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Assessment of PM10 concentration and its prediction using meteorological parameters in the air of Isfahan, Iran

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Abstract

In the present study, air quality analyses for particulate matters (PM_{10}) were conducted in the Iranian city of Isfahan. The measurements were taken in three different locations to prepare average data in the city. The average concentrations were calculated for every twenty-four hours, each month and each season in the city of Isfahan. Results showed that the highest concentration of PM_{10} occurs generally in the morning, while the least concentration was observed in the evening. Monthly concentrations of PM_{10} showed the highest value being in July, while the least value was found in August. The seasonal concentrations showed that the least amounts were found in winter and the highest amounts in spring. Relations between the air pollutant and some meteorological parameters were calculated statistically using the daily average data. The wind data (velocity, direction), temperature, evaporation, and rainfall are considered as independent variables. The relationships between concentration of the pollutants and the meteorological parameters are expressed by multiple linear regression equations for both annual and seasonal conditions using SPSS software. The RMSE test showed that among different prediction models, the stepwise model is the best option.

Keywords: PM_{10}, Air pollution, Meteorological Parameters, Regression model, Isfahan.

1. Introduction

Air sustains life, but the air we breathe is not pure. It contains a lot of pollutants and most of these pollutants are toxic (Sharma, 2001). While developed countries have been making progress over the last century, air quality has been getting much worse especially in developing countries where air pollution exceeds all health standards. For example, in Lahore and Xian (china), dust is ten times higher than health standards (Sharma, 2001).

Particulate Matter (PM) is one of the seven conventional (criteria) pollutants including SO_2, CO, particulates, hydrocarbons, nitrogen oxides, O_3 and lead (Cunningham and Cunningham, 2002). These pollutants produce the highest volume of pollution in the air and pose the most serious threats for human health and welfare (Haque and singh, 2017; Masoudi et al., 2017). Concentration of these pollutants, especially in cities, has been regulated by Clean Air Act since 1970 in the USA (Cunningham and Cunningham, 2002). Particulate pollutants may be classified according to their nature and size into the following constituents: smoke, mist, spray, fumes, soot, and dust; the latter being the main part of PM. Dust is composed of fine solid particulates ranging in size from 1 to 100 micron (Masoudi et al., 2016).

The presence of pollutants in the atmosphere, causes a lot of problems, thus the study of pollutant' behavior becomes necessary (Asrari et al., 2007). The health risks of PM depend upon the size. Some of the main problems include: their toxicity, lung damages (e.g. silicosis, black lung disease), mutagenic and carcinogenic effects, Irritation (eye, nose and throat) and heart damage (Lung not as efficient, heart must work harder to get oxygen) (Masoudi et al., 2016).

The status of pollutants' concentrations and the effects of meteorological and atmospheric parameters on these pollutants compose the base for the following studies: Ho and Lin (1994) studied semi-statistical models for evaluating the NO_x concentration by considering source emissions and meteorological effects. The street level of NO_x and SPM in Hong Kong has been studied by Lam et al. (1997). In another study, the relationship 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 the multiple linear regression analysis, in some months there was a moderate and weak relationship between air pollutants such as the PM level and the meteorological factors in Trabzon city (Cuhadaroglu and Demirci, 1997).

Mandal (2000) has shown the progressive decrease of air pollution from west to east in Kolkata. Statistical modeling of ambient air pollutants in Delhi has been studied 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 and various air quality parameters. The results of this study showed that the artificial neural network (ANN) is

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a promising method for air pollution modeling. The observed behavior of pollution concentrations to the prevailing meteorological conditions has been studied over the period from June 13 to September 2, 1994, for the Metropolitan Area of Sao Paulo (Sánchez-Ccoyllo and Andrade, 2002). Results show low concentrations 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 predicting CO, Sabah et al. (2003) used a statistical model.

Elminir (2005) confirmed the dependence of air pollutants on meteorology over Cairo in Egypt. The results state that wind direction was found to have an influence not only on pollutant concentrations but also on the correlation between pollutants. As expected, the pollutants associated with traffic were at the highest ambient concentration levels when wind speed was low. At higher wind speeds, dust and sand from the surrounding desert were entrained by the wind, thus contributing to ambient particulate matter levels. It was also found that the highest average concentrations of NO_2 and O_3 occurred at humidity being ≤ 40 % which is indicative of strong vertical mixing. For CO, SO_2 and PM_{10} the highest average concentrations occurred at humidity being 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 the 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 being 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 the effect of meteorological factors for predicting CO. Also, variations in the concentration of CO at different times have been shown in this study.

Dundar et al. (2013) determined some heavy metal contents in PM_1 and PM_{10} by AAS analysis. Sample solutions were FAAS-analyzed for Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn elemental contents. The highest values were found for Zn and Fe, respectively.

Li et al. (2014) presented the spatial and temporal variation of Air Pollution Index (API), and examined the relationships between API and meteorological factors during 2001–2011 in Guangzhou, China. Correlations were found 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 is estimated as: $PM_{10} > SO_2 > NO_2 > CO > O_3$, indicating that PM_{10} was most effectively cleaned by rainfall.

Ozelkan et al. (2015) determined PM_{10} data using multispectral satellite images' reflectance values in Izmir, Turkey. The results showed that the B5/B7 and B7/B5 ratio values of Landsat 5TM were more correlated and appropriate than other band ratios to determine PM_{10}.

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

Statistical modeling of PM_{10} in Tehran was studied by (Masoudi et al., 2016). According to the results obtained through multiple linear regression analysis of the seasonal and annual conditions, there were significant relationships between PM_{10} levels and the meteorological factors in this city. Such results between other pollutants and meteorological factors in other Iranian cities were observed such as O_3 in Ahvaz (Masoudi et al., 2014), SO_2 in Ahvaz (Masoudi et al., 2017a), NO_2 in Tehran (Masoudi et al., 2017b) and CO in Shiraz (Masoudi et al., 2017c).

The present study exhibits diurnal, monthly and seasonal variations in the concentration of PM_{10} and also a statistical model that is able to predict amount of PM_{10}. This is based on multiple linear and nonlinear regression techniques. Multiple Regression estimates the coefficients of the linear and nonlinear equations involving one or more independent variables that best predict the value of the dependent variable (PM_{10} amount in this study). So, a large statistical and graphical software package (SPSS, Software Package of Social Sciences, V. 20) as one of the best known statistical packages has been used (Kinnear, 2002).

2. Materials And Methods

2.1. Study Area

The research area, Isfahan, capital of Isfahan Province, is the biggest city in the central part of Iran (Fig. 1) located around 32° 38' N and 51° 40' E and the elevation is about 1590 m above the mean sea level. It has a semi-arid climate with four distinct seasons. Its residential population was about 1,834,000 in 2011. Isfahan is built on the banks of the Zayandeh-rud River. There is heavy traffic in the city as well as many factories and industrial sites around the city. Because of these problems, Isfahan is considered as one of the most polluted cities in Iran particularly in terms of PM_{10} (Mansouri and Hamidian, 2013). Hence, it was necessary to carry out an ambient air quality analysis in the city of Isfahan.

Also, high amounts of PM_{10} have been observed more over the recent years in the western and southern parts of Iran. The main source of this pollution is the arid lands of Iran's western neighboring countries especially Iraq. Following the wars of USA with Iraq, the number of the critical zones for the detachment of soil particles through wind erosion processes increased because of the mismanagement and negligence in taking remedial measures and conservation actions against wind erosion. This was more evident at the end of spring and summer seasons with the precipitation being very low, and the wind speed and evaporation being high,which left the soil very dry allowing for wind erosion and carrying soil suspended particles to long distances.

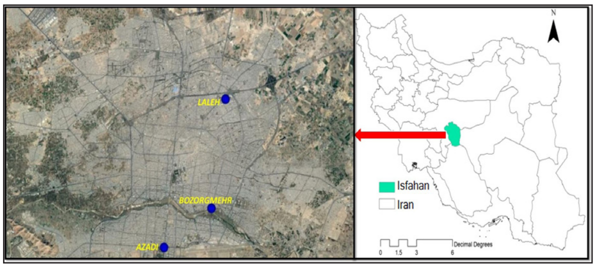

Figure 1. Position of Isfahan in Iran and its air pollution measurement stations.

2.2. Data and Methodology

Three available sampling stations in the city, namely: Azadi, Bozorg-mehr and Laleh belonging to the Iranian Department of Environment were selected to represent different traffic loads and activities (Fig. 1).

The sampling was performed every thirty minutes daily for each pollutant during all months of 2010 and 2011 in the three stations. the samples were recorded in the stations and were then transferred to the Department of Environment in Isfahan. Among the measured data in the three stations, PM_{10} was chosen and the data were taken from the Department of Environment in Isfahan. Averages were then calculated for every hour, monthly and seasonally for the three stations by Excel. Finally, the averages of data at the three stations were used to show the air pollution situation as diurnal, monthly and seasonal graphs of the concentration of PM_{10} in the city. Two models of devices namely, Ecotec and Enviro–Tech, have been used for measuring air pollution in the stations.

Studying the correlation between PM_{10} and metrological parameters in the synoptic station of the city was the next step. The metrological parameters studied include: temperature (min, max), rain, wind direction, wind speed and evaporation extracted from the Meteorological Organization of the country (Iran).

In the next step, the daily average data at the three stations in 2011 were considered as dependent variables in the statistical analysis, while daily data of the meteorological parameters during this year were selected as independent variables in SPSS (V. 20). The linear regression equation showed that the concentration of PM_{10} depends on the kind of meteorological parameters, and gives an idea about the levels of this relation. The relationship between the dependent variables and each independent variable should be linear because linear regression equation is simpler and closer to reality (Masoudi et al., 2016).

The model for predicting PM_{10} was determined using two multiple regression modeling procedures of 'enter method' and 'stepwise method'. In 'enter method', all the independent variables selected were added to a single regression model. In the 'stepwise method' which is better, all the variables can be entered or removed from the model depending on significance. Therefore, only those variables which have more influence on the dependent variable are observed in a regression model.

3. Results and Discussion

In Figs. 2, 3 and 4, the diurnal, monthly and seasonal variations in the concentration of PM_{10} have been presented based on average over the two years of 2010 and 2011. As shown in fig. 2, the high concentration of PM_{10} occurs in the morning, while the least concentration occurs in the evening. The main cause of high PM_{10} during this time is likely to be the morning rush hours. The monthly concentration of PM_{10} showed the highest values in July and the least amounts occurred in August (Fig. 3). Seasonal concentration (Fig.4) shows the highest values being in spring (April to June), and the least amounts were in winter (January to March). These results are almost in good agreement with other results obtained in other cities such as Shiraz (Ordibeheshti and Rajai poor, 2014) and Ahvaz (Asadifard, 2013), but differ somewhat with the results of Tehran city (Masoudi et al., 2016).

Precipitation is low and evaporation is high during these times especially at the end of spring and the beginning of summer, therefore, the soil would be very dry allowing for wind erosion and carrying soil suspended particles over long distances. The origin and source of most of the particle matters during this period are the dry lands of a western neighboring country especially the critical zones in the country of Iraq (Fig. 5 and 6) (Masoudi et al., 2016).

Unfortunately, all graphs showed that the concentrations of the PM_{10} are greater than the Primary Standards of PM_{10} (50 $\mu g/m^3$) recommended by the National Ambient Air Quality Standards (NAAQS) of USA and Iran, respectively to protect human health. Increase in PM can have different consequences and health problems. This pollution can cause and increase a number of related illnesses such as cancer and lung damaging (Kelly and Fussell, 2015; Liu et al., 2018). Unfortunately such health problems have been recorded by Health offices in the region over the recent years. Currently Ahvaz, a big city in the south western part of Iran is introduced as the worst polluted city in the world according to a survey in 2011 carried out by the World Health Organization because of the high concentration of dust during the year (Guinness World Records, 2013).

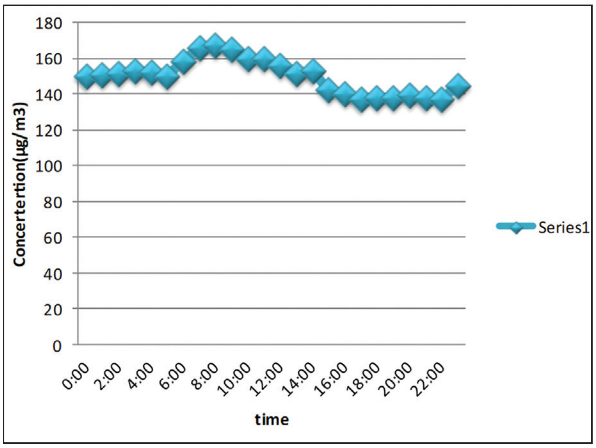

Figure 2. Diurnal variation of PM10 concentration in Isfahan (average of 2010 and 2011).

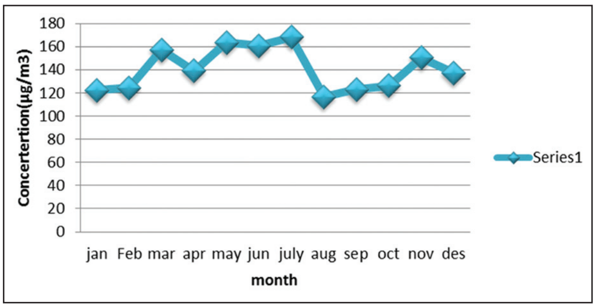

Figure 3. Monthly variation of PM10 concentration in Isfahan (average of 2010 and 2011).

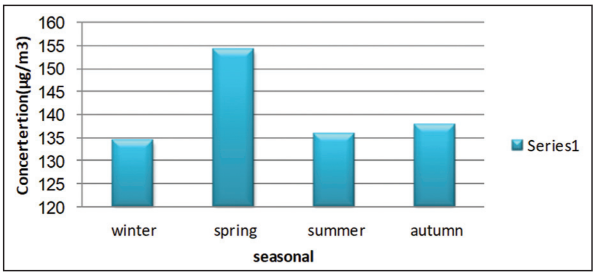

Figure 4. Seasonal variation of PM10 concentration in Isfahan (average of 2010 and 2011).

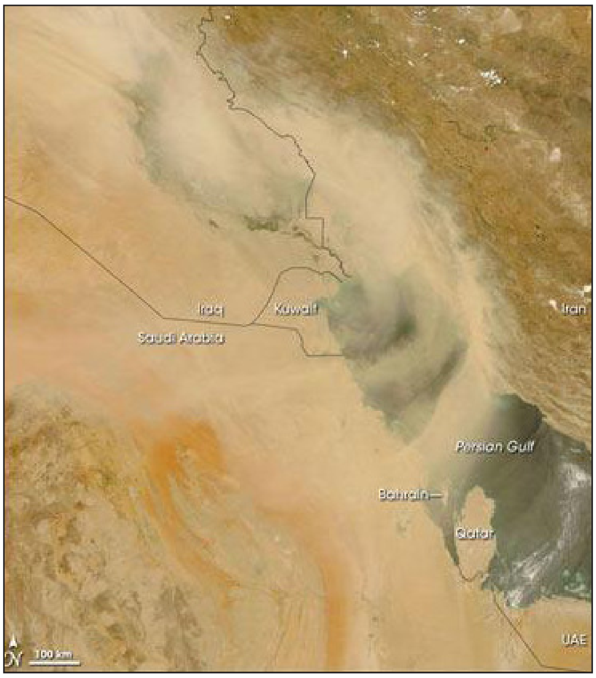

Figure 5. A satellite image showing that the origin and source of most of the dust pollution carried by wind in Iran are the dry lands of western neighboring countries especially the country of Iraq.

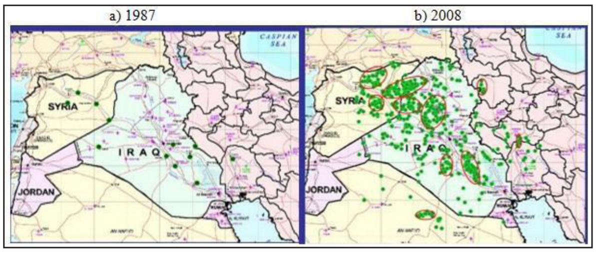

Figure 6. Two maps of western neighboring countries of Iran showing the increasing number of critical points for the detachment of soil particles during wind erosion processes especially in Iraq over the recent years.

Table 1 shows the relationships between PM_{10} and other air pollutants. For example the concentration of PM shows negative correlation with O_3, NO_2, NOx, while it shows positive correlation with CO and SO_2. These results are almost in good agreement with other results of PM_{10} assessment in other Iranian cities of Shiraz (Ordibeheshti and Rajai poor, 2014) and Ahvaz (Asadifard, 2013), but are not in agreement with the results of Tehran city (Masoudi et al., 2016). Correlation coefficients significant at the 0.05 level are identified with a single asterisk (significant), and those significant at 0.01 level are identified with two asterisks (highly significant).

Table 1. Correlation between air pollutants and PM_{10}.

	NO_2	NOx	O_3	SO_2	CO
Pearson Correlation	-.409**	-.172**	-.334**	.083	.235**
Sig. (2-tailed)	.000	.001	.000	.123	.000
N	344	344	344	344	344

Table (2) regarding the analysis of variance shows that both regressions of 'enter' and 'stepwise' methods for the annual condition are highly significant indicating a significant relation between the different variables.

Analysis of variance (a)

Table 2. Tables of analysis of variance for both regressions of 'enter' (a) and 'stepwise' (b) methods for annual condition.

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	443535.225	5	88707.045	37.111**	.000
Residual	807918.904	338	2390.293		
Total	1251454.129	343			

Predictors: (Constant), Rain, Wind direction (max), Wind speed (max), Temperature (max), Temperature (min), Evaporation
Dependent Variable: PM_{10}

Analysis of variance (b)

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	437622.996	3	145874.332	60.943**	.000
Residual	813831.133	340	2393.621		
Total	1251454.129	343			

Predictors: (Constant), Rain, Wind Speed$_{(mean)}$), temperature
Dependent Variable: PM_{10}

In the following tables (3) the coefficients of PM_{10} pollution model and regression lines for both enter and stepwise methods in annual condition are presented. Regression coefficients, standard errors, standardized coefficient beta, t values, and two-tailed significance level of t have been shown in the Tables.

Table 3. Coefficients of PM 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)	114.802	14.720		7.799	.000
Temperature (max)	3.183	.913	.497	3.485**	.001
Temperature (min)	-.005	1.103	-.001	-.004	.997
Rain	-4.452	1.502	-.142	-2.963**	.003
Wind direction	-.041	.026	-.075	-1.566	.118
Wind speed(mean)	-4.342	.949	-.224	-4.576**	.000

Dependent Variable: PM

Coefficients (b)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	109.063	8.746		12.470	.000
Temperature (max)	3.260	.294	.509	11.094**	.000
Wind speed (mean)	-4.898	.868	-.253	-5.642**	.000
Rain	-4.391	1.431	-.140	-3.068**	.002

Dependent Variable: PM

The linear regression equations show that the PM_{10} pollution depends on the meteorological parameters, and also gives an idea about the levels of relations. The linear model equations after using the 'enter method' and the 'stepwise method' for annual condition are:

- *PM_{10} amount (μg/m³) using the 'enter method' for annual condition = 114.802 + (-.005) $Temperature_{(min)}$ + (3.183) $Temperature_{(max)}$ + (-4.452) Rain + (-.041) Wind $direction_{(max)}$ + (-4.342) Wind $speed_{(max)}$ R= 0.595 (significant at 0.001)*
- *PM_{10} amount (μg/m³) using the 'stepwise method' for annual condition = 109.063 + (-4.391) Rain+ (-4.898) Wind $speed_{(mean)}$ + (3.260)Temperature(max) R= 0.591 (significant at 0.001)*

Results of the linear regression model show that when wind speed and rain have reverse effect on the concentration of PM_{10}, i.e., when these parameters increase, the concentration of PM_{10} decreases. On the other hand, when temperature (max) increases, the concentration of PM_{10} significantly increases (Table 3b). Other meteorological parameters show different effects on PM_{10} amounts; however, these results are not significant. For example, wind direction has reverse effects on the concentration of PM_{10} (Table 3a). These results are almost in good agreement with other results regarding PM_{10} measurements in other Iranian cities like Ahvaz (Asadifard, 2014), Shiraz (Ordibeheshti and Rajai poor, 2014) and Tehran (Behzadi and Sakhaei, 2014) and other regions (Li et al., 2014; Yoo et al., 2014). Actually some of these events happen in real conditions. Increase in the rainfall and wind speed usually decrease most of air pollutants (Asrari et al., 2007).

The values and significance of R (multiple correlation coefficient) in both equations show the capability of these to predict PM_{10} amount. The amount of Adjusted R^2 in both equations is almost 0.35 showing that different parameters can calculate almost 35 % variability of PM_{10}. This result indicates that to predict most air pollutants such as PM_{10}, the natural and anthropogenic sources of their production such as consumption of fossil fuel and wind erosion processes must be taken into consideration. On the other hand, R in the enter method (0.595) is equal to that in the stepwise method (0.591), showing no difference. Therefore, the second equation based on the stepwise method can be used to predict PM_{10} in the city instead of using the first equation which needs more data. On the other hand, no difference between the two R values indicates that the excluded variables in second equation have less effects on measuring PM_{10} in the city.

Beta in Table 3 shows the independent variables (meteorological parameters) which have more effects on the dependent variable (PM_{10}). The beta in the both Tables (4) shows a highly significant effect of some variables such as rain, temperature(max) and wind speed compared to other meteorological parameters for measuring PM_{10} which is close to the results of Asadifard (2013), Ordibeheshti and Rajai poor (2014), Masoudi et al. (2014) and Behzadi and Sakhaei (2014). Parameter Sig (P-value) from Table (4) shows the degree of relation between PM_{10} and meteorological parameters. For example, Table (4a) shows that wind speed has a higher effect on PM_{10} than wind direction.

On the other hand, in Table (4), the linear regression equations of PM_{10} amount are presented for both enter and stepwise methods in different seasonal conditions. Almost all of the models are significant. Stepwise methods show those meteorological parameters which are most important during these seasons for estimating the pollution. Among the models, spring models have the highest R compared to the R of other seasonal models. R in autumn and spring models are higher than in annual models, also indicating that relations between the pollutant and meteorological parameters are stronger than the whole year during these seasons. These results differ somewhat with other results regarding PM_{10} assessment in other Iranian cities of Ahvaz (Asadifard, 2013) and Shiraz (Ordibeheshti and Rajai poor, 2014), but they are consistent with the results of Tehran (Behzadi and Sakhaei, 2014).

Table 4. PM_{10} amount (μg/m³) using two methods of enter and stepwise for different seasonal condition.

Season	enter method	R	stepwise method	R
Spring	= -22.475+(7.115) Tmax + (.030) Tmin + (-1.387) WSmax + (-.065) WDmax+ (-.459) R + (0.364) E	.763 (significant at 0.01)	=- 54.660 + (7.373) Tmax	.751 (significant at 0.01)
Summer	= 330.725 + (-9.519) Tmax + (11.942) Tmin + (-5.851) WSmax + (.039) WDmax + (-88.934) R + (1.317) E	.472 (significant at 0.05)	= 90.577 + (5.584) Tmin	.292 (significant at 0.05)
Autumn	= 74.404 + (5.548) Tmax + (1.038) Tmin+ (.351) WSmax + (-.052) WDmax + (-3.431) R + (-6.012) E	.693 (significant at 0.01)	= 65.239 + (4.861) Tmax	.649 (significant at 0.01)
Winter	= 134.112 + (3.209) Tmax + (-3.901) Tmin + + (-3.487) WSmax + (-.084) WDmax + (-6.138) R	.616 (significant at 0.01)	= 171.403 + (-8.077) R + (-5.444) WSmax	.566 (significant at 0.01)

Note: Tmax =Temperature (max), Tmin=Temperature (min), WSmax =Wind speed (max), WDmax =Wind direction (max), R=Rainfall, E=Evaporation

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. Predicted amounts using the different annual models for 24 days during 2012 are calculated and compared with observed data during those days using RMSE equation:

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

O_{obs}: observed PM_{10} value O_{pre}: predicted PM_{10} value using model

The values of RMSE in both linear models of enter (42.771) and stepwise (41.978) show the capability of the stepwise model in predicting PM amount compared to the enter model. This result which is the same as the results of Asadifard (2013), Ordibeheshti and Rajai poor (2014), Masoudi et al. (2014) and Behzadi and Sakhaei (2014) indicates that to predict most air pollutants such as PM_{10}, one may take into consideration only the linear models of stepwise which need less data and an easier calculation than the enter model.

In conclusion it can be said that Isfahan is one of the polluted cities in Iran. Hence, a need was felt to carry out an ambient air quality analysis in the city. Results showed that there were significant relationships between PM_{10} and some meteorological parameters. Based on these relations, different multiple linear regression equations for PM_{10} for annual and seasonal conditions were prepared. Results showed that among the different prediction models, the stepwise model was the best option. Also, different variations in concentration during the day, months, and seasons were observed. These results agree to Asadifard (2013), Ordibeheshti and Rajai poor (2014) and (Masoudi et al., 2016). So, in regard to the pollution situation of the study area, further research must be carried out. Also, According to the obtained model, if the conditions of this present study do not change, life in the study area will be impossible in the future years owing to the increasing proportion of pollutants. Therefore, as far as possible, some strategies such as the reduction in the number of imported vehicles and the proportion of distance traveled by vehicles etc. and dust consolidation in the source areas can be applied to achieve pollution reduction.

References

[1] Abdul-Wahab, S.A., and Al-Alawi, S.M. (2002). Assessment and prediction of tropospheric ozone concentration levels using artificial neural networks. Environmental Modelling & Software 17(3): 219–228.

[2] 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. Environmental Modelling & Software 20 (10): 1263–1271.

[3] Asadifard, E. (2013). Study of Air Pollution and its relationship with meteorological parameters in Ahvaz city. Project of B.Sc. degree in Shiraz University.

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

[5] Behzadi, F., and Sakhaei, M.(2014). Study of Air Pollution and its relationship with meteorological parameters in Tehran city. Project of B.Sc. degree in Shiraz University.

[6] Chelani, A.B., Gajghate, D.G., Tamhane, S.M. Hasanet, M.Z. (2001). Statistical modeling of ambient airpollutants in Delhi. Water, Air and Soil Pollution 1326: 315-331.

[7] Cuhadaroglu, B. and Demirci, E. (1997). Influence of some meteorological factors on air pollution in Trabzon city. Energy and Buildings 25 (3) : 179–184.

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

[9] Dundar, M.S., Altundag, H., Yilmazcan, O., Kaygaldurak, S. (2013). Determination of some heavy metal contents in PM1 and PM10 airborne particulate matters by AAS analysis. Fresenius Environmental Bulletin , 22: 3179–3183.

[10] Elminir, H.K. (2005). Dependence of urban air pollutants on meteorology. Science of the Total Environment, 350: 225–237.

[11] Guinness World Records (2013). Page 036 (Hardcover edition). ISBN 9781904994879.

[12] Haque, M.S., and Singh, R.B. (2017). Air Pollution and Human Health in Kolkata, India: A Case Study. Climate 2017, 5, 77; doi:10.3390/cli5040077. 1-16.

[13] Ho, L.C., and Lin, W.Y. (1994). Semi-statistical model for evaluating the effects of source emissions and meteorological effects on daily average NOx concentrations in South Taiwan. Atmospheric Environment 37: 2051-2059.

[14] Kelly, F., and Fussell, J. (2015). Air pollution and public health: emerging hazards and improved understanding of risk. Environ Geochem Health. 2015; 37(4): 631–649.

[15] Kinnear, P.R. (2002) SPSS for windows made simple release 10. Psychology press.

[16] Lam, G.C.K., Leong, D.Y.C. (1997). Street level concentration of NOX and suspended particulate matter in Hong Kong. Atmospheric Environment 93: 1-11.

[17] 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. Environmental Pollution 190: 75-81.

[18] Liu, H.Y., Dunea, D., Iordache, S., and Pohoata, A. (2018). A Review of Airborne Particulate Matter Effects on Young Children's Respiratory Symptoms and Diseases. Atmosphere 2018, 9, 150; doi:10.3390/atmos9040150. 1-18.

[19] Mandal, S. (2000). Progressive decrease of air pollution level from west to east at Calcutta', Indian Journal of Environmental Protection 20: 6-10.

[20] Mansouri, B., and Hamidian, A. (2013). Assessment of the Air Quality of Isfahan City, Iran, Using Selected Air Quality Parameters. Iranian Journal of Toxicology. 7(21): 842-848.

[21] Masoudi M., Asadifard E., Rastegar M. (2014). Status and prediction of ozone as an air pollutant in Ahvaz City, Iran. Caspian Journal of Environmental Sciences. 12: 215-224.

[22] Masoudi, M., Sakhaei, M., Behzadi, F. and Jokar, P. (2016). Status Of PM10 as an air pollutant and its prediction using meteorological parameters in Tehran, Iran. Fresenius Environmental Bulletin. 25 (6): 2008-2017.

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

[24] Masoudi, M., Behzadi, F., Sakhaei, M. (2017b). Concentration of NO_2 in the Air over Tehran, Iran. Russian Meteorology and Hydrology, 42: 728–730.

[25] Masoudi M., Rajaipoor N., Ordibeheshti F. (2017c). Status and prediction of CO as an air pollutant in Shiraz, Iran. Fresenius Environmental Bulletin. 26: 3697-3704.

[26] 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.

[27] Ozelkan E., Karaman M., Mostamandy S., Uça Avcı Z.D., Toros, H. (2015). Derivation of PM10 Levels Using OBRA on Landsat-5TM Images: A Case Study in Izmir, Turkey. Fresenius Environmental Bulletin, 24(4b): 1585-1596.

[28] Sabah, A., Al-Rubiei, R., and Al-Shamsi, A. (2003). A statistical model for predicting carbon monoxide levels. International Journal of Environment and Pollution 19: 209-224.

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

[30] Sharma, B.K. (2001). An Introduction to environmental pollution. Krishna prakashan media (p) ltd.

[31] 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. Fresenius environmental bulletin, 24 (9), 2699-2706.

[32] 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, O_2, SO_2, and PM10) by summertime rain. Atmospheric Environment, 82: 226-237.