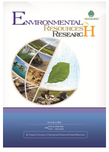

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Status of PM_{10} as an air pollutant and its prediction using meteorological parameters in Ahvaz, Iran

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Abstract

In the present study, air quality analyses for particulate matters (PM_{10}) were conducted in Ahvaz, a city in the south of Iran. The measurements were taken from 2009 through 2010 in two different locations to prepare average data for the city. The average concentrations were calculated for every 24 hours, and each month and each season which showed the highest concentration of PM_{10} in the morning while the least concentration was found in the afternoon. Monthly concentrations of the PM_{10} showed the highest value in July and the least in January. The seasonal concentrations show the highest amounts in summer. Relationships between air pollutant and meteorological parameters were assessed statistically using the daily average data. The wind data (velocity, direction), relative humidity, temperature, sunshine periods, dew point and rainfall were considered as independent variables. The relationships were expressed by multiple linear and nonlinear regression equations for annual and seasonal conditions using SPSS software. Results showed significant relationships between PM_{10} and some meteorological parameters. RMSE test showed that among the different prediction models, stepwise model is the best option. Unfortunately, mostly the concentration of the PM_{10} was very higher than primary standards of PM_{10} (50 $\mu g/m^3$) for human health, that is why recently, Ahvaz is considered one of worst polluted cities in the country.

***Keywords*:** Particulate Matters, Ahvaz, Air Pollution, RMSE، Regression model

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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 economic progress during the last century, air quality has been getting much worse and especially in most developing countries the air pollution exceeds all health standards. For example, in Lahore and Xian (china) dust is ten times higher than the health standards (Sharma, 2001).

Particulate Matters (PM) is one of the seven conventional (criteria) pollutants that include SO_2, CO, particulates, hydrocarbons, nitrogen oxides, O_3 and lead. These pollutants comprise the highest volume in the air and cause the most serious threat to human health and welfare (Wang *et al.*, 2015; Asghari and Nematzadeh, 2016; Khader *et al.*, 2016). Concentration of these pollutants, especially in cities, has been regulated by Clean Air Act since 1970 (W.P. Cunningham and M.A. Cunningham, 2002). Particulate pollutants can be classified according to their nature and size as follows: smoke, mist, spray, fumes, soot and dust which is the main part of PM. Dust is composed of fine solid particulates and their size range from 1 to 100 micron.

The presence of pollutants in the atmosphere causes a lot of problems, thus the study of pollutant' behavior is necessary (Asrari *et al.*, 2007). Health effects of PM depend upon size and some of their main problems are their toxicity, lung damages (like silicosis, black lung disease), mutagenic and carcinogenic effects, irritation (eye, nose and throat) and heart damage due to lung inefficiency, as heart must work harder to get oxygen.

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

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 a promising method for air pollution modeling. The observed behavior of pollution concentrations with regards to the prevailing meteorological conditions has been studied for 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) mentioned dependence of air pollutants on meteorology over Cairo in Egypt. He found that, wind direction has an influence not only on pollutant concentrations but also on the correlation between pollutants. As expected, the pollutants associated with traffic were at highest ambient concentration levels when wind speed was low. At higher wind speeds, dust and sand from the surrounding desert was entrained by the wind, thus contributing to the ambient particulate matter levels. It was also found that the highest average concentration for NO_2 and

O_3 occurred at humidity ≤ 40% indicative for strong vertical mixing. 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 became 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 for predicting CO. Also variations in concentration of CO in different times have been shown in this study.

Dundar *et al.* (2013) determined some heavy metal contents in PM_1 and PM_{10} using flame atomic absorption spectroscopy (FAAS) 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. Relationships 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 to be: $PM_{10} > SO_2 > NO_2 > CO > O_3$, 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 show 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. Statistical analysis of SO_2, PM_{10} and NO_2 concentrations was conducted from 2002 to 2012. The Pearson correlation indicated that concentrations of SO_2, PM_{10} and NO_2 were positively correlated with atmospheric pressure, but negatively with temperature and wind speed. The analysis of Multi-Pollutant Index (MPI) showed that air quality in Chongqing was seriously low.

Statistical modeling of PM_{10} was conducted in Iranian cities of Tehran (Masoudi *et al.*, 2016b), Isfahan (Masoudi & Gerami, 2018a) and Shiraz (Masoudi *et al.*, 2018b). According to the results obtained through multiple linear regression analysis for seasonal and annual conditions, there were significant relationships between PM_{10} levels and meteorological factors in these cities. Relationships between other pollutants and meteorological factors in other Iranian cities were also observed including NO_2 in Ahvaz (Masoudi & Asadifard, 2015), Tehran (Masoudi *et al.*, 2017b) and Isfahan (Masoudi & Gerami 2018b); SO_2 in Ahvaz (Masoudi *et al.*, 2017a) and Tehran (Masoudi *et al.*, 2018a); O_3 in Ahvaz (Masoudi *et al.*, 2014a), Tehran (Masoudi *et al.*, 2014b) Shiraz (Masoudi *et al.*, 2016a) and Isfahan (Masoudi *et al.*, 2017c); CO in Isfahan (Masoudi and Gerami, 2017), Shiraz (Masoudi *et al.,* 2017d) and Ahvaz (Aasdifard and Masoudi, 2018).

Due to the increased air pollution caused by dust and particulate matters in Iran, especially in southern cities such as Ahvaz damages to the physical, financial and other aspects are inevitable. So it is very important and necessary to study and control and monitor and finally, propose useful methods for controlling dust pollution. The present study exhibits diurnal, monthly and seasonal variations in concentration of PM_{10} and also a statistical model that is able to predict the 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} in this study). The software package SPSS V. 20 was used for analyses (Kinnear, 2002).

Materials and Methods

Study Area

The research area, Ahvaz, capital of Khuzestan Province, is the biggest city in the south-western part of Iran (Fig. 1) located between 31° 19' N and 48º 40' E, the elevation is about 20 m above the mean sea level. Annual precipitation of Ahvaz is about 230 mm. It has arid climate and the population was 1,425,000 in 2006. Ahvaz is consistently one of the hottest cities on the planet during summer, with summer temperatures regularly at least 45°C, and sometimes exceeding 50°C with many sandstorms and dust storms being common during the summer period, while in winters the minimum temperature could fall around +5°C. Ahvaz is built on the banks of the Karun River and is situated in the middle of Khuzestan Province. Iraq attempted to annex Khuzestan and Ahvaz in 1980, resulting in the Iran–Iraq War (1980–1988). Ahvaz was close to the front lines and suffered severe damages during the war. There are lots of cars in the city and also many factories and industrials around it. So, Ahvaz is one of the most polluted cities in Iran and is in dire need of the ambient air quality analysis.

Recently, Ahvaz has been ranked as the worst polluted city of the world according to a survey by the World Health Organization in 2011 because of high concentration of dust year round (Guinness World Records, 2013). The increasing amount of dust (Fig. 2) can cause different problems such as increasing number of cancer and lung damages.

Figure 2. Two photographs from the same place in Ahvaz showing impacts of dust pollution during recent years (left a clean condition and right a dusty condition).

Data and methodology

Two available sampling stations in the city called administration and Naderi, belonging to Department of Environmental Protection of Iran were selected to represent different traffic loads and activities.

The sampling was performed every 30 minutes daily for each pollutant during all months of 2009 and 2010. PM_{10} was chosen among the measured data in the two stations. Then, the averages were calculated for every hour, each month and each season for both stations in Excel. Finally averages of data at two stations were used to show air pollution situation as diurnal, monthly and seasonal graphs of concentration of PM_{10} in the city.

Studying correlation of PM_{10} and metrological parameters of synoptic station of city was the next step. The metrological parameters studied included temperature (min & max), humidity (min & max), precipitation, sunshine, wind direction, wind speed and evaporation.

In the next step, daily average data at two stations in 2010 was considered as dependent variable while daily data of meteorological parameters during this year were selected as independent variables in SPSS and the multiple regression equations showed that the concentration of PM_{10} depends on meteorological parameters and produced the strength of these relations. The relationship between the dependent variables and each independent variable were considered for both linear and nonlinear techniques. The significant values in output are based on fitting a single model. Also linear regression equation was made for different seasons to test likely difference of the relationships not observable for annual data.

Regression options including 'enter', 'forward', 'backward', or 'stepwise' variable selection method were tested. Method selection allows to specify how independent variables are entered into the analysis. Using different methods, one can construct a variety of regression models from the same set of variables. The model for predicting PM_{10} was determined using two multiple regression modeling procedures of 'enter method' and 'stepwise method'. In 'enter method' all independent variables selected are added to a single regression model. In 'stepwise' method, all variables can be entered or removed from the model depending on the significance. Therefore, only those variables which have more influence on dependent variable are included in the regression model.

Results and Discussion

In Figures 2, 3 and 4, the diurnal, monthly and seasonal variations in concentration of PM_{10} have been presented. As shown in Fig. 1 the high concentration of PM_{10} occurs in the morning while the least concentration occurs in the afternoon. Monthly concentration of PM_{10} showed the highest values in July and the least in January (Fig. 3). Seasonal concentration of the PM_{10} showed the highest values in summer and the least in winter (Fig. 4). These results are almost in good agreement with other results regarding PM_{10} assessment in Iranian cities of Tehran (Masoudi *et al.*, 2016b), Isfahan (Masoudi and Gerami, 2018a) and Shiraz (Masoudi *et al.*, 2018b).

Precipitation is very low and evaporation is very high during these times especially in the end of spring and beginning of summer, therefore soil is very dry allowing for wind erosion and carrying soil suspended particles to long distances. Origin and source of most of the particles during this period is in dry lands of western neighbors especially in some critical zones of Iraq (Figure 5).

Unfortunately, all graphs showed that the concentrations of the PM_{10} are upper than primary standards of PM_{10} (50 $\mu g/m^3$) recommended by National Ambient Air Quality Standards (NAAQS) of USA and Iran, respectively for protecting human health. High amounts of PM_{10} are observed more during recent years in western and southern parts of Iran and the main source of this pollution is arid lands of Iraq. Especially after USA war in this country, the number of critical zones for detachment of soil particles in wind erosion process has bas increased because of mismanagements and lack of remedial measures and conservation against wind erosion (Fig. 6). Currently, Ahvaz is introduced as the most polluted city of the world because of high concentration of PM during the year. Increase of PM causes different impacts and problems like related illnesses such as cancer and lung damages which have been increasingly recorded by health offices of the region during recent years.

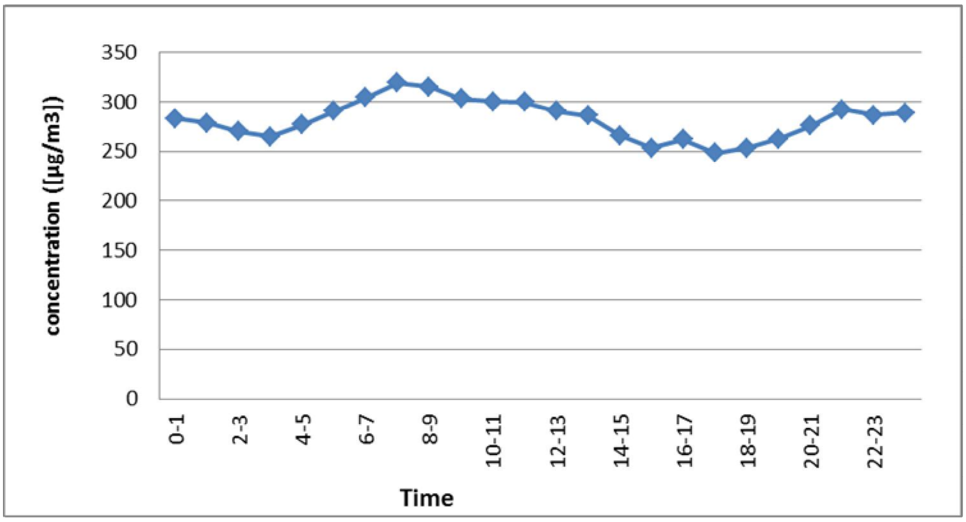

Figure 2. Diurnal variation of PM_{10} concentration in Ahvaz (2009-2010).

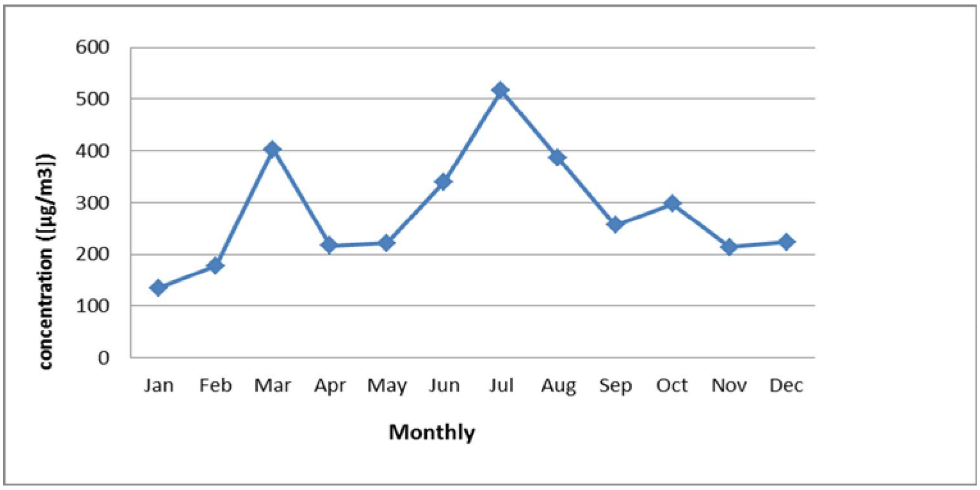

Figure 3. Monthly variation of PM_{10} concentration in Ahvaz (2009-2010).

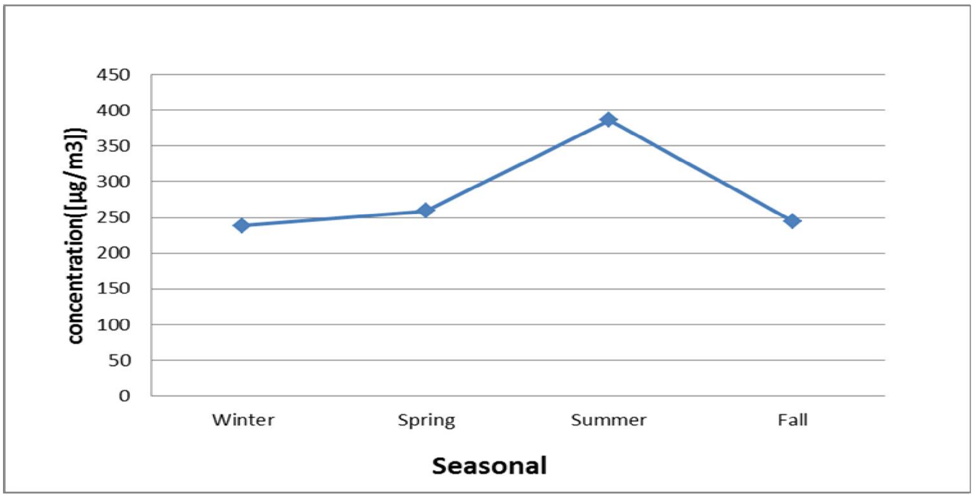

Figure 4. Seasonal variation of PM_{10} concentration in Ahvaz (2009-2010).

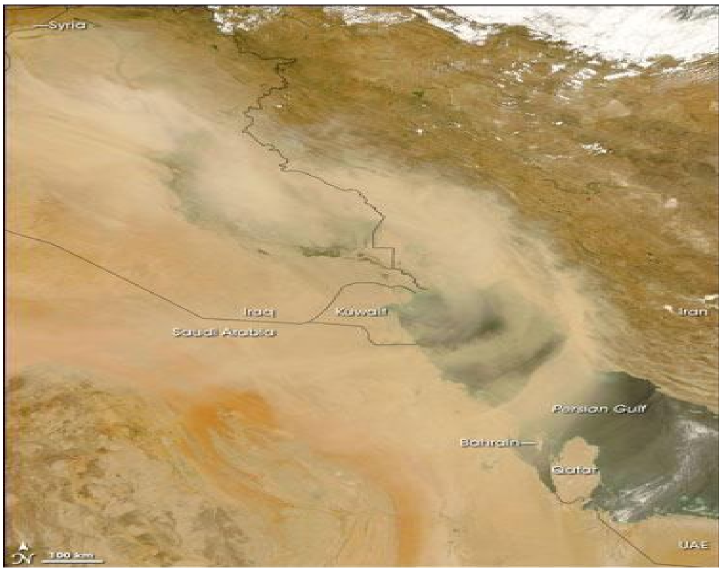

Figure 5. Satellite image showing origin and source of most of the dust pollution carried by wind in Iran from dry land of western neighbors especially Iraq.

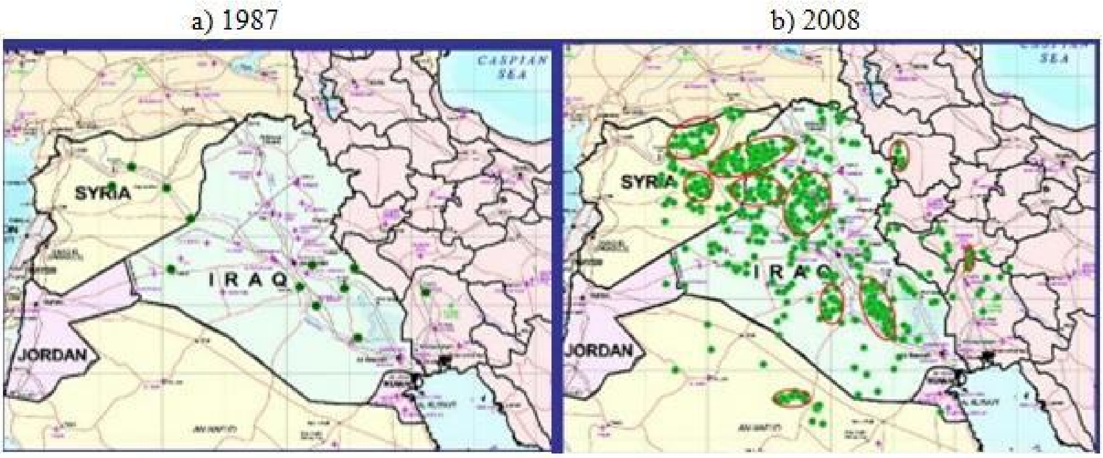

Figure 6. Two maps from the western neighbors of Iran showing the number of critical areas for detachment of soil particles in wind erosion process especially increasing in Iraq during recent years.

Table 1 shows the relationships between PM_{10} and other air pollutants. The concentration of PM_{10} shows negative correlation with NO_2, NOx, O_3 and SO_2. These results are not the same as those regarding PM_{10} assessment in other Iranian cities like Tehran (Masoudi *et al.*, 2016b) and Shiraz (Masoudi *et al.*, 2018b) but they are in good agreement with Isfahan (Masoudi and Gerami, 2018a). 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}.

	CO	NO_2	O_3	NO_X	SO_2
Pearson Correlation	-.091	-.155**	-.092	-.153**	-.044
Sig. (2-tailed)	.118	.009	.112	.009	.449
N	298	286	298	286	298

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

Table 2. Analysis of variance for 'enter' (a) and 'stepwise' (b) regression methods for annual condition.

Analysis of variance (a)

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	14186793.184	10	1418679.318	12.187	.000**
Residual	41209505.534	354	116411.033		
Total	55396298.718	364			

Predictors: (Constant), Rain, Evaporation, Wind direction (max), Wind speed (max), Temperature (max), Temperature (min), Sunshine Hours, Ratio of Humidity (min), Ratio of Humidity (max), Ratio of Humidity (mean).
Dependent Variable: PM_{10}

Analysis of variance (b)

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	13548731.346	5	2709746.269	23.246	.000**
Residual	41847567.373	359	116567.040		
Total	55396298.718	364			

Predictors: (Constant), Wind speed (max), Temperature (max), Temperature (min), Sunshine Hours, Ratio of umidity (min).
Dependent Variable: PM_{10}

In Table 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 beta coefficient, t values, and two-tailed significance level have been shown in the Table.

Table 3. Coefficients of PM_{10} 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)	897.527	249.635		3.595	.000
Temperature (max)	-23.624	8.645	-.619	-2.733	.007**
Temperature (min)	31.858	9.744	.633	3.270	.001**
Ratio of Humidity (max)	-24.741	36.455	-1.681	-.679	.498
Ratio of Humidity (min)	-32.387	36.457	-1.556	-.888	.375
Ratio of Humidity (mean)	49.125	72.981	2.732	.673	.501
Rain	-10.064	5.866	-.088	-1.716	.087
Sunshine Hours	-38.404	7.160	-.352	-5.363	.000**
Evaporation	5.522	7.751	.081	.712	.477
Wind direction (max)	.276	.262	.059	1.052	.294
Wind speed (max)	-14.049	6.475	-.108	-2.170	.031*

Dependent Variable: PM_{10}

Coefficients (b)

Model	Unstandardized Coefficients		Standardize Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1006.098	176.354		5.705	.000
Temperature (min)	36.756	8.561	.731	4.294	.000**
Sunshine Hours	-34.976	6.827	-.320	-5.123	.000**
Ratio of Humidity (min)	-9.734	1.952	-.468	-4.986	.000**
Temperature (max)	-26.154	8.299	-.686	-3.151	.002**
Wind speed (max)	-13.621	6.445	-.105	-2.113	.035*

Dependent Variable: PM_{10}

The linear regression equations show that the PM_{10} pollution depends on the meteorological parameters and also give an idea about the strength of the relationships. The linear model equations after using 'enter method' and 'stepwise method' for annual condition are as follows:

PM_{10} ($\mu g/m^3$) using 'enter method' for annual condition =
897.527 + (31.858) $Temperature_{(min)}$ + (-23.624) $Temperature_{(max)}$ + (-32.387) Ratio of $Humidity_{(min)}$ + (-24.741) Ratio of $Humidity_{(max)}$ + (49.125) Ratio of $Humidity_{(avg)}$ + (-10.064) Rain + (-38.404) Sunshine Hours +(0.276) Wind $direction_{(max)}$ + (-14.049) Wind $speed_{(max)}$ + (5.522)Evaporation R= 0.506 (significant at 0.01)

PM_{10} ($\mu g/m^3$) using 'stepwise method' for annual condition = 1006.098+ (36.756) Temperature (min) + (-34.976) Sunshine Hours+ (-9.734) Ratio of Humidity (min) + (-26.154) Temperature (max) + (-13.621) Wind $speed_{(max)}$ R= 0.495 (significant at 0.05)

Results of regression model show $temperature_{(max)}$ ratio of humidity (max), sunshine hours and wind $speed_{(max)}$ have reverse effect on concentration of PM_{10}, so that when these parameters increase, the concentration of PM_{10} decreases. However, when $temperature_{(min)}$ increases the concentration of PM_{10} significantly increases (Table 3b). Other meteorological parameters show different effects on PM_{10} although these results are not significant. For example, rainfall has reverse effect on concentration of PM_{10} (Table 3a). These results are almost in good agreement with other results regarding PM_{10} measurements in other Iranian cities of Tehran (Masoudi *et al.*, 2016b), Isfahan (Masoudi & Gerami, 2018a) and Shiraz (Masoudi *et al.*, 2018b) and other regions (Sánchez-Ccoyllo and Andrade, 2002; Elminir, 2005; Li *et al.* ,2014).

Actually, some of these events happen in real condition. Increase in rainfall, ratio of humidity, wind speed and temperature (inversion happens in low temperatures) usually decrease most of air pollutants (Asrari *et al.*, 2007).

The values and significance of R (multiple correlation coefficient) in both equations show their capability in predicting PM_{10} amount. The amount of Adjusted R^2 in the enter model is 0.256 and in the stepwise model is 0.245 showing that different parameters used can explain almost 25% of variability of PM_{10}. This result indicates for predicting most of air pollutants like PM_{10}, we should take into consideration natural and anthropogenic sources of their production such as consumption of fossil fuel and wind erosion process as well. On the other hand, R in the enter method (0.506) is equal to the stepwise method (0.495), showing no difference. Therefore, the second equation based on stepwise method can be used to predict PM_{10} in the city instead of the first equation which needs more data. Additionally, no difference between the two R values indicates that the excluded variables in the second equation have less effect on assessing PM_{10} in the city.

In Table 3, beta shows those meteorological parameters with more effect on the dependent variable PM_{10}. The beta in the Table 3a shows a highly significant effect of some variables like ratio of humidity and temperature compared to other meteorological parameters for measuring the PM_{10} which is close to the results of other Iranian cities of Tehran (Masoudi *et al.*, 2016b), Isfahan (Masoudi & Gerami, 2018a) and Shiraz (Masoudi *et al.*, 2018b). Parameter significance (P-value) from Table 3 shows the strength of relationship between PM_{10} and the meteorological parameters. For example, Table 3a shows wind speed has higher effect than wind direction on PM_{10}.

In Table 4, the linear regression equations of PM_{10} are presented for the enter and stepwise methods for different seasonal conditions. Results show all of the seasonal models are significant. Stepwise methods show those meteorological parameters which are most important during these seasons for estimating the pollution. Again those parameters showing increasing in sun radiations like temperature and sunshine hours are observed as the most important among others. Models for the summer have the highest R and for the spring the lowest R. In all seasonal models except stepwise models of spring and winter, R is higher than in annual models indicating that relationships between the pollutant and meteorological parameters are stronger than other conditions during this season. These results differ somewhat with results regarding PM_{10} assessment in other Iranian cities of Tehran (Masoudi *et al.*, 2016b), Isfahan (Masoudi & Gerami, 2018a) and Shiraz (Masoudi *et al.*, 2018b).

Table 4. PM10 (µg/m3) using two methods of enter and stepwise for different seasonal conditions.

Season	enter method	R	stepwise method	R
Spring	= 332.116 + (21.330) $Temperature_{(min)}$ + (-24.145) $Temperature_{(avg)}$ + (24.129) Ratio of $Humidity_{(min)}$ + (32.949) Ratio of $Humidity_{(max)}$ + (-61.398) Ratio of $Humidity_{(avg)}$ + (-3.603) Rain + (-16.601) Sunshine Hours + (-0.302) Wind $direction_{(max)}$ + (12.071) Wind $speed_{(max)}$ + (29.965) Evaporation	0.534 (significant at 0.01)	= 139.911 +(-25.823) Evaporation + (18.105) Sunshine Hours	0.486 (significant at 0.01)
Summer	= 553.460 + (52.967) $Temperature_{(min)}$+ (11.266) $Temperature_{(max)}$ + (-16.311) Ratio of $Humidity_{(min)}$ + (-23.262) Ratio of $Humidity_{(max)}$ + (35.908) Ratio of $Humidity_{(avg)}$ + (-157.957) Sunshine Hours + (-0.044) Wind $direction_{(max)}$ + (-63.937) Wind $speed_{(max)}$ + (-1.717) Evaporation	0.815 (significant at 0.01)	= -302.447 + (-170.384) Sunshine Hours + (73.572) $Temperature_{(avg)}$ +(-47.223) Wind $speed_{(max)}$	0. 804 (significant at 0.01)
Autumn	= -171.314 + (-2.843) $Temperature_{(min)}$+ (12.521) $Temperature_{(max)}$ + (-10.045) Ratio of $Humidity_{(min)}$ + (-9.107) Ratio of $Humidity_{(max)}$ + (20.478) Ratio of $Humidity_{(avg)}$ + (-2.215) Rain + (-0.192) Sunshine Hours + (-0.043) Wind $direction_{(max)}$ + (-1.089) Wind $speed_{(max)}$ + (-0.071) Evaporation	0.550 (significant at 0.05)	= 16.372 + (8.124)$Temperature_{(max)}$	0.510 (significant at 0.01)
Winter	= 1654.454 + (44.263) $Temperature_{(min)}$+ (-38.059) $Temperature_{(max)}$ + (5.406) Ratio of $Humidity_{(min)}$ + (14.514) Ratio of $Humidity_{(max)}$ + (-35.175) Ratio of $Humidity_{(avg)}$ + (-8.099) Rain + (-41.912) Sunshine Hours + (0.538) Wind $direction_{(max)}$ + (-30.870) Wind $speed_{(max)}$ + (-6.511) Evaporation	0.583 (significant at 0.01)	= 1553. 485 + (-12.339) Ratio of $Humidity_{(max)}$+ (-41.333) Sunshine Hours	0.488 (significant at 0.01)

Also, the nonlinear multiple regression equation of PM_{10} using the linear stepwise method for annual condition is calculated as below which is significant:

PM_{10} (ppb) using nonlinear regression for annual condition = 2218.252+ (250.594) $Temperature_{(min)}$ + (-14.842) $Temperature_{(min)}{}^2$+ (0.276) $Temperature_{(min)}{}^3$ + (-242.038) Sunshine Hours + (37.567) Sunshine $Hours^2$+ (-1.890) Sunshine $Hours^3$ +(-10.07) Ratio of $Humidity_{(min)}$ + (-0.013) Ratio of $Humidity_{(min)}{}^2$+ (0. 0) Ratio of $Humidity_{(min)}{}^3$ + (-201. 988) $Temperature_{(max)}$ + (5.638) $Temperature_{(max)}{}^2$+ (-0.053) $Temperature_{(max)}{}^3$+ (-46.343)Wind speed+ (2.776) Wind $speed^2$+ (-0.041) Wind $speed^3$

R^2= 0. 407(significant at 0.01)

To test which annual model is better, RMSE (Root Mean Square of Error) was calculated for the enter and stepwise and nonlinear models. The predicted amounts using the two annual models for 30 days during 2010 were calculated and compared with observed data using RMSE equation:

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

O_{obs}: observed PM_{10} value

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

The values of RMSE in the enter (430.27) and stepwise (221.48) models show their capability in predicting PM_{10} compared to nonlinear model value (270.03). This result which is the similar to those of Tehran (Masoudi *et al.*, 2016b), Isfahan (Masoudi & Gerami, 2018a) and Shiraz (Masoudi *et* *al.*, 2018b) and also other studies about other pollutants in Ahvaz like O_3 (Masoudi *et al.*, 2014a), NO_2 (Masoudi & Asadifard, 2015), SO_2 (Masoudi *et al.*, 2017a) and CO (Aasdifard & Masoudi, 2018), indicates for predicting most of air pollutants like PM_{10}, we may safely use only linear stepwise model requiring less data compared to the enter model and also being easier than nonlinear model.

Conclusion

In this research, air quality analyses were conducted in Ahvaz for PM_{10} particulate matters (PM) as one of the seven indicators of pollutants. Ahvaz is the most polluted city in Iran in terms of dust pollution, so the need to this study. Results showed in the enter and stepwise regression models there were significant relationships between PM_{10} and some meteorological parameters. The regression coefficient R was highest in the summer for both models. Using the RMSE (Root Mean Square of Error) value, we can conclude that the stepwise model is more suitable for this pollutant. Finally, we conclude a significant relationship between the amount of air pollutants and atmospheric parameters that can be used to predict the amount of contaminant in the coming years. Also, results in almost all sampling times showed that the concentration levels of PM_{10} were very higher than primary standard of PM_{10}, exhibiting unhealthy condition.

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