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Influence of Meteorological Parameters on Air Quality at Hashemite University, Jordan

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Abstract

Four threshold air pollutants (SO_2, NO, NO_2, and O_3) in addition to meteorological parameters were monitored at the Campus of the Hashemite University (HU) for two years (1/1/2012 through 30/12/013). Correlations between air pollution and meteorological parameters were derived. The results showed that O_3 has a positive correlation with air temperature, wind speed and wind direction, but has a negative correlation with the relative humidity (RH). SO_2 was found to have a negative correlation with the RH and wind speed, but positive correlation with air temperature. NO has negative correlation with air temperature, RH, and wind speed. And finally, NO_2 has a negative correlation with RH and wind speed, but it has positive correlation with air temperature. Justify the reasons in brief with recommendations to improve the air quality

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Introduction

Air pollution in North Africa and the Middle East is receiving increase attention due to its health consequences[1,2,3,4]. The Middle East is impacted by frequent dust storms in addition to regional long range transport of air pollution, carried by winds from three neighboring continents: Europe, Africa, and Asia[5].

The Hashemite Kingdom of Jordan with a population of eleven million and a land area of 89,000 square kilometers, has undergone an unprecedented rate of growth in the last fifteen years due to regional political crises. Rapid development of the industrial sector, coupled with the lack of zoning and environmental protection legislation, has contributed to the deterioration of the Jordanian environment. For example, emissions from motor vehicles or old industrial establishments are not regulated throughout the country[6].

Anthropogenic sources of air pollution in north Jordan include motor natural dust, vehicles, utility, smelters, cement factories, and open burning. The

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city of Zarqa at the middle region in Jordan where the Hashemite University Campus (HUC) is located is exhibiting rapid growing industrial activities with a population of about one million inhabitants[7]. It contains more than 35% of the Jordanian industry by number including an oil refinery, a thermal power plant, steel factories, a pipe factory, a cement factory, a fertilizers factory, a waste water treatment plant, as well as several other small industrial facilities[4]. As a result of such concentrated anthropogenic activities, air quality in Zarqa is questionable.

This paper aims at studying air quality at HUC and examined the influence of weather conditions on the concentrations of NO, NO2, SO2, and Ozone. More than 40,000 students and employees are spending most of their daily hours inside the campus, which is located downwind from the oil refinery and the thermal power plant.

Methodology

Sampling Location

The Hashemite University (Figure 1) is a public Jordanian university commissioned in the academic year 1995/1996. It has become one of the largest universities in Jordan.Total area of the campus is about 8500 hectares; 15% of which are designated for buildings, roads, sport facilities and other structures. The rest is meant to be planted by different tress, but in reality only one fourth of the campus is planted with olive trees. The Hashemite University has 13 Colleges including the Faculty of Natural Resources and Environment which owns and operates the air quality monitoring station that is deployed to collect required data for this study.

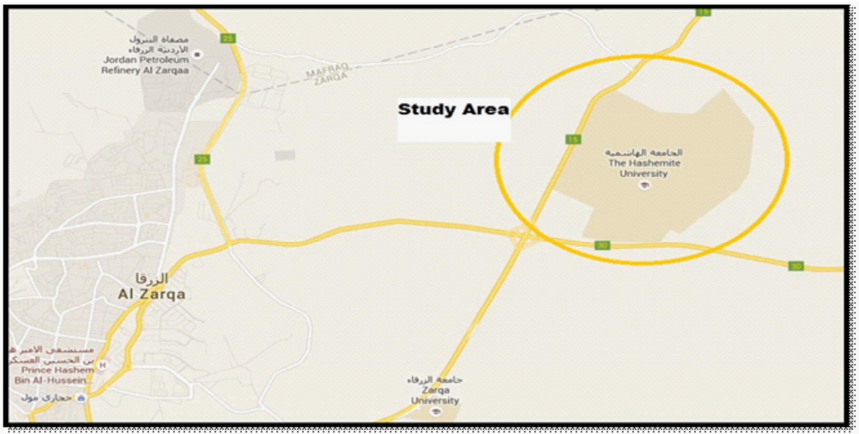

Fig. 1: sample location at the campus of the Hashemite University, (32.099207, 36.200353) coordinates[8].

Data Collection

Instrumentation

Air quality and meteorological parameters were monitored by the air quality monitoring station in the research and teaching laboratory in the faculty of natural resources and environment inside the campus of the Hashemite University. The station is designed to provide continuous readings of criteria atmospheric pollutants including O_3, NO_2 , NO, NOx and SO_2 concentrations; and meteorological parameters such as temperature, relative humidity, and wind speed. Continuous automatic measurement of above parameters were recorded every five minutes for the periods of1/1/2012 to 30/12/2013. Ozone is measured by a UV Photometric O_3 Analyzer, NO_x by a Chemiluminnescence NO-NO_2-NO_x Analyzer and SO_2 by pulsed Fluorescence SO_2 Analyzer (Thermo Fisher Scientific, Waltham, MA-USA). Mention reference for methodology[7].

Statistical Analysis

Collected air quality data was exported into SPSS software format in order to perform advanced statistical analysis including basic statistics; temporal variability and correlations multivariate.

Results and Discussion

Statistical characterization of climatic variables and air pollutants

Data analyses were started by calculating ordinary statistics including mean, standard deviation (SD), maximum, minimum, Coefficient of Variation (CV), Skewness, and Kurtosis (Table 1).

Table 1: Descriptive statistics for Air Pollutants and climatic variables

Parameter	Min	Max	Average	SD	CV	Skewness	Kurtosis
NO_x	0	390.16	9.03	9.20	101.81	77.7	159.39
NO_2	0	410.14	15.67	11.90	75.97	3.69	58.06
NO	0	228.76	1.17	2.94	250.20	16.98	744.03
O_3	0	500.31	55.56	23.78	42.81	0.72	1.13
SO_2	0	221.41	2.83	4.95	174.90	12.57	240.02
Wind Direction	0.76	350.04	225.46	70.10	31.09	-0.66	-0.52
Wind Speed	0.271	29.70	3.35	2.29	68.43	1.04	1.54
RH%	5.31	97.90	51.50	20.89	40.55	-0.09	-1.08
Temperature	-4.45	43.34	18.40	7.52	40.87	0.08	-0.61

Temporal Variation of Oxides

The results of linear regression analyses for $SO_{2,}$ NO, NO_2, NO_x and O_s in time, daily, monthly, and yearly basis, using ANOVA tests, are presented in Tables 2-5, respectively. The results indicate that the changes are not exactly linear, however the attenuations could be attributed to many factors such as human induced activities (e.g. daily factories working hours, vacations, diversity of burning fuel type, factory malfunctions, etc) or could be attributed to climatic variables as temperature, wind speed and relative humidity. The severity of the change in pollutant concentration with time can be estimated by the magnitude of the slope.

Table 2: Changes of air pollutants on Time basis

RMSE	R^2	F-test	Linear Equation	Pollutants
54.9	0.001271	<.0001*	SO2 = 36.16 - 9.6879e-9*Time	SO_2
52.7	6.43E-05	0.0002*	NO = 5.32 - 1.2099e-9*Time	NO
511.5	0.049919	0.0000*	NO2 = 515.51 - 1.4533e-7*Time	NO_2
9.12	0.002371	<.0001*	NOx = -74.96 + 2.44e-8*Time	NO_x
23.27	0.061755	<.0001*	O3 = -1071.84 + 3.28e-7*Time	O_3

Table 3: Changes of air pollutants over Day Time

RMSE	R^2	F-test	Linear Equation	Pollutants
4.95	6.64E-05	0.0002*	SO2 = 2.90 - 0.00459*Day	SO_2
2.75	0.00056	<.0001*	NO = 1.04 + 0.01*Day	NO
11.84	0.001599	<.0001*	NO2 = 14.69 + 0.054*Day	NO_2
9.13	5.11E-05	0.0010*	NOx = 8.87 + 0.01*Day	NO_x
24.02	0.000404	<.0001*	O3 = 55.1 + 0.055*Day	O_3

Table 4: Changes of air pollutants over Month Time

RMSE	R2	F-test	Linear Equation	Pollutants
4.95	0.000553	<.0001*	SO2 = 3.053 - 0.034*Month	SO_2
2.74	0.009068	0.0000*	NO = 0.66 + 0.08*Month	NO
10.86	0.159523	0.0000*	NO2 = 6.49 + 1.38*Month	NO_2
9.099	0.007333	0.0000*	NOx = 7.49 + 0.23*Month	NO_x
21.71	0.183735	0.0000*	O3 = 36.28 + 3.002*Month	O_s

Table 5: Changes of air pollutants over years

RMSE	R2	F-test	Linear Equation	Pollutants
4.95	0.000754	<.0001*	SO2 = 549.84 - 0.27*Year	SO2
2.74	0.004239	<.0001*	NO = 721.74 - 0.36*Year	NO
10.33	0.239152	0.0000*	NO2= 23338.92 - 11.59*Year	NO2
9.13	4.23E-05	0.0027*	NOx = -230.15 + 0.12*Year	NOx
24.01	0.001654	<.0001*	O3 = -3877.79 + 1.95*Year	O3

Comparison between Mean Values using Tukey-Kramer HS

Monthly Variation

A comparison between mean values calculated using the Tukey-Kramer HSD method is presented in Table (6) for monthly variation of climatic variables and air pollutants. Concentrations are classified into classes where class A denotes highest concentration, while class L represents the lowest concentration or pollution level. For example higher ozone values are recorded in September and August, whereas January and February experienced the lowest O3 concentration. Temperature exhibits a similar trend.

Table 6: Monthly variation and means of Climatic Variables and Air Pollutants through months

Air Pollutants					Climatic Variables				Month
O_3	NO_2	NO	NO_x	SO_2	Wind Direction	Wind Speed	RH%	Temperature	
32.49L	9.53I	1.20D	9.14CD	4.01A	194.83JK	3.05G	62.05A	11.17J	1
37.75K	9.77HI	1.08E	9.38C	2.94D	203.27I	3.35E	58.89B	11.90I	2
40.28J	10.05H	0.92F	9.38C	2.59E	216.37G	3.29EF	55.23D	15.35G	3
45.75I	9.66I	0.81GH	8.88D	2.41F	232.51F	3.23F	44.03H	18.44F	4
51.57H	11.94G	0.84FG	8.40E	2.72E	243.52E	3.54D	41.04I	21.87E	5
60.23D	18.26C	1.06E	7.84F	3.46C	247.57D	4.18A	46.04G	23.54B	6
59.31E	17.20D	0.93F	6.61G	3.30C	257.64A	3.70C	53.09E	23.38B	7
82.17A	14.84F	0.76GH	5.46I	1.99H	254.29B	4.02B	48.70F	24.69A	8
78.62B	16.64E	0.74H	5.83H	1.33I	251.00C	3.65C	52.67E	22.50C	9
66.25C	21.55B	1.32C	11.06B	2.19G	209.22H	2.65I	37.31J	22.18D	10
57.01F	23.34A	2.06B	13.18A	3.37C	192.58K	2.57J	56.99C	13.32H	11
54.35G	23.19A	2.20A	13.25A	3.78B	196.11J	2.80H	62.48A	11.11J	12

The concentrations of NO, NO_2 ,NO_x and SO_2 are high in winter months (January, February, November and December), and low in Spring and Summer months (April, May, June, July, August and September). It seems that in June month there is relatively high concentration of these pollutants and the reason for this also, is due to low abnormal temperature or heavily working hours at that time. Whereas the concentration of O_3 are high in summer months (June, July, August and September) and low in winter and Autumn months (January, February, November and December) and this because Ozone is a greenhouse gas depends on temperature in its formation which they have a strong positive relationship between them and have the same tend.

All of air pollutants including (NO, NO_2, NO_x, SO_2) have shown a negative relationship with ozone concentration. The levels of various air pollutants are closely correlated with the level of heavily working hours. Therefore heavily working hours affects the concentration of these pollutants.

Annual Variation

Table (7) indicates that there is little deferent between annual means of air pollutants and meteorological parameters as calculated using the nonlinear regression analysis of the Tukey-Kramer HSD. Temperature, SO_2 ,NO and NO_2 are higher in the year of 2012 which take A class, but considered to be class B in 2013. However, O_3, NO_x, RH%, and wind speed are higher in 2013.

Table 7: Annual variation and means of meteorological parameters and air pollutants

Climatic Variables			Air Pollutants						Year
NO_x	NO_2	NO	O_3	SO_2	Wind Direction	Wind Speed	RH%	Temperature	
8.92B	21.44A	1.34A	54.96B	2.96A	225.13A	3.33B	50.6B	18.9A	2012
9.04A	9.85B	.098B	56.91A	2.69B	225.65A	3.35A	52.3A	17.9B	2013

Step Regression Analysis (Fit Model)

According to stepwise regression analyses using Fit Model algorithm within JMP software, indicated that all climatic variables are highly effective on pollutant concentrations (P<0.0001) and thus cannot be removed from the full model. According to Table (8) the concentration of pollutants varies in its relation to climatic variables. The rate of each climatic variable on the final prediction of the air contaminant can be distinguished by the associated slope that has a scientific meaning Figure (2) to Figure (13).

Table 8: Stepwise regression analyses for the measured air pollutants as affected by all Climatic variables

RMSE	R2	F-test	SWR Equation	Parameter
4.89	0.02342	0.0000*	SO_2= 5.5120626-0.008771*Temperature -0.035511* RH%-0.207024*Wind Speed	SO_2
42.7	0.00671	<.0001*	NO=2.1239881-0.017782*Temperature -0.007371* RH%-0.077986*Wind Speed	NO
511.6	0.03323	0.0000*	NO_2=13.049102+0.2281184*Temperature +0.0308087*RH%-0.987845*Wind Speed	NO_2
98.8	0.05318	0.0000*	NO_x=16.603619-0.138474*Temperature -0.04792* RH%-0.779246*Wind Speed	NO_x
18.99	0.37529	0.0000*	O_3=5.90+1.92*Temperature +0.159*RH%+1.97*Wind Speed	O_3

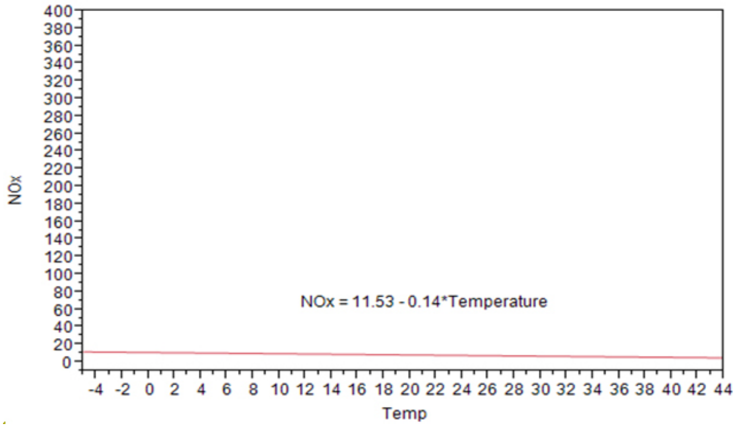

Fig. 2: NO_x relationship with temperature and their correlation

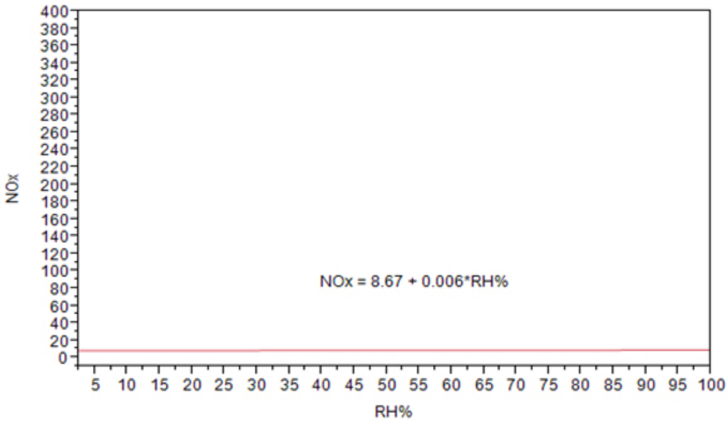

Fig. 3: NO_x relationship with Relative Humidity and their correlation

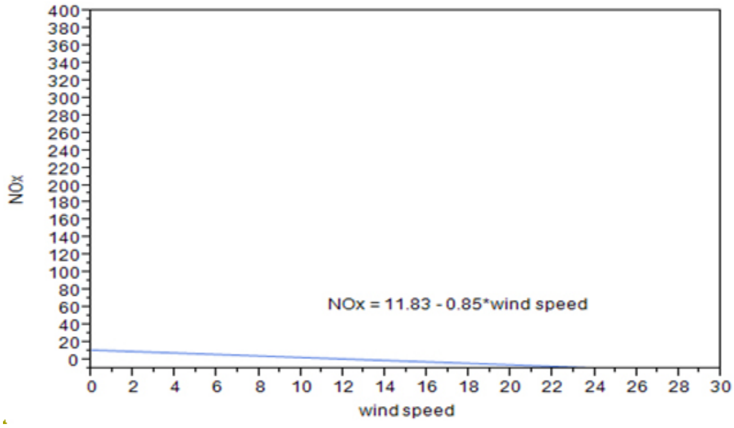

Fig. 4: NO_x relationship with wind speed and their correlation

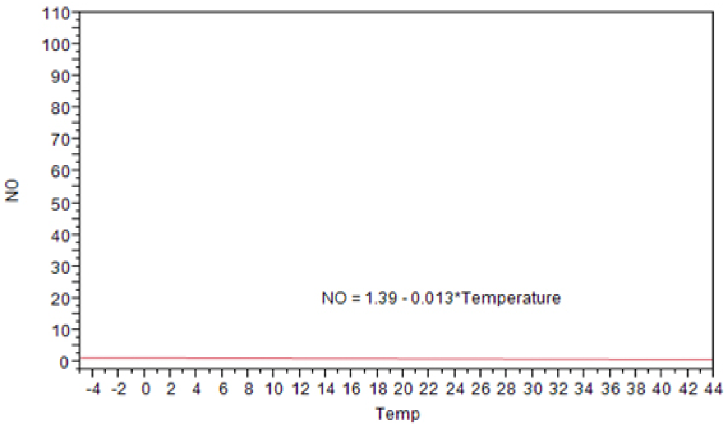

Fig. 5: NO relationship with temperature and their correlation

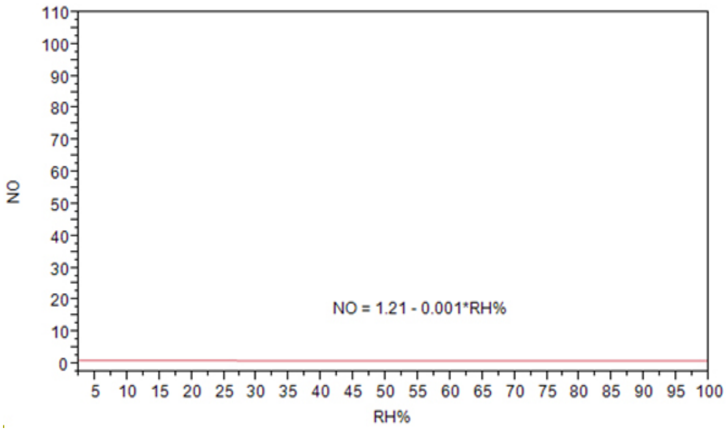

Fig. 6: NO relationship with relative humidity and their correlation

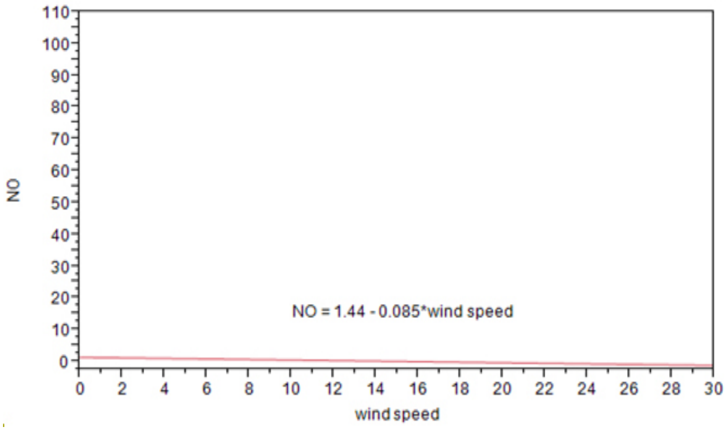

Fig.7: NO relationship with wind speed and their correlation

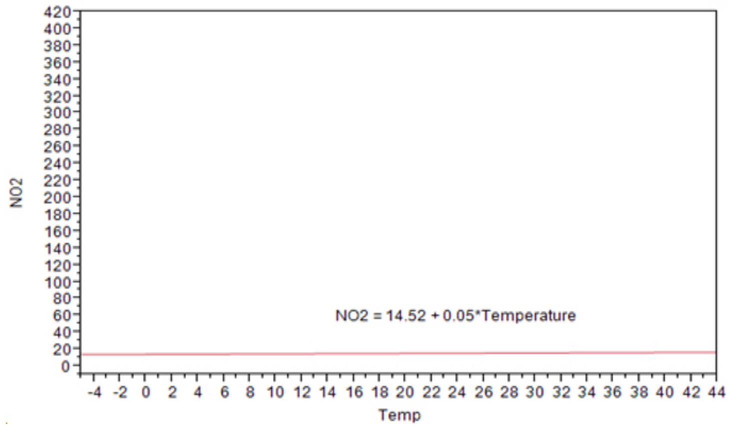

Fig. 8: NO_2 relationship with temperature and their correlation

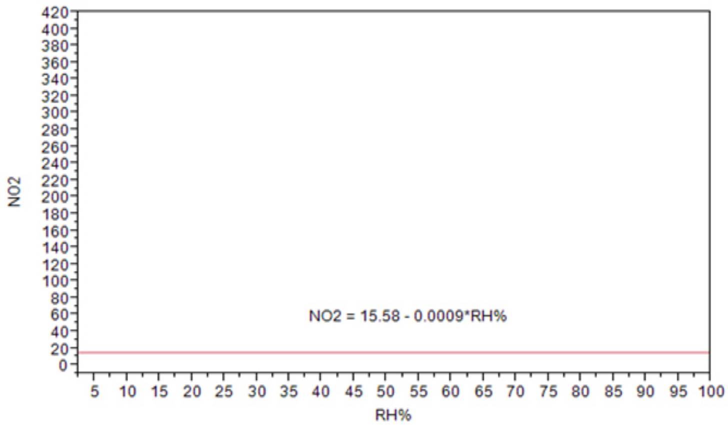

Fig. 9: NO_2 relationship with relative humidity and their correlation

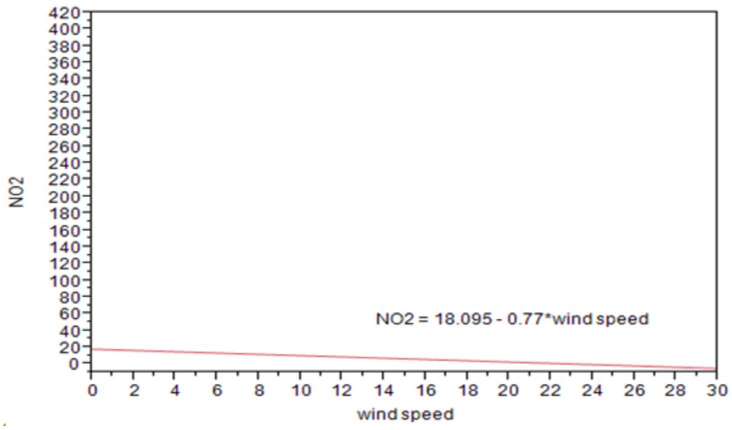

Fig. 10: NO_2 relationship with wind speed and their correlation

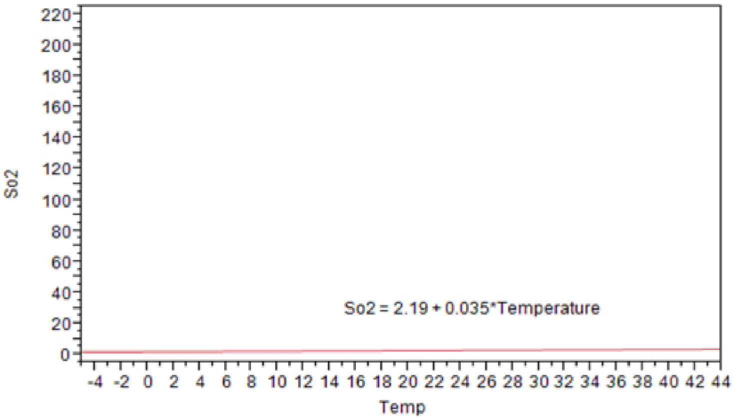

Fig. 11: SO_2 relationship with temperature and their correlation

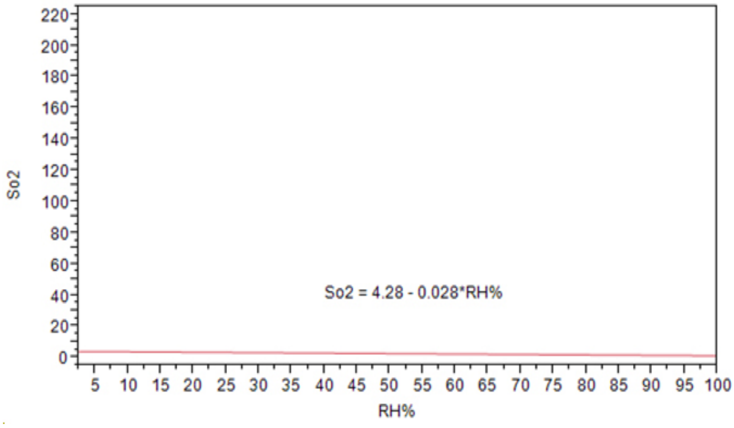

Fig. 12: SO_2 relationship with relative humidity and their correlation

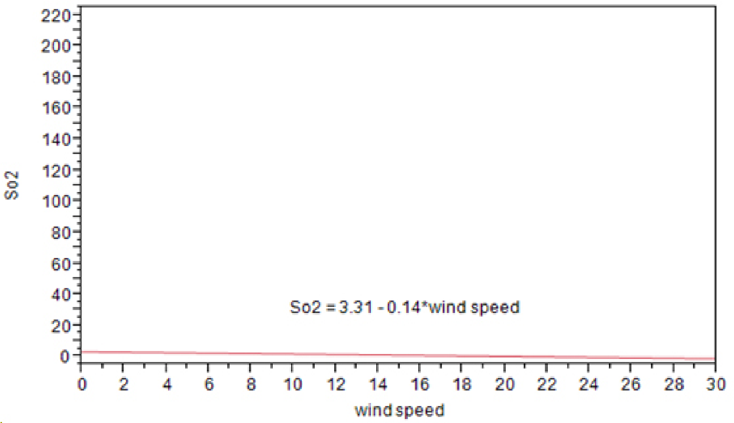

Fig. 13: SO_2 relationship with wind speed and their correlation

Multivariance Correlation Between Climatic Variables and Air Pollutants

The Multivariance method is deployed to retrieve correlations between air pollutants and basic meteorological parameters. Results are summarized in Table (9):

Based on the findings presented in Table (9), the following remarks are derived:

Table 9: Correlation between air pollutants and meteorological

O_3	NO_2	NO	NO_x	SO_2	Wind Speed	RH%	Temperature	
0.58	0.035	-0.035	-0.114	0.05	0.38	-0.69	1	Temperature
-0.32	-0.002	-0.008	0.014	-0.12	-0.23	1	-0.69	RH%
0.38	-0.14	-0.071	-0.21	-0.07	1	-0.23	0.38	Wind Speed
0.31	0.007	-0.03	-0.04	-0.1	0.33	-0.02	0.31	Wind Direction
-0.07	0.14	0.24	0.25	1	-0.07	-0.12	0.05	SO_2
-0.25	0.65	0.62	1	0.25	-0.21	0.014	-0.114	NO_x
-0.12	0.39	1	0.62	0.24	-0.07	-0.008	-0.04	NO
-0.02	1	0.39	0.65	0.14	-0.15	-0.002	0.035	NO_2
1	-0.02	-0.12	-0.25	-0.07	0.38	-0.32	0.58	O_{SS}

Temperature has strong negative relationship with RH%, weak negative relationship with NO_x and NO, moderate positive relationship with Wind Speed, Wind Direction, week positive relationship with NO_2 and SO_2, and strong positive relationship with O_3.

RH% has strong negative relationship with temperature, moderate negative relationship with wind speed, weak negative relationship with O_3, SO_2, NO, and NO_2. However, it has weak positive relationship with Wind Speed and NO_x.

Wind Speed has weak negative relationship with SO_2, NO, NO_2, moderate negative relationship with RH%, NO_x, and moderate positive relationship with Temperature and Wind Direction and O_3.

SO_2 has weak negative relationship with Wind Speed, Wind Direction, RH%, and O_3, and weak positive relationship with Temperature, NO_2, moderate positive relationship with NO_x and NO.

O_3 has weak negative relationship with SO_2, NO, NO_2, moderate negative relationship with RH%, NO_x, moderate positive relationship with Wind Speed, and Wind Direction, and strong positive relationship with temperature.

NO has weak negative relationship with temperature, wind speed and wind direction, RH% and O_3, moderate positive relationship with SO_2, NO_2, strong positive relationship with NO_x.

NO_2 has weak negative relationship with wind direction, RH%, O_3, weak positive relationship with temperature, SO_2 and wind Speed, moderate positive relationship with NO, and strong positive relationship with NO_x.

NO_x has weak negative relationship with temperature, wind direction, and moderate negative relationship with Wind speed, O_3 and weak to moderate positive relationship with SO_2, RH% and strong positive relationship with NO, NO_2.

Conclusion

The findings of this study show that variation trends of SO_2, NO, NO_2, NO_x and O_3 correlate well with meteorological conditions parameters. O_3 demonstrates a positive correlation with air temperature, wind speed and wind direction and a negative correlation with the relative humidity. SO_2 has a negative correlation with the relative humidity and wind speed and a positive correlation with air temperature. NO shows a negative correlation with air temperature, relative humidity and wind speed. And NO_2 demonstrates a negative correlation with relative humidity and wind speed and a positive correlation with air temperature.

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