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## Temporal variations of air pollution and meteorological effects in Al-Hashimeya town, Zarqa - Jordan

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### ABSTRACT

Air pollutants including SO<sub>2</sub>, H<sub>2</sub>S, NO<sub>x</sub> and TSP were measured in Al-Hashimeya town in Zarqa Governorate, where there are three main sources contributing in different degrees to the pollution of air and these are Jordan Petroleum Refinery, Al-Hussein Thermal Power Station, and Assamra Purification station for household sewage Water. The reports and data relating to pollution in al-Hashimeya have been collected from all sources that had measured the level of pollution in this area during the period from 2005 to 2009 are presented. The effects of local meteorological conditions were studied by statistical analysis. The concentration variations in air pollutants are closely related to those in local meteorological conditions. Both temperature and relative humidity have significant negative correlations, whereas wind speed has a significant positive correlation with these pollutants.

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### KEYWORDS

Meteorological parameter;  
Temporal variation;  
Statistical analysis;  
Air pollution;  
ANOVA;  
Al-Hashimeya.

### INTRODUCTION

Increased concern over the adverse health effects of air pollution has highlighted the need for air pollution measurements, especially in urban areas, where many sources of air pollutants are concentrated<sup>[1]</sup>. Air becomes polluted when it contains substances in quantities that could harm the comfort or health of humans and animals, or could damage plants or materials. These substances are called air pollutants and can be solid particles, liquid droplets or gases and they can occur naturally or as a result of human activity<sup>[2]</sup>.

Development and use of statistical and other quantitative methods in the environmental science have been a major communication between environmental scien-

tists and statisticians<sup>[3]</sup>. In recent years many statistical analysis have been used to study air pollution as a common problem in urban areas<sup>[4]</sup>. The common descriptive statistical approach used for air quality measurement and modeling is rather limited as a method to understand the behavior and variability of air quality<sup>[5]</sup>. Many investigators have used probability models to explain temporal distribution of air pollutants<sup>[6,7]</sup>.

Meteorology plays an important role in air pollutants formation, dispersion, transport and dilution. Therefore, the variations in local meteorological conditions, such as wind direction, wind speed, temperature, and relative humidity, can affect the temporal variations in pollutant concentration<sup>[8,9]</sup>. An analysis of the influences of meteorological parameters on the pollutants at a spe-

cific site can contribute to a better understanding of the causes of air pollution.

Al-Hashimeya area is located north of Zarqa, about 35km northeast to Amman. This town is the most polluted city in Jordan; the air pollution has resulted from many factories and companies in the area, such as are Jordan Petroleum Refinery, al-Hussein Thermal Power Station, and Assamra Purification station for household sewage Water. Different studies have been performed to understand the source and level of air pollution in Al-Hashimeya. Most of them were restricted to water and soil.

This paper studies the temporal variations of pollutants and the meteorological effects at Al-Hashimeya by analyzing measurements of air pollutants over 5 years from 2005 to 2009 to determine the impact of pollution controlling parameters (wind speed, temperature and relative humidity) on the behavior of pollutants in this town.

### METHODOLOGY

#### Study site

Al-Hashimeya area is located north of Zarqa city, 35km northeast of Amman It is bounded by Longitude 36° 04' to 39° 09' east and Latitude 32° 04' to 32 10 north (Figure 1). This town is the most polluted city in Jordan. The air pollution has resulted from many factories and companies in the area. Potential air pollution sources including, Jordan Oil Refinery, Khirbit Al-Samra Waste water treatment plant and Al-Hussein Thermal Power station. These sources are called “Triangle of Pollution”. And each of them has a different impact on air quality. Asemi-arid Mediterranean type climate is dominant in Al- Hashimeya town which characterized by hot and dry in summer and lack rain in winter. The average annual rate of rainfall is 142 mm. The low precipitation rate worsen the air quality in Al-Hashimeya, because rain is natural process that washing out soluble substances of air<sup>[10]</sup>.

#### Data collection

Several studies conducted by the Royal Scientific Society (RSS) and the Ministry of Environment to monitor basic pollutants in the area, from 1992 to 2009 (TABLE 1 and Figure 1). Instruments installed

in the monitoring sites samples ambient air continuously and analyze it automatically, (TABLE 2 illustrate the instruments).

#### Preparing data analysis

Using yearly mean concentration of pollutants SO<sub>2</sub>,H<sub>2</sub>S, NO<sub>x</sub> and TSP. The data were obtained from unpublished sources (RSS). Missing values were substituted. If, for example, for a particular year the value was missing, then it was substituted by taking the average of the preceding and succeeding years. This was

**TABLE 1 : Monitoring sites and their position from pollution sources in Al-Hashimeya.**

Monitoring sites	Distance and direction of station from pollution sources
IBN EL Anbary School	6 km south west from SWTP 0.5 km north from HTPS 1.5km east from JOR
UM SOLEH	3 km from al hashymia town 5.5km southwest from SWTP
THERMAL PLANT	0.5 km south /southeast from HTPS 2km southeast from JOR
ELEMENTARY SCHOOL	4 km west from SWTP
SECONDARY SCHOOL	1 km northeast from JOR
ELECTRICAL TRAINING CENTER	0.5 km south from HTPS
HASHIMYEH MUNICIPALITY	Main highway of Irbid- Al hashymia-Azarqa
POLICE STATION/ZARQA	Main highway zarqa Amman 2km south east from SWTP
PROJECT SITE	2 km north from HTPS 2km northeast from JOR 2 km from south east from SWTP
E. SCHOOL/ KHERBEH	6.8 km from northeast HTPS 7 km northeast from JOR 2 km south /southwest from SWTP
UM SHURYK	2.5 km north from HTPS 3km from northeast JOR

**TABLE 2 : Instruments and their uses.**

Instruments name	USES
Sulfure Dioxide Analyser	Analyse Sulfure Dioxide
UV-Flourescence	continously
Hydrogen Sulfide Analyser	Analyse Hydrogen Sulfide
UV-Flourescence	continuously
Portable Calibrator	Calibrate instruments of
Permeation Oven.	pollutants measurement.
Wind Recorder	Measured of wind direction and
Mechanical.	wind speed.

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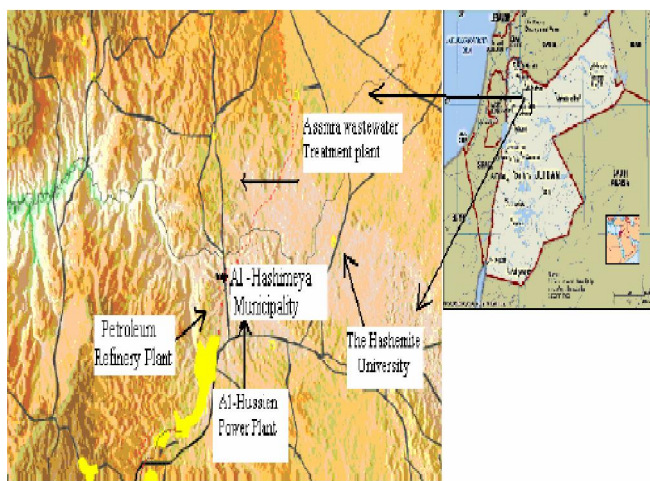


Figure 1 : The location of the study area.

done to preserve the seasonal patterns (as opposed to the effect of the procedure of substituting by the annual average.).

### Statistical analyses

The data were entered into a personal computer to be analysed using the statistical package for special science (SPSS) version 11 and JMP and JMP IN Software version 4. The Kolmogorov–Smirnov test, histogram plot, and  $Q-Q$  plot are used to examine the normality of air pollutants and meteorological data. It was found that most of the variables were normally distributed. Thus, a non-parametric correlation, Spearman rank correlation analysis, was employed to analyze the relationships between air pollutants and meteorological parameters. The descriptive statistics of the variables: Mean, standard deviation, One-way-ANOVA and Two-way ANOVAs were calculated.

## RESULTS AND DISCUSSION

### Univariate Statistical Analysis

The first step involved in the data analysis was the computation of basic statistics Mean and Standard deviation as shown in (TABLES 3). These statistics are useful in the description of the distribution and to know the level of pollution in the air.

### Monthly variation of noxious gases and suspended particulate matter (TSP) in Al-Hashimeya Atmosphere during 2005 -2009:

Average emission rates of pollutants and meteoro-

logical parameters results are presented in (TABLE 3). The summary involved Mean and Standard deviation for the years from 2005 to 2009.

TABLE 3 : The means and standard deviations of pollutant concentrations and meteorological parameters during the years 2005 - 2009.

Variable	Mean	Standard deviation
SO <sub>2</sub> concentration ppm	2.17E-2	1.94E-2
H <sub>2</sub> S concentration ppm	1.02E-2	2.32E-2
NO <sub>x</sub> concentration ppm	6.11E-3	1.81E-2
TSP concentration $\mu\text{g}/\text{m}^3$	189	98
Temperature, °C	18.2	5.15
Relative humidity %	59.43	13.42
Wind Direction°	266.4	77.31
Wind speed, m/s	4.31	1.63

### Monthly variation of Sulfur Dioxide (SO<sub>2</sub>): -

SO<sub>2</sub> Concentration varied from 0.0 to 1.01 ppm with a mean of 0.00217 ppm and a standard deviation of 0.00194 ppm. The Shapiro-Wilk W statistical test was applied to SO<sub>2</sub> concentrations and the data were found to follow normal distribution (Figure 2).

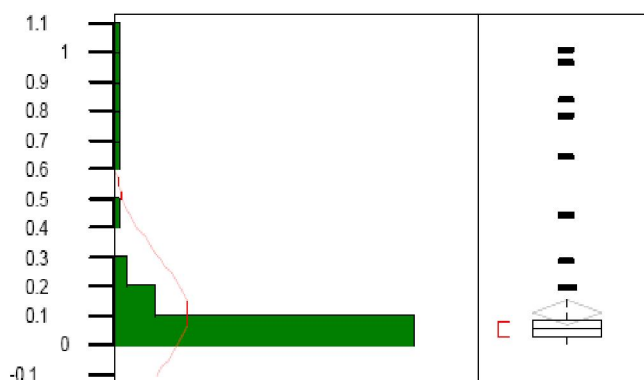


Figure 2 : Distributions of SO<sub>2</sub> Concentration at Al – Hashimeya from 2005 -2009.

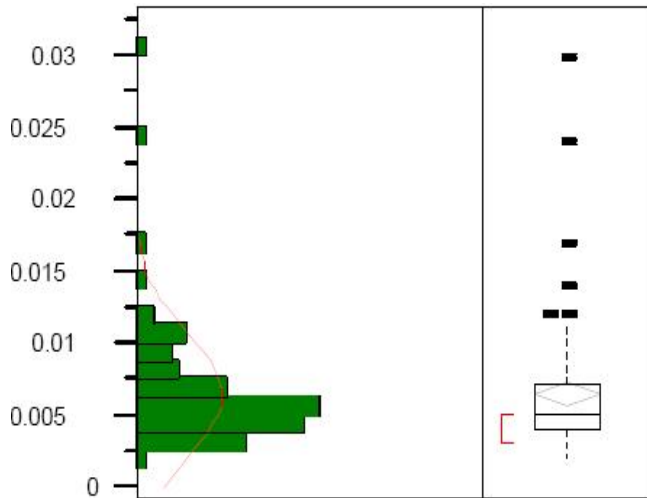
### Monthly variation of Hydrogen Sulfide (H<sub>2</sub>S):

The concentration of H<sub>2</sub>S range from 0.002 - 0.030ppm with a mean of about 0.00102 ppm and standard deviation of 0.00232, The Shapiro-Wilk W statistical test was applied to H<sub>2</sub>S concentrations and it was found to follow normal distribution, (Figure 3).

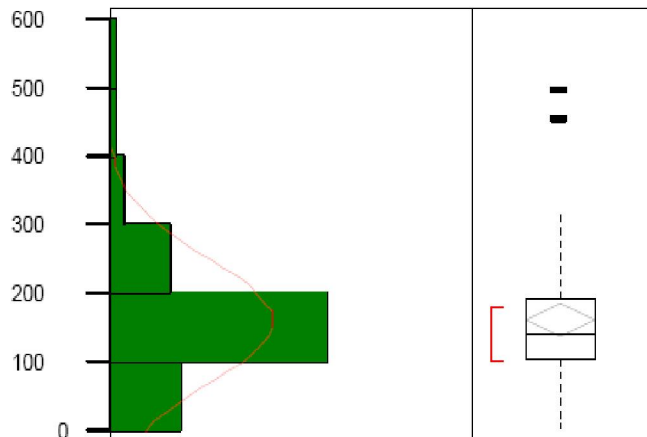
### Monthly variation of Total Suspended Particles (TSP)

The monthly average of Total Suspended Particles (TSP) are shown in TABLE 3. Monthly average of TSP

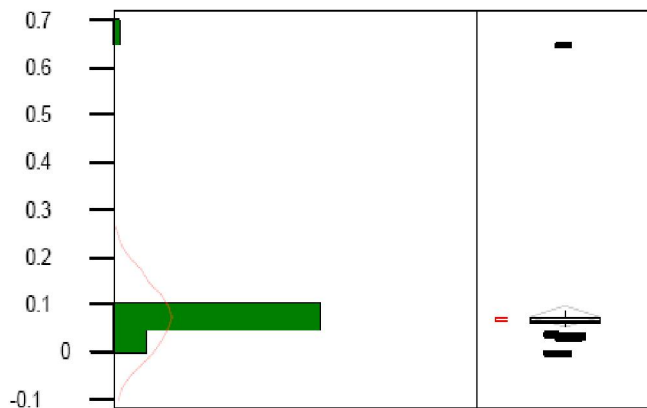
range from 87–355  $\mu\text{g}/\text{m}^3$  ppm with mean of about 189  $\mu\text{g}/\text{m}^3$  and standard deviation of 98. Figure 4 shows that TSP concentrations follow a normal distribution according to Shapiro-Wilk W statistical test (Figure 4).



**Figure 3 : Distributions of H<sub>2</sub>S concentration at Al- Hashimeya from 2005 -2009.**



**Figure 4 : Distribution of TSP Concentration at Al-Hashimeya from 2005 -2009.**



**Figure 5 : Distributions of NO<sub>x</sub> Concentration at Al-Hashimeya from 2005 -2009.**

**Monthly variation of Nitrogene Oxides ( NO<sub>x</sub> )**

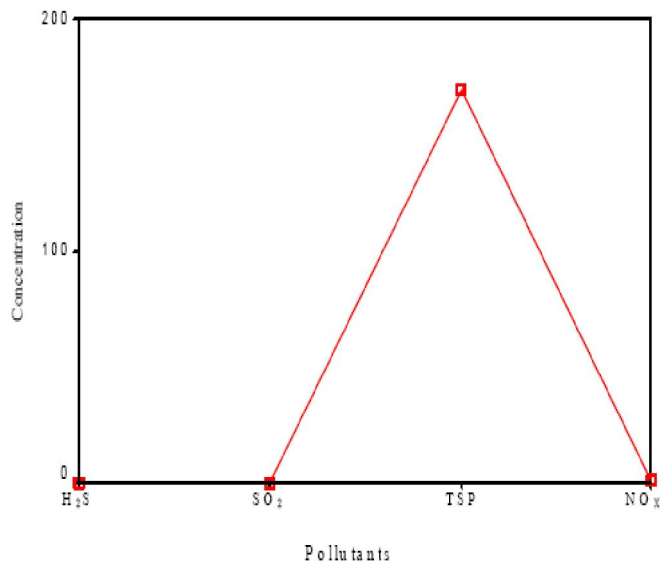
The Concentrations of NO<sub>x</sub> vary between 0.0–0.03 ppm with a mean value that equals 0.000611ppm and a standard deviation of about 0.0181 The Shapiro-Wilk W statistical test was applied to NO<sub>x</sub> concentrations and found to follow normal distribution, (Figure 5).

**Analysis of variance (ANOVA)**

**One way ANOVA**

One Way ANOVA test was used to discover test for differences among pollutants. (TABLE 4), shows that there are relationships with a significant statistic between the concentration of pollutants. The value of F reached 274.8 with significant level less than P =0.05. Dennett’s C Post Hoc Test was used to determine the mean differences between pollutants.

The result of One Way Analysis test proved that there is a relation between pollutants. TSP is the main pollutant that has a significant effect on the other pollutants. In other words, there is ascending relationship between TSP and other pollutants. TABLE 5 shows that there is a strong relationship between NO<sub>x</sub>, SO<sub>2</sub> and H<sub>2</sub>S. The mean difference between NO<sub>x</sub> and SO<sub>2</sub> reaches 0.91, between NO<sub>x</sub> and H<sub>2</sub>S reaches 1.2, and between SO<sub>2</sub> and H<sub>2</sub>S 0.10 . All of these differences have a significant statistical level less than P =0.05, which proved the strong relationship between them, and this is shown by the mean plot, (Figure 6).



**Figure 6 : Mean Plots between the mean differences of Concentration for Pollutants using One Way ANOVA Test.**

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**TABLE 4 : One Way ANOVA Analysis for pollutants relationship in Al-Hashimeya.**

Variable	Sum square of	Df	Mean square	F	Sig.
Group between	1234.84	3	411495.36		
Group within	419303.64	280	1497.51	274.79	0.00
Total	1653789.74	283			

**TABLE 5 : Dunnett's C Post Hoc Test for multiple comparisons between pollutants.**

Dependent Variable: CONCEN  
Dunnett C.

Pollut.	POLLUTANTS	Mean Difference (I-J)	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
H2S	SO2	-.1028*	5.8339	-.1579	-4.7717E-02
	TSP	-169.5011*	6.7285	202.2310	136.7713
	NO <sub>x</sub>	-1.0168*	6.6517	-1.6899	-.3437
SO2	H2S	-1.028*	5.8339	4.772E-02	.1579
	TSP	-169.3984*	6.7285	202.1283	136.6684
	NO <sub>x</sub>	-9.140*	6.6517	-1.5894	-.2386
TSP	H2S	169.5011*	6.7285	136.7713	202.2310
	SO2	169.3984*	6.7285	136.6684	202.1283
	NO <sub>x</sub>	168.4843*	6.4487	135.7475	201.2211
NO <sub>x</sub>	H2S	1.0168*	6.6517	.3437	1.6899
	SO2	.9140*	6.6517	.2386	1.5894
	TSP	-168.4843*	7.4487	201.2211	135.7475

\*. The mean difference is significant at the .05 level.

### Meteorological factor affecting the concentration of pollutants in Al-Hashimeya region

The relation between SO<sub>2</sub>, H<sub>2</sub>S, NO<sub>x</sub>, TSP and meteorological parameters (wind speed, temperature and relative humidity) during the year 2005 -2009 were investigated by correlation analysis. The correlation coefficient (R) between the average SO<sub>2</sub>, H<sub>2</sub>S, NO<sub>x</sub>, TSP concentrations and the average meteorological parameters are shown in TABLE 6. As seen in TABLE 6, Correlation coefficient for SO<sub>2</sub> concentration shows the strong negative correlation with relative humidity and temperature thus: -0.61 and -0.59 respectively and strong positive correlation with wind speed it reached 0.67. All these results are statistically significant at P

less than 0.05. Whereas a strong negative correlation between the concentration of H<sub>2</sub>S with relative humidity and wind speed, where the correlation coefficient mounted up to -0.65 and -0.56 respectively. This value is significant at the 99% significance level. While for TSP to relative humidity, the correlation coefficient reached to -0.59 whereas it reached -0.50 between TSP and temperature. Where all of them were statistically significant at P less than 0.05. The most meteorological factor effects on NO<sub>x</sub> concentration were relative humidity where correlation coefficient reached -0.55. This value is significant at the 99% significance value.

**TABLE 6 : Correlation Coefficient (R) and their probability for pollutants concentration levels and meteorological parameters.**

Variables		W.S	T	R.H
SO2	(R)	0.67	-0.59	-0.61
	P	0.03	0.00	0.02
H2S	(R)	-0.56	0.31	-0.65
	P	0.03	0.00	0.003
NOX	(R)	-0.12	0.30	-0.55
	P	0.04	0.00	0.00
TSP	(R)	-0.14	-0.50	-0.59
	P	0.03	0.01	0.01

### The most important factors that affect the increase of SO<sub>2</sub> percent are Relative humidity

Humidity is considered among the meteorological factors that increase the percent of SO<sub>2</sub> concentration. It has a negative correlation equal to -0.61, at the 99% significance level. When humidity increased, the concentration value decreased. The negative correlation is attributed to the role of humidity in increasing the chemical interactions between gases and water vapor as well as forming the photochemical fog and acid rain, (Figure 7).

### Temperature

Temperature affects the concentration of SO<sub>2</sub> with a negative correlation coefficient that equals -0.59. The highest concentration for the gas reached 0.291 whereas the average temperature reached 12.4 °C. The negative correlation is attributed to a decrease in temperatures, which contributes in cooling the air in contact with

the earth surface prevents convection currents, and therefore gas concentrate in the air (Figure 8).

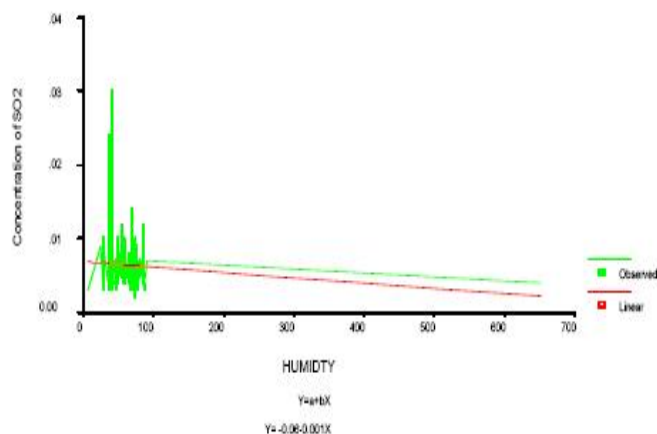


Figure 7 : The relation between Humidity & SO<sub>2</sub> at Al-Hashimeya.

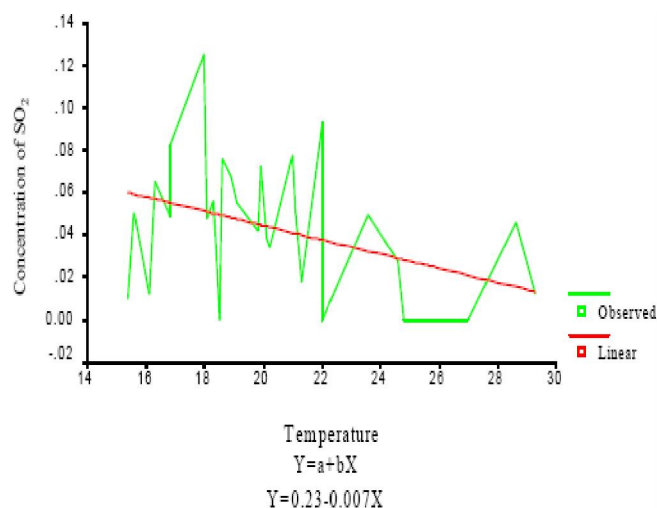


Figure 8 : The Relation between Temperature & SO<sub>2</sub> at Al-Hashimeya.

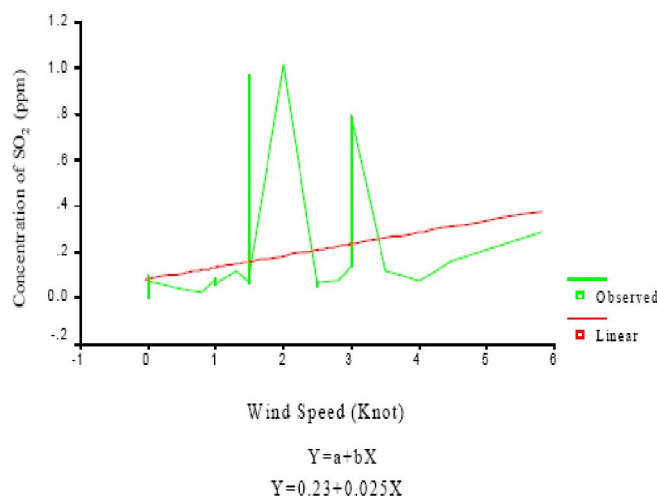


Figure 9 : The relation between Wind Speed & SO<sub>2</sub> at Al-Hashimeya.

### Wind Speed

The speed of the wind plays a big role in increasing the SO<sub>2</sub> concentrations, (Figure 9). It shows a positive correlation at 0.67 at the 99% significance level. i.e., when the calm winds increase, the chance of air pollution in Al-Hashimeya increases. Winds with low speed are unable to carry pollutants away.

### Meteorological factors affecting the increase of H<sub>2</sub>S concentration

#### Wind speed

It is clear that the speed of the wind plays a big role in increasing the H<sub>2</sub>S concentrations, (Figure 10). It shows with a negative correlation of about -0.56 at the 99% significance level. i.e., when the wind Speed decrease, the level of air pollution increased in Al – Hashimeya air.

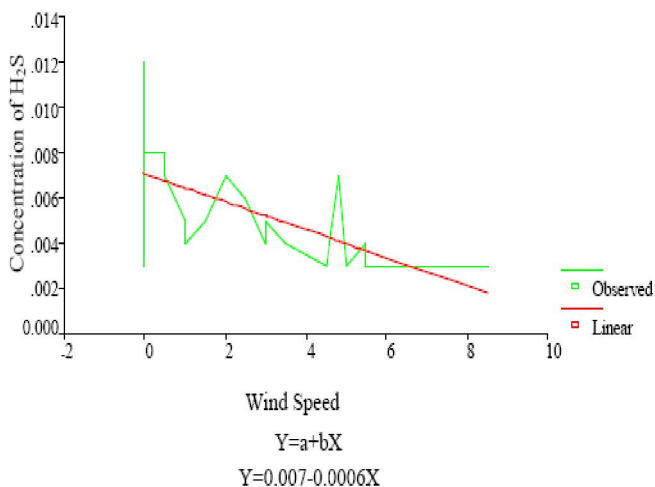


Figure 10 : The relation between Wind Speed & H<sub>2</sub>S at Al-Hashimeya.

#### Relative humidity

Humidity is an important factors that increase the H<sub>2</sub>S concentration. It shows a negative correlation – 0.65, at 99% of confidence. When there is an increase relative humidity in the atmosphere, the concentration value decreases. The negative correlation is attributed to the role of humidity in increasing the chemical interactions for the gases and acid rain as well as forming the photochemical smog (Figure 11).

Relative humidity constitutes a moderate atmosphere for the photochemical interactions in which is H<sub>2</sub>S changed into another forms of gases like SO<sub>2</sub>, which in turn changes into sulfuric acid which causes

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the acid rain. The reduction of the relative humidity reduces the photochemical interactions which will preserve H<sub>2</sub>S. Also, the increase in humidity increase the chance of acid formation and wet deposition decreases H<sub>2</sub>S concentration.

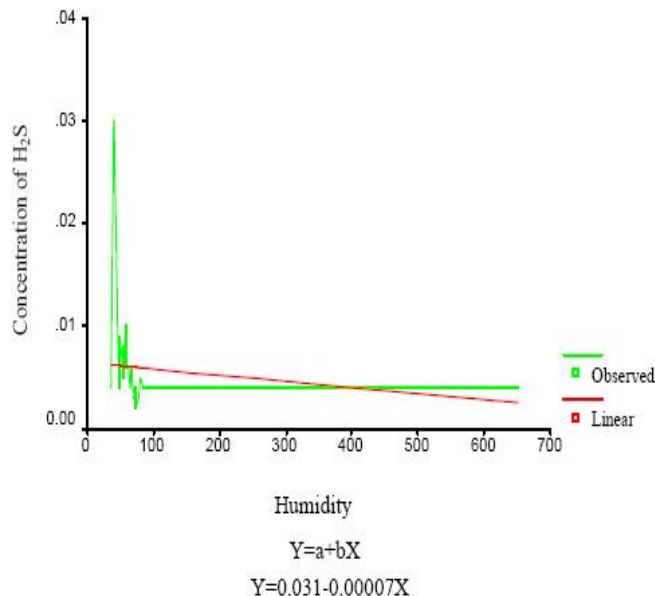


Figure 11 : The relationship between Relative Humidity & H<sub>2</sub>S at Al- Hashimeya.

### Metrological conditions Affecting Nitrogen Oxides NO<sub>x</sub> concentrations

#### Relative Humidity

Humidity is considered among the meteorological factors that increase the percent of NO<sub>x</sub> concentration. A negative correlation -0.55, at 99% of confidence between them. When there is an increase in the relative

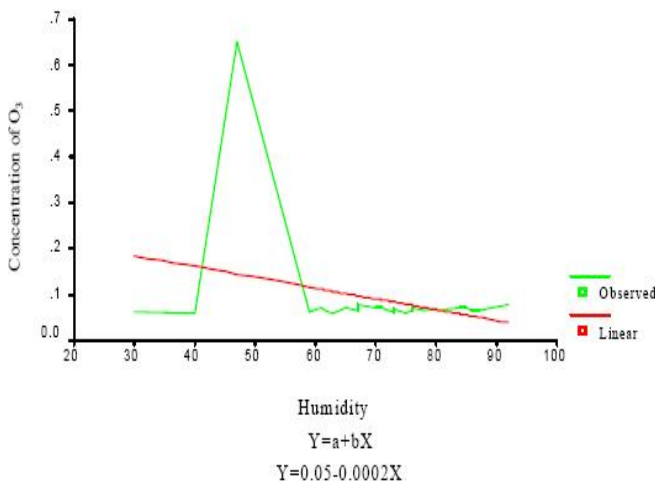


Figure 12 : The relation between Relative humidity & NO<sub>x</sub> at Al- Hashimeya.

humidity, the NO<sub>x</sub> concentration decreases, (Figure 12).

### Meteorological factors affecting the increase of TSP percent

#### Temperature

Temperature affects on the concentration of TSP. The values of this gas show a negative correlation coefficient of about -0.50. The reason after the negative correlation is attributed to a decrease in the temperatures, which contributes in cooling the air touching the surface of the earth, which thus weakness the ascending air currents and the vertical, and horizontal mixing for the air which increases the process of gas concentrate in the air, (Figure 13)

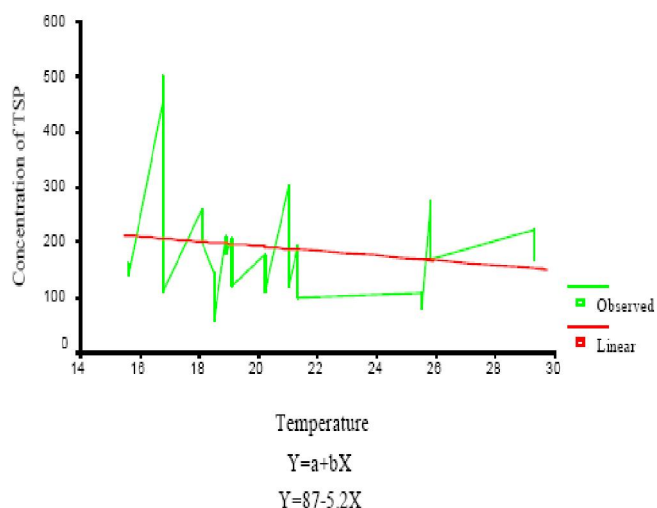


Figure 13 : The relation between Temperature & TSP in at Al- Hashimeya.

## DISSCUTION

The effect of metrological parameters on the ambient concentrations of the gases will be discussed below

#### Temperature

The annual average of temperature degree in Al-Hashimeya area is 18°C. It rises in Summer to 25.7°C and the average decrease to 8.6 °C in Winter. Decreases in temperatures considered main reasons for pollutants' concentration, which plays a role in cooling the air touching the surface of the earth, thus reducing the vertical and horizontal mixture for air and its ascendance.

We found that temperature show an inverse relation with most of the pollutants because of the role of

the heat in warming up the surface of the earth by the oncoming radiation from the sun which strikes the earth and warms it, thus making the air that touch it warm and consequently reducing its density, so it expands and goes upward to be replaced by cold air and so on. This process increases the amounts of the up going air currents. When the horizontal and vertical air mixing processes increase, they reduce the concentration of the pollutants in it. Further, the decrease in temperature for some pollutants increases the production of some pollutants due to an increase in the burning times and using of the central heating, which result in the increase of these pollutants.

### Relative humidity

Humidity decreases in Al- Hashimeya city. It's annual rate amount 61%. The percent of humidity differs in seasons of winter and summer, where it reaches 55% in Summer and 71% in winter. Also, the process of humidity decrease leads to more concentrations of gas contaminations and suspended dust in the air, which results from Oil Refinery, Al- Hussien thermal power station and Al- Kherbh Al- Sammra which paves the way for a suitable environment for certain photochemical interactions of the gases in which it is changed into different forms.

It has been evidenced from the results of this study that the relation of relative humidity with the concentration of the pollutants is an inverse relation, which could be attributed to the role of the humidity in forming acid rain. On the other hand, the inverse relationship between relative humidity and TSP is due to the role played by TSP as it functions as density nuclei on which the drops of vapor dense thus reducing its existence in air, in addition to settling down when they get larger and bigger, especially when the upcurrents start to slow down and the atmosphere gets much stable.

### Wind speed

Pollutants are expected to be carried away and diluted during day times with high wind speeds. Low speed winds are prevailing in Al - Hashimeya region. The annual average of speed is 3.7 knot which gradually decreases in winter to reach 1.6 knot. More than 50% of Al - Hashimeya wind blow at speed between 3 –6 knot and less than 10% has speed higher than 8

knot. This will play apart in having more concentration in gas and dust in Al - Hashimeya. It not possible by any means for low speed winds to carry pollutants for further distance .

Results have proved that the concentrations of TSP were higher might be attributed to the prevailing Khamasin winds, which become active in spring, especially April and May in addition to the high temperature and the low average of rainfall and the lack of humidity, thus helping the increase of the suspended air in the atmosphere.

## CONCLUSIONS

An understanding of pollution sources and emissions, and their interactions with the atmosphere, is a most important first step in developing appropriate air pollution management plans and action strategies. Without this type of knowledge, incorrect decision making related to air pollution management is possible, creating wasted resources and undesirable results<sup>[11]</sup>. This study is only based on measurements made at one urban location. Undoubtedly, there is need for a more comprehensive study to improve the monitoring and evaluation systems for urban air pollution.

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