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RESEARCH PAPER

Analysing the Pollutants Dispersion in Erbil City-Kurdistan with Support of Statistical Analysis.

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A B S T R A C T:
Most of the countries in the world are suffering from the air pollution problem, including both developed and developing countries, due to their urban expansion and overpopulation. Erbil has seen a significant expansion in its population. This was complemented by significant progress in a variety of sectors. The increase in numbers of power generators and increasing the number of cars lead to an increase in the number of pollutants emitted into the atmosphere. This study is concerned with the analyses and evaluation of our air quality in gaseous Pollutants such as CO, NO, NO_2 O_3, and SO_2, then compare the concentrations of these gases with the allowable limits issued by the Environmental Protection Agency (EPA). The dependence of ground-level ozone levels was modelled using statistical analysis and the multiple linear regression approach. The data were obtained from the Board of Environmental Protection and Improvement, Erbil-government-office for 2015 to 2018, which includes the concentration of the pollutants mentioned above and metrological conditions such as (wind direction, wind speed, temperature, air pressure, the relative humidity for the same period. The results show there was some increase in air pollutants. The best prediction equation (R^2 = 0.671) presents the dependence of ozone concentration in Erbil city depending on data for two years (2015 and 2016) by utilizing multiple linear regression analysis. The following software was used to analyze and plot the data (Microsoft Excel 2013, WRplot V.7.0.0 and SPSS version 14).

KEY WORDS: Pollution,Air Contamination,Wind,Metrology;EPA
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1.INTRODUCTION :

Air pollution in big cities throughout the world has emerged as a significant environmental problem, with anthropogenic activities emitting a significant percentage of gases and particles (Sicard et al., 2021) Air pollution is the presence of unwanted impurities in the air in large quantities to produce negative impacts. From sources currently beyond human control, many of these dangerous substances enter the atmosphere. However, the primary sources of these pollutants are human activities in the most densely inhabited parts of the globe, especially in industrialized countries (De Nevers, 2010).

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Both indoor and outdoor air pollution is considered one of the most significant environmental dangers to human health. Air pollution can cause health problems such as breathing difficulties, asthma, wheezing, coughing, aggravation of existing respiratory, heart disorders, and death. According to the World Health Organization WHO (2019), an estimated 7 million people die due to inhaling air pollutants; approximately half of these deaths are caused by breathing indoor air pollutants when the majority of them are in Asia. Like other emerging countries, Iraq is dealing with this issue (Chaichan et al., 2018, Majid, 2011, Sissakian et al., 2013).

In this way, Air Quality Monitoring (AQM) is essential for assessing air quality levels and health effects. AQM's objective is to safeguard human health, the environment, and animals and plant life (Stockholm Environment Institute, 2008). There is no denying that air pollution, particularly in the respiratory system, is harmful to health. The London smog in December 1952, when four thousand people were reported dead in one day, is a dramatic instance of the health effects of air pollution. In addition to asthma, air pollution can cause chronic illness and even death. Carbon monoxide, for example, is a major air pollutant since it is an invisible gas created by the incomplete combustion of carbon-based fuels. It reduces the oxygen load capacity of the circulation and affects the central nervous system. The primary source of nitrogen oxides (NOx) produced by humans is the burning of diesel engines, which are the major source of NOx in transportation facilities.

Nitrogen dioxide (NO_2) is highly toxic and causes irritation of the throat and eyes, and in kids, it is also found to cause respiratory disease. In the presence of sunlight, nitrogen oxides interact photochemically with hydrocarbons from vehicle exhaust to form ozone (O_3). Inhaling ozone has been shown to have adverse effects on human health, particularly in children. It also has negative consequences for plants and ecosystems (Chaichan, 2015a, Chaichan, 2015b, Voskamp et al., 2018). Ozone is a molecule of unstable oxygen and is a potent oxidizing agent. According to the World Health Organization (WHO), low quantities of ozone in the atmosphere can induce nose, eye, and throat irritation, cough and headache, and chest pain. People with asthma or bronchitis are vulnerable. Volatile organic compounds (VOC) are substances that evaporate quickly. As reactions occur with nitrogen oxides in the presence of sunlight, they can produce photochemical oxidants; some are toxic or carcinogenic. Exhaust fumes, smoke, recycled products, household chemicals, benzene and polycyclic aromatic hydrocarbons (PAH) are available in these products. Other gases which are toxic to humans, like sulfur dioxide (SO2) and particulate matter (PM), are harmful air contaminants. A toxic substance is a contaminant that affects the nervous system, such as lead. The primary source of lead in the air is automobile exhaust. Air, light quality, soil, and water are all important factors in determining the health of humans, animals, and plants; pollution of the air can significantly impact all of these key elements, affecting their functioning(Faiz et al., 1996) (Rancière et al., 2017, Shams et al., 2014, D’Amato et al., 2015, Ma et al., 2016). Primary pollutants are those that are emitted directly from recognized sources. Secondary air pollutants are those formed in the air due to the interaction of two or more main air pollutants. Primary air examples: (i) Fine (less than 100µm) and coarse (more than 100µm) particulate matter, (ii) Sulfur oxides, (iii) Carbon monoxide, (iv) Nitrogen oxides, (v) Radioactive compounds, Nitrogen oxides, (vi) Organic compounds, (vii) Halogen, Organic compounds (vii) Radioactive compounds. The Secondary air pollutants comprise: (i) Ozone, (ii) Photochemical smog, (iii) PAN **(**peroxi acetyle nitrate) (iv). The most significant and harmful of the above is Acid Mist Smog. Smog is a combination of two terms: smoke and fog. It can be of two kinds, photochemical or coal-produced (Gaur, 2008). Ozone is not a major contaminant generated by automobile exhaust systems. It is a secondary pollutant created by photochemical interactions between NOx, VOC, and sunlight in the atmosphere (Chaichan, 2016). Tropospheric ozone is a significant atmospheric secondary air pollutant that has received considerable attention (Abdul-Wahab et al., 2005, Al-Alawi et al., 2008, Al-Khalaf, 2006, Al-Azmi et al., 2008). It has been observed that ozone is the main oxidant and is the most significant photochemical smog index substance reported as a one-off main contaminant that affects air quality (Arya, 1999). Temperature, radiation and humidity drive ozone-producing chemical processes, while the characteristics of the wind boundary layer and its stagnant state are the factors that enhance O3 precursors and limit their dispersion, respectively. The concentration varies widely with the time of day and year, from one region to another (Lengyel et al., 2004, San José et al., 2005, Al-Alawi et al., 2008).

(Jassim et al., 2013)study was conducted to determine Erbil's environmental effects on air quality. Pollution was caused by an increase in the number of automobiles in Erbil city, suggesting a 10.87-times e in traffic volume during six years (2006 - 2011). Pollution caused by increasing power generators numbers in Erbil, demonstrating a 76.1 per cent increase in the number of used generators over ten years between (2003 - 2012). (Jassim et al., 2014) have studied the effects of increasing polluting gases (HC, NOx, CO and CO2). The results of this study indicated: From 2007 to 2013, there was a 437 % increase in the number of automobiles. This was caused by a rise in daily emissions of HC, CO, NOx, and particle mass, including CO2, from 441 tons per day in 2007 to 1913 tons per day in 2013.

Moreover, there was a rise in CO2 from 6068 tons per day in 2007 to 27382 tons per day in 2013. (Mahmood et al., 2021) conducted a study on estimating air quality in Kirkuk depending on PM10particulates. The data were compared to international standards, and GIS spatial analysis techniques indicated that the northwestern part of Kirkuk governorate was the most polluted area with PM10 particles than another area linked to nearby oil and gas production and its impact on air quality. (Mustafa and Mohammed, 2012) the concentration of ground-level ozone in several parts of Baghdad were measured. The findings suggest that power plant stations have a more significant impact on ozone formation than traffic. The ground-level ozone concentrations recorded during the study period in spring and fall were compared to the ambient air levels. (Mustafa et al., 2011) The concentration of ground-level ozone in several parts of Baghdad was measured. The impact of power plant stations on the formation of ozone was greater than the traffic load.

2.MATERIALS AND METHODS

2.1 Study Site

Erbil city is the capital of Kurdistan and is located in the northern part of Iraq. Erbil covers approximately (18,170) square kilometres. Its Boundaries extend between 43°15¯E to 45°14¯E longitudes and from 35°27¯N to 37°24¯N latitudes. Details of climate, geology and Limnology of the area are given in (Zohary, 1950). The data was obtained from the (BEPI), Erbil-government office. Erbil city contains one air quality monitoring station depending on the information of the government office (BEPI). The coordinates of the air quality monitoring station are (44° 1'21.00"E) longitude and (36°11'21.10"N) latitude. See Figure1.

Figure 1: Location of air quality monitoring station according to Erbil City [Satellite image]

2.2 Measurement of Ground-level Ozone

Multiple regression linear analysis is one of the most commonly utilized methods to design the dependence of several independent variables of the response variable (predictand) (Khiem et al., 2010). Even then, when the independent variables are related, the multiple regression approach can solve real problems of (multi-collinearity). Multi-collinearity is an unwanted situation in the linear function of independent factors. Due to multi-collinearity, small changes in the data values might cause significant changes in the coefficient estimates (Paschalidou et al., 2009).

(Abdul-Wahab et al., 2005) showed that multi-collinearity, or high correlation in an equation of regression between independent variables, can make it hard to indicate valuable contributors to a physical process. The problem can be solved by using the method adopted by (Paschalidou et al., 2009). The data were analyzed with the help of the statistical program SPSS (Statistical Package for Social Science, version 14).

3.RESULTS AND DISCUSSION

3.1 Data Analysis

The pollutants produced continually from the Power Plant, such as (Erbil power station, electric power control of Erbil and Erbil 29MW PP) are closed to the air monitoring station, power generators, and traffic load predicted to have an impact on Erbil city. The wind rose over 2018 was illustrated in Figure 2, plotted using the Wrplot V.7.0.0 program. The wind rose indicates that the wind direction was mainly from the North West.

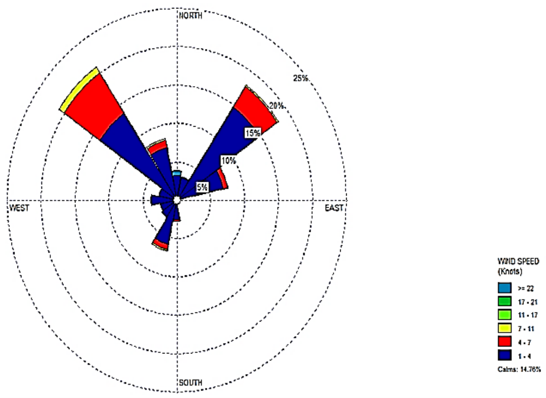


Figure 2: Wind rose for Erbil City on full year (2018).

From a comparison of the data, shown in Figure 3, for years 2015 and 2016), there is an exceedance to allowable limits of environmental protection agency [national ambient air quality standard (NAAQS)], when equal to (0.075 ppm (8-hours). The ozone concentration needed; the allowable limits in October/2016 due to NOx and VOC emissions caused by traffic congestion and power generators. On the other hand, the highest ozone concentration was recorded from March to August, but it does not exceed the standard.

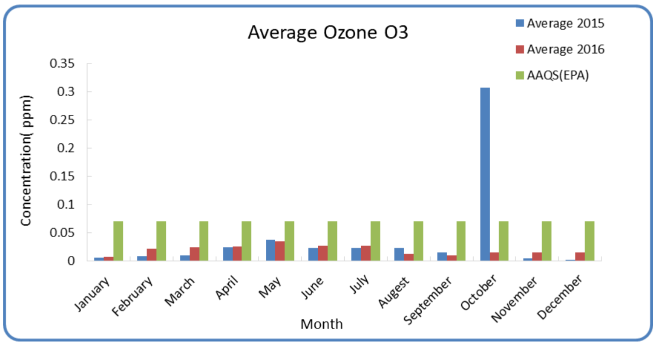


Figure 3: Variation of level O_3 concentration during years (2015 and 2016).

The exceedance of limits appears after 12 PM as shown in Figures 4 and 5 for the years 2015 and 2016 because of the availability of appropriate conditions for the reactions of photochemical reaction such as the intensity of solar radiation, low wind speed and high temperature in these months.

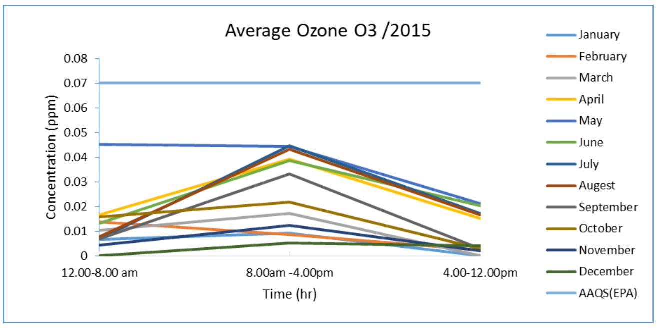


Figure 4: Variation of level O_3 concentration during year (2015) which is shown the change during the monthly hours.

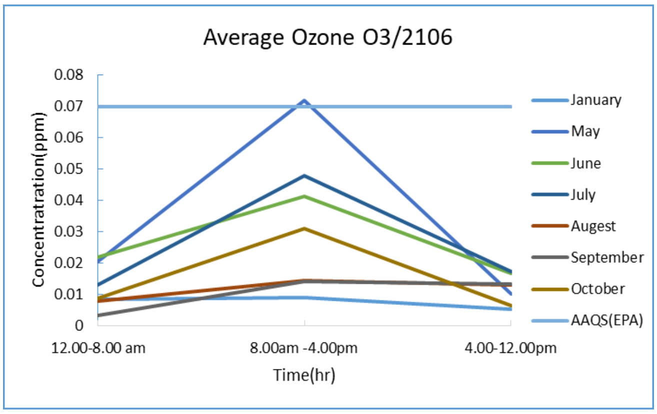


Figure 5: Variation of level O_3 concentration during year (2016) which is shown the change during the monthly hours.

Carbon monoxide is a poisonous gas. It results from the incomplete combustion of carbon-containing material. A comparison of the data is shown in Figure 6 for 2015, 2016, 2017 and 2018. It can be observed that the CO concentration did not exceed the permissible limits of (9ppm (8-hours)) according to AAQS. Figure 6 represents the average monthly variation of CO concentration over four years. 2016 showed the highest concentration of CO. In December 2015, the highest concentration of CO was recorded. Figure 7 shows the variation in CO concentration during 2108. The highest concentration was recorded between (8 AM to 11 AM) and after 6.30 PM, maybe because of traffic congestion.

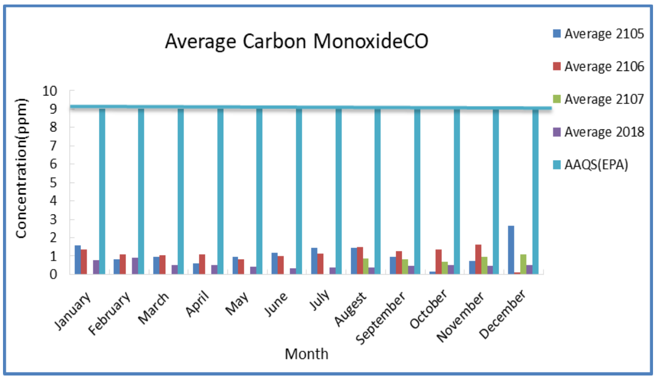


Figure6: Variation of level CO concentration during years (2015, 2016, 2017and 2018).

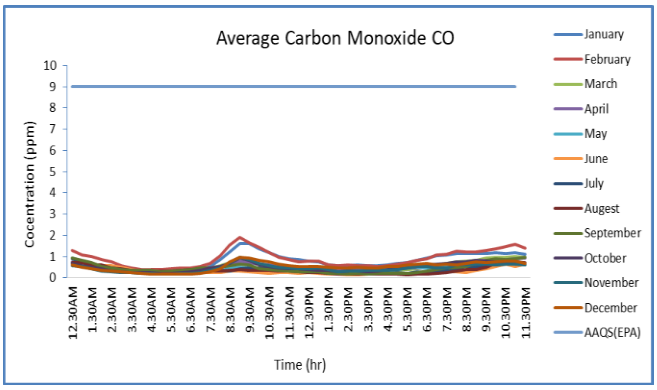


Figure7: Variation of level CO concentration during years (2018) which is shown the change during the monthly hours.

The main source of sulfur dioxide in the air is industrial activity that processes materials containing sulfur, generating electricity from coal, oil, or gas (Iraqi oil has a high sulfur content). Some mineral ores also contain sulfur, and sulfur dioxide is released when they are processed. In addition, industrial activities that burn fossil fuels containing sulfur can be important sources of sulfur dioxide.

Figure 8 shows the average variation of SO_2 concentration through 2015, 2016, 2017 and 2018. It can be observed that the concentration of SO_2 did not exceed the allowable limits of (NAAQS), which is equal to (0.075ppm for 1hour exposure) except for August /2017, which was about 0.0839ppm. Therefore, the highest concentration was recorded in 2016, and the lowest concentration was recorded from May to December 2018 may be related to human activities such as traffic congestion.

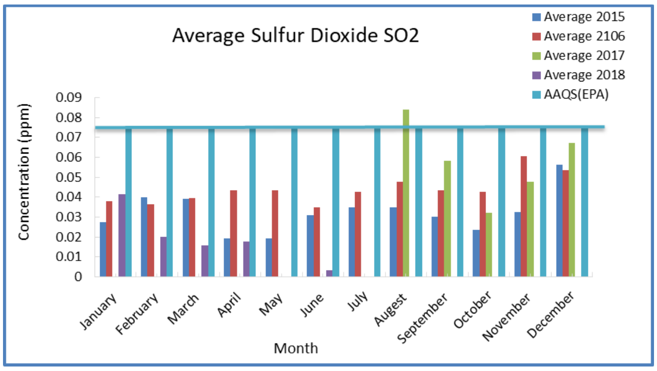


Figure 8: Variation of level CO concentration during years (2015, 2016, 2017and 2018).

Figure 9 illustrates the variation of SO_2 when January has recorded the highest concentration, while June recorded the lowest concentration. Again, there is no exceedance of the allowable limit of SO_2.

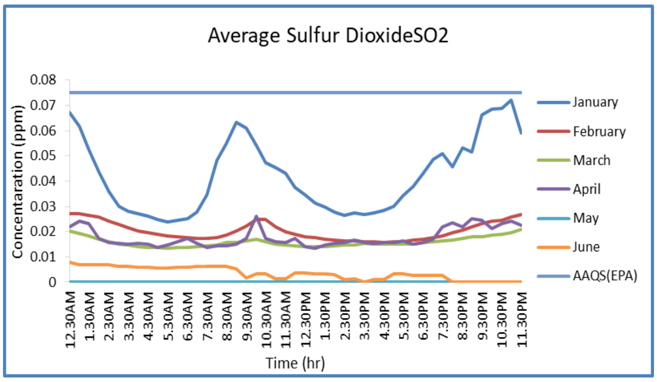


Figure 9 : Variation of level SO_2 concentration during year (2018) which is shown the change during the monthly hours.

The burning material (oil, diesel engines, etc.) in the air produces nitrogen (NOx) oxides, which NO_2 is a major product. From a comparison of the data of NO_2 shown in Figure 10 during the years 2015, 2016, 2017 and 2018 and Figure 11 to NO for the years 2017and 2018. It can be realized that the allowable limit of (NAAQS) equal to (0.053ppm annually) was not exceeded in all months. Figures 12 and 13 show the NO2 and NO concentration variation during monthly hours (the analysis of NO2 concentration during each month depending on variation in hours).

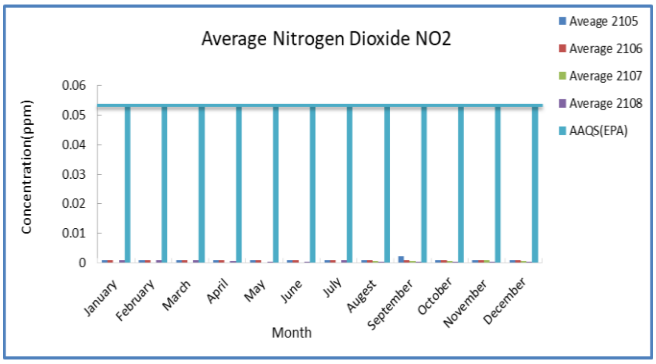


Figure 10: Variation of level NO_2 concentration during years (2015, 2016, 2017and 2018).

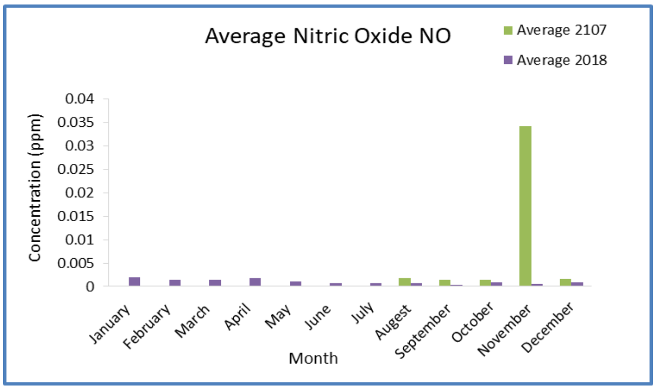


Figure 11: Variation of level NO concentration during years (2017and 2018).

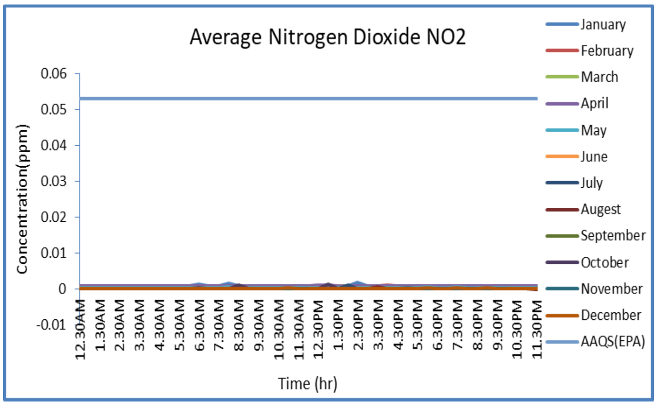


Figure 12: Variation of level NO_2 concentration during (2018) which is shown the change during the monthly hours.

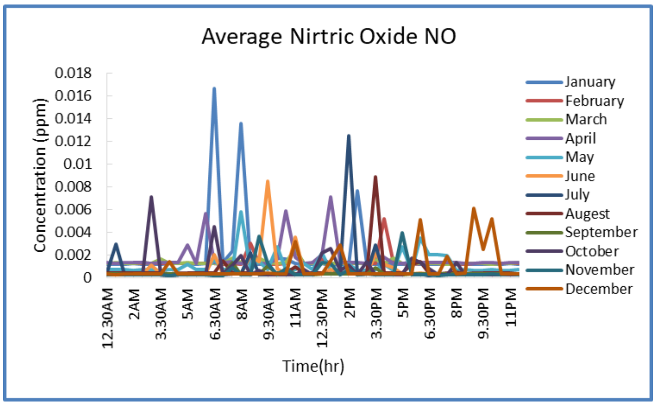


Figure 13: Variation of level NO concentration during (2018) which is shown the change during the monthly hours

3.2 Prediction of Ozone Concentration for (2015 and 2016)

3.2.1 Monthly Average for 2015 and 2106

First: the correlation matrix is constructed for the variables measured in Erbil city for the research period and tabulated in Table 1. The independent variables are relative humidity (RH), pressure (PR) in (mbar), temperature (Temp) in ^{0} C, precipitation in mm, wind speed (WS) in m/sec, the concentration of NO2, CO, SO2 in ppm.

Table 1. also shows a positive correlation between ozone and other variables except for temperature, wind speed and year.

Table (1) Correlation matrix between the variables

	O3	NO2	Precipitation	Pressure	year	CO	SO2	Temperature	Humidity	WS
O3	1.000	0.310	0.087	0.108	-0.003	0.025	0.027	-0.337	0.112	-0.537
NO2	0.310	1.000	0.012	0.058	-0.165	0.042	-0.072	-0.089	0.138	-0.292
Precipitation	0.087	0.012	1.000	-0.273	-0.164	0.040	-0.138	-0.221	-0.664	-0.060
Pressure	0.108	0.058	-0.273	1.000	-0.039	-0.092	-0.014	0.149	0.336	-0.182
Year	-0.003	-0.165	-0.164	-0.039	1.000	-0.132	0.456	0.106	0.092	-0.056
CO	0.025	0.042	0.040	-0.092	-0.132	1.000	-0.428	0.101	0.094	-0.005
SO2	0.027	-0.072	-0.138	-0.014	0.456	-0.428	1.000	-0.047	-0.080	0.175
Temperature	-0.337	-0.089	-0.221	0.149	0.106	0.101	-0.047	1.000	0.371	-0.346
Humidity	0.112	0.138	-0.664	0.336	0.092	0.094	-0.080	0.371	1.000	-0.283
Wind speed	-0.537	-0.292	-0.060	-0.182	-0.056	-0.005	0.175	-0.346	-0.283	1.000

Second: multiple-regression linear analysis is used for the independent variables to produce an estimation model for the logarithmic transformation of ozone concentrations [ln O3]. It is noted that transformation of the logarithmic concentration of ozone [ln O3] is utilized instead of O3 because its frequency distribution is near to the normal and it is well known that the regression analysis works better with standard variables.

The results of the analyses are presented in Table 2, where the estimated regression coefficients, their standard error, the standardized regression coefficients, the coefficients of determination R^2, the tolerances and the variance inflation factor VIFs can be seen.

Multi-collinearity can be noticed in Table 2, the small tolerances (e.g. 0.091 for temperature, 0.08

for humidity, 0.215 for pressure and 0.237 for SO_2) show that a high percentage (e.g., 79.3 % for NO_2, 57.6% for precipitation and 55.4% for the year) of the variance in a given predictor can be presented by other predictors. This means that there is high multi-collinearity, and the standard error of regression coefficients will be inflated. Also, in everyday practice, a VIF greater than 3 is considered problematic. Thus, high VIF values (10.971, 4.649, 12.464, and 4.212 for temperature, pressure, humidity and SO_2, respectively) are considered unacceptable. Hence, the above regression analyses are inappropriate for modelling ozone concentrations.

Table (2) Linear regression analysis for Erbil city monitoring station.

R^2= 0.723 R=0.850	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	-1115.580	748.890		-1.490	.158		
year	.530	.356	.281	1.489	.159	.554	1.805
Temperature	-.013	.045	-.136	-.291	.775	.091	10.971
Pressure	-.003	.003	-.367	-1.212	.246	.215	4.649
Humidity	-.027	.021	-.619	-1.246	.233	.080	12.464
WS	.239	.374	.169	.640	.532	.283	3.539
Precipitation	.029	.059	.092	.494	.629	.576	1.735
CO	-.931	.484	-.432	-1.924	.075	.392	2.548
NO_2	-100.242	496.590	-.032	-.202	.843	.793	1.261
SO_2	-8.538	26.876	-.092	-.318	.755	.237	4.212

Variables with a high VIF can be eliminated to improve the model, as illustrated in Table 3. As a result, multi-collinearity was reduced, and tolerance and VIF were enhanced. The following model can thus explain 67.1 % of the variation in the Ln [O3] variable. **Table (3):** Linear Regression analysis after improvement, by removing humidity and SO_2.

R^2=0.671 R=0.819		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-840.895	628.730		-1.337	.199		
	year	.398	.299	.211	1.332	.200	.772	1.296
	Temperature	.049	.017	.514	2.915	.010	.623	1.604
	Pressure	-.001	.001	-.066	-.432	.671	.841	1.189
	Precipitation	.020	.056	.063	.362	.722	.642	1.558
	CO	-1.089	.342	-.505	-3.187	.005	.771	1.297
	NO_2							
		-176.474	457.569	-.056	-.386	.705	.915	1.093

Equation 1. can predict ground-level ozone concentration in Erbil city monitoring station (2015 – 2016 as average).

$$Ln[O_3] = -840.895 + 0.398\text{year} + 0.049\text{Tempreture} - 0.001\text{Pressure} + 0.02\text{precpitation} - 1.089\text{CO} - 176.47 \dots\dots\dots\dots\dots\dots\dots (1)$$

Figures 14 and 15 show the measured and predicted ground-level ozone values according to the monthly average for 2015 and 2016.

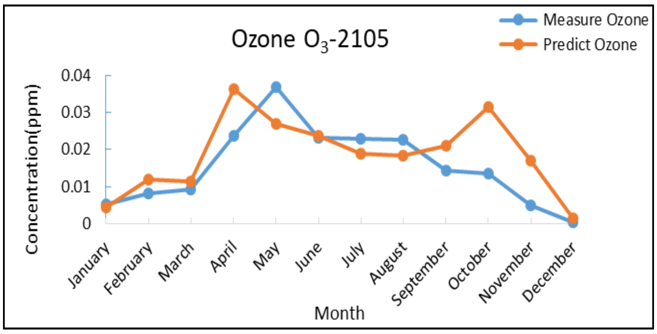


Figure 14: Predicted and measure values of ozone ground level according to monthly average in 2015.

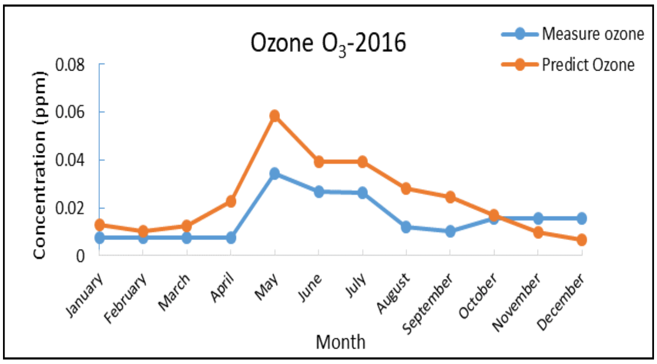


Figure 15: predicted and measure values of ozone ground level according to monthly average in 2016.

The discrepancies between estimated and measured values could be due to the predictors (independent variables) not being considered in this study. These are solar radiation and non-methane hydrocarbon, which was not variable in Board of Environmental Protection and Improvement, Erbil-government-office but R2 = 0.67 mean it depends on the variables that are shown in equation 1 to about 67% and on other variables that are not present in study to about

33% according to result in shows in Table 3.

3.2.2 Monthly hour Average for 2015 and 2106

Multi-collinearity can be noticed from Table 4, the tolerances with small values (e.g., 0.400 for humidity, 0.430 for temperature, and 0.428 for wind speed) show that a high percentage (e.g., 90.5% for NO2, 85.2% for pressure and 72.3% for CO) of the variance in a given predictor can be explained by other predictors. This indicates a great deal of multi-collinearity, and the regression coefficients' standard errors will be overstated. It is also general knowledge that a VIF of more than 3 is deemed problematic. The model below equation 2. can describe 57 % in the Ln [O3] variables.

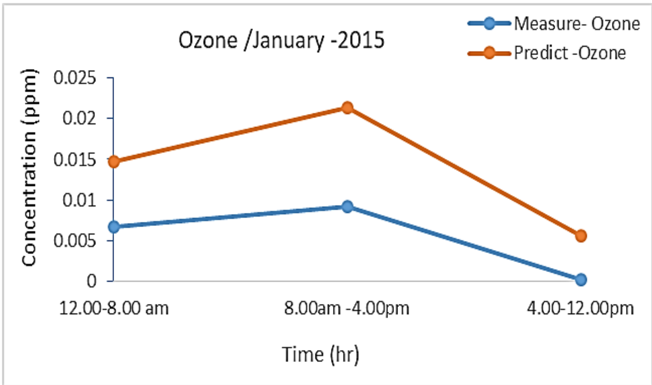
Table (4) Linear regression analysis for Erbil city monitoring station (Monthly hours average)

R^2= 0.570 R= 0.755		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	7.277	5.929		1.227	.224		
	year	-.005	.003	-.200	-2.015	.048	.705	1.419
	Temperature	.039	.012	.406	3.203	.002	.430	2.323
	pressure	-.001	.002	-.062	-.684	.496	.852	1.174
	Humidity	-.007	.007	-.139	-1.054	.296	.400	2.500
	WS	.190	.089	.273	2.148	.036	.428	2.334
	precipitation	.021	.023	.111	.907	.368	.461	2.171
	NO_2	-485.690	351.480	-.121	-1.382	.172	.905	1.105
	CO	-.403	.196	-.201	-2.053	.044	.723	1.383
	SO_2	-9.412	13.502	-.079	-.697	.488	.537	1.861

Equation (2) can be used to predict ground-level ozone concentration during (2015 – 2016 as monthly hours average) in Erbil city monitoring station.

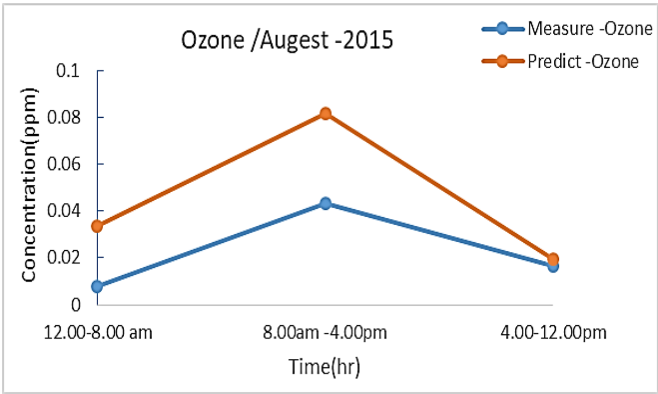
$$\begin{aligned}\mathrm{Ln}[O_3] &= 7.277 + 0.039\mathrm{Temperture} \\ &- 0.001\mathrm{Pressure} - 0.007\mathrm{Humidity} \\ &+ 0.190\mathrm{Wind\ Spee} + 0.021\mathrm{Precipitation} \\ &- 485.690\mathrm{NO2} - 0.403\mathrm{CO} - 9.412\mathrm{SO2} \\ &- 0.005\mathrm{year} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)\end{aligned}$$

Figure 16 (a, b, c) and 17 (a, b) show the predicted and measured values of ground-level ozone according to monthly hours average for 2015 and

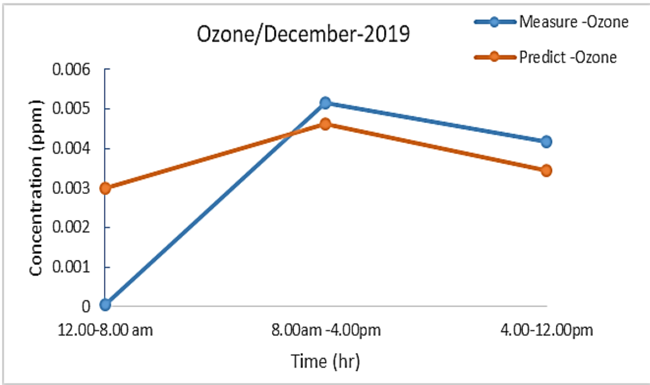


2016.

(a)

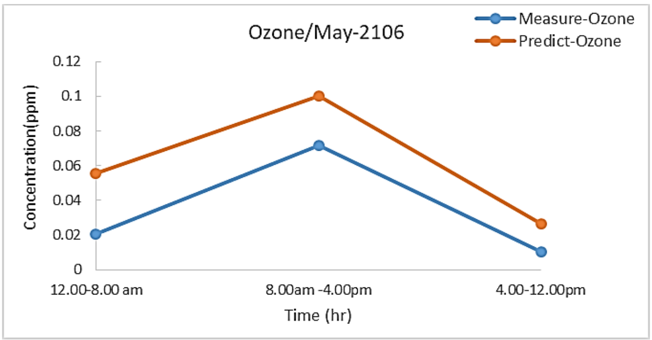


(b)

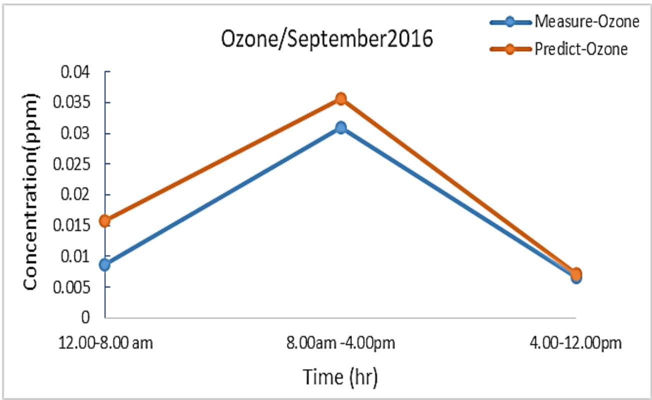


(c)

Figure16(a,b,c): predicted and measure values of ground level according to monthly hour average in January , August and December- 2015



(a)



(b)

Figure 17 (a,b) :predicted and measure values of ground level according to monthly hour average in May and September -2016

4.CONCLUSIONS

The study analyzed the data obtained from the BEPI about the air pollutants such as (CO, NO, NO_2, O_3, and SO_2) with support of statistical analyzing .

- It can be noted that the ground-level ozone concentration increased after 12 PM in all months, and the highest concentration was recorded in October/2016. The other months it was within the allowable limit may be due to excessive use of diesel generators, traffic congestion. In addition, October is considered the beginning of working years for schools and universities.
- Carbon monoxide did not exceed the allowable limit in all the years, but we can note that the highest concentration was recorded between 8 AM to 11 AM and after 6.30 PM, maybe because of traffic congestion.
- Sulfur dioxide did not exceed the permissible limit of EPA; the highest concentration was recorded in 2016, and the lowest concentration was recorded from May to December 2018. Therefore, there is no increased concentration of Oxides of Nitrogen all the year used in this study.
- The best prediction equation that presents the ozone concentration dependence on predictors in Erbil city monitoring station for two years (2015 and 2016) uses multiple regression linear analysis $R^2 = 0.671$.

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