Analysis Study of Meteorological Parameters and their Relationship with Some Concentration of Tropospheric Gases over Erbil City

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INTRODUCTION

Due to the impact of air pollution on human health and its role in global warming, many studies have been achieved over the world to study air pollution by monitoring the ambient air level of different pollutant concentrations. The main four pollutant gases in the atmosphere are Ozone (O₃), sulfur dioxide (SO₂), carbon monoxide (CO), and nitrogen dioxide (NO) (Hejazi, 2012). Air pollution is caused by many factors such as emissions, local and synoptic meteorological scale, topography, and atmospheric chemical process.

A photochemical oxide is also considered as one of the pollutants problems in urban areas that produce ozone (O₃) and nitrogen dioxide (NO₂) (WHO, 2000).

The oxide compounds have many different forms such as; nitrous oxide (N₂O), nitrogen oxide (NO), nitrogen dioxide (NO₂), nitrous acid (HNO₂), nitric acid (HNO₃), and NOx (NO+NO₂). NO is reacting with Ozone forming NO₂ through industrial process. In contrast NO is formed through anthropogenic process by the reaction of oxygen with nitrogen. While NOx is emitted from vehicles production. Vehicle engines and power plant

ABSTRACT

The humanity efforts and the progress civilization for a better life without taking the atmospheric condition in consideration have a negative impact on the environment balance of our planet. So, it is very necessary to start doing studies about the interaction effects between the atmospheric components and meteorological parameters. For this purpose data were collected from a meteorological station nearby Erbil castle, the center of Erbil city. In this research the behavior analysis of the Meteorological parameters (temperature, dew point and relative humidity) and the concentrations of tropospheric gases (CO, SO₂, NOx, NO and NO₂) per half-hour for days 10, 20 and 30 for two consecutive months September and October (autumn) of 2013. The monthly average of tropospheric gases and meteorological parameters were calculated for the first of September and October as well in order to find the relationship between them. It was found that there is a clear drop of temperature and dew point associated with an increase in relative humidity and decrease of pollutants concentrations in October compared to September. Pollutant concentration showed an increase during the night and decrease during the day for each half-hour of study period. A positive correlation between pollutant concentration and temperature and negative correlation between pollutant concentration and relative humidity and dew point were observed.

Keywords: Concentrations of gases, Meteorological parameters, Commercial area, Erbil Citadel, Kurdistan.

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are the major sources for NO and NO\textsubscript{2}. Sulfur dioxide (SO\textsubscript{2}) is produced from many factors such as: burning sulfur-containing fossil fuels, power and transport generation, and volcanoes. Carbone dioxide is considered as the most toxic gases that are produced from incomplete combustion of fossil fuels and biofuels. The highest CO levels are found in urban areas due to the road transport emission.

The concentrations of SO\textsubscript{2}, CO, and NO\textsubscript{x} are strongly correlated among each other, indicating that they are emitted by some common sources (Lin \textit{et al}.2011). The atmospheric chemical components were examined by previous research by which the relationship between O\textsubscript{3}, NO and NO\textsubscript{2} was investigated to understand the chemical reaction among them (Han \textit{et al}. 2011). Other studies measured the concentration of SO\textsubscript{2}, CO, and NO\textsubscript{x} in New Delhi and found that the maximum concentration of them occurs during winter while the minimum value occurs during the summer due to the effect of meteorological condition and photochemical activity (Aneja \textit{et al}. 2001). The relationships among ambient levels of O\textsubscript{3}, NO and NO\textsubscript{2} to improve the understanding of the chemical coupling among them (Clapp and Dodd, 2001; Mazzeo \textit{et al}. 2009).

The correlation between meteorological parameters and air pollution and found that only wind speed have a strong relationship with CO. An statistical method was used by pollution 1 to analyze air pollution and meteorological parameters in the center of the Estonian and found from wind direction analysis that sulfur oxide peak is mostly related to the oil shale retorting plant and wastewater treatment plant. Statistical methods were used for better understanding the trend of their concentrations (Chou, 2006).

**STATISTICAL ANALYSIS**

**Simple Linear Regression**

Linear Regression correlate independent and dependent variables and produce a straight line when it is graphed on a Cartesian coordinate system. The straight line describes the value of the independent variable. The equation that is used for a Simple Linear Regression is the equation for a straight line:

$$y = a + bx$$

(1)

$$b = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

(2)

Where \(y\) is the dependent variable, \(x\) is the independent variable, is the intercept, or constant term (value of the dependent variable when \(x=0\), the point where the regression line intersects the \(y\) axis), and \(b\) is the slope, or regression coefficient (increase in the value of \(y\) per unit increase in \(x\)). When \(x\) value increases, the corresponding \(y\) value increases or decreases depending on the sign of the slope \(b\). Linear Regression is a parametric test, that is, for a given independent variable value, the possible values for the dependent variable are assumed to be normally distributed with constant variance around the regression line. The slope of the line represents the amount of change in the \(y_i\) corresponding to a change in the \(x_i\) is incremented by one unit (William, 1992; Seidenglanz, 2012).
P-Value

Is the probability of being incorrect in terms of whether the data is not normally distributed, p-value is defined as the risk of falsely rejecting the null hypothesis that the data is normally distributed. Depending on the accurate way of computing p value we can decided whether it is accepted or no. for example, if the test is greater than p set here then the test one is more accurate. To require a stricter adherence to normality and/or constant variance, increase the P-value. Because the parametric statistical methods are relatively robust in terms of detecting violations of the assumptions, the suggested value in SigmaPlot is 0.05. Larger values of P (for example, 0.10) require less evidence to conclude that the residuals are not normally distributed or the constant variance assumption is violated. To relax the requirement of normality and/or constant variance, decrease P-value require smaller values of P to reject the normality assumption means that you are willing to accept greater deviations from the theoretical normal distribution before you flag the data as non-normal. For example, a P-value of 0.01 for the normality test requires greater deviations from normality to flag the data as non-normal as a value of 0.05 (Padua, 2000).

Pearson Correlation Test

Use Pearson Correlation when:

- Measure the strength of the association between pairs of variables without regard to which variable is dependent or independent.
- Determine if the relationship, if any, between the variables is a straight line.
- The residuals (distances of the data points from the regression line) are normally distributed with constant variance.

The Pearson Correlation coefficient is the most commonly used correlation coefficient. To predict the value of one variable from another, use Simple or multiple Linear Regression. If you need to find the correlation of data measured by rank or order, use the nonparametric Spearman Rank Order Correlation. When an assumption is made about the dependency of one variable on another, it affects the computation of the regression line. Reversing the assumption of the variable dependencies results in a different regression line. The Pearson Correlation coefficient does not require the variables to be assigned as independent and dependent. Instead, only the strength of association is measured. Pearson Correlation is a parametric test that assumes the residuals (distances of the data points from the regression line) are normally distributed with constant variance, Pearson’s correlation coefficient when applied to a sample is commonly represented by the letter r and may be referred to as the sample correlation coefficient or the sample Pearson correlation coefficient. We can obtain a formula for r by substituting estimates of the covariance and variances based on a sample into the formula above. So if we have one dataset \{x1,\ldots,xn\} containing n values and another dataset \{y1,\ldots,yn\} containing n values then that formula for r is: (Levesque, 2007; MEI,2007).

\[
r = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \bar{x})^2} \sqrt{\sum_{i=1}^{n} (y_i - \bar{y})^2}}
\]

(3)
\[ x = \frac{1}{n} \sum_{i=1}^{n} x_i \]  

**DATA AND STUDY AREA**

It was obtained Meteorological parameters (temperature, dew point and relative humidity) data and the concentrations of gases (CO, SO\(_2\), NO\(_x\), NO and NO\(_2\)) data per half-hour for the day (10, 20, and 30) for two months (September and October) 2013 from station of weather monitoring US-made where this station measured Meteorological parameters as well as the measurement of concentrations of gases continuously every half hour has been set up this station in 2013 in the Al-Qalaa area (Erbil Citadel) Erbil city center, a densely populated, commercial area and a busy area traffic due to the increase of various of transportation (cars, motorcycles, trucks and other transport vehicles), Al-Qalaa area located on the Kurdistan region of northern Iraq (away from the capital Baghdad, a distance of 450 km to the north) at longitude (44° 00' 32" E), latitude (36° 11' 28" N) and on height (415) meter above sea level (see “FIGURE 1”).

**THE PRACTICAL SIDE**

**Analysis the Hourly Change (Every Half Hour) for Meteorological Parameters and Concentration of Gases for Study Days**

This can be seen that there is a clear decrease in temperature during the hours of early morning with an increase in relative humidity and the air is unable to raise the water vapor and when the air up to a state of saturation is air cooling with pressure and water vapor are known temperature by dew point temperature. In addition to that there is a decrease in the concentrations of gases during the day hours and increased during the night. As in “FIGURES 2 and 3”.

Gases during the day hours and increased during the night. As in “FIGURES 2 and 3”.

**Analysis the Hourly Change (Every Half Hour) for Meteorological Parameters and Concentration of Gases for Months (September and October)**

In September it found increase in temperature, dew point and an decrease in relative humidity and decrease in temperature, dew point and an increase in relative humidity in October and the concentrations of the gases was almost constant in the two months since the highest value recorded for the gas concentration (CO) in the middle of the month of September and October (0.75 PPM), see “FIGURE 4”.

**The Relationship between Meteorological Parameters and Concentration of Gases for Months (September and October)**

It found a strong positive relationship between the temperature and the concentrations of the gases in the two months, and the relationship of negative between the concentrations of gases and relative humidity, dew point, see “FIGURES 5 and 6” and “Table 1”.

**Analysis the Hourly Change (Every Half Hour) for Meteorological Parameters and Concentration of Gases for Two Consecutive Months September and October**

Through the curve fitting it found that there are low concentrations of gases with time during the consecutive months September,
October and low temperature, dew point with time and increasing the relative humidity with time and this confirms the accuracy of the data and work, see “FIGURES 7 and 8”.

CONCLUSIONS

- Low concentration of gases during the day and high concentration of the gases during the night.
- Temperature and dew point in October are less than in September and the relative humidity in October more than in September.
- In daily relationship;
  1- The positive relationship between the concentrations of gases and temperature, and dew point were observed.
  2- Negative relationship between the concentrations of gases (NO₂, SO₂) and relative humidity.
- Slight positive correlation or no correlation (nonlinear) between the concentrations of gases (CO, NO, NOₓ) and relative humidity.
- In monthly relationship (September and October) the relationship is negative between the concentrations of gases and relative humidity, and dew point, while the relationship is positive between the concentrations of gases and temperature.
- The highest value of the concentration of gases were in the middle of September and October. The concentration of gases in October was more than September.

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FIGURE 1. Study area, station of weather monitoring in the Erbil Citadel, Kurdistan region of northern Iraq.
FIGURE 2. Hourly change (every half hour) for Meteorological parameters and concentration of gases for the days of study (10, 20, and 30), September 2013 in Erbil Citadel.
FIGURE 3. Hourly change (every half hour) for Meteorological parameters and concentration of gases for the days of study (10, 20, and 30), October 2013 in Erbil Citadel.
FIGURE 4. The hourly change (every half hour) for Meteorological parameters and concentration of gases for months (September and October).
FIGURE 5. The relationship between Meteorological parameters and concentration of gases (every half hour) for September 2013 in Erbil Citadel.
FIGURE 6. The relationship between Meteorological parameters and concentration of gases (every half hour) for October 2013 in Erbil Citadel.
TABLE 1. Simple linear regression equation and the interpretation of the relationship between the Meteorological parameters and concentration of gases (every half hour) for September, October 2013 and the strength of the Pearson Correlation Coefficient test.

| Correlation | Simple linear regression equation | P-Value | Interpretation of the relationship | Pearson test |
|-------------|----------------------------------|---------|------------------------------------|--------------|
| **September** |                                  |         |                                    |              |
| T vs. CO    | \( CO = 0.337 + (0.0520 \times T) \) | 0.0001  | Linear                             | 0.191        |
| T vs. SO\(_2\) | \( SO_2 = 0.00715 + (0.000930 \times T) \) | 0.014   | Linear                             | 0.064        |
| T vs. NOx   | \( NOx = 0.0346 + (0.00280 \times T) \) | 0.001   | Linear                             | 0.138        |
| T vs. NO    | \( NO = 0.0278 + (0.00178 \times T) \) | 0.001   | Linear                             | 0.096        |
| T vs. NO\(_2\) | \( NO_2 = 0.00474 + (0.00110 \times T) \) | 0.001   | Linear                             | 0.333        |
| Td vs. CO   | \( CO = 1.962 - (0.0223 \times Td) \) | 0.007   | Linear                             | -0.071       |
| Td vs. SO\(_2\) | \( SO_2 = 0.0103 - (0.000117 \times Td) \) | 0.007   | Linear                             | -0.070       |
| Td vs. NOx  | \( NOx = 0.125 - (0.00218 \times Td) \) | 0.001   | Linear                             | -0.094       |
| Td vs. NO   | \( NO = 0.0858 - (0.00151 \times Td) \) | 0.007   | Linear                             | -0.071       |
| Td vs. NO\(_2\) | \( NO_2 = 0.0398 - (0.000671 \times Td) \) | 0.001   | Linear                             | -0.177       |
| RH vs. CO   | \( CO = 2.572 - (0.0350 \times RH) \) | 0.001   | Linear                             | -0.216       |
| RH vs. SO\(_2\) | \( SO_2 = 0.0122 - (0.000118 \times RH) \) | 0.001   | Linear                             | -0.137       |
| RH vs. NOx  | \( NOx = 0.165 - (0.000242 \times RH) \) | 0.001   | Linear                             | -0.201       |
| RH vs. NO   | \( NO = 0.115 - (0.000177 \times RH) \) | 0.001   | Linear                             | -0.161       |
| RH vs. NO\(_2\) | \( NO_2 = 0.0511 - (0.000686 \times RH) \) | 0.001   | Linear                             | -0.349       |
| **October** |                                  |         |                                    |              |
| T vs. CO    | \( CO = 0.291 + (0.0550 \times T) \) | 0.001   | Linear                             | 0.195        |
| T vs. SO\(_2\) | \( SO_2 = 0.00750 + (0.000112 \times T) \) | 0.004   | Linear                             | 0.074        |
| T vs. NOx   | \( NOx = 0.0659 + (0.00112 \times T) \) | 0.031   | Linear                             | 0.056        |
| T vs. NO    | \( NO = 0.0441 + (0.000713 \times T) \) | 0.114   | Non linear                         | 0.041        |
| T vs. NO\(_2\) | \( NO_2 = 0.0218 + (0.000417 \times T) \) | 0.001   | Linear                             | 0.114        |
| Td vs. CO   | \( CO = 1.593 - (0.000709 \times Td) \) | 0.940   | Non linear                         | -0.001       |
| Td vs. SO\(_2\) | \( SO_2 = 0.00998 - (0.000217 \times Td) \) | 0.001   | Linear                             | -0.112       |
| Td vs. NOx  | \( NOx = 0.0922 - (0.000228 \times Td) \) | 0.731   | Non linear                         | -0.008       |
| Td vs. NO   | \( NO = 0.0610 - (0.000979 \times Td) \) | 0.866   | Non linear                         | -0.004       |
| Td vs. NO\(_2\) | \( NO_2 = 0.0314 - (0.000331 \times Td) \) | 0.007   | Linear                             | -0.070       |
| RH vs. CO   | \( CO = 2.112 - (0.0246 \times RH) \) | 0.001   | Linear                             | -0.157       |
| RH vs. SO\(_2\) | \( SO_2 = 0.0130 - (0.000136 \times RH) \) | 0.001   | Linear                             | -0.161       |
| RH vs. NOx  | \( NOx = 0.111 - (0.000886 \times RH) \) | 0.002   | Linear                             | -0.079       |
| RH vs. NO   | \( NO = 0.0732 - (0.000583 \times RH) \) | 0.020   | Linear                             | -0.060       |
| RH vs. NO\(_2\) | \( NO_2 = 0.0382 - (0.000311 \times RH) \) | 0.001   | Linear                             | -0.153       |
FIGURE 7. Hourly change (every half hour) for concentration of gases for two consecutive months September and October (autumn 2013) in Erbil Citadel.
FIGURE 8. Hourly change (every half hour) for Meteorological parameters for two consecutive months September and October (autumn 2013) Erbil Citadel.

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