JULY 2015 M.Sc. THESIS IN CIVIL ENGINEERING OMER MOHAMMED TAHA

UNIVERSITY OF GAZIANTEP
GRADUATE SCHOOL OF
NATURAL AND APPLIED SCIENCES

EVALUATION OF AIR POLLUTION ON DUHOK CITY ROAD NETWORK

M.Sc. THESIS
IN
CIVIL ENGINEERING

BY
OMER MOHAMMED TAHA
JULY 2015

Evaluation of Air Pollution on Duhok city Road Network

M.Sc. Thesis

in

Civil Engineering

University of Gaziantep

Supervisor:

Assist. Prof. Dr. Yusuf Kağan DEMIR

By

Omer Mohammed TAHA

15th July 2015

REPUBLIC OF TURKEY
UNIVERSITY OF GAZIANTEP
GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES
CIVIL ENGINEERING DEPARTMENT

Name of the thesis: TheEvaluation of Air Pollution on Duhok city Road Network

Name of the student: Omer Mohammed TAHA

Exam date: 15. 07. 2015

Approval of the Graduate School of Natural and Applied Sciences.

Prof. Dr. Metin BEDİR
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Mustafa GÜNAL
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope of quality as a thesis for the degree of Master of Science.

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by this rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

EVALUATION OF AIR POLLUTION ON DUHOK CITY ROAD NETWORK

TAHA, Omer Mohammed

M.Sc. in Civil Engineering

Supervisor: Assist. Prof. Dr. Yusuf Kağan DEMIR

15th July 2015, 110 pages

Abstract

In this study, air pollution problem in Dohuk City is discussed in detail in order to evaluate the main factors concerning the problem, and how to control them. Data required implementing this study including two main parts. The first part of the data collected is concerning the socio-economic characteristics of the Dohuk City Society living within a geographical area including 43 traffic analysis zones. Travel data was collected using a special questionnaire form. The second part of the data compile by the author of this study is air pollution measurements using a special instrument called WSAP-D_4 Gas Analyzer. Four types of hazardous gases were collected, which are Carbon Monoxide CO, Nitrogen Monoxide NO, Nitrogen Dioxide NO_2, and Sulphur Dioxide SO_2. Different socio-economic parameters such as, trips by private cars and taxi, trips by public transit and min bus, car-ownership four levels are considered in this study as zero, one car, two cars, and more than two cars owned levels are considered in the analysis. Step-wise Multiple Linear Regression Technique is followed in this study to correlate the socio-economic parameters with air pollution measured data as dependent parameters. Correlation of the four classes of toxic gases with the different social-economic parameters produced twenty step-wise type empirical models. It is concluded that, air pollution concentrations with the different four gases introduced in this study are going to reduce with using public transit as a cheap mode of transport, but increase with using private cars and taxi, car ownership, income level increase, and total trips number. Results for this topic revealed that, all the four gases are going to be less in concentration than average values from mid-day up to mid-night time without passing the maximum recommended levels. Key Words, Dohuk City, Air Pollution, step-wise regression

ÖZET

Duhok Kentine Ait Yol Ağında Hava Kirliliğin Değerlendirilmesi

TAHA, Omer Mohammed

Yüksek Lisans Tezi, İnşaat Mühendisliği Bölümü

Tez Yöneticisileri: Assist. Prof. Dr. Yusuf Kağan DEMIR

15 Temmuz 2015, 110 sayfa

Bu çalışmada Duhok Kentindeki hava kirliliği problemi ele alınmış ve kirliliği etkileyen değişkenler belirlenerek kirliliğin nasıl kontrol edilebileceği incelenmiştir. Çalışmayı gerçekleştirmek için ihtiyaç duyulan veri toplama süreci iki ayrı bölümden oluşmaktadır. İlk bölüm, 43 trafik bölgesine ayrılan Duhok kentine yaşayan toplulukların sosyo-ekonomik yapısına ilişkin veri çalışmasını içermektedir. Veriler bu amaçla hazırlanan özel bir anket formu yardımıyla toplanmıştır. İkinci bölümde, WSAP-D_4 gaz analiz cihazı kullanarak hava kirliliği ölçümleri gerçekleştirilmiştir. Bu ölçümlerde zararlı olduğu bilinen, Karbon-monoksit (CO), Nitrojen-monoksit (NO), Nitrojen-dioksit (NO_2), ve Sülfur-dioksit (SO_2) yoğunlukları ölçülmüştür. Özel otomobille ve taksi ile yapılan yolculuklar, toplu taşıma ve minibus ile yapılan yolculuklar ve dörtten fazla olan araba sahiplikleri gibi farklı sosyo ekonomik değişkenler modele sokulmamıştır. Ancak bir, iki ve daha fazla olan araba sahiplikleri çözümlemeye katılmıştır. Sosyo ekonomik değişkenlerle, kirlilik değerlerini ilişkilendirmek için adımsal regresyon tekniği kullanılmıştır. Dört farklı gaz yoğunluğunun farklı sosyo-ekonomik değişkenlerle ilişkilendirmek için 20 farklı model üretilmiştir. Bu modellemeler sonucunda toplu taşımanın hava kirliliğini azaltmasına karşın, özel otomobil ve taksi kullanımının, araba sahipliği sayısının, gelir seviyesindeki yükselmenin ve yolculuk sayısının kirliliği arttırdığı sonucuna varılmıştır. Ayrıca çalışma sonucunda zararlı dört gazın yoğunluğunun en yüksek olduğu öğlen ile geceyarısı arasında standarlarda belirlenen maksimum yoğunlukları geçmediği görülmüştür.

Anahtar kelimeler: Duhok Kenti, hava kirliliği, adımsal regresyon,

To my Father's soul,

My kind Mother,

My dear Wife for her support and encouragement,

My lovely Kids.

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In the name of ALLAH the most Merciful and Beneficent

The author wishes to express his deepest gratitude to his supervisors Assist. Prof. Dr. Yusuf K. DEMIR for their guidance, advice, criticism, encouragements and insight throughout the research.

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LIST OF CONTENT

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF SYMBOLS/ABREVIATIONS

ANOVA	Analysis of Variance Table
CBD	Central Business District
LISA	Local Indicator Spatial Association Method
GIS	Geographic Information System
F	Fisher Statistical Parameter
PHF	Peak Hour Factor
A.M	Morning Time Period
P.M.	Evening Time Period
R	Correlation Coefficient
Oxidation	Reaction of oxygen with material surface if temperature and pressure required are provided.
Reaction	Chemical change in the material composition of the material surface.
t	Student t-Test Parameter
γ	Level of Significance usually considered 5% for Significance Testing of Best Fit Models
VOCs	Volatile Oxidation Compounds
Environmental Deterioration	It is the corrosion and decay of material surface due to chemical reactions.
STD	Standard Deviation or difference of a Certain Value from the Mean.

CHAPETR 1

INTRODUCTION

1.1 General

Most of the people associated with air pollution are highly from visible sources, such as industries with tall stacks. This may include power plants, smelters, refineries, steel plants, pulp and paper plants, manufacturing plants and incinerators. The types of air pollutants released depend on the types of processes taking place at the plant. Industrial emissions aren't the only source of air pollution. Vehicle exhaust contains a number of gaseous and particulate pollutants including carbon monoxide, nitrogen oxides, particulate matter and unburned hydrocarbons. This emission source includes personal, as well as commercial vehicles (i.e., trucks, construction and agricultural equipment). The primary sources of residential air pollution including home heating, use of fuel-powered household tools (i.e., lawnmowers and snow blowers), recreational vehicles (i.e., snowmobiles and all-terrain vehicles), campfires, open burning of yard waste, and consumer products (i.e., cleaning products, paints and inks). Agricultural operations also release air pollutants, mainly in the form of particulates from wind-blown dust, as well as ammonia from livestock and fertilizers. Unpaved roads are a major source of wind-blown dust in rural areas. Air pollutants can be carried out by wind for long distances and may have effects in areas far away from their original release location.

Air pollution also comes from the following natural sources:

• Biological decay and food consumption by animal.

• Forest fires from wild area fire release carbon monoxide and Smoke.

• Vegetation that produces huge amounts of VOCs on warm days which react with primary anthropogenic pollutants such as NOx and anthropogenic organic carbon compounds producing secondary pollutants. This process of vegetation results ozone levels up to eight times higher than the low-impact tree species.

• Radioactive decay from the natural decay of radium resulting radon gas that causes lung cancer and considered as a health hazard;

• Volcanoes ash particulates are a natural source of volcanic activity as well as sulphur and chlorine.

• Dust storms which forms in open areas with few or no vegetation.

• Others Fumes, varnish, paint, aerosol sprays, hair spray and other solvents.

Figure 1.1 is showing some of the main origins of polluters in the nature starting from mobile exhaust system (2013) [1].

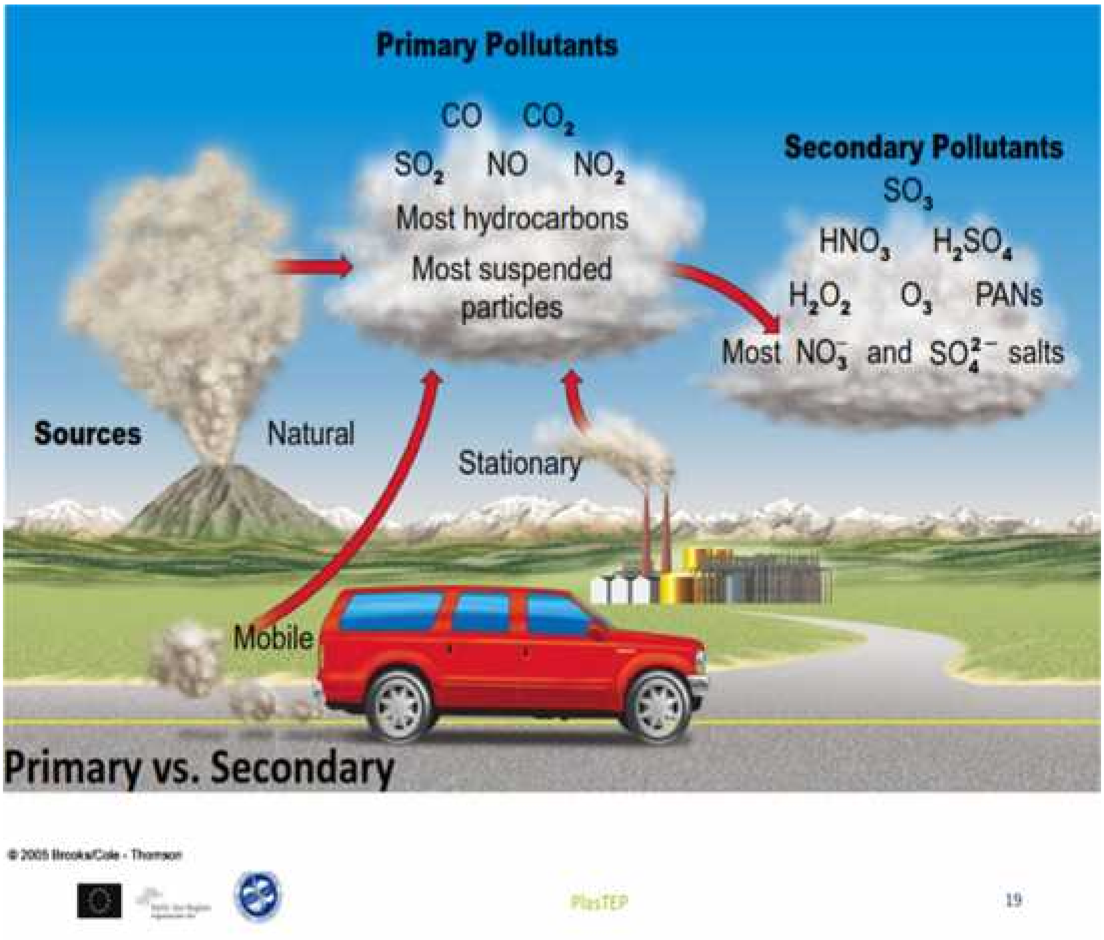


Figure 1.1 Natural Sources of Main Polluters Threatening Citizens Life (2013) [1]

1.2 Problem Definition

Population increase and their high intent to own cars are the main causes of generating more traffic demand on the urban road networks and then more effluents from mobile as a source. Nowadays, Duhok City is dealing with an explosive growth in the car ownership and the personal utilization of his/or her car to execute trips is enormous as shown in Figure 1.2. The population total number is less than double during the last fourteen years in the Duhok City CBD and sub-urban areas composed of 43 citizen districts as given from the Duhok City Census Directorate(2014) [1]

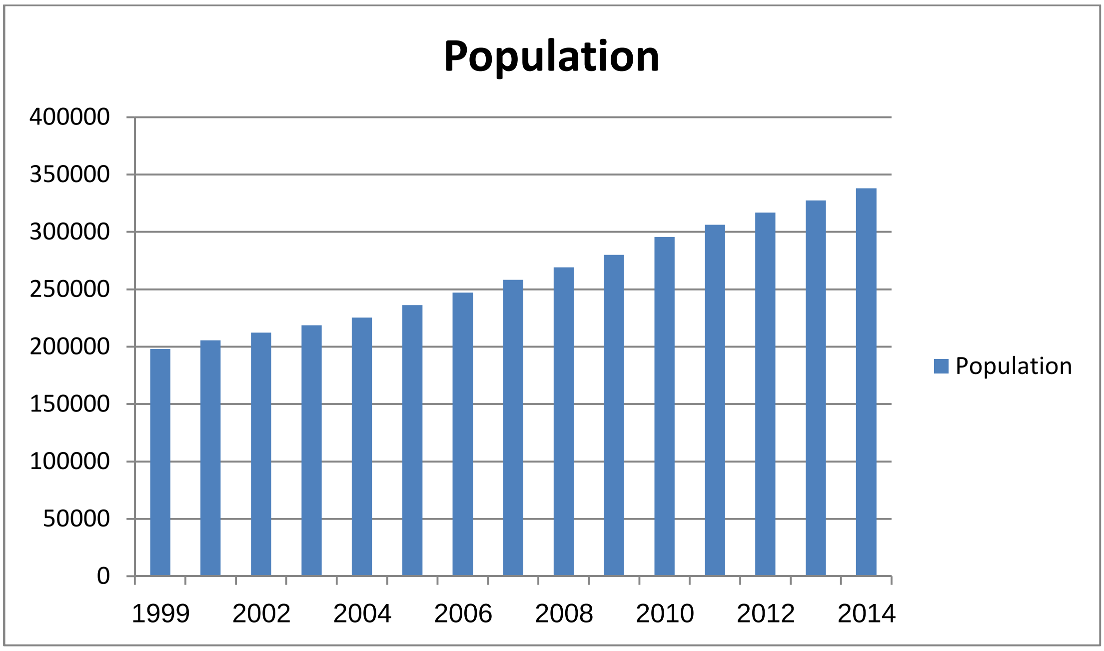


Figure 1.2 Duhok City Centre Population Growths during (2010-2014) (2014) [2]

Preferences in using the private cars increased the travel demand which caused rapid motorization in many countries around the world. Now, most people are highly dependent on the private car travel as a part of their freedom. This phenomenon was caused mainly due to the attractiveness of car and people like to drive privately. New roads are generating faster traffic and longer trips. More trips by car and higher vehicles-miles of travel led to more traffic congestion and caused the longer travel time and traffic delays, high fuel consumption of non-renewable energy resource and pollution. In addition to congestion, private motorization is also affecting the safety of the vulnerable road users, high consumption of fuel, and caused serious threats to the quality of human environment. Figure 1.3 is showing the high increase in car ownership in Duhok City as given by the Directorate of Traffic Police (2014) [3].

Public transport is an important solution to alleviate this problem. To minimize many problems caused by increasing motorization, it is highly recommended by the decision makers as well as many researchers to provide an attractive public transport service as an alternative transport mean because, the public transportation reduces energy toxic effluent emissions, and provide efficient movement to children and handicapped road users. Public transit is usually known as low effluents producer and relatively economic in travel cost amount.

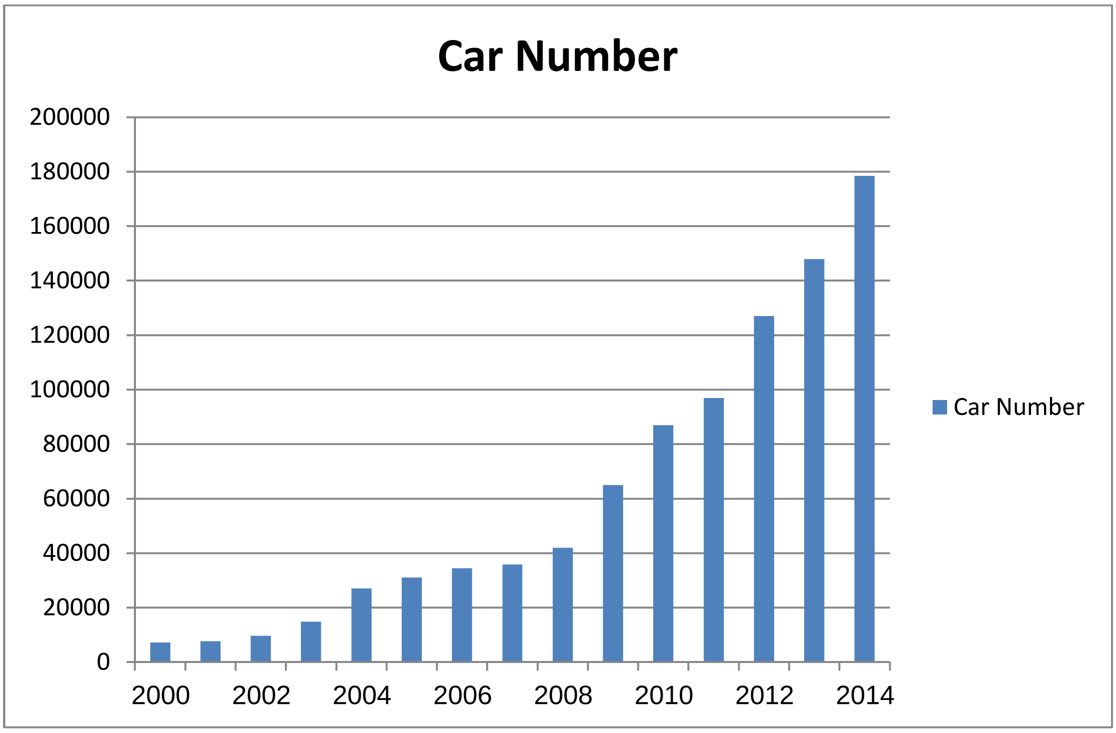


Figure 1.3 Number of Cars Owned by the People in Duhok City during the Period (2000-2014) (2014) [2].

1.3 Purpose of the Study

In order to perform an air pollution evaluation study in a highly congested popular and traffic city like Duhok considered in Iraq and all other relative countries as a very beautiful and tourist attractive city in order mainly to give instructions of how to improve the general climate and living environment in it. The main purposes the author thinks that it should be satisfied from this study are:

-To compare maximum limits of the concentrations of each gas with the recommended level by the Iraqi Ministry of Environment.

-To take opinion about the time period during a certain day when the gas concentration is going to increase and/or decrease.

-Monthly variation of the different gas type emissions when and where within Duhok City urban area.

-Using GIS technique for comparison of the concentration of different toxic gases, and to test the efficiency of this technique in the presentation of air pollution collected data.

-To study air pollution of different gases along Kurdistan Arterial Road which is the major road in Duhok City, and how toxic gas production from traffic is going to vary?

-Time distribution of the concentration of different toxic gases on and along this road; which one of the measured gases is going to be generated more along Barzan Arterial Road, when, and where.

-Travel count on the income level of each household by performing a large scale Home Interview Survey.

-Classification of household trips by mode of travel to know how much air pollution produced daily as emissions from each of the 43 traffic zones to which the city is now divided.

-To estimate the emissions level of each one of the toxic gases known to be produced from mobile exhaust gases, and compare the different city traffic zones using the air pollution measurements compared with the maximum recommended limit given by local standards.

-To study the effect of socio-economic characteristics, like public and private trips, income, and car-ownership on the phenomenon of producing air pollution and four types of popular hazardous gases like CO, NO, NO2, and SO2 found in Duhok City, in order to put solutions to improve climate.

-Preparation of different empirical step-wise linear models to predict and update amounts of air pollution of each one of the four gases mentioned above.

-The study is the up-to-date trail in the Duhok City to perform such measurements related to air pollution.

1.4 Structure of the Study

The main chapters the study is designed to satisfy related to the different topics of the air pollution effect on climate as a new application in the Transportation Engineering in the Third World Nations like what is going on in USA and Europe:

Chapter One: is dealing with discussing the introduction of air pollution tragedy to public societies, and the main size of the air pollution problem in Duhok City as an example problem in Kurdistan Region. The main objectives of the study are given too in this chapter.

Chapter Two: is related to inform readers with the up-to-date studied conducted in the topic of air pollution and the effect of the different factors in a group of worldwide countries, and they are going to deal with the air pollution problem which threatening the quality of life in most of the developed and developing countries, with some tables and figures showing the national standards of the air pollution acceptable levels to be applied in order to control the climate in Duhok City whether is it acceptable or not from health point of view.

Chapter Three: is a chapter usually dealing with discussing and describing the methodology of executing the different stages of the study and how they are going to be related with each other. The application of the different technical tools such as the GIS and other types of software helping in giving very detailed analysis.

Chapter Four: is including the long process of analysis and evaluation of the different phases of the thesis using different statistical packages of data presentation and processing to describe results. Result analysis is usually guiding the author to make his main conclusions from which to draw out real improvements to the system. Chapter four will include the empirical models drawn from the SPSS package coming from conservative data analysis and what are the powerful factors increasing or decreasing the air pollution of different types of gases. GIS maps are given in this chapter just to show the capacity of the GIS tool to give the points of high air pollution, and their locations that people should stay far from during the seasons of high temperatures.

Chapter Five: is including the main conclusions will be drawn out of the results obtained in chapter four to the final outcome of the research problem. Recommendations for further research will be taken out for the points not possible to be executed in the thesis.

The study will include appendices and further tables to store the additional results usually repeated or not in use for the different stages of the analysis of the thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Air pollution is defined as the presence of one or more contaminants in the atmosphere such as dust, fumes gas mist, odors, smoke or vapor in quantities, of characteristics and of duration. Such as to be injurious to human, plant animal life or to property or which unreasonably interfaces with the comfortable enjoyment of life and property.

Air pollution problem is the disadvantage of any transportation movement or activities executed by inhibitors or citizens in the society. Effluents generated from the internal combustion engines bushing different traffic vehicles forward are the main generators of this air pollution. In most of the cities around the world, population sprawl and the corresponding explosion in the increase of the number of traffic vehicles, especially passenger cars and taxi are going to produce their effluents containing toxic gases, such as Cox, , H2s, NOx...etc., which were found very harmful to the human being health. In addition, particulate materials containing very fine materials generated due to dust, brake linings corrosions….etc. are more severe than toxic gases as it mostly contains poisonous materials like lead, and carbon.

2.2 Transportation Air Pollution and Public Health

Air pollution health concern is the main problem most of the research workers going to write reports and scientific papers about as it threatening the human being living on the surface of the earth.

Paul W., (1996) [4] gave the main types of gases, and particulate matter emitted from the different transport facilities. These materials are generally natural or man-made contaminants in the atmosphere. They may be classified into five major categories:

1-Carbon monoxide (CO),

2-Hydrocarbons (HC), and photochemical oxidants,

3-Nitrogen oxides (NOx),

4-Particulate matter (1-10) µm in size, and

5-Sulfur dioxide (Sox).

Factors that influence deterioration are temperature; moisture, sunlight, and position of the exposed material are among the important factors that affect the rate of deterioration. Moisture is the source of any deterioration mechanism to occur.

Higher air temperature increases the reaction rates. Cooling of the surfaces to a point may condense moisture and increases deterioration rates (2005) [5].

In addition to the oxidation of the ultraviolet wave lengths, sunlight simulates air pollution damage by providing energy for pollutant formation and cyclic reformation. The cracking of rubber and the fading of dyes have been attributed to ozone produced by these photo-chemical reactions. The position of the exposed surface influences the rate of deterioration in two ways;

Whether the surface is vertical or horizontal or at some angle affects deposition and wash-off rates; and
Whether the surface is an upper or lower one may alter the rate of damage.

Solubilization and oxidation-reduction reactions typify direct chemical attack. Frequently, water must be present as a medium for these reactions to take place. Sulfur dioxide and SO_3 in the presence of water react with limestone ($CACO_3$) and gypsum ($CaSO_4.2H_2O$). Both $CaSO_4$ and $CaSO_4.2H_2O$ are more soluble in water than $CaSO_4$, and both are leached away when it rains. The tarnishing of silver by H_2S is a classic example of an oxidation-reduction reaction.

Carbon dioxide (CO_2) is a greenhouse gas that traps the earth’s heat and contributes to climate change (Mann M.E., et al, 1999) [6]. Global climate change has become a serious problem in the world nowadays. Reports show that the anthropogenic carbon emissions and atmospheric CO2 are the most significant of the greenhouse gases causing global warming.

Kusuma, M.R.(1999) [7], in his research developed a heuristic transportation-air quality study especially designed to achieve understanding of how congestion mitigation strategies applied to different types of land use developments, defined by transportation system characteristics, affect the improvement of emission-related air quality in the area. Land use developments are defined by four transportation system characteristics: land use type, land use density, traffic signal density, and through traffic volumes.

Jire.R. and others (2005) [8], examined the potential associations between exposure to episode of air pollution and alterations in semen quality. The air pollution, resulting from combustion of coal for industry and home heating in the Teplice District of the Czech Republic, was much higher during winter than at the other times of year with peaks exceeding US air quality standards of the tests conducted on adult persons. Routine semen analysis on male sperms during two classified periods as low and high exposure from ambient air pollution monitoring. Results from repeated measure analysis show a significant association between exposure to periods of high air pollution (i.e., at or above the US standards air quality limits), and the percentage of sperm with DNA fragmentation according to sperm chromatin structure assay (SCSA). The study concluded that, exposure to air pollution to a long period of time may damage the sperm DNA structure and thereby the rates of male-mediated infertility, miscarriage, and other adverse reproduction outcomes.

Gordon C., and Barry P.,(2008) [9], described the poor air quality in Britain that has negative effects on our health, our environment and our economy health effects include eye and throat irritation, breathing difficulties, and the aggravation of existing heart and lung conditions. Air pollution can also lead to people taking more medications, visiting their doctor or emergency room more often, being admitted to hospital more often, or even dying prematurely. For example, according to the provincial Health Officer, outdoor air pollution contributes to as many as 250 premature deaths was province every year and increases health care costs by an estimated as $85 million.

Impacts on the environment range from smog in the air, to damaged plant tissues to the transfer of pollutants from the air to land and water. Economic impacts include potential losses in sectors such as tourism and agriculture. Poor air quality can also limit opportunities for economic growth.

Outdoor air pollution has a number of components that vary in intensity according to their sources. They include sulphur dioxide, a gas produced from fossil, fuel combustion and natural sources such as volcanoes; volatile organic compound and nitrogen oxides, produced by combustion processes such as those in engines and furnaces. Both sulphur dioxide and nitrogen oxides can lead to acid rain. Nitrogen oxides and volatile organic compounds can also lead to production of ground-level ozone, one of the main ingredients in smog – and one of the worst offenders in terms of its impact on human and environmental health.

Aliakbar K., Ali V., and , Ahmed K., (2012) [2]**,** conducted a study about the measuring of the amount of CO_2 greenhouse gas in Tehran as it represents the most popular gas emitted from different types of vehicles using different types of roads in Iran. A case survey had been conducted to measure CO_2 in four popular vehicles, which moved in the city with 78,000 buses, 82,358 taxis, 560,000 motorcycles and 2.4 million private cars per day in 2012. Results indicated that the contribution of CO_2 emissions increased in the following order: private car, motorcycle, bus and taxi. It was needed also to have the average run in kilometer to calculate the total fuel consumption (liter) and the total CO2 emission (E_M). Other required data such as specific gravity, calorific power, and emission factor of both diesel and petrol are also needed to calculate the amount of CO2 emission in the atmosphere. Briefly, the model is specified as follows:

$F_C = A_C \times V \times R_D$ ……… (2.1)

Where:

F_C = fuel consumption (diesel or petrol) (L)

A_C = Average fuel consumption by each type of vehicle per kilometer (L/km)

V = Number of each type of vehicle

R_D = Amount of running per day by the vehicle (km)

$EM (CO_2) = F_C \times SG_F \times CP_F \times EF_F$ ……………… (2.2) Where

$EM (CO_2)$ = amount emitted material of CO2 gas

SG_F = Specific gravity of the used fuel (kg/m^3)

CP_F = Calorific power of the fuel (kcal/kg)

EF_F = Emission factor of the fuel (tco2/TJ)

In the estimate, the vehicles running on CNG (i.e., compressed natural gas) and other types of fuel are not taken into account.

Todd L., (2010) [11] stated that, travel activity affects public health in several ways. Figure (2-1) indicates ways that travel activity affects the ten leading causes of Potential Years of Life Lost (PYLL) which takes into account age of death and therefore reflects the greater costs to society of risks to younger people). For example, pollution contributes to cancer and congenital anomalies (birth defects), and sedentary living (i.e., inadequate physical activity) contributes to heart disease and strokes. Transport activity is the affects five of these health risks, including the three largest, which cause more than 60% of total potential years of life lost.

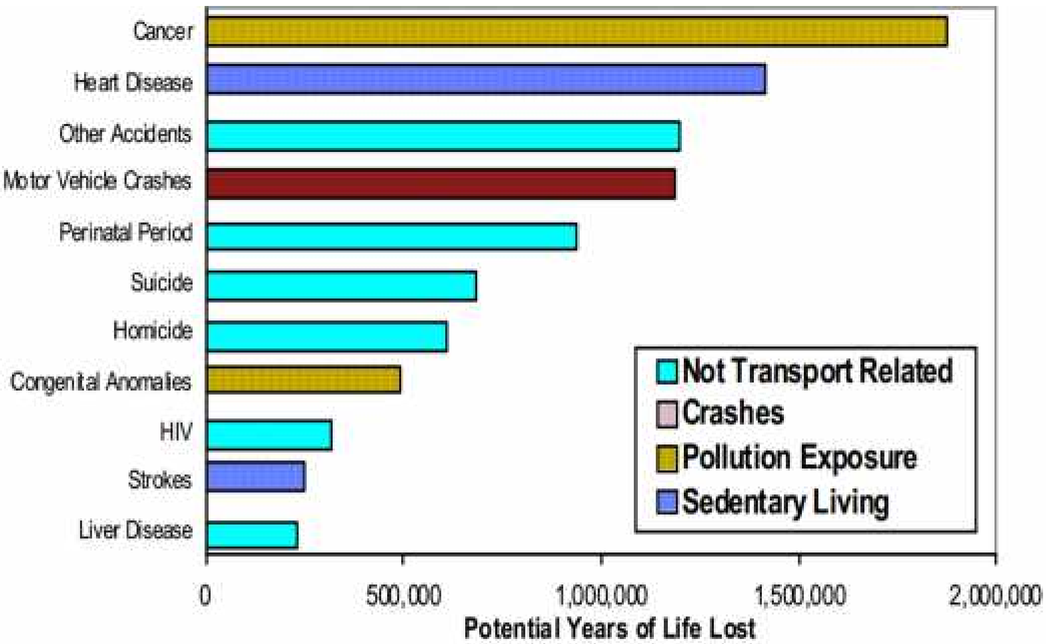


Figure 2. 1 Ten Leading Causes of Potential Years of Life Lost by Air Pollution (2010) [11]

Steve B., (2000) [12] listed the most comprehensive study of urban toxic air pollution ever undertaken which produced by motor vehicles and other mobile sources of air pollution are the predominant source of cancer-causing air pollutants in Southern California. Overall, the study showed that motor vehicles and other mobile sources accounted for about 90 percent of the cancer risk from toxic air pollution, most of which was from diesel soot (i.e.,70 percent of the cancer risk). Industries do not need to be a public health official to know that it is dangerous to breathe diesel exhaust. Highway Health Hazards to other stationary sources accounted for the remaining 10 percent. The study showed that the highest risk is in urban areas where there is heavy traffic and high concentrations of population and industry.

Roya K., and Parinaz P., (2013) [13], defined Chronic non-communicable diseases (NCDs) are as an emerging global epidemic. A growing evidence data base suggests that the adverse effects of early life exposure to air pollutants may predispose individuals to increased risk of chronic diseases in later years. The increasing incidence of NCDs does match the rapid rise in urbanization, and in turn the rise in air pollution. Studying the effects of environmental factors on the early stages of health disorders can aid future studies and may offer strategies for primary prevention of (NCDs). A growing body of evidence supports the role of vitamin D deficiency on (NCDs) such as cardiovascular diseases, type-2 diabetes, and metabolic syndrome, as well as on their risk factors for obesity dyslipidemia, insulin resistance, and high blood pressure.

Farias.F, and ApSimon, H. (2006) [14], studied the temporal and spatial contributions to NOx concentrations from aircraft and traffic around Heathrow Airport in West London. Their analysis showed that in the areas where people are exposed to air pollution, the impact of traffic emissions was larger than that of aircraft emissions.

2.3 Traffic Air Pollution International Standards

Legislation to limit exhaust pollutants emissions has been in force in U.S.A, Western Europe and other countries for a number of years and furthermore restrictive, limitations were proposed for the future (Case, D.J., 1982) [15].

Legislation on air pollution generally was introduced in 1955 in the USA, and for motor vehicles is now concerned both with standards for the desirable purity of air and with permissible levels of pollutants from exhausts. However, UK legislation has been concerned mainly with the control of visible emissions with the exceptions of legislation on the lead content of petrol.

Al-Omari, B.**,** (1997) [16] stated that, there are two main USA laws issued in the current decade and significantly affected the relationship between the transportation sector and the environment: the Clean Air Act Amendments (CAAA) of 1990 and the International Surface Transportation Efficiency Act (ISTEA) of 1991.

EED, (2005) [17] presented that the National Air Quality Standards (NAADS), was proposed the following air pollution standard values for ambient air temperature for outdoor air that normally surrounds us. These criteria shown in Table (2-1) called criteria pollutants because they were developed on health-based criteria. The primary standard was established to protect human health with "adequate margin of safety" The secondary standards are intended to prevent environmental and property damage. The standard for hydrocarbons was dropped and the standard for Total Suspended Particulate (TSP) was replaced with a particulate standard based on the mass with an aerodynamic diameter less than or equal to 10µm. This standard is referred to as the PM_{10} standard. In 1997 a new $PM_{2.5}$ standard was added. States are divided into air quality control regions (AQRs). An AQR that has air quality equal to or better than the primary standard was called an attainment area. Those areas that didn't meet the primary standard were called nonattainment areas**.**

Lenner M., et al., (1987) [18] in Sweden, showed that, NOx emissions from passenger cars made after 1976 were maximized not distinguish between NO, and NO_2. Accordingly, with few exceptions, NO_x emissions from cars are registered as NO_x totals during some specified driving cycle, and with no distinction between the relative amounts of NO and NO_X.

Table 2.1 National Ambient Air Quality Standards (NAAQS) (2005) [17]

Criteria Pollutant	Standard Type	Concentration ($\mu g.m^{-3}$)	(ppm)	Average Period Or Method	Allowable Exceedances
CO	Primary	10,000	9	8-hour average	Once per year
	Primary	40,000	35	1-hour average	
Lead	Primary and secondary	1.5		Maximum arithmetic mean measured over a calendar quarter	
NO_2	Primary and secondary	100	0,053	Annual arithmetic mean	
Ozone	Primary and secondary	235	0.12	Maximum hourly average	Once per year
Ozone[b]	Primary and secondary	157	0.08	8-hr average	C
Particulate matter (PM10)[d]	Primary and secondary	150		24-hr average	One day per Year
	Primary and secondary	50		Annual arithmetic mean	
$(PM_{2.5})$[b]	Primary and secondary	65		24-hr average	One day per Year
		15		Annual arithmetic mean	
SO_2	Primary	80	0.03	Annual arithmetic mean	
	Primary	365	0.14	Maximum 24-hr concentration	Once per year
SO_2	Secondary	1300	0.5	Maximum 3-hr concentration	Once per year

[a]Allowable exceedances may actually be an average over a multiyear period.

[b]Proposed by EPA July 1997.

[c]Average fourth highest concentration over 3-year period.

[d]Particulate matter standard applies to particulate with an aerodynamic diameter ≤10μm.

AL-Ani M., (1997) [19] most of Iraqi large cities such as Baghdad suffering from high NOX concentrations which was near 0.19 ppm , and the allowable concentration is 0.05 ppm only.

Table 2.2 Standards for Smoke Intensity (1988) [20]

Country	Allowable Capacity
USA	20%
Japan	50%
Italy	65%
Hong Kong	60%
Jordan	65%

Matzoros, A., (1988[20]) currently measured the lead content of patrol fuel sold in the UK and other EEC countries are 0.15 g/liter, and EEC. Tables 2.2, up to 2.7, give the standards used in different countries for different pollutants.

Table 2.3 Air Quality Standards in the USA (1988) [20]

Pollutant	Type of Standard	Averaging Time	Frequency Parameter	Concentrations	
				μg/m^3	ppm
CO	P,S P,S	1hr 8hr	1yr-max 1yr-max	40,000 10,000	35 9
NO_X	P,S P,S	1yr	Mean	100	0.05
O_3	P,S	1hr	Exc1	235	0.12
Pb	P,S	3months	Mean	1.5	
SO_3	P	24hr 1yr 3hr	1yr-max Mean 1yr-max	365 80 1300	0.14 0.03 0.5
TSR	P,S P,S	24hr 1yr	1yr-max mean	150 50	

Table 2.4 Air Pollution Criteria and Standards of Canada, USA, and WHO (1988) [20]

Pollutant	Canadian*	USA	WHO**
SO_2			
Annual	23 pphm	3.0pphm	(15.2-3)pphm
24hrs	11pphm	13.9pphm	4.7pphm
1hr	34ppm	49.7pphm	13.4pphm
98^{th} percentile			(3.8-5.7)pphm
CO			
8hrs	13ppm	9ppm	9ppm
1hr	31ppm	35ppm	26ppm
NO_2			
Annual	5.3pphm	5.3pphm	
24hrs	11pphm		7.9pphm
1hrs	21pphm		21pphm
TSP			
Annual	70 ($\mu g.m^{-3}$)	75 ($\mu g.m^{-3}$) ***	(60-90) ($\mu g.m^{-3}$)
24hrs	120($\mu g.m^{-3}$)	260 ($\mu g.m^{-3}$)	120 ($\mu g.m^{-3}$)
98^{th}percentile			(150-230) ($\mu g.m^{-3}$)

*Maximum acceptable level, ** Proposed guidelines, *** Annual geometric average

Table 2.5 Standards for CO and HC Concentrations Emitted from Gasoline Vehicle (1988) [20]

Country	CO% Volume	HC ppm
USA	1.5	275
Sweden	0.5	100
India	3(4 wheel) 4.5(2&3 wheels)	
Singapore	4.5	800
Europe	(1.5-3.0)	(275-4100) depends on engine displacement
Jordan	4.5	750

Table 2.6 Air Quality Standards (1988) [20]

Pollutant	Standard Quantity	Exposure Time	Notes
			Not to be exceeded more than once a year
CO	9 ppm+	8 hr.	Not to be exceeded more than once a year
	35 ppm+	1 hr.	
	10 ppm+	8-24 hr.	Chosen to prevent carboxyhaemoglobin levels exceeding exceeding (2.5-3)% in non-smoking population
	13 ppm+	1-8 hr.	
	25 ppm+	0.5-1 hr.	
	50 ppm+	15-30 min	
	100 ppm+	15 min	Maximum permitted exposure even for very short period
NO2	0.05 ppm+	1 year	
	0.17 ppm+	1 hr.	Not to be exceeded more than once a month
	100 ppm+		
Pb	2μg/m3+	1 year	Not to be exceeded where people are continuously exposed for long periods

Pollutants produced by automobiles NO_x, hydrocarbons (HC_S) and CO are subjected to legislative control in the UK. To meet restrictions on the allowed emissions of these pollutants, car manufacturers have devised emissions control equipment of various kinds. One of the serious problems facing traffic engineers from the operations and planning standpoint is the requirement that certain standards for CO concentrations near streets and highways is particularly important for meeting these standards. From the planning viewpoint, the question was what the effect will be on air quality if land use near a traffic facility is changed in such a way as to increase the traffic burden on the facility.

Table 2.7 Air Quality Standards as Set by the EEC and WHO (1988) [20]

Pollutant	**Body**	**Averaging Time**	**Frequency Parameter**	**Concentrations µg/m3**
CO	WHO	1 hr.	(1)	40,000
		8 hr.	(1)	10,000
NO_X	EEC	≤ 1 hr.	1yr-98 Percentile	200 (2)
		≤ 1 hr.	1yr-50 Percentile	50(3)
		≤ 1 hr.	1yr-98 Percentile	135(3)
	WHO	1 hr.	1 month-max	320
O_3	WHO	1hr	1yr-max	200
Pb	EEC	24 hr.	1yr-mean	2
SO2	EEC(4)	24 hr.	1yr-50% max	80 TSP > 40
				120 TSP≤ 40
		24 hr.	50% (5)	130 TSP> 60
				180 TSP ≤60
		24 hr.	1yr-98 Percentile	250 TSP > 150
				350 TSP > 150
		24 hr.	1yr- 98 percentile	150
	WHO	1 yr.	mean	60
TSP	EEC	24 hr.	1 yr-50 percentile	80
		24 hr.	50 percentile(4)	130
		24 hr.	1yr-98 percentile	250

2.4 Methods of Measuring Air Pollution and Vehicle Emissions

Haibo C., Anil N., and Margaret B.(2008)[21], from the Leicester City Council (LCC), monitored air quality at roadside mainly using 10 RPMs and seven air quality monitoring stations (i.e. not at roadside). At other specific locations, regular monitoring is carried out for short-term periods of typically one month using a mobile van Leicester AURN site is located in a pedestrian piazza (i.e., an open space for pedestrian's use) between eight and eleven story council offices. It was situated approximately 30 m from a three lane one-way road, which was subjected to congestion at peak times. Sampling heights were typically within 2-3m .The AURN sites serve as important sources of information about field pollution concentrations and hence indirect estimation of exposure at these fixed locations. Although there were over 1500 sites across the UK which monitors air quality such coverage wasn't sufficient for the monitoring and modeling of street pollution. In Leicester, the local authority had installed 10 air quality units near the busy roads to measure the roadside pollution. Data from these units were used in this study. Firstly, the AURN site maintained and run by DEFRA (i.e., Department for Environment Food and Rural Affairs) measures levels of SO2, O_3, CO, PM10, and NOx. The Leicester AURN site was classified as an Urban Centre. The study area location is shown in Figure 2.2.

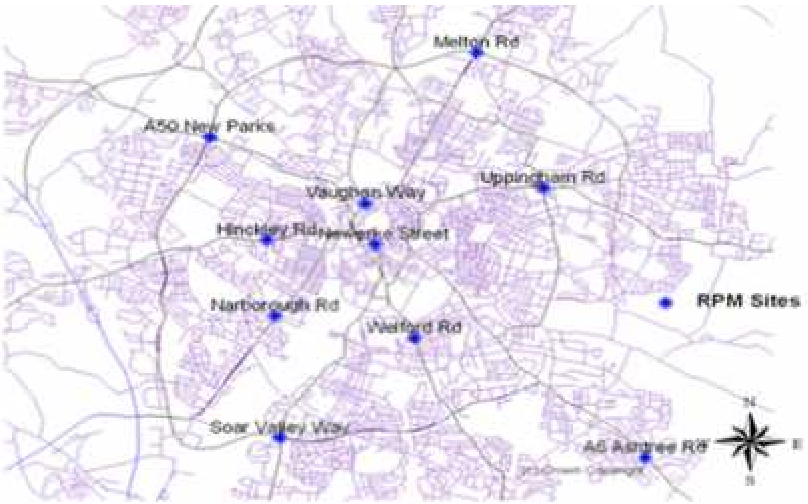


Figure 2.2 Location of Roadside Pollution Monitors (PRMs) in Leicester (Latitude: 52.38N, Longitude: 01.08W, Population, 280,000 inhabitants) (2008) [21].

One of the results in the previous study is showing how the average hourly PM_{10}, material is linearly correlating with the average hourly $PM_{2.5}$ material as shown in Figure 2.3 given below.

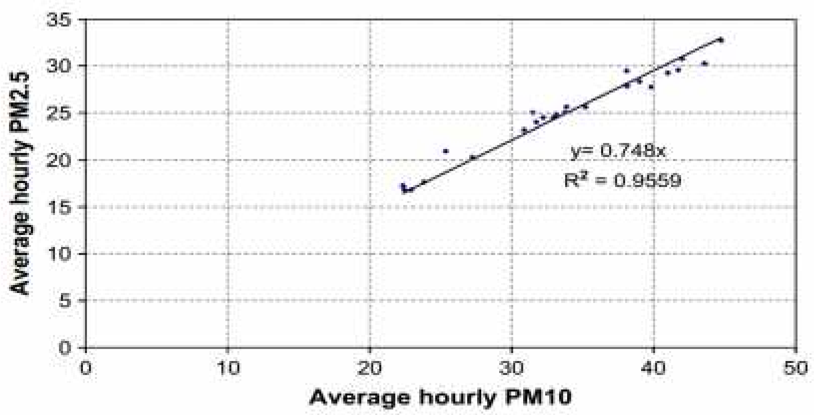


Figure 2.3 Average Hourly PM2.5 versus PM10 (2001, Marylebone Road, London) (2008) [21]

One of the studies about air pollution executed in France, in the Capital Paris, where more than 40million automobiles were using the road network in this country by ICI,AIR PARIF Institute to measure the different concentrations of the NO_2,and NO_X pollutants.

Figure 2.4 MEGATEC Instrument Used to Collect NO2, and NOX Air Pollution Data in Paris Capital Urban Road Network (2007) [22]

Figure (2-4), is showing the instrument used to measure the pollutant concentrations type (MEGATEC), from (Thermo Electron Communication) in France. Figure (2- 5) is showing the position of the main instrument used to collect the data from the surrounded traffic stream flowing behind the cabinet where the instrument is fixed with its piping connections (2007) [22]

Figure 2.5 Air Pollution Data Collection Cabinet with Piping Connections (2007) [22]

Figure (2-6) is showing how air pollution from vehicle exhaust is blacking and polluting the white glass tray used to collect the data from vehicle exhaust directly.

Figure 2.6 Pollution of White Testing Tray Cans due to Vehicle Exhaust Gases (2007) [22]

Velmurugan.S. et al., (2005) [23], studied the dis-advantages of air pollution in Chennai one of eight States in India, where traffic congestion is continuing to increase leading to environmental degradation. Traffic counting stations were chosen in such a way that the survey points cover most appropriately the entire length of the city road traffic interaction between the city and the outside selected mid world. Systematically planned classified traffic counts were carried at network blocks and intersections (i.e., traffic count stations) for 12- hour, 16- hour and 24- hour periods. To understand the level of service and operating characteristics, spot speeds were measured at mid blocks whereas journey speed and associated delays were also measured along the major road network of Chennai city. On the basis of classified traffic volumes, the quantity of criteria pollutants like Carbon Monoxide (CO), Oxides of Nitrogen (NOx), Hydro Carbons (HC) and have been estimated as per the category (inter-city and Particulate Matter (PM) travel in the city of Chennai. This was accomplished by using the intra-city) of emission factors and appropriate deterioration factors of different types of vehicles assess what was likely to be the contribution of the external used in India. Further, to by external traffic on city roads of Chennai traffic to air pollution, the travel made and corresponding pollution loads have been estimated. Thereafter, an attempt had been made to estimate the future classified traffic volumes (2010) and corresponding pollution loads for different options of automobile technology and fuel quality options. Figure 2.7 is showing the Chennai city road network where the study was implemented upon.

Figure 2.7 Road Network of Chennai Metropolitan Area, China (2005) [23]

The method used to estimate the air pollution loads is given below:

$E_i = \sum (Veh_j\ Dj)\ e_{ijkm}$………. (2.3) Where

Ei is the total estimated emission of each pollutant (expressed as gr./day or tons/day), Vehj, is the number of vehicles of type j, Dj is the distance travelled by vehicle type j, and ei is the emission factor of vehicle type i (expressed as gr./km). The estimated pollution loads using the above method (i.e., given in Eq.2.3) as per the category of travel (i.e., inter-city and intra-city) in the city is presented in Table 2.8.

Table 2.8 Estimated Loads of Pollutants as per Vehicle Type in Chennai as of (2002) (2005) [23].

Vehicle Type	Vehicle - kilometers *(in millions)*	Pollution Load in Tonnes Per Day			
		CO	NO_x	HC	PM
Cars	5.03 *(20.18%)*	26.60 *(15.03%)*	6.86 *(25.13%)*	4.31 *(4.51%)*	1.04 *(14.27%)*
Taxis	0.56 *(2.25%)*	3.01 *(1.7%)*	1.11 *(4.07%)*	0.22 *(0.23%)*	0.38 *(5.21%)*
Two Wheelers	13.45 *(53.95%)*	59.34 *(33.53%)*	2.26 *(8.28%)*	38.46 *(40.21%)*	1.61 *(22.09%)*
Autos	4.24 *(17.01%)*	76.94 *(43.47%)*	0.49 *(1.79%)*	50.82 *(53.14%)*	1.73 *(23.73%)*
Goods_Local	0.41 *(1.66%)*	1.45 *(0.82%)*	0.94 *(3.44%)*	0.14 *(0.14%)*	0.18 *(2.53%)*
Goods_Inter City	0.63 *(2.51%)*	6.45 *(3.64%)*	5.02 *(18.39%)*	0.80 *(0.84%)*	1.00 *(13.65%)*
Intra-City Bus	0.49 *(1.96%)*	2.54 *(1.44%)*	8.42 *(30.84%)*	0.71 *(0.74%)*	1.07 *(14.68%)*
Inter City Bus	0.12 *(0.49%)*	0.67 *(0.38%)*	2.20 *(8.06%)*	0.18 *(0.19%)*	0.28 *(3.84%)*
Total	24.93 *(100%)*	177.00 *(100%)*	27.30 *(100%)*	95.64 *(100%)*	7.29 *(100%)*

To achieve maximum efficiency in traffic operations, it was proposed to develop the major arterial road network of the city as express route system having grade separators and signal free environment as shown in Figure 2.8.

Figure 2.8 Road Network Identified for Upgrading to Expressway System in Chennai, China (2005) [23]

Devarakonda S., el al., (2007) [24], stated that, current pollution measurement equipment at fixed locations or dedicated mobile methodology uses expensive equipment. Today, the scarcity of fine-grained air quality information is hindering public awareness of health issues arising from pollution, especially for fine-grained particulate matter. We anticipate that, with the help of fine grained air quality measurements, people could be advised to take actions based on real time pollution levels to accommodate individual health needs .Availability of data about air pollution may help drivers to anticipate the real air pollution danger before taking place. Several manufacturers such as Aeroquip or Variable Technologies have recently introduced. Figure 2.9 is showing the configuration of the fast and accurate air pollution collection data system handheld pollution measurement devices.

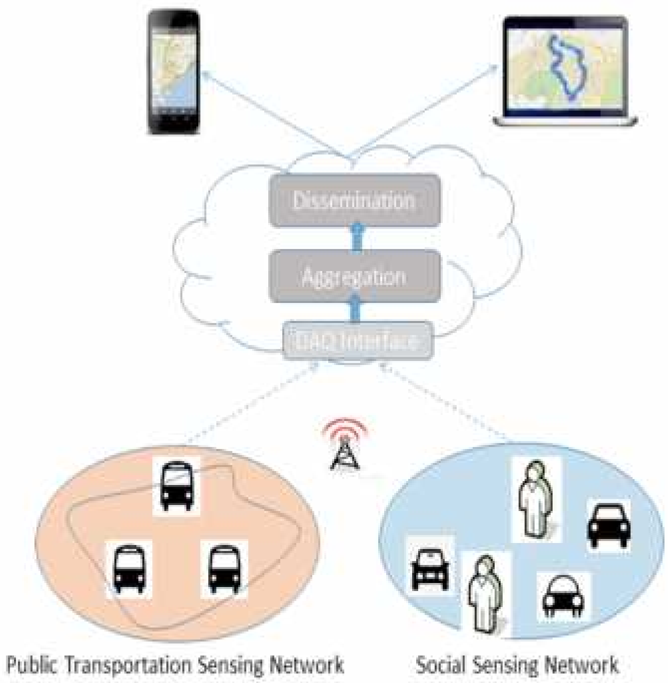


Figure 2.9 Handheld Mobile Air Pollution Data Collection System Design (2007) [24]

Different sensors produce different data formats, and this variation falls into two categories. (1) Variation in measured content - sensors has different pollution measurement capabilities. As a result, they produce different pollutant measurements with different levels of accuracy and variation. (2) Variations in - location, for data representation, can be represented in various formats.

A Mobile Sensing Box is another type of air pollution collection data collection instrument; it is shown in Figure 2.10 below.

A NODE sampler is mobile form instrument could be fixed near air intake of car air conditioning system to measure different pollutant concentrations during driving the car. A type of this instrument is shown in Figure 2.11 below. This NODE was used to collect air pollution data on Staten Island. The results are shown in Figures 2.10, and 2.11 respectively. In the same study, the thermal map of the studied area, or state is shown in Figure 2.12. Similar variations between the data from the two platforms.

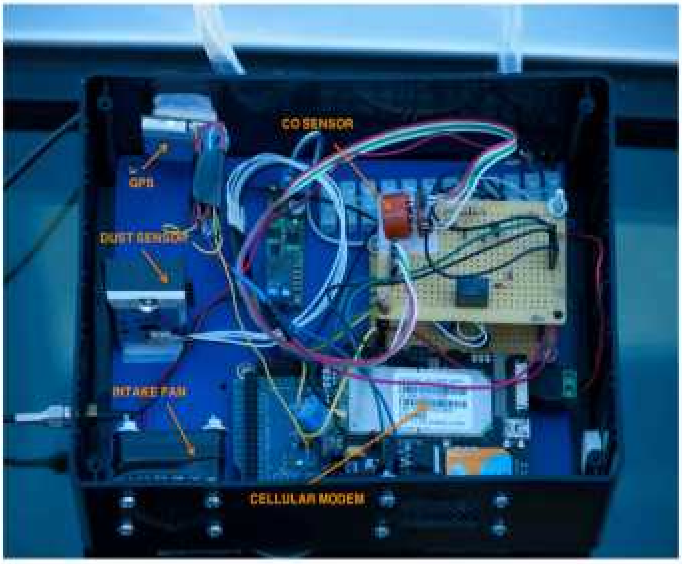


Figure 2.10 Mobile Sensing Box used for Air Pollution Data Collection (MSB) (2007) [24]

For linear regression, results were calculated using the average of each cluster of MSB readings and the average of the corresponding cluster from the NODE values. The results of the correlation analysis are shown in Figure 2.13.

Figure 2.11 Node Instrument for Air Pollution Data Collection inside Car (2007) [24]

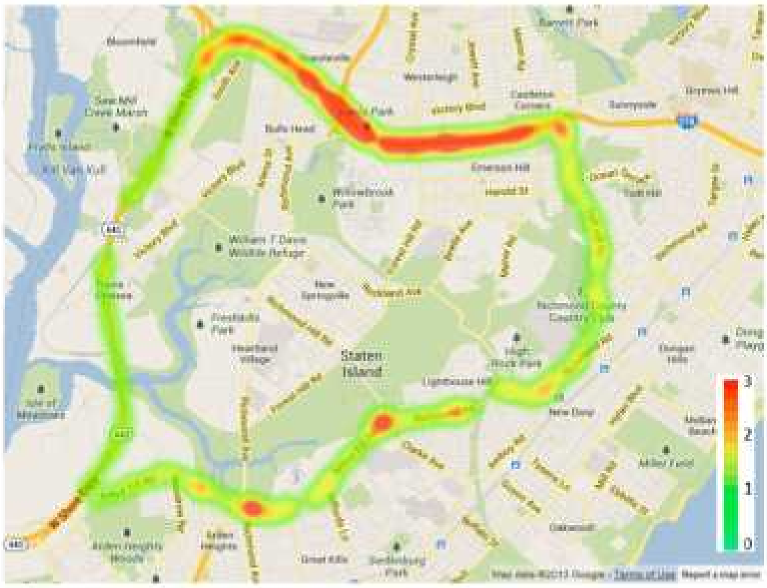


Figure 2.12 Heat Maps of CO2 Concentrations on Staten Island (2007) [24]

The frequency at which measurements were done was related to vehicle speed and to the spatial gradient of pollution using both NODE, and MSB data collection instruments

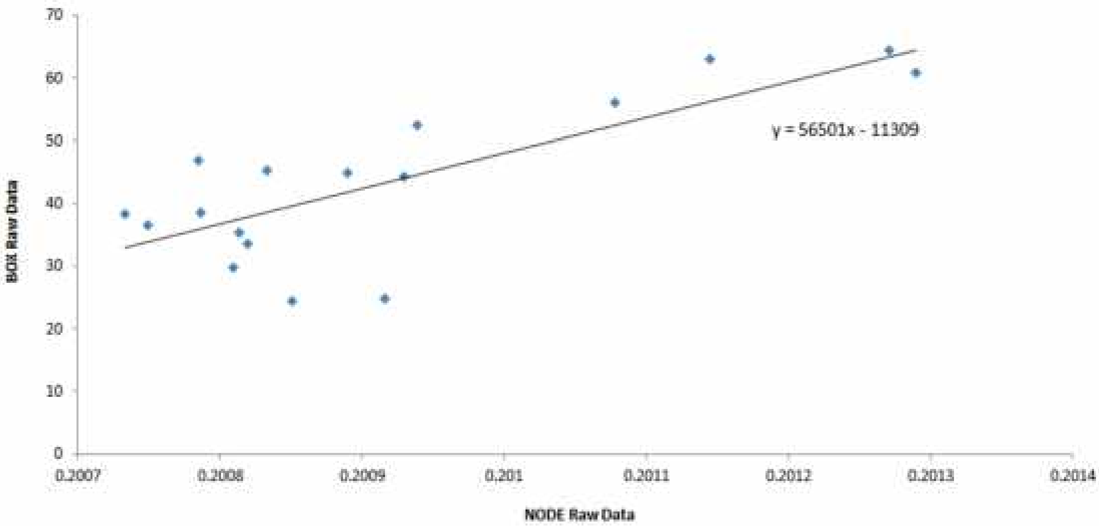


Figure 2.13 Linear Regressions in Pollution Measurement on Staten Island (2007)

. For instance, at highway speeds, a frequency of one sample per minute means the measurements were one mile apart assuming a vehicle speed of (60 MPH). Is this measurement frequency really necessary given the rate at which pollution level changes relative to distance? .If not, what factors should the client sensing app consider to decide the best sampling time for accuracy?. Geography of the road, speed, and changes in traffic were the obvious candidates.

2.5 Moran Technique as a Spatial GIS Solution for Epidemics Locations in Urban Areas

Pankaj W. and Kishor K. (1998) [25] cleared that; highway networks face deterioration problems due to the lack of funds for infrastructure. The adoption of newly emerging technologies such as Geographic Information System (GIS) can help to improve the decision making process in this area for better use of the available limited funds. GIS are becoming more widely used in transportation planning agencies, especially among metropolitan transportation organizations. Traffic accidents, air, and noise pollution are usually considered as epidemic problems facing society, mostly affected by the spatial movement of different vehicles passing through sections, and intersections located within the infrastructure of the city road network. The most important objectives for using GIS are map/display and data integration. The interaction between the transportation system and its surrounding environment makes the GIS technology ideally suited for hazardous materials, routing design, risk analysis, and decision making. GIS can also be integrated with sophisticated mathematical models and search procedures to analyze different management options and policies.

Elke M., Tom B., and Geert W. (2005) [26]**,** defined Moran Technique as one of the statistical analysis tools used in the last ten years to find the spatial effect of these epidemics happening in one location upon another. GIS is usually supported with statistical software able to compute the different parameters to find the above mentioned effects. Global measures of spatial autocorrelation have been applied for several decades and mainly stem from the work of Moran P., (1948) [27] Griffith, D.A, (1987) [28], and Haining, R., (1990) [29]. Moran’s I is mostly often used and its usefulness for transport fluxes and traffic accident analysis had been thoroughly discussed in the literature (Black, W.R., 1992) [30], and (Black, W.R., Thomas, I.,

1998) [31]. Each location is now characterized by one value of the index that denotes the individual contribution of the location in the global autocorrelation measure. These local indices are considered to be Local Indicators of Spatial Association: (LISA's) if they meet two conditions:

- It needs to measure the extent of spatial autocorrelation around a particular observation, and this for each observation in the data set. and
- The sum of the local indices needs to be proportional to the global measure of spatial association.

(LISA) method have been used, which satisfies the two conditions mentioned above and depends on Moran's I index, the equation of Moran's I index is as following:

$$I_i = \frac{N}{(N-1)S^2} (X_i - \bar{X}) \sum_{j}^{n} W_{ij} (X_j - \bar{X}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.4)$$

Where:

I_i = Moran's I Index.

N= Total number of zones under study.

n= total number of j zones surrounded by zone i.

X_i = Total number of accidents in zone i.

X_j = Total number of accidents in zone j.

$\bar{X}$ = Average number of total accidents in all zones.

W_{ij} = Weights representing proximity relationship between location *i* and neighboring location j.

Three weight functions used in this study, which are as followings:

$$W_{ij} = \frac{1}{(d_{ij})^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.5)$$

$$W_{ij} = \frac{1}{(d_{ij})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.6)$$

$$W_{ij} = \frac{1}{\sqrt{(d_{ij})}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2.7)$$

Where:

d_{ij} = Distance between zone *i* and its nearest neighbors zone *j.*

S^2 = Variance of the observed values given by:

$$S^2 = \frac{1}{N-1} \sum_{i=1}^{N} (X_i - \bar{X})^2 \quad \ldots\ldots\ldots\ldots \quad (2.8)$$

In the application area of traffic safety, however, one is only interested in locations that have:

1- A high number of accidents in regard to the total average number

of accidents (i.e. $(x_i-\bar{x})>0$). , and

2- Where the neighborhood also shows more accidents than was expected (i.e., $\sum_j w_{ij} (x_i - \bar{x}) > 0$) on average.

Next, to determine the hot spots, it was decided upon to filter out the locations with a high number of accidents contiguous with high neighboring values. For this, subsample of locations the 95% percentile (P_{95}) of the distribution of the remaining Moran values were determined. This value will be utilized as the cut-off value to determine an accident hot spot in the study area. If the local Moran's I value location true data has similar high values between the location under study and its contiguous locations and it exceeds this 95% percentile (i.e., If $I_i > P_{95}$), then this location could be considered as hazardous, and hence a hot spot location.

Brauer et al. (2003) [32] compared traffic- related $PM_{2.5}$ air pollution models in Multiple European cities using the land use regression (LUR) technique. In each of the study cities, investigators fir two types of models: one available through a geographic information system for (GIS) environment and another that included additional variables not available in the GIS. The results obtained for the Netherland, Munich, and Stockholm in the GIS environment showed R^2 values of 0.81, 0.67, and 0.66 for particle filter absorbance, respectively. The alternate model or "best" model included variables such as high traffic locations and street canyons. This model produced results with better R^2 values respectively of 0.90, 0.83, and 0.76.

Jerret.M.A. et al (2006) [33] tried the land use regression (LUR) model to build a new study in Toronto City, Canada, in North America. They selected 95 locations to measure the concentrations of NO_2 using OGAWA ™ passive samplers for 72 hours on 2.5m height to collect the data needed for the model development study during two weeks' time period. The study area is shown in Figure 2.14 with the locations of data collection. For each location, the arithmetic mean, standard deviation, and coefficient of variation of NO_2 results were calculated. ArcGIS8 had been used to implement data manipulation, and analysis. The study selected 85 independent variables to build the models using the ArcGIS8 , some of which are, different land uses, traffic variables like volume speed, population density, dwelling units density, physical geographical dimensions like x, y and elevation coordinates, and metrological variables such as wind speed, and direction.

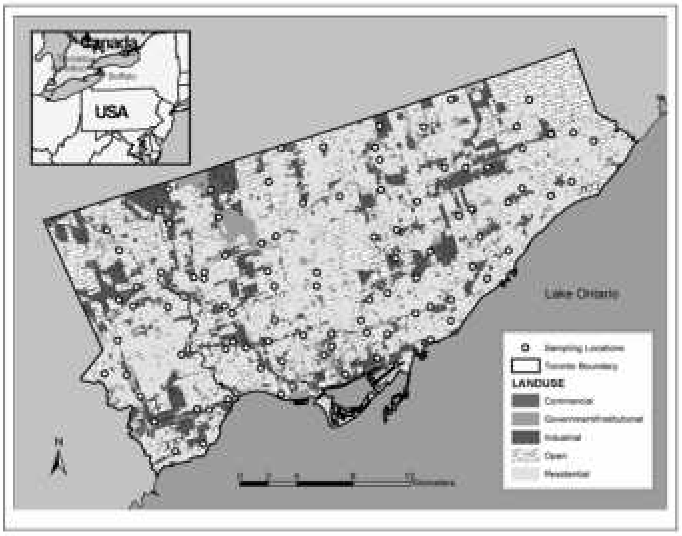


Figure 2.14 Toronto Sampler Locations against a Backdrop of Land Use Classification (2006) [33]

Stepwise multiple regression analysis was used to obtain the most perfect statistical model. Validation results are shown in Figure 2.15 considered as a final conclusion in this study. The final regression model yielded R^2 value of 0.69. The results suggest that good predictive surface can be obtained for the North America cities using LUR method with small area variation in NO_2 concentrations. These small-area variations in traffic pollution are probably important to the exposure experience of the population and may detect health effects that would have gone unnoticed with other exposure estimates.

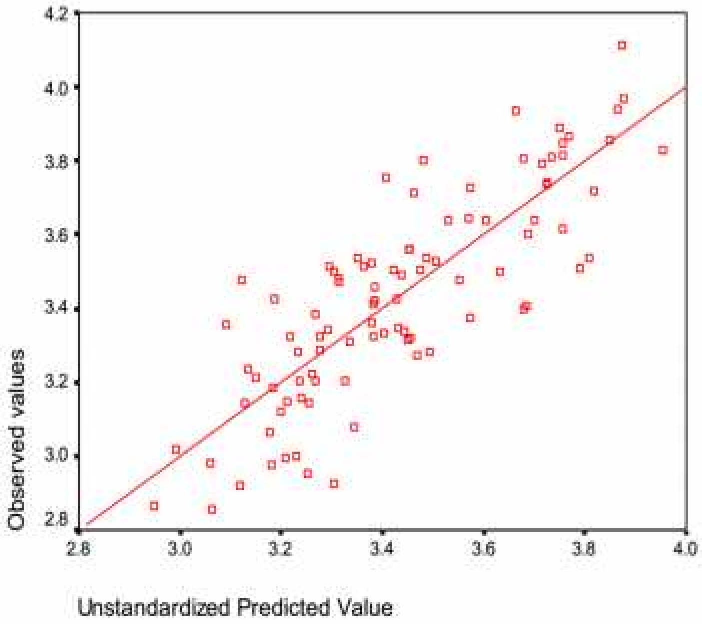


Figure 2.15 Logarithmic-Observed Mean NO_2 on Predicted Value (2006) [33]

2.6 Air Pollution and Different Traffic Variables

Total air pollution emissions generated from traffic vehicles are completely varied due to the variation of different traffic flow parameters, such as traffic volume, speed, acceleration, travel time delay, composition, density, land use, and residential density…etc. A lot of literature was given to correlate the different traffic variables as independent, with air pollution emissions types, and how they are going to interrelate positively or negatively.

David J. B.et al., (2000) [34], assessed the use of a GIS-based, regression mapping technique to model spatial patterns of traffic-related air pollution. The model developed using data collected from 80n sites from Huddersfield as a part of Small Area Variation in Air Quality and Health uses data of traffic flow and land cover in the 300m buffer zone around each site, and altitude of each site to predict the concentrations of NO_2. This study was applied in four cities around London, which are Huddersfield, Northampton, Sheffield, and Part of London. The following model called SAVIAH was recommended out of this study:

C=38.52+0.003705xTraff. +0.232 Land. – 5.673 Log10 (Alt.) ………… (2.9)

Where C is the mean annual NO2 concentration measured on 2m above ground Traff. Is coming from:

Traff. = 15xTvol0-40 +Tvo40-300 ……………………………………. (2.10)

and

Land. = 8x HDH0-300 +Ind0-300……………………………………… (2.11)

Where

$TVOL_{0-40}$, and $TVOL_{40-300}$, are the traffic volumes within a buffer zone of 40, and 40-300 –meanwhile.

HDH_{0-300}, is the population area in (ha) within a buffer zone of 300m, while, Ind_{0-300}, was the area of industrial land within the 300-m buffer zone in (ha) around the site. Alt. = altitude of the site (meters above ordnance datum) in meters. Table 2.9 is showing the four derived models for the four selected sites, while the validation analysis of the same sites is shown in Figure 2.16, which reflects the degree of goodness of fit obtained.

Table 2.9 Local Calibration of the SAVIAH Model (2000) [33]

Location	**n**	**R^2**	**P**	**Constant**	**Slope**	**S.E.E μg/m^3**
Huddersfield	10	0.51	0.02	-14.29	2.08	10.98
Hammersmith and Ealing	11	0.76	0.001	-0.30	0.97	5.58
Northampton	10	0.60	0.008	-10.6	0.96	6.86
Sheffield	10	0.61	0.000	-32.2	1.93	10.31

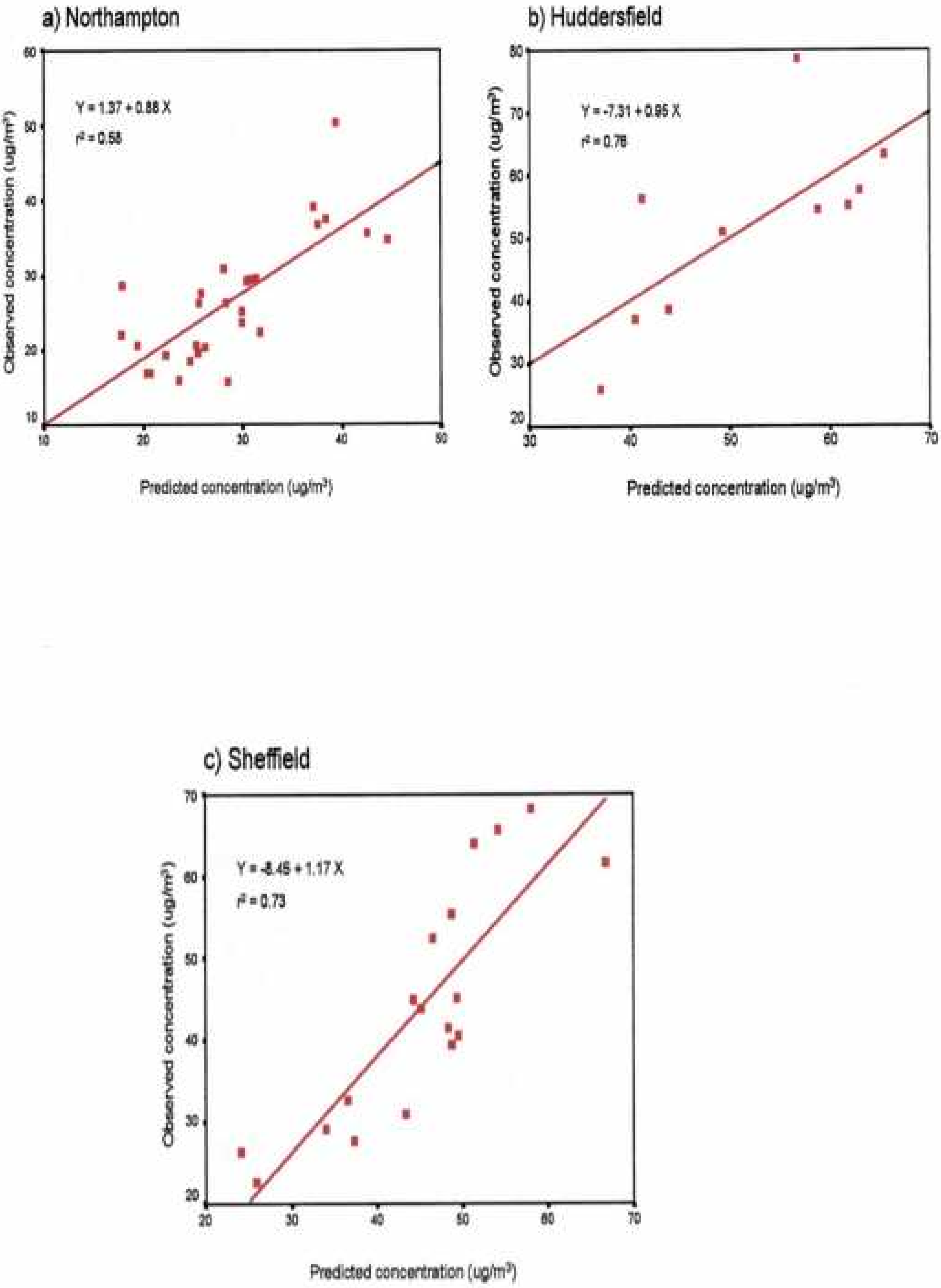


Figure 2.16 Validation of the Locally Adjusted SAVIAH Model against the Remaining Three Sites (2000) [34]

Alois. K., (2005) [35] stated that, hot emissions depended mainly on vehicle technology (i.e., emission control and after treatment) and driving conditions.

Figure 2.17 shows the variation of the mean travelling speed with the concentrations of the different type of pollutants. Medium speed values produced minimum concentrations of harmful exhaust gases. High speed encountered on motorways demand high power output, which again increases emission levels.

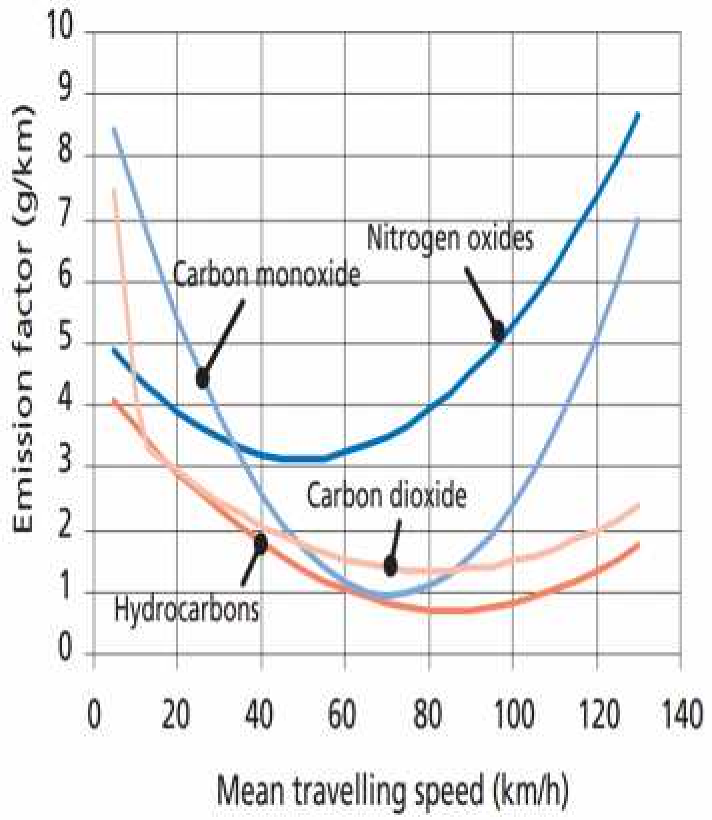


Figure 2.17 Effect of Mean Travelling Speed on Emissions Levels from Passenger Cars with Catalysts (2005) [35]

The same above authors compared the amount of PM emitters from diesel cars with the amount of materials produced due to clutch, road, car, brake, and tires. Figure 2.18 shows the contribution of each part of vehicle to the percentage of emissions produced.

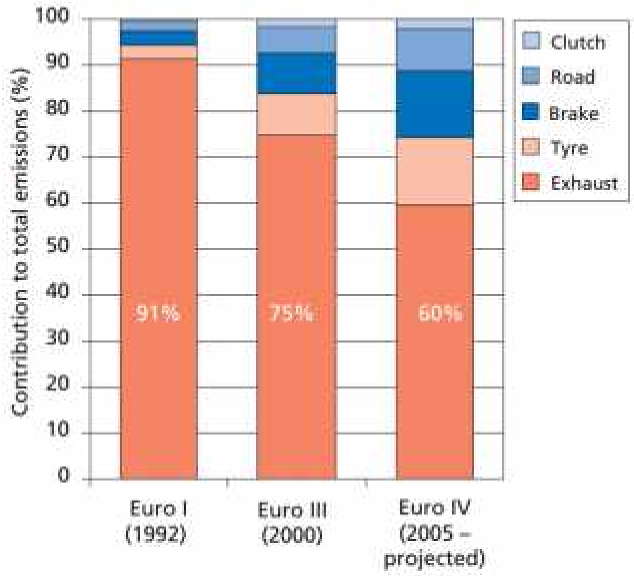


Figure 2.18 Contributions of Exhaust and Non-Exhaust Particle Sources to Total PM Emissions from Diesel Passenger Cars of Improving Technology (2005) [35]

Table 2.10, shows the EU emission standards for passenger cars and Table 2.11 shows the corresponding standards for heavy-duty engines. They regulate exhaust emissions of carbon monoxide, hydrocarbon, nitrogen oxides and PM. The Euro II to lower carbon Euro IV standards for passenger cars differ for diesel fuel and petrol monoxide, but higher nitrogen oxides for vehicles that using diesel fuel.

Table 2.10 EU Emission Standards for Passenger Car (2005) [35]

Standard	year	Diesel Car(g/km)				Petrol Cars (g/km)			
		Carbon Monoxides	Hydrocarbons and Nitrogen Oxides	Nitrogen Oxides	PM	Carbon Monoxide	Hydro-carbons	Hydro-carbon and Nitrogen Oxides	Nitrogen Oxides
Euro I	1992	2.72	0.97	-	0.14	2.72	-	0.97	-
Euro II	1996	1.0	0.90	-	0.10	2.2	-	0.50	-
Euro III	2000	0.64	0.56	0.50	0.05	2.30	0.20	-	0.15
Euro IV	2005	0.50	0.30	0.25	0.025	1.0	0.10	-	0.08

Table 2.11 Emission Standards for Heavy-Duty-Vehicle Diesel Engines (2005) [35]

Standard	**Year**	**Carbon Monoxide (g/km)**	**Hydrocarbons (g/km)**	**Smoke (m^3)**	**Nitrogen Oxides(g/km)**	**PM (g/km)**
Euro I	1992	4.5	1.1	-	8.0	0.36
Euro II	1996	4.0	1.1	-	7.0	0.25
Euro II	1998	4.0	1.1	-	7.0	0.15
Euro III	2000	2.1	0.66	0.80	5.0	0.10
Euro IV	2005	1.5	0.46	0.50	3.5	0.02
Euro V	2008	1.5	0.46	0.50	2.0	0.02

Vehicle class seems to have a considerable effect on the emission level produced by the traffic movement of these types of vehicles. Figure 2.20 is showing the effect of different classes of vehicles. Passengers' cars show a lower level of emissions, but buses and coaches are producing the highest levels.

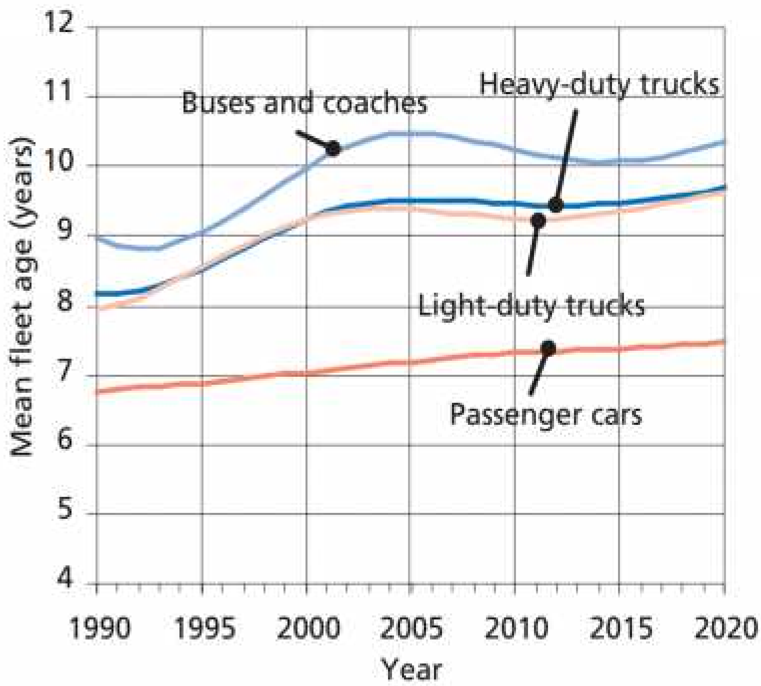


Figure 2.19 Mean Age of on-Road Vehicles in the EU According to Vehicle Category, (1990- 2020) (projected) (2005) [35]

2.7 Air Pollution and Road Geometric Variables

Roads classified according to their geometric design to freeways, or expressways, which are always selected to serve traffic in rural or sub-urban areas. Arterials are usually responsible for moving traffic along city boundary connected with higher standard roads such as freeways. Other minor roads, such as collectors and locals usually located inside the CBD area connected with the suburbs. Road class means its geometry or standards, like, cross section, spacing between intersections and interchanges, design speed, grades…etc. These geometrics may have a certain effects on the degree of pollution transmitted from vehicles maneuvering along the different segments of these different roads. In the literature, there is small number of research works dealt with. Figure 2.20 given by Jens B., Jürgen S. ,Menno K., Eric S. and others,(2004)[36], is showing how air pollution transmissions from high speed motorways in Europe are going to increase until during 10 years, from (1900-2000):

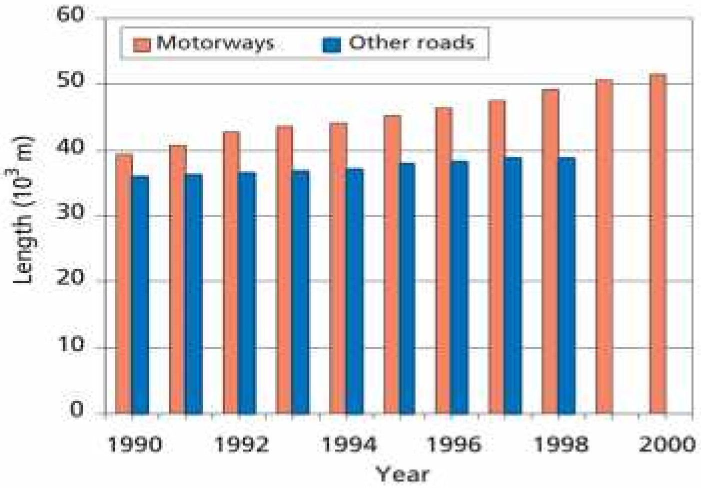


Figure 2.20 Lengths of Motorways and other Roads in the 15 Countries Belonging to the EU before May 2004, (1990–2000**)**, (2004) [36]

The same above authors reported that transport dominated PM_{10} emissions in 1999 suggested that, road and other transport accounted for 39% of PM_{10} emissions in the EU (EEA, 2002a) Rotterdam Area. Between 1990 and 1999, advances in the reduction of PM from transport contributed to the overall reduction of PM_{10} emissions. Traffic-related PM however, still represents a large source of PM_{10}, especially in urban areas with large volumes of road traffic. Figure 2.21 is showing the annual contribution of pollution transmission concentrations of PM_{10}, $PM_{2.5}$, and elemental carbon along the two sides East, and West directions of the road cross-section, and where they are going to asymptotic.

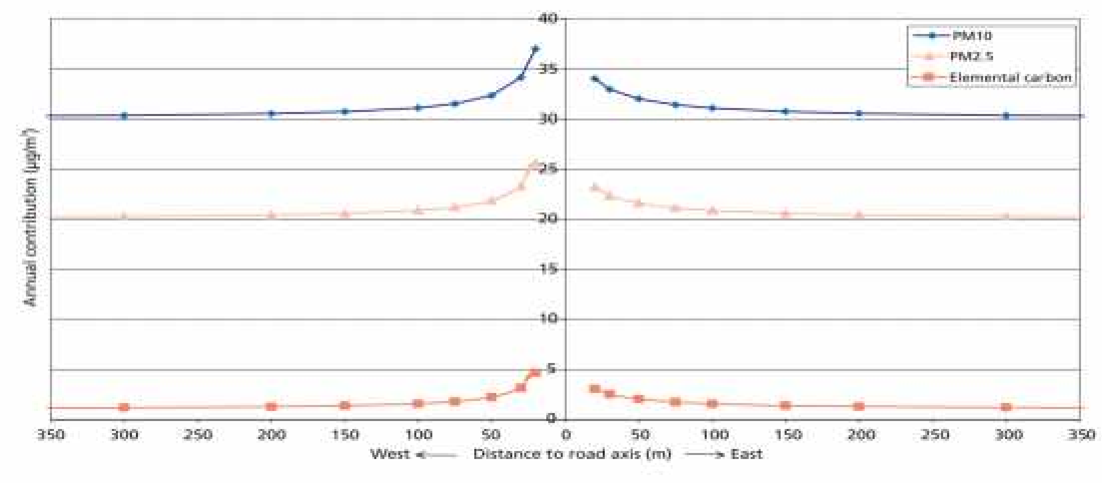


Figure 2.21 Annual Contribution of PM and Elemental Carbon from Highway Traffic to the Air Quality as a Function of the Distance from the Highway Centerline (2004) [36]

Figure 2.22, shows that air quality may vary within a city, depending on traffic intensity, physical topography (such as the width of a street versus the height of buildings) and weather conditions given by Menno Keuken, Eric Sanderson, Roe (2005). The next section focuses on traffic-related hot spots, where people are exposed to higher concentrations, and emphasize traffic-related PM_X and NO2.

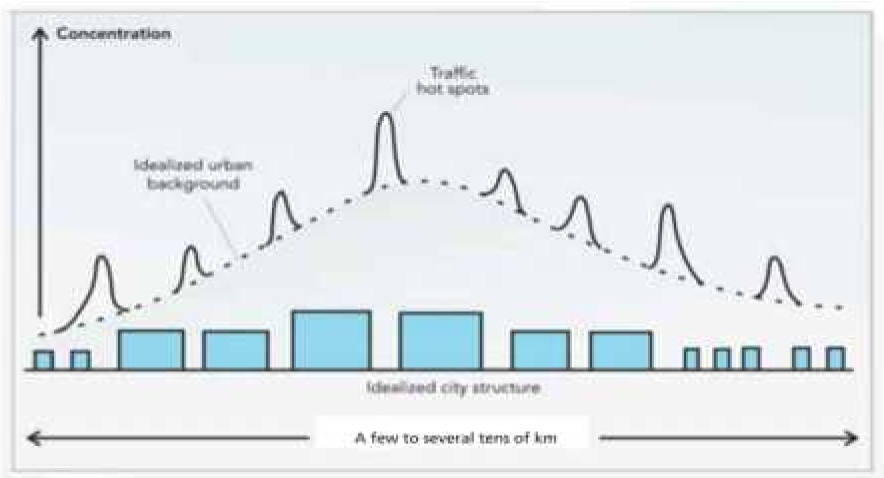


Figure 2.22 City Structure and Pollution Levels: Urban Background and some Traffic Related Hot Spots, (2004) [36]

The figure 2.23 reports the percentage contribution of transport and not transport sector to total emission of air pollutants in EEA32. Transport sector includes road transport, shipping, aviation and railways.

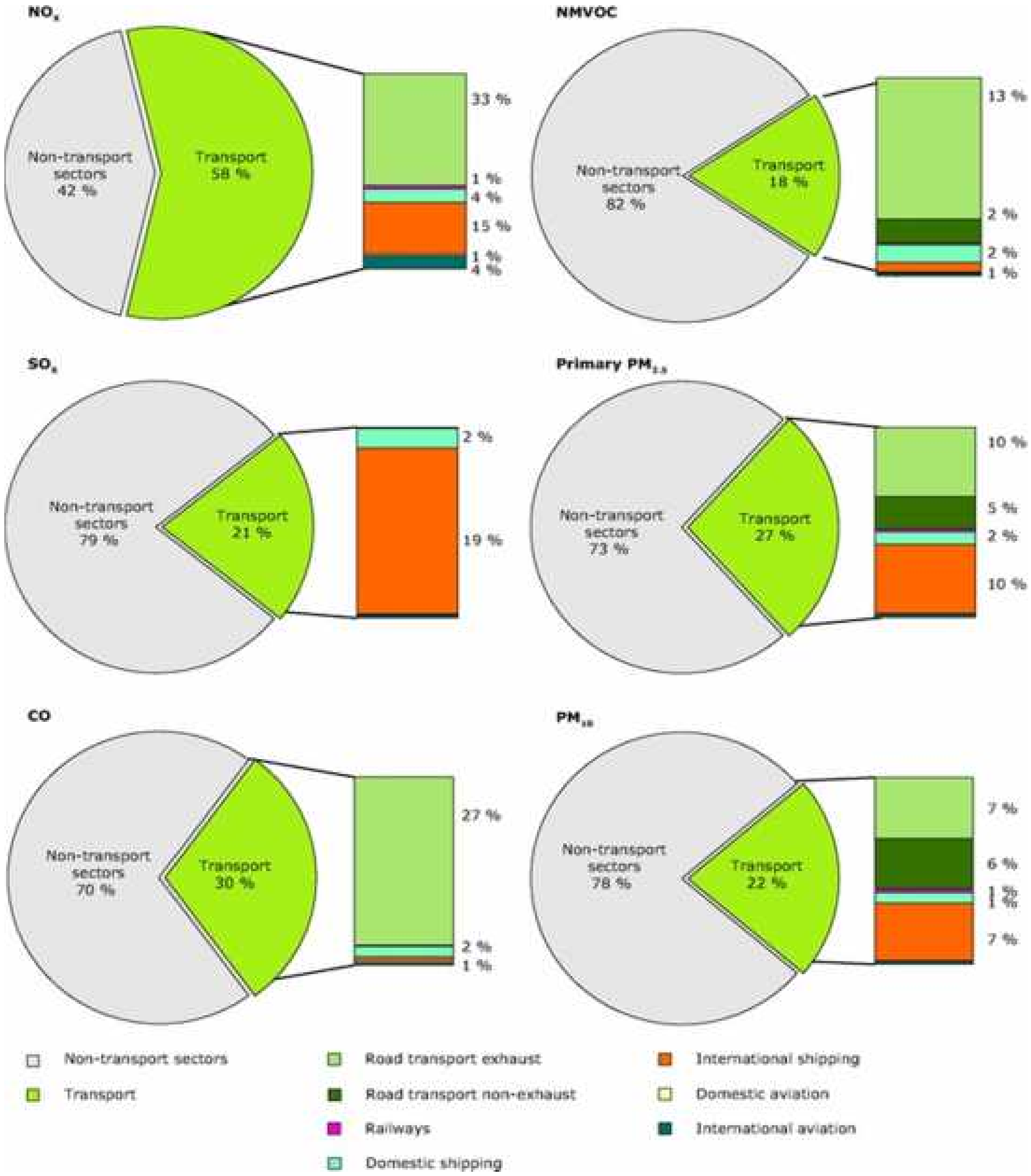


Figure 2.23 The contribution of the transport sector to total emissions of the main air pollutants, (EEA-32) [52]

CHAPTER 3

RESEARCH METHODOLOGY

3.1 General

In the methodology of this study, different stages were proposed in order to achieve the required and intended objectives for which the study have been proposed. Air pollution study is a special topic needing to include the overwhelming infrastructure of Duhok City to pinpoint the sectors, and zones where air pollution problem is the most feasible. The methodology of air quality improvements and the type of solutions to be decided and proposed should be directed for further implementation program by decision makers related to air pollutants concentration reduction. Figure 3.1 is showing the different stages of the methodology to be executed in this study in order to correlate the most socio-economic, and traffic factors producing travel trips from each household, and the main of the air pollution producing sources. The research methodology will introduce the GIS technique in order to represent the main 43 traffic zones to which Duhok City infrastructure was divided according to the policy of the Duhok Municipality Planning Directorate (2015)[37]. Study methodology was planned to implement the GIS map of the city in order to select the random points on the traffic zones and the main roads of the city road network to collect the air pollution data. Home Interview Survey is also included to collect data about the amount of travel in vehicle-km in order to correlate the amount of pollution emitted by the different classes of vehicles registered in the Traffic Police Directorate in Duhok City. A lot of data is needed for the final analysis included within the different stages of the study method. A special air pollution instrument will be used in this study to compile the different hazardous gases concentration measurements at different locations in Duhok City Infrastructure using GPS as a tool to geo-reference the points of data needed.

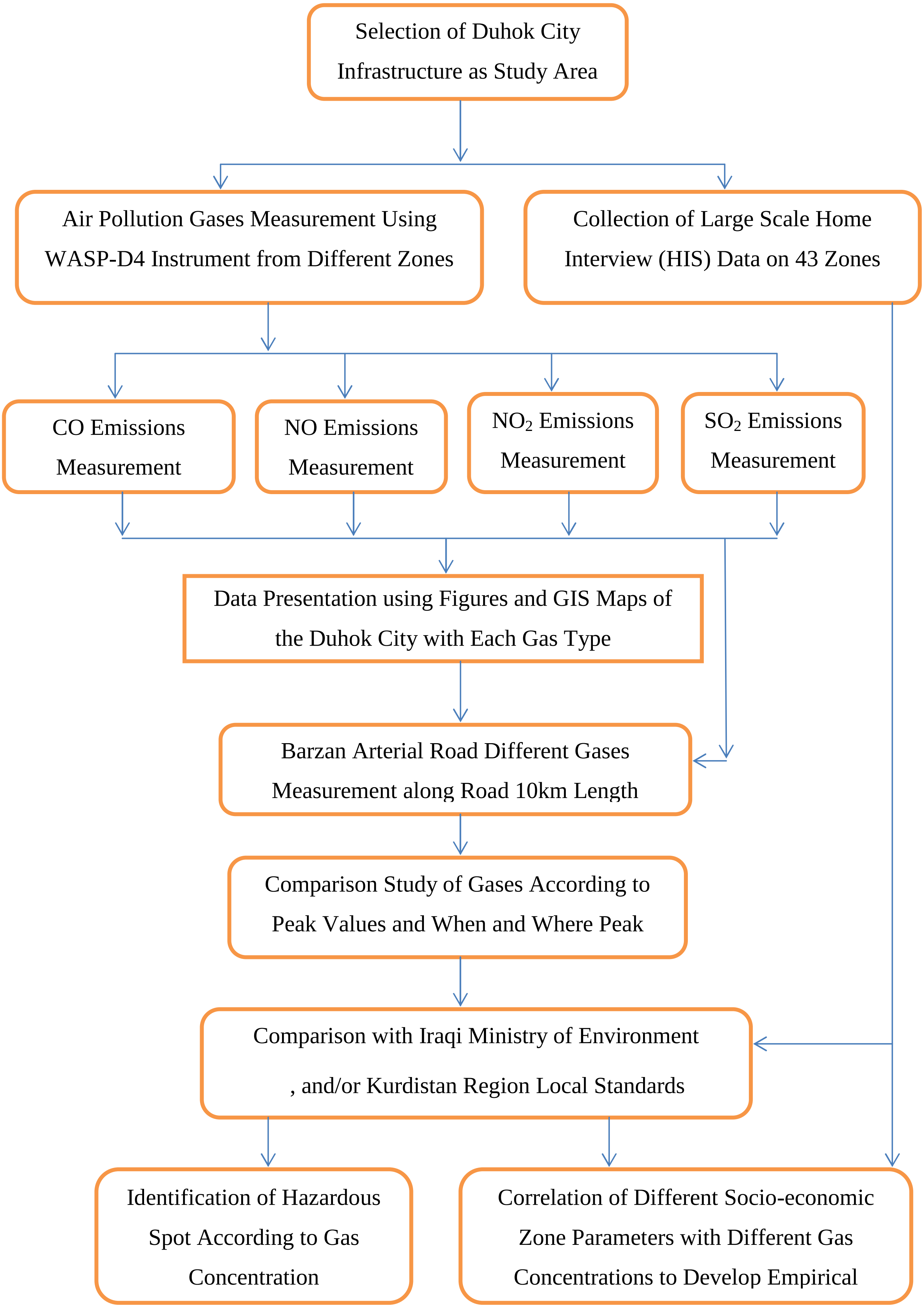


Figure 3.1 Research Work Flow Diagram

3.2 Study Area

Duhok City, as shown in the Figure 3.2, is located in the north part of the country in the Iraqi Kurdistan Region; it connects Iraq with Syria in Asia and Turkey with Europe (2015) [38]. Its geographical coordinates are (37.3°′N 43°9′E / 37.05°N 43.15°E).The study area on which the research methodology is to be applied is shown in Figure 3.3, which includes a GIS Map for Duhok City with its population number measured by colours. The map is showing the 43 traffic zones to which the city infrastructure was divided, including more than75 signalized and un-signalized intersections by which the road network is working.

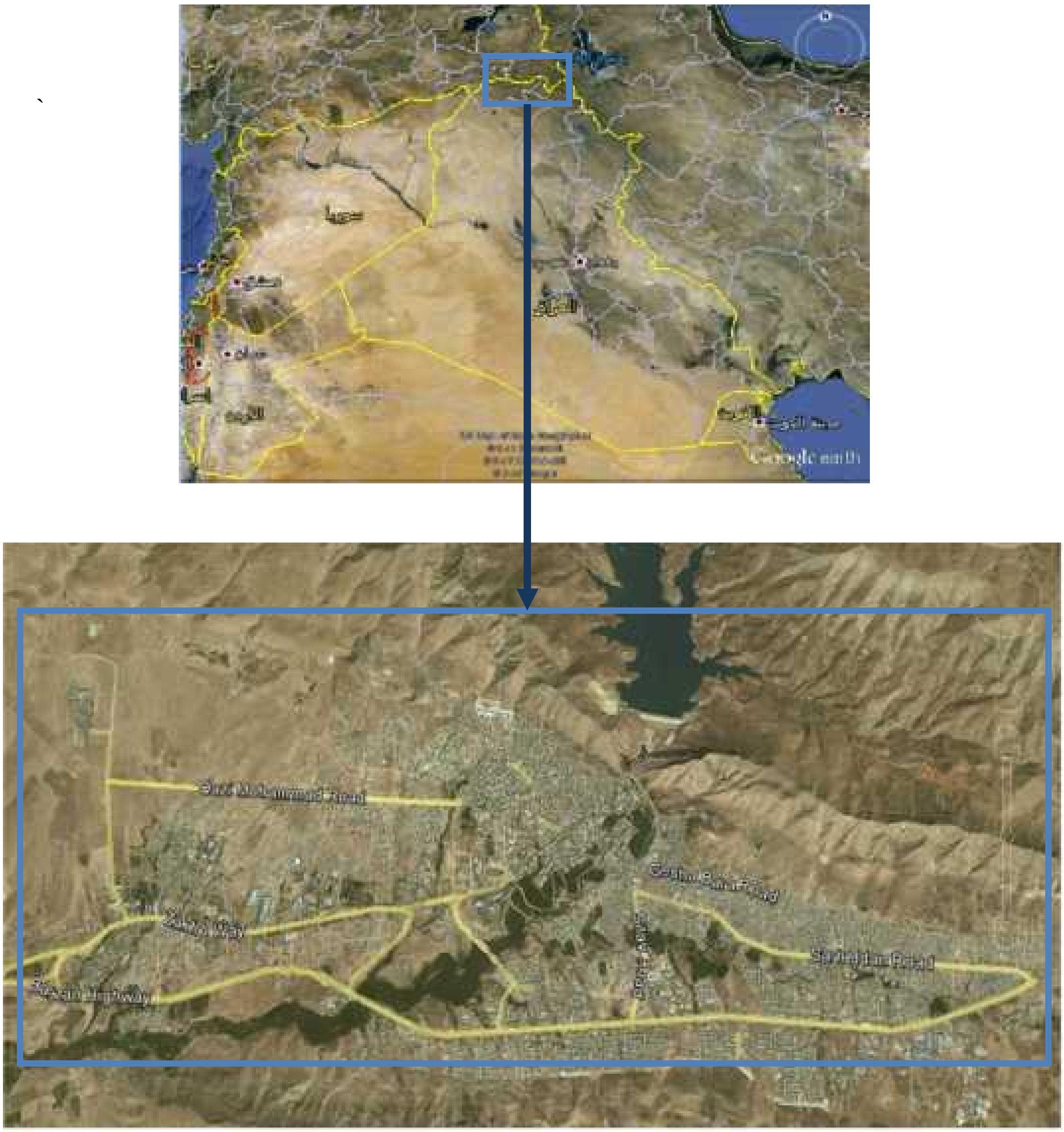


Figure 3.2 Google Image Showing Duhok City Study Area Located on (37.3°′N 43°9′E / 37.05°N 43.15°E) (2015)[38]

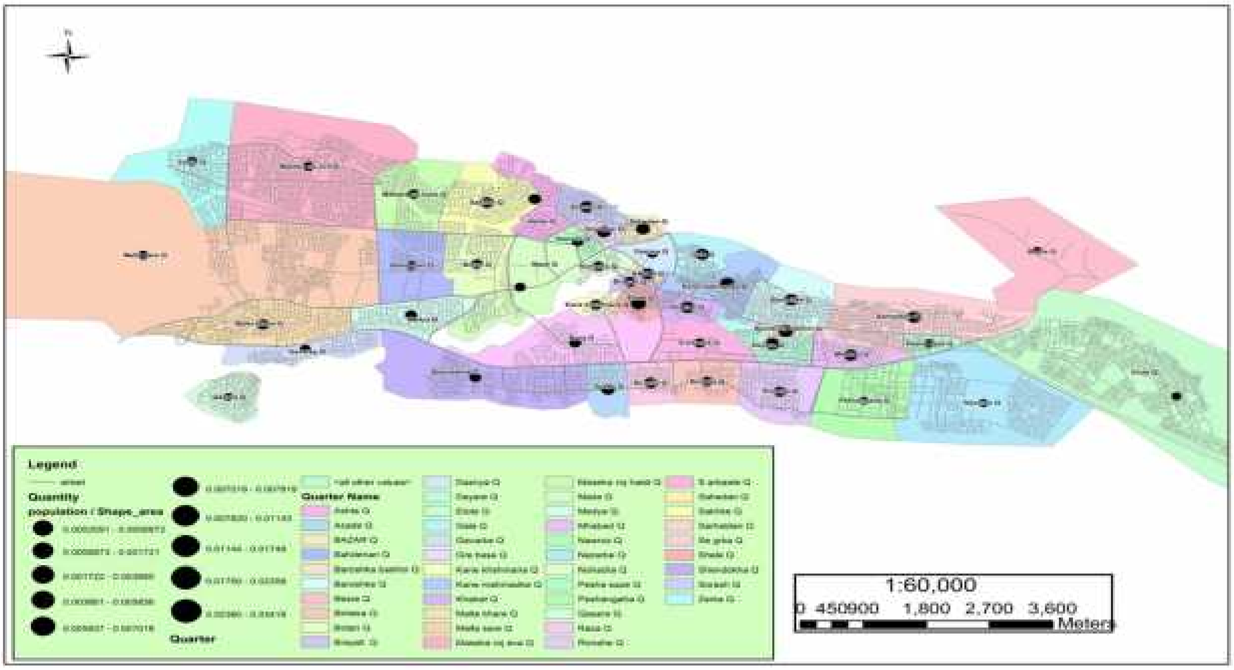


Figure 3.3 Duhok City Study Area GIS Map (2015) [37]

The study area is located between two mountains from North and South Directions and selected for the following considerations:

1-Duhok City geographical position, as it lies in the portable area, which means between the wavy area and high mountainous that surrounding the city from three directions, the White Mountain in the north, Shindokha (Zawa) Mountain in the South and Mamseen Mountain in the East and the Western direction. It is considered to be one of the most significant and important city especially in historical, tourism and geographical point of view;

2 -There is a strategic international road passing across Duhok City which connects

Kurdistan Region with Turkey and the external wide world through Ibrahim Al Khalil Border point;

3 - The standard of living of people in Duhok has grown gradually during the last eight years, which lead to a lot of people to drive cars privately and increase in traffic flow then increase of traffic accidents, and more air pollution;

4 - Identification and remedies study in air pollution levels was not achieved in

Duhok City during the last eight years, and

The City of Duhok consists of complete street network system with a variety of land use such us: residential, industrial, commercial and recreational zones although a lot of expansions in road network are going on.

3.3 Data Collection

The main two files of data collected for achieving the purpose of this study were human travel behavior, and air pollution due to emissions of pollutants from vehicles data file:

3.3.1 Time Coverage

The time period selected for this study is ten months from (9-2014) to (6-2015). Many studies suggested that air pollution measurements shouldn't be less than (4-8) hour period to know the actual level, and to compare with National and Local Standards. In this study both types of standards are used, the first is related to the Iraqi Ministry of Environment Standards (IMES) (2008) [39], and the second is the Kurdistan Region Local Standards (2013) [40] shown in appendix (A).

3.3.2 Measurement of Human Travel Behavioral File

In order to measure this valuable and effective travel parameters related to the estimation of the amount of travel produced from each 43 traffic zone included within the study area. Home Interview Survey (HIS) was selected as the most proper method to estimate the amount of trips produced and attracted from, and to each home or apartment during a random workday respectively .A special questionnaire form was used for the collection of HIS data is shown in appendix (B).A well trained team of observers were employed to collect the HIS ,data from the 6750 families with a 2.0 % sample size considering that Duhok City population is more than half million in this fiscal year (i.e., 337,570) persons as estimated by the Duhok Municipality Directorate ,(2014) [37]. In addition to the final population number living in the study area , the number of the people migrated to the study area due to the war started from more than eight month in the North Part of Iraq close to Kurdistan Region was added which is unknown, then the number will be too much higher. Due to that, the selected sample size was according to the statistical approach recommended by Public Administration Service given in Table 3.1 (1997) [41]

Table 3.1 Home Interview Sample Rates (1997) [41]

Population	Minimum Sample Size	Sample Rate %
Under 50,000	10	20 or 1 in 5 DU
50,000-150,000	5	12.5 or1 in 8 DU
150,000-300,000	3	10 or 1 in 10 DU
300,000-500,000	2	6.67 or 1 in 15 DU
500,000-1,000,000	1.5	5 or 1 in 20 DU
Over 1,000,000	1.0	4 or 1 in 25 DU

The size of the sample is dependent upon the total population of the study area and the analysis methods to be used (1985)[6],(1990)[7],(1997)[8]. The traffic Appraisal Manual gives the following equation for the calculation of the HIS sample size:

$$n = P(1-P)\,N3/\,(E/1.96)^2(N-1) + P(1-P)\,N2 \quad \ldots\ldots\ldots\ldots\ldots (3.1)$$

In this study, HIS was conducted on 675 families

Where:

n =total sample size of (D.U) needed for sampling;

N =total number of households within the survey area;

E =required accuracy expressed as a number of households; and

P = proportion of households with the attribute of interest.

According to this equation a proportion of households P will be 1.034 is enough to satisfy the recommendations in Table 3.2, but for more accuracy, the study considered a 675 household for questionnaire which is representing a 2% from total city household which is more than required. The sample size (i.e., the range of sample size tested), had little effect on the accuracy of the trip estimates in the residential zones (1985) [42].

The HIS is usually executed by direct interview to obtain the maximum amount of information to be collected on household habits. Dwelling units file was prepared to summarize the most useful information pertaining to the whole household and have great effect on trip making activities such as;

Total number of persons living in the HH;
Number of persons older than five years living in the HH;
Car-ownership;
Origin, and destination locations;
Work finishing time;
Time of arrival to the house;
Number of workers in the HH;
Residence address;
Trip purpose;
Type of mode with which the trip was completed; and
Number of employments in the HH;

The main questions found in the form were prepared for certain purpose of data collection. Population intensity of each area was further computed from the available data in the GIS Map given above as it represents the most important parameter in producing pollution from each residential zone within the study area limits. Distance of travel was considered as the time limits of trip from departure until arrival from business to residence or vice versa, for the determination of the amount of travel executed by a specified mode of transport.

3.3.3 Air Pollution Measurement File

This file is very important and sensitive to be compiled and measured around the limited study area including the whole infrastructure of Duhok City. Well trained observers were distribute along a ten month period located between(2014-2015) fiscal year to collect the major body of the data needed for this study. The instrument used by observers to collect the air pollution data about four popular types of gases known by Duhok Environmental Directorate were measured (2015) [43]. The four known type of hazardous and dangerous gas pollutants measured are, Carbon Monoxide CO, Nitrogen Monoxide NO, Nitrogen Dioxide NO_2, and Sulphur Dioxide SO_2. Duhok City Map given in Figure 3.4 is showing the main locations of the data collection selected by different observers to look for the four gases concentrations mentioned before. Data collection period was long , about ten months, in order to discover not only the average daily variation of each gas concentration, but also to discover the monthly variation too, which might be dangerous compared with maximum recommended national, or local limits.

3.3.3.1 Data Measurement Instrument Description

The instrument used to collect data around the city of Duhok City during a ten month period using more than ten units for observers to cover that wide area. Figure 3.4 is showing the schematic diagram of the WASP-D4 Analyzer Multi-Gas Detector (2014) [44]

Figure 3.4 WASP-D_4 Gas Analyzer, A Multi-Gas Detector (2014) [44]

Figure 4.5, is showing the bottom type functions during the measurement and data storage process in the field using this instrument. This instrument is able to measure a lot of types of gases, not only the types included here in this study. It is able to measure about twenty types of toxic gases just at one place with some touches on its certain buttons and storage collected could be stored for four months period. A USB system could be attached to this analyzer to store measured data on for further analysis. It is 136x82x43mm in size easily handled with hand to move, detect, measure, and store, with built in rechargeable lithium battery full power for 8hrs continuous working time.

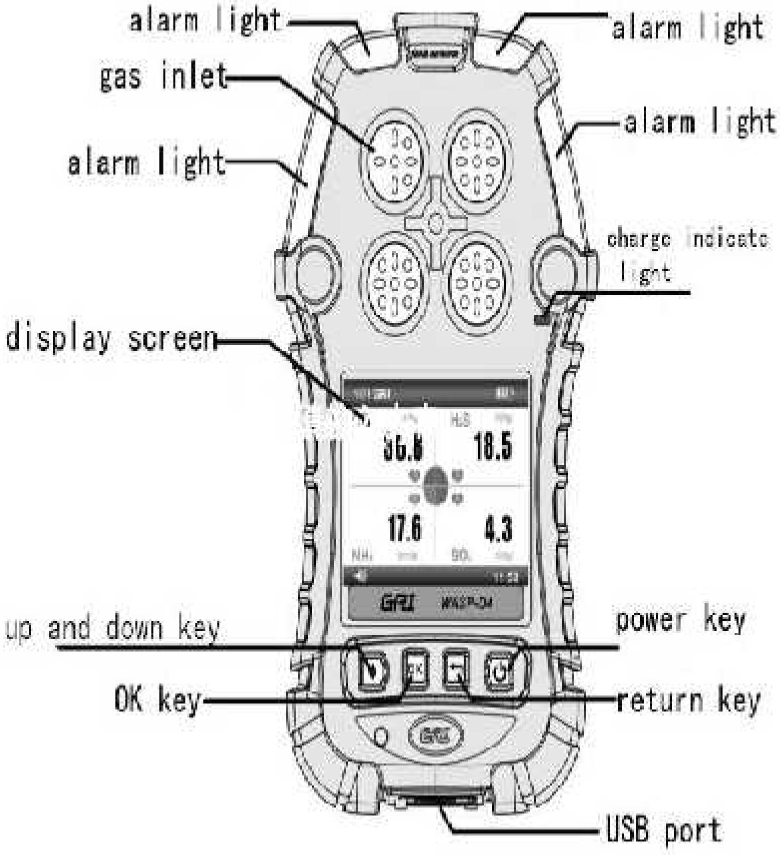


Figure 3.5 WASP-D_4 with Bottom Types Used for Measurement and Data Storage (2014) [44]

In this study, Barzan Arterial Road, which is the main road in Duhok City was selected for data collection and analysis as it is considered as the backbone of traffic movement along the different sectors of Duhok City, and its Official Offices and Directorates, and thousands of people are spending a lot of time exposed to the effluent generated for the heavy traffic load served by it. Special articles are devoted to discuss in detail what is going on in this arterial during the 24 hrs. of the day during ten months of measurement and observation.

3.3.4 Wind Direction and Ambient Temperature

Data related to wind direction and ambient temperature was taken from DED collected along the annual observations for these two parameters (2015) [43]. It is felt that wind direction and temperature might affect the air pollution concentrations along the different traffic zones in the Duhok City. Temperatures found with both minimum and maximum values, meanwhile wind direction was denoted by the four directions as North, South, East, and West, South East, North East, South West, and North West, with their average wind speed values.

3.4 Step-wise Multiple Regression Analysis

Regression analysis is a statistical procedure between dependent and independent variables related to air pollution concentrations in the study area. The approach is mathematical, and all variables are considered random with normal distribution.

Predicate air pollution for each of the four gases included in this study could be obtained and estimated in the future by using the statistical package (SPSS Package Version 20) (2014). [44] They are integral systems of statistical transform, and graphics designed to assist user in exploring and modeling data.

Based on the previous notion from different literatures, step-wise multiple linear regressions were used to develop air pollution models for each of the four gases pollutants selected for analysis in this study.

3.4.1 Variables Definition

The following dependent variables were used for disaggregate models at street sections:

X_1 = Total number of trips done by family members using public transit ;

X_2 = Total number of trips done by family members using private car, and /or taxi;

X_3 = Number of cars owned by each individual family,classifed in this study as 0,1,2,2 or more and introduced as a variable in the regression models;

X_{13} = Number of household having zero cars;

X_{23} =Number of households having one car only;

X_{33} =Number of households having two cars only;

X_{34} =Number of households having more than two cars;

X_4 = Family income in I.D.;

X_5 = Total number of trips made by each family citizens by both private , and public mode of transport (i.e., X_1+X_2);

Y_{1CO} = Amount of carbon monoxide gas measured within each zone boundary in ppm.

Y_{2NO} = Amount of nitrogen monoxide gas measured within each zone boundary in ppm.

Y_{3NO2} = Amount of nitrogen dioxide gas measured within each zone boundary in ppm.

Y_{4SO2} = Amount of sulphur dioxide gas measured within each zone boundary in ppm.

3.4.2 Best Model Selection

Following the rules on which the step-wise multiple regression linear analysis was based by using the SPSS Package Version 20, different correlation coefficients were produced from correlating the above dependent and independent variables. Partial correlation matrix is the column of best model selection, by testing which independent variables are collinear with each other. One of each one or more collinear independent variables was selected in each case to be introduced in the models developed in each of the five models build for each pollutant concentration case out of the four cases. Twenty linear regression models was developed and tested by F Testing Statistic, for whole mode after scanning under collinearity. Statistical special tables were consulted for this purpose. Model validation was conducted by some of the package outputs like predicted values of each dependent variable value frequency histograms and scattregraphs showing predicted data distributions around the diagonals of the Normal Probability Distribution Sheets given as output from analysis.

CHAPTER 4

RESULTS ANALYSIS AND DISCUSSION

4.1 Introduction

Air pollution problem in Kurdistan Region is very serious and critical due to the sprawl in the growth of both people, and vehicles number as it is shown very clearly from the congested intersections and road sections located within the Duhok City Road Network. Data in this study is divided into different branches for analysis and discussion of results. The first part of the study is related to the analysis and presentation of the different pollutant concentrations measured from Road Network of different zones of the city after comparing them with the data of the Directorate of Environment in Duhok City (DED)(2015) [44]. This data were measured and collected around the Duhok City urban area, which concentrates on the general features of the air pollution problem in the city.

The second branch of the problem is related to the deep and rigorous statistical analysis of each type of pollutants on zonally level as the city was divided into 43 traffic zones. Analysis on the second level is related to air pollution resulted due to the socio-economic characteristics of each zone, such as, economic status, size of household using different modes of transport. Modes of transport was classified into two categories including those using private cars, and taxes, and the second category those using public transit in Duhok City, as each one of them will produce effluents different than the other.

Evaluation of the existing air pollution condition will be very clear through comparison of the produced levels of pollution with the local standards of pollutants in the Region, and the International Levels like those used in USA recommended by the EPA(Environmental Protection Agency)(2010) [46], and applied annually by the National Ambient Air Quality Standards (NAAQS)(2010) [47].

4.2 Environmental Air Pollution Features in Duhok City Urban Area.

The Directorate of Environment in Duhok is the main office in the city responsible on publishing the main data related to city pollution condition from time to time (2013) [40]. Data periodically published is depending on main data collection from different stations in the city of Duhok like Shorash station near Shorash Bridge, and professionals are used to read concentration measurements of different pollutants from time to time usually each eight hours along the different weak days, along months annually. Their data describe in some detail the environmental condition all around the City of Duhok. In this study a special device mentioned in chapter three was used to measure the air pollution concentrations for the four popular gases selected and they are, CO, NO, NO2, and SO2

4.2.1 Hourly Variation of Pollutant Concentrations in Duhok City

According to the data collected in this study during a ten month period during (2014-2015), showing the hourly variation of the concentrations of four main pollutants usually found in the air of the city which are, CO,NO_2, NO, and SO_2. The following description is showing how each one of them is going to vary in concentration during the hours of a certain day:

4.2.1.1 Hourly Variation of CO Pollutant in Duhok City

The first feature reflecting air pollution hazard in Duhok City is the CO gas measured concentration. Figure 4.1, is showing the eight hour period measurement of the CO gas, depending on the measured of data collection. The Figure showing that, CO variation is going to be less than average during night time from (00.00-8:00) A.M. then it is starting to increase more than average during the noon , and afternoon period to be more than average values. Maximum permissible value of the concentration of this pollutant in Kurdistan Region is 9.0 ppm measured for eight hours period as shown in Figure 4.1 the obtained hourly concentration of CO gas is highly lower than this recommended value. From this result, it could be concluded that, CO gas as highly hazardous pollutant is still under control in Duhok City. Figure 4.2 is showing the maximum concentration of the CO gas as noticed in some places in Duhok City.

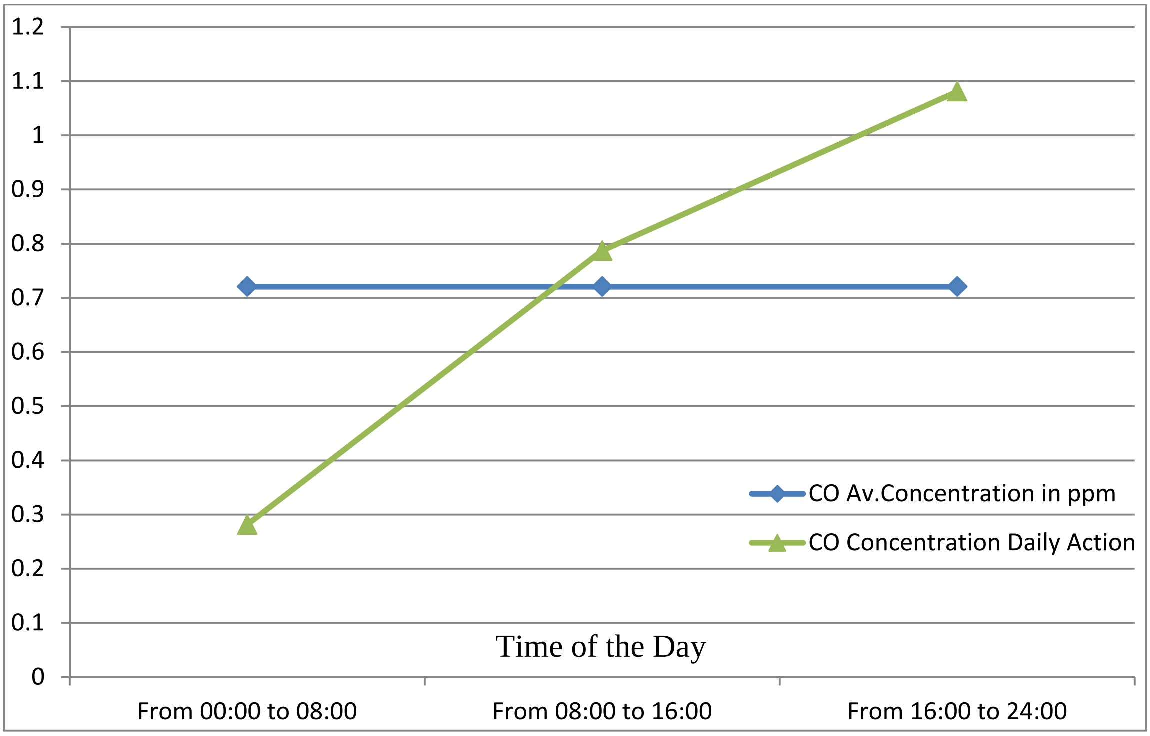


Figure 4.1 Average Measured Hourly Annual CO Gas Concentrations in Duhok City during Ten Months in (2014-2015).

. Figure 4.2 is going to give the same indication and variation of results of the lower values, but little higher during the period afternoon until midnight.

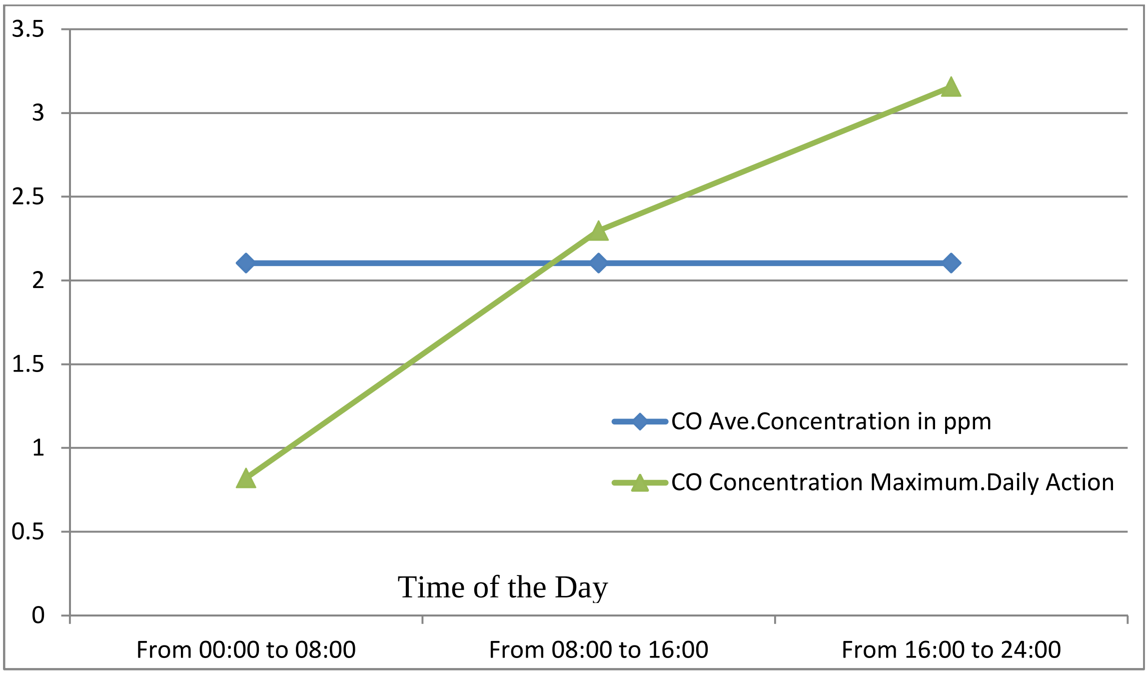


Figure 4.2 Maximum Observed Hourly CO Gas Concentrations in Duhok City during Ten Months in (2014-2015).

The following GIS maps shown in Figures 4.3, 4.4, and 4.5 are showing the average values of CO air pollutant gas data obtained for ten months during the period (2014-2015) for all the Duhok City Urban Area.

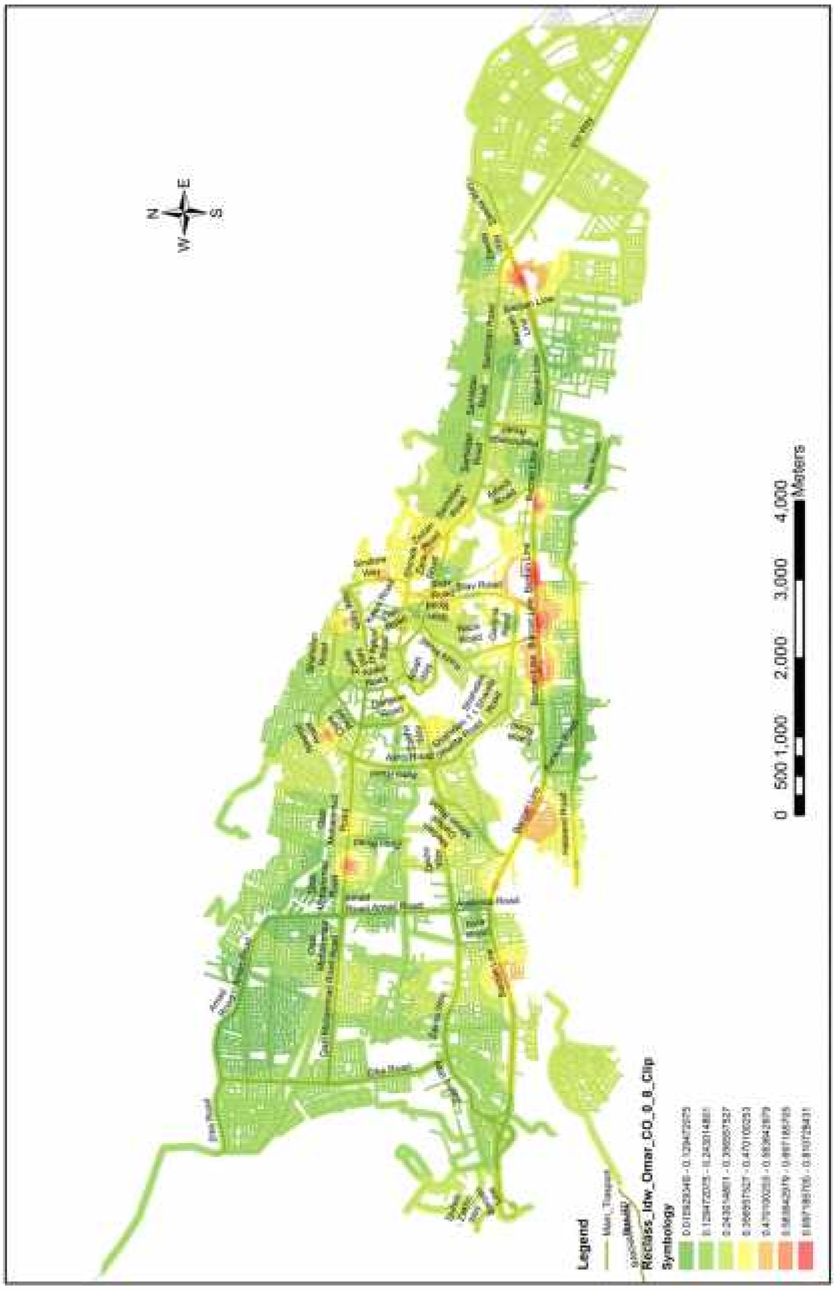


Figure 4.3 GIS Map for the Duhok City Showing CO Pollutant Concentrations on Urban Area during the Period (00:00-8:00) at Morning.

The three Figures showing that, CO concentrations are going to increase step by step from Morning up to Evening periods drastically but still higher lower than the standards

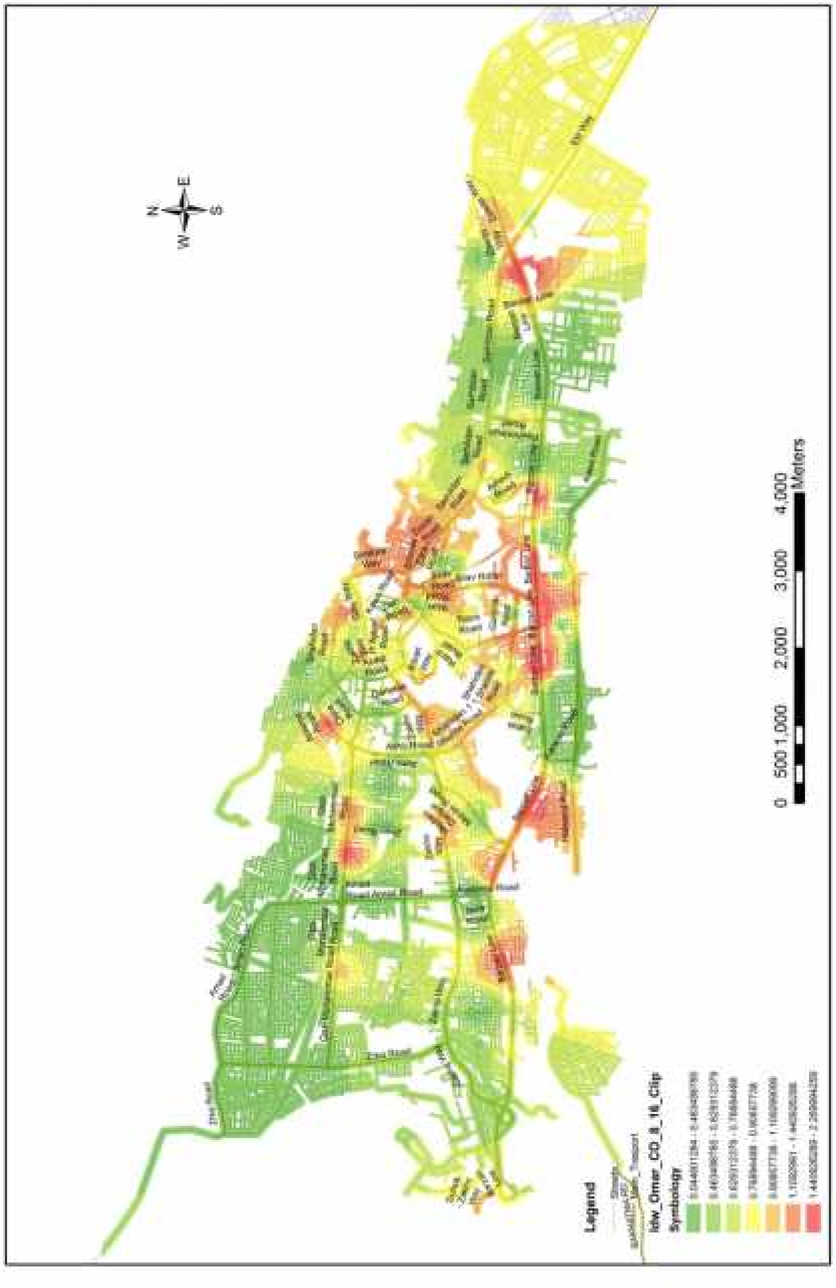


Figure 4.4 GIS Map for the Duhok City Showing CO Pollutant Concentrations on Urban Area during the Period (00:08-16:00) at Mid-day.

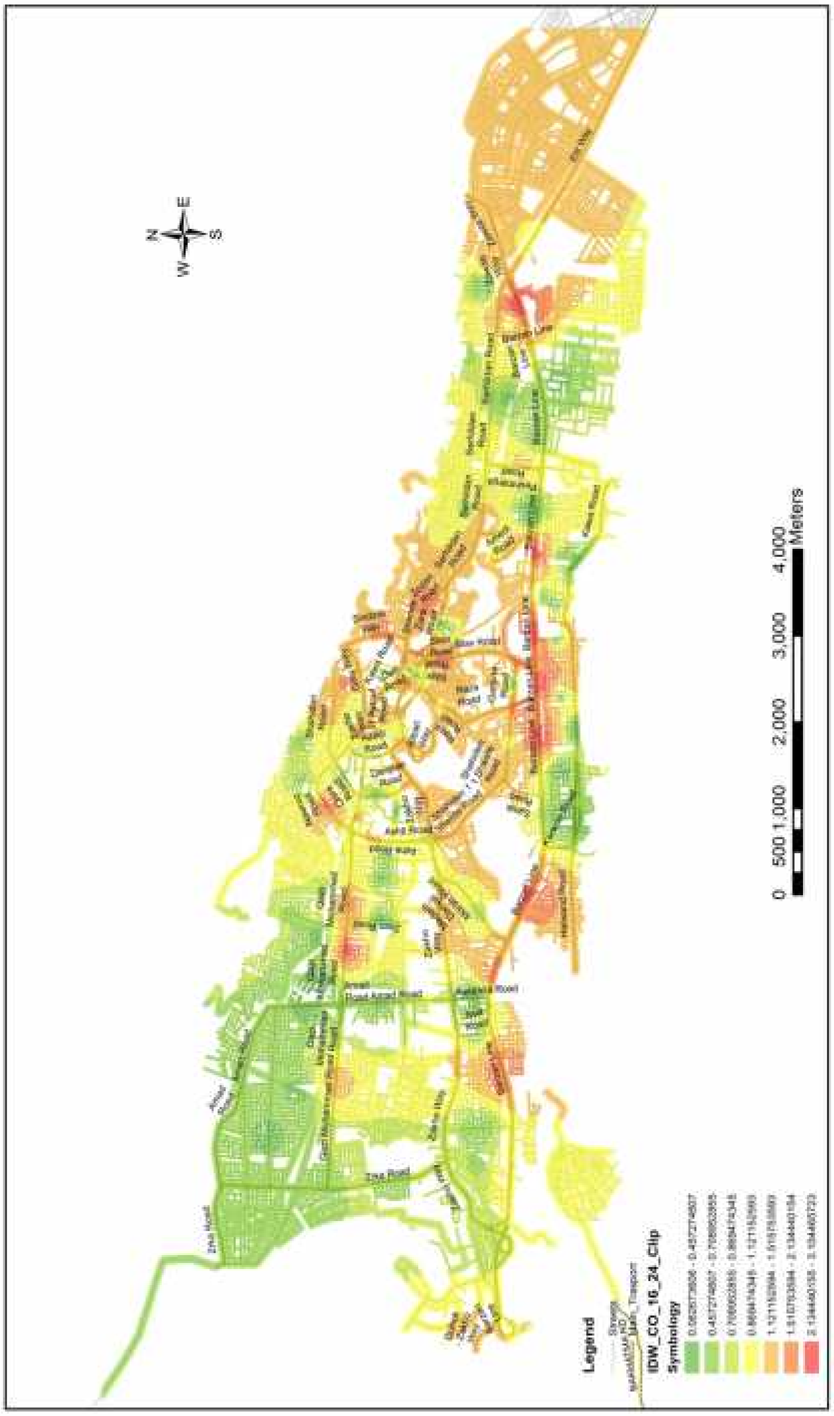


Figure 4.5 GIS Map for the Duhok City Showing CO Pollutant Concentrations on Urban Area during the Period (16:00 -24:00) at Evening.

4.2.1.2 Hourly Variation of NO Pollutant in Duhok City

Nitrogen monoxide is the second air pollution feature could be represented in this article using the study measured ten month data. Figure 4.6, is showing the hourly variation of NO concentrations around Duhok City urban area. The Figure shows that NO amount polluted from vehicles is under the total average value during the first eight hour at night from (00:00-8:00) A.M. after that, it is going to be higher as the number of vehicles is increasing on road network. After mid-day period it is increasing more to be high during the last eight hours of the day. The results obtained for NO concentrations are still under the average standard amount recommended in the Region which is 0.053 ppm as one year measurement period given by the Kurdistan Region Standards. NO is a serious dangerous gas as it is affecting the human health by air during breath, and at drinking water.

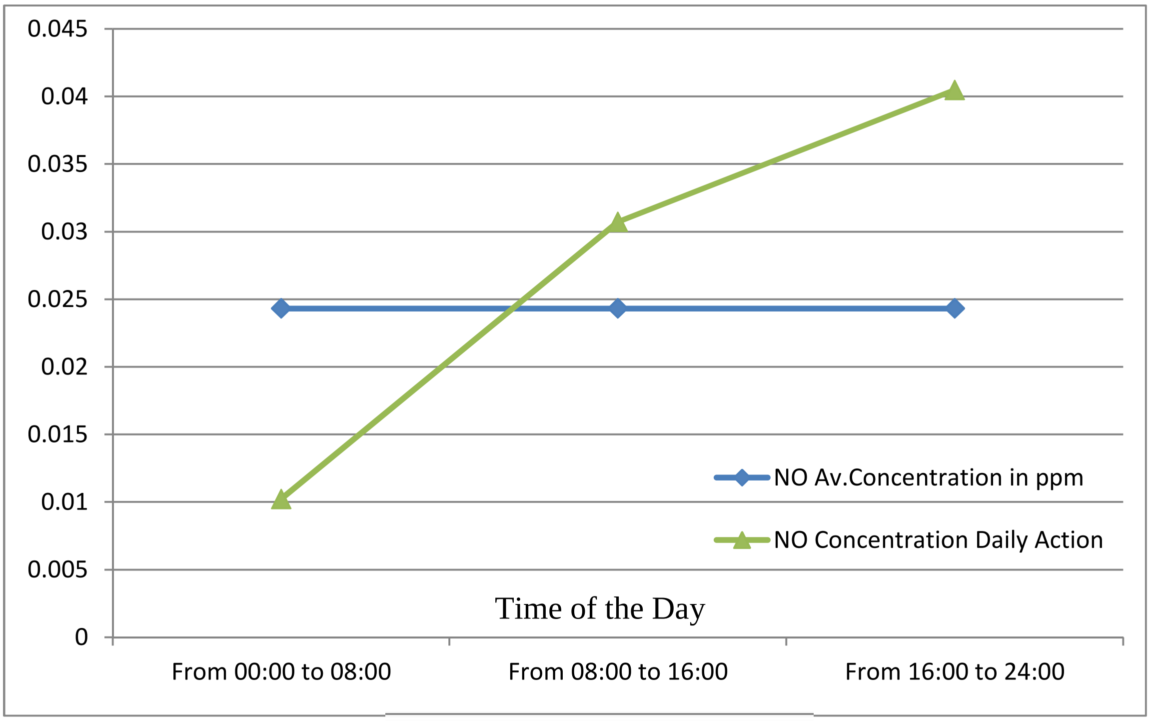


Figure 4.6 Average Measured Hourly Annual NO Gas Concentrations in Duhok City during Ten Month Period on (2014-2015)

Maximum observed values of NO gas concentrations in some hot spots shown on the map of the city in Figure 4.3 to Figure 4.5 in red color is showing a similar trend shown in Figure 4.6 for the same NO pollutant.

The following GIS maps shown in Figures 4.7, 4.8, and 4.9 are showing the average values of NO air pollutant gas data obtained for ten months during the period (2014-2015) for all the Duhok City Urban Area.

Figure 4.7 GIS Map for the Duhok City Showing NO Pollutant Concentrations on Urban Area during the Period (00:00-08:00) at Morning.

The three Figures are showing that, NO concentrations are going to increase step by step from Morning up to Evening periods drastically.

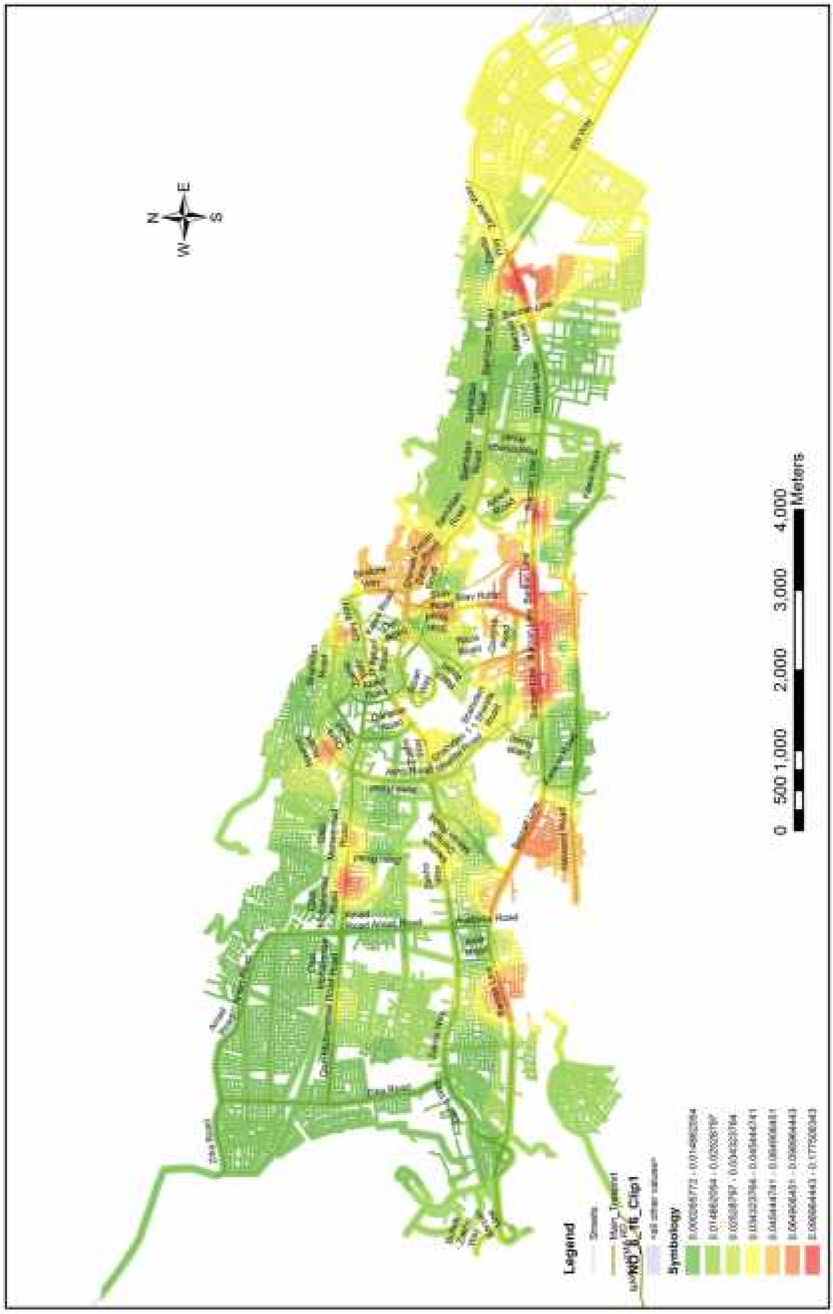


Figure 4.8 GIS Map for the Duhok City Showing NO Pollutant Concentrations on Urban Area during the Period (08:00-16:00) at Mid-day.

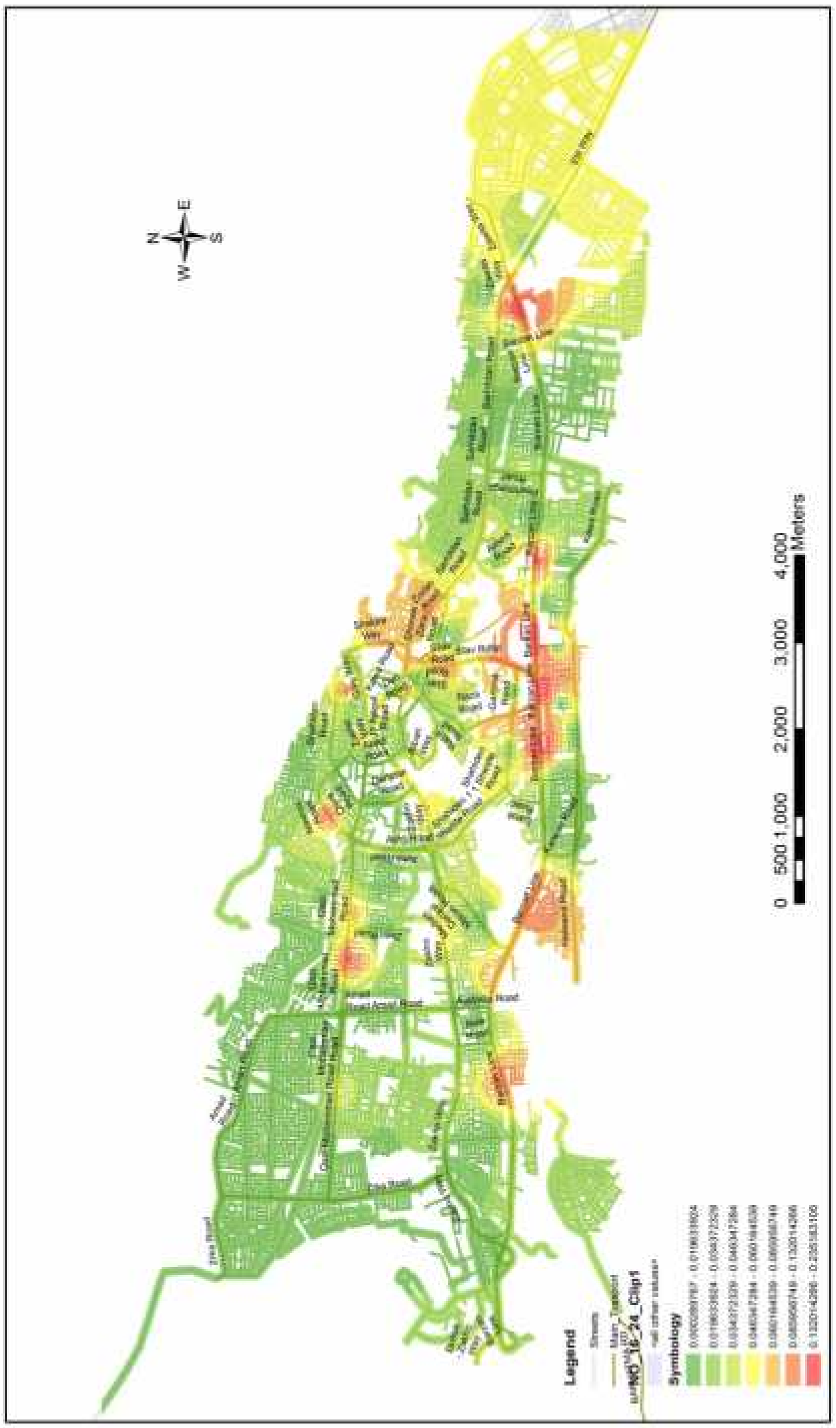


Figure 4.9 GIS Map for the Duhok City Showing NO Pollutant Concentrations on Urban Area during the Period (16:00-24:00) at Evening.

4.2.1.3 Hourly Variation of NO2 Pollutant in Duhok City

Nitrogen dioxide is one of the main pollutants to the environment generated from transport movement in the urban road network. Data obtained from this study, and plotted in Figure 4.10 is showing how the NO_2 concentrations are going to vary with the hours of the day in Duhok City area. NO_2 recommended value by the Iraqi Ministry of Environment Standards (IMES) considering one year period of measurement that not should be more than 0.05ppm, and the values actually measured are not more, but on the contrary they are farther less (2008) [39]. Total average value of the concentrations during the last ten month period was 0.02ppm only, which is less than standard recommended, listed above. Figure 4.10 is showing also how the NO_2 concentration is varying during average day that it is highly less than total average during night time until morning, and due to the increase in traffic movement it is going to increase to be more than this average at noon, and afternoon periods. NO_2 amount is going to increase abruptly until night time due to further increase in traffic movement. This dangerous condition should enhance decision makers to build a program for better control to the growth of such pollutants in the future.

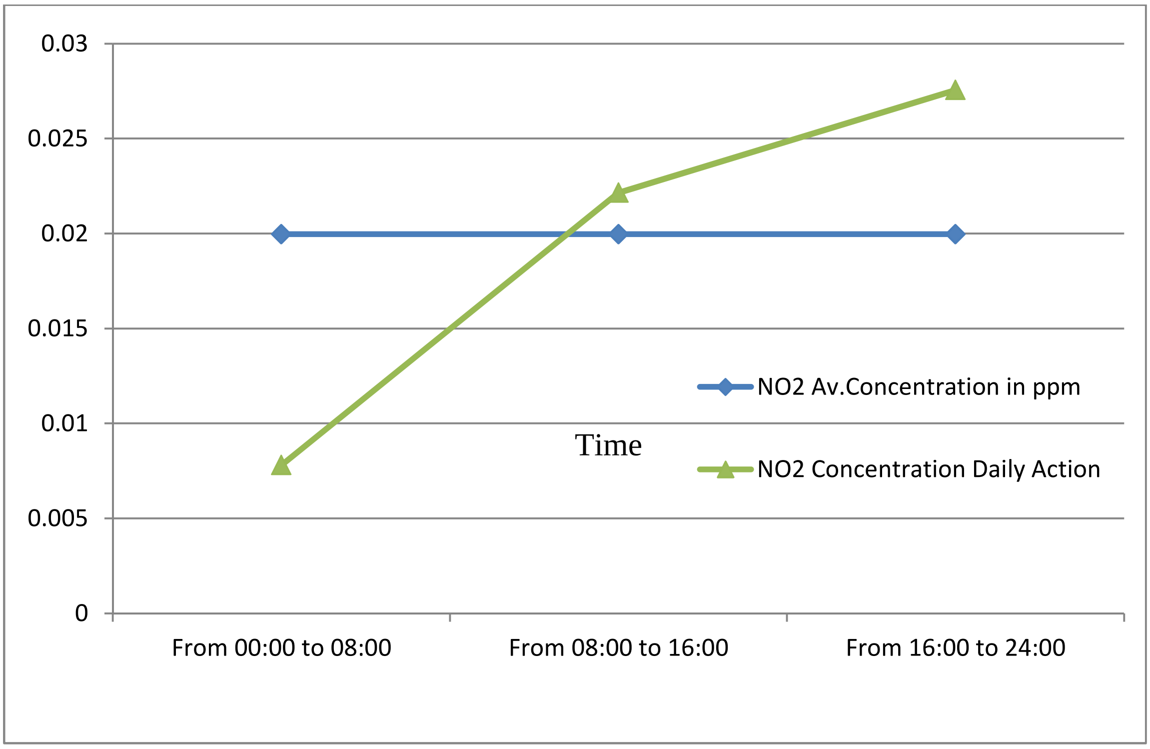


Figure 4.10 Average Measured Hourly Annual NO2 Gas Concentrations in Duhok City during Ten Month Period on (2014-2015)

Maximum observed values of NO_2 gas concentrations in some hot spots shown on the map of the city in Figure 4.11 up to Figure 4.13 in Duhok City Urban Area.

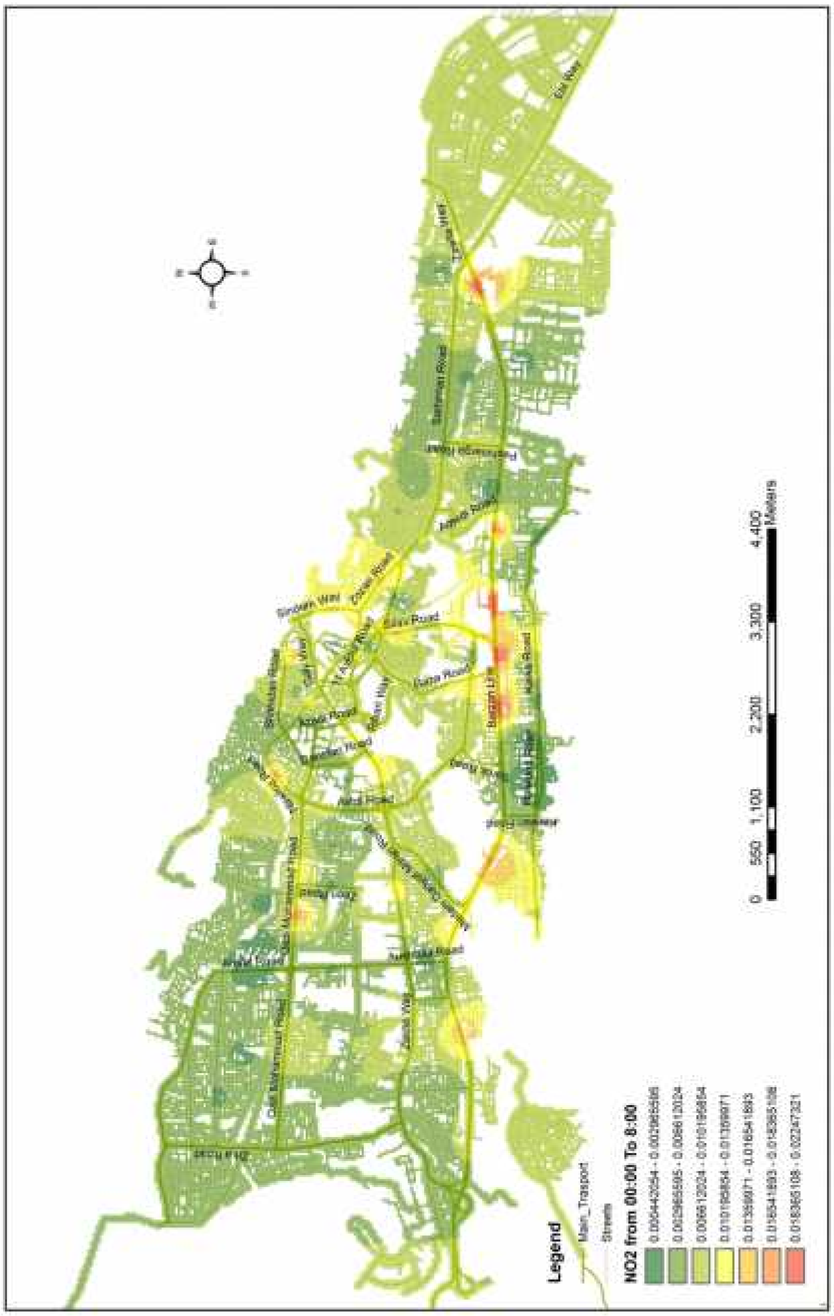


Figure (4-11): GIS Map for the Duhok City Showing NO_2 Pollutant Concentrations on Urban Area during the Period (00:00-08:00) at Morning.

The red color is showing a similar trend shown in Figure 4.10 for the same NO_2 pollutant.

Figure (4-12): GIS Map for the Duhok City Showing NO_2 Pollutant Concentrations on Urban Area during the Period (08:00-16:00) at Mid-day.

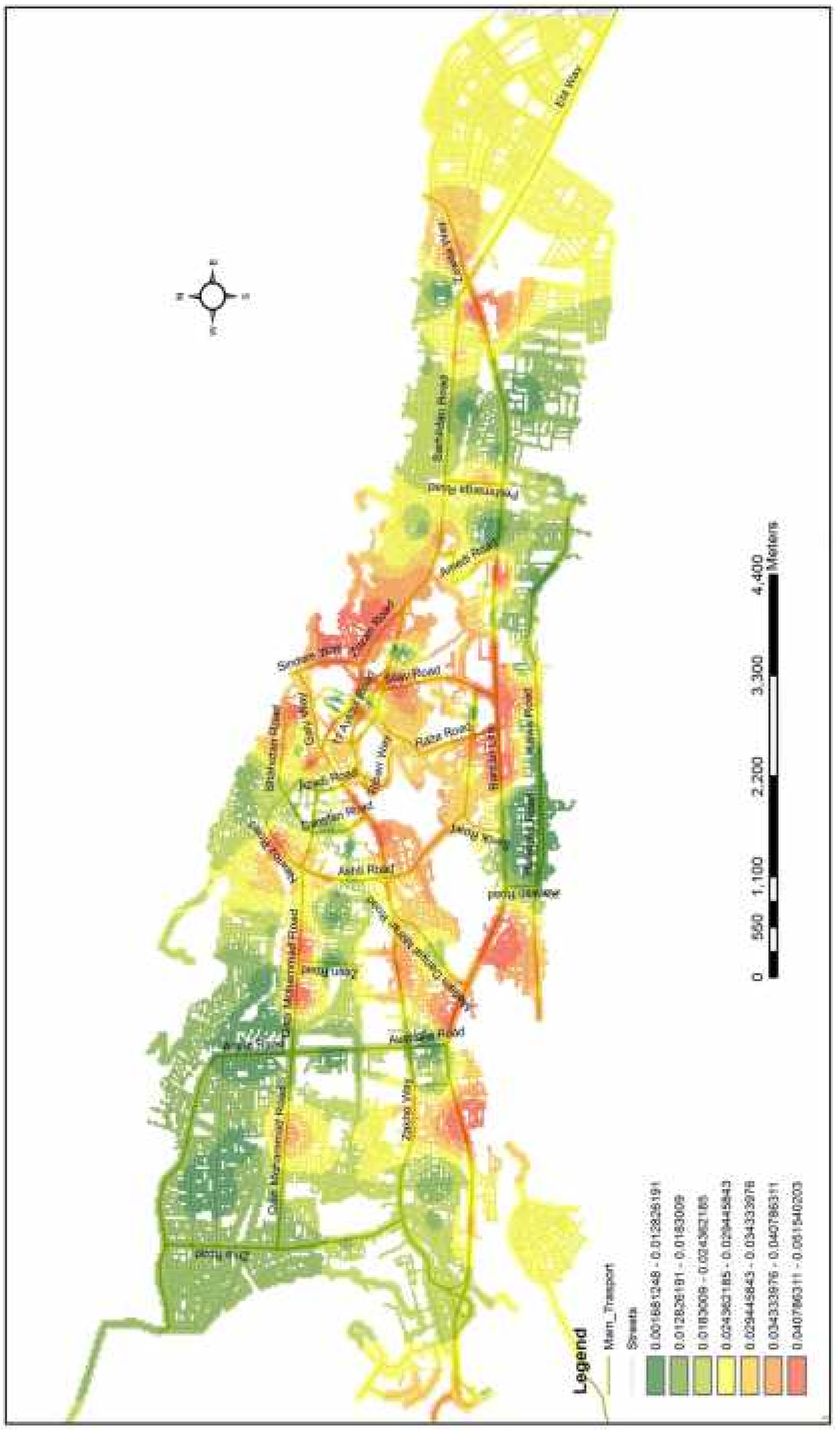


Figure (4-13): GIS Map for the Duhok City Showing NO2 Pollutant Concentrations on Urban Area during the Period (16:00-24:00) at Evening.

4.2.1.4 Hourly Variation of SO2 Pollutant in Duhok City

The fourth parameter of the measurement of pollutant in Duhok City in this study is the concentrations of a most dangerous gas produced due to traffic movement and their internal combustion engines, is SO_2. Figure 4.14 is showing how this gas is going to increase in its amount from mid-night period up to the end of the day. SO_2 trend in increasing along the day and night is looking like the other above three pollutants mentioned above. It is increasing at the first 8.10 hours at A.M period, then it becomes above the total average value for the last ten months of data measured for Duhok City. After mid-day it is going to increase above the average limit and still continuously increasing until midnight period. The values described in Figure 4.14 are not coming to overpass the maximum value recommended by (IMES) , which is 0.03 ppm considering one year measurement period(2008) [39]. Sulphur dioxide occurs both naturally and as a result of man's activities. Sulphur dioxide is a colorless gas with a strong choking smell which easily dissolves in water to form sulphuric acid H2SO4. It is relatively dense; about 2.5 times heavier than air as given by SEPA (2012) [48].

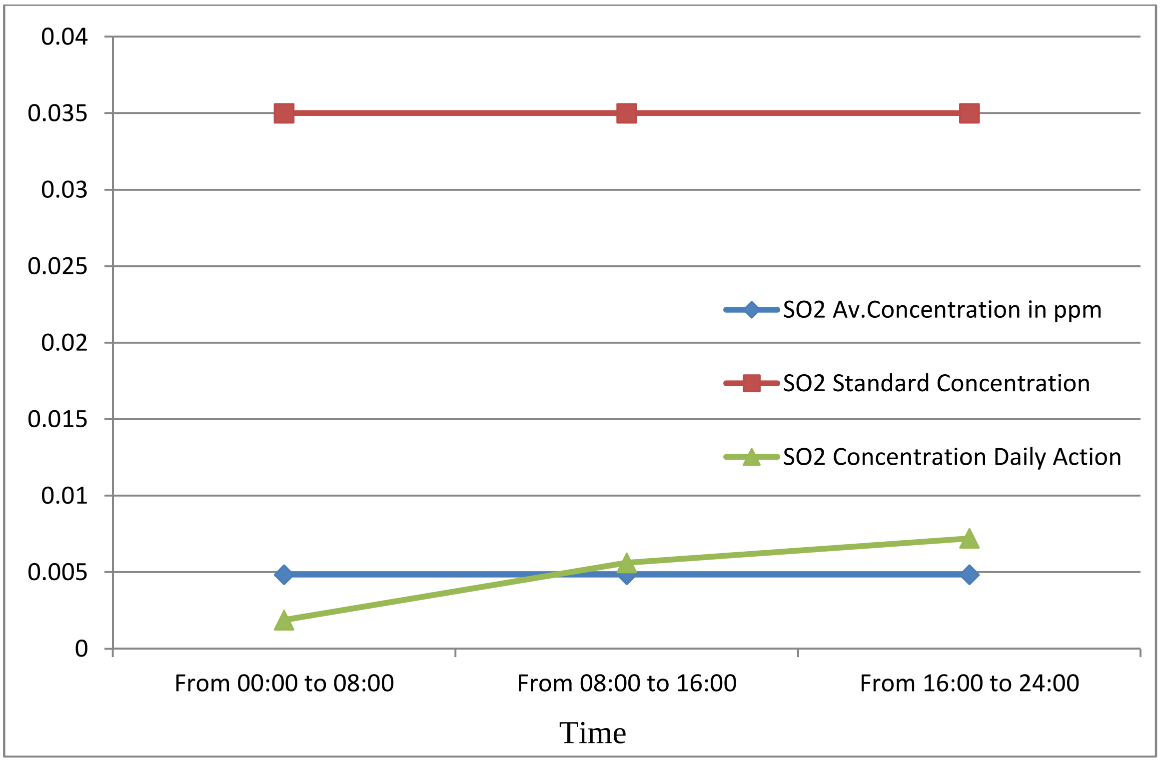


Figure 4.14 Average Measured Hourly SO2 Gas Concentrations in Duhok City during Ten Month Period on (2014-2015).

Maximum observed values of SO_2 gas concentrations in some hot spots shown on the map of the city in Figure 4.16 up to Figure 4.18 in red color is showing a similar trend shown in Figure 4.15 for the same SO_2 pollutant, which gives the same trend in the variation of the gas concentrations, but sometimes higher in values close to the maximum recommended especially at afternoon periods in Barzan Road).

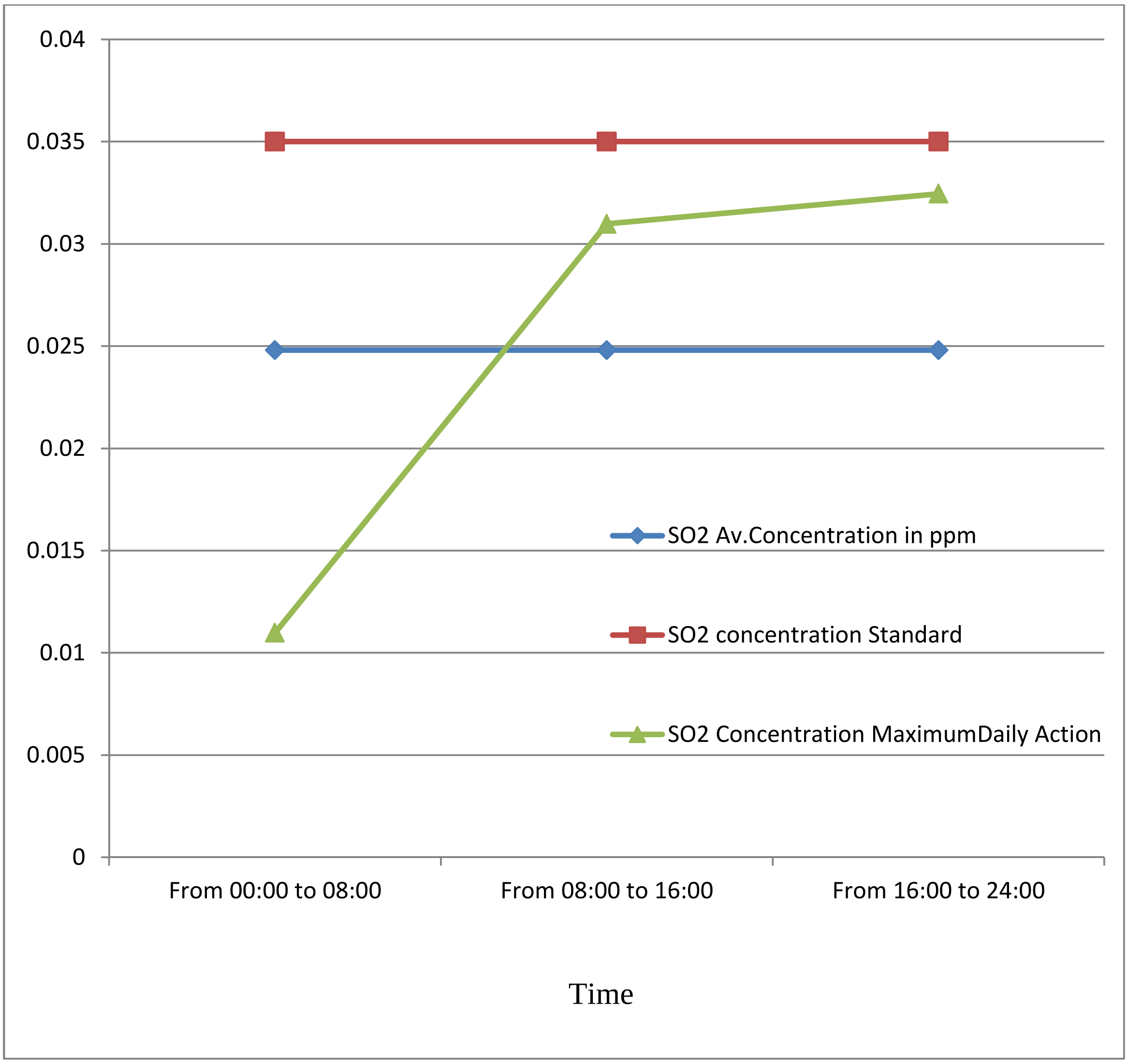


Figure 4.15 Maximum Observed Hourly SO2 Gas Concentrations in Duhok City during Ten Months Period on (2014-2015)

The following GIS maps shown in Figures 4.16, 4.17, and 4.18 are showing the average values of SO2 air pollutant gas data measured for ten months during the period(2014-2015) for all the Duhok City Urban Area. The three Figures are showing that, SO2 concentrations are going to increase step by step from Morning up to Evening periods drastically, which is a dangerous phenomenon in this city.

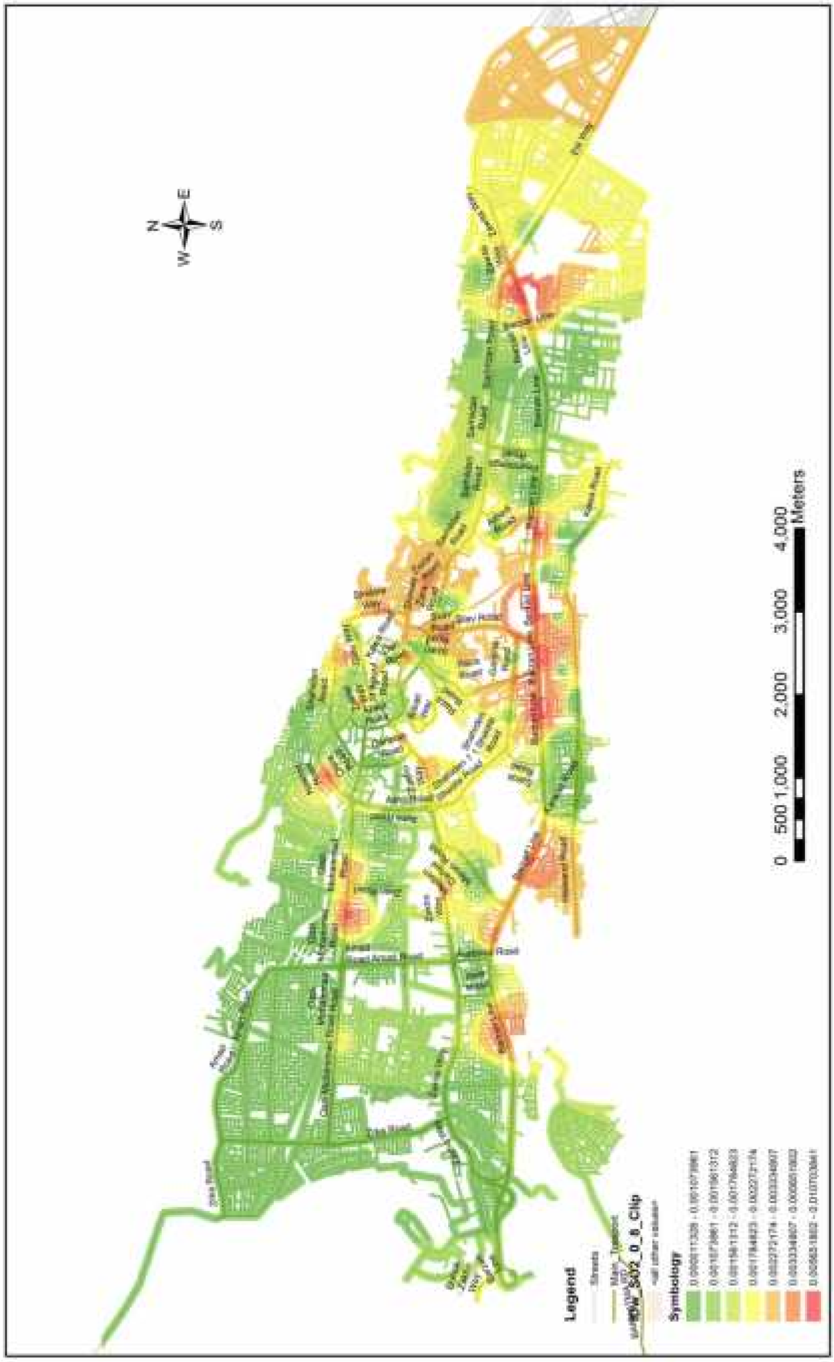


Figure 4.16 GIS Map for the Duhok City Showing SO_2 Pollutant Concentrations on Urban Area during the Period (00:00-8:00) at Morning.

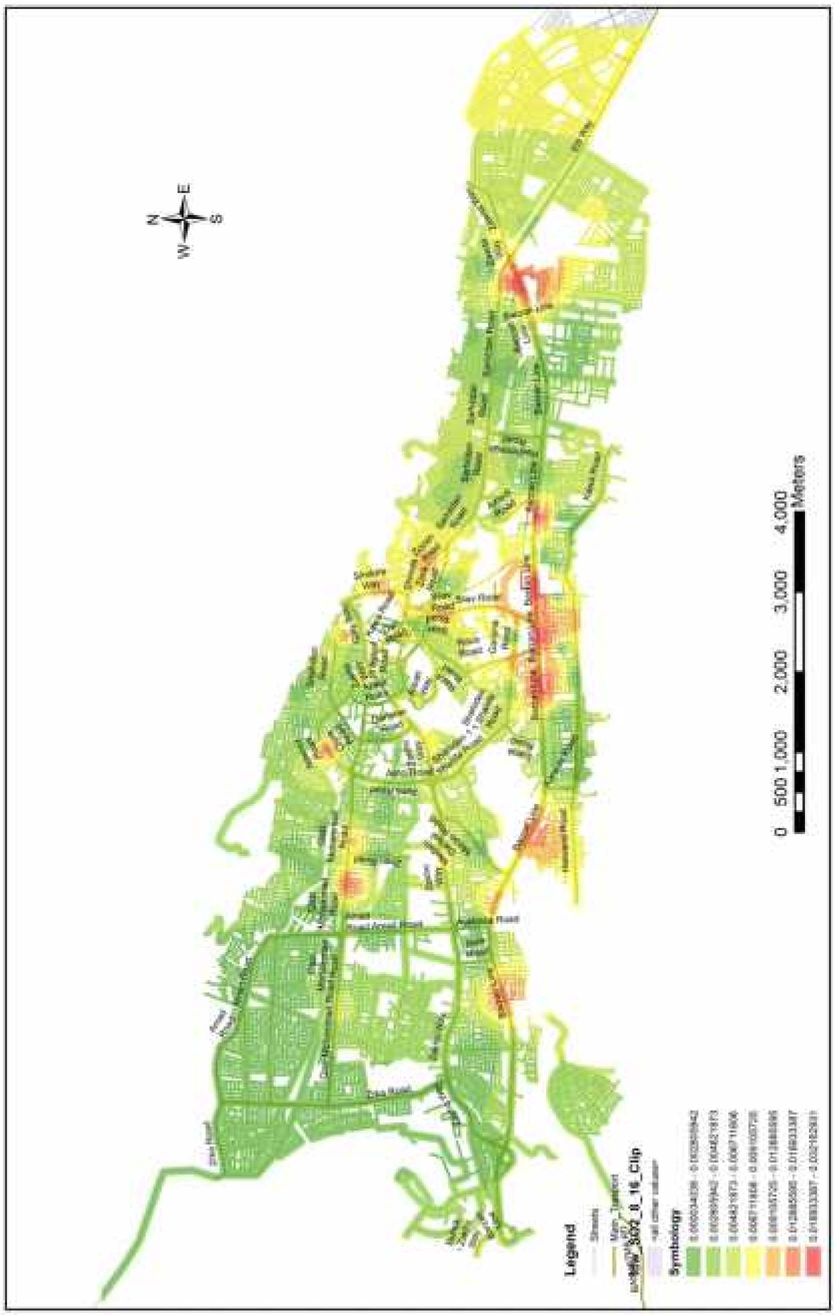
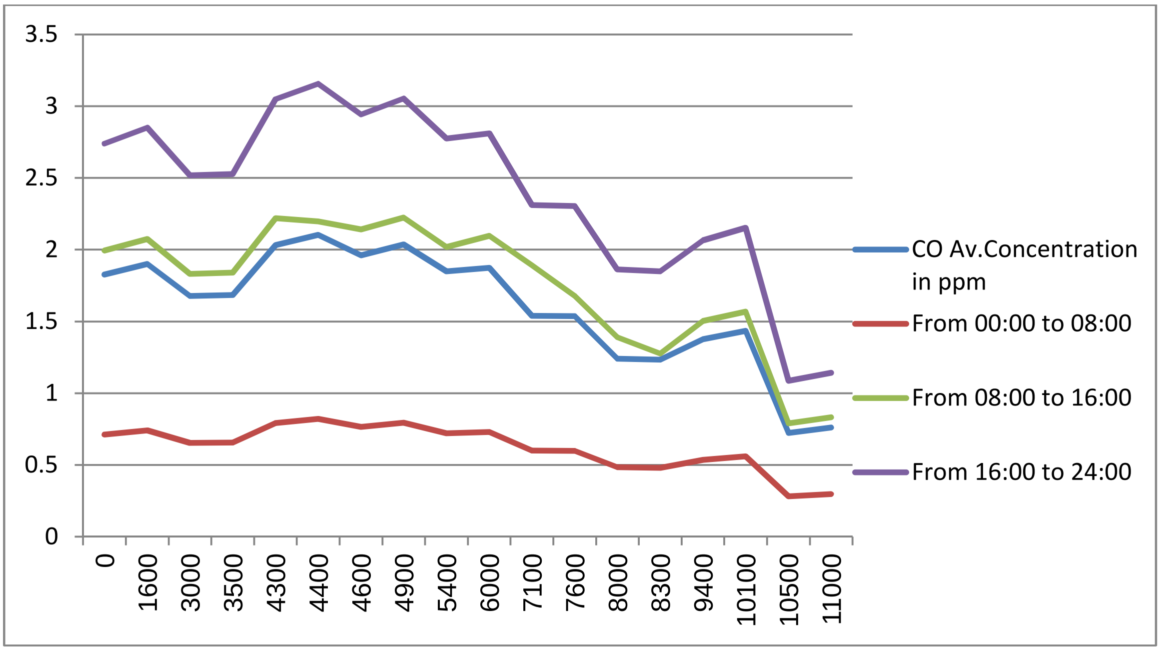


Figure 4.17 GIS Map for the Duhok City Showing SO_2 Pollutant Concentrations on Urban Area during the Period (08:00-16:00) at Mid-day Period.

Figure 4.18 GIS Map for the Duhok City Showing SO_2 Pollutant Concentrations on Urban Area during the Period (16:00-24:00) at Evening Period.

4.2.1.5 CO Pollutant Variation along Barzan Arterial Road Length

Carbon monoxide pollutant average concentrations measured in this study is plotted in Figure 4.19 to show how it is coming to change on the different segments of Barzan arterial road. Maximum values of this gas are taken to be presented in the Figure. Gas concentration is going to be low at the (00:00-08:00) A.M. period with low values at the beginning of the road ,then it is increasing with increase in the length of this road up to (16:00-24:00) midnight period the peak gas concentration values is located between(4,000-6,000) meters. Values of CO concentration are shown in Figure 4.19 to decrease for all periods with the increase in road length of this road, especially after 6,000 meters value of distance from beginning. Average values of CO concentration is following the same trend discussed above, but it is lower than both pollutant values obtained for the two periods from (8:00-24:00).



Length of the Road in meters

Figure 4.19 Maximum Observed Hourly CO Gas Concentrations on Barzan Arterial Road Located in Duhok City during Ten Months Period on (2014-2015)

The maximum measured concentration value of this dangerous gas is lower than the standard permissible limit of 9 ppm given in article (4-2-1-1). Figure 4.3 is showing the concentrations of this gas during the period from (00:00-8:00) period in red color, meanwhile Figure 4.19 is showing that, the concentrations of this gas during the period (8:00-16:00) at mid-day period. It is shown from Figure 4.19 that CO concentrations on Barzan Road during this period is higher and distributed along a wider area than the other period as given in Figure 4.4.

4.2.1.6 NO Pollutant Variation along Barzan Arterial Road Length

Nitrogen monoxide pollutant average concentrations measured in this study is plotted in Figure 4.20 to show how it is coming to change with road length measured from beginning of the different segments of Barzan arterial road. Maximum values of this gas are taken to be presented in this Figure. Gas concentration is going to be moderate in value at the (00:00-08:00) A.M. period at the beginning of the road length ,then it is increasing with the increase in length up to (16:00-24:00) midnight period however, when road length is increasing, peak values of gas concentration is obtained when road length is located between(4,000-5,000) meters . A value of NO concentration is shown in Figure 4.10 to decrease for all periods with the increase in road length of this road, especially after 5,000m value. Average values of NO concentration are following the same trend discussed above and more than the three hourly variation period values. The maximum measured concentration value obtained of this dangerous gas is lower than the standard permissible limit of 0.053 ppm given in article (4-2-1-2).

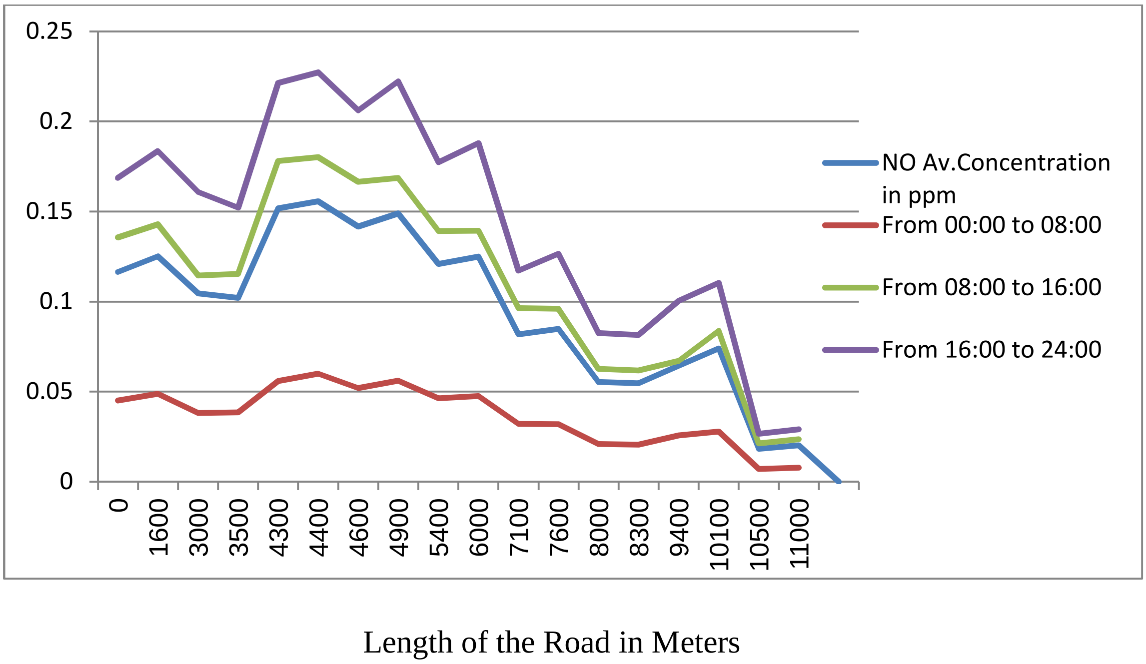
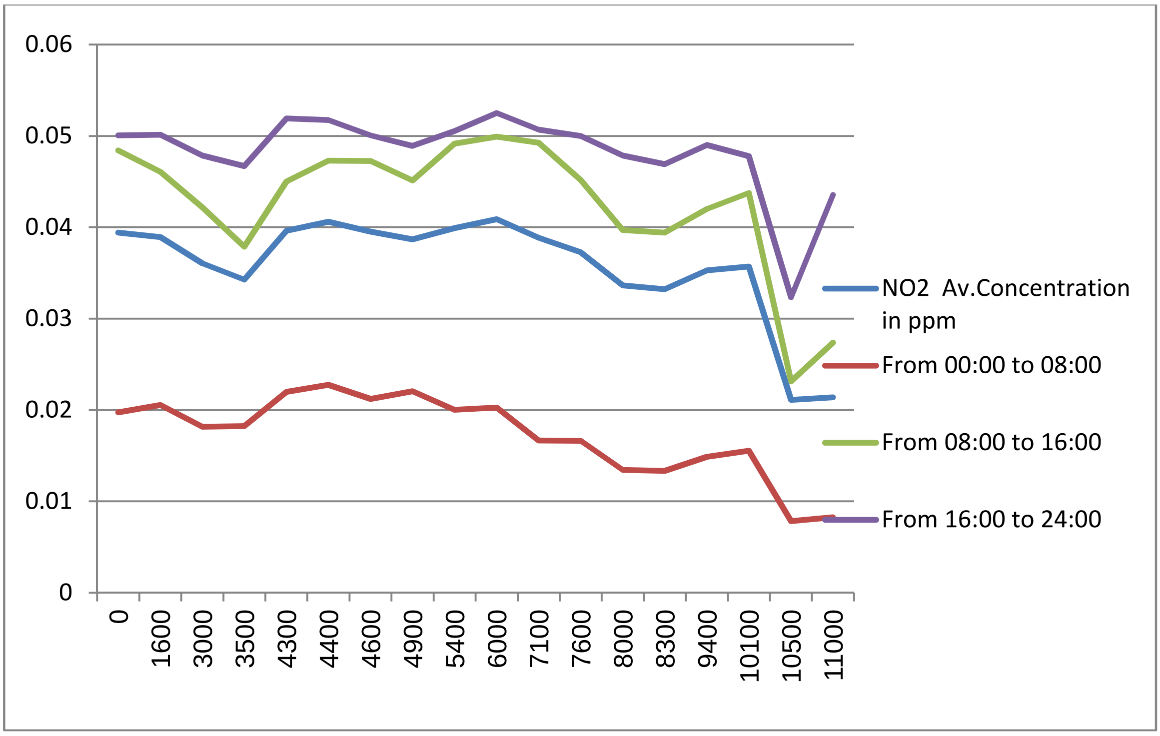


Figure 4.20 Maximum Observed Hourly NO Gas Concentrations on Barzan Arterial Road Located in Duhok City during Ten Months Period on (2014-2015)

4.2.1.7 NO2 Pollutant Variation along Barzan Arterial Road Length

Nitrogen dioxide pollutant average concentrations measured by this study are plotted in Figure 4.21 to show how it is coming to change with distance on the different segments of Barzan arterial road. Maximum values of this gas are taken to be presented in this Figure. Gas concentration is going to be moderate in value at the (00:00-08:00) A.M. period with the beginning of the road ,then it is slightly increasing with the increase in length on this road up to (16:00-24:00) midnight period however, distance is increasing to obtain peak values of gas concentration on a section located between(3,000-10,000) meters. Values of NO_2 concentration is shown in Figure 4.21 to increase for all periods with the increase in road length, especially after 3,000 meters value. Average values of NO_2 concentration is following the same trend discussed above, but it is lower than both pollutant values obtained for the two periods from (8:00-24:00) hr. The maximum obtained concentration value obtained of this dangerous gas is lower than the standard permissible limit of 0.050ppm given in article (4-2-1-3).

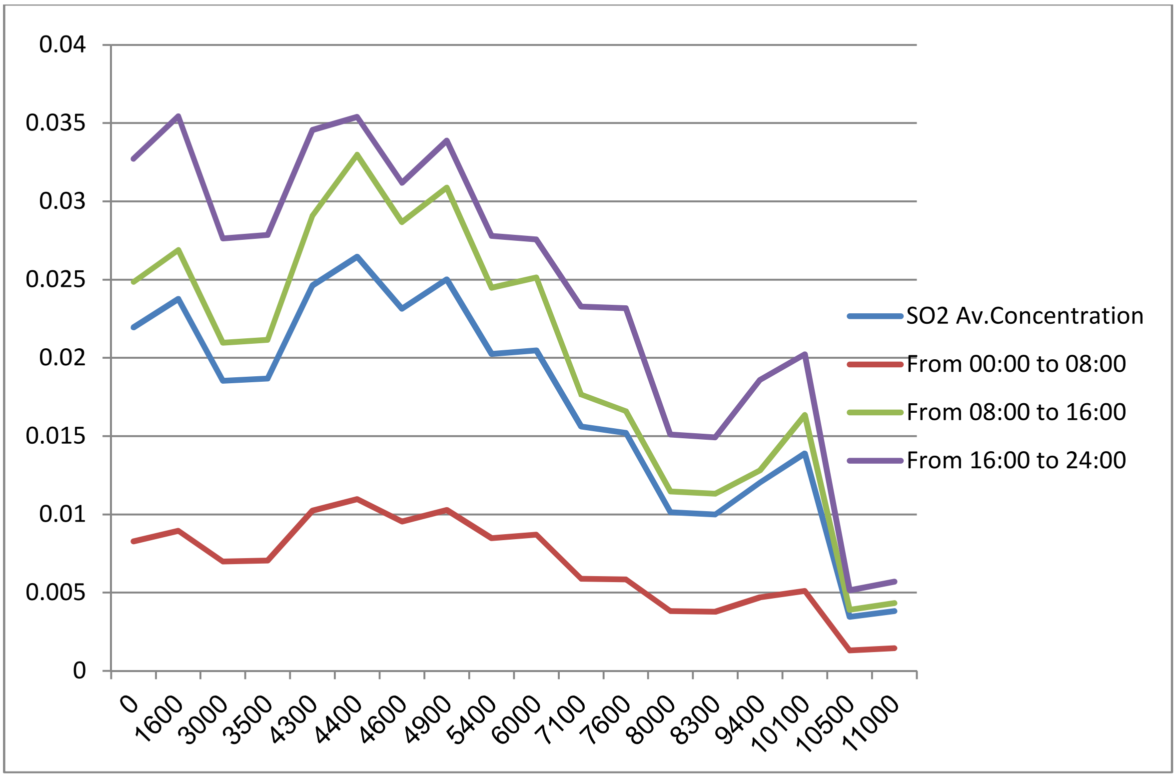


Length of the Road in Meters

Figure 4.21 Maximum Observed Hourly NO2 Gas Concentrations on Barzan Arterial Road Located in Duhok City during Ten Months Period on (2014-2015)

4.2.1.8: SO2 Pollutant Variation along Barzan Arterial Road Length

Sculpture dioxide pollutant average concentrations measured in this study is plotted in Figure 4.22 to show how it is coming to change with the different segments of Barzan arterial road. Maximum values of this gas are taken to be presented in this Figure. Gas concentration is going to be moderate in value at the (00:00-08:00) A.M. period at the beginning length of the road ,then it is slightly increasing with the increase in length of this road up to (16:00-24:00) midnight period however, road length is increasing to obtain peak values of gas concentration at sections located between(3,500-5,000) meters. Values of SO_2 concentration is shown in Figure 4.22 to increase for all periods with the increase in road length of this road, especially after 3,500 meters value. Average values of SO_2 concentration is following the same trend discussed above, but it is lower than both pollutant values obtained for the two periods from (8:00-24:00) hr.



Length of the Road in Meters

Figure (4-22): Maximum Observed Hourly SO2 Gas Concentrations on Barzan Arterial Road Located in Duhok City during Ten Months Period on (2014-2015)

The maximum concentration value obtained of this dangerous gas is more than the standard permissible limit of 0.030ppm given in article (4-2-1-4), especially at the section located between (4,000-5,500) meters during the hourly period from (8:00-24:00) hr. which is a long time period of subjecting people to this dangerous gas during which most human activities are being executed.

4.2.1.9 Four Pollutants Average Concentration Comparison Found in Barzan Arterial Road in Duhok City

One of the main air pollution phenomenon features necessary to be understood in this study is to compare the concentrations of the four health threatening gases in Duhok City .Barzan arterial road is selected with its measured amounts of the four pollutants given by these study measurements to find this relationship. Figure 4.23 is showing the comparisons of the average values among the four gas concentrations included in this study. The amounts plotted against road length values from the beginning of Barzan Road length. Carbon monoxide, which is the most hazardous gas, is having the highest values than the other three pollutants along the Barzan Arterial Road length from start to end from east to west direction of movement.

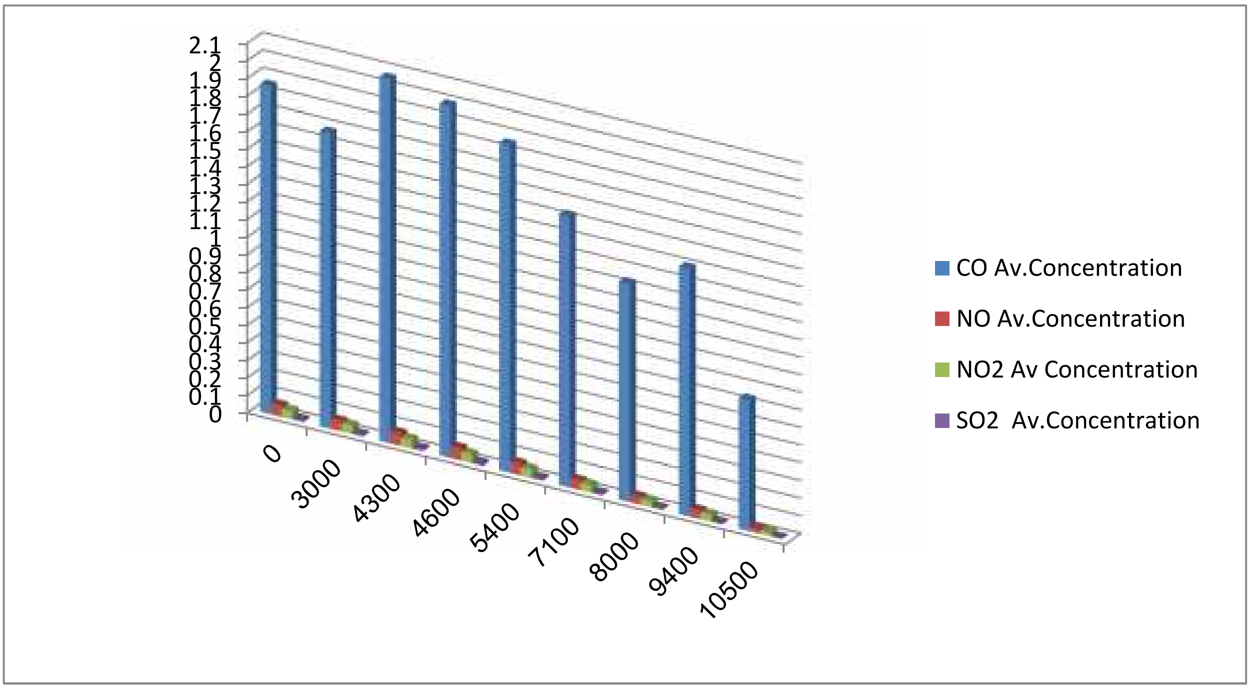


Figure 4.23 Four Gas Pollutant Concentrations Comparision on Barzan Arterial Road Located in Duhok City during Ten Months Period on (2014-2015)

Concentration values occurring along the high ocncentration value periods mentioned above (i.e, after 8:00 hr A.M. period). This result is really important for decision makers to think about a decissive solution about how to control the toxic effect of these four gases.

4.2.1.10 Monthly Variation of the Average Four Pollutant Concentrations Along Barzan Arterial Road

In this study ,the concentartions of the four pollutants are plotted on Figure 4.24 using Word Excel Version 20 Package to show the monthly variation of them (2014) [49]. It is shown that, CO gas concentration is higher than the other three gases along the whole length of Barzan Road, especially in the month of April ,and May,as tourists are coming during this months to Duhok City passing to the most significant recreational areas located in the north part of Duhok City urban area . Values of CO gas concentrations observed are less than the value recommneded by the Kurdistan Region Standards for this gas(2013)[40]. Other three gases are showing lower results of ocncentrations than CO and standards.

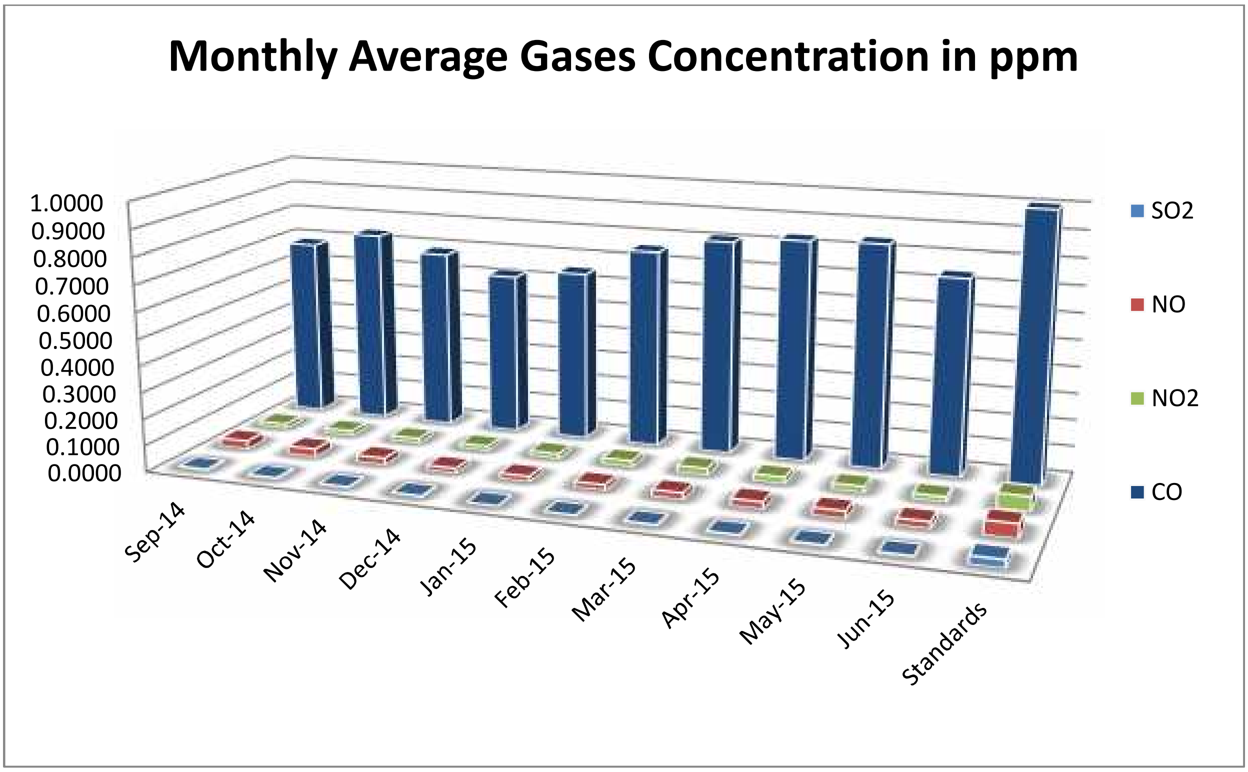


Figure 4.24 Monthly Variation of the Concentrations in ppm of the Four Gase Measured Along Barzan Arterial Road Length During the Period(2014-2015) in Duhok City.

Monthly concentrations of the four pollutants data is presented in this article against the monthly variation of each one of them according to the ten month period included in this study. Figure (4-25) is showing the variation of CO gas along the ten month period, and how average values are going to change from month to month according to the traffic produced on Duhok City Urban Area. Data variation shows that, CO concentrations are still about the same during the study period and average daily, and/or monthly averages are about the same. Measurement of CO concentrations might be limited as short period as possible to reduce time and effort of the data collection team. Team In April, and May it might be a little bit higher, due to heavy traffic entering the city at the beginning of tourism period, and still highly lower than the standard value of 9 ppm.

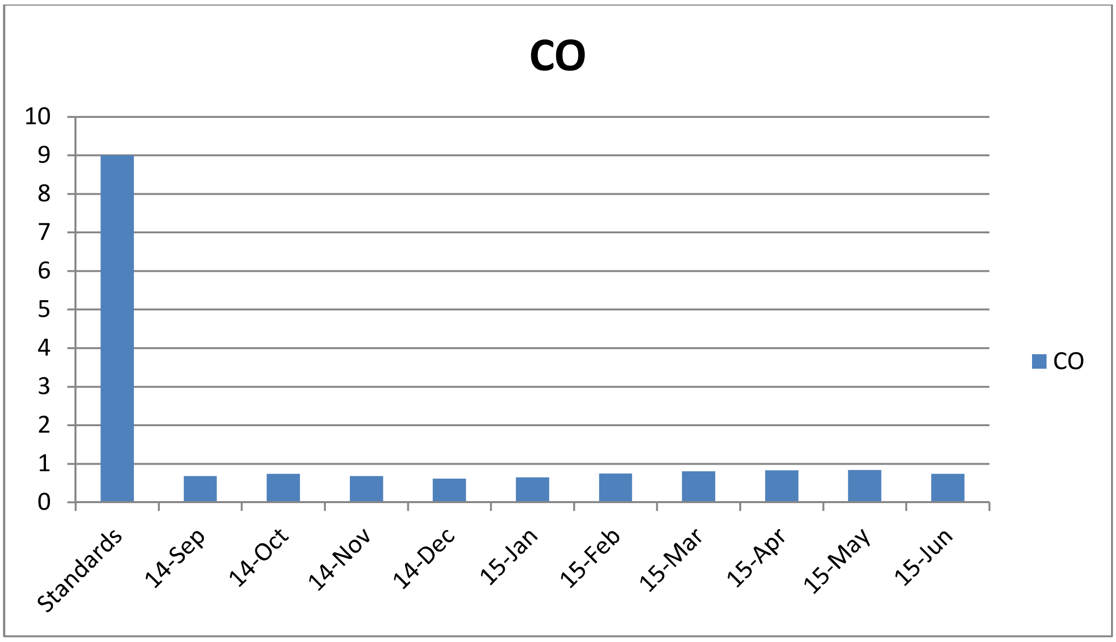


Figure (4-25): Carbon Monoxide Pollutant Variation along Ten Month Period from 14-September -2014 up to 15-June-2015 in Duhok City Urban Area.

Concentrations of NO pollutant are varying in Figure (4-26) during the same ten month period mentioned above. Figure (4-26) is showing, NO gas is still having low values from September-2014 up to February-2015, but started to increase after that

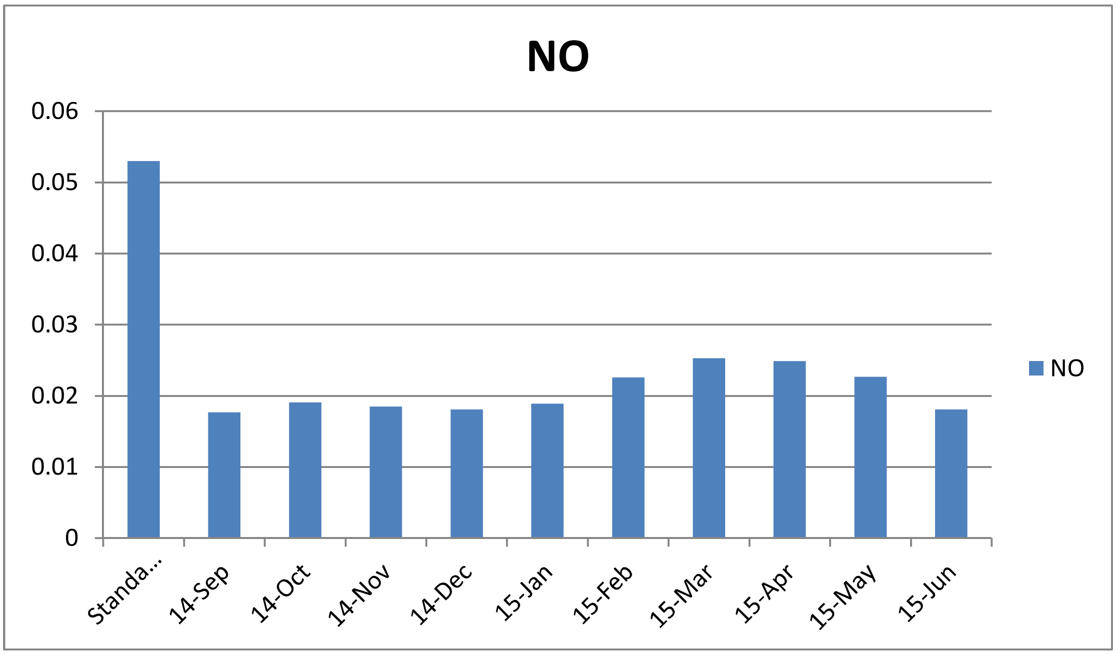


Figure (4-26): Nitrogen Monoxide Pollutant Variation along Ten Month Period from 14-September -2014 up to 15-June-2015 in Duhok City Urban Area.

during the peak tourism period due to traffic congestion on most of the road network of the Duhok City. All ten month measured NO pollutant concentrations are still lower than the standard limited value of 0.053 ppm. Data measurement period of this gas might be limited during peak period from February up to May month.

Figure (4-27) is showing how the NO_2 concentrations are changing from month to month during the ten month studied period in Duhok City Urban Area. Figure (4-27) Shows that, NO_2 pollutant concentration variation is taking some different style of change than the other mentioned above gases. NO_2 amounts are decreasing from September-2014 up to December-2014 to give minimum concentrations, then started to increase again to be optimum at May-2015, then decreased again. This trend is concluding that, measurement of these gas concentrations should limited to optimum period values in September, and October. Peak values measured of this gas are not going to pass the standard limited value of 0.053 ppm, which is quite safe.

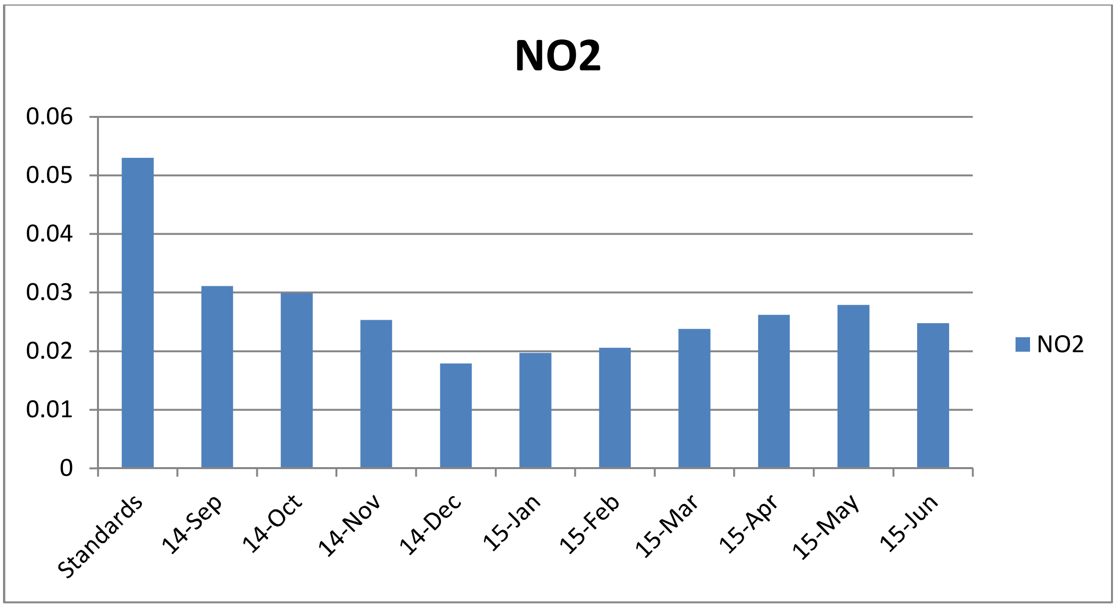


Figure (4-27): Nitrogen Dioxide Pollutant Variation along Ten Month Period from 14-September -2014 up to 15-June-2015 in Duhok City Urban Area.

The fourth gas concentrations of SO_2 are shown in Figure (4-28) with low values of concentrations measured for this gas measured along the ten month period mentioned

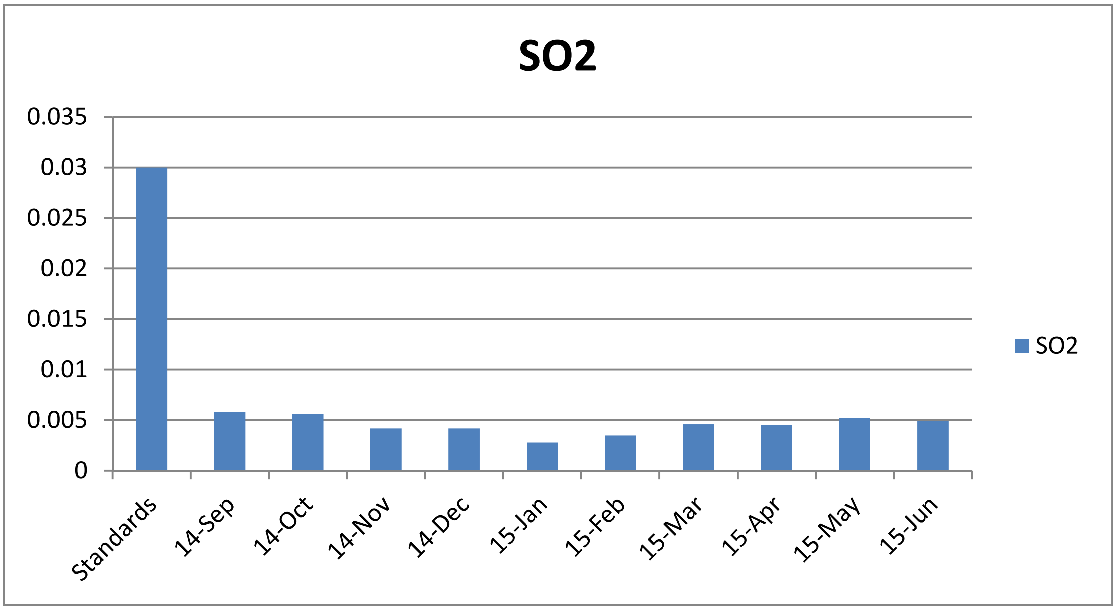


Figure (4-28): Sulphur Monoxide Pollutant Variation along Ten Month Period from 14-September -2014 up to 15-June-2015 in Duhok City Urban Area.

above, and all values are about the same in change from month to month according to the average monthly value. The same peak periods mentioned for NO_2 gas are repeated for SO_2, but with highly lower values. The optimum concentrate measured values for this gas is on September, and October, which are highly less than the recommended standard value of 0.03 ppm.

4.2.1.11 Effect of Wind Speed and Ambient Temperature on Pollution

To study this parameter, Table 4.1 is showing how wind direction and ambient temperature are going to change during ten months of data collection supported by DED(2013) [43]. Air pollution results are slightly affected by wind speed, and maximum and minimum amounts of temeperature, that is because Duhok City is sorounded by montaines, except from the West Direction. Wind is going to flow in th East, and South East direction, so it will not chaning air pollution variation phenomenon in Duhok City.

Table 4.1 Monthly average of Temperature (C°) (Max., Min.)& speed and direction wind/ St. Duhok-source the Directorate of Forecasting in Duhok.

Monthly average of Temperature (C°) (Max., Min.)& speed and direction wind/ St. Duhok																								
2015																2014								
AUGUST		JULY		J Plot Area		MAY		APRIL		MARCH		FEBRUARY		JANUARY		DECEMBER		NOVEMBER		OCTOBE R		SEPTEMBER		Month
min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	
						18.2	30.8	11.6	22.7	8.2	17.5	5.4	14.1	3.7	11.9	6.8	14.4	8.7	17.5	16.4	25.6	21.3	33.9	Temp.
Dir. (o)	Sp. m/s	Dir. (o)	Sp. m/s	Dir. (o)	Sp. m/s	Dir. (o)	Sp. m/s	Dir. (o)	Sp. m/s	Dir. (o)	Sp. m/s	Dir. (o)	Sp. m/s	Dir. (o)	Sp. m/s	Dir. (o)	Sp. m/s	Dir. (o)	Sp. m/s	Dir. (o)	Sp. m/s	Dir. (o)	Sp. m/s	
						SE	1.37	E	1.28	SE	1.22	S	1.19	SE	1.15	E	0.97	E	1.19	SE	1.20	NE	1.28	Wind

4.3 Effect of Socio-economic Characteristics on Air Pollution in Duhok City

Air pollution is known to be generated due to traffic vehicles movement in the different parts of the urban area, especially the road network as it impedes drivers to drive in more higher speeds than local roads. In the theory of urban transportation planning, family is usually the main generator of the trips going out, and in to home by citizins liivng in it. For this reason, it is important to find how much this production , and attraction of trips by both private car, and public including bus, and taxi could effect imperically the proudction of hazardous pollutants emitted to environment. Any indiivdual in society is free to make trips direct(i.e., to and from home), or indirect(i.e., outside the boundry of home. Number of trips generated (i.e., produced, and attracted) is a pwerful indicator about the family activities, when trips increased, it means that, more traffic will be moved in the road sections, and intersections, and then more fuel is burning by mechanical car engines used. This movement will producemore gases threatening cirizens life.

In this study, HIS was conducted in order to know the types of activities done by families in Duhok City by preparing a special quetionnaire form distribute on 2 percent of the total population to compile a lot of statistics about ciitzen trips, and by which mode of transport. Trip purpose as found not so important to look for, as the problem in th estudy is just evaluation of air pollution problem in the city. Out of the data collected by handededs of citizens aging more than five years old and more about their trips from home as a major origin to different other destinations for different purposes. All the factors that might produce movement by vehicles, whether public, or private are considered here in this analysis as indepenedent variables, like, number of trips by bus, and taxi, by private, car number owned by each household, family income, and total number of other trips done out of homea as origin , or destination. Gas pollutant emitted by traffic measured within the boundary of the zone including four gases which are, CO,NO, NO2, and SO2 were considered as dependent variables in the step-wise multiple linear analysis implemented using SPSS Software Package Version 20(2014) [20]. Description of the main dependent, and independent variables considered in the analysis is as follows:

X_1 = Total number of trips done by family members using public transit.

X_2 = Total number of trips done by family members using private car, and /or taxi.

X_3 = Number of cars owned by each individual family,classifed in this study as 0,1,2,2 or more and introduced as a variable in the regression models.

X_{13} = Number of household having zero cars.

X_{23} =Number of households having one car only.

X_{33} =Number of households having two cars only.

X_{34} =Number of households having more than two cars.

X_4 = Family income in I.D.

X_5 = Total number of trips made by each family citizens by both private , and public mode of transport (i.e., X_1+X_2).

Y_{1CO} =Amount of carbon monoxide gas measured within zone boundary in ppm.

Y_{2NO} = Amount of nitrogen monoxide gas measured within zone boundary in ppm.

Y_{3NO2} = Amount of nitrogen dioxide gas measured within zone boundary in ppm.

Y_{4SO2} = Amount of sulphur dioxide gas measured within each zone boundary in ppm.

The four dependent variables were correlated in this study to all other five independent variables in step-wise manner to obtain the main effective generators of air pollution produced in the 43 zones to which Duhok City urban area was divided.

Two other indicators might be important for problem of air pollution were not introduced in this analysis, which are, zone poputaion density, and total trip time from origin to destination measured in minutes . The main reason for that is ot reduce analysis time and effort, and might be introduced in other updated study. Step-wise regression analysis by SPSS Software Package Version 20 for the above mentioned dependent and independent air pollution variables revealed the following partial correlation matrix shown in Table 4.2 (2014) [50]

Table 4.2 Patial Correlation Matrix Among Dependent and Independent Variables Showing Collinearity.

	X_1	X_2	X_3	X_4	X_{13}	X_{23}	X_{33}	X_{34}	Y_{1CO}	Y_{2NO}	Y_{3NO2}	Y_{4SO2}
X_1	1.00	*0.864*	*0.923*	-0.177	*0.769*	*0.816*	0.656	0.411	-0.233	-0.216	-0.186	-0.163
X_2	*0.864*	1.00	*0.959*	-0.207	-0.707	*0.780*	0.707	0.362	-0.149	-0.138	-0.104	-0.084
X_3	*0.923*	*0.959*	1.00	-0.098	*0.803*	*0.828*	*0.725*	0.434	-0.159	-0.149	-0.116	-0.101
X_4	-0.177	-0.207	-0.098	1.00	0.001	-0.059	-0.200	0.222	0.083	0.080	0.072	0.026
X_{13}	*0.769*	0.707	*0.803*	0.001	1.00	*0.886*	*0.779*	0.458	-0.195	-0.190	-0.166	-0.180
X_{23}	*0.816*	*0.780*	*0.828*	-0.059	*0.886*	1.00	*0.805*	0.284	-0.166	-0.161	-0.140	-0.144
X_{33}	0.656	0.707	*0.725*	-0.200	*0.779*	*0.805*	1.00	0.304	-0.194	-0.190	-0.171	-0.176
X_{34}	0.411	0.362	0.434	0.222	0.458	0.284	0.304	1.00	-0.097	-0.094	-0.077	-0.106
Y_{1CO}	-0.233	-0.149	-0.159	0.083	-0.195	-0.166	-0.194	-0.097	1.00	*0.999*	*0.987*	*0.937*
Y_{2NO}	-0.216	-0.138	-0.149	0.080	-0.190	-0.161	-0.190	-0.094	0.999	1.00	*0.991*	*0.938*
Y_{3NO2}	-0.186	-0.104	-0.116	0.072	-0.166	-0.140	-0.171	-0.077	*0.987*	*0.991*	1.00	*0.907*
Y_{4SO2}	-0.163	-.084	-0.101	0.026	-0.180	-0.144	-0.176	-0.106	*0.937*	*0.938*	*0.907*	1.00

*****Inclined figures mean that, confounding exists.

Out of the partial correlation matrix, it could be understood that, most of the independent variables are found confounded with each other, and might be week, or very poorly correlated with the four dependent variables mentioned above. For example X1 is highly internally correlated with X2,X3,X13,X23, but it has a relatively weak correlation with X33,X34. It means that, in any one of the derived final step-wise model, either X1, or the other X's should exist, and no problem with the other dependent variables whether, weak, or strong correlation it have with. Under this principle, derived best model selection will be going on. SPSS will consider all these factors in the analysis process.

4.3.1 Effect of Socio-economic Characteristics on CO Gas Generation in Duhok

To study how much the variation in socio-economic parametrs in Duhok Society might affect the production of the CO gas, a detailed statistical analysis by SPSS (2014) [50] was implemented including all the HIS data, and air pollution measured data in this study. In this analysis , the main parameters introduced above are shown how to affect the CO gas generation, which one of them will increasing it, and which one is going to decrease it. The five main models obtained from the analysis are given below in Table 4.3.

Table 4.3 Five Selected Imperical Models with Five Socio-econiomic Parameters Producing CO Gas Concentrations in Duhok City Urban Area

Model Selected out of the Analysis	**R**	**STD**
Y_{1CO}= - 0.08 – 0.002X_1	0.233	0.156791716
Y_{1CO} = - 0.086 - 0.003X_1 + 0.001X_2	0.240	0.158101301
Y_{1CO} = - 0.076 - 0.004X_1+0.003X_3	0.256	00.159432527
Y_{1CO} =- 0.245- 0.004X_1+0.003X_3+0.001X_4	0.256	0.161503950
Y_{1CO} =- 0.271- 0.004X_1+0.002X_3+0.092X_5	0.267	0.163174004

Analysis of variance table related to the five models given above is shown in Table 4.4 for the 43 traffic analysis zones as product from the step-wise multiple linear regression analysis by SPSS Package. Out of the three Tables 4.2, and 4.3, it is shown that, X_1, which is the number of daily trips made by public transit is going to reduce the pollution due to CO gas emission, but X_2, which is the number of trips made by private car ,or taxi is going to increase CO concentrations. Car number owned by the family represented by X_3 is going to increase CO emissions as well. Family monthly income X_4 in model four is going to increase the amounts of CO emissions polluted to our environment causing a lot of diseases and health problems. In the fifth model total number of trips represented by X_5 is going to increase the CO pollutant amounts as private car use is usually more than public transit. These results conclude that, special attention should be devoted to public transit to reduce the amounts of CO pollution in Duhok City. In order to compare which one of these five models should be recommended for final, model application and updates, R, and STD values are needed for this purpose to select the most interesting model. Out of Table 4.3, it could be concluded that, all values of R, and STD values are about the same value and each one of them is able to be applied according to measurement and data provided condition.

Table 4.4 ANOVA for the Analysis of Variance of the Five CO Gas Production Socio-economic Parameters in Duhok Society.

Model	Sum of Squares	df	Mean Square	Actual F Value	Significance	F Standard on 5% Significance
1 Regression	.053	1	.053	2.146	0.151	9.72
Residual	1.008	41	.025			
Total	1.061	42				
2 Regression	.061	2	.030	1.217	0.307	3.45
Residual	1.000	40	.025			
Total	1.061	42				
3 Regression	.069	3	.023	0.910	0.445	2.47
Residual	.991	39	.025			
Total	1.061	42				
4 Regression	.070	4	.017	0.666	0.619	2.08
Residual	.991	38	.026			
Total	1.061	42				
5 Regression	.076	5	.015	0.567	0.724	1.88
Residual	.985	37	.027			
Total	1.061	42				

Table 4.4, which is the analysis of variance table showing how much deviation is going to be produced due to the correlation of each independent variable, with Y1CO in each of the five produced empirical models from the step-wise analysis. The last three columns are the guide for the decision of selecting the significance of each model given out of the analysis in this study. Standard Fisher Statistic (i.e. F) is taken from Statistical Tables shown in the last column (1987) [51]. F values obtained from analysis are less than F Statistic from tables on 5% level of significance, it means that null hypothesis is accepted , and practically these five models are significantly weak , but from logic point of view ,the five variables are described the CO emission production very well. Rest of the variables which are excluded out of this step-wise analysis are shown in Table 4.5 given below:

Table 4.5 Model Number and Independent Variables Excluded in Each Case of CO Modeling in Duhok City due to Collinearity.

						Collinearity Statistics
		Beta In	**t**	**Significance**	**Partial Correlation**	**Tolerance**
1	x2private	Model.173	.569	.573	.090	.254
	x3carsno	.317	.799	.429	.125	.149
	x4income	.045	.286	.777	.045	.969
	x5trips	.255	.904	.371	.142	.292
2	x3carsno	.422	.579	.566	.092	.045
	x4income	.055	.348	.730	.056	.957
	x5trips	.232	.707	.484	.112	.222
3	x4income	.014	.077	.939	.013	.733
	x5trips	.183	.487	.629	.079	.173
4	x5trips	.186	.476	.637	.078	.164

This exclusion is mainly due to collinearity of the excluded variables with the other accepted and entered variables decided by the SPSS Package, and the partial R values are given in each of the first analysis cases. Model five have nothing to be excluded from. Figure 4.29 is showing the histogram of the Y_{1CO} frequency distribution with the regression standardized residual with its mean and standard deviation values as SPSS Package analysis output. Figure 4.30 is showing how the predicted and actual values of Y_{1CO} are going to scatter around the diagonal line of the Normal Probability Plot given by the same output.

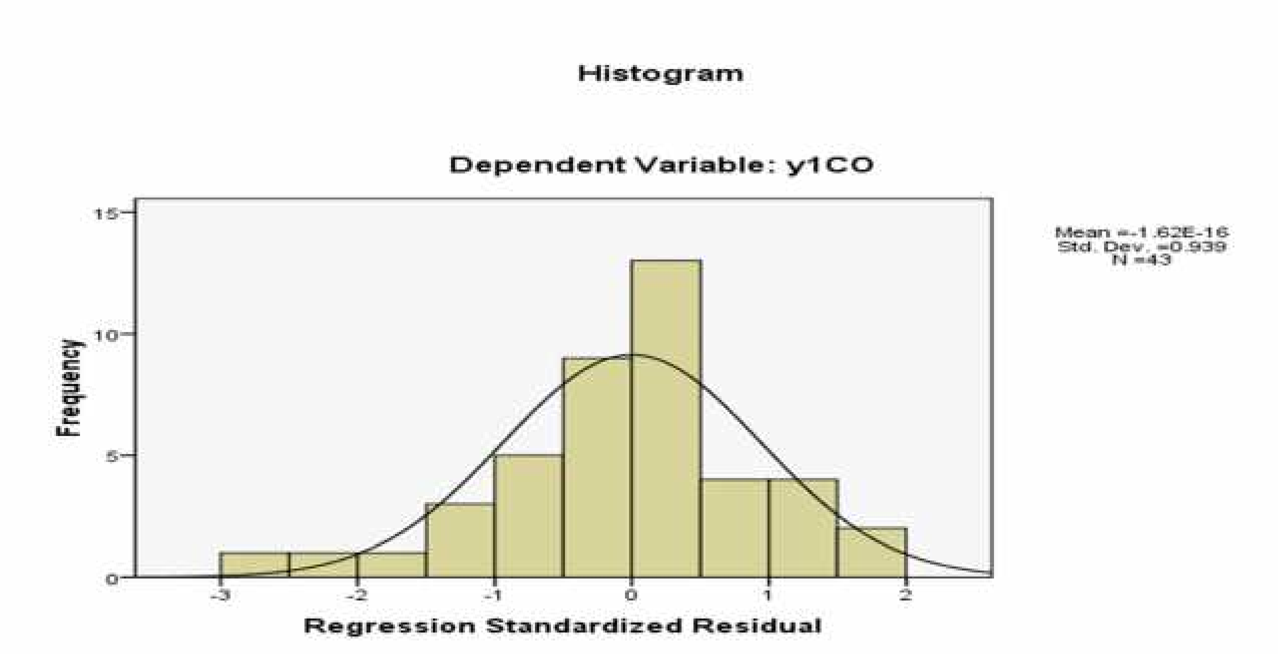


Figure 4.29 CO Pollutant Emissions Frequency Distribution Histogram with its Standardized Value from Analysis.

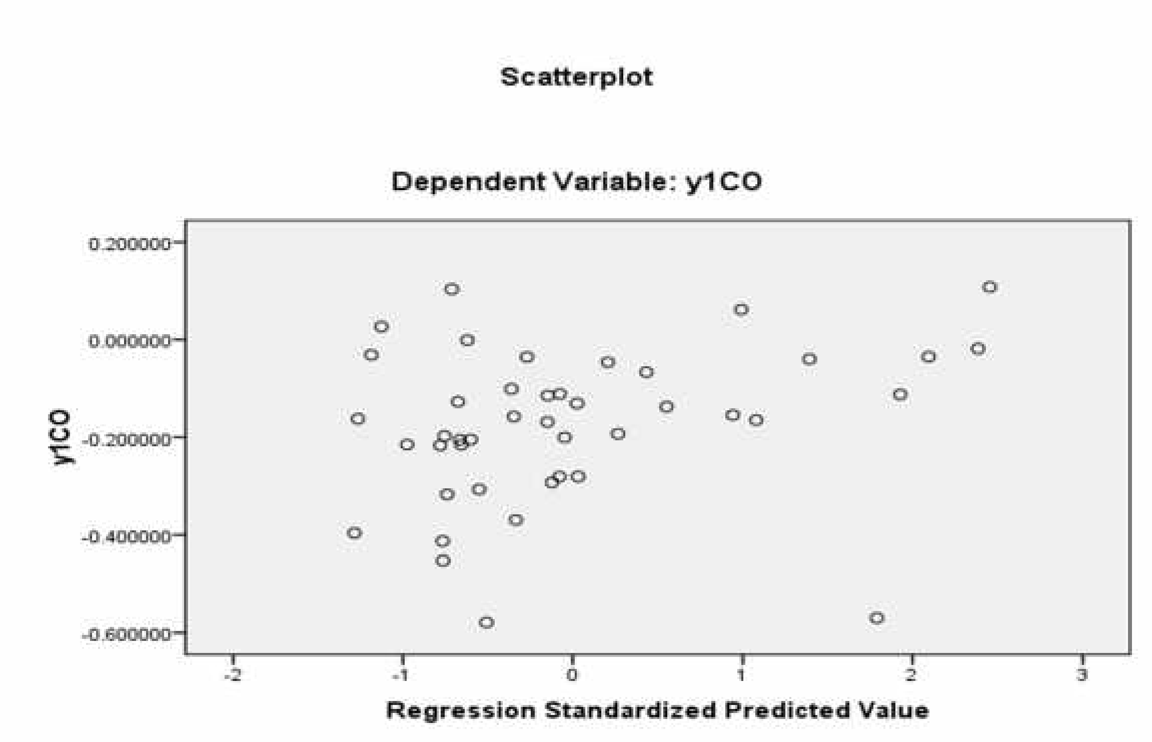


Figure 4.30 Scatterplot of the Actual and Predicted Values of CO Pollutant Concentrations.

4.3.2 Effect of Socio-economic Characteristics on NO Gas Generation in Duhok City

To study how much the variation in socio-economic parametrs in Duhok Society might affect the production of the NO gas, a detailed statistical analysis by SPSS (2014) [50] was implemented including all the HIS data, and air pollution measured data in this study. In this analyis , the main parameters introduced above are shown how to affect the NO gas generation, which one of them will increasing it, and which one is going to decrease it.The five main models obtained from the analysis are given below in Table 4.6.

Table 4.6 Five Selected Imperical Models with Five Socio-econiomic Parameters Producing NO Gas Concentrations in Duhok City Urban Area.

Model Selected out of the Analysis	**R**	**STD**
Y_{2NO}= -1.556 - 0.001X_1	0.216	0.157147152
Y_{2NO} = -1.563-0.003X_1 +0.001X_2	0.236	0.158344243
Y_{2NO} = -1.552- 0.004X_1 +0.003X_3	0.252	0.59672344
Y_{2NO} = -1.717- 0.004X_1 +0.003X_3 +0.001X_4	0.253	0.161748726
Y_{2NO} = -1.737 - 0.004X_1 +0.002X_3 +0.109X_5	0.268	0.163209749

Analysis of variance table related to the five models given above is shown in Table 4.6 for the 43 traffic analysis zones as product from the step-wise multiple linear regression analysis by SPSS Package(2014)[50]. Out of the two tables mentioned 4.2, and 4.6, it is shown that, X_1, which is the number of daily trips made by public transit is going to reduce the pollution due to NO gas emission, but X_2, which is the number of trips made by private car ,or taxi is going to increase NO concentrations. Car number owned by the family represented by X_3 is going to increase NO emissions as well. Family monthly income X_4 in model four is going to increase the amounts of NO emissions polluted to our environment causing a lot of diseases and health problems. In the fifth model total number of trips represented by

X_5 is going to increase the NO pollutant amounts as private car use is usually more than public transit. These results conclude that, special attention should be devoted to public transit to reduce the amounts of NO pollution in Duhok City.

In order to compare which one of these five models should be recommended for final, model application and updates, R, and STD values are needed for this purpose to select the most interesting model. Out of Table 4.6, it could be concluded that, all values of R, and STD values are about the same value and each one of them is able to be applied according to measurement and data provided condition.

Table 4.7, which is the analysis of variance table showing how much deviation is going to be produced due to the correlation of each independent variable, with Y_{1CO} in each of the five produced empirical models from the step-wise analysis. The last three columns are the guide for the decision of selecting the significance of each model given out of the analysis in this study. Standard Fisher Statistic (i.e. F) is taken from Statistical Tables shown in the last column (1987) [51]. F values obtained from analysis are less than F Statistic from tables on 5% level of significance, it means

Table 4.7 ANOVA for the Analysis of Variance of the Five NO Gas Production Socio- economic Parameters in Duhok Society.

Model	Sum of Squares	df	Mean Square	F	Significance	F Standard on 5% Significance
1 Regression	0.049	1	0.049	2.002	0.165	9.72
Residual	1.013	41	0.025			
Total	1.062	42				
2 Regression	0.059	2	0.030	1.177	0.319	3.45
Residual	1.003	40	0.025			
Total	1.062	42				
3 Regression	0.068	3	0.023	0.884	0.458	2.47
Residual	0.994	39	0.025			
Total	1.062	42				
4 Regression	0.068	4	0.017	0.647	0.632	2.08
Residual	0.994	38	0.026			
Total	1.062	42				
5 Regression	0.076	5	0.015	0.573	0.720	1.88
Residual	0.986	37	0.027			
Total	1.062	42				

that null hypothesis is accepted and practically these five models are significantly weak, but from logic point of view the five variables are described the NO emission production very well. Rest of the variables which are excluded out of this step-wise analysis are shown in Table 4.8 given below: This exclusion is mainly due to collinearity of the excluded variables with the other accepted and entered variables decided by the SPSS Package, and the partial R values are given in each of the first analysis cases. Model five have nothing to be excluded from.

Figure 4.31 is showing the histogram of the Y_{2NO} frequency distribution with the regression standardized residual with its mean and standard deviation values as SPSS Package analysis output(2014) [50]. Figure 4.32 is showing how the predicted and actual values of Y_{2NO} are going to scatter around the diagonal line of the Normal Probability Plot given by the same output.

Table 4.8 Model Number and Independent Variables Excluded in Each Case of NO Modeling in Duhok City due to Collinearity

Model		Beta In	t	Significant	Partial Correlation	Collinearity Statistics
						Tolerance
1	x2private	0.189[a]	0.618	0.540	0.097	0.254
	x3carsno	0.334[a]	0.842	0.405	0.132	0.149
	x4income	0.043[a]	0.276	0.784	0.044	0.969
	x5trips	0.283[a]	1.001	0.323	0.156	0.292
2	x3carsno	0.424[b]	0.581	0.565	0.093	0.045
	x4income	0.055[b]	0.344	0.733	0.055	0.957
	x5trips	0.258[b]	0.789	0.435	0.125	0.222
3	x4income	0.013[c]	0.072	0.943	0.012	0.733
	x5trips	0.216[c]	0.577	0.568	0.093	0.173
4	x5trips	0.222[d]	0.568	0.573	0.093	0.164

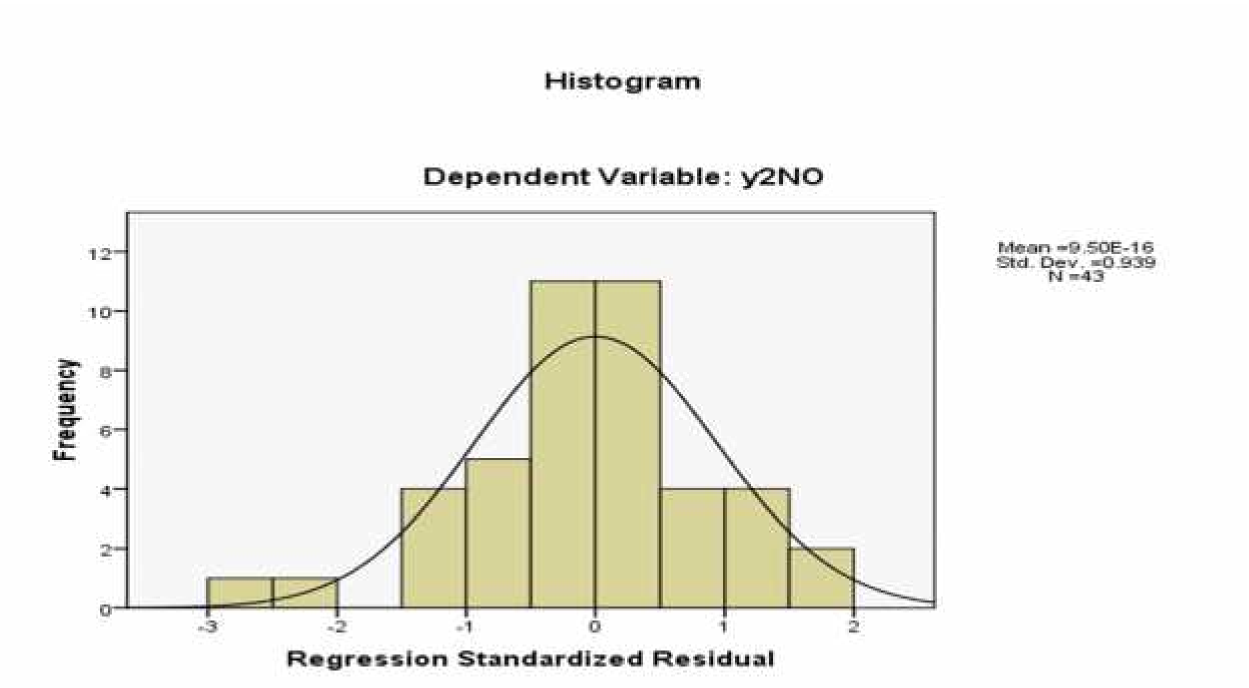


Figure 4.31 NO Pollutant Emissions Frequency Distribution Histogram with its Standardized Value from Analysis.

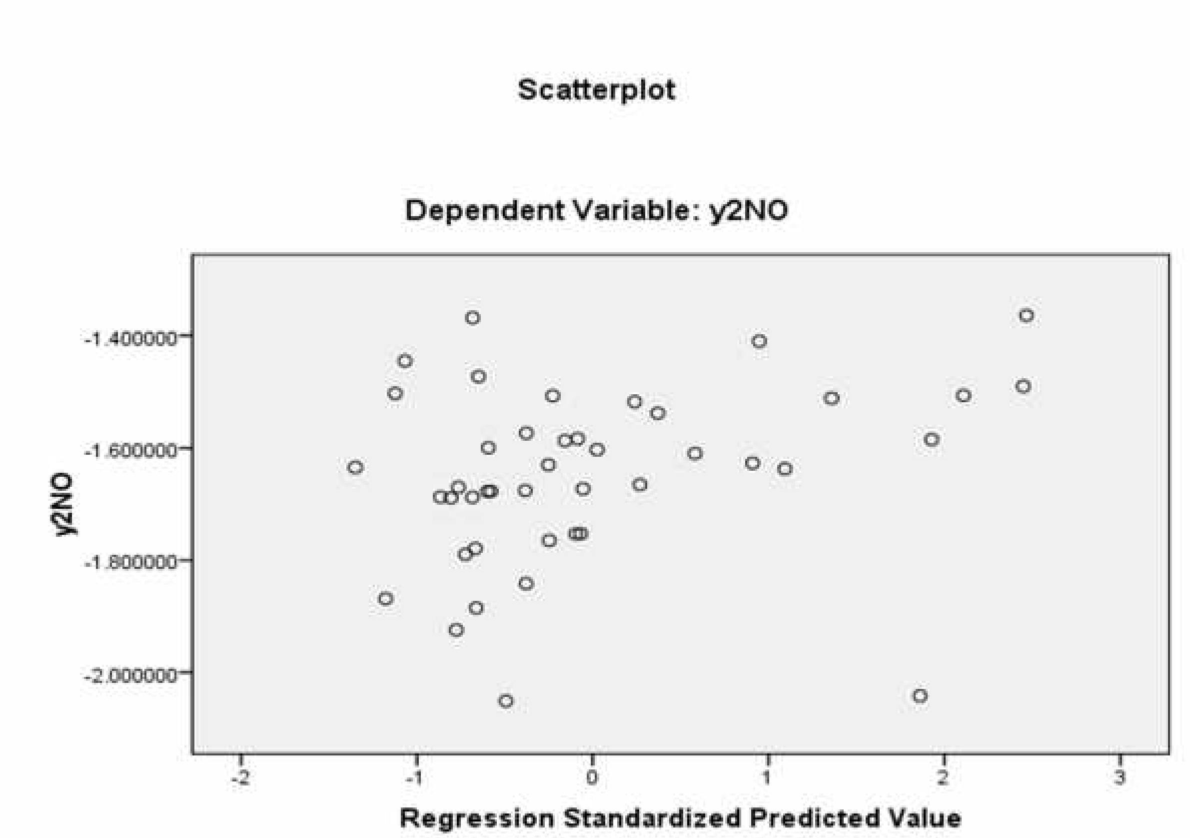


Figure 4.32 Scatterplot of the Actual and Predicted Values of NO Pollutant Concentrations.

4.3.3 Effect of Socio-economic Characteristics on NO2 Gas Generation in Duhok City

To study how much the variation in socio-economic parametrs in Duhok Society might affect the production of the NO_2 gas, a detailed statistical analysis by SPSS (2014) [50] was implemented including all the HIS data, and air pollution measured data in this study. In this analyis , the main parameters introduced above are shown how to affect the NO_2 gas generation, which one of them will increasing it, and which one is going to decrease it.The five main models obtained from the analysis are given below in Table 4.9

Table 4.9 Five Selected Imperical Models with Five Socio-econiomic Parameters Producing NO_2 Gas Concentrations in Duhok City Urban Area.

Model Selected out of the Analysis	R	STD
$Y_{3NO2} = -1.656- 0.001X_1$	0.186	0.156088813
$Y_{3NO2} = -1.664- 0.003\ X1+0.001X2$	0.218	0.156967481
$Y_{3NO2} = -1.654 -.004X_1 +0.003X_3$	0.236	0.158298548
$Y_{3NO2} = -1.812- 0.004X_1 +0.003X_3 +0.001X_4$	0.236	0.160357710
$Y_{3NO2}=-1.843-0.004X_1+0.002X_3-0.001X_4 +0.109X_5$	0.274	0.160845635

Analysis of variance table related to the five models given above is shown in Table 4.8 for the 43 traffic analysis zones as product from the step-wise multiple linear regression analysis by SPSS Package. Out of the two mentioned Tables 4.2, and 4.9, it is shown that, X_1, which is the number of daily trips made by public transit is going to reduce the pollution due to NO_2 gas emission, but X_2, which is the number of trips made by private car ,or taxi is going to increase NO_2 concentrations. Car number owned by the family represented by X_3 is going to increase NO_2 emissions as well. Family monthly income X_4 in model four is going to increase the amounts of NO_2 emissions polluted, but in the fifth model, unfortunately income seems to increase NO_2 emissions polluted to our environment to increase diseases and cause health problems. In the fifth model total number of trips represented by X_5 is going to increase the NO_2 pollutant amounts as private car use is usually more than public transit. This result concludes that, special attention should be devoted to public transit to reduce the amounts of NO_2 pollution in Duhok City.

In order to compare which one of these five models should be recommended for final, model application and updates, R, and STD values are needed for this purpose to select the most interesting model. Out of Table 4.9, it could be concluded that, all values of R, and STD values are about the same value and each one of them is able to be applied according to measurement and data provided condition.

Table 4.10 ANOVA for the Analysis of Variance of the Five NO_2 Gas Production Socio-economic Parameters in Duhok Society.

Model		Sum of Squares	df	Mean Square	F	Significant	F Standard on 5% Significance
1	Regression	0.036	1	0.036	1.472	0.232	9.72
	Residual	0.999	41	0.024			
	Total	1.035	42				
2	Regression	0.049	2	0.025	0.999	0.377	3.45
	Residual	0.986	40	0.025			
	Total	1.035	42				
3	Regression	0.058	3	0.019	0.765	0.521	2.47
	Residual	0.977	39	0.025			
	Total	1.035	42				
4	Regression	.058	4	0.014	0.560	0.693	2.08
	Residual	.977	38	0.026			
	Total	1.035	42				
5	Regression	0.078	5	0.016	0.599	0.701	1.88
	Residual	0.957	37	0.026			
	Total	1.035	42				

Table 4.10, which is the analysis of variance table showing how much deviation is going to be produced due to the correlation of each independent variable, with Y_{1CO} in each of the five produced empirical models from the step-wise analysis. The last three columns are the guide for the decision of selecting the significance of each model given out of the analysis in this study. Standard Fisher Statistic (i.e. F) is taken

from Statistical Tables shown in the last column (1987) [51] F values obtained from analysis are less than F Statistic from tables on 5% level of significance, it means that null hypothesis is accepted, and practically these five models are significantly weak, but from logic point of view, the five variables are described the NO_2 emission production very well. Rest of the variables which are excluded out of this step-wise analysis are shown in Table 411 given below: This exclusion is mainly due to collinearity of the excluded variables with the other accepted and entered variables decided by the SPSS Package, and the partial R values are given in each of the first analysis cases. Model five have nothing to be excluded from.

Table 4.11 Model Number and Independent Variables Excluded in Each Case of NO_2 Modeling in Duhok City due to Collinearity.

Model		Beta In	t	Significant	Partial Correlation	Collinearity Statistics
						Tolerance
1	x2private	0.225	0.736	0.466	0.116	0.254
	x3carsno	0.374	0.938	0.354	0.147	0.149
	x4income	0.041	0.257	0.798	0.041	0.969
	x5trips	0.366	1.302	0.200	0.202	0.292
2	x3carsno	0.422	0.575	0.569	0.092	0.045
	x4income	0.054	0.339	0.737	0.054	0.957
	x5trips	0.347	1.060	0.296	0.167	0.222
3	x4income	0.013	0.069	0.945	0.011	0.733
	x5trips	0.330	0.881	0.384	0.141	0.173
4	x5trips	0.343	0.877	0.386	0.143	0.164

Figure 4.33 is showing the histogram of the Y_{3NO2} frequency distribution with the regression standardized residual with its mean and standard deviation values as SPSS Package analysis output(2014) [50]. Figure 4.34 is showing how the predicted and actual values of Y_{3NO2} are going to scatter around the diagonal line of the Normal Probability Plot given by the same output. All of the values distribution is located on the left-side upward; giving indication that, distribution is not uniform around the diagonal line of the scatter graph shape.

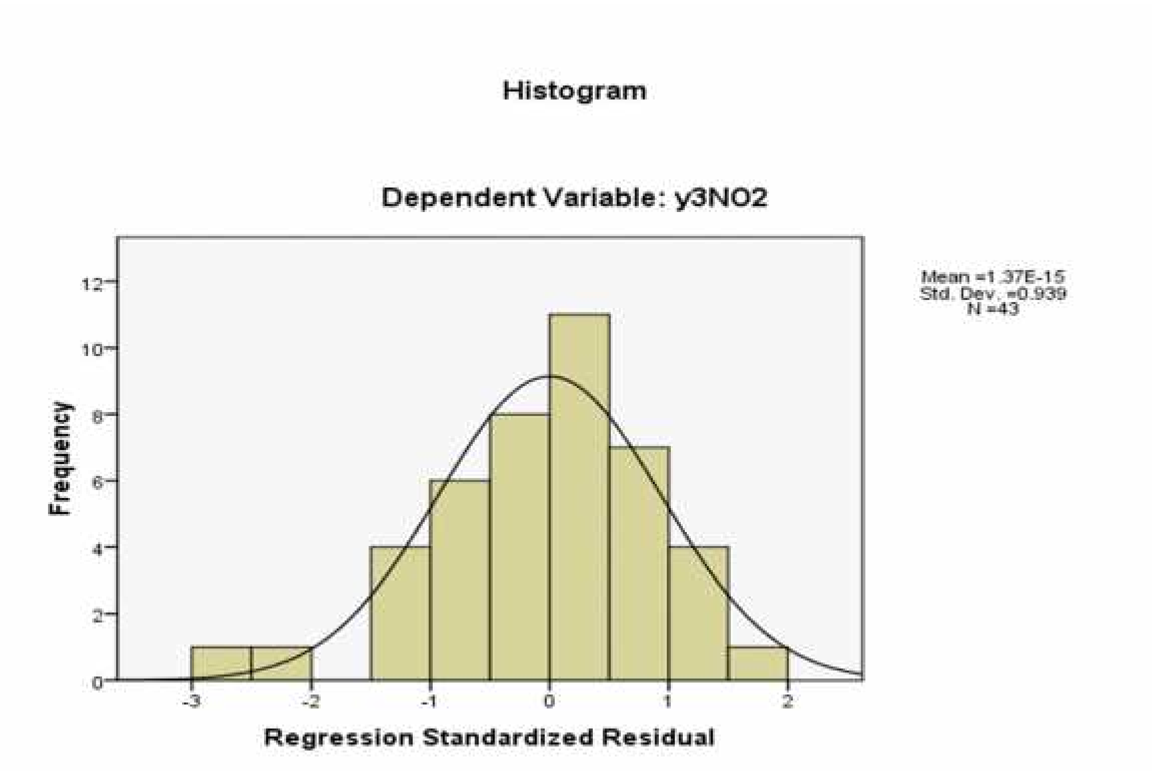


Figure 4.33 NO_2 Pollutant Emissions Frequency Distribution Histogram with its Standardized Value from Analysis Produced in Duhok City Urban Area

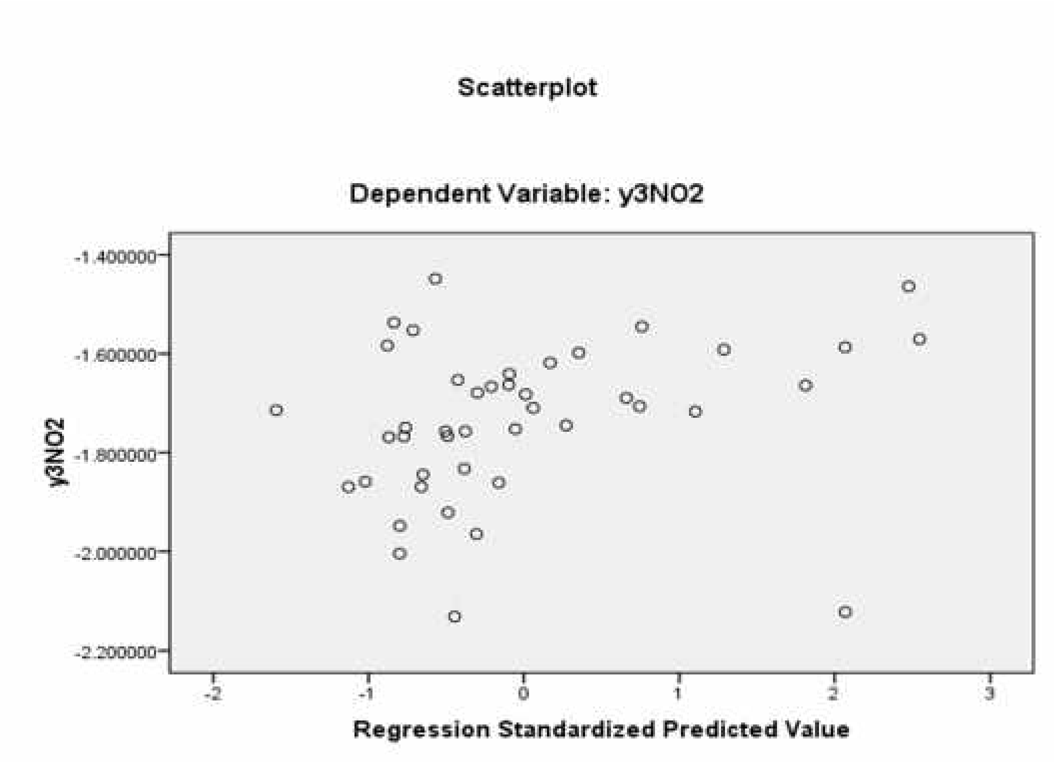


Figure 4.34 Scatterplot of the Actual and Predicted Values of NO Pollutant Concentrations.

4.3.4 Effect of Socio-economic Characteristics on SO2 Gas Generation in Duhok City

To study how much the variation in socio-economic parametrs in Duhok Society might affect the production of the SO_2 gas, a detailed statistical analysis by SPSS (2014) [7] was implemented including all the HIS data, and air pollution measured data in this study. In this analyis , the main parameters introduced above are shown how to affect the SO_2 gas generation, which one of them will increasing it, and which one is going to decrease it.The five main models obtained from the analysis are given below in Table 4.12.

Table 4.12 Five Selected Imperical Models with Five Socio-econiomic Parameters Producing SO_2 Gas Concentrations in Duhok City Urban Area.

Model Selected out of the Analysis	**R**	**STD**
Y_{3NO2} =-2.279 - 0.001X_1	0.163	0.1847105
Y_{3NO2} = -2.288- 0.003 X_1+0.001X_2	0.198	0.1857770
Y_{3NO2} = -2.280-0.004X_1 +0.003X_3	0.208	0.1877664
Y_{3NO2} = -1.889- 0.004X_1- +0.003X_3 - 0.001X_4	0.209	0.1901684
Y_{3NO2} = -1.903- 0.004X_1+0.002X_3-0.002X_4+0 .078X_5	0.216	0.1924146

Analysis of variance table related to the five models given above is shown in Table 4.12 for the 43 traffic analysis zones as product from the step-wise multiple linear regression analysis by SPSS Package. Out of the two tables mentioned 4.2, and 4.12, it is shown that, X_1, which is the number of daily trips made by public transit is going to reduce the pollution due to SO_2 gas emission, but X_2, which is the number of trips made by private car ,or taxi is going to increase SO_2 concentrations. Car number owned by the family represented by X_3 is going to increase SO_2 emissions as well. Family monthly income X_4 in model four and five is going to decrease the amounts of SO_2 emissions polluted to our environment causing a lot of diseases and health problems. In the fifth model total number of trips represented by X_5 is going to increase the SO_2 pollutant amounts as private car use is usually more than public transit. This result concluding that, special attention should be devoted to public transit to reduce the amounts of SO_2 pollution in Duhok City.

In order to compare which one of these five models should be recommended for final, model application and updates, R, and STD values are needed for this purpose to select the most interesting model. Out of Table 4.12, it could be concluded that, all values of R, and STD values are about the same value and each one of them is able to be applied according to measurement and data provided condition.

Table 4.13 ANOVA for the Analysis of Variance of the Five SO_2 Gas Production Socio-economic Parameters in Duhok Society.

Model		Sum of Squares	df	Mean Square	F	Significance	F Standard on 5% Significance
1	Regression	0.036	1	0.036	1.472	0.232	9.72
	Residual	0.999	41	0.024			
	Total	1.035	42				
2	Regression	0.049	2	0.025	0.999	0.377	3.45
	Residual	0.986	40	0.025			
	Total	1.035	42				
3	Regression	0.058	3	00.019	0.765	0.521	2.47
	Residual	0.977	39	0.025			
	Total	1.035	42				
4	Regression	0.058	4	0.014	0.560	0.693	2.08
	Residual	0.977	38	0.026			
	Total	1.035	42				
5	Regression	0.078	5	0.016	0.599	0.701	1.88
	Residual	0.957	37	0.026			
	Total	1.035	42				

Table 4.13, which is the analysis of variance table showing how much deviation is going to be produced due to the correlation of each independent variable, with Y_{4SO2} in each of the five produced empirical models from the step-wise analysis. The last three columns are the guide for the decision of selecting the significance of each model given out of the analysis in this study. Standard Fisher Statistic (i.e. F) is taken from Statistical Tables shown in the last column (1987) [51]. F values obtained from

analysis are less than F Statistic from tables on 5% level of significance, it means that null hypothesis is accepted , and practically these five models are significantly weak , but from logic point of view ,the five variables are described the NO_2 emission production very well. Rest of the variables which are excluded out of this step-wise analysis are shown in Table 4.14 given below: This exclusion is mainly due to collinearity of the excluded variables with the other accepted and entered variables decided by the SPSS Package, and the partial R values are given in each of the first analysis cases. Model five have nothing to be excluded from.

Table 4.14 Model Number and Independent Variables Excluded in Each Case of SO_2 Modeling in Duhok City due to Collinearity.

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	x2private	0.225	0.736	0.466	0.116	0.254
	x3carsno	0.374	0.938	0.354	0.147	0.149
	x4income	0.041	0.257	0.798	0.041	0.969
	x5trips	0.366	1.302	0.200	0.202	0.292
2	x3carsno	0.422	0.575	0.569	0.092	0.045
	x4income	0.054	0.339	0.737	0.054	0.957
	x5trips	0.347	1.060	0.296	0.167	0.222
3	x4income	0.013	0.069	0.945	0.011	0.733
	x5trips	0.330	0.881	0.384	0.141	0.173
4	x5trips	0.343	0.877	0.386	0.143	0.164

Figure 4.35 is showing the histogram of the Y_{4SO2} frequency distribution with the regression standardized residual with its mean and standard deviation values as SPSS Package analysis output. Figure 4.36 is showing how the predicted and actual values of Y_{3SO2} are going to scatter around the diagonal line of the Normal Probability Plot given by the same output. All of the values distribution is located on the left-side upward; giving indication that, distribution is not uniform around the diagonal line of the scatter graph shape.

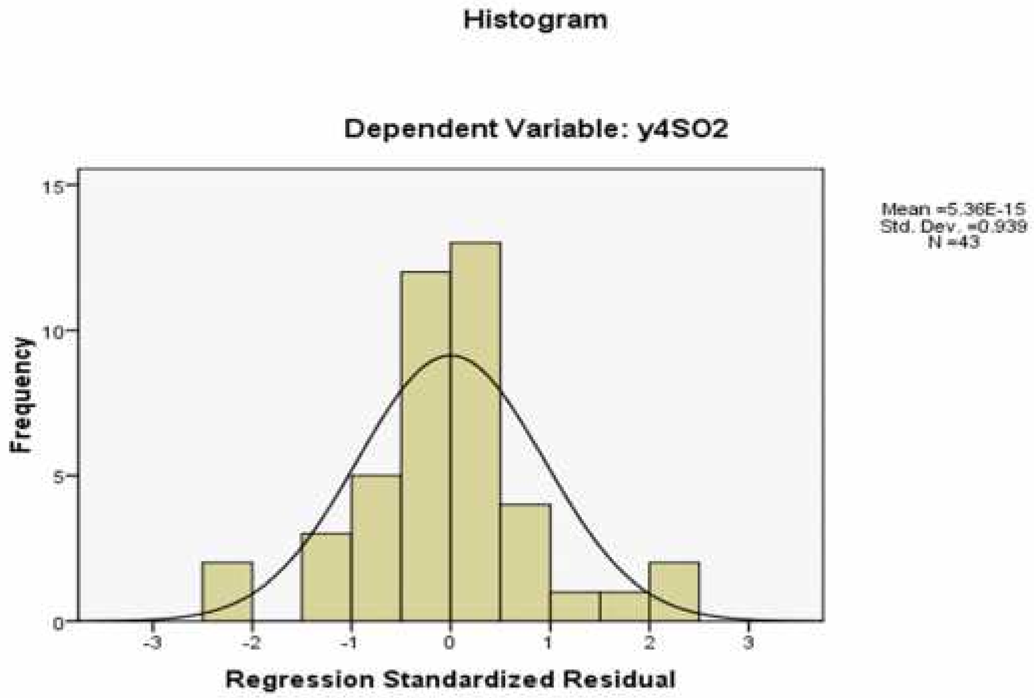


Figure 4.35 SO_2 Pollutant Emissions Frequency Distribution Histogram with its Standardized Value from Analysis Produced in Duhok City Urban Area

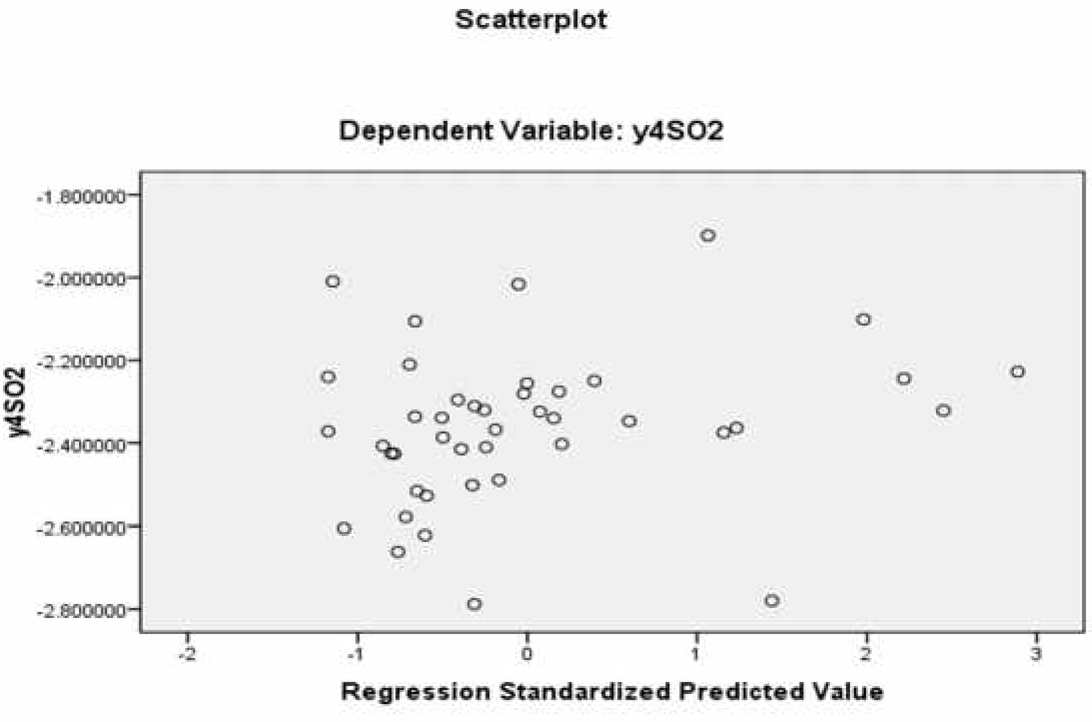


Figure 4.36 Scatterplot of the Actual and Predicted Values of SO_2 Pollutant Concentrations

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

In this study, a lot of data concerning air pollution main gases found in the environment of Duhok City was collected around the urban area of the city presented by some GIS maps for the city during a period of ten months. At the same time, a very detailed HIS for a certain sample of the Duhok City citizens to compile data about their behaviour of daily travel, including the main socio-economic characteristics using a standard questionnaire form. Correlations of data obtained from 43 traffic zones existing now on the geography of Duhok City using SPSS Package Version 20 revealed to a lot of results discussed in some detail in chapter four. Out of the discussions, many conclusions are found interesting to be given here in this chapter for application, and further future studies, and/or updates. Conclusions drawn out from this study are given below:

1- CO pollutant variation is going to be less than average during night time from (00.00-8:00) A.M. then it is starting to increase more than average during the noon, and afternoon period to be more than average values ,and the obtained hourly concentration of CO gas is highly lower than the recommended value, so it is under control.

2- Maximum concentrations of CO pollutant are following the same trend as average value, but they still remain lower than Kurdistan Region recommended values of 9.0 ppm.

3- NO emission amount polluted from vehicles is under the total average value during the first eight hours at night from (00:00) A.M. until 8:00 .A.M. ,but after that, it is going to be higher as the number of vehicles is increasing on road network;

4- Results obtained for NO concentrations is still under the average standard amount recommended in the Region which is 0.053 ppm as one year measurement period given by the Kurdistan Region Standards.

5- Maximum observed values of NO gas concentrations in some hot spots shown on the GIS map of the city in red color is showing a similar trend shown in for the average NO pollutant variations.

6- Total average value of the NO_2 concentrations during the last ten month period was 0.02ppm only, which is less than standard recommended given by the Iraqi Ministry of Environment Standards of 0.05 ppm.

7- NO_2 concentration is varying during average day that it is highly less than total average during night time until morning , and due to the increase in traffic movement it is going to increase to be more than this average at noon, and afternoon periods;

8- SO_2 is increasing at the first (8-10) hours at A.M period, then it becomes above the total average value for the last three years of data obtained for Duhok City. After mid-day it is going to increase above the average limit, and still continuously increasing until mid-night period.

9- 9- SO_2 values are not coming to overpass the maximum value recommended by Iraqi Ministry of Environment Standards, which is 0.03 ppm considering one year measurement period, but higher in values close to the maximum recommended especially at afternoon periods.

10- CO gas concentration along Barzan Arterial Road is going to be low at the (00:00-08:00) A.M. period with low values at the beginning of the road , then it is increasing with increase in the length of this road up to (16:00-24:00) midnight period to obtain peak gas concentration values when distance is located between (4,000-6,000) meters.

11- On Barzan Arterial Road, maximum CO concentration value obtained in this study of this dangerous gas is lower than the standard permissible limit of 9 ppm given above.

12- NO gas concentration is going to be moderate in value at the (00:00-08:00) A.M. period at the beginning of the Barzan Road length ,then it is increasing with the increase in length up to (16:00-24:00) midnight period however, when road length is increasing peak values of gas concentration is obtained when road length is located between (4,000-5,000) meters.

13- NO_2 gas concentration is going to be moderate in value at the (00:00-08:00) A.M. period with the beginning of Barzan Road , then it is slightly increasing with increase in length on this road up to (16:00-24:00) midnight period however, distance is increasing to obtain peak values of gas concentration on a section located between(3,000-10,000) meters.

14- Maximum obtained concentration value obtained of NO_2 gas on Barzan Road is lower than the standard permissible limit of 0.050ppm recommended by Iraqi Ministry of Environment Standards.

15- SO_2 gas concentration is going to be moderate in value at the (00:00-08:00) A.M. period at the start length of Barzan Arterial Road ,then it is slightly increasing with increase in length of this road up to (16:00-24:00) midnight period however, road length is increasing to obtain peak values of gas concentration at sections located between (3,500-5,000) meters.

16- Maximum concentration of SO_2 value obtained of this dangerous gas is more than the standard permissible limit of 0.030ppm given above, especially at the section located between (4,000-5,500) meters during the hourly period from (8:00-24:00)hr. which is a long time period of exposure to this dangerous gas during which most human activities are being executed.

17- CO which is the most hazardous gas is having the highest average values than the other three pollutants along the Barzan Arterial Road length from start to end Concentration values occurring along the high concentration value periods mentioned above (i.e., after 8:00 hr. A.M. period).

18- Monthly variation among the four pollutants show that CO gas concentration is higher than the other three gases along the whole length of Barzan Road, especially in the month of April ,and May. Values of CO gas concentrations observed are less than the value recommneded by the Kurdistan Region Standards for this gas, and the other three gases are showing lower results of ocncentrations than CO and standards;

19- In the modelling of air pollution with socio-economic parameters of Duhok city Society, high degree of collinearity is found among the different variables collected From HIS as concluded from the step-wise analysis conducted by SPSS Package.

20- Five models generated from regression for CO pollutant show about the same values of R, and STD, it means that, all models concluded are useful to be used to predict CO concentrations as far as the data provided. Models derived generally get low Values of R, and STD.

21- CO Concentrations are going to directly increase with family income, total trips by private, and taxi, and car-ownership number, but reduces with public trips.

22- ANOVA analysis concludes that, the five CO pollutant derived models are weak statistically, and insigincant by F test, but logically accepted.

23- Predicted and measured values of CO concentrations are not uniformly distributed around the diagonal of the Normal Probability Diagram obtained as output from analysis.

24- Five models generated from regression for NO pollutant show about the same values of R, and STD, it means that, all models concluded are useful to be used to predict NO concentrations if data is not provided. Models derived generally get low values of R, and STD.

25- NO concentrtions are going to directly increase with family income, total trip by private, and taxi, and car-ownership number, but reduces with public trips.

26- ANOVA analysis concludes that, the five NO pollutant derived models are weak statistically, and insigincant by F test, but logically accepted.

27- Predicted and measured values of NO concentrations are not uniformally distributed around the diagonal of the Normal Probability Diagram obtained as output from analysis.

28- Five models generated from regression for NO2 pollutant show about the same value of R, and STD, it means that, all models concluded are useful to be used to predict NO2 concentrations if data is not provided. Models derived generally get low values of R, and STD.

29- NO2 concentrtions are going to directly increase with family income, total trips by private , and taxi, and car-ownership number, but reduces with public trips.

30- ANOVA analysis concludes that, the five NO2 pollutant derived models are weak statistically, and insigincant by F test, but logically accepted.

31- Predicted and measured values of NO2 concentrations are not uniformly distributed around the diagonal of the Normal Probability Diagram obtained as output from analysis.

32- Five models generated from regression for SO2 pollutant show about the same value of R, and STD, it means that, all models concluded are useful to be used to predict NO2 concentration if data is no provided. Models derived generally get low values of R, and STD.
33- SO2 concentrtions are going to directly increase with family income, total trips by private, and taxi, and car-ownership number, but reduces with public trips.
34- ANOVA analysis concludes that, the five SO2 pollutant derived models are weak statistically, and insigincant by F test, but logically accepted.
35- Predicted and measured values of SO2 concentrations are not uniformly distributed around the diagonal of the Normal Probability Diagram obtained as output from analysis.

5.2 Recommendations

Out of the analysis, and the main conclusions derived from the complete discusion of the air pollution problem in Duhok City Urban Area, the following recommendations for further sudy was found interesting and necessary to complete the full understanading of this problem and whatare the main and direct solution needed for:

1- Population density for all 43 traffic zones, and trip distance and/or time are not introduced here in this study, so it recommended that, they are necessary to be considered for further research.
2- Spatial effect of the air pollution problem among the different 43 zones located within the Duhok City is recommneded to be further studied using GIS technique following Moran Principle of analyis.
3- Data compiled out of this study is recommended for building a lot of emperical models related to the effect of different traffic, and geometric variables on the main roads in Duhok City to put further sought decisions about the air pollution problem in this city;
4- Air pollution data base is recommneded to be built by DED for the Duhok City to be updated from time to time and execute more evaluation studies about the air pollution problem threatening a lot of people living in this city as original citizens, or tourists. More advanced air pollution system including well-trained staff, and up-to-date measuring instrumnetations;

5- Points of high concentrations of toxic gase found in this study recommneded to be deeply studied and sought decisions to be put to overcome more severe healthy problems in the future;

6- Fuel used by car engine should be more treated to get more pure type without lead contents, that produce some types of toxic pollutants to environment such as high Octane Benzene with 95% content or more; and

7- Adoption of gases test at Periodic Vehicles inspection (P.V.I) at Duhok City and Development of the Public Transportation Network in Duhok City.

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APPENDIX A

Iraqi Ministry of Environment Standards- Air Pollution Department for the year (2008) [39].

Ministry of environmental , Iraq	World Limits WHO	Air Pollutant
1 hour / 35 ppm 8 hour / 9 ppm	8 hour / 10 mg/m^3 8 hour / 9 ppm Year / 100 mg/m^3	Carbon monoxide CO ppm
1 hour / 0.25 ppm year / 0.05 ppm	hour / 0.11 ppm 24 hour / 150 g/m^3 Year / 40 g/m^3	Nitrogen Dioxide NO2 ppm
hour / 0.14 ppm Year / 0.03 ppm	hour / 0.01 ppm Year / 0.03 ppm	Sulfur Dioxide SO2 ppm
24 hour / 350 g/m^3 Year / 150 g/m^3	hour / 150 g/m^3 Year / 60-90 g/m^3	Total Suspended particle TSP g/m^3
24 hour / 2 g/m^3 Year / 1.5 g/m^3	Year / 0.5-1 g/m^3	Lead Pb g/m^3
1hour /250 ppm	1hour / 250 ppm	Carbon dioxide CO2 ppm

APPENDIX B

Ambient Air Quality Standards in Kurdistan Region of Iraq, Environment Directorate of Duhok City, (2013) [40].

Duration	Criteria	Type	Pollutant
24 hours	0.14 ppm 356	Primary	SO2
Annual	0.030 ppm 80	Primary	SO2
3 hours	0.5 ppm 1300	Secondary	SO2
24 hours	150	Primary and Secondary	PM10
24 hours	35	Primary and secondary	PM 2.5
Annual	15	Primary and Secondary	PM 2.5
1 hours	35 ppm 40	Primary	CO
8 hours	9 ppm 10	Primary	CO
8 hours	0.075 ppm 235	Primary and Secondary	O3
Annual	0.053ppm 100	Primary and Secondary	NO2
Seasonal	1.5	Primary and Secondary	Pb

APPENDIX C

Gaziantep University		post-Graduate study
College of Engineering		2015

Natural and applied sciences

Civil Engineering / Transportation Department

Air Pollution Evaluation in Duhok City Road Urban Area

Home interview survey

1. /Dwelling unit card:		structure type	
Zone No. :	Date:	house or apartment	owned or rented
Sample No. :	Address:	☐ ☐	☐ ☐

No. of person live in this unit:

No. of person older than 5 years:

How many employed residents:

Income level of family:

How many cars in use at this unit:

It's type:

2. / Trip card:

Per. No.	Relation to head of family	Sex	Where did the trip begin	Where did the trip end	Land use	Time of travel		Mode of travel
						Time start	Time end	

Per. No.	Relation to head of family	Sex	Where did the trip begin	Where did the trip end	Land use	Time of travel		Mode of travel
						Time start	Time end	