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Diurnal and Seasonal Variation of Air Pollution at Al-Hashimeya Town, Jordan

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Abstract

This study aimed at using the statistical methods to assess air quality at Al-Hashimeya town in Zarqa Governorate. Three main sources at Al- Hashimeya are contributing to air pollution; Jordan Petroleum Refinery, Al-Hussein Thermal Power Station, and Assamra waste water treatment plant. Reports and data relating to pollution in al-Hashimeya were collected from different sources that measured the level of pollution in this area during spring season of the year 1992. Sets of data were processed, using statistical analysis. The results of the study indicated that Jordan Petroleum Refinery and al-Hussein Thermal Power Station were the two main sources of SO_2 because of the combustion of fuel that contains sulphur and SO_2 concentration that violated Jordanian standards. The study also showed that Assamra Station was the main source of H_2S and its concentration had exceeded the Jordanian standards throughout the monitoring months. CO and NOx concentrations were within Jordanian standard. Ozone was in violation of Jordanian standards in more than 90% of the field measurements. Examination of the levels of TSP has shown that they exceeded the national standards with different degrees. Weather conditions (air Temperature, wind speed, rainfall, wind direction, cloud and relative humidity) have contributed to the high levels of air pollution.

Keywords: Statistical Analysis; Air Pollution; ANOVA; SO_2; TSP; CO.

1. Introduction

In the last 200 years, or so, the growth in the world population and the industrial revolution has resulted in an increased demand for energy. Until now these energy requirements have been supplied largely by the combustion of fossil fuels, the plant's resources of conventional carbonaceous fuel, coal, and oil, have been used for heating purposes, power industry, transport and synthesis of chemicals. The by-products of these operations (particulates, the oxides of carbon, nitrogen and sulphur) have been emitted to the atmosphere in enormous quantities (Reida and John, 1988). Air becomes polluted when it contains substances in quantities that could harm the comfort or health of both 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 occur naturally or as a result of human activity (Seinfeld, 1985).

Al-Hashimeya area is located north to Zarqa city 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, most important of which are Jordan Petroleum Refinery, al-Hussein Thermal Power Station, and Assamra wastewater treatment plant.

Different studies have been performed to understand source and level of air pollution in Al-Hashimeya. Most studies are restricted to water and soil .This study aims to use statistical analysis to give both qualitative and quantitative information about air pollution for the primary study for Al-Hashimeya during spring season in the year 1992, and to determine the impact of pollution controlling parameters (wind speed, wind direction, temperature, rainfall, solar radiation and relative humidity) on the behaviour of noxious gases in this town.

2. Methodology

2.1. 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 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 include, Jordan Oil Refinery, Khirbit Al-Samra Waste water treatment plant and Al-Hussein Thermal Power station. These sources are called "Triangle of Pollution”. And every one of these has a different impact on air quality. A semi-arid Mediterranean type climate is dominant in Al- Hashimeya town which is characterized by hot and dry conditions in summer and lack of rain in winter. The average annual rate of rainfall is 142 mm. The low precipitation rates worsen the air quality in Al-Hashimeya because rain is natural

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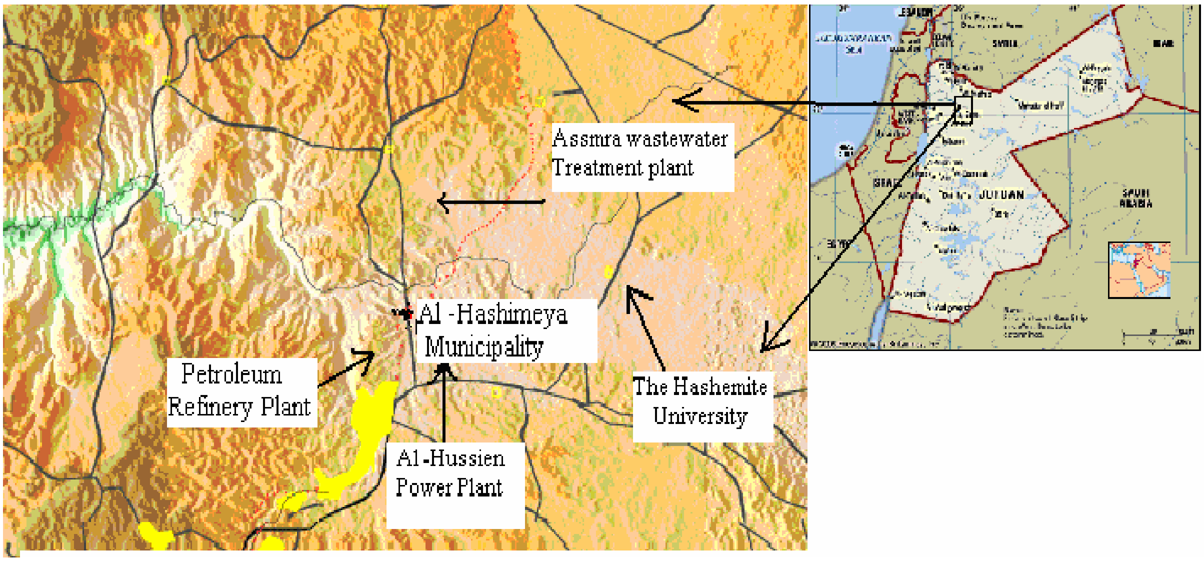

Figure 1. the Location of the Study Area.

processes that help washing out soluble substances from the air (Shehadeh and Noaman, 1991).

2.2. Data Collection

There have been several studies conducted by the Royal Scientific Society (RSS) and the Ministry of Environment to monitor basic pollutants in the area during 1992 (Table 1 and Fig.1). Instruments installed in the monitoring sites sample ambient air continuously and analyze it automatically, (Table 2 illustrate the instruments).

2.3. Preparing for Data Analysis

The yearly mean concentration of seven criteria pollutants PM_{10}, TSP, CO, NOx SO_2, H_2S and Pb was used obtained from unpublished sources (RSS). Missing values were substituted. If the value was missing, for example, for a particular year, , 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.).

2.4. Statistical Methods

A personal computer was used to deal with data, using the statistical package (SPSS) version 11 and JMP and JMP IN Software version 4. The descriptive statistics of the variables: Mean, standard deviation, median and others of dependent variable were calculated, student t-test detect for significant between pairs of a variable ($p<0.05$) unpaired data, One-way-ANOVA and Two-way ANOVAs were used to results.

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
ELECTRICAL TRAINING CENTER	0.5 km south from HTPS
HASHIMYEH MUNICIPALITY	Main highway of Irbid- Al hashymia-Zarqa
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

3. Result

3.1. Univariate Statistical Analysis

The first step in the data analysis involved the computation of basic statistics (e.g. Minimum, Maximum, Mean, Medians and Standard deviation as shown in (Table 3). These statistics are useful in the description of the distribution and to know the degree of pollution in the air. The concentrations of pollutants were compared with standard values recommended by WHO (Table 4).

Table 2. Instruments and their uses.

Instruments name	USES
Sulphure Dioxide Analyser UV-Flourescence	Analyse Sulphure Dioxide continously
Hydrogen Sulfide Analyser UV-Flourescence	Analyse Hydrogen Sulfide continuously
Carbon Monoxide Analyser Non- Dispersive Infrared	Carbon Monoxide continuously
High Volume Sampler with Selective PM10 Inlet, Gravimetric.	Collect of PM10
Portable Calibrator Permeation Oven.	Calibrate instruments of pollutants measurement.
Wind Recorder Mechanical.	Measured of wind direction and wind speed.

3.2. Diurnal and monthly variation of Sulphur dioxide (SO_2)

The average of SO_2 concentrations at Al- Hashimeya region registered was 0.062 ppm. This average exceeded the Jordanian standards and the directions of WHO for 46 days out of 80 sampled days. The highest monthly average for SO_2 was 0.071 ppm for April. The average was yet similar to March and May 0.059ppm. This rise of the concentrations in April is due to the low air temperatures, humidity, lack of rainfall, and the lack of Ozone (O_3). This helps a lot in the process of SO_2 removal through oxidization. It was noted that the levels of concentrations were not affected during weekends and other formal vacations.

Table 3. Minimum ,Maximum ,Mean and St. Dev. of pollutants at Al -Hashimeya in 1992

Variable	Minimum	Maximum	Mean	St. Dev.	Number of violation (Days)
SO_2 (ppm)	0.00	1.01	0.111	0.197	87
H_2S (ppm)	0.002	0.030	0.0064	0.0042	88
O_3 (ppm)	0.00	0.650	0.0743	0.082	53
TSP(mg/m^3)	1.90	500	160.67	91.07	52

Table 4 . Monthly average of pollutants and no. of exceeding according to WHO standard for 1992.

Monthly average of pollutants and no. of exceeding	WHO Standard	Month March	 April	 May	Monthly average
Average monthly of SO2 (ppm)	0.047	0.059	0.071	0.056	0.062
Number of exceeding		13	17	16	16
Average monthly of TSP (µg/m^3)	120	183.25	169.7	221.8	176.6
Number of exceeding		4	8	12	8
Average monthly of H2S (ppm)	0.006	0.006	0.006	0.007	0.0063
Number of exceeding		12	6	15	11
Average monthly of O3 (ppm)	0.06	0.07	0.06	-	0.065
Number of exceeding		28	18	-	23

3.3. Diurnal and Monthly Variation of Hydrogen Sulphide (H_2S)

The Concentrations of H_2S for all monitoring days ranged from 0.002 -0.030 ppm with mean of 0.0064 ppm and standard deviation of 0.004. This average exceeds WHO standards. Royal Scientific Society (RSS) recorded 33 violations of the standards in 88 days, with 28% of all samples. The Average Concentrations of H_2S in May was 0.007 ppm with 15 violations, i.e., 50% of the total samples. This average decreased in March to 0.006 ppm with 12 violations that gave rise to 43% of the total, and this monthly average is the same as in April but with about 6 days, (Table.3).

3.4. Diurnal and Monthly Variation of Ozone (O_3)

The Concentrations of O_3 vary between 0.0 -0.65 ppm with a mean value that equals 0.074 ppm and a standard deviation of about 0.082. This average exceeds WHO standards. It violated the standard 46 times out of 51 days, which means that the violation is 90% from all the samples (Figure 2).

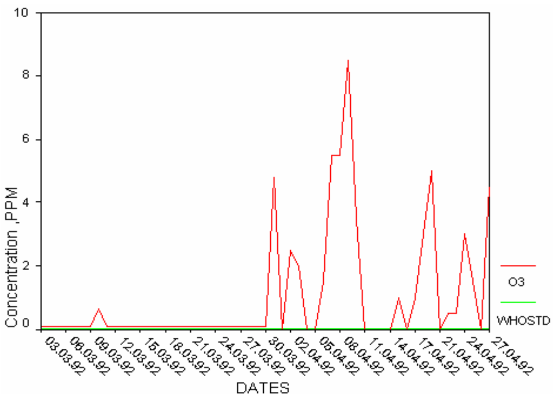

Figure 2. Concentration of O3 and WHO Standard at Al-Hashimeya in 1992.

The Average Concentrations of O3 in March was 0.07 ppm in 28 days ,i.e., 100% , but the concentration decreased in April to 0.06 ppm , 18 sample exceeded standards, that mean 78% of the samples in this month .The high concentration of O3 might correspond to increases in sunlight that helps nitrogen oxides and volatile organic compounds reacting with each other to form photochemical oxidants (also known as photochemical smog) of which ozone is the principal component. Whereas the values ranged in April between 0.030 - 0.084 ppm, (Table 3).

3.5. Diurnal And Monthly Variation of Total Suspended Particles (TSP):-

The monthly average of Total Suspended Particles (TSP) exceeded the 120 µg/m³ ppm WHO Standard days out of 31 day i.e. 77%. The average concentrations of TSP in May reached 221.8 µg/m³ ppm with 12 days violations, 92 %, this is due to low wind speed and humidity and west wind direction. In April, the average exceeded WHO standards with a mean value of about 169.7 µg/m³ ppm with 8 days violation, i.e., 80%. But in March the average monthly of TSP reached to 138.25 µg/m³ ppm with 4 days that reach ed to 50% of all the samples (Figure 3). The average exceeds WHO standards with a mean value of about (84.4 µg/m³) with 37 days violate from all the samples.

Figure 3. Concentration of TSP and WHO Standard at Al-Hashimeya in 1992.

The highest monthly average of TSP is that of May that ranges from 108 – 455 µg/m³ ppm, and the lowest average was found in March which ranged from 56 – 352 µg/m³, and this concentrations exceeds WHO standards. In April, it was 62 –316 µg/m³. These percentages exceed the international standards. This is more obvious when we compare these results with Umm Soleh, 3kms far from the study area. Studies indicate that the percentage of concentrations reached one third of the total percentage i.e., 38% of the whole exceedings.

Figure (4) shows that the comparison of the TSP concentration in Ibn el-anbari (inside Al- Hashimeya area) and Um Suleh, (far 3Km west from Al- Hashimeya). TSP concentration in Ibn el-anbari is higher and exceeds to one-third, compared to Um suleh.

3.6. Diurnal and Monthly Variation of Carbon Monoxide (CO)

Levels of this gas were low at the observance period, where it didn't exceed WHO standards, 9 ppm i.e., 8 hours as an average in the light of the day where the highest concentration of this gas reached 5 ppm in April.

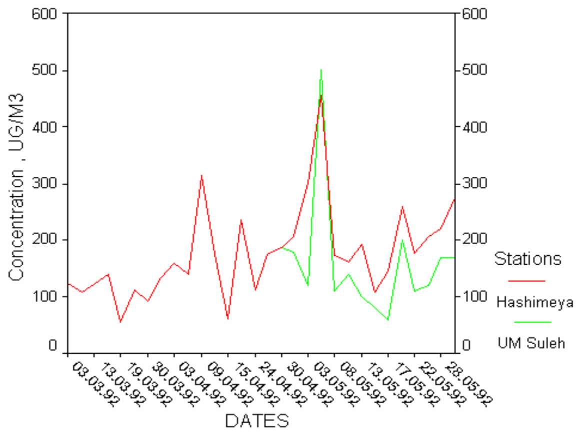

Figure 4. Variation in TSP levels at Al- Hashimeya and Um Suleh in 1992.

4. the Factors Affecting the Concentration of Air Pollutants At Al –Hashimeya

Meteorology plays a great role in influencing the air pollutants at Al-Hashimeya ,where the total explanation caused by these factors reach 43% of the percentage of pollution during spring season (March ,April and May).This percentage varies from 22% in March to 52% in April and 21% in May.

4.1. Meteorological Impact on SO2 Concentration:-

(Table 5) shows the most important metrological factors that influenced SO_2 concentration in the air. These factors explained 37% of dissimilarity in March, 84% in April and 29% in May.

Table 5. Metrological Factors affect on the Concentration of SO2 at Al-Hashimeya in 1992.

Month	Variables	R^2	R^2 Adjusted	Correlation coefficient	Significant level
March	Rainfall	0.37	0.37	-0.61	0.01
April	Temperature	0.58	0.58	-0.76	0.01
	Wind Speed	0.14	0.73	0.67	0.01
	Wind direction	0.08	0.81	0.34	0.05
	Cloud	0.02	0.84	0.47	0.01
May	Wind Speed	0.29	0.29	0.54	0.01
All Months	Wind Direction	0.21	0.21	0.43	0.01
	Relative Humidity	0.16	0.37	0.39	0.01

4.2. Metrological Impact on H2S Concentration:-

The most important meteorological factors that affected the H_2S concentration in spring was Wind Direction. Calm winds are prevailing in Al –Hashimeya region, 38.6%. Also West winds blow on the region in 31.8%, south winds with 18.2% .The Eastern winds blow reached 2.3%, southeast reached 4.5%, southwest 2.3% and northwest reached 1.1%.

Clearly, winds play a big role in affecting the percentage of H_2S gas ,14% of distraction in H_2S value with -0.32 negative correlated with coefficient value are explained at 99% reliability (Table 6). This relation is mainly due to the increase in the percentage of calm winds, and west winds, which increased the air pollution level in the study area, wind in carrying these pollutants from their resources (Petroluem Refinery and Al-Sammra station) to the sampling location.

It is clear that the speed of the wind plays a big role in increasing the H_2S concentrations in March. It explains 31% of the dissimilarity of the gas values with a negative correlation of -0.56 at the 99% significance level. i.e., when the wind speed is decreased, the level of air pollution is increased in Al-Hashimeya.

The average relative humidity in Al –Hashimeya is approximately 81.3% for the month of April. Humidity is an important factors that decreases the H_2S concentration. It explains 27% of the dissimilarity in the gas value with a negative correlation –0.52, at 99% of confidence. When there is an increase in 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 water vapour in order to form droplets, as well as forming the photochemical smog .

Table 6. most important metrological factors that affect the increase of H2S in the air.

Month	Variables	R^2	R^2 Adjusted	Correlation Coefficient	Significant level
March	Wind Speed	0.31	0.31	-0.56	0.01
April	Relative Humidity	0.27	0.27	-0.52	0.01
	solar radiation	0.06	0.33	-0.37	0.05
All Months	Wind Direction	0.14	0.14	-0.32	0.01

4.3. Metrological Impacts on Ozone Concentration

Humidity is considered among the meteorological factors that influences O_3 concentration. It explains 22% of the dissimilarity in the gas value with a negative correlation –0.48, at 99% of confidence (Table 7) . When there is an increase in the relative humidity, the O_3 concentration 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.

Table 7. most important metrological factors that affect the increase of O3 in the air.

Month	Variables	R^2	R^2 Adjusted	Correlation coefficient	Significant level
March	Relative Humidity	0.22	0.22	-0.48	0.01
May	Relative Humidity	0.22	0.22	-0.47	0.01

4.4. Metrological Impact on TSP Concentration:-

The main factors affecting TSP are temperature and clouds (Table 8). The mean average of temperature at Al –Hashimeya is approximately 17.3 C° with a maximum value of 29.30 C° and a minimum of 7.2C°. Thus such temperatures have an effect on on the concentration of TSP. It therefore explains 22% of the dissimilarity in the values of this gas with a negative correlation coefficient –0.50. The reason behind the negative correlation is that high temperatures enhance convection currents, which helps in good air mixing and reducing TSP concentration. Low air temperatures results in stable atmosphere and poor air quality.

The amount of clouds affects the percentage of TSP concentration; it explains 14% of dissimilarity in the values of TSP at a positive correlation of 0.37 at 99 % .

Table 8: Metrological Factors that Affect the Increase Of TSP in the Air.

Month	Variables	R^2	R^2 Adjusted	Correlation coefficient	Significant level
March	Temperature	0.19	0.19	-0.44	0.01
May	Cloud	0.14	0.14	0.37	0.05
All months	Temperature	0.22	0.22	-0.50	0.01

5. Discussion

It is observed that the main sources of Sulphur dioxide emissions in Al- Hashimeya town are Jordanian Petroleum Refinery and Al –Hussein Thermal Power station due to burning heavy fuel oil with high Sulphur content. It was also noticed that the areas located north, northeast and southeast are mainly affected by SO_2 emissions from the refinery, as Al-Husain station's influence is low in comparison with the refinery because the prevailing winds in Al-Hashimeya region are west headed. The study also showed that Assamra Station is the main source for the emanation of H_2S and the density of this gas has exceeded the Jordanian standards in this respect throughout the monitoring months whereas the levels of nitrogen oxides and CO concentrations are low in the ambient air in this town, but for TSP the concentration is high and it exceeds the WHO standards.

Results have proved that the high concentrations of TSP were attributed to the prevailing Khamasin winds, which is common in spring, especially in April and May, in addition to the high temperature and the low average of rainfall and low humidity, thus helping responding fugitive dust.

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 touches 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 results in the increase of these pollutants like NO_x, SO_2, CO. The relation of TSP with temperature is proportional, as the increase in temperature leads to generating more air currents and shaping vertical winds, thus causing dust and therefore TSP increases in the area. Humidity is low in Al-Hashimeya city. It's annual rate amount 65% .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.

The relation of relative humidity with the concentration of the pollutants is proportional relation, which could be attributed to the role of the humidity in causing the heat discrepancies as the increase of humidity in the atmosphere reduces the amount of solar radiation that reaches the earth , and when sunshine collides with these drops, then it absorbs these scattered drops in the surrounding atmosphere, so they start to evaporate and launch their embedded heat in the surrounding air, which contributes in forming heat variations where the air near to the surface of the earth is becoming colder than that in the upper parts, thus reducing the up going air currents and accordingly increasing the pollutants in the atmosphere.

6. Conclusion

The results have shown that the observed levels of air pollution exceeded the Jordanian standard for air quality and the study proved that the effect of meteorological factors play a great role in influencing the air with gases and dust in Al – Hashimeya area.

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