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STATISTICAL ANALYSIS OF AIR POLLUTION IN ZARQA CITY - JORDAN

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ABSTRACT

In the current study changes in air pollutant concentration were examined including an annual average particulate matter (PM_{10}) concentration, sulfur dioxide (SO_2) and nitrogen dioxide (NO_2). Reports and pollution data from all sources that assessed pollution level in the region between May 2014 and May 2016 were collected in the town of Zarqa. Three variables with total variance of 85% were derived. The influence of local meteorological conditions is evaluated using factor analysis. The first element indicates the highest variation (45%) primarily charged by relative humidity, wind speed and PM_{10}. This factor may suggest a mixed source including air-borne pollution from dust and soil, PM_{10} levels directly related to wind speed and relative humidity. The second factor of 22.3 % is high loading of SO_2 and the typical temperature of vehicle emissions, electric power plants, combustion of fuel in the industry and refining. The third factor is predominantly loaded by NO_2 and wind direction. Since wind direction in Zarqa is mostly from the west, it is realized that high levels of NO_2 were emitted from the various activities in the cities (Motor, domestic and industrial heating). The key results of this study show that the monitoring of the levels of gaseous contaminants were small and the annual average concentrations were within the Jordanian ambient air standards no. 1140/2006 except for the PM_{10}, where they exceeded Jordanian annual standards and may be attributed to the dust storms as well as to emissions from local sources, including engines.

KEY WORDS : Zarqa, Meteorological parameter, $PM_{10;}$ (SO_2); (NO_2).

INTRODUCTION

Air pollution is a well-known global environmental problem in urban areas. Specific monitoring programs, by producing large quantities of data about the concentration of each of the above-mentioned air pollutants in different parts of the world, were used to assess the air quality. Also, the broad data sets do not give the scientific community, government officials, politicians, and the general public air quality status in a simple and clear way (Murena, 2004; EPA, 1994). Inhalation of air polluted by particulates (PM_{10}) or irritants (NO_2 or SO_2) is linked to both short-term and long-term health effects, the majority of which affect the breathing and cardiovascular system (Moreno *et al.*, 2009)

In recent years, concentrations of urban air pollution increased worldwide. The World Health Organization (WHO) has estimated this increase at 8 percent between 2008 and 2013 and at levels above WHO limits over 80 percent of people in urban areas that monitor air pollution (Wilks, 2011).

Factor analysis has been widely used to define several interrelationships between various variables and to summarize them. Inter-related variables are merged into a smaller number of different variables (factors) in a factor analysis. This will simplify the dataset and also provide insight into the underlying risks and true exposures associated with adverse health effects (Qian *et al.,* 2004) .

The main goal of this study is to assess air pollutant rates in Zarqa City for 2014 and 2015, and to comparison the averages of air pollutants reported annually with Jordanian JS 1140/2006. It also aimed to research concentration and weather effects using factor analyses for the impact on the actions of pollutants in this position by the criteria for pollution control (wind speed, wind direction, temperature and relative moisture) and information on pollutant sources.

METHODOLOGY

Air Monitoring Sites

The monitoring sites in Zarqa city consist of 3 stations distributed as follows: WadiHajar –Zarqa (HAJ), Masane – Zarqa (MAS) and Arab Bank Garden – Zarqa (ABK). The locations of the measurement stations were chosen based on a preliminary mapping at the city and the monitoring sites were chosen in a way that ensures a fair and comprehensive representation of anthropogenic activities. Data obtained during the monitoring effort between May 2014 until May 2016. Figure 1 indicates the geographical locations of the monitoring stations.

Procedures for monitoring

Air samples are analyzed with the use of Chemiluminescence, PM_{10} analysis, Beta – Attenuation .analysis, and Ultra Aggressive Fluorescence analysis of Nitrogen dioxides (NO_2) and Sulphur dioxide (SO_2), (Ministry of Environment 2014 -2016). Furthermore, weather data in the monitoring stations include wind speed, direction of the wind, temperature and relative humidity. Table 1 show which pollutants are monitored at each station.

Statistical Analysis

The average daily pollutants, SO_2, NO_2 and PM_{10} were obtained from unidentified sources in the Royal Scientific Society (RSS) and the Minister for the Environment. The knowledge was entered on a personal computer for review using the Social Science Statistical Package (SPSS) version 18. The Kolmogorov-Smirnov method, histogram plot and QQ conspiracy are used to analyze the normality of air pollutants and weather data. Many variables have been shown to be normally distributed.

Findings and Discussion

Statistics

Table 2 show the yearly average concentration for all the pollutants which monitored at each station during two years 2014 and 2015 and the type anthropogenic pollution in each station.

Variation of Pollutant Levels

Sulphur dioxide (SO_2) Trend

A colorless, non-flammable gas, suffocating and choked odor, is the sulfur dioxide (SO_2). It is produced by geothermal activity naturally. Nevertheless, nearly 99% of SO_2 is artificially generated in the atmosphere. Anthropic origins include the mining and burning of fossil fuels (mostly coal and petroleum), non-ferrous smelting machines, iron ore mills, pulp, pulp and paper mills and steel mills. Residential, industrial and commercial space heating sources are part of the area (Donna and Farah, 2004).

Sulphur dioxide is an irritant when inhaled and in people exposed to sulphur dioxide, elevated levels can cause trouble in breathing. Asthma patients and chronic lung disease can especially be

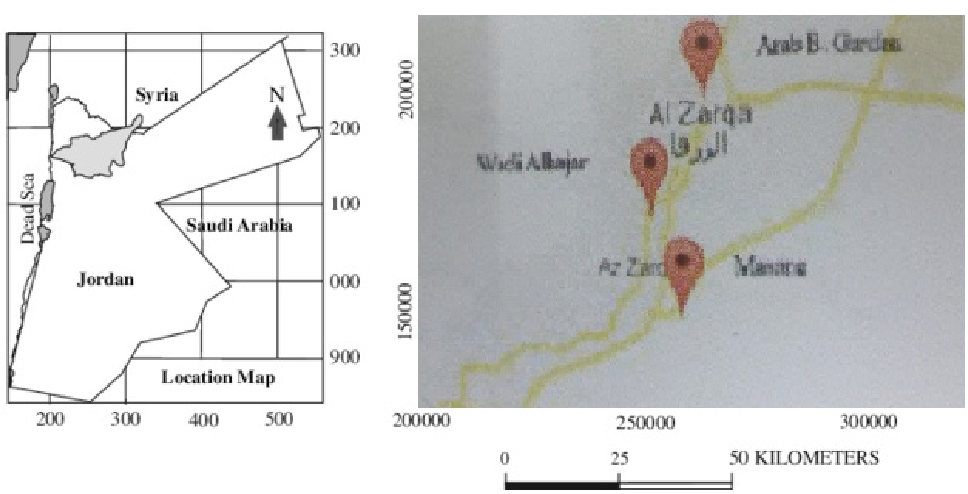

Fig. 1. Study area's location map.

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

Type of station	Station Name	Short Name	SO_2	NO_2	PM_{10}
Traffic	Health Center Wadi Hajjar	HAJ	1	1	1
Industrial	Main Slaughter house Masane's Zone	MAS	1	1	1
Urban	Arab Bank Garden	ABK	1	1	1

Table 2. Yearly Average concentrations for the air pollutants in each station.

Type of station	Station Name	Short Name	Year	SO_2	NO_2	PM_{10}
Traffic	Health Center Wadi Hajjar	HAJ	2014	8.74	25.53	110
			2015	5.45	14.54	117.29
Industrial	Main Slaughter houseMasane's Zone	MAS	2014	7.46	17.62	148
			2015	3.51	15.25	146.33
Urban	Arab Bank Garden	ABK	2014	10.94	22.34	123
			2015	6.67	18.64	117.20

prone to adverse effects of SO_2 which may cause asthma attacks within a range of concentrations that occur in extreme pollution (Odat, 2013).

Figure 2 illustrates the yearly average SO_2 concentration for all stations during two years. The highest annual average SO_2 readings can be readily seen in the course of 2014 at ABK station, and we can find that the concentration in 2014 is higher in all stations relative to 2015.

The yearly average Jordanian Standard for ambient air quality for SO_2 is 40 ppb. The annual average SO_2 concentration satisfied of the Jordanian standards requirement for all station during monitoring two years, (Figure 2).

(PM_{10}) Trend

Particular (PM) rates attract more attention due to an growing number of people living in urban centers worldwide. PM emissions are the main cause of respiratory health problems in developed countries. (Yang, 2002). Vehicle exhausts, pneumatic and brake wear pollution and road congestion are the major sources of atmospheric pollutant concentrations on urban roads.

The average annual PM_{10} in Jordan is 70 mg/m^3.

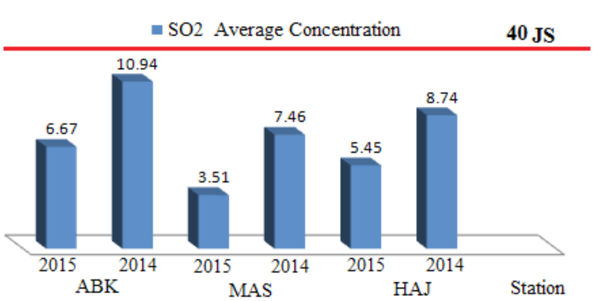

Fig. 2. SO_2 yearly average all stations

Figure 3 shows that every station exceeded this average for two years, and that high PM_{10} readings in all the stations are caused by regional dust events and local soil erosion. Many local contaminants, including motor vehicles, light and domestic heating were also emitted. Unstable atmospheric events can also contribute to higher PM10. You may also remember that compared to other stations, MAS was the highest calculated.

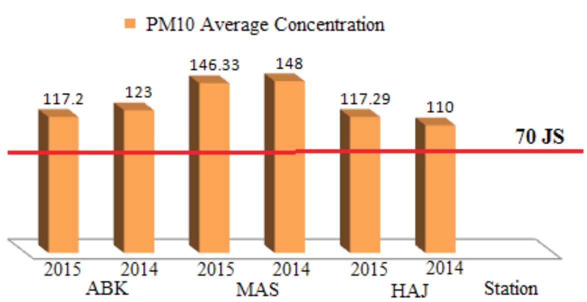

Fig. 3. PM_{10} yearly average in all stations during the years 2014 and 2015

Nitrogen dioxide (NO_2) Trend

Nitrogen dioxide (NO_2) is one of the toxins factors for a variety of human health consequences. Hospital admission, high and low respiratory disorder, bronchitis, chronic toxins and increased child mortality are among the health effects of NO_2 (WHO, 2000). The yearly average Jordanian Standard for ambient air quality is 50 ppb. Despite high maximum NO_2 levels, the average concentration was within the JS standard and there were no exceedances for all stations during two years (Figures 4). The highest average yearly of NO_2 readings occurs in HAJ station during the year 2014.

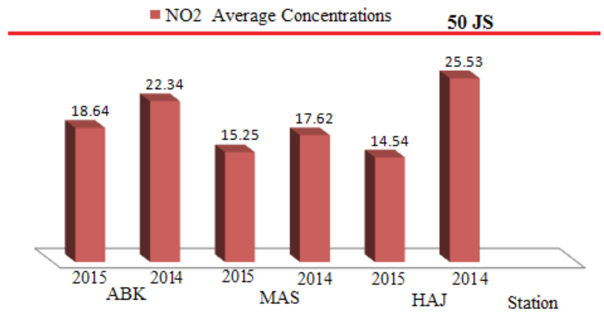

Fig. 4. NO_2 yearly average in all stations during the years 2014 and 2015

Comparison of Tukey-Kramer's annual mean values

The Table 3 shows that the mean annual air pollutants and meteorological parameters are very different as determined by means of the Tukey-Kramer HSD nonlinear regression analysis. SO_2, PM_{10} and NO_2 were higher in 2014 and took class A but in 2015 considered class B. But in 2015 RH level, temperature, wind speed and wind direction higher. This raises the weather impact on pollutant concentration.

Figure 5 and 6 compare the average yearly concentrations of NO_2, SO_2 and PM_{10} between three locations in Zarqa city, respectively. we can notice that the yearly average variations of PM_{10}, NO_2 and SO_2 display a gradual increase in 2014 comparing with 2015. Due to local dust and soil abrasion, regional dust storms and local soil abrasion have in the next two years resulted in high PM_{10} levels in each station.

Plot series for meteorological parameters

Yearly average of temperature

Table 4 shows the maximum, minimum and yearly average of temperatures in all stations during the monitoring period. The result show a convergence of the frequency pattern in the yearly rates of temperatures during the study period.

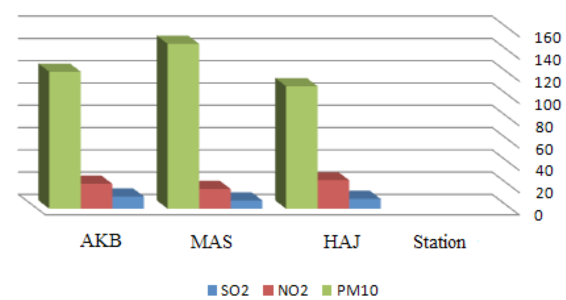

Fig. 5. Comparing between yearly average Pollutants in all stations during the years 2014

Yearly average of relative humidity

Relative humidity is a form of major weather event that efficiently reduces air pollution by wet deposition and prevents air pollutants. Table 5 shows the maximum, minimum and yearly average of RH% in all stations during the monitoring period. The result shows a convergence of the frequency pattern in the yearly rates of relative humidity during the study period.

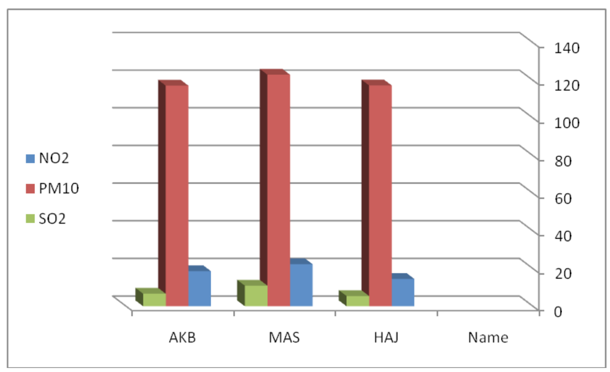

Fig. 6. Comparing between yearly average Pollutants in all stations during the years 2015

Table 3: Annual variability of meteorological conditions and sources of air pollutants.

Climatic Variables							Year
NO_2	PM_{10}	SO_2	Wind Direction	Wind Speed	RH%	Temperature	
21.84A	127.01A	9.06A	228.12B	3.33B	49.2B	19.9 B	2014
19.02B	91.60 B	5.22B	269.52A	3.35A	51.9A	22.7 A	2015

Table 4. Maximum, minimum and average of Temperatures during the monitoring period.

Meteorological Parameters	Year	Maximum	Minimum	Average
Temperature °C	2014	41.2	0.75	20.9
	2015	44.5	1	22

Table 5. Maximum and minimum average of relative humidity during the monitoring period.

Meteorological Parameters	Year	Maximum	Minimum	Average
Relative Humidity %	2014	100	0.0	50
	2015	100	12	51.6

Yearly average of wind speed

Table 6 and Figure 7 show the results of monitoring wind speed during the two years 2014 and 2015. It can be clearly seen that calm winds (i.e wind less than 5 km/h) prevail about 54.9 % in 2014, where it reach about 43% in 2015 and this is improved the effect of speed of wind on increasing the level of pollutants in 2014, thus calm wind will concentrate pollutant in place and do not allow to reduce emissions from various pollution sources.

Table 6. Wind speed and wind direction in all stations during the monitoring period.

% 2014	% 2015	Wind speed
0.0	0.1	> 25 km/h
0.7	7.3	15 > 25 km/h
12.6	19.8	10 > 15km/h
31.8	29.8	5 < 10 km/h
31.6	26.8	2 < 5km/h
13.1	16.2	0.5 < 2km/h
10.2	0.0	< 0.5 km/h

On the other hand, strong winds (i.e wind more than 5 km/h) prevail about 45.1 % in 2014, where it reaches about 57 % in 2015. The powerful wind also followed by dust, which caused the air pollution but also allowed the anthropogenic source to scavenge local contaminants (Xie *et al.*, 2005; Wang *et al.*, 2014a). For other tests, similar findings were also obtained (Guerra *et al.*, 2006; Pateraki *et al.*, 2012). Wind speed affects the distribution of pollutants while wind direction affects the transportation of pollutants through regions.

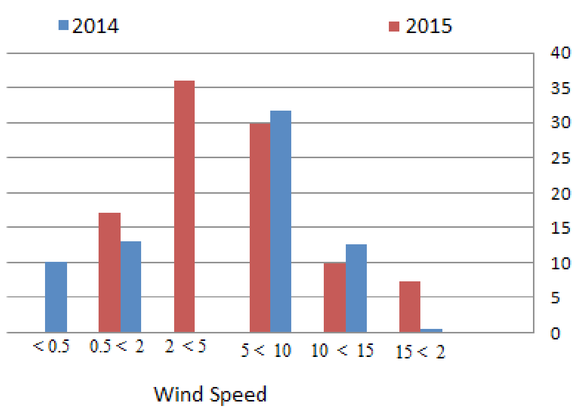

Fig. 7. Wind speed for 2014/2015.

Yearly average of wind Direction

Figure 8 shows the results of monitoring wind direction during the monitoring period (year 2014 and 2015) showed that west wind is the dominant during two years.

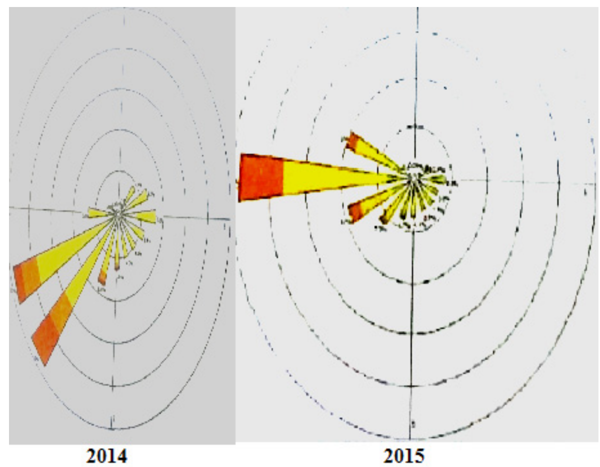

Fig. 8. Wind direction for 2014/2015.

Multivariate Analysis: Factor Analysis (FA)

The main aim of FA is to define a set of p parameters X as a smaller number m (or so-called Factor (F)), of a linearly independent matrix, comparing different "dimensions" in the initial data set. This FA mode leading to objective reduction/grouping of parameters with specific time variance is called P mode (Richman, 1986).

The key matrix analysis of the components is given in Table 7. Main component analyzes (PCA) were performed to evaluate the possible contributing factors to pollutants and meteorological parameters. Three variables have their own values > 1 (Hopke, 1991). Those three reasons for the overall difference were 85.4%. The first factor is the largest variance (45%) that is mostly charged with relative humidity, wind speed and PM_{10}. This factor may indicate the source of mixed sources like airborne pollution resulting from street dust and soil dust. PM_{10} concentrations rely directly on wind velocity and relative humidity. Light winds, by comparison, do not support diffusion and also lead to the development of nocturnal temperature reversals linked to increased pollution (Katsoulis, 1988).

The second element (22.3 %) is characterized by high SO_2 loading and temperature characteristic of vehicle emissions, power plants, fuel combustion in industry and refining operations. The third factor (17.1%) is predominantly loaded by NO_2 and wind direction. Since wind direction in Zarqa is mostly from the west, it is realized that high levels of NO_2 were emitted from the various activities in the cities (motor vehicles, industry and domestic heating).(N´uñez-Alonso.D.,et. Al.,2019).

DISCUSSION

Wadi Hajar (HAJ)

The yearly average concentrations of sulfur dioxides (SO_2) in HAJ station were 8.74, 5.45 for 2014 and 2015, respectively, (Table 2). These concentrations satisfied with JS limit. While the level of PM_{10}were 110 for 2014 and 117.29 in 2015, it record number of violation, this phenomenon can be explained by analyzing weather factors that have a role in transporting emissions to monitoring sites. In addition to wind speed and direction, the distance that can enter pollution and concentration in the surrounding air plays a significant role in atmospheric stability. The highest average levels of NO_2 were recorded in this station as the type of pollution come from traffic source, where the yearly average concentrations of NO_2 were 25.53 for 2014 and 14.54 in 2015 without any exceedance of yearly limits of the Jordanian standard No. 1140/2006 for both years, Figure 9.

Main Slaughter house Masane's Zone (MAS)

The results showed that the monitoring site in MAS station was exposed to high levels of PM_{10}, where it recorded many exceeding the yearly allowable limits of the Jordanian standards. While the levels of NO_2 and SO_2 were within the yearly limits and no excess was recorded.

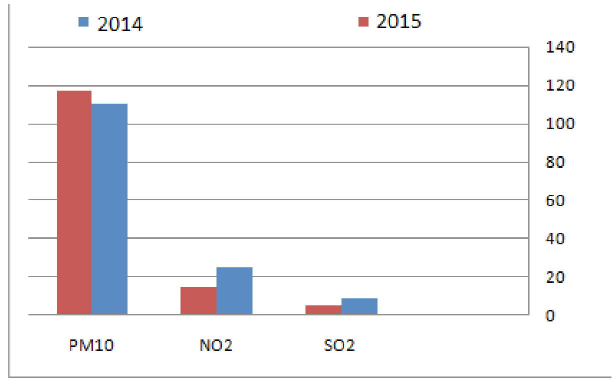

Fig. 9. HAJ Station for 2014/2015.

Result of PM_{10} showed rises in the yearly average concentration, it excesseded the Jordanian standard limits of 70 mg / m^3. It is also noticeable that winds speed plays an important role in increasing the level of PM_{10} concentration in this site beside the presence of many sources resulting from burning fuel in fixed and mobile stations, manufacturing processes, as well as natural dust.

MAS station present higher concentrations comparing with the other stations among two years. This is improving the effect of meteorological conditions, since wind direction in Zarqa is mostly from the west, it is realized that pollution levels in measurement stations in the center of Zarqa (i.e MAS station) is the higher as they include air pollution emitted from the various activities in the cities (motor vehicles, industry and domestic heating).

Arab Bank Garden (ABK)

The results of monitoring in (ABK) station showed that the levels of NO_2 and SO_2 were low, as no

Table 7. Heavy metal factor loadings and communalities (statistically important bold loads).

Parameter	Factor 1	Factor 2	Factor 3
Temperature		0.85	
Relative Humidity	0.83		
Wind Speed	0.89		
Wind Direction			0.79
SO_2		0.87	
NO_2			0.81
PM_{10}	0.92		
Total Variance	6.26	2.81	2.29
Percent of Variance	45%	22.3%	17.1%
Percent of Cumulative Variance	45%	67.3%	85.4%

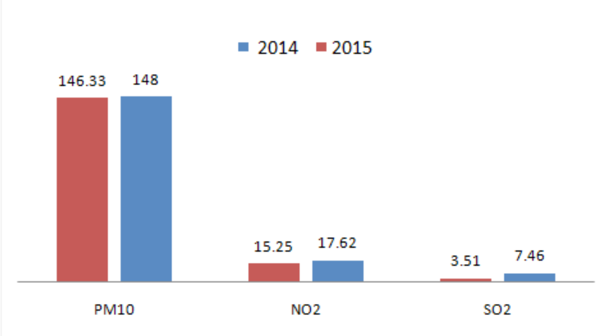

Fig. 10. MAS Station for 2014/2015.

exceeding the yearly in the Jordanian standard. While the levels of PM_{10} are high and it record number of yearly violations, Figure 11.

And this result 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 and natural dust. Beside the effect of calm winds that do not help reduce emissions from various pollution sources.

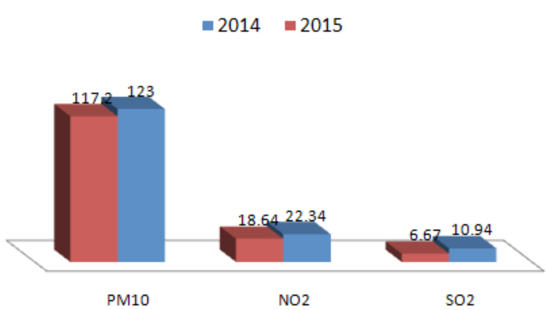

Fig. 11. ABK Station for 2014/2015.

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. Also, calm winds 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).

CONCLUSION

Results show that the monitored pollutants: SO_2 and NO_2 were generally within the current Jordanian standard guideline limits; however PM_{10} concentrations in most sites exceeded the standard.

Three variables with total variance of 85.4 percent were extracted to examine the effects of local meteorological conditions. The first factor is due to the largest variation (45%), primarily powered by relative humidity, wind velocity and PM_{10}. Second, the high load of SO_2 and the temperature (22.3%) is differentiated. NO_2 and wind direction are often mounted on the third element.

A little variation is marginally found between the annual averages of atmosphere contaminants and environment parameters, determined from the nonlinear regression test of the SO_2, PM_{10} and NO_2 by Tukey-Kramer HSD. In 2015, though, RH %, wind and wind speed increased. This improves the effect of weather conditions on pollutant concentrations.

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Disclaimer

The opinions and conclusions of the authors are those of the authors and are not necessarily those of the Jordanian Environment Ministry, or any of the organizations 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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