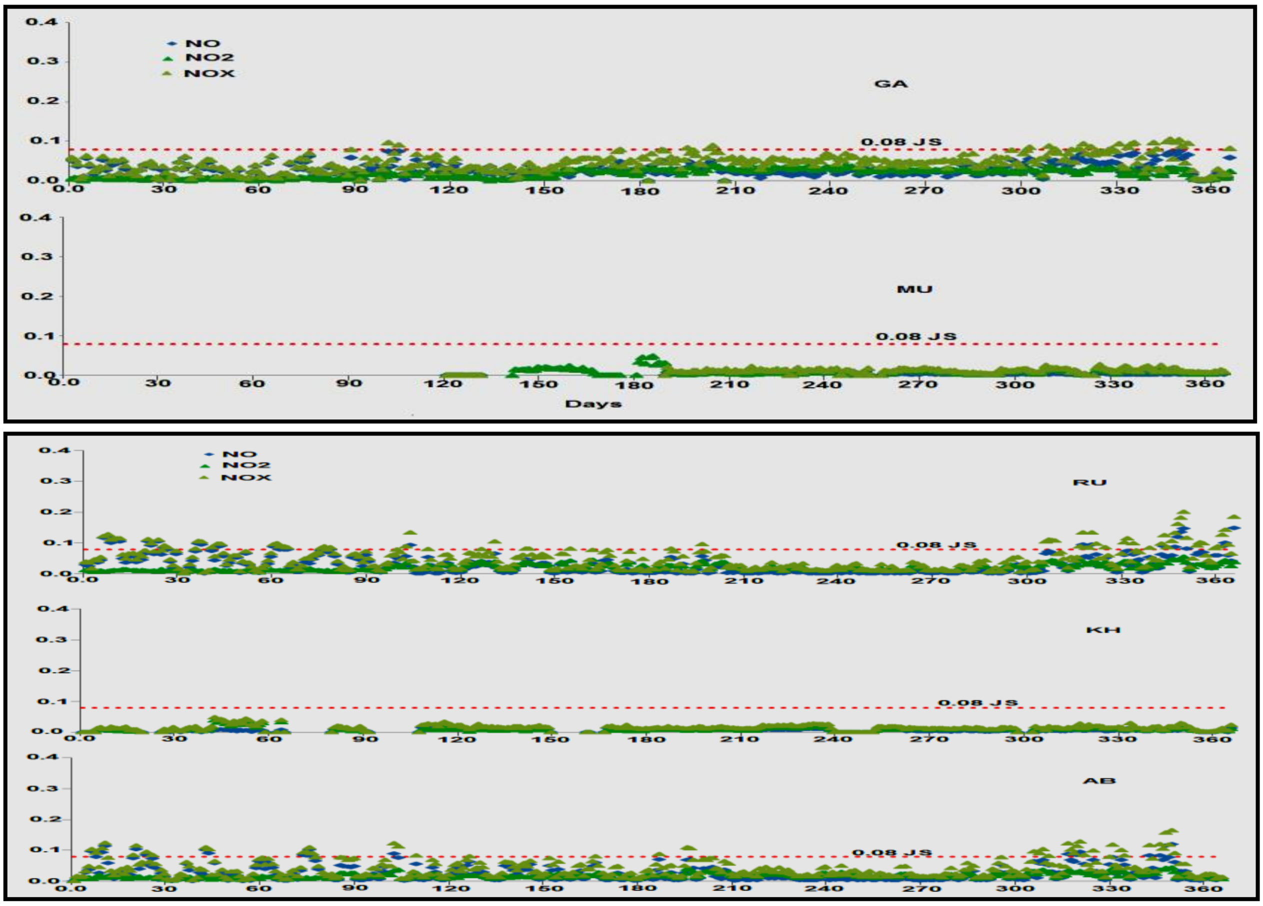


Figure 5: The daily averages of NO, NO_2 and NO_X concentrations recorded at all stations.

3.2.5 Hydrogen Sulphite (H_2S) Trend

Hydrogen sulphide (H_2S) is a colourless gas with an unpleasant odour, penetrating and strong smell resembling the smell of rotten eggs and is found naturally in the environment. This gas is produced where the solid or liquid waste contains sulphur when it is biodegradable. Therefore, landfills, livestock waste, human-made drains, trucks transporting waste and sewage stations, and sanitation and waste treatment plants are considered major sources of H_2S gas emissions to ambient air. Also, this gas can be found in groundwater, especially in wells near oil fields. Hydrogen sulphide is also produced from industrial activities, including petroleum refineries (Lana Skrtic, 2006).

The health effects of exposure to H_2S gas vary depending on its levels in the inhaled air. Exposure to high levels of this gas can irritate the eyes, nose, and lung. In the event of exposure to concentrations in excess of 25 ppm of H_2S gas, it may affect the ability to breathe, especially with asthma patients.

Figure 6 shows the number of the daily averages and the number of maximum hourly average excesses in AB station, where the highest daily average was 0.012 ppm and the daily average of H_2S has exceeded Jordanian standard No. 1140/2006 of 010.0 ppm only once, at a rate of 0.292%. This is less than the number of violations that are allowed to be registered in the standard limit, which is three times during a 12 month period.

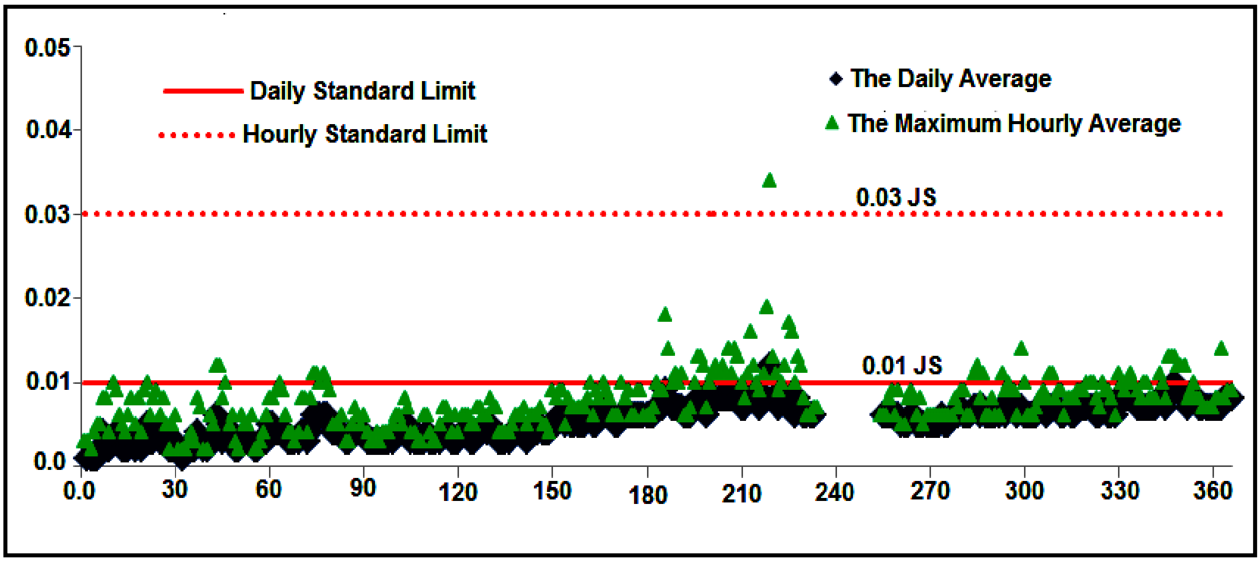


Figure 6: The daily averages and the maximum hourly average of H_2S concentrations recorded at AB station.

3.3 Plot Series for Meteorological Parameters:

3.3.1 Daily Average of Temperature

Table 3 shows the maximum, minimum daily average and the maximum and minimum monthly average of temperatures in all stations during the monitoring period. Whereas Figure 7 shows the maximum and minimum monthly average temperatures in the five monitoring stations for the duration (12/12/2015/11/30/2016). The result shows a convergence of the frequency pattern in the monthly rates of temperatures in all the monitoring sites during the study period.

Table 3: Maximum and minimum daily, monthly average of temperatures in all stations during the monitoring period.

Station Name	Short Name	Maximum Daily Average ºC	Minimum Daily Average ºC	Maximum monthly average ºC	Minimum monthly average ºC
Al-Baq'a	AB	37.2	3.2	31.3-6/2016	8.9 -1/2016
Al- Giza	AG	31.5	3.1	26.9- 8/2016	7.8 -12/2016
Khalidiya	KH	32.2	3.5	28.7 - 6/2016	8.5 - 1/2016
Russeifa	RU	35.8	3.4	31.8 - 6/2016	28.8 -1/2016
Muwaqqar	MU	34.8	4.2	31.9 - 8/2016	10.1 -1/2016

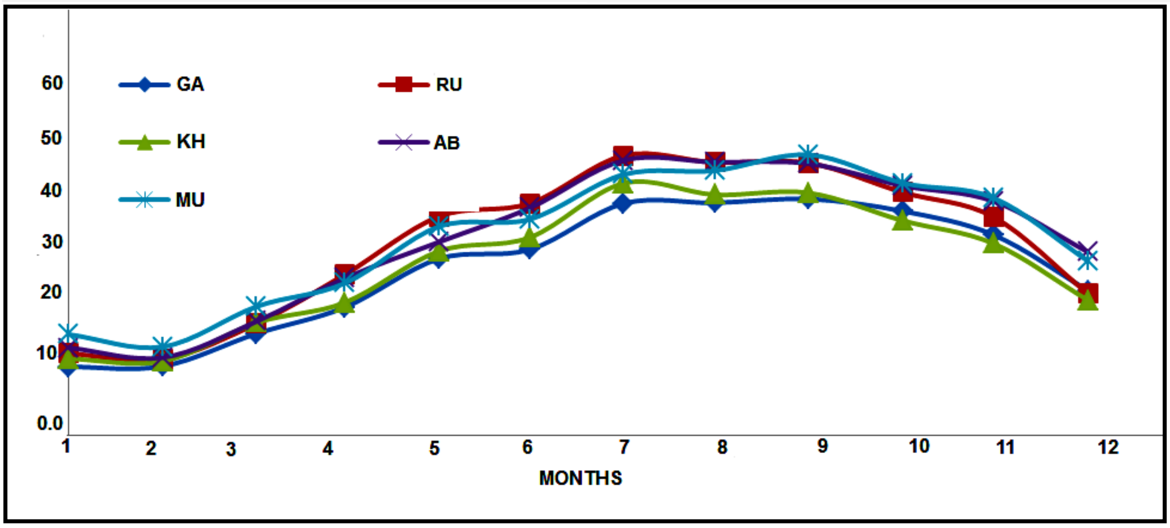


Figure 7: Temperatures Time series plot.

3.3.2 Relative Humidity Average

Table 4 shows the maximum, minimum daily average and the maximum and minimum monthly average of RH% in all stations during the monitoring period. Whereas Figure 8 shows the maximum and minimum monthly average relative humidity in the five monitoring stations for the period (12/12/2015/11/30/2016). The result shows a convergence of the frequency pattern in the monthly rates of relative humidity in all the monitoring sites during the study period.

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Table 4: Maximum and minimum daily, monthly average of RH% in all stations during the monitoring period.

Station Name	Short Name	Maximum Daily Average %	Minimum Daily Average %	Maximum monthly average %	Minimum monthly average %
Al-Baq'a	AB	90.3	4.3	72.6 -1/2016	32.2 - 6/2016
Al- Giza	AG	93	4.3	75.3- 1/2016	35.4 - 6/2016
Khalidiya	KH	90.7	10.5	72.9- 1/2016	36.8 - 6/2016
Russeifa	RU	85.8	9.8	73.8- 1/2016	28.8 - 6/2016
Muwaqqar	MU	84.9	5.5	64.8 - 1/2016	24.7 - 6/2016

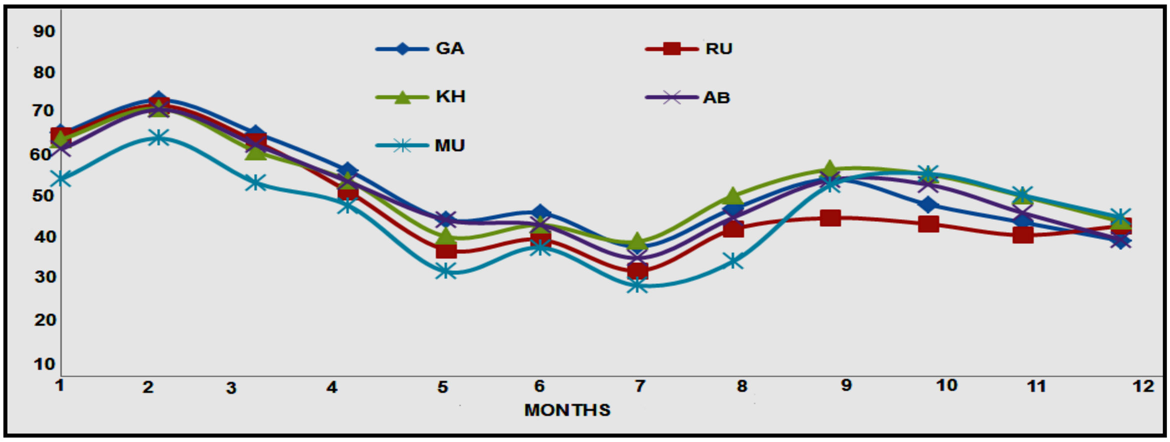

Figure 8: Time series plot for relative humidity.

3.3.3 Wind Speed and Wind Direction Average

Table 5 shows the results of monitoring wind direction and windspeed during the monitoring period (12/1 2015 - 11/30/2016). It showed that calm winds prevail in all monitoring sites.

Table 5: Wind direction and wind speed in all stations during the monitoring period.

Station Name	Wind speed	Wind direction
AB	Calm 46.8% West 25.7%	0 - 2 knot 46.8% 2 – 5 knot 26.5%
AG	Calm 32.4% Southwest 28.3%	0 - 2 knot 32.4% 5 – 10 knot 32.1%
KH	Calm 27.3% Southwest 15.7%	2 - 5 knot 35.2% 5 – 10 knot 33.7%
RU	Calm 51.4% West 27.7%	0 - 2 knot 51.4% 2 – 5 knot 29%
MU	Calm 37.1% West 22.3%	2 – 5 knot 42.5% 0 - 2 knot 37.1%

4. Discussion

4.1 AG station:

The results of the monitoring showed that the GA station was exposed to high levels of PM_{10}, as the number of daily excesses exceeded 96 days. While there was no exceedance of the daily or hourly limits of the Jordanian standard No. 1140/2006 for both sulphur dioxides (SO_2) and nitrogen dioxide (NO_2) in the surrounding air.

The results showed that the highest average levels of SO_2 were recorded in the winter, while the highest average levels of NO_2 in the summer, as it was found that the concentrations of these two gases are directly proportional to the rate of wind speed, both of which reach the lowest levels in the early morning and to the highest levels at the end of the day. This phenomenon can be explained by analysing weather factors that have a role in transporting emissions to monitoring sites. In addition to wind speed and direction, the distance that pollutants can travel and their concentration in the surrounding air play a major role in atmosphere stability.

As the percentage of northwest and western winds in this region reached 0.6% and 22.5%, respectively, this means that the monitoring site is not affected by emissions of industrial and service activities located in the northeast, east, southeast, south and southwest of the monitoring site 23.1% of the time. Also, calm winds were present 32.4% during the study period, which does not help to reduce emissions from various pollution sources such as vehicles for the proximity of the monitoring site to the desert road, as well as the southern winds (southeast, south and southwest), with a percentage of 32.6% able to transfer emissions. 11.5% of the fixed pollution sources for the eastern and northeast winds monitoring site are capable of transporting emissions from the airport to the monitoring site.

4.2. KH station:

The results showed that the monitoring site in KH municipality was exposed to high levels of PM_{10}, where it recorded 27 days exceeding the daily allowable limits of the Jordanian standards. While the levels of NO_2 and SO_2 were within the hourly and daily limits and no excess was recorded.

The highest average levels of NO_2 concentrations were recorded in the winter, while the highest average levels of SO_2 concentrations were recorded in the autumn. And this is due to the effect of wind speed that showed a proportional relation between them. SO_2 concentrations reached its lowest levels in the early morning and its highest levels during the day. While the annual and quarterly average of NO_2 changed in a different pattern with the average wind speed, as it reached its lowest levels in the early morning and afternoon hours and to its highest levels in hours between 8:00 - 11:00 and between 19:00 - 24:00.

Result of PM_{10} showed rises in the daily average concentration, it exceeded the Jordanian standard limits of 120 µg / m^3 , where 27 days exceeded in KH with 21.8%. It is also noticeable that winds with medium velocities (5-10 knots and 2-5 knots) are dominant, reaching 60.1% and the second are high-speed winds (greater than 20 knots, 15-20 knots and 10-15 knots) with a ratio of 18.7%. These winds play an important role in increasing the level of PM_{10} concentration in this site in addition to the presence of many sources resulting from burning fuel in fixed and mobile stations, manufacturing processes in the white cement plant, as well as natural dust.

4.3. RU station:

The results of monitoring in RU station showed that the levels of NO_2 and SO_2 were low, and there was no exceeding of the hourly or daily limits of the Jordanian standard. While the levels of PM_{10} are high and it recorded a number of daily violations reaching 81exceedances. This results from many sources of pollution in the region like burning fuel, especially in vehicles, as well as nearby industries such as handicrafts, brick and stone factories, the remains of phosphate mines and natural dust. Beside the effect of calm winds which prevailed by 67.1% during the days of exceedances, it does not help reduce emissions from various pollution sources.

The highest average levels of NO_2 were recorded in the autumn, while the highest average levels of SO_2 were recorded in the winter. It is noticed that the average rate of SO_2 are directly proportional to the average wind speed while the average concentration of NO_2 changes in a different pattern with the average wind speed, which reached its lowest level in the afternoon hours between (13:00 - 17:00) and to the highest levels in the hours between 8:00 - 10:00 and evening from 20:00 - 24:00.

4.4. MU station:

The monitoring results indicated that the NO_2 concentrations are within the average hourly and daily limits of the Jordanian standards, and no excess was recorded. While the results of SO_2 showed a noticeable increase, as two excess hourly limits were recorded. This is because the presence of a 10% of western winds that help in transporting pollutants emitted from factories located east, northeast and southeast of the monitoring site, were the western winds prevailed at 18:00 on 5/15/2016 which recorded the highest hourly rate of SO_2 concentration of 0.323 ppm, and calm winds were present at 35% on that day, which contributed to recording these two excesses.

The highest average levels of NO_2 and SO_2 were recorded in spring, as the reason is due to wind speed, which showed a direct proportional between them, both reached the lowest levels in early morning and high levels during the day.

4.5. AB Station:

The results of monitoring in AB station showed that the levels of NO_2 and SO_2 were low, as no days exceeded the hourly or daily limit in the Jordanian standard. While the levels of H_2S are high and one record exceeding the hourly and daily limit of the Jordanian standards was recorded. Whereas for the results showed high levels of $PM_{2.5}$ and it recorded 18 exceedances of hourly and daily of the Jordanian standards.

The levels of SO_2 and H_2S were close for most of the day, and the highest concentrations were recorded in the fall for SO_2 and in the summer for H_2S. The main source of H_2S is the wastewater purification plant and the main reason for increase of H_2S concentration is the dominance of calm winds that play an important role in delivering these emissions to the monitoring site located south of the treatment plant.

The annual and seasonal rates (autumn, summer, and spring) of NO_2 changed in a different pattern with the change in the average of wind speed. It reached its lowest levels in between 12:00 - 16:00 hours and the highest average was between 8:00 - 9:00 and between 19:00 - 24:00 hours.

There are multiple sources of $PM_{2.5}$ and $PM_{10,}$ the most prominent of which are the particles resulting from burning fuel in fixed and mobile sources especially that run on diesel, as well as dust from quarries and lime milling operations as well as natural dust. Calm winds were prevalent 58.1% of the time, and they do not help disperse emissions from nearby pollution sources such as vehicles. Also, eastern winds increased by 4.6% and are able to transfer emissions from the lime plant to the monitoring site.

This results from many sources of pollution in the region like burning fuel, especially in vehicles, as well as nearby industries such as handicrafts, brick and stone factories, the remains of phosphate mines and natural dust. Beside the effect of calm winds which prevailed 67.1% during the days of exceedances, this does not help reduce emissions from various pollution sources.

5. Conclusion

The monitored pollutants Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2) were generally within the current Jordanian standard guideline limits; however particulate matter of PM_{10} and $PM_{2.5}$ concentrations in most sites exceeded the standard and this was due to regional dust storms and local soil abrasion that contributed to the high PM_{10} and $PM_{2.5}$ levels. While the levels of H_2S were high in AB station, only one record of exceedance of hourly and daily limits of the Jordanian standards was recorded.

Air pollution can be prevented only if industrial manufacturing stops fossil fuel-burning processes that cause air pollution in the first place. It is important to encourage the use of public transport. Citizen authorities should conduct more regular tests on emissions under regulation to ensure that vehicles discharge gases according to acceptable standards.

Recommendations

Measure $PM_{2.5}$ particulates in all stations in order to quantify inhalable aerosols that are less than $_{2.5}$ µm in diameter as such a size usually emanates from local sources of vehicle exhaust emissions and industry and has adverse health impacts.

Measure criteria gas pollutants that are missing in stations.

Measure other pollutants that would create odour and are hazardous

Cleaner fuels such as natural gas, which contain less ash and less carbon, will replace coal and high sulphur oil.

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Disclaimer

The views and assumptions of the authors of this document are not necessarily those of the ministry of environment of Jordan, the authors or any of the organisations associated with the measurements of air quality parameters. Any reference to trade names does not constitute an endorsement of the product.

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