Research Journal of Recent Sciences ISSN 2277-2502
Vol. **2(4),** 36-45, April **(2013)** *Res. J. Recent Sci.*

Estimation of Air Pollution in Urban Streets by Modeling of PM_{10}, O_3 and CO Pollutants according to Regression Method (Case study-Yadegar and Azadi streets intersection, Tehran, IRAN)

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Available online at: www.isca.in
Received 5th January 2013, revised 14th January 2013, accepted 19th February 2013

Abstract

Nowadays, the growth of civilization rate, expansion in use of vehicles and development of economic activities all leads to increase of urban air pollution. Daily increase of urban traffic and emission of various pollutants has confronted the human to severe environmental problems, so that, it's effects are evident in the areas of physical health, psychological and economical losses. So, in order to reach to sustainable development and having clean air and transportations, we need a means to investigate the projects which are related to transportations with sufficient accuracy and numerically. In this study, the analysis and modeling of PM_{10}, O_3 and CO pollutants concentrations was investigated in Tehran. Parameters affecting the concentration of pollutants was specified according to weather and traffic statistics and the relation between various variables such as transportation, precipitation, maximum and minimum temperature and also relation between humidity and air pollution was investigated and finally, a model was presented according to regression method which will be capable to estimate the concentration of PM_{10}, O_3 and CO pollutants in city streets with appropriate accuracy for future years. one of applications of this model is assessment and prediction of production factors of these pollutants for manage and control tools.

Keywords: air pollution, urban streets, weather variables, traffic, modeling, regression.

Introduction

Air pollution is one of major problems of human and its importance in increasing daily. Unlike past, not only poor air quality resulted of industrial and household heating systems, but also vehicles movement is main reason of air pollution. Since, for design of a strategy for reducing air pollution, it's necessary to determine the air pollution sources and the amount of its emissions, and then control and manage it by an appropriate method[1], so, urban air quality studies are required. In Iran, by regarding of land usage, topography, traffic manner and so on, this issue is under discussion. Specification of various contaminants and adapting them with standards and finally practical solutions for reduction of air pollution, are some key parameters for specification and resolve of this problem in urban streets[2,3].

Currently, to achieve environmental goals and clarify the environmental issues for managers, preparing of environmental effects computational studies in traffic management designs and road design in order to control the air pollution has been under attention [4,5]. So, various studies in most parts of the world by using various methods have been done. in Denmark, a research under the title of "real estimations of automobile exhaust pollution by measuring of air quality and streets pollution models" has been done which is concentrated on benzene among the other present contaminants. Benzene is in fuel and Denmark could reduce the amount of benzene from 0.38 g/km to 0.11 g/km by reduction of benzene in fuel and increase of vehicles powered by catalyst[6]. in Taiwan, another research has been done under the title of "measurement and modeling of air pollution emissions in narrow urban streets" that measure the concentrations of SO_2, NO_X and CO contaminants and applied RNG K-4 model for modeling [7]. Also in Russia, for estimation of air pollution emission in narrow urban streets, the semi-empirical and mathematical model and urban model (USM) was used and in addition to weather and traffic variables, the arrangement and density of the buildings around the street has been studied and the influence of high density and arrangement of buildings in air pollution and concentration of contaminants has been mentioned[8].

Generally, modeling of air pollution in urban areas require of research in various scientific fields such as emissions science, fluid mechanics, meteorology, mathematic science and other sciences [9,10]. Along with well done researches and application of models such as CFD, USM, RNG K-4, semi-empirical-mathematical model and so on, the regression model is also used in this study. Regression analysis is a statistic technique for investigation and conversion to model of relationships between variables[11]. Another step in regression analysis is so called "appropriate relationship of the model" which satisfies the suitability of under study model and quality of fit [12]. The results of relationships of the model help us to say that the model is defensible or correct the main fit. Finally, the general aim is presentation of a model which able us to estimate the air pollution of urban streets and hereby pay to management and proper control of air pollution.

Material and Methods

In this study, modeling was done based on various variables such as traffic, precipitation, maximum and minimum of temperature, maximum and minimum of humidity and the amount of pollutants, and also the relationship between traffic and weather variables and air pollution was determined. In Tehran metropolis, the intersection of two main streets (Yadegare-Emam St. and Azadi St.) was determined as place of study. The reason for selection of this place is that at present according to statistics of Tehran Air Quality Control Company, this place is considered as one of important parts of pollution and traffic[13]. Gathering of required data were done by measuring devices and some data sources. Meteorological data were taken from the weather measurement station of Mehr-Abad in Tehran.

By placing of selected place (intersection of Yadegar and Azadi) within this station, the data obtained from Mehr-Abad station such as at various hours were used. Also the BABUK-A measurement device which has very sensible sensors was used to obtain data about the amount of pollutants. Measurement devices, in peak hours of traffic, were placed at two places of the intersection to make possible the accurate and comprehensive measurement of the amount of pollutants. Generally, during the gathering of information for this study, measurement of climate and traffic variables and emission measurement were done at peak hours (7 to 8 A.M. and 5-6 P.M.) according to statistics of Traffic and Transportation Company of Tehran [14].

Results and Discussion

In this study, the amount of air pollution was investigated for CO, O_3 and PM_{10} pollutants according to the climate and traffic conditions and relationship between them. Also, relationship between each of these pollutants and it's meaningfulness with traffic and weather data were separately investigated and finally, a specific model for each pollutant was presented. The variables used in the models include is as follow:

X_1: the amount of traffic, X_2: the amount of precipitation, X_3: minimum temperature, X_4: maximum temperature, X_5: minimum humidity, X_6: maximum humidity, Y_1: CO, Y_2: O_3, Y_3:PM_{10}.

The model related to CO: For determination of optimum model, at first, the relation between various variables and amount of CO is determined and then, the amount of correlation coefficient is calculated according to statistics studies[15,16]. (table-1)

The results obtained from correlation coefficient, according to level of significance (Sig<0.06) showing that there is a meaningfulness relation between the amount of CO and traffic, maximum and minimum of temperatures and amount of precipitation. Then, the scatter plots of CO pollutant related to various variables are showed in figure1.

By using of above diagram, only the linear model can be reviewed. (table-2)

As can be seen, the results obtained from variance analysis, shows the meaningfulness regression of the variables. After the variance analysis, now, fitting of the model parameters is done (table-3).

The results obtained from variables determination, according to level of significance (Sig<0.06), shows that none of coefficients except the coefficient related to the traffic amount, are non-zero with confidence of more than 0.95%. But, it is possible to make a linear model between the amount of CO pollutant and maximum temperature with confidence of 0.93%. Now, by correction of coefficients, model is fitting (table 4).

Finally, by regarding of results obtained from correction of coefficients, for CO pollutant, the linear model is obtained as follow:

$$Y_1 = 2.32 + 0.00073\ X_1 + 0.046\ X_4 \quad (1)$$

As can be seen, the obtained model shows that with a unit increase of maximum temperature, the amount of pollution related to CO pollutant is increases 0.046 unit, and also, with a unit increase in traffic amount, the amount of CO pollution increases 0.00073 units. After presenting of the model, finally, correlated or uncorrelated error and the amount of Watson - Camera index is investigated (table 5).

The amount of coefficient of determination (R2) in above table shows that about 81% of CO pollutant pollution is described by defined variables in model. Also, the amount of Watson Camera index shows that errors are uncorrelated. Watson - Camera index confirms the Regression model assumption that the value is between 1.5 to 2.5.

Validation of the model: After presenting the model, its validity in 2012 should be assessed to competence the model for estimation of the pollution in the coming years. This model is based on data of year 2011 and is set to estimate the pollution in year 2012 based on data that measured in same year. These data selected randomly from 4 different days of the year 2012 (table 6)

Validation of the model shows that the model works relatively good.

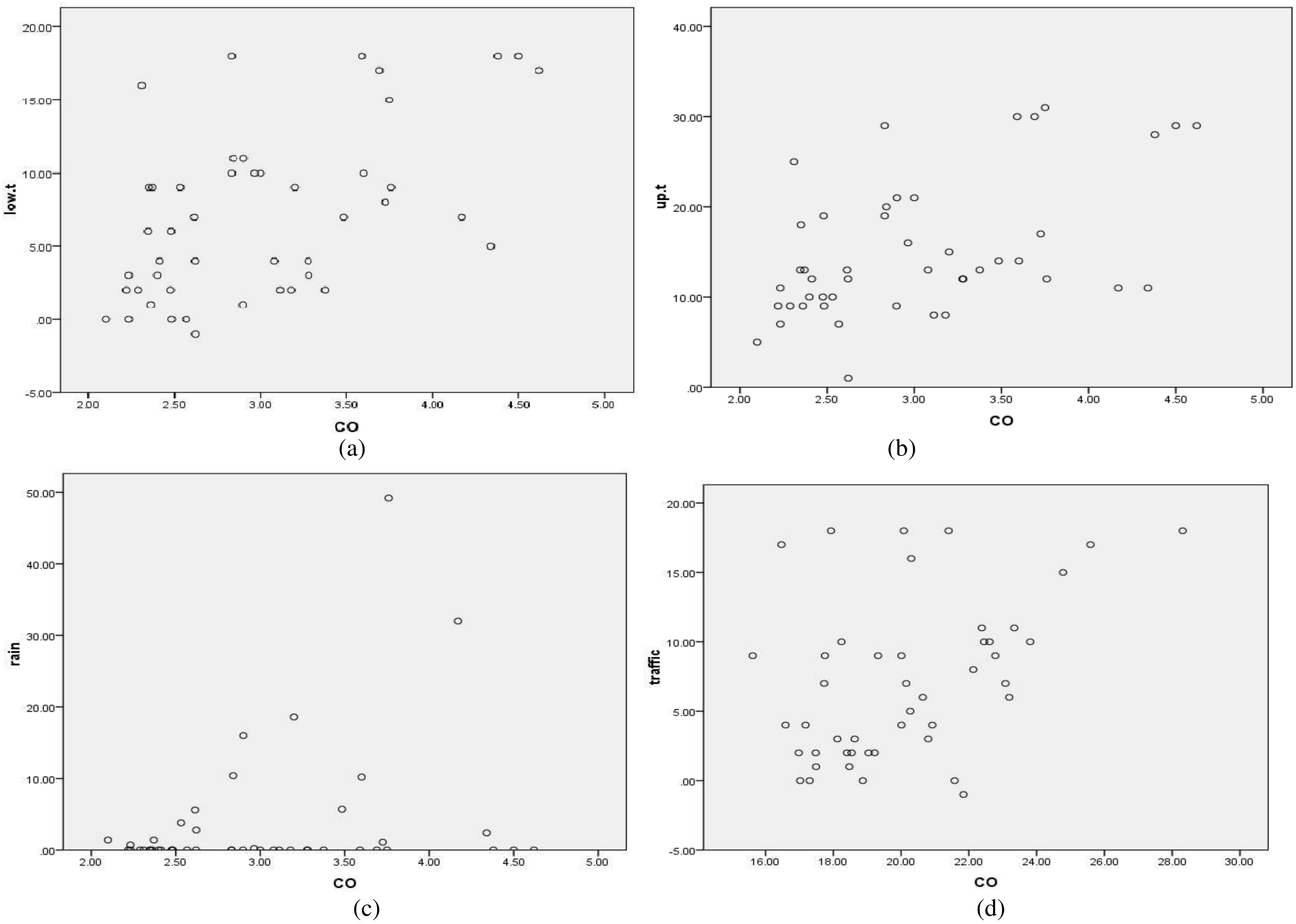


Figure-1
Scattering of CO pollutant related to variables of (a) minimum temperature, (b) maximum temperature, (c) precipitation, (d) volume of traffic

The model related to O_3: For determination of optimum model of O_3 pollutant, first, the relation between various variables and the amount of O_3 is determined and then, according to statistic studies, the amount of correlation coefficient is calculated[17]. (table-7)

The results obtained from correlation coefficients, according to level of significance (Sig<0.06), shows that there is not any relation between O_3 pollutant emissions and the amount of precipitation, but there is a meaningfulness relation between the amount of O_3 and the amount of traffic and maximum and minimum of temperatures and maximum and minimum of humidity. Then, the scatter curve of O_3 pollutant related to other various variables is plotted according to figure-2.

By using of above diagrams, only the second model can be reviewed (table-8).

As can be seen, the results obtained from variance analysis, according to level of significance (Sig<0.06) showing the meaningfulness of regression on variables. The meaningfulness of regression on variables means that at least one of the coefficients is none-zero. Now, this issue is investigated that which of the coefficients are none-zero (table-9).

The results obtained from analysis of coefficients, according to level of significance (Sig<0.06) showing the coefficients of maximum and minimum humidity, amount of traffic, and second-order of maximum humidity are became meaningful. Now, by correcting the coefficients and estimation of them by meaningful variables, model fitting is done (table-10).

Finally, by regarding the results obtained from correction of coefficients, a model has been presented for O_3 pollutant as below:

$$Y_2 = 19.069 - 0.026\, X_5 - 0.196\, X_6 + 0.0002\, X_1 + 0.001\, X_6^{\,2} \quad (2)$$

As can be seen, obtained model shows that with a unit increase in minimum humidity, the contamination level of O3 pollutant is decreased 0.026 units and with a unit increase in maximum air humidity, the contamination level of O_3 pollutant is decreased 0.196 units. Also, with a unit increase in the amount of traffic, the amount of O_3 pollutant is increased 0.0002 units. Now after presentation of this model, correlated or uncorrelated error and the amount of Watson - Camera index is investigated (table-11).

Table-1
Determination of correlation coefficient related to CO pollutant

CO	Traffic	up.wet	low.wet	m.rain	up.t	low.t
Correlation	0.68	-0.247	-0.075	0.280	0.506	0.540
Sig.(2-tailed)	0.06	0.098	0.62	0.06	0.000	0.000

Table-2
Variance analysis of CO pollutant

CO	Sum of Squares	df	Mean Square	F	Sig.
Regression	5.576	2	2.788	7.710	0.001
Residual	15.548	43	0.362	-	-
Total	21.123	45	-	-	-

Table-3
Determination of coefficients related to CO pollutant

CO	Non-standardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.510	0.960	-	0.532	0.598
low.t	0.000	0.048	-0.002	-0.005	0.996
up.t	0.078	0.042	0.866	1.839	0.073
m.rain	0.016	0.011	0.215	1.442	0.157
low.wet	0.012	0.007	0.369	1.727	0.092
up.wet	0.003	0.008	0.099	0.380	0.706
traffic	0.056	0.001	0.852	2.157	0.036

Table-4
Corrected coefficients

CO	Non-standardized Coefficients		Standardize Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.321	0.549	-	3.587	0.001
up.t	0.046	0.012	0.508	3.880	0.000
traffic	0.00073	0.010	0.089	3.092	0.000

Table-5
Coefficient of determination

CO	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
	0.1058	0.816	0.782	0.59765	1.643

Table-6
Validation results of CO

NO.	CO	$\widehat{CO}$
1	5.62	5.48
2	4.19	4.30
3	3.71	4.35
4	2.70	3.5

Table-7
Determination Correlation coefficient for O_3 pollutant

O_3	traffic	up.wet	low.wet	m.rain	up.t	low.t
Correlation	-0.532	-0.75	-0.668	-0.24	0.783	0.742
Sig.(2-tailed)	0.048	0.000	0.000	0.109	0.000	0.000

Table-8
Variance analysis of O_3 pollutant

O_3	Sum of Squares	Df	Mean Square	F	Sig.
Regression	84.896	10	8.490	12.371	0.000
Residual	24.018	35	0.686	-	-
Total	108.914	45	-	-	-

Table-9
Determination of variations related to O_3 pollutant

O_3	Non-standardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	22.829	5.852	-	3.901	0.000
low.t	0.139	0.151	0.515	0.920	0.364
up.t	0.047	0.155	0.228	0.301	0.765
low.wet	-0.061	0.036	-0.862	-1.684	0.01
up.wet	-0.270	0.076	-3.698	-3.567	0.001
traffic	-0.072	0.005	-2.502	-2.362	0.040
low.t2	-0.014	0.010	-0.923	-1.368	0.180
up..t2	0.000	0.004	-0.085	-0.111	0.912
low.wet2	0.000	0.000	0.420	0.956	0.346
up.wet2	0.002	0.001	3.141	3.371	0.002
traffic2	3.296E-7	0.000	0.310	0.223	0.825

Table-10
Corrected coefficients

O_3	Non-standardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	19.069	1.271	-	15.000	0.000
low.wet	-0.026	0.010	-0.367	-2.518	0.016
up.wet	-0.196	0.034	-2.679	-5.732	0.000
traffic	0.0002	0.000	-0.191	-2.374	0.022
up.wet2	0.001	0.000	2.251	4.581	0.000

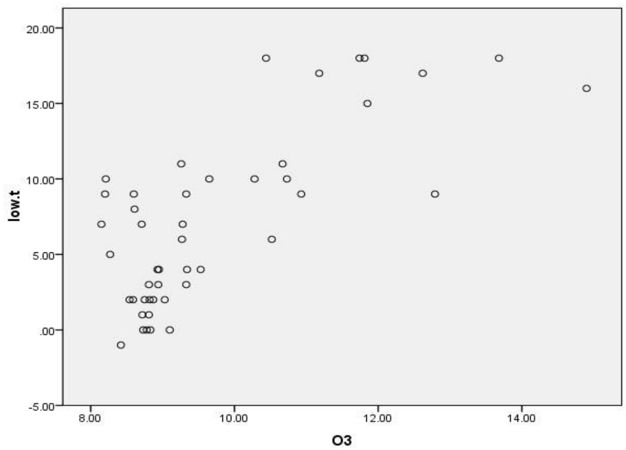
The amount of coefficient of determination (R^2) in above table shows that about 73.6% of O_3 pollutant pollution is well defined by mentioned variables in model. Also, the amount of Watson - Camera index shows the that errors are uncorrelated.

Validation of the model: After presenting the model, its validity in 2012 should be assessed to competence the model for estimation of the pollution in the coming years. This model is based on data of year 2011 and is set to estimate the pollution in year 2012 based on data that measured in same year. These data selected randomly from 4 different days of the year 2012 (table 12)

Validation of the model shows that the model works very well.

The model related to PM_{10}: For determination of optimum model for PM_{10} pollutant, initially the relationship between various variables and the amount of PM_{10} is determined and then, according to statistical studies, the amount of correlation coefficient can be calculated (13,14). (table 13)

The results obtained from correlation coefficients, according to level of significance (Sig<0.06), shows that the amount of PM_{10} pollutant only has a meaningful relation with the maximum and minimum of humidity, the amount of precipitation and maximum temperature. But it must be mentioned that, the relation between the amount of traffic and PM_{10} pollutant is accepted with confidence of 0.93%. Then, the curve of PM_{10} pollutant relative to various variables is drawled according to figure 3.



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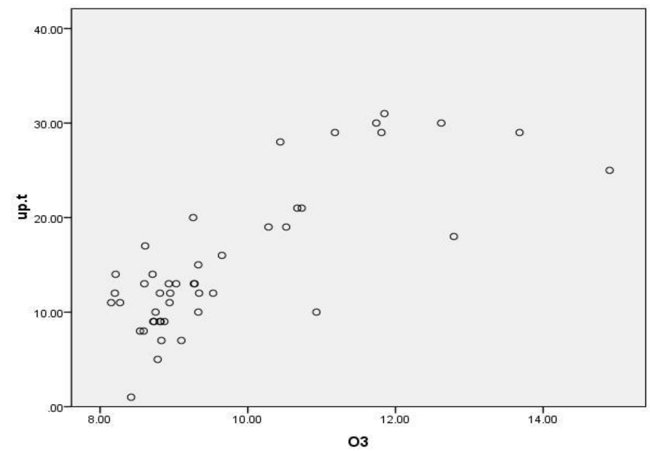

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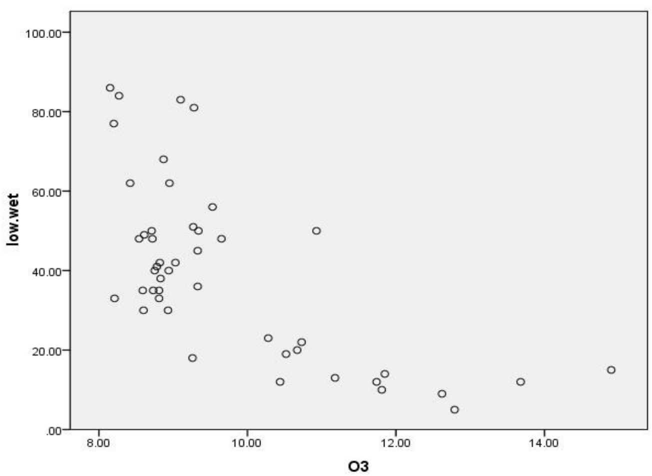

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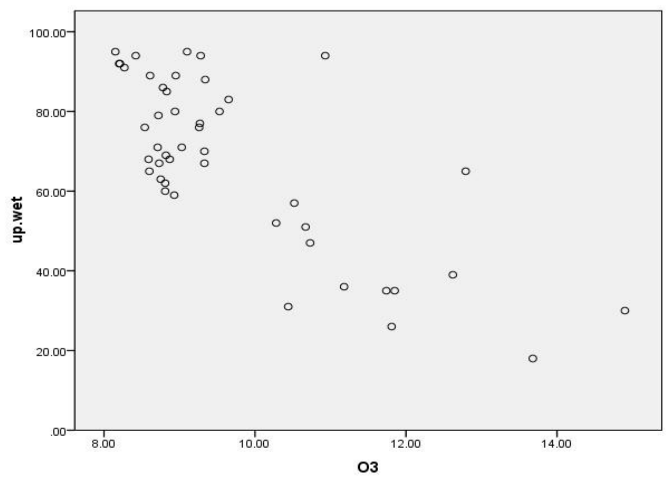

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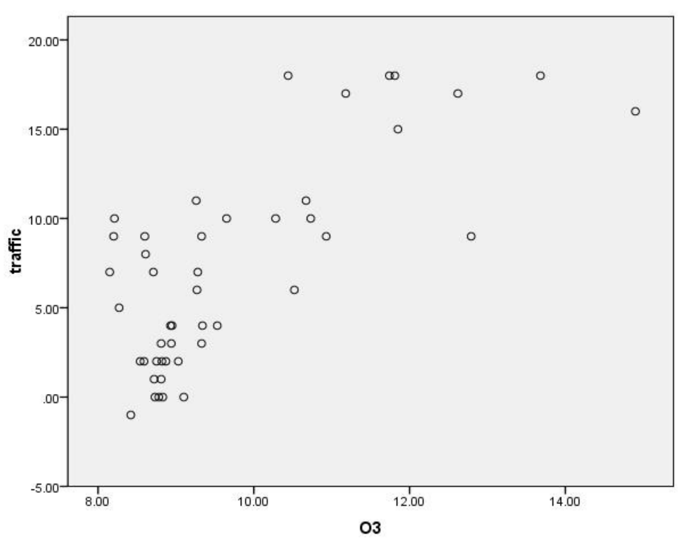
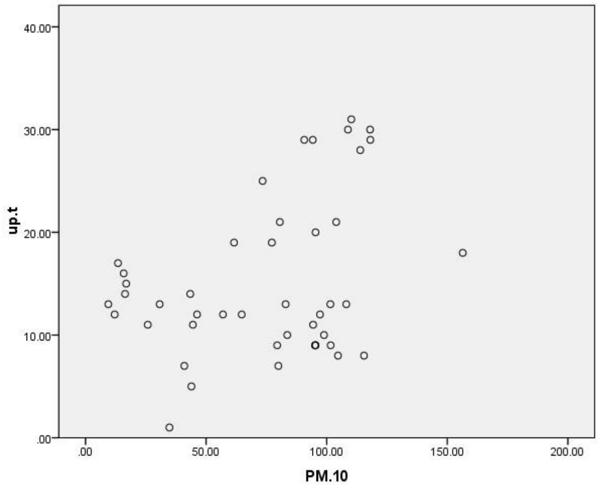


(e)

Figure-2

Scattering of O_3 pollutant related to variables of (a) minimum temperature, (b)maximum temperature, (c) minimum humidity, (d) maximum humidity and (e) volume of traffic



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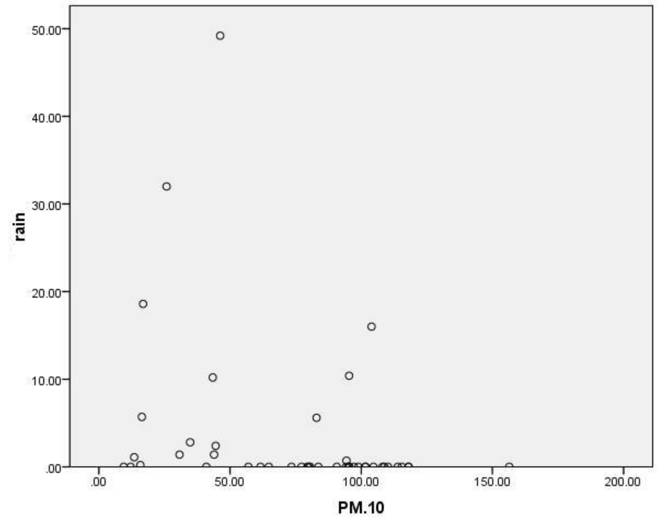

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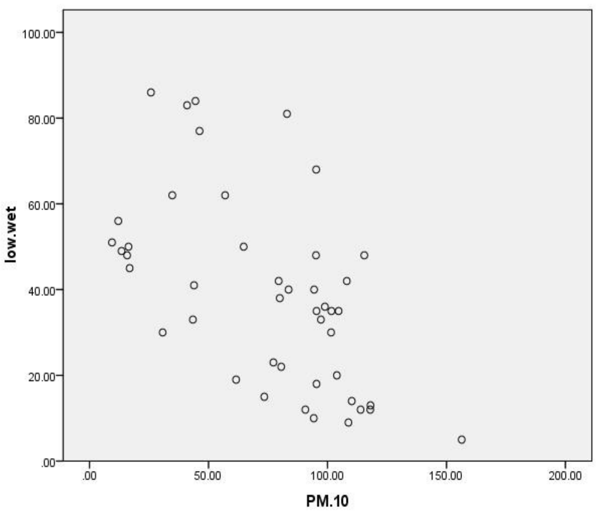

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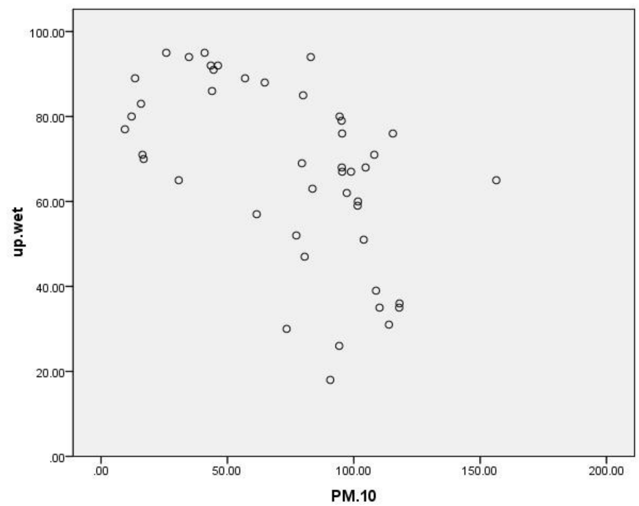

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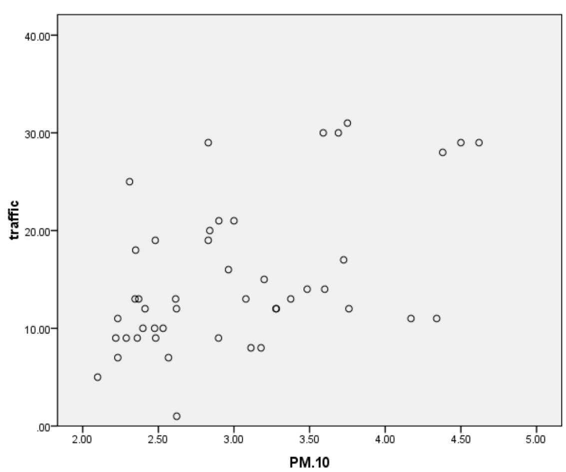

(e)

Figure-3

Scattering of PM_{10} pollutant related to variables of (a) maximum temperature, (b) precipitation, (c) minimum humidity, (d) maximum humidity and (e) volume of traffic

By application of above diagrams, the linear model is investigated and variance analysis is done (table 14).

As can be seen, the results obtained from variance analysis, showing at least one of the coefficients is none-zero. Now, by determining of coefficients, this issue is investigated that which of the coefficients are none-zero (table 15).

The results obtained from correlation coefficients, according to level of significance (sig>0.05), shows that the correlation coefficients of maximum and minimum of humidity and amount of traffic and minimum temperature have became meaningful. Now, the model is fitted by correction of coefficients (table 16). Finally, by regarding the results obtained from correction of coefficients, a linear model has been obtained for PM_{10} pollutant as below:

$Y_3 = 201.054 – 2.571\ X_3 – 0.636\ X_5 – 0.904\ X_6 + 0.001\ X_1$ (3)

Obtained model for PM_{10} shows that with a unit increase in minimum temperature, maximum and minimum of humidity, the contamination level of PM_{10} is decreased 2.571, 0.636 and 0.904 units, respectively and with a unit increase in traffic, the contamination level of PM_{10} is increased 0.001 units. now after presentation of the model, correlated or uncorrelated error and the amount of Watson - Camera index is investigated (table 17).

The amount of coefficient of determination (R^2) in above table shows that about 60% of PM10 pollutant pollution is well defined by mentioned variables in model. Also, the amount of Watson - Camera index shows that errors are uncorrelated.

Validation of the model: After presenting the model, its validity in 2012 should be assessed to competence the model for estimation of the pollution in the coming years. This model is based on data of year 2011 and is set to estimate the pollution in year 2012 based on data that measured in same year. These data selected randomly from 4 different days of the year 2012 (table 18)

Validation of the model shows that the model works very well.

Table-11
Coefficient of determination

	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
O_3	.858	0.736	0.710	0.83708	1.602

Table-12
Validation results of O_3

NO.	O_3	$\widehat{O_3}$
1	12.34	13.52
2	8.15	8.20
3	9.34	9.19
4	10.81	10.69

Table-13
Determining of correlation coefficient for PM10 pollutant

PM10	Traffic	up.wet	low.wet	m.rain	up.t	low.t
Correlation	-0.564	-0.542	-0.572	-0.290	0.347	0.196
Sig.(2-tailed)	0.074	0.000	0.000	0.054	0.019	0.197

Table-14
Variance analysis of PM10 pollutant

PM10	Sum of Squares	df	Mean Square	F	Sig.
Regression	24998.994	5	4999.799	5.934	0.000
Residual	32860.983	39	842.589	-	-
Total	57859.977	44	-	-	-

Table-15
Determining of coefficient related to PM10 pollutant

PM10	Non-standardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	203.610	40.741	-	4.998	0.000
low.t	-2.743	1.222	-0.439	-2.244	0.031
m.rain	0.178	0.587	0.046	0.303	0.763
low.wet	-0.666	0.359	-0.404	-1.855	0.050
up.wet	-0.935	0.430	-0.545	-2.173	0.036
traffic	-0.0010	0.011	-0.105	-2.047	0.042

Table-16
Corrected coefficients

PM10	**Non-standardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
	B	**Std. Error**	**Beta**		
(Constant)	201.054	39.405	-	5.102	0.000
low.t	-2.571	1.072	-0.412	-2.399	0.021
low.wet	-0.636	0.341	-0.386	-1.865	0.070
up.wet	-0.904	0.413	-0.527	-2.188	0.035
traffic	0.0010	0.011	-0.112	-2.421	0.043

Table-17
Coefficient of determination

PM10	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Durbin-Watson**
	0.826	0.614	0.537	28.69606	1.681

Table-18
Validation results of PM 10

NO.	**PM**	$\widehat{PM}$
1	100.07	91.02
2	42	38.82
3	64.65	61.37
4	100.64	103.84

Conclusion

By regarding of modeling results and according to the issue that the results obtained for each pollutant (according to traffic and weather variables) is different, studies have been conducted separately for each variable. After presentation of the model and investigation of relationship between variables and the amount of air pollution, it has been cleared that with a unit increase of maximum temperature, the amount of pollution related to CO pollutant is increases 0.046 unit, and also, with a unit increase in traffic amount, the amount of CO pollution increases 0.00073 units. These results showing that among 6 available variables, maximum temperature and traffic variables have the greatest impact on CO. About the O_3 pollutant, with a unit increase in minimum humidity, the contamination level of O_3 pollutant is decreased 0.026 units and with a unit increase in maximum air humidity, the contamination level of O_3 pollutant is decreased 0.196 units. Also, with a unit increase in the amount of traffic, the amount of O_3 pollutant is increased 0.0002 units. These results showing that the amount of traffic, maximum humidity and minimum humidity are influential variables on O_3. Also, for PM_{10} pollutant, the obtained results from model indicate that with a unit increase in minimum temperature, maximum and minimum of humidity, the contamination level of PM_{10} is decreased 2.571, 0.636 and 0.904 units, respectively and with a unit increase in traffic, the contamination level of PM_{10} is increased 0.001 units. Finally, by presenting of these models in this study, the influences of various parameters in the desired location and city, on the concentrations of CO, O_3 and PM_{10} pollutants are obtained and these models are capable to estimate the air pollution resulted from traffic.Validation of the model shows that the model works very well and modeling by regression method is suitable and works well for the streets of Iranian cities. Finally, the overall conclusions of this study are as below:

Regression analysis is a suitable method for investigation of relation between air pollution and variables. Regression analysis is a statistical method for investigation and modeling of relation between variables and one of the main objectives is the estimating the parameters of model.

The main influential variable on the amount of various pollutants concentrations in urban streets is traffic volume.

By prediction and estimating of pollutants in urban streets, management and better control of air pollution can be paid and presented model in this study can be used as a tool in this regard.

Traffic educations, increase of public transportations systems and modification of the streets geometry and surrounding buildings can be considered as some ways for management and controlling of the air pollution in urban streets in order to reduce the amount of air contaminants.

Abbreviation: T = Temp, Sig = Significant, F = Fisher, Df = Degree of freedom, Std = Standard, T = T- student.

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