Pollution, 3(4): 527-537, Autumn 2017
DOI: 10.22059/POLL.2017.62770
Print ISSN: 2383-451X Online ISSN: 2383-4501
Web Page: https://jpoll.ut.ac.ir, Email: jpoll@ut.ac.ir

Status of CO as an air pollutant and its prediction, using meteorological parameters in Esfahan, Iran

Masoudi, M.[1*] and Gerami, S.[2]

1. Associate Professor, Department of Natural Resources and Environmental Engineering, Shiraz University, Iran

2. Department of Natural Resources and Environmental Engineering, Shiraz University, Iran

Received: 15 Dec. 2016 Accepted: 11 Jun. 2017

ABSTRACT: The present study analyzes air quality for Carbon monoxide (CO), in Esfahan with the measurements taken in three different locations to prepare average data in the city. The average concentrations have been measured every 24 hours, every month and every season with the results showing that the highest concentration of CO occurs generally in the morning and at the beginning of night, while the least concentration has been found in the afternoon and early morning. Monthly concentrations of CO show the highest values in August and the lowest values in February. The seasonal concentrations show the least amounts in spring, while the highest amounts belong to summer. Relations between the air pollutant and some meteorological parameters have been calculated statistically, using the daily average data. The data include Temperature (min, max), precipitation, Wind Direction (max), Wind Speed (max), and Evaporation, considered independent variables. The relations between the pollutant concentration and meteorological parameters have been expressed by multiple linear regression equations for both annual and seasonal conditions, using SPSS software. Analysis of variance shows that both regressions of 'enter' and 'stepwise' methods are highly significant, indicating a significant relation between the CO and different variables, especially for temperature and wind speed in annual condition. RMSE test shows that among different prediction models, stepwise model is the best option.

Keywords: air pollution, CO, meteorological parameters, regression model.

INTRODUCTION

Air sustains life; however, the air we breathe is not pure. It contains lots of pollutants, most of which are toxic (Sharma, 2001; Majidnezhad, 2014; Fleischer et al., 2014; Asghari Esfandani & Nematzadeh, 2016; Khader et al., 2016). While developed countries made progress in the last century, air quality has been becoming much worse. Particularly, in developing countries air pollution exceeds all health standards, e.g. in Lahore and Xian (China) dust is ten times higher than health standards (Sharma, 2001).

Carbon monoxide (CO) is one of the seven conventional (criteria) pollutants (in addition to SO_2, particulates, hydrocarbons, nitrogen oxides, O_3, and lead), which release the highest amount of pollutants to the air, posing the most serious threat for human health and welfare. Concentration of these pollutants, especially in cities, has been

---

[*] Corresponding author E-mail: masoudi@shirazu.ac.ir

regulated by Clean Air Act, since 1970 (Cunningham & Cunningham, 2002). CO pollution occurs primarily from emissions from fossil-fuel-powered engines, such as motor vehicles along with non-road engines and vehicles (like construction equipment and boats). Higher levels of CO generally occur in areas with heavy traffic congestion.

The presence of pollutants in the atmosphere causes lots of problems, making a study of pollutant's behavior necessary (Asrari et al., 2007; Masoudi & Asadifard, 2015). CO can have harmful health effects by reducing oxygen delivery to the body's organs and tissues. Exposure to lower levels of CO is most serious for those, suffering from heart disease, and can cause chest pain, reduce the ability to exercise, or –on more frequent exposures– may contribute to other cardiovascular problems. Even healthy people can be affected by high levels of CO. People, who breathe high levels of CO, can develop vision problems, reduced ability to work or learn, reduced manual dexterity, and difficulty performing complex tasks. At very high levels, CO is poisonous, capable of causing death.

The status of pollutant concentration, on one hand, and the impacts of meteorological and atmospheric parameters on these pollutants, on the other, compose the foundation of the following studies: Ho and Lin (1994) studied semi-statistical model for evaluation of NO_x concentration by considering source emissions and meteorological effects. What is more, street level of NO_x and SPM in Hong Kong was studied by Lam et al. (1997). In another study, the relation between monitored air pollutants and meteorological factors, such as wind speed, relative humidity ratio, and temperature, was statistically analyzed, using SPSS. According to the results obtained through multiple linear regression analysis, for some months there was a moderate and weak relation between the air pollutants like CO level and the meteorological factors in Trabzon city (Cuhadaroglu & Demirci, 1997).

Adamopoulos et al. (1996). Studied the meteorological factors that influence CO concentration and gave formulae to correlate them for the year 1982. Their results showed that there were considerable relations between the meteorological factors and CO concentrations.

Mandal (2000) showed the progressive decrease of air pollution from west to east in Kolkata, while statistical modeling of ambient air pollutants in Delhi was carried out by Chelani et al. (2001). Abdul-Wahab and Al-Alawi (2002) developed a neural network model to predict the tropospheric (surface or ground) ozone concentrations as a function of meteorological conditions along with various air quality parameters. The results of this study showed that the Artificial Neural Network (ANN) is a promising method for air pollution modeling. The observed behavior of pollution concentrations to the prevailing meteorological conditions was studied for the time period between June 13 and September 2, 1994, in the Metropolitan Area of Sao Paulo (Sánchez-Ccoyllo & Andrade, 2002). Results showed that the low concentrations were associated with intense ventilation, precipitation, and high relative humidity, while high values of concentrations prevailed due to weak ventilation, absence of precipitation, and low relative humidity for some pollutants. Also for the purpose of predicting CO, Sabah et al. (2003) used a statistical model.

Elminir (2005) claimed that air pollutants in Cairo, Egypt, depended on meteorology. His results hinted that wind direction was found to have an influence not only on pollutant concentrations but also on the correlation between pollutants. As expected, traffic-associated pollutants were at the highest ambient concentration levels when wind speed was low. At higher wind speeds, dust and sand from the surrounding desert was carried by the wind, thus contributing to ambient particulate matter levels. It was also found that, the highest average concentration for NO_2 and O_3 occurred at humidity ≤40%, indicative of strong vertical mixing. As for CO, SO_2, and PM_{10}, the highest average concentrations occurred at humidity above 80%. In another research, data on the concentrations of seven air pollutants (CH_4, NMHC, CO, CO_2, NO, NO_2, and SO_2) and meteorological variables (wind speed and direction, air temperature, relative humidity, and solar radiation) were used to predict the concentration of ozone in the atmosphere, using both multiple linear and principal component regression methods (Abdul-Wahab et al., 2005). Results showed that while high temperature and high solar energy tended to increase the day time ozone concentrations, the pollutants NO and SO_2, emitted to the atmosphere, were being depleted. However, the model did not predict the night time ozone concentrations as precisely as it did for the day time. Asrari et al. (2007) studied effect of meteorological factors on CO prediction. Also variations in concentration of CO in different times were dealt with in this study.

Li et al. (2014) presented the spatial and temporal variation of Air Pollution Index (API) and examined the relations between API and meteorological factors during 2001–2011, in Guangzhou, China. It was found that there were some relations between API and a variety of meteorological factors: temperature, relative humidity, precipitation, and wind speed were negatively correlated with API, while diurnal temperature range and atmospheric pressure were positively correlated with API in the annual condition. Yoo et al. (2014) mentioned that all of the pollutants showed significant negative correlations between their concentrations and rain intensity due to washout or convection. The relative effect of the precipitation on the air pollutant concentrations was estimated to be PM_{10}> SO_2> NO_2> CO> O_3, indicating that PM_{10} was most effectively cleaned by rainfall.

Model evaluation in an urban site in the Indo-Gangetic plain (Michael et al., 2014) showed an increase in model biases in simulation of O3 and CO towards the onset of monsoon, compared to spring.

Wang et al. (2015) studied air quality in Chongqing, the largest mountainous city in China, conducting statistical analysis of SO_2, PM_{10}, and NO_2 concentrations from 2002 to 2012. The analysis of Pearson correlation indicated that concentrations of SO_2, PM_{10}, and NO_2 were positively-correlated with atmospheric pressure, but negatively-associated with temperature and wind speed. The analysis of Multi-Pollutant Index (MPI) showed that air quality in Chongqing was serious.

The climatology of tropospheric ozone at Irene was investigated using SHADOZ network data to assess the correlation between the observed seasonal ozone enhancement and meteorological factors (Mulumba et al., 2015). A multiple linear regression model was used to provide seasonal correlation between ozone and temperature and relative humidity with all seasons displaying strong regression coefficients between ozone and temperature. Similar trends were also observed for relative humidity and ozone concentrations in autumn, spring, and summer.

Asperen et al. (2015) suggested the potential importance of abiotic degradation in arid ecosystems. Their study assessed the role of photo- and thermal degradation in ecosystem CO_2 and CO exchange, recognizing the possible importance of abiotic degradation for arid regions, such as photo- and thermal degradation.

Halimi et al. (2016) investigated the spatial distribution of three air pollutants in Tehran’s atmosphere: carbon monoxide (CO), nitrogen dioxide (NO_2), and atmospheric particulate matters, less than 10 μm in diameter (PM10 μm). Their results indicated that by using two auxiliary variables, having strong correlation with CO, the ordinary Cokrigingа scheme for CO consistently outperformed all interpolation methods for estimation of this pollutant, while simple Kriging was the best model to estimate NO_2 and PM_{10}.

Statistical modeling of ozone in Ahvaz, Tehran and Shiraz was conducted by Masoudi et al. (2014a, 2014b, 2016a). According to the results, obtained through multiple linear regression analysis, for seasonal and annual conditions there were significant relations between ozone and meteorological factors in these cities. The following results were observed between other pollutants and meteorological factors in other Iranian cities: NO_2 in Ahvaz (Masoudi & Asadifard, 2015), PM_{10} in Tehran (Masoudi et al., 2016b), SO_2 in Ahvaz (Masoudi et al., 2017a), and CO in Shiraz (Masoudi et al., 2017b).

The present study exhibits diurnal, monthly, and seasonal variations of CO concentration as well as a statistical model, able to predict amount of CO. It is based on Multiple Linear Regression Technique, which estimates the coefficients of the linear equation, involving one or more independent variables that best predict the value of the dependent variables (CO amount in this study). So, a large statistical and graphical software package (SPSS, Software Package of Social Sciences, v20) has been used as one of the best known statistical packages (Kinnear, 2002).

MATERIALS AND METHODS

Study area

The research area, Esfahan, capital of Esfahan Province, is the biggest city in central Iran (Fig. 1), located around 32° 38' N and 51º 40' E with an altitude of about 1590 m above the mean sea level. It has semi-arid climate with four distinct seasons. Residential population was 1,834,000 in 2011. Esfahan is built on the banks of the Zayandeh-rud River.

There are lots of cars in the city with many factories and industrials places around the city. Because of these problems, Esfahan is one of the most polluted cities in Iran, thus arising the need to carry out an ambient air quality analysis in the city.

Data and Methodology

Three available sampling stations in the city called, Azadi, Bozorg-mehr, and Laleh (Fig. 1), belonging to Environmental Organization of Iran, were selected to represent different traffic loads and activities.

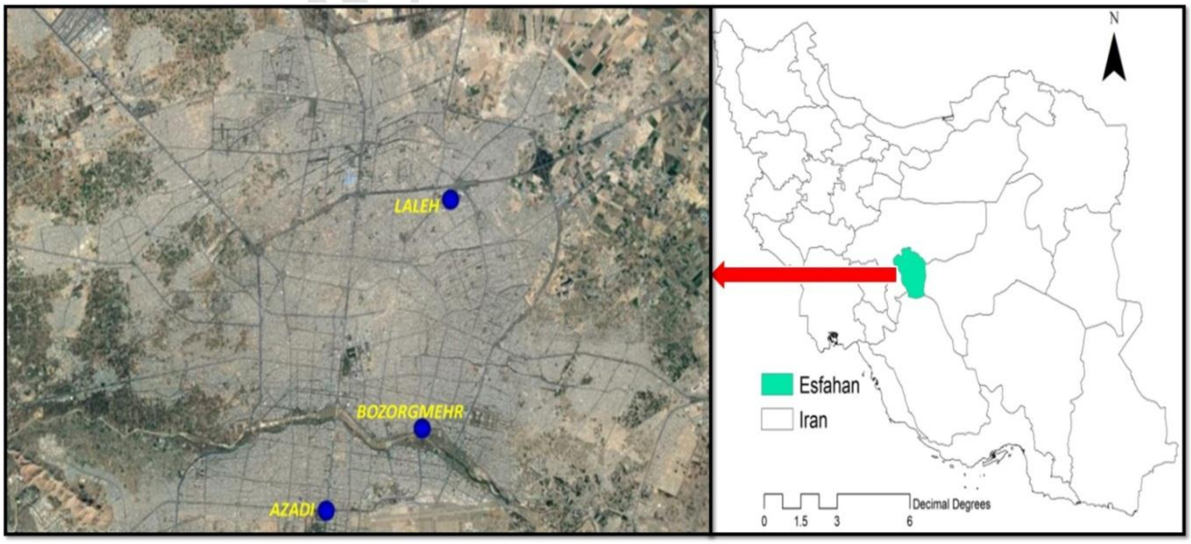

Fig. 1. Position of Esfahan in Iran and its air pollution measurement stations

The sampling was performed every 30 minutes daily for each pollutant throughout 2010 and 2011. Among the measured data in the three stations, CO was chosen. Then the averages were calculated for every hour, monthly and seasonally for the three stations by Excel. Finally, data averages at three stations were used to show air pollution situation as diurnal, monthly, and seasonal graphs of CO concentration in the city.

The next step entailed studying CO correlation and metrological parameters of synoptic station in the city. The metrological parameters studied included temperature (min, max), precipitation, wind direction (max), wind speed (max), and evaporation.

In the next step, daily average data at three stations in 2011 was considered dependent variable for statistical analysis while daily data of meteorological parameters during this year, regarded as independent variables in SPSS, were used for this purpose with the multiple regression equations showing that CO concentration depended on the kind of meteorological parameters, giving an idea about the levels of these relations. The relation between the dependent variable and each independent variable was taken into consideration for linear technique. The significant values in output were based on fitting a single model. Moreover, linear regression equation was made for different seasons, perhaps to show the relations, not observed using annual data.

The model for CO prediction was determined, using two multiple regression modeling procedures of ‘enter method’ and ‘stepwise method’. In the former, all independent variables selected were added to a single regression model, whereas in the latter, which is better, all variables can be entered or removed from the model, depending on the significance. Therefore, only those variables with more influence on dependent variable were observed in a regression model.

RESULTS AND DISCUSSION

Figures 2, 3, and 4 illustrate the diurnal, monthly, and seasonal variations in CO concentration. As shown in Figure 2, high concentration of CO occurs in the morning and in the beginning of night. Heavy traffic during this time may be responsible for this high concentration. Monthly concentration of CO showed the highest values in August and the lowest ones in February (Fig. 3). Seasonal concentration showed the highest values in summer and the lowest ones in spring (Fig. 4). Fortunately, all graphs (with the exception of August) showed that the concentrations of Carbon monoxide were lower than Primary Standards of Carbon monoxide (9 ppm), recommended by National Ambient Air Quality Standards (NAAQS) of USA and Iran. However, these graphs almost concern annual and monthly conditions, not the hourly ones, even though 9 ppm is the Primary Standard for the latter condition. Therefore, the real standard annual and monthly amounts should be less than this amount. Thus, it is assumed that some of these amounts in the figs. are more than the real standards, showing unhealthy conditions. The results were almost in good agreement with the ones, obtained in other cities like Shiraz (Ordibeheshti & Rajai poor, 2014) and Tehran (Behzadi & Sakhaei, 2014), but differed from monthly and seasonal graphs of Ahvaz (Asadifard, 2013).

Table 1 shows the relations between CO and other air pollutants. For example, the concentration of CO shows negative correlation with NO_2, NO_X, and SO_2. On the other hand, it shows positive correlation with PM_{10}, both of which both were observed in emission of auto exhausts. These results are almost in good agreement with other results regarding CO assessment in other cities like Ahvaz (Asadifard, 2013) and Tehran (Behzadi & Sakhaei, 2014). Correlation coefficients, significant at 0.05 level, are identified with a single asterisk (significant), and the ones,

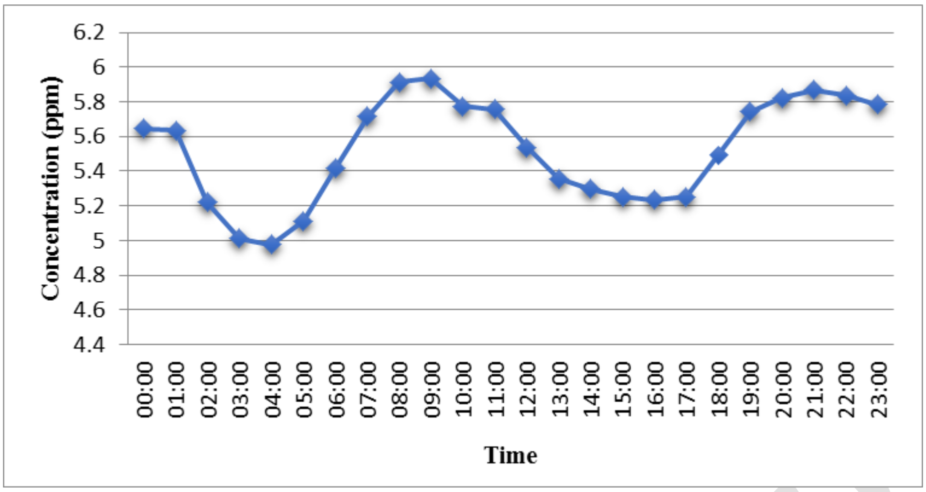

Fig. 2. Diurnal variation of CO concentration in Esfahan

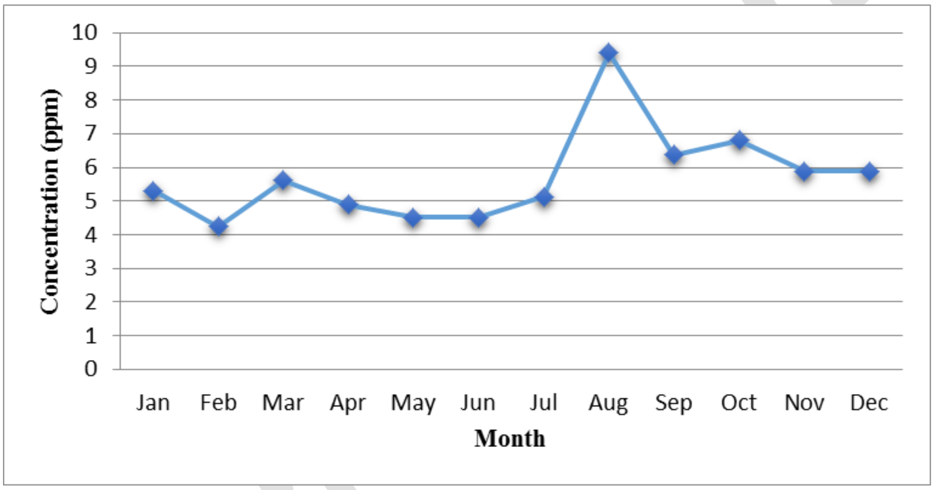

Fig. 3. Monthly variation of CO concentration in Esfahan

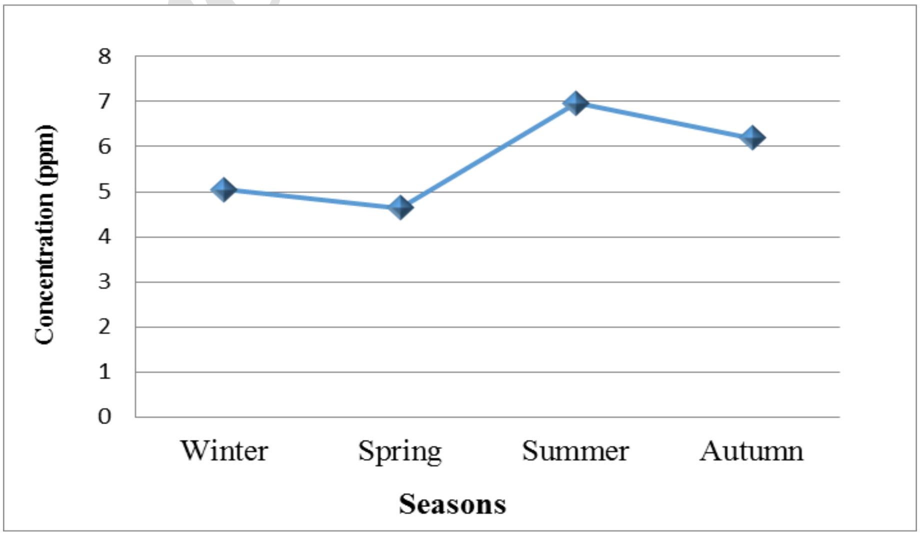

Fig. 4. Seasonal variation of CO concentration in Esfahan

significant at 0.01 level, are identified with double asterisks (highly significant).

Table of variance analysis (Table 2) shows that both regressions of ‘enter’ and ‘stepwise’ methods for annual condition are highly significant, indicating a considerable relation among the different variables.

Table 3 demonstrates the coefficients of CO pollution model and regression lines for both enter and stepwise methods in annual condition, showing regression coefficients, standard errors, standardized coefficient beta, t values, and two-tailed significance level of t.

Table 1. Correlation between air pollutants and CO

	PM_{10}	**NO_2**	**NO_X**	**O_3**	**SO_2**
Pearson Correlation	$.235^{**}$	$-.128^{*}$	-.087	.072	-.156**
Sig. (2-tailed)	.000	.018	.107	.182	.004
N	344	344	344	344	344

Table 2. Variance analysis for regressions of both ‘enter’ (a) and ‘stepwise’ (b) methods for annual condition.
Analysis of variance (a)

Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	47.268	6	7.878	3.697	.002**
Residual	549.776	258	2.131		
Total	597.044	264			

Predictors: (Constant), Temperature (min, max), precipitation, Wind Direction (max), Wind Speed (max), and Evaporation.
Dependent Variable: CO

Variance Analysis (b)

Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	45.009	3	15.003	7.093	.000**
Residual	552.034	261	2.115		
Total	597.044	264			

Predictors: (Constant), Temperature (min, max), Wind speed (max)
Dependent Variable: CO

Table 3. Coefficients of CO pollution model and regression lines for both enter (a) and stepwise (b) methods for annual condition.
Coefficients (a)

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
	B	**Std. Error**	**Beta**		
(Constant)	5.019	.538		9.321	.000
Evaporation	-.032	.052	-.073	-.601	.549
Temperature $_{max}$	.110	.034	.608	3.235	.001**
Temperature $_{min}$	-.108	.041	-.465	-2.607	.010*
Rain	.012	.051	.016	.238	.812
Wind Direction $_{max}$	-.001	.001	-.052	-.794	.428
Wind Speed $_{max}$	-.070	.034	-.134	-2.074	.039*

Dependent Variable: CO

Coefficients (b)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	4.993	.461		10.831	.000
Wind Speed $_{max}$	-.081	.032	-.154	-2.552	.011*
Temperature $_{max}$	.104	.030	.574	3.495	.001**
Temperature $_{min}$	-.114	.038	-.489	-2.957	.003**

Dependent Variable: CO

The linear regression equations show that the CO pollution depends on the meteorological parameters, also giving an idea about the levels of relations. The linear model equations after using 'enter method' and 'stepwise method' for annual condition are:

CO amount (ppm) using 'enter method' for annual condition = 5.019 + (-.032) Evaporation + (.110) Temperature $_{max}$ + (-.108) Temperature $_{min}$ + (.012) Rain + (-.001) Wind Direction (max) + (-.070) Wind speed $_{max}$ R= .281 (significant at 0.01)

CO amount (ppm) using 'stepwise method' for annual condition = 4.993 + (.104) Temperature $_{max}$ + (-.114) Temperature $_{min}$ + (-.081) Wind speed $_{max}$ R= .275 (significant at 0.01)

Results of linear regression model show that Temperature $_{min}$ and Wind speed $_{max}$ have reverse effect on CO concentration, thus when these parameters increase, CO concentration is decreased, whereas when Temperature $_{max}$ ascends, CO concentration soars considerably (Table 3b). Other meteorological parameters show different effects on CO amounts, though these results are not significant, e.g. evaporation has reverse effect on CO concentration (Table 3a). These results are almost in good agreement with other results, regarding CO measurements in other Iranian cities like Shiraz (Ordibeheshti & Rajai poor, 2014), Ahvaz (Asadifard, 2013), and other regions (Elminir, 2005; Li et al., 2014). Actually some of these events happen in real conditions. Increase in rainfall, wind speed, and temperature (inversion occurs in low temperatures) usually decrease most of air pollutants (Asrari et al., 2007). The values and significance of R (multiple correlation coefficients) in both equations show their capability when predicting the CO amount. The amount of Adjusted R^2 in both equations is almost 0.06, showing that different parameters can calculate almost 6% variability of CO. This result indicates that in order to predict most of air pollutants like CO, we should consider consumption of fossil fuels, especially in motor vehicles. Half of the emission of Hydrocarbons (VOC) and NOx in cities is because of motor vehicles. The automobile exhaust produces 75% of total air pollution, releasing poisonous gases like CO (77%), NOx (8%), and Hydrocarbons (14%) (Sharma, 2001). On the other hand, R in "enter method" (0.281) is almost equal to "stepwise method" (0.275), not showing any outstanding difference. Therefore, the second equation, based on "stepwise method", can be used to predict CO in the city instead of the first one which needs more data. What is more, no difference between the two R values indicates that the excluded variables in second equation have less effect on measurement of CO in the city. Beta in Table 3 shows those independent variables (meteorological parameters) which have more influence on dependent variable (CO). The beta in both parts of Table 3 shows a highly significant effect of some variables like Wind speed$_{max}$, Temperature $_{max}$, and Temperature $_{min}$, compared to other meteorological parameters for measurement of CO. Parameter Sig (P-value) from Table 3 shows the significance of relation between CO and meteorological parameters. For example, Table 3b shows that Temperature$_{max}$ has higher effect on CO.

On the other hand, Table 4 presents the linear regression equations of CO for both enter and stepwise methods for different seasonal condition. Results show all of the seasonal models, except for summer, are significant, which is close to the results of Masoudi et al. (2017b). Stepwise methods show those meteorological parameters, most important during these seasons for estimation of the pollution. Among the models, autumn models have the highest R, while in summer models R is the lowest. R amounts in different methods of spring, autumn, and winter models are higher than the annual ones, also indicating that relations between the pollutant and meteorological parameters are stronger than whole year during these seasons. These results are almost in good agreement with other results regarding CO assessment for different seasonal condition in other Iranian cities like Tehran (Behzadi & Sakhaei, 2014) and Ahvaz (Asadifard, 2013), though they differ a little from the results of Shiraz (Ordibeheshti & Rajai poor, 2014).

Table 4. CO amount (ppm), using two methods of "enter" and "stepwise" for different seasonal condition

Season	Enter method	R	Stepwise method	R
Spring	= 7.258+ (.078) Evaporation + (-.088) Temperature $_{max}$ + (-.019) Temperature $_{min}$ + (-.047) RAIN + (.000) Wind Direction $_{max}$, + (-.042) Wind speed $_{max}$	.452 (significant at 0.05)	= 6.547+ (-.063) Temperature $_{max}$	.379 (significant at 0.01)
Summer	= 5.978+ (.179) Evaporation + (-.038) Temperature $_{max}$ + (-.010) Temperature $_{min}$ + (-.001) Wind Direction $_{max}$ + (.385) Rain + (.049) Wind speed $_{max}$	.203 (not significant)	-	Not prepared by software showing no significance relationship
Autumn	= 3.725+ (.243) Evaporation + (.161) Temperature $_{max}$ + (-.180) Temperature $_{min}$ + (.054) Rain + (-.001) Wind Direction $_{max}$ + (.019) Wind speed $_{max}$	.689 (significant at 0.01)	= 3.873+ (.237) Evaporation + (.151) Temperature $_{max}$ + (-.166) Temperature $_{min}$	.680 (significant at 0.01)
Winter	= 7.258+ (.078) Evaporation + (-.088) Temperature $_{max}$ + (-.019) Temperature $_{min}$ + (-.047) Rain + (.000) Wind Direction $_{max}$ + (-.042) Wind speed $_{max}$	.452 (significant at 0.05)	= 6.547+ (-.063) Temperature $_{max}$	.379 (significant at 0.01)

To test which annual model is better to use, RMSE (Root Mean Square of Error) is calculated for different linear models of "enter" and "stepwise: models. The amounts, predicted using different annual models for 30 days during 2011, are calculated and compared with the observed data during those days, using RMSE equation:

$$\mathrm{RMSE}=\sqrt{\frac{\sum_{i=1}^{n}\left(O_{obs}-O_{pre}\right)^{2}}{n}}$$

O_{obs}: observed CO value
O_{Pre}: predicted CO value using model

The values of RMSE in both linear models of "enter" (1.25) and "stepwise" (1.25) show capability of the latter (i.e. "stepwise model") in prediction of the amount of CO, compared to the former, thanks to its easy calculation. This result, the same as the results of Masoudi and Asadifard (2015) and Masoudi et al. (2014a, 2014b, 2016a, 2016b, 2017a and 2017b), indicates that in order to predict most air pollutants like CO, we may take only linear models of stepwise into consideration, which not only need less data in comparison to "enter model", but entails easier calculation also.

CONCLUSION

The current research analyzed air quality of CO in Esfahan, one of the most polluted cities in Iran. Hence the need to carry out an ambient air quality analysis in this city arose. Results showed that there was a significant relation between CO and some meteorological parameters. Based on these relations, different multiple linear regression equations for CO for annual and seasonal conditions were prepared with their results showing that among different prediction models, "stepwise model" is the best option. Also there were different variations in the concentrations during the days, months, and seasons. It is assumed some of the amounts of CO concentration in the morning and in the beginning of night (especially in summer and autumn seasons) showed that the concentrations of Carbon monoxide were above Primary Standards, showing unhealthy condition.

Acknowledgements

The authors are thankful to the Organization of Environment in Iran, for providing the data, for this risk-assessment work.

REFERENCES

Abdul-Wahab, S.A. and Al-Alawi, S.M. (2002). Assessment and prediction of tropospheric ozone concentration levels using artificial neural networks. Environ. Modell. Softw., 17(3): 219-228.

Abdul-Wahab, S.A., Bakheit, C.S. and Al-Alawi, S.M. (2005). Principal component and multiple regression analysis in modelling of ground-level ozone and factors affecting its concentrations. Environ. Modell. Softw., 20(10): 1263-1271.

Adamopoulos, A.D., Kambezidis, H.D. and Sipsas, A.B. (1996). Meteorological factors that influence CO concentration in the Athens basin. Fresen. Environ. Bull., 5(5-6): 351-356.

Asadifard, E. (2013). Study of air pollution and its relationship with meteorological parameters in Ahvaz city. Project of B.Sc. degree in Shiraz University.

Asghari Esfandani, M. and Nematzadeh, H. (2016). Predicting air pollution in Tehran: Genetic algorithm and back propagation neural network. J. Air and Data Min., 4(1): 49-54.

Asperen, H., Warneke, T., Sabbatini, S., Nicolini, G., Papale, D. and Notholt, J. (2015) The role of photo- and thermal degradation for CO_2 and CO fluxes in an arid ecosystem. Biogeosci., 12: 4161-4174.

Asrari, E., Sen, P.N. and Masoudi, M. (2007). Status of carbon mono oxide in Tehran City- Iran. Pollut. Res., 26(4): 531-535.

Behzadi, F. and Sakhaei, M. (2014). Study of air pollution and its relationship with meteorological parameters in Tehran city. Project of B.Sc. degree, Shiraz University.

Chelani, A.B. et al. (2001). Statistical modeling of ambient air pollutants in Delhi. Water Air Soil Pollut., 1326: 315-331.

Cuhadaroglu, B. and Demirci, E. (1997). Influence of some meteorological factors on air pollution in Trabzon city. Energ. Build., 25(3): 179-184.

Cunningham, W.P. and Cunningham, M.A. (2002). Principles of Environmental Science inquiry and applications (MxGraw Hill Company).

Elminir, H.K. (2005). Dependence of urban air pollutants on meteorology. Sci. Total Environ., 350: 225-237.

Fleischer, N.L., Merialdi, M., van Donkelaar, A., Vadillo-Ortega, F., Martin, R.V. and Betran, A.P. (2014). Outdoor air pollution, preterm birth, and low birth weight: Analysis of the world health organization global survey on maternal and perinatal health. Environ. Health Perspect, 122, 425-430.

Halimi, M., Farajzadeh, M. and Zarei, Z. (2016). Modeling spatial distribution of Tehran air pollutants using geostatistical methods incorporate uncertainty maps. Pollut., 2(4): 375-386.

Ho, L.C. and Lin, W.Y. (1994) Semi-statistical model for evaluating the effects of source emissions and meteorological effects on daily average NO_x concentrations in South Taiwan. Atmosp. Environ., 37: 2051-2059.

Lam, G.C.K., Leong, D.Y.C. and et al. (1997). Street level concentration of NO_X and suspended particulate matter in Hong Kong. Atmosp. Environ., 93: 1-11.

Li, L., Qian, J., Ou, C.Q., Zhou, Y.X., Guo, C. and Guo, Y. (2014). Spatial and temporal analysis of Air Pollution Index and its timescale-dependent relationship with meteorological factors in

Guangzhou, China, 2001–2011. Environ. Pollut., 190: 75-81.

Khader, Y., Abdelrahman, M., Abdo, N., Awad, S., Al-Sharif, M. and Elbetieha A. (2016). Exposure to air pollution and pregnancy outcomes in the East Mediterranean Region: a systematic review. Int. J. Pediatr, 4(1): 1255-71.

Kinnear, P.R. (2002). SPSS for windows made simple release 10. Psychology Press.

Majidnezhad, V. (2014). A novel hybrid method for vocal fold pathology diagnosis based on Russian language. J. Air and Data Min., 2: 141-147.

Mandal, S. (2000). Progressive decrease of air pollution level from west to east at Calcutta', Indian. Indian Eval. Clin. Pract., 20: 6-10.

Masoudi, M., Asadifard, E. and Rastegar, M. and Shirvani, A. (2017a). Status and prediction of sulfur dioxide as an air pollutant in Ahvaz City, Iran. Pollut., 3(2): 201-211.

Masoudi, M., Rajaipoor, N. and Ordibeheshti, F. (2017b). Status and prediction of CO as an air pollutant in Shiraz, Iran. Fresen. Environ. Bull., 26, under publication.

Masoudi, M., Ordibeheshti, F., Rajaipoor, N. and Sakhaei, M. (2016a). Status and preparation of prediction models for ozone as an air pollutant in Shiraz, Iran. Pollut., 2(4): 387-397.

Masoudi, M., Sakhaei, M., Behzadi, F. and Jokar, P. (2016b). Status of PM_{10} as an air pollutant and its prediction using meteorological parameters in Tehran, Iran. Fresen. Environ. Bull., 25(6): 2008-2017.

Masoudi, M. and Asadifard, E. (2015). Status and prediction of Nitrogen Dioxide as an air pollutant in Ahvaz City, Iran. Pollut. Atmos., 225: 1-10.

Masoudi, M., Asadifard, E. and Rastegar, M. (2014a). Status and prediction of ozone as an air pollutant in Ahvaz City, Iran. Caspian J. Environ. Sci., 12: 215-224.

Masoudi, M., Behzadi, F. and Sakhaei, M. (2014b). Status and prediction of Ozone as an air pollutant in Tehran, Iran. Ecol., Environ. Conserv., 20(2): 771-776.

Michael, M., Yadav, A., Tripathi, S.N., Kanawade, V.P., Gaur, A., Sadavarte, P. and Venkataraman, C. (2014) Simulation of trace gases and aerosols over the Indian domain: evaluation of the WRF-Chem model, Geosci. Model Dev. Discuss., 7: 431-482.

Mulumba, J.P., Venkataraman, S. and Afullo, T.J.O. (2015). Modeling tropospheric ozone climatology over Irene (South Africa) using retrieved remote sensing and ground-based measurement data. J. Remote Sens. GIS, 4(3): 1-11.

Ordibeheshti, F. and Rajai poor, N. (2014). Study of air pollution and its relationship with meteorological parameters in Tehran city. Project of B.Sc. degree in Shiraz University.

Sabah, A., Al-Rubiei, R. and Al-Shamsi, A. (2003). A statistical model for predicting carbon monoxide levels. Int. J. Environ. Pollut., 19: 209-224.

Sánchez-Ccoyllo, O.R. and Andrade, M.F. (2002). The influence of meteorological conditions on the behavior of pollutants concentrations in São Paulo, Brazil. Environ. Pollut., 116(2): 257-263.

Sharma, B.K. (2001). An introduction to environmental pollution. Krishna Prakashan Media (p) ltd.

Wang, S.M., Yu, H., Song, L., Xie, Y. and Zhu, Q. (2015). Air quality in a mountainous city: A case study in Chongqing, China. Fresen. Environ. Bull., 24(9): 2699-2706.

Yoo, J.M., Lee, Y.R., Kim, D., Jeong, M.J., Stockwell, W.R., Kundu, P.K., Oh, S.M., Shin, D.B. and Lee, S.J. (2014). New indices for wet scavenging of air pollutants (O_3, CO, NO_2, SO_2, and PM_{10}) by summertime rain. Atmos. Environ., 82: 226-237.