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Assessment of NO_2 levels as an air pollutant and its statistical modeling using meteorological parameters in Tehran, Iran

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ABSTRACT

In the present study, air quality analyses for NO_2 were conducted in Tehran, capital of Iran. The measurements were taken in four different locations to provide average data in the city. The average concentrations were calculated diurnally, monthly and seasonally. Results exhibited that the highest NO_2 concentration occurs generally in the early morning and early night, while the least in the afternoon and after mid-night. Monthly NO2 concentrations displayed the highest value in April, while the least in June and July. The seasonal concentrations exhibited the least amounts in summer, while the highest in autumn. Relationships between the air pollutant and some meteorological parameters were also calculated 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 between pollutant concentrations and meteorological parameters were expressed by multiple linear and nonlinear regression equations for both annual and seasonal conditions using SPSS software. RMSE test displayed that the stepwise, among different prediction models, is the best option.

Keywords: NO_2, Air pollution, Meteorological parameters, Regression model.

INTRODUCTION

Air sustains life, however, 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 during the last century, air quality has been getting much worse especially in developing countries, hence air pollution exceeds all health standards. For example, in Lahore and Xian (China) dust is ten times higher than health standards (Sharma 2001).

NO_2 is one of the seven conventional (criteria) pollutants (including SO_2, CO, particulates, hydrocarbons, nitrogen oxides, O_3 and lead) which comprise the highest volume of pollutants in the air and the most serious threat for human health and welfare. Emphasis on these pollutants, especially in cities, has been regulated by The Clean Air Act since 1970 (WP Cunningham & MA Cunningham 2002).

NO_2 is a reddish brown gas, formed by fuel burnt in car. It is a strong oxidizing agent and forms nitric acid in air. Its sources are divided into two parts: 1) natural emissions including forest fires, volcanoes, bacteria in soil, lightning, etc. 2) anthropogenic activity including motor vehicle emissions and power generation. Fuel combustion increases NO_2 emission. Half of HC and NOx emissions in cities caused by motor vehicles.

Nitrogen oxides (NO_x) include different oxide forms of nitrogen. NO_2 generally derives from NO emissions (in high temperature). About 95% of nitrogen oxides are emitted as NO, while 5% as NO_2. Other oxides are N_2O, N_2O_3 and N_2O_5 which do not play so important role in air pollution. NO_2, among NO_x, causes respiratory problems, hence is considered as the most important form of NO_x. The presence of pollutants in the atmosphere, causes a lot of problems, making the study of pollution behavior inevitable (Asrari *et al*. 2007). Some of the main health effects of NO_2 as follows: lung and heart problems, NO_2 poisoning, asthma, lowered resistance to infection. Other effects on plants and materials: damages of leaves, retard photosynthesis activity, causing chlorosis, damages on various textile fibers, multiplying the photochemical smog problems and damages of acid rain. Ho &

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Lin (1994) studied semi-statistical model 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 multiple linear regression analysis, for some months there was a moderate and weak relationship between the air pollutants such as PM level and the meteorological factors in Trabzon city (Cuhadaroglu & Demirci, 1997). Mandal (2000) has reported 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 & 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 concluding that the artificial neural network (ANN) is a promising method for air pollution modeling. The observed behavior of pollutant concentrations 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 & Andrade 2002), exhibiting lower concentrations associated with intense ventilation, precipitation and high relative humidity, while higher levels prevailed due to weak ventilation, absence of precipitation and low relative humidity for some pollutants. Sabah *et al.* (2003) used also a statistical model for predicting CO.

Elminir (2005) mentioned dependence of air pollutants on meteorology over Cairo in Egypt, reporting that wind direction had an influence not only on pollutant concentrations but also on the correlation between pollutants. So that, 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 concentration for NO_2 and O_3 occurred at humidity $\leq 40\%$ indicative for strong vertical mixing. For CO, SO_2 and PM_{10} the highest average concentrations occurred at humidity above 80%. In another study, 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 ozone concentration in the atmosphere using both multiple linear and principal component regression methods (Abdul-Wahab *et al.* 2005). They repored 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, as well as variations in concentration of CO at different times.

Ashrafi *et al.* (2012) predicted daily CO concentration in the urban area of Tehran using a hybrid forward selection-ANFIS (adaptive neuro-fuzzy inference system) model based on atmospheric stability analysis. So that, temperature and wind speed gradients were used in the best model for predicting of the CO concentration.

Li *et al.* (2014) presented the spatial and temporal variation of the air pollution index (API) and examined the relationships between API and meteorological factors during 2001–2011 in Guangzhou, China. They found relationships 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) reported that all of the pollutants displayed 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.

Wang *et al.* (2015) studied on air quality in Chongqing, the largest mountainous city in China. Statistical analysis of NO_2 concentrations was conducted from 2002 to 2012.

The analysis of Pearson correlation indicated that NO_2 concentrations 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 serious. Choi *et al.* (2017) conducted nitrogen dioxide (NO_2) exposure assessment with four methods including LUR in the Republic of Korea, to compare the model performances, and to estimate the empirical NO_2 exposures of a cohort. The LUR models exhibited high performances in an industrial city in this country, despite the small sample size and limited data. They suggested that the LUR method may be useful in similar settings in Asian countries where the target region is small and availability of data is low.

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Statistical modelings of NO_2 were studied in Iranian cities of Ahvaz (Masoudi & Asadifard 2015), Isfahan (Masoudi & Gerami 2018) and Shiraz (Masoudi *et al.* 2019) using multiple linear regression analysis for seasonal and annual conditions, concluding that there were significant relationships between NO_2 levels and meteorological factors in these cities. The relationships between other pollutants and meteorological factors in Tehran and other Iranian cities were as follows: SO_2 in Tehran (Masoudi *et al*. 2018); O_3 in Ahvaz (Masoudi *et al.* 2014a) and Tehran (Masoudi *et al.* 2014b); CO in Shiraz (Masoudi *et al.* 2017) and Ahvaz (Aasdifard & Masoudi 2018); PM_{10} in Tehran (Masoudi *et al.* 2016).

The present study exhibits diurnal, monthly and seasonal variations in NO_2 concentrations and also employing a statistical model enabling to predict its amounts, 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 (NO_2 in this study). So, a best-known large statistical and graphical software package (SPSS, Software Package of Social Sciences, V. 20) was employed (Kinnear 2002).

MATERIALS AND METHODS

Study Area

The study area, Tehran (Fig. 1) is the capital of Iran located between 35° 35' N to 35º 50' N latitudes 51° 05' E to 51º 35' E longitudes and the elevation is 1280 m above the mean sea level. Area of Tehran is 730 km². It has a moderate climate and the residential population was 8.5 million in 2011. There are about one million cars in the city and many factories and industrials place around the city. So, Tehran is one of the most polluted cities in Iran and needs to carry out an ambient air quality analysis in this city.

Fig. 1. Location of Tehran in the region.

Data and methodology

Four available sampling stations in the city called, Azadi, Gholhak, Tajrish and Sorkhe-Hesar, belonging to Environmental Organization of Iran were selected to represent different traffic loads and activities.

The samplings have been performed every 30 minutes daily for each pollutant during all months in 2009 and 2010. Among the measured data in the four stations NO_2 was chosen.

Then the averages were calculated for every hour, each month and each season for the four stations using Excel. Finally averages of data at four stations were used to show air pollution situation as diurnal, monthly and seasonal graphs of NO_2 concentrations in the city.

Examining the correlation between NO_2 and metrological parameters of synoptic stations was carried out in the next step. The metrological parameters recorded include: temperature (min, max and mean), ratio of humidity (min, max and mean), precipitation, sunshine hours, dew point (mean), wind direction (max), wind speed (max & mean) and evaporation.

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In the next step, daily average data at four stations in 2010 was considered as dependent variable for statistical analysis while daily data of meteorological parameters during this year were selected as independent variables in SPSS program. The multiple regression equations exhibited the relationships between NO_2 concentrations and meteorological parameters and also gave an idea about the levels of these relations. The relationships between the dependent variables and each independent ones have been considered for both linear and nonlinear techniques. The significant values in output are based on fitting a single model. Furthermore, linear regression equation for different seasons probably exhibited those relationships which were not observed using annual data.

The model for predicting NO_2 was determined using two multiple regression modeling procedures including 'enter method' and 'stepwise method'. In the former method, all independent variables selected, are added to a single regression model, while in the latter which seems to be a better method, all variables can be entered or removed from the model depending on the significance. Therefore, only those variables which have more influences on dependent variables, are observed in a regression model.

RESULTS AND DISCUSSION

Figs. 2, 3 and 4 illustrate the diurnal, monthly and seasonal variations in the NO_2 concentrations. As shown in Fig. 2 the highest NO_2 concentration occurred in the morning and at night which may be due to higher traffic levels during these times. Monthly NO_2 concentrations exhibited the highest values in April, while the least in June and July (Fig. 3). Seasonal NO_2 concentrations displayed the highest values in autumn, while the least in summer (Fig. 4). Unfortunately, all graphs illustrated that the NO_2 concentrations were higher than primary standards of NO_2 recommended by the National Ambient Air Quality Standards (NAAQS) in Iran (0.021 ppm) to protect human health. These results are almost in good agreement with those obtained in other cities such as Shiraz (Masoudi *et al.* 2019), Isfahan (Masoudi & Gerami 2018) and Ahvaz (Masoudi & Asadifard 2015).

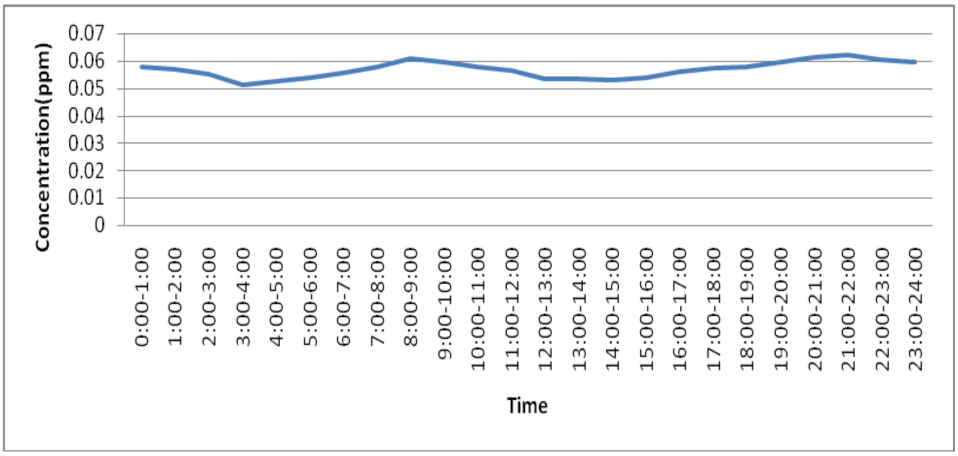

Fig. 2. Diurnal variations of NO_2 concentrations in Tehran.

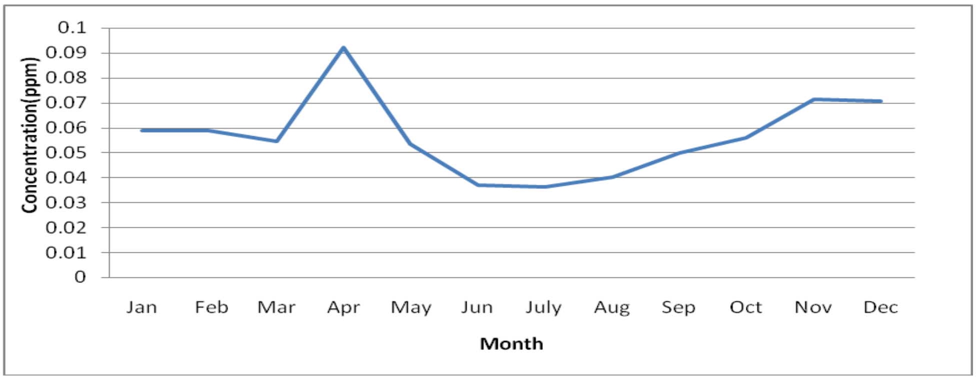

Fig. 3. Monthly variations of NO_2 concentrations in Tehran.

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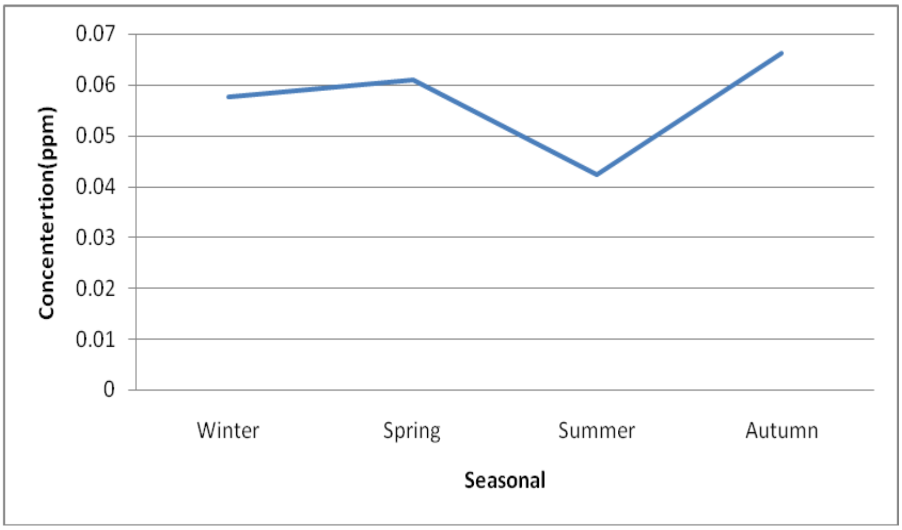

Fig. 4. Seasonal variations of NO_2 concentrations in Tehran.

Table 1 illustrates the relationships between NO_2 and other air pollutants. As shown in this Table, the NO_2 concentrations exhibited negative correlation with O_3, while positive with CO, NO_x and PM_{10} existing in the emission of car exhausts. Ozone is increased by sunlight, while other pollutants are related to traffic load which is higher in the morning and at night. Hence, negative relation is observed between ozone and other pollutant (Jhun *et al.* 2015). These results are almost in good agreement with those regarding NO_2 assessment in other Iranian cities such as Shiraz (Masoudi *et al.* 2019) and Isfahan (Masoudi & Gerami 2018). Correlation coefficients significant at the 0.05 level are indicated with a single asterisk (significant), whereas two ones were used to indicate at 0.01 level (highly significant). Table of analysis of variance (Table 2) exhibits both regressions of 'enter' and 'stepwise' methods for annual condition which are highly significant, indicating a significant relation between the different variables.

Table 1. Correlation between air pollutants and NO_2.

	CO	**O_3**	**NOx**	**PM_{10}**	**SO_2**
Pearson Correlation	.621**	-.225**	.566**	.228**	.006
Sig. (2-tailed)	.000	.000	.000	.000	.913
N	357	357	357	357	357

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

Analysis of variance (a)

Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	45310.966	12	3775.914	7.240**	.000
Residual	179401.379	344	521.516		
Total	224712.344	356			

Predictors: (Constant), Rain, Wind Direction (max), Wind Speed (max), Wind Speed (mean), Temperature (max), Temperature (min), Temperature (mean), Sunshine Hours, Ratio of Humidity (min), Ratio of Humidity (max), Ratio of Humidity (mean), Dew Point.
Dependent Variable: NO_2

Analysis of variance (b)

Model	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Regression	39725.208	4	9931.302	18.898**	.000
Residual	184987.136	352	525.532		
Total	224712.344	356			

Predictors: (Constant), Temperature (mean), Ratio of Humidity (mean), Dew Point, Wind Speed (mean)
Dependent Variable: NO_2

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Table 3 presented the coefficients of NO_2 pollution model and regression lines for both enter and stepwise methods in annual condition. Regression coefficients, standard errors, standardized coefficient beta, t values, and two-tailed significance level of t have been exhibited in the Table. The linear regression equations display that the NO_2 pollution depends on the meteorological parameters and also give an idea about the levels of relationships. The linear model equations after using 'enter method' and 'stepwise method' for annual condition are:

NO_2 amount (ppb) using 'enter method' for annual condition = 156.097 + (11.189) Temperature$_{(min)}$+ (10.147) Temperature$_{(max)}$ + (-24.098) Temperature$_{(mean)}$+ (.079) Ratio of Humidity $_{(min)}$ + (-.129) Ratio of Humidity$_{(max)}$ + (-.968) Ratio of Humidity$_{(mean)}$ + (-.952) Rain + (-.069) Sunshine Hours + (.029) Wind Direction$_{(max)}$ + (-.476) Wind Speed$_{(max)}$ + (-1.407) Wind speed$_{(mean)}$ + (2.229) Dew point R= 0.449 (significant at 0.01)

NO_2 amount (ppb) using 'stepwise method' for annual condition = 153.339 + (-2.872) Temperature$_{(mean)}$+ (-1.996) Wind Speed$_{(mean)}$ + (-1.048) Ratio of Humidity$_{(mean)}$ + (2.230) Dew Point R= 0.420 (significant at 0.01)

According to the linear regression model, temperature (mean), wind speed (mean) and ratio of humidity (mean) have reverse effect on NO_2 concentration? So that, by elevating in these parameters, the NO_2 concentration will be increased, while, by increased Dew point, the NO_2 concentration will be significantly elevated (Table 3b). Increased wind speed can disperse pollutants from emission source to far distants. By increasing in sunlight and subsequently temperature, NO_2 changes to NO and O. It is also assumed that by increasing in humidity, most of NO_2 may be deposited as acid deposition. Other meteorological parameters induce different effects on NO_2 levels, although these results are not significant. For instance, rainfall has reverse effect on NO_2 concentration (Table 3a). These results are almost in good agreement with those measuring NO_2 in other Iranian cities such as Shiraz (Masoudi *et al*. 2019), Isfahan (Masoudi & Gerami 2018) and Ahvaz (Masoudi & Asadifard 2015) as well as other regions (Sánchez-Ccoyllo & Andrade 2002; Elminir 2005; Li *et al.* 2014). Actually some of these events happen in real condition. Increased rainfall, wind speed and temperature (inversion happens in low temperatures) usually reduce most of air pollutants (Asrari *et al*. 2007). The values and significance of R (multiple correlation coefficient) in both equations show capability of them in predicting NO_2 level. The value of adjusted R^2 in both equations is almost 0.18 exhibiting that different parameters employed can calculate almost 18% variability of NO_2. This result can be employed for predicting most of air pollutants like NO_2. We should take into consideration consumption of fossil fuel especially in Motor vehicles. Half of emission of volatile organic compounds (VOCs), Hydrocarbons and NOx in cities are produced by Motor vehicles. The automobile exhaust produces 75% of total air pollution. It releases poisonous gases such as CO (77%), NOx (8%) and Hydrocarbons (14%) (Sharma 2001). On the other hand, R in enter method (0.449) is equal to stepwise one (0.420), with no difference. Therefore, second equation based on stepwise method can be used to predict NO_2 in the city instead of using 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 effect on measuring NO2 in the city. Beta in Table 3 presents those independent variables (meteorological parameters) which have more effect on dependent variable (NO_2). The beta in the both Tables 3 (a and b) exhibits a highly significant effect of some variables such as temperature and ratio of humidity (mean) compared to other meteorological parameters on measuring NO_2 which is close to the results of Shiraz (Masoudi *et al*. 2019), Isfahan (Masoudi & Gerami 2018) and Ahvaz (Masoudi & Asadifard 2015). Parameter Sig (P-value) from Table 3 presents relationship values between NO_2 and meteorological parameters, e.g., Table 3a exhibits that temperature (mean) has higher effect than other temperature parameters (max and min) on NO_2. On the other hand, in Table 4 the linear regression equations of NO_2 levels are presented for both enter and stepwise methods in different seasonal condition. Almost all of the models (except winter ones) were significant. Stepwise methods exhibit those meteorological parameters which are most important during these seasons for estimating the pollution. Among the models, autumn ones displayed the highest R value, while the winter model values exhibited the least which is a little differ from the results of Shiraz (Masoudi *et al.* 2019), Isfahan (Masoudi & Gerami 2018) and Ahvaz (Masoudi & Asadifard 2015).

R values in spring, summer and autumn models were higher than in annual ones, also indicating that relationships between the pollutant and meteorological parameters were stronger than whole year during these seasons.

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Table 3 (a,b). Coefficients of NO_2 pollution model and regression lines for both enter (a) and stepwise (b) methods in annual condition.

Coefficients (a)

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	156.097	20.597		7.579	.000
Temperature (mean)	-24.098	10.962	-10.558	-2.198*	.029
Temperature (max)	10.147	5.515	4.814	1.840	.067
Temperature (min)	11.189	5.565	4.547	2.011*	.045
Wind speed (mean)	-1.407	.656	-.158	-2.147*	.033
Wind speed (max)	-.476	.313	-.115	-1.521	.129
Wind direction (max)	.029	.020	.080	1.482	.139
Ratio of humidity (mean)	-.968	.365	-.791	-2.656**	.008
Ratio of humidity (max)	-.129	.165	-.119	-.782	.435
Ratio of humidity (min)	.079	.245	.054	.323	.747
Rain	-.952	.792	-.071	-1.202	.230
Dew point	2.229	.657	.447	3.392**	.001
Sunshine hours	-.069	.538	-.010	-.128	.898

Dependent Variable: NO_2

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Constant	153.339	17.991		8.523	.000
Temperature (mean)	-2.872	.532	-1.258	-5.393**	.000
Wind speed (mean)	-1.996	.457	-.224	-4.367**	.000
Ratio of humidity (mean)	-1.048	.223	-.855	-4.699**	.000
Dew point	2.230	.611	.447	3.650**	.000

Dependent Variable: NO_2

Table 4. NO_2 level (ppb) using two methods of enter and stepwise in different seasonal condition.

season	Enter method	R	Stepwise method	R
Spring	= 70.356 +(-17.285) Tmean + 8.761 Tmax + 7.476 Tmin + (-.615) WSmean + .205 WSmax + (-.001) WDmax + (-.522) RHmean + (-.063) RHmax + (-.037) RHmin + (.854) Rain + (-.026) Dew + (.068) Sunshine	.561 (0.01 significant)	= 37.250 + (-.979) Dew	.431 (significant at 0.01)
Summer	= 101.633 + (9.491) Tmean + (-7.036) Tmax + (-3.707) Tmin + (.345) WSmean + (.668) WSmax + (.030) WDmax + (-.456) RHmean + (-.120) RHmax + (.047) RHmin + (-2.417) Rain + (-1.524) Dew + (.699) Sunshine	.547 (0.01 significant)	= 49.691 + (.780) WSmax + (-2.763) Dew	.480 (significant at 0.01)
Autumn	= 154.608+ (-58.032) Tmean + (32.645) Tmax + (20.497) Tmin + (-5.181) WSmean + (.600) WSmax + (.042) WDmax + (-.125) RHmean + (-.694) RHmax + (-.054) RHmin + (-.391) Rain + (2.058) Dew + (-2.173) Sunshine	.708 (significant at 0.01)	= 145.894+ (-3.002) Tmin + (-4.780) WSmean + (-.443) RHmax	.638 (significant at 0.01)
Winter	= 158.891+ (-25.943) Tmean + (13.143) Tmax + (8.726) Tmin + (-.380) WSmean + (-.235) WSmax + (.010) WDmax + (-1.300) RHmean + (-.260) RHmax + (.272) RHmin + (-.246) Rain + (5.530) Dew + (.575) Sunshine	.440 (not significant at 0.05)		Not prepared by software showing no significance relationship

Note: Tmean=Temperature (mean) , Tmax=Temperature (max), Tmin=Temperature (min), WSmean=Wind Speed (mean), WSmax=Wind Speed (max), WDmax=Wind direction (max), RHmean=Ratio of Humidity (mean), RHmax=Ratio of Humidity (max), RHmin=Ratio of Humidity (min), Dew=Dew Point, Sunshin=Sunshine Hours

The nonlinear multiple regression equation of NO_2 level was calculated using parameters of linear stepwise method in annual condition which was significant:
NO_2 level (ppb) using nonlinear regression in annual condition = 57/506 × [(2/718)$^{(-/011\ Tmean)}$] + 75/840 + [-15/229 × LN (WSmean)[+ 14/974 + [10/752 × LN (RHmean)] + 46/468 × [(2/718)$^{(/018\ Dew)}$] R^2= 0.174 (significant at 0.01)

RMSE (Root Mean Square of Error) was calculated for different linear models of enter and stepwise and nonlinear model in order to examine which annual model is better to use. Predicted amounts using the different annual models for 30 days during 2011 were calculated and compared with observed data during those days using RMSE equation:

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

O_{obs}: observed NO_2 value O_{Pre}: predicted NO_2 value using model
The RMSE values in both linear models of enter (51.73) and stepwise (51.19) exhibited their capability in predicting NO_2 levels compared to nonlinear model value (191.84). This result which was similar to those of other Iranian cities such as Shiraz (Masoudi *et al*. 2019), Isfahan (Masoudi & Gerami 2018) and Ahvaz (Masoudi & Asadifard 2015) as well as those of other pollutants in Tehran such as O_3 (Masoudi *et al.* 2014b), PM_{10} (Masoudi *et al.* 2016) and SO_2 (Masoudi *et al.* 2018), is applicable for predicting most of air pollutants such as NO_2. We may take into consideration only linear models of stepwise which need less data compared to enter model and also its calculation is easier than nonlinear model.

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ارزیابی سطوح دی اکسید نیتروژن به‌عنوان یک آلاینده هوا و مدلسازی آماری آن با استفاده از پارامترهای هواشناسی در تهران، ایران

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چکیده

در پژوهش فعلی، آنالیز کیفیت هوا برای آلاینده‌ی دی اکسید نیتروژن (NO_2) در شهر تهران، پایتخت ایران، بررسی شد. برای تهیه داده‌های میانگین، اندازه‌گیری‌ها در چهار مکان مختلف در این شهر انجام شد. غلظت میانگین برای هر ۲۴ ساعت، هر ماه و هر فصل محاسبه شد. نتایج نشان داد که بیشترین غلظت دی NO_2 به طور کلی در اوایل شب و صبح رخ می دهد، این در حالی است که حداقل غلظت این آلاینده در ظهر و همچنین بعد از نیمه شب مشاهده می‌شود. غلظت ماهانه دی NO_2 در ماه آوریل بالاترین میزان و در ماه ژوئن و جولای کمترین میزان را نشان داد. بیشترین غلظت فصلی آلاینده دی NO_2 مربوط به فصل پاییز و کمترین آن مربوط به تابستان بود. سپس روابط آماری بین آلاینده هوا و برخی پارامترهای هواشناسی با استفاده از داده‌های میانگین روزانه محاسبه شد. داده‌های باد (سرعت، جهت)، رطوبت نسبی، دما، ساعت آفتابی، نقطه شبنم و بارندگی به عنوان متغیرهای مستقل در نظر گرفته شدند. میزان ارتباط بین غلظت آلاینده و پارامترهای هواشناسی با استفاده از معادلات رگرسیون خطی و غیر خطی برای شرایط سالانه و فصلی با استفاده از نرم افزار SPSS محاسبه شد. آزمون RMSE نشان داد که در میان مدل‌های مختلف برای پیش‌بینی در این تحقیق، مدل stepwise (گام به گام) بهترین مدل است.

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