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Data Analysis of Air pollution and meteorological effects in Al-Hashimeya Town, Zarqa- Jordan

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ABSTRACT

Air pollutants, including SO_2, H_2S , NO_X 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. These are Jordan Petroleum Refinery, Al-Hussein Thermal Power Station, and Al-samra Waste Water Treatment Plant. 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.

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 (Chaloulakou et al., 1998) [1]. 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 (Seinfeld, 1985) [2].

Development and use of statistical and other quantitative methods in the environmental science have been a major communication between environmental scientists and statisticians (Hertzberg and Frew, 2003) [3]. In recent years many statistical analysis have been used to study air pollution as a common problem in urban areas (Lee, 2002) [4]. 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 (Voigt, 2004) [5]. Many investigators have used probability models to explain temporal distribution of air pollutants (Bencala and Seinfeld, 1979) [6]; Yee and Chen, 1997) [7].

Meteorological parameters play important roles 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 (Elminir, 2005 [8] and Satangi et al., 2004)[9]. An analysis of the influences of meteorological parameters on the pollutants at a specific site can contribute to a better understanding of the causes of air pollution.

An understanding of pollution sources and emissions, and their interactions with the atmosphere, is the most important 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 (Bridgman et al., 2002) [10].

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 (HTPS), and Al-samra Waste Water Treatment Plant (SWTP). 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 (Ministry of Environment, 2005) [11].

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 January 2005 to December 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 39º 09′ east and Latitude 32º 04′ to 32 º 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 Petroleum Refinery, Al-Samra Waste water treatment plant and Al-Hussein

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Thermal Power station. These sources are called "Trianlge of Pollution", and each of them has a different impact on air quality. A semi-arid Mediterranean type climate is dominant in Al- Hashimeya town which characterized by hot and dry in summer and low rain in winter. The average annual 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 (Shehadeh, 1991) [12].

Data Collection:

Several studies conducted by the Royal Scientific Society (RSS) and the Ministry of Environment to monitor the basic pollutants in the area, from 1992 to 2009 (Table1 and Fig.1). Instruments installed in the monitoring sites measures ambient air continuously and analyze it automatically, (Table 2) illustrate the instruments.

Table1: 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
Thermal Plant	5.5km southwest from SWTP 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
Elctrical Training Center	0.5 km south from HTPS
Hashimteh Municipality	Main highway of Irbid- Al hashymia-Azarqa
Police Station / Zarqa	Main highway zarqa Amman
Project Site	2km south east from SWTP 2 km north from HTPS 2km northeast from JOR
E. School/ Kherbeh	2 km from south east from SWTP 6.8 km from northeast HTPS 7 km northeast from JOR
Um Shuryk	2 km south /southwest from SWTP 2.5 km north from HTPS 3km from northeast JOR

Table 2: Instruments and their uses.

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

Table 3: Descriptive statistic for pollutants concentration and meteorological parameters during the years 2005 - 2009.

Variables	Units	Min.	Max.	Mean	Standard deviation	C.V	N
SO_2	ppm	0.00	1.01	0.00217	0.00194	0.89	116
H_2S	ppm	0.002	0.030	0.00102	0.00232	2.27	116
NOx	ppm	0.00	0.03	0.00611	0.0181	2.96	10
TSP	$\mu g/m^3$	87	355	189	98	0.52	112
Temperature	°C	8.9	28.70	18.2	5.15	0.28	60
Relative humidity	%	43	79	59.43	13.42	0.23	60
Wind speed	m/s	1.40	7.30	4.31	1.63	0.38	60

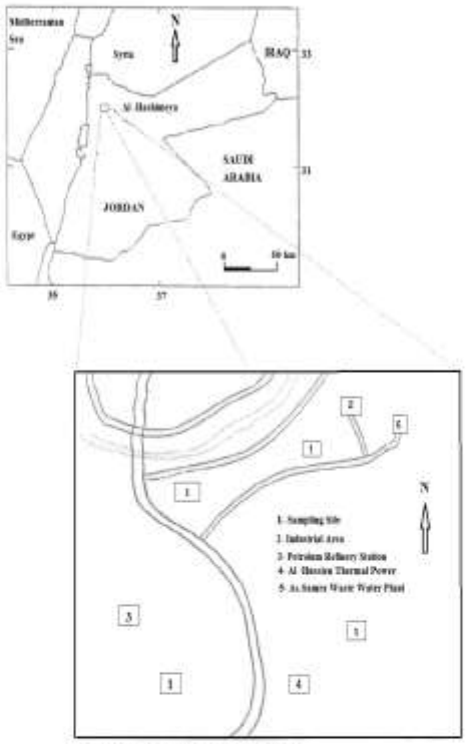

Figure (1) : The location map of the study area.

Preparing data analysis

The yearly mean concentrations of pollutants SO_2, H_2S , NOx and TSP were obtained from unpublished sources of 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 done to preserve the seasonal patterns (as opposed to the effect of the procedure of substituting by the annual average).

Statistical Analysis

The data were entered into a personal computer to be analysed using the statistical package for social sciences (SPSS) version 18 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: maximum ,minimum, mean, standard deviation,coeffient of variation (C.V), 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 such as maximum ,minimum, mean, standard deviation and coeffient of variation (c.v) 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 meteorological parameters results are presented in (Table 3). The summary involved Means and Standard deviations for monthly average during the years from January 2005 to December 2009.

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

Variable	Sum squre of	df	Mean squre	F	Sig.
group between	1234.84	3	411495.36	274.79	0.00
group within	419303.64	280	1497.51		
total	1653789.74	283			

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

Dependent Variable: Concentrartions
Dunnett C

Pollut.	POLLUTANTS	Mean Difference (I-J)	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
H_2S	SO_2	-.1028*	5.8339	-.1579	-4.7717E-02
	TSP	-169.501*	6.7285	-202.2310	-136.7713
	NOx	-1.0168*	6.6517	-1.6899	-.3437
SO_2	H_2S	.1028*	5.8339	4.772E-02	.1579
	TSP	-169.3984*	6.7285	-202.1283	-136.6684
	NOx	-.9140*	6.6517	-1.5894	-.2386
TSP	H_2S	169.501*	6.7285	136.7713	202.2310
	SO_2	169.3984*	6.7285	136.6684	202.1283
	NOx	168.4843*	7.4487	135.7475	201.2211
NOx	H_2S	1.0168*	6.6517	.3437	1.6899
	SO_2	.9140*	6.6517	.2386	1.5894
	TSP	-168.4843*	7.4487	-201.2211	-135.7475

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

Monthly variation of Sulfur Dioxide (SO_2): -

The SO_2 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_2 concentrations and the data were found to follow normal distribution (Figure 2).

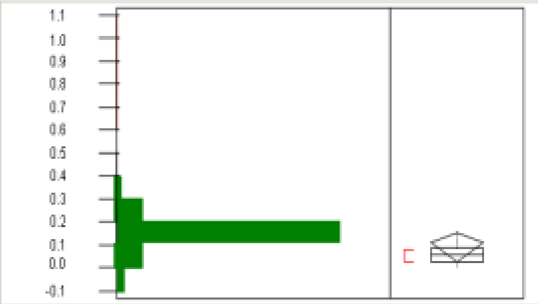

Figure 2: Distributions of SO_2 Concentration at Al – Hashimeya from 2005 -2009.

Monthly variation of Hydrogen Sulfide (H_2S):

The concentration of H_2S 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_2S concentrations and it was found to follow normal distribution, (Figure 3).

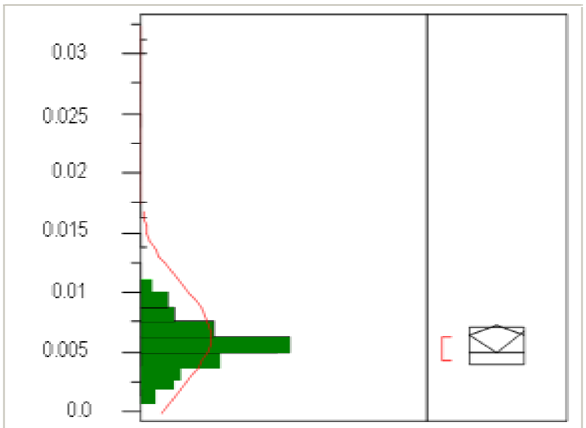

Figure 3: Distributions of H_2S concentration at Al-Hashimeya from 2005 -2009.

Monthly variation of Total Suspended Particles (TSP):

The monthly average of Total Suspended Particles (TSP) are shown in Table 3. Monthly average of TSP ranges from 87 – 355 µg/m³ ppm with mean of about189 µg/m^3 and standard deviation of 98 . TSP concentrations follow a normal distribution according to Shapiro-Wilk W statistical test (Figure 4).

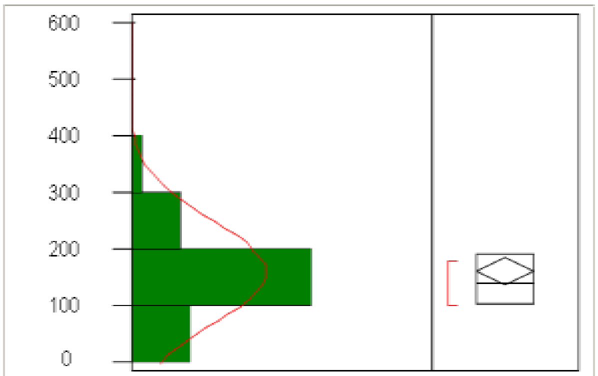

Figure 4: Distribution of TSP Concentration at Al – Hashimeya from 2005 -2009.

Monthly variation of Nitrogene Oxides (NO_X):-

The Concentrations of NO_X vary from 0.0 to 0.03 ppm with a mean value that equals 0.00611ppm and a standard deviation of about 0.0181. The Shapiro-Wilk W statistical test was applied to NO_X concentrations and found to follow a normal distribution, (Figure 5).

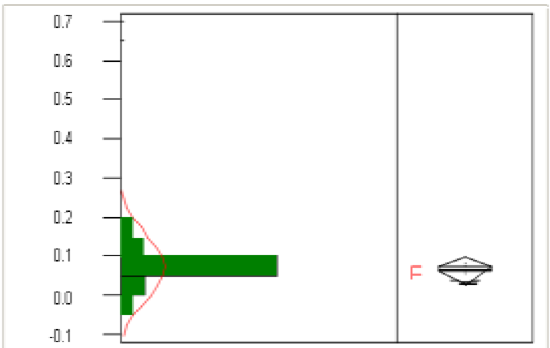

Figure 5: Distributions of NOx Concentration at Al-Hashimeya from 2005 -2009.

Analysis Of Variance (ANOVA)

One Way ANOVA: -

One Way ANOVA test was used to discover differences among pollutants. (Table 4), shows that there are significant differenes 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 show that there is differenes 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_X , SO_2 and H_2S .The mean difference between NO_X and SO_2 reaches 0.91, between NO_X and H_2S reaches 1.2, and between SO_2 and H_2S 0.10. All of these differencesare statstically significant at level less than P =0.05, which show the strong relationship between them, and this is shown by the mean plot, (Figure 6).

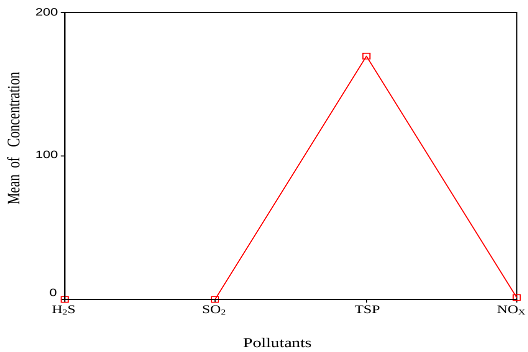

Figure 6: Mean Plots between the mean differences of Concentration for Pollutants using One Way ANOVA Test.

Meteorological factor affecting the concentration of pollutants in Al –Hashimeya region:

The relation between SO_2, H_2S, NO_X, 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_2, H_2S, NO_X ,TSP concentrations and the average meteorological parameters are shown in Table 6. As seen in Table 6, Correlation coefficient for SO_2 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. A strong negative correlation between the concentration of H_2S with relative humidity and wind speed, where the correlation coefficient mounted up to - 0.65 and -0.56, respectively. While for TSP to relative humidity, the correlation coefficient reached to -0.59 whereas it reached -0.50 between TSP and temperature. All of them were statistically significant at P less than 0.05. The most meteorological factor effects on NO_x concentration were relative humidity, correlation coefficient reached -0.55.

The most important factors that affect the increase of SO_2 percent are:

Relative Humidity:

Humidity is considered among the meteorological factors that increase the percent of SO_2 concentration. It has a negative correlation equal to –0.61. 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).

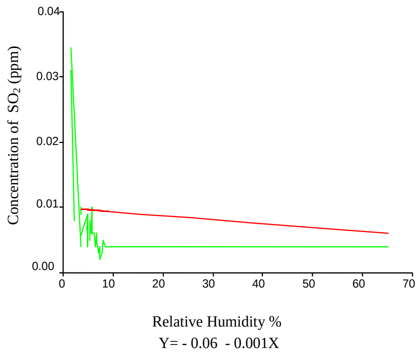

Figure 7: The relation between Humidity & SO_2 at Al-Hashimeya.

Temperature:

Temperature affects the concentration of SO_2 with a negative correlation coefficient that equals -0.59. The highest concentration for the gas reached 0.11ppm whereas the average temperature reached 18.2 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 therfore gas concentrate in the air (Figure 8).

Wind Speed:

The speed of the wind plays an important role in increasing the SO_2 concentrations, (Fig 9). It shows a positive correlation at 0.67. 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.

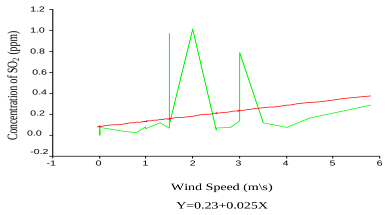

Figure 9: The relation between Wind Speed & SO_2 at Al-Hashimeya .

Meteorological Factors Affecting The Increase of H_2S concentration:

Wind Speed:

It is clear that the speed of the wind plays a big role in increasing the H_2S concentrations, (Fig 10). It shows with a negative correlation of about -0.56 at significant p- value less than 0.05, i.e., when the wind speed decrease, the level of air pollution increased in Al –Hashimeya air.

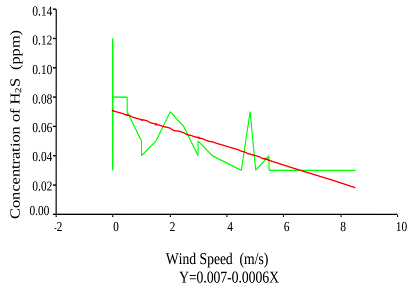

Figure 10 : The relation between Wind Speed & H_2S at Al-Hashimeya

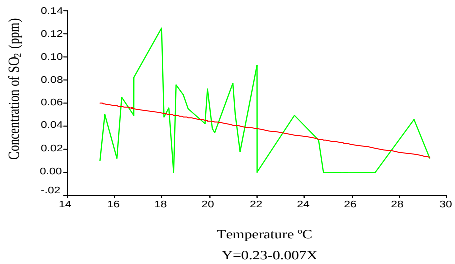

Figure 8 : The Relation between Temperature & SO_2 at Al-Hashimeya .

Table 6: Correlation Coefficient (R) and their (p – value) for pollutants concentration levels and meteorological parameters.

Variables	W. S	T	R.H
SO_2 (R)	0.67	-0.59	-0.61
P	0.03	0.00	0.02
H_2S (R)	-0.56	0.31	-0.65
P	0.03	0.00	0.003
NO_X (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

Note: R.H: Relative Humidity, W.S: Wind Speed and T: temperature.

Relative Humidity:

Humidity is important factors that increase the H_2S concentration. It shows a negative correlation –0.65, i.e.: 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 (Fig. 11).

Relative humidity constitutes a moderate atmosphere for the photochemical interactions in which is H_2S changed into another forms of gases like SO_2 ,which in turn changes into sulfuric acid causes the acid rain .The reduction of the relative humidity reduces the photochemical interactions which will preserve H_2S.Also, the increase in humidity increase the chance of acid formation and wet deposition decreases H_2S concentration .

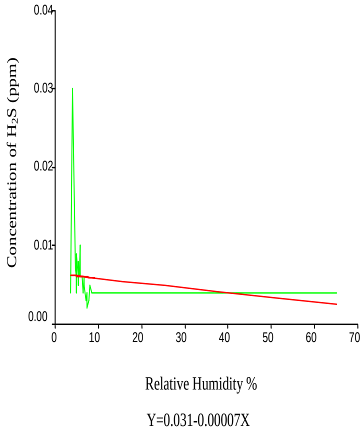

Figure 11: The relationship between Relative Humidity & H_2S at Al- Hashimeya.

Metrological conditions Affecting Nitrogen Oxides NO_X concentrations:

Relative Humidity:-

Humidity is considered among the meteorological factors that increase the percent of NO_X concentration. A negative correlation –0.55, at 99% of confidence between them. When there is an increase in the relative humidity, the NO_X concentration decreases, (Fig. 12).

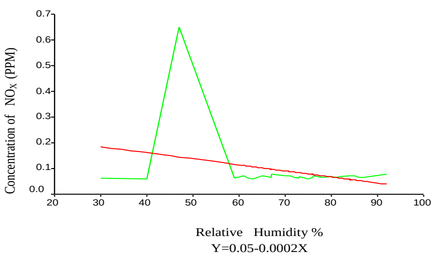

Figure 12: The relation between Relative humidity & NO_X at Al- Hashimeya.

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, (Fig. 13)

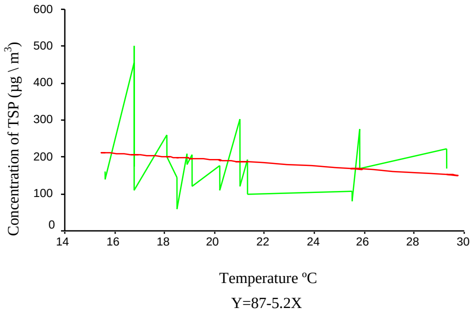

Figure 13: The relation between Temperature & TSP in at Al- Hashimeya.

Disscution:

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

Temperature

The annual average temperature at Al- Hashimeya area is 18.2°C . It rises in Summer to 28.7 °C and the average decreases 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 shows 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 59% .The percent of humidity differs in seasons of winter and summer, where it reaches 43% in Summer and 79% 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-samra Waste Water Treatment Plants 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 relashion 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 4.31 m\s which gradually decreases in winter to reach 1.4 m\s. More than 50% of Al - Hashimeya wind blow at speed between 1.40 – 7.30 m\s and less than 10% has speed higher than 7 m\s. 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:

This study was aimed at determining the temporal variations of pollutants and the meteorological impact on the behavior of pollutants concentration in the most polluted city in Jordan. Result proved that the effect of meteorological factors play great role in influencing the air gases and dust in Al- Hashimeya area. 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. Undoubtedly, there is a need for more comprehensive studies to improve the monitoring and evaluation systems for urban air pollution.

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